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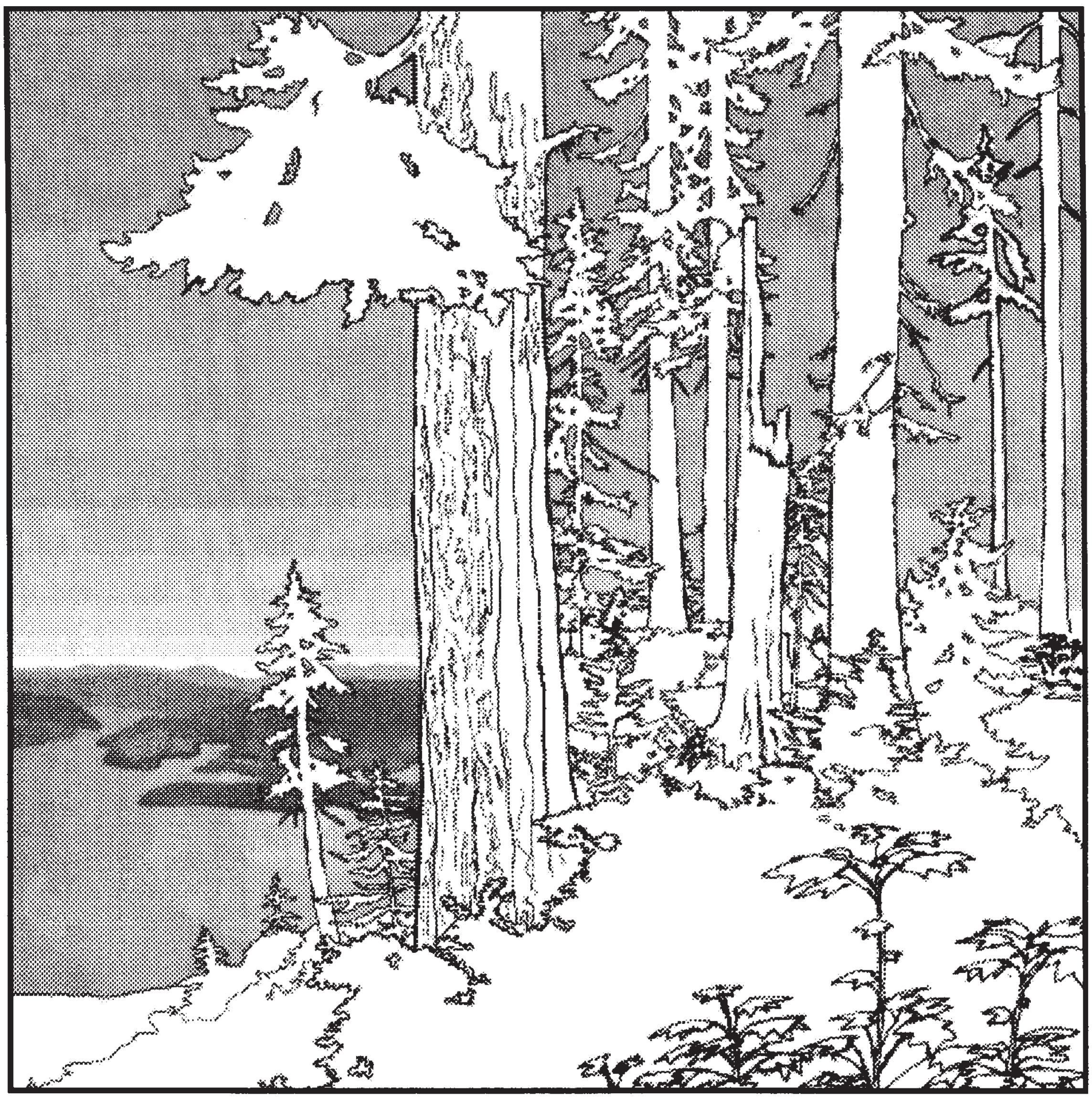
Assessments of Wildlife Viability, Old-Growth Timber Volume Estimates, Forested Wetlands, and Slope Stability



Conservation and Resource Assessments for the Tongass Land Management Plan Revision

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Assessments of Wildlife Viability, Old-Growth Timber Volume Estimates, Forested Wetlands, and Slope Stability

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Compiler

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Abstract

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Resource assessments on wildlife viability, old-growth timber volume estimates, forested wetlands, and slope stability are presented. These assessments were used in the formulation of alternatives in the revision of the Tongass land management plan.

Keywords: Wildlife viability, timber volume, forested wetlands, slope stability, Tongass, Alaska.

Preface

This volume presents resource assessments used as part of the Tongass land management planning process. Included here are assessments on (1) approaches to maintaining well-distributed, viable wildlife populations; (2) options for estimating old-growth timber volume; (3) suitability of forested wetlands for timber production; and (4) slope stability factors with discussion of mass movement hazard indexing.

Our intent in providing this publication is to create a readily accessible and retrievable record of the best available information on issues emphasized in the revision of the Tongass land management plan.

Contents

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Conceptual Approaches for Maintaining Well-Distributed, Viable Wildlife Populations: A Resource Assessment

George C. Iverson and Bruce René

Background

The National Forest Management Act of 1976 (NFMA; 16 USC §1604 [g] [3] [B]) requires that the USDA Forest Service provide for the diversity of plants and animals, based on the suitability and capability of each National Forest. As part of meeting overall multiple-use objectives, the implementing regulations (36 CFR §219.3) of NFMA interpret the diversity requirement as maintaining habitat to support viable and well-distributed populations of existing native and desired nonnative species in the planning area. Maintaining the abundance and distribution of habitat necessary to support well-distributed and viable populations of old-growth-associated wildlife across the Tongass National Forest (Tongass) was one of five major issues considered in the Tongass land management plan (TLMP) revision. To address this issue, several assessments were chartered to synthesize available information on wildlife species with potential viability concerns at the Tongass. Individual assessments were conducted for the northern goshawk (*Accipiter gentilis*; Iverson and others 1996), Alexander Archipelago wolf (*Canis lupus ligoni*; Person and others 1996), marbled murrelet (*Brachyramphus marmoratus*; DeGange 1996), and anadromous salmonids (Salmonidae; U.S. Department of Agriculture, Forest Service 1995). Broader, system-oriented assessments also were conducted for habitat conservation areas: old-growth forest patch inventory (DeGayner and Iverson, in prep.), karst and caves (Baichtal and Swanston 1996), and natural disturbance with an emphasis on wind (Nowacki and Kramer, in prep.).

A workshop was held June 7-9, 1995, to synthesize information that related to fish and wildlife viability and ecosystems within southeast Alaska and the Tongass.[1] At this workshop, several possible Forest-wide integrated strategies were developed for maintaining habitat to support viable fish and wildlife populations and functional old-growth ecosystems across the Tongass. These conceptual strategies, which used key landscape parameters as building blocks, were made available to the interdisciplinary team for use in drafting alternatives for the TLMP revision. This paper summarizes the deliberations and findings of a viability synthesis workshop. The workshop charter is given in appendix A; workshop participants are listed in appendix B.

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[1] The workshop was held at the Tongass Land Management Plan office, Juneau, AK.

A Working Definition of Viability

The concept of viability and well-distributed populations initially was debated to establish a common understanding and a working foundation for addressing workshop objectives. A consensus emerged that there is no generally accepted definition of viability and that some commonly used terms within the definitions, such as “well distributed,” also are not clearly defined. Based on definitions used in recent large-scale viability analyses, such as that by the Forest Ecosystem Management Assessment Team (FEMAT) in the Pacific Northwest (FEMAT 1993), the following working definition of viability was developed. For purposes of the workshop, the term “viability” was defined as “the likelihood that habitat conditions will support persistent and well distributed fish and wildlife populations over time.” The concept of “well distributed” was based on the natural distribution and dispersal capabilities of individual species, and it included the full range of their current or historically recent distribution within southeast Alaska. “Dispersal” included the concepts of metapopulation dynamics and gene flow.

The concepts of “minimum viable” populations and “productive” or “usable” populations also were debated. The fish and wildlife populations of southeast Alaska support many commonly accepted human uses (subsistence hunting, commercial fishing, recreational activities, and tourism, for example) that are difficult to meaningfully separate from some level of viability determined without considering these uses. Many wildlife populations depend on others as prey, and the viable level for one species (Sitka black-tailed deer [*Odocoileus hemionus*], for example) must consider the needs for that species by other species (Alexander Archipelago wolf, for example) along with human demands. These and other considerations also form parts of “sustained yield” for fish and wildlife resources under NFMA (PL 86-517; 16 USC §528) and the Multiple-Use Sustained-Yield Act of 1960 (PL 94-588; 16 USC §1600).

A consensus was reached among workshop participants that to provide information to use in constructing TLMP revision alternatives, and to have a reasonable assurance of maintaining habitat sufficient to support populations of all fish and wildlife species of the Tongass, the term “viable” should include all these factors. An evaluation of the TLMP revision alternatives themselves, in terms of maintaining viable populations pursuant to NFMA, was conducted later by independent scientific panels (Smith and Shaw, in prep.; Swanston and others 1996).

Analysis of Information

The first phase of the workshop consisted of summary presentations of the results (often preliminary) of ongoing assessments, resource analyses, or other studies concerning specific aspects of animals and ecosystems of the Tongass. These included verbal presentations (presenters shown in parentheses) on the following topics:

- Anadromous fish habitat assessment (USDA Forest Service 1995) and related proposals (Fred Everest)
- Watershed reserve strategy and riparian prescriptions (Steven Kessler)
- Karst and cave resources (Douglas Swanston)

- Northern goshawk (George Iverson)
- Alexander Archipelago wolf (Matthew Kirchhoff)
- Marbled murrelet (Carol Hale)
- Inventory of existing old-growth forest blocks (Eugene DeGayner)
- Brown bear (Kimberly Titus)
- Principal disturbance processes in the temperate rain forest (Gregory Nowacki)
- Marten (Rod Flynn)
- Alternatives to clearcutting (Richard Zaborske)
- Reliability of timber inventory for differentiating timber volume classes (John Caouette)
- Possible Forest plan scenarios (Steven Brink)
- Viability in relation to FEMAT (1993) (Martin Raphael)
- Interagency viable population committee conservation strategy (Suring and others 1993; Suring and others, in prep.), a review of this strategy (Kiester and Eckhardt 1994), and the response to the review of this strategy (Suring and others 1994) (George Iverson; see appendix C)

Landscape Building Blocks for Viability Strategies

The first step in developing an array of Forest-wide, landscape-level management options was to identify the key parameters relevant to viability by using information presented about individual species and habitat components. This step was conducted for five wildlife species of concern, fish in general, and the old-growth ecosystem (table 1). For each species or issue, considerations for habitat management were developed from the key parameters.

Elements common among parameters for the different species and issues were then identified for specific habitats or management practices on which to focus. These elements served as the components or building blocks of Forest-wide viability approaches. Four components ultimately were identified: riparian areas, silvicultural systems, old-growth reserves, and the beach fringe. Some of the important considerations for these components are discussed below. A fifth component, areas currently in a withdrawn status (withdrawn from most forms of land-disturbing management activities, including commercial timber harvesting), such as wilderness and research natural areas, is an assumed land allocation applied equally to all approaches.

Riparian options—This subject includes consideration of fish viability and productivity, as well as other aquatic organisms and riparian-associated wildlife. To the extent that they contribute appropriate habitat, riparian areas may function as wildlife travel corridors and provide important connectivity among habitats within watersheds. From the anadromous fish habitat assessment (USDA Forest Service 1995) and subsequent work by the interdisciplinary team, three options for riparian area habitat management are available; these options, together with current TLMP direction (as amended after the Tongass Timber Reform Act), provided four conceptual choices for this viability component: proposed options 1 through 3 and the current TLMP, as described below.

Table 1—Key parameters and range of recommendations used in the viability synthesis workshop to develop management options for the Tongass land management plan

Species or issue	Key parameters	Range of recommendations
Marten *(Martes americana)*	High-productivity old growth (volume class 5+[a]) 2 square miles per female, 3 square miles per male 16-mile mean dispersal range Roaded access-level of trapping Forest-wide application	A habitat conservation area (HCA) network consisting of HCAs of 34,000 acres, 25 miles apart, to support 25 reproductive pairs; HCAs of 6,800 acres, 9 miles apart, to support 5 reproductive pairs or 13,600 acres, 16 miles apart, to support 10 pairs; and HCAs of 2,100 acres, 1 for each 15 square miles or larger watershed to support 1 pair At a minimum, HCAs should be 50 percent volume class 4+, and 25 percent volume class 5+; they should be nonlinear in shape, as much as possible Forested riparian corridors and beach fringe Consider road density and management Reserves may be unnecessary if the stated stand characteristics for HCAs could be achieved through uneven-aged management, longer rotations, or both Could be applied within HCAs, or Forest-wide if no HCA system is provided (the latter is more risky) If no HCAs, then spatial control of habitat juxta-position required Road management still required
Northern goshawk *(Accipiter gentilis)*	Volume class 4+ habitat Home ranges (surveyed to date) contain 20 to 80 percent productive old-growth forest Productive forest preferred (nonrandomly selected) for nesting habitat Most nests below 800 feet in elevation Use areas range from 10,000 to 30,000 acres Significant avoidance of clearcuts and nonforest Need for continuous reserves not evident Forest-wide application	No more than 33 percent of the productive forest land within a watershed, including private land, should be in stands less than 100 years old Representative nesting habitat (>600 acres) available in each watershed (10,000 to 30,000 acres)
Marbled murrelet *(Brachyramphus marmoratus)*	Nest on large branches of the oldest and largest diameter trees available within 31 miles of the ocean Nesting associated with low-elevation (300-foot average; 800-foot maximum) forest in heads of bays Prefer trees with high epiphytic cover Gill net mortality and other at-sea effects a concern Forest-wide application	Maintain volume class 4+ in heads of bays, with emphasis on those near aquatic or terrestrial concentration areas

Table 1—Key parameters and range of recommendations used in the viability synthesis workshop to develop management options for the Tongass land management plan (continued)

Species or issue	Key parameters	Range of recommendations
Wolf *(Canis lupus)*	Road density and roaded access for trapping Prey availability: primarily deer on the islands, moose and goats on mainland Application: Yakutat Peninsula, mainland, and the islands south of Frederick Sound	Manage mortality from trapping and illegal kills Maintain habitat to maintain productive prey populations, especially deer (for deer, emphasize volume class 5+ for winter habitat) Consider a deer-density objective within wolf range
Fish	Fish viability Fish productivity Watershed integrity Forest-wide application	Viability: Maintain multiple, well-distributed, undisturbed watersheds within each evolutionary significant unit (ESU); the current proposal uses the State's statistical troll units—other options for identifying ESUs also could be used, or the National Marine Fisheries Service may define ESUs for the Tongass Productivity: Also use one of the Riparian Conservation Area options, which variously allow some silviculture
Brown bear *(Ursus arctos)*	Availability of anadromous fish Road density and roaded access concerns Availability of summer alpine habitat Camp and community waste disposal sites Application: mainland, and Admiralty, Baranof, and Chichagof Islands	Reserves of 40,000 acres, with no roaded access, that include productive fisheries every 20 miles Maintain 300-foot buffers on low-gradient class I streams to provide visual barrier and foraging habitat Provide for movement to alpine habitat Manage human activity to minimize the chance of encounters and illegal kills Consider ways to concentrate human activity within landscapes If an HCA-type approach is used, then the above reserves would not be an additional need if each large HCA contains a class I stream
Old-growth ecosystem	All other old-growth-associated wildlife species Other riparian forest associates All animal and plant ecosystem components Biological diversity Old growth as an ecosystem How well these parameters are covered (or not covered) by the individual species considered above	Include a "full array" of habitats and environmental conditions within an old-growth conservation network This full array should include representation by ecological province, elevation, plant association-cover type, island size, channel type, and old-growth patch sizes Maintain connectivity between the components of the network Include unique and rare features (research natural areas and special interest areas, for example)

[a] See Julin and Caouette, this volume, for clarification of volume class.

