SUSITNA HYDROELECTRIC PROJECT
TERRESTRIAL ENVIRONMENTAL WORKSHOP
AND PRELIMINARY SIMULATION MODEL

ESSA

ENVIRONMENTAL AND SOCIAL SYSTEMS ANALYSTS LTD.

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by
Robert R. Everitt
Nicholas C. Sonntag
ESSA Environmental and Social Systems Analysts Ltd.
Vancouver, B.C., Canada

Gregory T. Auble
James E. Roelle
U.S. Fish and Wildlife Service
Fort Collins, Colorado

William Gazey
LGL Ecological Research Associates
Bryan, Texas

for
LGL Alaska
Anchorage and Fairbanks, Alaska

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Once again Jean Zdenek worked magic in typing and correcting this and earlier drafts of this report under impossible time constraints.

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1.0 INTRODUCTION

The technical feasibility, economic viability, and environmental impacts of a hydroelectric development project in the Susitna River Basin are being studied by