Proposed option 1—This option has the widest stream buffers and the lowest level of risk to fish compared to other options. It provides the greatest benefit to organisms in addition to fish (USDA Forest Service 1994).

Proposed option 2—This option incorporates the basic recommendations of the anadromous fish habitat assessment (USDA Forest Service 1995). Were this option implemented, it would result in a moderate level of risk to fish compared to other options. Organisms other than fish would experience a moderate level of benefit under this option. Stream buffer widths are generally intermediate, between those in options 1 and 3.

Proposed option 3—This option adopts the riparian direction of the 1991 TLMP revision supplement (USDA Forest Service 1991), which goes beyond the Tongass Timber Reform Act (TTRA) stream buffer requirements. This option has the highest level of risk to fish compared to other options and is least beneficial to other organisms.

TLMP—The current TLMP follows the stream buffer requirements in TTRA and best management practices (Forest Service Handbook [FSH] 2509.22—Soil and Water Conservation Handbook). This option would have a higher risk to fish and riparian-associated wildlife (brown bear [*Ursus arctos*], for example) than any of the proposed options. Risks were broadly categorized by participants into high, moderate, and low groups, with the understanding that all such labels are intended only as relative comparisons among the approaches considered and do not relate to any outside standards per se. The evaluations also were predicated on our limited ability to predict actual habitat conditions (changes) over time under each set of “building blocks.” This effort thus was not a formal analysis of risks to viability—that will come later when Forest plan alternatives have been developed—but it simply used the concept of risk to combine elements of possible approaches and array those approaches comparatively.

Wildlife corridors would experience reduced function as a result of this option. Uneven-aged systems, long rotations, and an extensive reserve system could compensate for the higher level of risk.

Silvicultural systems—Alternatives to clearcutting, including uneven-aged systems and some even-aged systems, and the use of intermediate treatments (thinning and pruning, for example), may reduce or mitigate the adverse effects of large, even-aged clearcuts on forest fragmentation and help to maintain or promote the development of certain stand characteristics found in old-growth forests. Using longer “rotations” or cutting cycles (the number of years between final harvests for even-aged management, or the age of the oldest tree for uneven-aged management) also could help to promote desired stand conditions by allowing timber stands more time to undergo natural stand development processes.

The current rotation age of about 100 years was considered insufficient for development of forest stand attributes approximating the composition, structure, and function of old-growth forests—attributes that generally do not develop until stands are at least 150 to 250 years old.

Uneven-aged silvicultural systems that may closely approximate the natural disturbance patterns occurring in the temperate rain forest have been used rarely in southeast Alaska. The long-term success of these alternative methods currently is unknown. We are concerned about the long-term health and species composition resulting from methods other than clearcutting. Extended rotations that help achieve desired late-successional and old-growth conditions may be successful in promoting forest health and biodiversity.

Longer rotations, uneven-aged management, and intermediate treatments also may have potential for maintaining desired riparian and beach fringe characteristics and could reduce size requirements for these areas. This approach has not been evaluated or tested, however, and was not considered in the anadromous fish habitat assessment (USDA Forest Service 1995). In all cases, these methods may only approximate certain old-growth forest attributes, and although they might meet needs of certain wildlife species, they are not likely to provide the full range of structure and composition characteristic of fully functioning, old-growth ecosystems. This incompleteness is partly because the periodic harvest of all areas suitable for timber production alters ecosystem dynamics, and partly because the removal of biomass alters ecosystem function.

Conventional silvicultural systems provided four conceptual choices for this viability component, which are described below.

Even-aged short rotation—This system prescribes the harvest of an entire timber stand about every 100 years. An even-aged, short-rotation system was considered to have the highest level of risk for old-growth-associated wildlife species.

Uneven-aged short cutting cycle—This system prescribes the periodic (<200 years) harvest of single trees or small groups of trees within a stand. This approach was judged to have a moderate level of risk for old-growth-associated wildlife species.

Even-aged long rotation—This system prescribes the harvest of an entire timber stand at intervals somewhat greater than 200 years. An even-aged, long-rotation system has a moderate level of risk for old-growth-associated wildlife species.

Uneven-aged long cutting cycle—This system prescribes the periodic (>200 years) harvest of single trees or small groups of trees within a stand. An uneven-aged, long cutting-cycle system was considered to have the lowest level of risk for old-growth-associated wildlife species.

Old-growth reserves—One basic approach to wildlife conservation is to provide a dispersed system of protected habitat areas or reserves of a specified size, forest composition, and spatial distribution that are appropriately spaced throughout a landscape and connected by suitable dispersal corridors. When based on the needs of representative species, such a system can effectively contribute to maintaining habitat to support viable populations of many old-growth-associated wildlife species. The Interagency Viable Population Committee (Suring and others 1993) used the habitat reserve approach in recommending a system of habitat conservation areas (HCAs), well distributed across the Tongass, to provide habitat for viable populations of old-growth-associated species.

We identified several limitations in the HCA strategy. The strategy was based on the known requirements of only a few wildlife species. Although they all have a range of needs related to old-growth forest, there is no assurance that all or even most other old-growth-associated species have similar needs or are adequately represented. Even our knowledge about the species used for the HCA system is limited. In addition, the HCA network is related more to the size and spacing requirements of certain wildlife species rather than to the actual distribution of old-growth blocks found on the Tongass; thus it may not accurately represent the extent or distribution of the old-growth forest ecosystem (DeGayner and Iverson, in prep.).

There is an even more fundamental concern: Our knowledge of the specific viability requirements of most Tongass wildlife species is limited. The key species may represent or be indicative of the requirements of other old-growth-associated species, but these relations have not been described. The old-growth forest ecosystem is, however, the dominant ecosystem in southeast Alaska that provides habitat for many species. Therefore, a “systems” approach examining the old-growth ecosystem by itself as a key component of a viability strategy is likely to address the requirements of all old-growth-associated species. A recent inventory of the old-growth resource, based on the size of the remaining contiguous old-growth areas, or “blocks,” provides this old-growth ecosystem information (DeGayner and Iverson, in prep.).

The old-growth inventory (DeGayner and Iverson, in prep.) divided contiguous old growth into four block sizes: category 1 (more than 10,000 acres), category 2 (1,000 to 10,000 acres), category 3 (less than 1,000 acres and with relatively high ecological value), and category 4 (under 1,000 acres and with relatively low value). Blocks were characterized by the proportion of interior forest, the range of elevations covered, adjacency to diverse habitats, and distribution within a landscape or island. Two old-growth reserve options were considered. The first selects one category 1 old-growth block for each of the 21 biogeographic provinces of the Tongass. The second selects a proportional amount of the remaining old growth based on its current distribution—in this case, 75 percent of the acreage of all category 1 and 2 blocks.

Four conceptual choices for the old-growth viability component were identified and are described below. For all reserve options, we assumed that risk to viability decreases as the number and size of old-growth areas increase and as these areas are more evenly distributed. It also was assumed that existing withdrawn areas will remain in place. Reserves are designed to preserve old-growth ecosystems and their inherent biodiversity, rather than for wildlife habitat conservation.

No old-growth reserves—This approach does not designate additional blocks or areas of specifically protected old-growth forest beyond those already contained in nontimber-harvest areas, such as wilderness. This option was considered to have the highest risk of losing a representative amount and distribution of old-growth-associated organisms. This risk could be lowered by using long-rotation, uneven-aged systems and maintaining large riparian buffers.

Habitat conservation areas—The HCA approach is a designed system of protected old-growth reserves meeting specified size and spacing requirements. This option was considered to have the lowest risk for many old-growth-associated species. There is a moderate to high risk of losing representative amounts and distributions of old-growth ecosystems Forest-wide. Use of long rotations or uneven-aged management within the matrix was thought to reduce viability risks.

One large block per ecological province—This approach provides old-growth habitat blocks of 10,000 acres or more selected from the old-growth inventory and maintained as habitat reserves. It was considered to have a moderate risk of losing old-growth ecosystems distributed by their natural occurrence. The risk to many old-growth-associated organisms was considered to be high, unless coupled with HCAs, extended rotations, or uneven-aged management.

Proportional representation of Forest-wide distribution—This option selects a proportional amount of the remaining old growth based on its current distribution—in this case, 75 percent of the acreage of all large and medium blocks. A moderate to low risk to old growth was thought to result from this option, depending on timber practices within the matrix. This option may not meet size or distributional needs for some species; connectivity needs to be considered.

Beach fringe—Beach fringe is the strip of vegetation adjacent to saltwater shorelines that serves as a wildlife travel corridor, a transition zone between interior forest and saltwater influences, and an important habitat for many wildlife species (Suring and others 1993). Beach fringes may provide important horizontal or low-elevation connectivity between watersheds. In conjunction with riparian areas, which provide elevation habitat connectivity within watersheds, beach fringes may function as an important forested landscape link among watersheds, especially in the heavily dissected landscape characterizing the Tongass.

It is not known if the beach fringe zone can be classified as its own ecosystem, perhaps analogous to the riparian ecosystem that is defined in part by its riparian soils, channel morphology, and forested component; however, the old-growth forest portion of much of the beach fringe is the primary habitat component for numerous wildlife species including bald eagle *(Haliaeetus leucocephalus)*, river otter *(Lutra canadensis)*, mink *(Mustela vison)*, marten, and American crow *(Corvus brachyrhynchos)*. A concern is that a narrowly defined beach fringe corridor (average 500-foot width, for example) would not maintain “interior old-growth” characteristics of this forested component (Concannon 1995). Thus, one option considered was to increase the beach fringe width to a 1,000-foot minimum to ensure that the old-growth portion of this zone retains its interior old-growth function. This approach also helps to eliminate the probably arbitrary distinction between beach fringe forest and maritime-influenced forest. Thus, three beach fringe options were considered: no beach fringe, 500-foot beach fringe, and 1,000-foot beach fringe. Each option is described below.

No beach fringe—The current Forest plan prescribes no beach fringe. Use of this option will reduce the beach forest ecosystem and interior old-growth functions. Loss of wildlife travel corridors and important winter habitat also will result. This option was considered to have the highest risk for wildlife viability associated with these habitat functions.

500-foot beach fringe—This option provides a beach fringe of generally 500 feet with a 1,000-foot corridor around estuaries. Use of this option will maintain a narrow beach-forest ecosystem. It results in the loss of interior old-growth function and was considered to present less risk to some species, but not to those requiring interior old-growth habitat near the beach.

1,000-foot beach fringe—This option would maintain 1,000-foot “no harvest” buffers along beaches. Use of this option will maintain the beach-forest ecosystem and the quality of interior old-growth habitat. It was considered to present a low risk to associated wildlife and to maintain connectivity among intact blocks of old-growth forest.

Nine conceptual approaches—From the above considerations for these four components, the various options within the components were variously combined to portray several possible Forest-wide approaches to maintaining wildlife viability (table 2).

For most of the conceptual approaches designed, the focus was on finding different combinations of building block components that would result in different likelihoods of ensuring viability. For example, the current TLMP has the following combination of building block components: minimum 100-foot riparian buffers for the riparian component, 85-percent even-aged short rotation and 15-percent even-aged long rotation for the silvicultural system, and no reserves or beach fringe (table 2). We consider these components to have a relatively high risk for wildlife viability. In contrast, another conceptual design was developed with riparian option 1, uneven- and even-aged long rotations, HCA reserves, and a 1,000-foot beach fringe with additional species-specific management standards and guidelines. This conceptual design was considered to have a relatively low risk of not maintaining viable wildlife populations.

A few general comments on risks and tradeoffs among options:

- The existing system of reserves within the Tongass (areas withdrawn, such as wilderness, legislated LUD II [LUD II lands are managed in a roadless state], and research natural areas—regardless of the habitat they include) do not in themselves provide sufficiently well-distributed or fully representative habitat across the Tongass to ensure maintenance of viability for all species.

- A relatively high risk was assumed to exist for fish without application of the proposed ecologically significant units (ESUs). This reserve system is designed around fisheries concerns, however, and may contribute only minimally to a wildlife or old-growth reserve system.

- The current Forest plan, due to its reliance on short-rotation clearcutting, lack of a Forest-wide reserve strategy, and limited riparian protection, was considered to have a high risk for all species of concern, for the old-growth ecosystem, and for biodiversity. Generally, uneven-aged silvicultural methods, and (in particular) extended rotations (>200 years), were considered to either reduce the need for the more extensive reserves or lower the risk category for an approach that otherwise used even-aged management and short rotations. Some information suggests that more than 300 years may be needed to achieve the structural characteristics of old-growth forests. For the present effort, however, more than 200 years was used to define extended or long rotations.

- The Interagency Viable Population Committee strategy (Suring and others 1993) with its habitat conservation area system, as applied to the current Forest plan, may be favorable for many species but is considered deficient in corridor design and matrix management. It retains a high risk for fish, and possibly also for marbled murrelet, northern goshawk, the old-growth ecosystem, and biodiversity.

Table 2—9 alternative conceptual approaches to a forest-wide viability strategy

Viability approaches[a]	Riparian options[b]				Silvicultural systems[c]				Old-growth reserves[d]			Beach fringe options[e]			VPOP S&Gs[f]
	1	2	3	TLMP	ES	US	EL	UL	HCA	1/prov.	%	None	500 ft	1,000 ft	
Higher risk:															
TLMP[g]				X	85%		15%					X			
High-risk approach 1 (H-1)				X	75%		25%				X				
High-risk approach 2 (H-2)				X			X					X			
Viable populations approach (Suring and others 1993; VPOP)				X	X				X				X		X
Moderate-risk approach 1 (M-1)	X				X				X	X			X		
Moderate-risk approach 2 (M-2)			X				X	X		X			X		X
Low-risk approach 1 (L-1)		X					X	X	X	X				X	X
Low-risk approach 2 (L-2)		X							X		X			X	X
Low-risk approach 3 (L-3)	X				X		X	X	X		X			X	X
Lower risk[h]															

[a] All approaches assume the same existing withdrawn areas (wilderness, research natural areas, legislated LUD II [lands managed in a roadless state]).

[b] Riparian options: 1, 2, and 3 are from the anadromous fish habitat assessment-related proposals (USDA Forest Service 1995). TLMP includes the Tongass Timber Reform Act buffers.

[c] Silvicultural options: ES = even-aged short rotation (<200 years); EL = even-aged long rotation (>200 years); US = uneven-aged short cutting cycle (<200 years); UL = uneven-aged long cutting cycle (>200 years).

[d] Old-growth reserves: HCA = the Viable Populations Habitat Committee's habitat conservation area guidelines (Suring and others 1993); 1/prov. = 1 large old-growth block per ecological province. Where this and HCA are both checked, they are additive. % = the distribution of reserves based on the historical distribution of old-growth forest (1954 condition). As applied here, this means 75 percent of large- and medium-sized old-growth block acreage, including HCAs, in reserves.

[e] Beach fringe buffers: 500 ft = beach fringe as used in the TLMP revision supplement; 1,000 ft = beach fringe of a minimum of 1,000 feet, more if the beach fringe ecosystem extends further.

[f] VPOP S&Gs: species-specific habitat management standards applied in addition to habitat conservation areas in Suring and others (1993).

[g] TLMP: current Tongass Forest plan.

[h] Conceptual approaches were ranked along a continuum from higher to lower potential risks to wildlife viability.

- Approaches lacking an old-growth reserve system, based on the old-growth inventory and distributed proportionately, were considered less likely to ensure a low level of risk for the old-growth ecosystem and for biodiversity (and also for the northern goshawk, depending on management actions within the matrix).

Approaches that include the following components were considered to be in a lower risk category:

- Species-specific standards and guidelines derived from the Viable Populations Committee strategy (Suring and others 1993), particularly those for road access management (i.e., wolf, brown bear, marten)
- Maintenance of the old-growth ecosystem across a full array of geographic and environmental conditions (table 2)
- The 1,000-foot option for the beach fringe to help maintain interior forest conditions in that zone
- One of the three riparian options, preferably option 1 or 2

Many possible tradeoffs exist between the type of silvicultural system(s) chosen and the need for an extensive reserve system or wider riparian and beach fringe zones, or both.

- One tradeoff of using extended rotations or uneven-aged systems is that, to achieve the same harvest level as could have been achieved under even-aged, short-rotation systems, more area would need to be harvested and more miles of road built in a given time. Thus, the risk of not maintaining fully functioning old-growth ecosystems may not decrease as a result of using these alternative systems.
- When the use of any silvicultural system as an alternative to reserves is being considered, the effects of roading and road use, which may in some cases equal the effects of harvesting, also need to be considered, particularly for wolf, brown bear, and marten.
- Many of these conceptual approaches assume a general tradeoff between areas in short-rotation, even-aged systems and areas set aside in reserves (including riparian and beach fringe). For instance, if the suitable timber base in an alternative were managed under an even-aged, short-rotation system, then more areas within reserves would be required for a comparable level of risk than if the suitable timber base in the same alternative were managed for long rotations. As another example, an alternative using only uneven-aged, longer cutting cycles and a less restrictive riparian option than one using even-aged or short-rotation systems may achieve a similar level of riparian risk.

All reserve options considered herein should be understood to exclude timber harvest within the reserve. It may be possible, however, to include a form of reserve that allows some types of light-intensity timber harvest closely emulating the size, scale, and intensity of natural disturbance processes (Nowacki and Kramer, in prep.).

Although there was not consensus among workshop participants concerning exact rankings, there was agreement on general levels of risk (i.e., low, moderate, high). Table 3 includes the rationale (based on the subjective judgment of meeting participants) used for these relative rankings, which is divided into riparian, terrestrial vertebrate, and old-growth ecosystem concerns. Much of this rationale is drawn from

Table 3—Rationale for the relative risks associated with each conceptual approach to viability (refer to table 2 for conceptual approaches)

Approaches and relative risk	Riparian	Terrestrial vertebrates	Old-growth ecosystem
Current TLMP and high-risk approach 1 (H-1)	Concern for fish and aquatic organisms Reduced connectivity within watersheds Concern for riparian-associated wildlife (such as brown bear)	Excess amount of landscape in early seral conditions Inadequate control on size and distribution of reserves Reduced connectivity between patches, complicated by lack of beach fringe habitat Potential impact of roads	Lack of adequate reserve system, extensive use of short rotations, and lack of connectivity Reduction in available interior old-growth conditions Will not provide full representation of old-growth ecological conditions
High-risk approach 2 (H-2)	Similar to above, but risk is reduced with higher percentage of landscape in late seral condition at any one time	Similar to above, except more connectivity provided within and between watersheds owing to extended rotations Road impacts could be higher	Potential high risk with more acreage under timber management
Viable populations approach (Suring and others 1993; VPOP)	Beach fringe and reserve system mitigate current riparian policy; may not meet long-term productivity goals Concern for riparian-associated wildlife and aquatic organisms	Moderate connectivity provided within beach fringe and riparian areas Percentage of landscape in late seral condition may be insufficient for some species (e.g., goshawk, deer, wolf)	Representation of old-growth conditions not ensured and not extensive Connectivity between many blocks remains low
Moderate-risk approach 1 (M-1)	Reserve system contributes to riparian ecosystem	Greater contribution of riparian Percentage of landscape in late seral condition may be insufficient for some species (e.g., goshawk, deer, wolf)	More extensive reserves and riparian areas Connectivity between many blocks remains low
Moderate-risk approach 2 (M-2)	Beach fringe and reserves contribute to riparian ecosystem	Tradeoff between lower amount in reserves and longer rotations	Tradeoff between lower amount in reserves and longer rotations Moderate connectivity provided
Low-risk approach 1 (L-1)	Intermediate coverage of riparian ecosystem	More productive riparian area Extended beach fringe connectivity High percentage of landscape in late seral stages	Adequate size and distribution of habitats and patches; less in late successional forest than L-2 or L-3 Connectivity provided by extensive riparian and beach fringe systems and well-distributed reserves
Low-risk approach 2 (L-2)	Intermediate coverage of riparian ecosystem	Same as L-1, except tradeoff between more reserves and short-rotation, even-aged management	Same as L-1, except better representation of late successional forest conditions
Low-risk approach 3 (L-3)	Extensive riparian area in combination with reserves and long rotations	Essentially the same as L-1 but a greater percentage of landscape in late seral stages	Greatest representation of late successional forest conditions

the species- and issue-specific information provided during workshop presentations (table 1) and consideration of landscape building block key components. This information provides in detail the criteria, rationale, and thought processes used to develop an array of conceptual approaches to manage for viability and to develop other approaches from the same components. This information was developed to provide the TLMP Revision Interdisciplinary Team with necessary input to incorporate reasonable strategies for maintaining the habitat necessary to ensure viable, well-distributed populations of fish and wildlife species across the Tongass.

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Appendix A

The Viability Synthesis Workshop Charter.

Introduction

As part of the revision process for the Tongass land management plan (TLMP), five assessments designed to synthesize available information on wildlife species of particular concern to management of the Tongass National Forest (Tongass) have been conducted. In addition to these species-specific assessments, which include the northern goshawk *(Accipiter gentilis)*, Alexander Archipelago wolf *(Canis lupus ligoni)*, marbled murrelet *(Brachyramphus marmoratus)*, and anadromous salmonids (Salmonidae), ecosystem-oriented assessments were conducted (i.e., habitat conservation areas, old-growth patch analysis, and karst terrain and caves). These assessments augment other information available on an array of species of management interest in the Tongass (e.g., Sitka black-tail deer [*Odocoileus hemionus*], brown bear [*Ursus arctos*], mountain goat [*Oreamnos americanus*], bald eagle [*Haliaeetus leucocephalus*], and marten [*Martes americana*]). Brief presentations on each assessment and on the other major species of interest will be provided at the workshop.

At present, the information contained within each individual assessment has not been evaluated in context with the other assessments. No attempt has yet been made to synthesize this array of assessments and other information sources to clarify habitat factors in common versus those that may be species specific. There is a strong need to accomplish this evaluation and synthesis and then package the combined information such that it provides direct input for development of alternatives for TLMP.

Objective

The objective of the workshop is to evaluate and synthesize available information obtained from recently conducted, Tongass-specific assessments and various other sources (Suring and others 1993). The process needs to identify habitat factors and other needs that may be in common across the various species of interest (e.g., old-growth association or dependence), as well as those factors that may still be highly important but more species specific (e.g., road density).

Product

Ideally, we would like to leave the workshop with an array of landscape-level management options for use in development of Forest plan alternatives that adequately address the issues associated with species and ecosystem viability. Specifically, the workshop needs to provide various combinations of the above-mentioned landscape designs, guidelines, and other “building blocks” that will maintain or restore:

- Terrestrial habitat conditions for the northern goshawk, Alexander Archipelago wolf, and marbled murrelet so that viable populations will persist in a well-distributed manner across their current ranges.
- Terrestrial habitat conditions to support viable populations, well distributed across their ranges, of terrestrial species associated with all Tongass ecosystems.
- Aquatic habitats to support viable populations of resident and anadromous fish species and stocks of other aquatic organisms.
- Functional and interactive ecosystems, including old-growth forests and aquatic systems.

The actual “risk” assessment that any particular Forest plan alternative will meet the species-specific viability needs will be independently evaluated through a panel review process.

We will develop sets of alternative landscape designs and management guidelines that incorporate (separately or in various combinations) reserves, matrix management, or other “building blocks” to provide various levels of assurance that any subsequent Forest plan alternative developed from these sets will maintain viable populations of all species as well as sustain overall ecosystem structure, composition, and function. In developing these sets, we need to ensure that land stewardship is not compromised and appreciate that some level of long-term, sustainable output of various resources (e.g., timber, recreational experiences) is desired.

Possible Approach

We should consider a landscape approach that builds on other spatially explicit components of the Forest plan (e.g., designated wilderness, anadromous fisheries habitat assessment [USDA Forest Service 1995], directed riparian management standards). To build this foundation, we append additional standards or landscape features as building blocks considered necessary to provide well-distributed habitat for the above-mentioned species and environments. These components can then be used to construct Forest plan alternatives. Four landscape-level themes serve as possible approaches:

1. Dynamic landscape management predicated on disturbance regimes and no reserves.

2. Some combination of small, medium, and large reserves connected by a matrix of lands experiencing various management actions (e.g., patch cuts of various sizes and distributions, partial cuts of various sizes and distributions, partial cuttings that remove various levels and components of stocking).

3. Fewer but very large reserves within each landscape stratum (e.g., biogeographic province or island) coupled with the matrix management approach indicated in number 2 above.

4. Combinations across the forest of numbers 1, 2, and 3 specifically applied to landscapes and predicated on the existing and desired condition.

Appendix B

Viability Synthesis Workshop participants, June 7-9, 1995.

Participants	**Affiliation**
Mike Brown	USDA Forest Service, Alaska Region
Steve Brink	USDA Forest Service, Alaska Region
Jack Capp	USDA Forest Service, Alaska Region
John Caouette	USDA Forest Service, Pacific Northwest Research Station
Eugene DeGayner	USDA Forest Service, Alaska Region
Richard Enriquez	U.S. Fish and Wildlife Service
Rod Flynn	Alaska Department of Fish and Game
Rick Griffen	USDA Forest Service, Alaska Region
Carol Hale	U.S. Fish and Wildlife Service
Dick Holthausen	USDA Forest Service, Alaska Region
George Iverson	USDA Forest Service, Alaska Region
Steve Kessler	USDA Forest Service, Alaska Region
Matthew Kirchhoff	Alaska Department of Fish and Game
Jerry McIlwain	USDA Forest Service, Pacific Northwest Research Station
Chris Meade	U.S. Environmental Protection Agency
Gregory Nowacki	USDA Forest Service, Alaska Region
Martin Raphael	USDA Forest Service, Pacific Northwest Research Station
Bruce René	USDA Forest Service, Alaska Region
Ted Schenk	USDA Forest Service, Alaska Region
Terry Shaw	USDA Forest Service, Pacific Northwest Research Station
Winston Smith	USDA Forest Service, Pacific Northwest Research Station
Douglas Swanston	USDA Forest Service, Pacific Northwest Research Station
Kimberly Titus	Alaska Department of Fish and Game
Richard Zaborske	USDA Forest Service, Alaska Region

Appendix C

Materials presented by George Iverson during the workshop.

Table 4—Criteria for habitat conservation areas proposed to maintain viable and well-distributed populations of wildlife associated with old-growth forests in southeast Alaska

Species	Large HCAs[a]	Medium HCAs[a]	Small HCAs[a]
Brown bear	40,000 acres 20 miles apart 1 class-I stream 5 females	—	—
Marten	40,000 acres 25 miles apart 25 percent volume class 4[b] 25 percent volume class 5+ 25 reproductive units	8,000 acres 9 miles apart 25 percent volume class 4 25 percent volume class 5+ 5 reproductive units	1,600 acres per watershed 50 percent volume class 4+ 1 reproductive unit
Flying squirrel	—	—	1,000 acres per watershed volume class 4+ 10-20 pairs
Northern goshawk	40,000 acres 20 miles apart 25 percent volume class 4 25 percent volume class 5+ 8 pairs	10,000 acres 20 miles apart 25 percent volume class 4 25 percent volume class 5+ 2 pairs	—
Combined standard	40,000 acres 20 miles apart 25 percent volume class 4 25 percent volume class 5+ 1 class-I stream	10,000 acres 20 miles apart 25 percent volume class 4 25 percent volume class 5+	1,600 acres per watershed 50 percent volume class 4+

[a] HCA = Habitat conservation area.
[b] See Julin and Caouette, this volume, for clarification of volume class.

Source: Suring and others 1993.

Table 5—Wildlife species associated with old-growth forest habitats that are recognized as having potential viability or distribution concerns in southeast Alaska

Common name	Scientific name
Bald eagle	*Haliaeetus leucocephalus*
Marbled murrelet	*Brachyramphus brevirostris*
Vaux's swift	*Chaetura vauxi*
Black bear	*Ursus americanus*
Least weasel	*Mustela nivalis*
Mink	*Mustela vison*
River otter	*Lutra canadensis*
Mountain goat	*Oreamnos americanus*
Sitka mouse	*Peromyscus sitkensis*
Coronation Island vole	*Microtus coronarius*

Source: Suring and others, in prep.

Table 6—Wildlife species associated with old-growth habitats that are recognized as having viability or distribution concerns in southeast Alaska

Common name	Scientific name
Osprey	*Pandion haliaetus*
Queen Charlotte goshawk	*Accipiter gentilis laingi*
Spruce grouse	*Dendragapus canadensis*
Alexander Archipelago wolf	*Canis lupus ligoni*
Brown bear	*Ursus arctos horribilis*
Wolverine	*Gulo gulo*
Marten	*Martes americana*
Lynx	*Lynx canadensis*
Northern flying squirrel	*Glaucomys sabrinus*

Source: Suring and others, in prep.

Table 7—Levels of concern[a] associated with viability or distribution, or both, for the 9 highest ranked wildlife species in southeast Alaska[b]

	Evaluation criteria[c]												
Species	1	2	3	4	5	6	7	8	9	10	11	12	Total[d]
Brown bear	3	0	0	2	3	2	1	3	1	3	3	1	22 (61)
Marten	3	0	0	1	3	2	3	3	2	1	0	2	20 (56)
Queen Charlotte goshawk	3	0	2	2	2	2	3	2	0	1	1	2	20 (56)
Osprey	2	3	0	3	1	1	2	2	0	2	2	2	20 (56)
Spruce grouse	3	2	0	2	1	2	2	3	2	0	0	3	20 (56)
Wolverine	3	1	0	3	2	2	1	1	0	2	1	3	19 (53)
Northern flying squirrel	3	0	0	—	2	—	3	0	2	2	0	3	19 (53)
Alexander Archipelago wolf	3	0	2	2	1	0	1	3	2	1	1	2	18 (50)
Lynx	3	2	0	—	1	1	0	3	1	1	1	3	18 (50)

[a] Level of concern:
— = information is inadequate (assigned 2 points)
0 = no concern
1 = low
2 = moderate
3 = high

[b] Ranked 50 percent or greater.

[c] Evaluation criteria:

Criteria	Assigned points
1. Seasonal occurrence in southeast Alaska	
a. Transient	0
b. Resident during winter or breeding season	1
c. Resident during breeding season	2
d. Permanent resident	3
2. Geographic distribution within southeast Alaska	
a. Species occurs in 7+ ecological provinces	0
b. Species occurs in 4-6 ecological provinces	1
c. Species occurs in 2-3 ecological provinces	2
d. Species occurs in 1 ecological province	3
3. Geographical distribution outside southeast Alaska	
a. Species distribution more than 200 percent of the size of southeast Alaska	0
b. Species distribution 100 to 200 percent of the size of southeast Alaska	1
c. Species distribution 50 to 100 percent of the size of southeast Alaska	2
d. Species distribution 0 to 50 percent of the size of southeast Alaska	3
4. Estimated size of the population in southeast Alaska	
a. More than 10,000 individual throughout its range	0
b. 2,500 to 10,000 individuals throughout its range	1
c. 250 to 2,500 individuals throughout its range	2
d. Less than 250 individuals throughout its range	3
5. Population trend throughout the species' range	
a. Population known or suspected to be stable or increasing	0
b. Population formerly experienced a downward trend but presently is stable or increasing	1
c. Population suspected to be decreasing over a 10-year period	2
d. Population known to be decreasing over a 10-year period	3

Table 7—Levels of concern[a] associated with viability or distribution, or both, for the 9 highest ranked wildlife species in southeast Alaska[b] (continued)

[c] Evaluation criteria: *(continued)*

Criteria	Assigned points
6. Population trend of the species in southeast Alaska	
a. Population known or suspected to be stable or increasing	0
b. Population formerly experienced a downward trend but presently is stable or increasing	1
c. Population suspected to be decreasing over a 10-year period	2
d. Population known to be decreasing over a 10-year period	3
7. Vulnerability of habitats in southeast Alaska	
a. Species' habitat is unlikely to be affected by land management activities, species is not negatively affected by habitat fragmentation, and species is an ecological generalist	0
b. Species' habitat is likely to be affected by land management activities, species is not negatively affected by habitat fragmentation, and species is an ecological generalist	1
c. Species' habitat is likely to be affected by land management activities, species is negatively affected by habitat fragmentation, or species is an ecological specialist	2
d. Species' habitat is likely to be affected by land management activities, species is negatively affected by habitat fragmentation, and species is an ecological specialist	3
8. Vulnerability to road construction and increased access	
a. Species unlikely to be affected by increased access	0
b. Species harvest likely to increase but will not affect population levels; species not susceptible to increased disturbance	1
c. Species not harvested but susceptible to increased disturbance	2
d. Species vulnerable to over harvest or other increased mortality as a result of increased access	3
9. Capability of a species to disperse	
a. Species are mobile and dispersal is not limited	0
b. Dispersal is limited	3
10. Demographic characteristics of the species. Average number of eggs or live young produced per adult female per year	
a. Less than 1 egg	3
b. 1 to 2 eggs	2
c. 3 to 5 eggs	1
d. More than 5 eggs	0
11. Demographic characteristics of the species. Minimum age of first reproduction.	
a. More than 5 years	3
b. 3 to 4 years	2
c. 2 years	1
d. Less than 2 years	0
12. Knowledge about the species in southeast Alaska	
a. Limited knowledge concerning a species beyond documentation of their occurrence in southeast Alaska	3
b. Species are monitored locally without statistical validity, and habitat associations are extrapolates from other areas	2
c. Species are monitored throughout southeast Alaska with statistical validity, and habitat associations are established in southeast Alaska	1
d. Species whose distribution and habitat relations are well documented in southeast Alaska and throughout their range	0

[d] Percent is shown in parentheses.

Source: Suring and others, in prep.

Appendix D
Immediate Actions Needed

The following is a summary of suggested actions that respond to comments made by the peer reviewers (Kiester and Eckhardt 1994). In particular, the peer reviewers' recommendations to keep landscape options open (i.e., avoid logging low-elevation, high-volume old-growth forests; maintain connectivity between habitat conservation areas; consider larger habitat conservation areas; pay attention to the matrix) until the revision of the Tongass land management plan has been completed are briefly addressed here. Pertinent suggestions from the review are given.

1. Restrict logging and road building to areas other than volume classes 6 and 7 in old-growth forests (as determined by field reconnaissance) below 800 feet in elevation.

2. Restrict logging, road building, and salvage sales to areas other than large- and medium-sized habitat conservation areas.

3. Restrict logging and road building to areas other than the three largest old-growth forest patches within each ecological province.

4. Establish a 0.5- to 1-mile buffer around all large- and medium-sized habitat conservation areas (as mapped in Suring 1993) as a "special management zone" in which road building and clearcutting are prohibited. Selection harvest may be permitted so long as no more than 25 percent of the volume in any 5-acre block is harvested and original species and size class distributions are maintained.

5. Connect large- and medium-sized habitat conservation areas (as mapped in Suring and others 1993) with corridors in which logging is not allowed (1,600 feet wide between large habitat conservation areas, which are further apart; 1,000 feet wide between medium habitat conservation areas, which are closer together). Keep corridors below 800 feet in elevation. Place a 3,300-foot-wide "special management zone" along the coastline.

6. Maintain old-growth forests that have been identified through local knowledge or field experience as important wildlife habitat (e.g., wildlife habitat retention areas mapped in records of decision before 1992).

7. The number of old-growth forest, volume class 5 acres scheduled for harvest in any sale should not exceed the number of acres scheduled for harvest in old-growth forest, volume class 4.

Options for Defining Old-Growth Timber Volume Strata: A Resource Assessment

Kent R. Julin and John P. Caouette

Issue Definition

The Alaska Region had to decide whether and how the interpreted timber type data layer (TIMTYP) database could be used in the revision of the Tongass land management plan (TLMP revision) for defining the old-growth forest resource. This database, in conjunction with other resource inventories, was used historically by planners at the Tongass National Forest (Tongass) for estimating the allowable sale quantity (ASQ), determining volume proportionality,[1] analyzing timber economics, and calculating wildlife habitat capability. The decision from the Wildlife Society and others vs. Barton (U.S. District Court for the District of Alaska 1994) raised questions about the suitability of the TIMTYP database for determining proportionality under the Tongass Timber Reform Act (TTRA § 301 [c] [2]). In this paper, we discuss five options for estimating old-growth volume and implications of their use on modeling wildlife habitat capability. We also present an approach for reducing the likelihood of overestimating timber volume on the Tongass.

Background

The key components used to define the old-growth volume strata options developed in this paper include the TIMTYP database, the common land unit (CLU) database, and the Tongass timber inventory. Each of these components is described below.

TIMTYP Database

A land type map was created in 1978 by ESCA-Tech[2] for the Tongass. The primary objective of this work was to delineate major land types and their attributes from aerial photographs of the Forest. These land types were mapped at a polygon level—areas generally homogenous in character and greater than 10 acres in size. Polygons in forested areas were assigned a single, representative set of attributes: species composition, age, stocking, volume class, and decadence rating. For example, if a 100-acre area was generally a Sitka spruce (*Picea sitchensis* (Bong.) Carr) forest type in an old-growth condition with uniform crown sizes, it could be classified as S4=5H. This classification means that for average conditions, this polygon was predominantly Sitka spruce (S) identified as old growth (4), was moderately stocked (=), had an estimated volume of 20-30 thousand board feet per acre (5), and had relatively high decadence (H). Within such a 100-acre polygon, however, openings, small stands of different species, and lower and higher volume strata often exist. Forest-wide, there are about 300,000 forested polygons with a mean size of about 60 acres. These land type map data were entered into the Tongass Geographic Information System (GIS) as the TIMTYP database in 1988-89.

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[1] The Tongass Timber Reform Act (Sec. 301 [c] [3]) requires that the harvest of high-volume old growth (volume classes 6 and 7) will not be at an accelerated rate. The act requires that the proportion of harvest in volume classes 6 and 7 will not exceed the proportion of volume of these classes currently represented in a contiguous management area.

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Common Land Unit Database

The CLU database was created independently by Administrative Area (Chatham, Ketchikan, and Stikine) and has been subject to a fairly rigorous field review. This database contains numerous features including but not limited to landform, plant association, and soil series. These features were mapped at a soil management unit (SMU) scale. About 825 separate SMU types were assigned to nearly 114,000 polygons across the Forest. The SMU polygons range from less than 1 acre to nearly 900,000 acres for the Brabazon Range near Yakutat; the Forest-wide average size of these polygons is 115 acres. In this analysis, we used slope class, soil type (hydric or nonhydric), and average site index in the development of options D and E for estimating old-growth timber volumes.

Tongass Timber Inventory

The most recent timber inventory of the Tongass, completed in the early 1980s, estimated net timber volume for each Administrative Area of the Forest plus or minus 10 percent per billion net cubic feet at a 68-percent confidence level. The original objective of the timber inventory was not to sample stands or polygons, but to sample the stratum to which the polygons belonged. The design provides a reasonable estimate of the true average net volume of a particular stratum within an Administrative Area. Because only a relatively small proportion of each polygon was sampled, however, the level of confidence in our estimates of net volume for a particular polygon within any stratum is poor.

The sampling design used in the Ketchikan and Stikine Administrative Areas was different from that used in the Chatham Area. Sampling units for the Ketchikan and Stikine Administrative Areas were 5-acre cluster plots consisting of five systematically placed points each (USDA Forest Service 1984). Whenever plot cluster points fell within two adjacent TIMTYP polygons, points were relocated into the polygon where the first randomly located point was established. In the Ketchikan Area, 201 polygons were sampled, and 139 in the Stikine Area. In the Chatham Area, the sampling unit was a 250-acre cluster plot consisting of about 55 subplots. Point locations were systematically established within polygons (USDA Forest Service 1982). A total of 176 polygons was sampled in the Chatham Administrative Area.

Of the 516 polygons sampled Forest-wide, 457 were within forested volume class (VC) 4-7 polygons. Wilderness areas were excluded from this timber inventory. The Forest inventory estimated volume for each Administrative Area by using the plots described above and areal coverage from the volume item of the TIMTYP database in a poststratified fashion. Using this approach, Rogers and van Hees (1992a, 1992b, 1992c) developed timber resource statistics for each Administrative Area of the Tongass.

Accuracy of Volume Strata Estimates

The spatial accuracy of the volume item of the TIMTYP database was tested by Jim Brickell (former USDA Forest Service, Northern Region, biometrician) with Stikine and Ketchikan data from the Tongass timber inventory (Brickell 1989). Brickell found that the inventory provides a Forest-wide and Administrative Area-wide assessment of the TIMTYP database for each volume stratum, but it cannot be used to assess the TIMTYP database on a polygon level. This inability arises from too few observation points within any given polygon. Brickell also found no statistical basis for

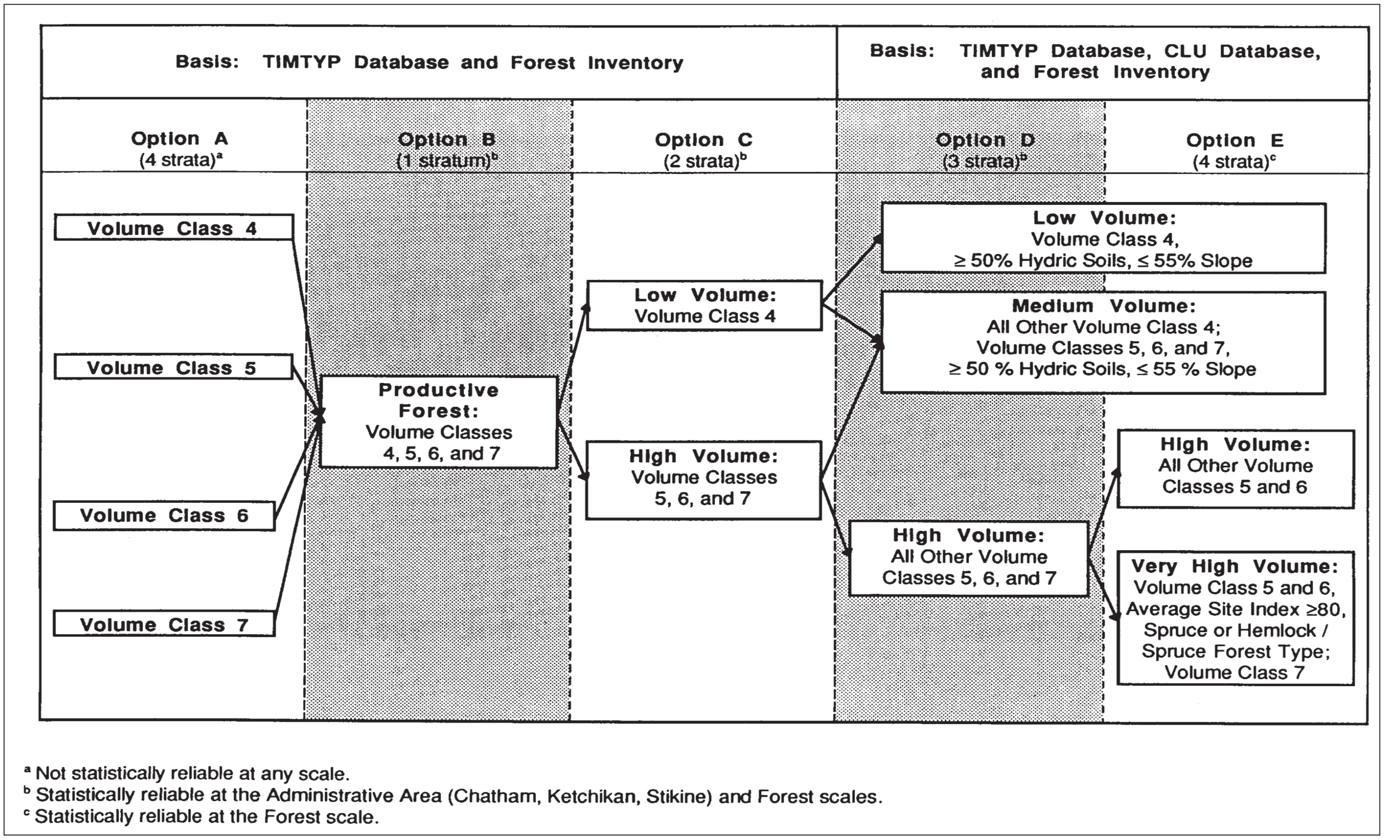

Figure 1—Descriptions and relations among options for estimating old-growth volume.

maintaining separate strata for VC5, VC6, and VC7, based on the timber inventory. Volume strata means were not analyzed by Brickell for the Chatham Area because unit volumes were not readily available. From his experience with timber inventories of similar design in the Northern Region, Brickell opined that “results would not have been substantially different” for the means for the Ketchikan and Stikine Administrative Areas. Our review of these data supports his conclusions (appendix).

Options for Estimating Timber Volume

Five options for estimating net timber volume were identified by TLMP revision team members in 1995. These five options are summarized in figure 1 and are described below. We used the volume class item (volume classes 4, 5, 6, and 7) from the TIMTYP database alone and in combination with the forest type item from the TIMTYP database and several items from the CLU database (slope, hydric and nonhydric soils, and site index) to redefine volume strata. Mean strata volumes and 95-percent confidence intervals are reported for all options for each Administrative Area and the entire Tongass (i.e., all areas combined). Differences in strata means for each option were tested by using analysis of variance (ANOVA) and the Scheffé multiple comparison tests ($\alpha = 0.05$; SAS Institute 1990). Statistics for individual polygon volume estimates within strata are not reported. These statistics are known to include a significant amount of added variation, primarily the result of the limited number of inventory sample points in each polygon.

Table 1—TIMTYP option A net volume estimates, sample sizes, and 95-percent confidence intervals

Volume strata and area	Mean volume	95-percent confidence interval	Sample size
	Mbf/acre[a]	*Mbf/acre*[a]	*Number*[b]
Volume class 4:			
Chatham Area	19.3	± 2.8	58
Ketchikan Area	20.4	± 2.3	72
Stikine Area	23.9	± 3.5	56
Forest wide	21.1	± 1.6	186
Volume class 5:			
Chatham Area	29.4	± 5.2	29
Ketchikan Area	33.1	± 2.8	71
Stikine Area	32.2	± 3.5	55
Forest-wide	32.1	± 2.0	155
Volume class 6:			
Chatham Area	38.3	± 9.5	6
Ketchikan Area	32.5	± 6.4	23
Stikine Area	35.4	± 13.5	8
Forest-wide	34.1	± 4.7	37
Volume class 7:			
Chatham Area	43.7	± 25.0	2
Ketchikan Area	37.1	± 15.5	8
Stikine Area	51.9	± 130.9	2
Forest-wide	40.7	± 10.5	12

[a] Mbf = thousand board feet, Scribner decimal C, 16-foot logs.
[b] 67 samples were excluded from our analysis because they had 3 or fewer subplots (Chatham Administrative Area), had a history of partial cutting, or were on private land.

Option A: Volume Classes 4, 5, 6, and 7

Option A retains the four strata used in the current draft plan revision (USDA Forest Service 1991; fig. 1, table 1). Although there is a statistical basis for segregating VC4 from the higher strata (Brickell 1989), there is none for dividing the higher volume strata. Adopting this option would invite the same type of criticism as received on the draft and supplement to the draft for the TLMP revision (USDA Forest Service 1990, 1991). Although option A appears to offer an opportunity to model habitat capability with the greatest resolution and widest range of conditions, it does not provide confidence because of a lack of statistical differences among the higher volume strata (see appendix).

Table 2—Option B net volume estimates, sample sizes, and 95-percent confidence intervals

Area	Mean volume	95-percent confidence interval	Sample size
	Mbf/acre[a]	*Mbf/acre*[a]	*Number*[b]
Chatham Area	24.1	± 2.7	95
Ketchikan Area	28.0	± 2.0	174
Stikine Area	28.9	± 2.5	121
Tongass-wide	27.3	± 1.4	390

[a] Mbf = thousand board feet, Scribner decimal C, 16-foot logs.
[b] 67 samples were excluded from our analysis because they had 3 or fewer subplots (Chatham Administrative Area), had a history of partial cutting, or were on private land.

Option B: Productive Forest

Under this option, all volume strata designations (VC4-7) from TIMTYP are collapsed into a single stratum and designated "productive forest" for each Administrative Area (fig. 1, table 2). This option uses Area-wide mean volumes from the timber inventory and volume class from TIMTYP. Option B does not distinguish between forest types (VC4 and a grouping of VCs 5, 6, and 7 as depicted on TIMTYP) that the timber inventory shows have statistically significant volume differences at the Forest or Administrative Area scales (see appendix).

The single designation of productive forest provided by this option includes sites representing an extremely broad range of conditions. Using this approach would essentially reduce the stand-level wildlife habitat coefficient to a single value for all sites, though the physical characteristics of each may differ considerably. For wildlife species that are most productive in a relatively narrow range of habitat conditions, this option does not permit a habitat capability analysis that discriminates among suitability of stands differing widely in habitat conditions. Use of a single value to represent stand condition, moreover, excludes specialist species requiring dense high-volume stands or open-canopied low-volume stands. Estimates of wildlife species that occupy a broad range of habitats will be poor because the single volume stratum value will reflect only a small portion of the spectrum of habitat capability that exists and changes across the Forest. For species that do best under disparate volume conditions, but especially those that do best in lower volume conditions, this option will result in underestimating habitat capability. Conversely, it will grossly overestimate habitat capability for species that do best under conditions represented by the mean volume value applied across the Forest. Significantly underestimating or overestimating capability may have implications for subsistence and viability effects analyses.

Table 3—Option C net volume estimates, sample sizes, and 95-percent confidence intervals

Volume strata and area	Mean volume	95-percent confidence interval	Sample size
	Mbf/acre[a]	*Mbf/acre*[a]	*Number*[b]
Low-volume stratum:			
Chatham Area	19.3	± 2.8	58
Ketchikan Area	20.4	± 2.3	72
Stikine Area	23.9	± 3.5	56
Forest-wide	21.1	± 1.6	186
High-volume stratum:			
Chatham Area	31.6	± 4.4	37
Ketchikan Area	33.3	± 2.5	102
Stikine Area	33.2	± 3.4	65
Forest-wide	33.0	± 1.8	204

[a] Mbf = thousand board feet, Scribner decimal C, 16-foot logs.
[b] 67 samples were excluded from our analysis because they had three or fewer subplots (Chatham Administrative Area), had a history of partial cutting, or were on private land.

Option C: Low- and High-Volume Strata

The low- and high-volume option segregates VC4 from a grouping of VCs 5-6-7 for each Administrative Area (fig 1., table 3). This option follows recommendations offered by Brickell (1989) and allows us to recognize statistical distinctions among TIMTYP volume strata shown by the timber inventory. For the Ketchikan and Stikine Administrative Areas, Brickell found that even though there was a statistical difference between VC4 and VCs 5-6-7, there generally were no differences among VCs 5, 6, and 7. Brickell did find one significant difference at the 0.05 probability level for VC5 and VC7 in the Stikine Area but cautioned that it would be unwise to base any inference on only two samples for VC7 (Brickell 1989). He concluded that we could combine VCs 5, 6, and 7 with little sacrifice to the precision of timber estimates.

Option C is an improvement over option B relative to wildlife modeling, because it provides for two stand-level habitat conditions that allow some discrimination of habitat suitability among stands with widely differing conditions. Option C still suffers, however, from some of the problems identified under option B, notably excluding evaluation of specialist species that need habitat conditions at the upper or lower portions of the range of volumes. Although not as often or as great as under option B, option C could result in appreciable underestimates and overestimates of habitat capabilities for some wildlife species across portions of the Forest.

Option D: Low-, Medium-, and High-Volume Strata

Option D uses soils and slope information from the CLU database to explain the variation in the low-and high-volume strata developed in option C (Brickell's [1989] recommendation). This option takes two basic, statistically defensible predictors of volume from the CLU database (i.e., hydric soils and slope) and combines them with

Table 4—Option D net volume estimates, sample sizes, and 95-percent confidence intervals

Volume strata and area	Mean volume	95-percent confidence interval	Sample size
	Mbf/acre[a]	*Mbf/acre*[a]	*Number*[b]
Low-volume stratum:			
Chatham Area	13.2	± 3.2	22
Ketchikan Area	16.1	± 2.5	39
Stikine Area	18.3	± 5.3	16
Forest-wide	15.7	± 1.9	77
Medium-volume stratum:			
Chatham Area	23.0	± 3.0	43
Ketchikan Area	26.2	± 2.7	55
Stikine Area	26.0	± 4.2	42
Forest-wide	25.1	± 1.9	140
High-volume stratum:			
Chatham Area	34.6	± 5.6	25
Ketchikan Area	35.0	± 2.9	80
Stikine Area	34.0	± 3.5	61
Forest-wide	34.6	± 2.0	166

[a] Mbf = thousand board feet, Scribner decimal C, 16-foot logs.
[b] 74 samples were excluded from our analysis: 67 samples because they had 3 or fewer subplots (Chatham Administrative Area), had a history of partial cutting, or were on private land; 7 samples were excluded because they did not have common land unit data.

the two most basic, statistically defensible predictors from the TIMTYP database (fig. 1, table 4). The result is a statistically significant delineation of the forest into three strata (i.e., low, medium, and high) for each Administrative Area (except for low vs. medium for the Stikine Area $0.05<p<0.10$). This option is the product of a study of the applicable "regression variables" suggested by Brickell (e.g., elevation, aspect, slope percentage, site index, landform-plant association, soil type, and forest type). The inventory plots established within a CLU polygon having hydric (≥50-percent areal coverage of hydric soils) and poorly drained soils (as inferred by having less than a 55-percent slope) had a statistically significant lower mean net volume than those that did not for both the "low" VC4 and "high" VC 5-6-7 strata in option C. Polygons in hydric, poorly drained soils often are mixed with or surrounded by nonforested peatlands and often are ecologically different from those polygons surrounded by upland forested areas.

Option D provides a wider range of volume conditions to evaluate habitat capability, which could improve the resolution of effects analysis for more wildlife species. One limitation of option D is that soils and slope information is not available for most wilderness areas within the Tongass, which has important implications for modeling wildlife populations.

Table 5—Option E net volume estimates, sample sizes, and 95-percent confidence intervals

Volume strata and area	Mean volume	95-percent confidence interval	Sample size
	Mbf/acre[a]	*Mbf/acre*[a]	*Number*[b]
Low-volume stratum:			
Chatham Area	13.2	±3.2	22
Ketchikan Area	16.1	±2.5	39
Stikine Area	18.3	±5.3	16
Forest-wide	15.7	±1.9	77
Medium-volume stratum:			
Chatham Area	23.0	±3.0	43
Ketchikan Area	26.2	±2.7	55
Stikine Area	26.0	±4.2	42
Forest-wide	25.1	±1.9	140
High-volume stratum:			
Chatham Area	29.0	±9.2	8
Ketchikan Area	32.4	±3.4	47
Stikine Area	30.6	±4.4	38
Forest-wide	31.4	±2.5	93
Very high-volume stratum:			
Chatham Area	37.2	±7.3	17
Ketchikan Area	39.6	±5.3	29
Stikine Area	39.6	±5.3	23
Forest-wide	39.0	±3.2	69

[a] Mbf = thousand board feet, Scribner decimal C, 16-foot logs.
[b] 78 samples were excluded from our analysis: 67 samples because they had 3 or fewer subplots (Chatham Administrative Area), had a history of partial cutting, or were on private land; 7 samples because they did not have common land unit data; and 4 samples because they did not have site index data.

Option E: Low-, Medium-, High-, and Very High-Volume Strata

This option uses site index from the CLU database, and volume class and forest type information from the TIMTYP database, to subdivide the three strata in option D into four strata: low, medium, high, and very high (fig. 1, table 5). This option is our best effort to statistically delineate the very high volume with available Tongass GIS data. Option E provides a statistically defensible four-strata coverage for the entire Tongass (i.e., all Areas combined) but not for each Administrative Area. This option is less statistically defensible than option D but still has sufficient statistical merit to be considered for quantifying the very high-volume stratum at the Forest scale.

An Approach for Reducing the Likelihood of Overestimating Timber Volume

A basic tenet of the forest planning process is that resources are to be managed sustainably (16 U.S.C. § 531, Multiple-Use Sustained-Yield Act of 1960). In estimating resource abundance, one usually overestimates or underestimates the availability of a given resource. If resources were uniformly distributed spatially, an across-the-area mean probably would not result in the continued underuse or overuse of a resource. In southeast Alaska, though, where the forest is clearly distributed in a spatially heterogeneous fashion, an Area-wide averaging approach will not prevent the possibility of resource overuse in certain segments of the landscape.

It seems prudent that if one wishes to manage resources sustainably, then one needs to prevent overestimating the abundance of resources under management. This approach is especially critical when one recognizes that the management of a keystone resource (fundamental component of an ecosystem, for example) has significant implications for numerous resources across the Forest (wildlife, for example).

Using the mean of a normal sampling distribution of the sample means for a population will, by definition, overestimate the true mean 50 percent of the time. Alternatively, one can reduce the probability of overestimating the true mean by using an estimate of the mean that is less than the mean of the sampling distribution. A conventional approach to characterizing the availability of a resource is to define the population with a mean and a range of values that are inclusive within a specified probability of occurrence within that population for a given sample size. This range of values is typically referred to as a "confidence interval." The confidence interval represents a range of values between which there is a given probability (95 percent, for example) of correctly estimating the true population mean. For example, the lower limit of a confidence interval provides a 5-percent chance of overestimating the true population mean and a 95-percent chance of underestimating the true population mean. Using a lower confidence interval value is one refinement that reduces the likelihood of overestimating the timber resource.

Key Results

Use of the timber volume item of the TIMTYP database in the TLMP revision is limited by the resolution and quality of information available from the timber inventory. The timber inventory used 457 plots distributed across the Forest to estimate volume within the Forest-wide strata identified on a land type map. Even though these data provided a statistical basis for discerning volume strata at the Administrative Area or Forest scale, they did not sample enough points per polygon to estimate the volume of individual polygons. We cannot currently use the timber inventory in a statistically reliable fashion to evaluate the accuracy of the TIMTYP database at scales finer than the Administrative Area (options B, C, and D) and at scales finer than the Forest (option E). None of the options is statistically reliable at the management area, value comparison unit (VCU), or project level. Table 6 presents several advantages and disadvantages of using each option presented above.

Table 6—Advantages and disadvantages of the TIMTYP options

Options	Advantages	Disadvantages
Option A, forest volume classes 4-7	Provides Forest-wide coverage Offers spatially explicit volume information May be useful in identifying stand attributes other than net volume (density, tree size, for example) that are useful in describing wildlife habitat quality	Is not statistically reliable at the Forest, Administrative Area, or finer levels
Option B, productive forest	Provides a single, Area-wide volume stratum for productive forest Simplifies modeling Statistically reliable at the Area- and Forest-wide levels	Does not distinguish between forest types that the timber inventory suggests are statistically different Does not distinguish the less economical land base from the rest Excludes ability to evaluate some volume-specific species Poorly estimates habitat capabilities for species that do best under extremely low- or high-volume conditions
Option C, low- and high-volume strata	Distinguishes among forest types that the timber inventory indicates are statistically different Offers spatially explicit volume information Provides Forest-wide coverage Is statistically reliable at the Area- and Forest-wide scales	Allows some discrimination of habitat suitability among stands with widely differing conditions Excludes our ability to evaluate some volume-specific species Could result in appreciable underestimates and overestimates for some wildlife species (less than option A)
Option D, low-, medium-, and high-volume strata	Provides differences among volume strata that are statistically significant at the Area- and Forest-wide levels Offers spatially explicit volume information Provides a wide range of volume conditions that could improve the resolution of effects analyses	Cannot be applied in most wilderness areas
Option E, low-, medium-, high-, and very high-volume strata	Provides differences among volume strata that are statistically significant at the Forest-wide level Offers spatially explicit volume information Provides the widest range of volume conditions that could improve the resolution of effects analyses	Cannot be applied in most wilderness areas

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Appendix
Summary of Statistical Tests

A summary of results from statistical tests is provided below, by option, that compares polygon sample means within Administrative Areas (Chatham, Ketchikan, and Stikine) and Tongass-wide (ANOVA, Scheffé multiple comparison, $\alpha = 0.05$; SAS Institute 1990). All tests used square root-transformed data to meet assumptions of ANOVA.

1. Option A—*Tests for differences among VC 4-5-6-7 Forest-wide*

H_0: μ (i) = μ (j)   Ha: μ (i) $\neq$ μ (j)

i,j = VC4, VC5, VC6, VC7

Results: The results of the tests are mixed and are tabulated below. Significant values are in **bold** type.

Area (Scheffé critical value) and volume strata	Scheffé test statistic, by volume strata		
	VC4	**VC5**	**VC6**
Chatham Area (2.849):			
VC5	**3.978**		
VC6	**3.861**	1.675	
VC7	2.843	1.560	0.477
Ketchikan Area (2.824):			
VC5	**6.911**		
VC6	**4.503**	0.322	
VC7	**3.779**	0.677	0.804
Stikine Area (2.837):			
VC5	**3.608**		
VC6	2.358	0.545	
VC7	2.788	1.836	1.410
Tongass-wide (2.808):			
VC5	**8.840**		
VC6	**6.137**	0.783	
VC7	**5.262**	2.021	1.392

2. Option B—*No test was made because there is only one volume stratum*

3. Option C—*Test for difference between low- (VC4) and high- (VC5-6-7) volume strata*

H_0: μ Low = μ High   Ha: μ Low $\neq$ μ High

Results: Rejected the null hypothesis. There is a difference between low- and high-volume strata for each Administrative Area and Tongass-wide. Significant values are in **bold** type.

Area (Scheffé critical value) and volume strata	Scheffé test statistic, by volume strata
	VC4
Chatham Area (1.986):	
VC5-6-7	**5.098**
Ketchikan Area (1.974):	
VC5-6-7	**7.555**
Stikine Area (1.980):	
VC5-6-7	**4.092**
Tongass-wide (1.966):	
VC5-6-7	**10.060**

4. Option D—*Tests for differences between low- and medium-, and medium-, and high-volume strata*

H_0: μ (i) = μ (j) Ha: μ (i) ≠ μ (j)

i,j = low, medium, high

Results: Rejected the null hypothesis for each Administrative Area and Tongass-wide. There is a significant difference for each Administrative Area except for low vs. medium in the Stikine Area (0.05<p<0.10). Significant values are in **bold** type.

Area (Scheffé critical value) and volume strata	Scheffé test statistic, by volume strata	
	Low	Medium
Chatham Area (2.491):		
Medium	**3.524**	
High	**6.940**	**4.398**
Ketchikan Area (2.469):		
Medium	**4.342**	
High	**8.731**	**4.546**
Stikine Area (2.480):		
Medium	1.984	
High	**4.263**	**3.064**
Tongass-wide (2.457):		
Medium	**5.701**	
High	**11.779**	**7.104**

5. Option E—*Tests for differences between low-, medium-, high-, and very high-volume strata*

H_0: μ (i) = μ (j)   Ha: μ (i) $\neq$ μ (j)

i,j = low, medium, high, very high

Results: Results were mixed. There is a significant difference between the high and very high strata at the Tongass-wide scale only. Significant values are in **bold** type.

Area (Scheffé critical value) and volume strata	Scheffé test statistic, by volume strata		
	Low	Medium	High
Chatham Area (2.852):			
Medium	**4.378**		
High	**4.180**	1.501	
Very high	**7.509**	**4.458**	1.631
Ketchikan Area (2.824):			
Medium	**5.348**		
High	**7.939**	**3.022**	
Very high	**9.421**	**5.188**	2.500
Stikine Area (2.837)			
Medium	2.269		
High	**3.603**	1.818	
Very high	**5.423**	**4.237**	2.619
Tongass-wide (2.808):			
Medium	**6.974**		
High	**10.164**	**4.310**	
Very high	**13.179**	**8.126**	**3.894**

Tentative Suitability of Forested Wetlands for Timber Production: A Resource Assessment

Kent R. Julin and Chris T. Meade

Issue Definition

The Alaska Region had to decide whether forested wetlands on Kaikli, Karheen, Kitkun, and Maybeso soil series would be retained in the tentatively suitable land base in the revision of the Tongass land management plan. The issue of retaining forested wetlands on organic soils within the tentatively suitable land base at the Tongass National Forest was raised by Forest Service soil scientists (Brock and Kissinger 1995). They recommend that forested wetlands be reclassified as unsuitable forest land owing to a lack of adequate response information (Forest Service Handbook [FSH] 2409.13). This paper examines the issue of tentative suitability as it relates to forested wetlands on the four soil series listed above.

Background

Forest Service regulations include criteria for identifying lands “not suitable” for timber production (36 Code of Federal Regulations [CFR] §219.14[a]) and lands “not appropriate” for timber production (36 CFR §219.14[c]). The Forest Service Handbook provides additional guidance on how to determine which lands are “tentatively suitable” fortimber production (FSH 2409.13-21) and which lands are “not appropriate” for timber production (FSH 2409.13-23).

Forest Service regulations also require that “forest planning shall provide for adoption of measures, as directed in applicable Executive orders, to minimize risk of flood loss, to restore and preserve flood plain values, and to protect wetlands” (36 CFR §219.23[f]). Executive Order 11990: Protection of Wetlands (1977) requires that:

> each agency shall provide leadership and shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency’s responsibilities for...managing...Federal lands....

Analysis of Information

In our analysis, we reviewed background information on forested wetlands in southeast Alaska and discussed the issue with Forest Service Regional and Area silviculturists and soil scientists. Our analysis emphasized the questions posed in the tentatively suitable forest land classification process (i.e., 36 CFR §219.14[a] and FSH 2409.13-21). The six questions used in this decision process for determining tentative suitability are addressed below relative to forested wetlands.

Is the Land Forested?[1]

Forested land is defined in 36 CFR §219.3 as "land at least 10 percent occupied by trees of any size or formerly having had such tree cover and not currently developed for non-forest use. Lands developed for non-forest use include areas for crops, improved pasture, residential, or administrative areas, improved roads of any width, and adjoining road clearing and powerline clearing of any width." Because all soil series in question can support forested plant associations (DeMeo and Loggy 1989), they could be carried forward to the next step in the tentatively suitable process.

Is the Land Withdrawn From Timber Production?[2]

Forested wetlands as a whole are not withdrawn from timber production under the current Tongass land management plan. However, forested wetlands within wilderness areas, national monuments, or other areas where timber harvest is prohibited by law (e.g., Tongass Timber Reform Act [1990] riparian buffers and land use designation II [LUD II] areas) are by definition unsuitable for timber production. The remaining forested wetlands within the Tongass National Forest are not withdrawn from timber production, and thus could be carried forward to the next step in the tentatively suitable process.

Is the Land Capable of Producing Crops of Industrial Wood?[3]

Lands capable of producing crops of industrial wood are those that support tree species currently used or likely to be used by the timber industry within the next 10 years. The soil series under consideration support commercial tree species including western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), western redcedar (*Thuja plicata* Donn ex D. Don), and Alaska-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach). Because these lands are capable of producing industrial wood crops, they could be carried forward to the next step in the tentatively suitable process.

Is Irreversible Damage Likely to Occur?[4]

Forest land is considered physically suitable if technology is available to ensure that timber production will not result in irreversible resource damage to soils, productivity, or watershed conditions. Research concerning damage to forested wetlands in southeast Alaska resulting from timber harvest is limited. Kissinger and others (1979) report severely stunted young-growth stands on Kaikli, Karheen, and Maybeso soils in the south Kupreanof area. Seven to nine years after stand initiation, they observed reduced height and diameter growth rates, which they attributed to nitrogen deficiency. It was not established whether this pattern of decline was a result of timber harvest or whether it represented the normal growth patterns of young-growth stands on wetland soils.

[1] 36 CFR 219.14[a][1] and FSH 2409.13-21.1.

[2] 36 CFR §219.14[a][4] and FSH 2409.13-21.2.

[3] FSH 2409.12-21.3.

[4] 36 CFR 219.14[a][2] and FSH 2409.13-21.41.

Weetman and others (1989) describe young-growth plantations of Sitka spruce that occurred after clearcutting and burning[5] on deep humic podzols on Vancouver Island, British Columbia. They attributed the sharp decline in height growth and needle chlorosis observed in 8- to 14-year-old plantations to nitrogen and phosphorus deficiencies and a suspected allelopathic effect from salal (*Gaultheria shallon* Pursh) colonizing the site after harvest.

Silviculturists at the Tongass National Forest have observed no short-term damage to forested wetlands harvested during the past 20 years. They have observed adequate restocking of forested wetland sites, which indicates that short-term damage has not occurred (Zaborske 1995).

There is no compelling scientific basis for concluding that harvest from forested wetlands will or will not result in irreversible damage to soil productivity or watershed conditions. Fertilization could be used to restore soil productivity, should it be demonstrated that timber harvest on forested wetlands negatively affects soil fertility. More information clearly is needed on the impacts to the functions and values of forested wetlands following timber management activities (i.e., road building, harvesting, thinning) to adequately address the question of irreversible damange.

Can the Area Be Restocked Within 5 Years?[6]

The purpose of this step in the tentatively suitable process is to “determine whether or not there is a reasonable assurance that it is possible to restock the remaining forest lands adequately within five years of final harvest, based on existing technology and knowledge” (FSH 2409.13-21.42). “Adequate restocking means that the cut area will contain the minimum number, size, distribution, and species composition of regeneration as specified in Regional silvicultural guides for each forest type” (36 CFR §219.27[c][3]).

The Alaska Regional silvicultural guide (FSH 2409.17-2.4) specifies the density (300 trees per acre), height (4 inches), and distribution goals (60 percent stocked in natural stands; 80 percent stocked in planted stands) in its restocking assessment. We believe that the Regional silvicultural guide could be improved by adding species composition to its assessment.

In the Alaska Region, natural regeneration accounts for over 93 percent of the reforestation program and is almost always successful. Many of these areas are certified as restocked in the third year. Those areas not certified as restocked after 3 years are closely monitored and, if necessary, planted to bring stocking levels to standards. Planting accounts for the remaining portion of the reforestation program and almost always is successful. For areas receiving final harvest in 1988 or 1989, almost 96 percent have been certified as restocked through either natural regeneration or planting. The remaining areas were planted within the past 2 to 3 years and will not be eligible for certification until 5 years after planting occurs (Zaborske 1995).

[5] Burning of slash after clearcutting is an uncommon practice in the Tongass National Forest (Zaborske 1995).

[6] 36 CFR 219.14[a][3] and FSH 2409.13-21.42.

Table 1—Site indices for several forested wetland soil series in southeast Alaska[a]

Soil series	50-year site index	Species	Reference
	Feet		
Maybeso	38	Sitka spruce	Stephens and others 1968a
Maybeso	41	Sitka spruce	Stephens and others 1968a
Maybeso	57	Sitka spruce	Babik 1983
Maybeso	43	Western hemlock	Babik 1983
Maybeso/Kaikli	45	Sitka spruce	Stephens and others 1968b
Kaikli	48	Sitka spruce	Farr 1984
Karheen	65	Sitka spruce	Stephens and others 1968b

[a] Yield tables for young-growth western hemlock-Sitka spruce stands provide a basis for relating site index and yield. Stands with a site index of 43 (50-year index age) produce 53 cubic feet per acre per year at the culmination of mean annual increment (Taylor 1934).

Evidence suggests that regeneration on the soils in question technically meets the criteria for adequate restocking as specified in the Regional silvicultural guide. Therefore, forest land on these wetland soils could be carried forward in the tentatively suitable process.

Is Adequate Response Information Available?[7]

The tentatively suitable determination process also evaluates whether adequate growth response information is available. Response information can include existing research and professional experience necessary to project responses to timber management practices.

Information concerning the productivity of forested wetlands in southeast Alaska is extremely limited for defining forested wetland yield. These data (table 1), collected primarily from stands growing on Maybeso soils, were used to construct site index curves for Sitka spruce. There is no information concerning growth on the Kitkun soils or for growth of western redcedar or Alaska-cedar at these sites. Current research, as summarized in table 1, although not statistically conclusive, suggests that Maybeso, Kaikli, and Karheen soils are capable of producing Sitka spruce and western hemlock within a moderate growth range.

Stephens and others (1968a) obtained site index values of 38 and 41 for Sitka spruce on Maybeso soils. In a subsequent study, Stephens and others (1968b) found that Maybeso and Kaikli soils had an average 100-year site index of 73 for Sitka spruce (estimated 50-year site index of 45) and that the Karheen soils studied had an average 100-year site index of 100 (estimated 50-year site index of 65).

Babik (1983) described soil profiles, measured tree heights, and estimated tree ages in a mixed western hemlock-Sitka spruce stand on Brownson Island in the Stikine Area. From this information, 50-year site indexes of 43 for western hemlock and 57 for Sitka spruce were estimated.

[7] FSH 2409.13-21.5.

A site index and height growth curve study by Farr (1984) includes one plot with wetland soils. The Young Bay plot was on Kaikli soils and showed a 50-year site index of 48 for Sitka spruce.

The cooperative stand density study[8] included two plots with organic wetland soils. One plot was at Falls Creek (no. 2830) on Maybeso Series and showed 50-year site indexes of 81 and 88 for Sitka spruce and western hemlock, respectively. This plot produced 840 cubic feet in the 19 years after stand initiation (44 cubic feet per year). Another plot was at Saks Cove (no. 1700) on Karheen Series and exhibited 50-year site indexes of 101 and 87 for Sitka spruce and western hemlock, respectively. This plot produced 10,624 cubic feet in the 58 years after stand initiation (183 cubic feet/year). These volumes may not be representative for the Karheen series owing to the presence of other soil series on the plot.

Stunted young-growth stands on Kaikli, Karheen, and Maybeso soils in the south Kupreanof area were investigated by Kissinger and others (1979) as described previously. Data presented in this report were insufficient to calculate site index values or yield. Kissinger and others (1979) noted, however, that height and diameter growth patterns for trees on these soils were comparatively lower than those for adjacent upland stands.

Because of a paucity of research and documented experience, we conclude that there is inadequate information for responses to timber management practices on the soils in question.

Key Findings

The Forest Service Handbook provides six criteria for determining whether land is tentatively suitable for timber production. We reviewed these criteria with consideration of forested wetlands on Kaikli, Karheen, Kitkun, and Maybeso soil series in the Tongass National Forest. Forested wetlands on the soil series in question satisfy four of these criteria: this land (1) is forested, (2) is not withdrawn from timber production, (3) is capable of producing crops of industrial wood, and (4) can be restocked within 5 years of final harvest. Two criteria clearly are not satisfied: (1) it is unknown whether irreversible damage is likely to occur to soils, productivity, or watershed conditions; and (2) there is inadequate response information to project the effects of timber management practices on this land. A current study on growth and yield of forested wetlands will address the response question. Additional work may be necessary to address fully the question of irreversible damage. Documenting the impacts to the functions and values of forested wetlands resulting from timber harvest could be accomplished as part of the monitoring program of the Forest.

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[8] Data on file with: Pacific Northwest Research Station, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

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Controlling Stability Characteristics of Steep Terrain With Discussion of Needed Standardization for Mass Movement Hazard Indexing: A Resource Assessment

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Issue Definition

This paper presents an overview of factors controlling soil stability on steep terrain in southeast Alaska. A Forest-wide standardized approach for stability hazard assessment in the Tongass National Forest (Tongass) also is presented.

Background

Failure Type

A debris avalanche, defined as the failure of a finite mass of water-charged overburden material along a more-or-less planar or flat surface (Swanston 1974b), is the dominant failure type on steep forested slopes in southeast Alaska. Once failure occurs, the initial mass rapidly breaks apart owing to internal stresses; because of the high water content, it is transformed into a mixture of water, soil, rock, and organic debris that rapidly moves downslope. This type of secondary failure is called a debris flow.

Failure Mode

These landslides primarily occur at a shallow depth (1 to 3 feet) and develop entirely in the soil overburden. Few involve bedrock failure or deep rotational failures in silts and clays. Failure generally occurs along a well-defined plane marking the boundary between soil overburden and either bedrock or compact glacial till (fig. 1).

Once failure occurs, movement is predominantly translational (all particles of the soil mass move with the same velocity along parallel paths) with displacement along and parallel to the failure surface. Because of the shallow nature of the soil overburden, the gradient of the potential failure surface is approximately equal to the slope gradient.

Soil Overburden Characteristics

The soil overburden texture is characteristically gravely sandy silt or gravely silty sand (MH-ML; SM-GM according to the Unified Classification System [U.S. Army Corps of Engineers 1953]); less commonly the texture may be sandy gravel (Schroeder and Swanston 1987). Soil overburden with these textural characteristics generally has low liquid limits and low plasticity, indicating little or no cohesion. The dominant steep-slope soil types in southeast Alaska are no exception (Schroeder and Swanston 1987). For the most part, these index properties (called Atterberg Limits) are of little value for judging strength characteristics. Plasticity is so low (except for marine silts) as to have little influence on cohesion. Organic content has no significant effect on cohesive strength. The organic content is highly variable, however, and may exceed 30 percent locally owing to downward migration of organic particles into the mineral soil zone. This occurrence could substantially increase plasticity and apparent cohesion at some sites.

Figure 1—Debris avalanche-debris flow in Marten Arm, northern shore of Bradfield Canal, southeast Alaska.

These soil overburden materials compress readily during shear, thereby reflecting low densities (80 to 100 pounds per square foot) and high void ratios (Wu and others 1979, Wu and Swanston 1980). The materials are commonly assumed to be cohesionless for general analysis purposes, although some cohesion usually is present. This becomes significant in determining the resistance to failure on very steep sites where the angle of internal friction of the material exceeds the slope gradient.

Potentially unstable slope gradients range from 60 to 72 percent. Engineering analyses of soils in southeast Alaska (Schroeder and Swanston 1987) indicate that slopes must be considered highly unstable when they exceed 72 percent. Based on statistical analysis of grouped samples of dominant soil types on steep terrain in southeast Alaska, the mean effective angle of internal friction for till and colluvial soils is 72 percent (Schroeder and Swanston 1987). This mean drops to 70 percent for residual soils. The mean values may be used for general assessment of soil behavior (i.e., for Forest planning purposes). The fifth percentile values for these soil groups is 51 percent for colluvium and till soils and 65 percent for residual soils. The fifth percentile is the value such that only 5 percent of the values of a normally distributed sample population are less than this. The fifth percentile values are comparative and should be used in sensitive situations where the consequences of occasional failures are undesirable.

Typical of coarse-grained materials in general, these soils have a high hydraulic conductivity or permeability (Terzaghi and Peck 1960). Unsaturated flow rate is about 1.3 inches per hour, and saturated flow rate is about 0.25 inch per hour (Vandre and Swanston 1977). Infiltration rates are rapid and capable of transmitting low-intensity precipitation virtually without surface runoff occurring. During high-intensity storms, input of rainfall may reach or exceed the infiltration rate, and a steady state of transmission of infiltrating water downward to an impermeable surface occurs. Because of the lower saturated flow rate for these materials, water ponds above this impermeable surface and a temporary water table develop. If precipitation intensities are great enough and rainfall duration is long enough, the water table will reach the surface and runoff will occur.

Slope microtopography is an important factor in determining where and how often landslides occur (Swanston 1974b, Swanston and Howes 1991). Linear depressions or "hollows" (also called zero-order basins) initially produced by differential weathering and erosion along fractures and joints in bedrock, and by prehistoric landslide activity, are widespread on steep slopes of southeast Alaska (Swanston 1974b, Sidle and others 1985). Over geologic time periods, these hollows fail cyclically. Once failure occurs, they refill with soil and debris from local slumping and with sliding from the sides of the hollows. Soils in these areas commonly display well-developed horizons and support mature forest growth, suggesting a minimum of 300- to 500-year land slide intervals in individual hollows. Such sites are natural foci of convergent ground water flows, where the accumulated soil and debris become locally saturated and form temporary water tables that initiate landslides. These features are the points of origin of most of the landslides in southeast Alaska (Swanston 1967). The degree of soil development (indicating relative age) within the hollows, the thickness of soil and debris infill, and the spacing of the hollows on steep slopes are strong indicators of landslide hazard. In general, land slide hazard increases with increases in deposit thickness and age and landslide spacing (number per unit area). Water table depth in these overburden materials depends on factors such as, but not limited to:

- Antecedent moisture conditions—how much rain has fallen and how much water is present in the overburden at the time of a high-intensity storm.
- Hydraulic conductivity along the soil-rock interface.
- Storm intensity—for overburden materials characteristic of southeast Alaska, a rainfall intensity of 6 inches per 24 hours is usually adequate to completely saturate the overburden and thus develop a temporary water table with a piezometric surface at or near the ground surface (Schroeder and Swanston 1987, Sidle and Swanston 1982, Swanston 1967).

Failure Mechanics

Because of the coarse soil textures, shallow overburden, and planar nature of the underlying bedrock or till surfaces on which sliding occurs, these debris avalanches and debris flows can be analyzed from a practical engineering standpoint by using the infinite slope model (Hough 1957, Swanston 1970, Terzaghi 1950, Terzaghi and Peck 1960, Wu 1966). The infinite slope model considers forces acting on a block of material of unit thickness and width situated on a slope of infinite length. The forces developed in the overburden material upslope of the block and tending to push the block downslope are countered by equal and opposite forces tending to maintain the block in situ. The same is true for lateral forces acting against the block.

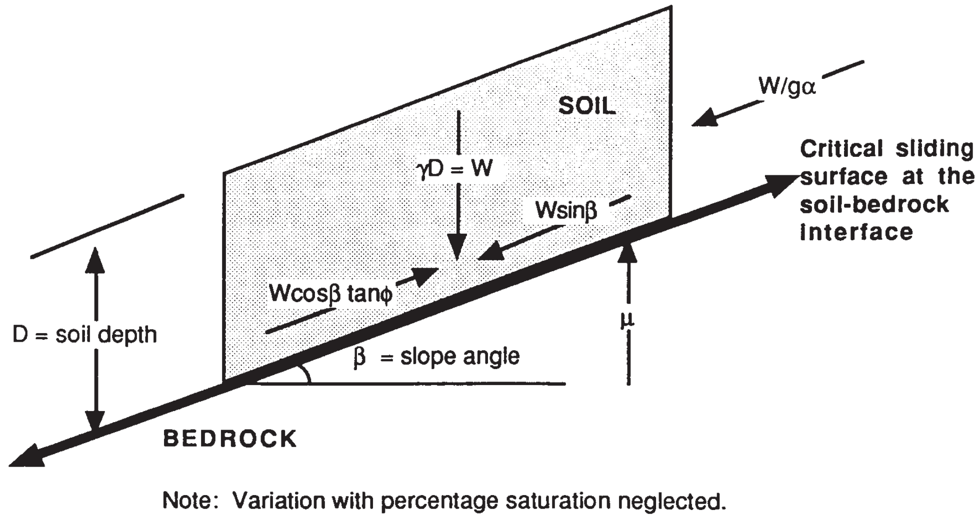

Figure 2—Infinite slope model.

The only forces that need to be considered in the analysis are illustrated in figure 2:

- Weight of the soil block (W).
- Component of the weight directed upslope as frictional resistance along the failure surface ($W\cos\beta\tan\phi$).
- Component of the weight directed downslope as gravitational stress ($W\sin\beta$).
- Cohesion (C), or the ability of individual soil particles to stick together because of weak electrical bonding of clay components or capillary tension during dry periods.
- Root stabilization (R) developed in the overburden by (a) anchoring of roots through the shallow overburden and into the underlying till, and (b) reinforcing and binding of the overburden materials laterally.

The relative stability of a site can be approximated by considering the factor of safety against failure (FS) developed along the potential failure surface (Swanston 1970). This factor is expressed as the ratio of the strength (S) or forces tending to resist failure and the shear stress (T) or forces tending to cause failure. Weight of the soil block is the product of the unit weight of the soil (γ), and soil depth (D). Cohesion (C), root strength effects (R), and the frictional resistance developed along the sliding surface ($W\cos\beta\tan\phi$) are forces within the overburden that help constitute its strength (S) or resistance to failure. Gravitational stress ($W\sin\beta$) and any external dynamic stresses developed due to cyclical loading caused by machinery, earthquakes, or blasting ($W/g\alpha$) constitute forces tending to cause failure:

$$FS = \frac{S}{T} = \frac{C + R + W\cos\beta\tan\phi}{W\sin\beta + W/g\alpha} \quad (1)$$

where:

β = gradient of the failure surface,

ϕ = angle of internal friction,

g = acceleration of gravity (32 feet per second per second), and

α = peak particle acceleration generated by vibrations of materials.

The stability of materials on steep forested slopes is strongly influenced by the development of a temporary water table and by slope gradient. Saturation of materials and development of a water table produce a vertical force called pore-water pressure (μ) that reduces the effective weight (and thus frictional resistance) of the material acting along the failure surface by creating a buoyancy effect. If slope gradient approaches or exceeds the angle of internal friction of the material, then stability of a site is decreased to a critical level. In the absence of any water table, gradient alone controls slope stability. This situation is illustrated by reformulation of the factor of safety equation and consideration of conditions typical of steep, unstable slopes in southeast Alaska:

$$FS = \frac{C + R + (W - \mu)\cos\beta\tan\phi}{W\sin\beta + W/g\alpha}. \quad (2)$$

Cohesion and root strength effects are small in these coarse granular materials but significant on extremely steep, unstable sites; cohesion is generally less than 206 pounds per square foot (Schroeder and Swanston 1987). Root strength is generally less than 144 pounds per square foot (Wu and others 1979). If these forces are ignored, then the factor of safety equation can be rewritten as:

$$FS = \frac{(W - \mu)\tan\phi}{W\tan\beta} \quad (3)$$

Under natural undisturbed conditions, the factor of safety and therefore the stability of a site, is controlled by the angle of internal friction, gradient of the slope, and the presence or absence of a temporary water table (Swanston 1970).

General Stability Situation of Forested Slopes in Southeast Alaska

Slopes with gradients at or near the angle of internal friction of the overburden materials are in a delicately balanced state relative to stability. They are highly susceptible to any activity that might upset the balance of forces acting to maintain the overburden materials in place. Factors affecting their stability include:

- Destruction or reduction of stabilizing root system effects through a windthrow, fire, or management activity.
- Destruction or reduction of cohesion by collapse of soil structure or saturation of overburden materials.
- Removal of the weight of trees. Although rare, this removal may be a stabilizing factor on steep slopes underlain by deep, fine-grained residual soils and elevated glaciomarine silts and glacial lake clays. This stability factor is generally not significant in southeast Alaska, but may be important on individual sites.

- Reduction in frictional resistance along the potential failure surface by:
  —development of a temporary water table.
  —reduction in weight of overburden.
- Increasing downslope stresses by:
  —removing downslope support of the soil block.
  —increasing overburden weight by saturation or surcharging.
  —dynamic loading of the soil mass by earthquake or other external stresses.

Management directly influences stability condition through timber harvesting, road construction, and quarry development. Clearcut harvesting results in degradation of anchoring and reinforcing root systems (Sidle 1991, 1992; Sidle and Swanston 1982; Swanston 1969, 1970; Wu and others 1979; Wu and Swanston 1980; Ziemer and Swanston 1987). It also changes the hydrologic regime through decreases in evapotranspiration and increased water levels in the soil during the fall rainy season. Road construction may (1) undercut slopes; (2) surcharge or load the surface by sidecast, rock overlayment, and stockpiling waste; (3) concentrate surface and subsurface water in ditches and culverts that may discharge into unstable sites; and from (4) cause dynamic loading of the soil mass by machinery vibration and right-of-way blasting (Swanston 1971a, 1971b, 1974a, 1975). Quarry development may increase surcharging from dumping of stripped materials onto unstable waste sites and from dynamic loading of steep-slope soil surfaces from ground vibration and rock-throw during blasting. Dynamic loading during periods of temporary water table development is important. The temporary water table couples soil and bedrock together and transmits lateral stresses to the soil from blasting vibration (Vandre and Swanston 1977).

A Revised Methodology for Mass Failure Hazard Indexing

Current Indexing Methodology

Hazard indexing for mass failure is a qualitative measure of the expected increase in frequency of mass failures when vegetation is cleared or the land is disturbed. Although sufficient baseline data are not available to develop a quantitative index of mass failure hazard, a qualitative system was developed to rate soils of the Tongass as part of the land management plan revision process (Alexander 1987). This mass movement index methodology is based on characteristics of identified and mapped soil units across the Tongass and on the inherent slope, drainage, and landform characteristics that control stability of the overburden on the slope. The methodology, with modifications by the Chatham, Ketchikan, and Stikine Administrative Areas of the Tongass, has been applied since 1989 and is used extensively in Forest- and project-level planning to assess risks related to the amount and method of timber harvest. The index values also are used in the Tongass FORPLAN model to construct soil management unit tables that identify lands with a high hazard of landslide initiation following management activity.[1]

In this indexing procedure, five mass movement classes were recognized across the Forest. These classes are listed with expected effects of disturbance in table 1.

As initially used, the susceptibility for mass failure identified by these indices was a function of slope gradient, expressed in 15-percent increments, and by parent material type (related to soil series) as mapped on Administrative Area soil resource inventories and displayed in the Alaska Region Geographic Information System (GIS).

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[1] Information available from the Tongass land management planning record, U.S. Department of Agriculture, Forest Service, 8465 Old Dairy Road, Juneau, AK 99801.

Table 1—Definitions of mass movement indices developed as part of the 1987 Tongass land management plan revision

Movement index	Expected effect of disturbance on the frequency of mass failures
Extreme	Highly probable increase
High	Likely increase
Moderate	Moderately probable increase
Low	Unlikely increase
Nil	Improbable increase

The locations are identified by surface characteristics related to slope gradient, vegetation cover, drainage, and soil properties measured in sample sections. These surface characteristics and properties are also soil resource inventory (SRI) and GIS mapping criteria.

Proposed Indexing Methodology

With new information and analyses, a more quantitative approach to hazard indexing was developed from identified critical slope gradients, soil (regolith) depth estimates, soil strength criteria as defined by measured engineering properties, simple soil drainage estimates, and limiting landform characteristics (Schroeder and Swanston 1987; Swanston 1969, 1974b; Swanston and Howes 1991; Wu and Swanston 1980). The direct effects of soil depth are greatest in very deep cohesive soils, such as unconsolidated marine silts and glacial lake deposits of silts and clays. In such materials, slope and failure surface gradients are low and thus mass of the potential sliding material becomes more important. In the soil overburden typically underlying forested slopes in southeast Alaska, depths are shallow, averaging about 3 feet or less, and mass plays a much less important role. Such materials are coarse textured, highly permeable, and underlain by relatively impervious substrata that inhibit or stop vertical water movement and promote saturation and lateral drainage through the shallow overburden. Soil strength is a function of particle size, shape, composition, and structure (Alexander and Poff 1985, Mitchell 1976, Terzaghi 1950, Terzaghi and Peck 1960). Together, these variables control porosity, permeability, intragranular friction, and friction along various planes within the soil mass. Strength is largely determined by intragranular friction and frictional resistance developed along the potential failure surface that is controlled by engineering properties inherent to the soil material. The mean and fifth percentile values of engineering properties of a limited sample of dominant surface geologic materials in southeast Alaska (Schroeder and Swanston 1987) are displayed in table 2.

These materials also have been mapped as soil series at the broad, Forest-wide, landscape level as part of the Tongass integrated resource inventory; as such they are part of the Tongass GIS database. Series corresponding to dominant steep-slope geologic material types are shown in table 3.

Table 2—Estimated range of engineering properties (angle of internal friction [ϕ'] and unit weight [γ] for surface geologic materials in southeast Alaska

Geologic origin	Mean[a] (ϕ')	5th percentile[b] (ϕ')	Mean[a] (ϕ')	5th percentile[b] (ϕ')	Mean[a] (γ)
	– – – Percent – – –		*– – – – – – – – lb/ft^2 – – – – – – –*		
Colluvium and till soils	72	51	206	0	116
Marine sediments	65	36	312	0	131
Alluvium	78	60	182	0	109
Volcanic ash	62	21	240	210	82
Residual soils	70	65	115	85	102

[a] Mean values should be used for general assessment of soil behavior.
[b] 5th percentile values should be used for conservative analysis of sensitive areas.

Table 3—Important soil resource inventory (SRI) series by geologic origin

Soil series	Geologic origin
Karta	Compact glacial till (basal till)
Tokeen	Residual soil derived from igneous rocks
Ulloa	Residual soil derived from carbonate rocks
Wadleigh	Compact glacial till (basal till)
Mitkof	Colluvium and ablation glacial till
Traitors (Vixen)	Residual soil high in micacious materials derived from phyllite and schist
Tolstoi	Residual soil derived from noncalcareous rocks

By using the existing soil series boundaries from individual maps, the Tongass GIS database, the mean engineering properties, and measured slope gradients (table 2), a revised and more accurate mass movement indexing methodology can be developed. At the Forest plan level, ratings made with this revised index are based on SRI soil series criteria and mapped boundaries, mean engineering properties of soil series obtained from the literature, and slope gradients estimated from the Tongass GIS database. At the Area and project levels, accuracy and reliability of the indexing system can be improved by considering several factors. These include direct sampling and analysis of soil engineering properties, using indirect indicators of instability—such as dissection frequency, soil drainage condition, and parent material characteristics—using more accurate mapping of soil series boundaries, and measuring slope gradients directly. Thus, the system can be used for any Administrative Area of the Tongass, regardless of variations in detailed soil map unit differentia, where the soil taxonomic units, or series, are the same. Detailed soil unit differentia including variations in soil properties, and topographic conditions can be used in the rating system to improve class definitions and hazard assessments, particularly at Administrative Area and project levels. These include (1) variations in parent material type and origin, which provide useful additional information on density, texture, porosity, permeability, and degree of weathering; (2) depth, local variations of which may alter estimated driving and resisting forces; (3) drainage class, which provides an indication of local groundwater conditions; and (4) landform type, which identifies specific terrain conditions, such as slope configuration and dissection, conducive to landslide initiation and increased frequency.

The soil material groups of the rating system are essentially those already in use, with little modification. The soil depth classes are based on the thickness of nonorganic material (mineral soil) over an impermeable boundary such as bedrock, compact glacial till, or fine sediments. Depths are divided into the following categories: micro—less than 7 inches; shallow—8 to 20 inches; moderately deep—21 to 40 inches; and deep—greater than 40 inches. Only the qualitative values of well, poorly, and very poorly drained classes are used to assess soil drainage. Poorly and very poorly drained soils on steep, unstable sites are strong indicators of rapid temporary water table development during storm periods and increased potential for failure.

This methodology provides a standardized base for Forest-wide stability hazard assessment at the Administrative Area and project levels. It can be expanded and adjusted to fit local needs, conditions, and knowledge. The primary purpose of the protocol is to assure that the same basic data and information are collected and used across the Forest so that effective comparisons and cross-correlations can be done on the Tongass. The framework for this suggested methodology was developed as part of the Alaska Region’s watershed analysis procedures to address the 1994 Amendment by Senator Ted Stevens to the Appropriations Act (Loggy and Swanston 1994) and is based on current Chatham and Ketchikan Area field procedures. The Chatham and Ketchikan Areas have agreed to this Region-wide standardization; the Stikine Area has tentative agreed to accept the methodology for limited field use. The protocol has been further modified by the information presented in this paper.

Criteria	Mass failure hazard classes (MFHC) 1	2	3	4	Weighting factor (WF)	Rating (MFHC э WF)
Landform:						
Slope shape	Vertical	Broken	Convex	Concave-straight	5	—
Slope length (ft)	0-300	301-700	701-1,500	>1,500	5	—
Slope gradient (percent)	5-35	36-55	56-72	>72	20	—
Drainage feature:						
Drainage density (percentage of area)	1-9	10-19	20-39	>40	10	—
Soils:						
Soil drainage class[a]	WD, MW	[b]	SPD	VP, PD	10	—
Soil depth (in)	>40	[b]	20-40	<20	5	—
Geology:						
Parent material	Carbonate, colluvium, alluvium	Noncarbonate, granitics, glacial till	Compact till, marine sediments	Volcanic ash	5	—
Textural class	Sand, gravel, fragmental loam	Loam	Silt	Silty clay	5	—
Total of ratings						—
Map unit mass failure hazard rating (100 э total of ratings / 260)						—
						—

[a] Soil drainage classes: MW = moderately well drained; PD = poorly drained; SPD = somewhat poorly drained; VP = very poorly drained; WD = well drained.

[b] No soil drainage class or depth information is available for broken slopes.

Figure 3—Form used to calculate the mass failure hazard of a map unit.

A combination of eight quantitative and qualitative variables considered to be controlling factors in determining the stability of a soil map unit are grouped into four mass failure hazard classes to estimate a map unit's natural mass movement (fig. 3).

A mass failure hazard class of 1 is for a factor having a lower potential for contributing to a mass failure; a rating of 4 indicates a factor having the highest potential for contributing to a mass failure. Each variable is weighted based on a qualitative estimate of its degree of importance in contributing to a mass failure. Numerical ratings, multiplied by the weighting factor, yield a total rating or index for each variable. Ratings are summed, divided by the total points possible (260) and then multiplied by 100 to obtain the mass unit failure hazard rating. The range in ratings by class or index and the GIS equivalents appear in table 4. The original five classes from table 1 are reduced to four by combining high and extreme categories.

Table 4—Distributions of mass unit failure hazard ratings in relation to current mass movement indices and Tongass GIS equivalents

Mass unit failure hazard rating	Class	Mass movement index	GIS equivalent
63+	High to extreme	MMI4	High to extreme
50-62	Moderate	MMI3	Moderate
28-49	Low	MMI2	Low
0-27	None	MMI1	Low

The reasons for and identification of factors used to assess each variable in determining mass failure hazard are documented by Swanston and Rosgen (1980), Swanston and Howes (1991), Howes and Swanston (1991), and Schroeder and Swanston (1987). The methodology is designed primarily for planning-level analyses but may be modified for use at the project level if sufficient field information is available for factor assessment. The basic procedure has been well documented and used with modifications throughout the Tongass.

The rating is based on how the soils will react at soil saturation but without water table development and without application of major destabilizing events, such as high-intensity storms, rockfall, windthrow, earthquakes, and human-caused disturbance. It thus reflects the natural stability (or instability) of a slope under normal or average conditions. Other factors, such as anchoring by roots, bedrock structure, and hollows, are important to maintaining soil and forest cover at an otherwise unstable site. These modifying factors can and should be used to adjust index values at the Area and project level to reflect local experience and knowledge. For example, rating limits have been adjusted in all Areas to allow for limited management activities on MMI4 soils that are found on historically stable land forms or have locally variable gradients verified in the field to be below critical levels (72 percent).

The stability hazard class ratings for mass movement listed in table 4 represent general guidelines only. At the project level, each soil map unit should be rated individually because various combinations (fig. 3) of landform, drainage, dissection frequency, soils, and geology may yield ratings either above or below individual class limits.

Descriptions of Mass Failure Rating Classes

Descriptions of the rating classes with their controlling and contributing variables are provided below.

High to Extreme

Map units in this class have a high to extreme risk of failure and fall into the 63+ value range of the high to extreme hazard class (table 4). Natural mass failures in this class are often frequent and large, and there is a high risk of management-induced failure. Standard management practices can be expected to have only limited success, and on-the-ground assessment is necessary to determine the need for mitigating measures. There is a moderate risk of failure even with the use of mitigation. Some portions of the units may have a significantly lower risk of failure due to local benching or higher risk due to cliffs and very steep slope breaks. Soils with gradients in the 72- to 85-percent range with low levels of dissection, well-drained soils, and stable parent materials may be operable with adequate on-the-ground verification and site-specific investigation before any management activity is undertaken.

Characteristics of this class include:

- Moderately steep slopes (36 to 55 percent) with high levels of dissection and either unstable parent materials or reduced soil drainage (i.e., somewhat poorly drained or poorly drained).
- Steep slopes (55 to 72 percent) with moderate to high levels of dissection and well-drained soils.
- Steep slopes (55 to 72 percent) with high to extreme levels of dissection, somewhat poorly to poorly drained soils, and unstable parent materials.
- Very steep slopes (>72 percent) with moderate to high levels of dissection and well to poorly drained soils.
- Very steep slopes (>72 percent) with evidence of prior mass wasting or snow avalanching.

Moderate

Map units in this class have a moderate risk of failure and fall into the 50-to-62 value range of the moderate hazard class (table 4). In this class, natural mass failures are usually small and infrequent, but there is a moderate risk of management-induced failure. Standard and best management practices are usually successful but on-the-ground investigation is still recommended. Mitigating measures occasionally may be needed. Characteristics of this class include:

- Gentle slopes (5 to 35 percent) with moderate to high dissection, poor to very poor drainage, and unstable parent materials.
- Moderately steep (36 to 55 percent) frequently dissected slopes with stable parent materials and somewhat poorly drained soils.
- Steep slopes (56 to 72 percent) with low levels of dissection, well-drained soils, and stable parent materials.

Low

Map units in this class have a very low risk of failure and fall into the 28-to-49 value range of the low hazard class. Natural mass failures in this class usually are rare or small. There is a low risk of management-induced failure except on unstable microsites, such as scarps, V-notches, and streambanks. Standard best management practices that control surface disturbance and stream flows can be expected to be highly successful without special mitigating measures. Characteristics of this class include:

- Gentle slope gradients (5 to 35 percent), with unstable parent materials or reduced soil drainage (somewhat poorly or poorly drained).
- Moderately steep slope gradients (36 to 55 percent) with low to moderate dissection, well-drained soils, and stable parent materials.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet	0.305	Meters
Miles	1.609	Kilometers
Square miles	2.59	Square kilometers
Acres	0.405	Hectares
Cubic feet	0.028	Cubic meters
Board feet	0.007	Cubic meters
Board feet per acre	0.017	Cubic meters per hectare
Pounds	0.45	Kilograms
Pounds per square foot	47.9	Newtons per square meter

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Resource assessments on wildlife viability, old-growth timber volume estimates, forested wetlands, and slope stability are presented. These assessments were used in the formulation of alternatives in the revision of the Tongass land management plan.

Keywords: Wildlife viability, timber volume, forested wetlands, slope stability, Tongass, Alaska.

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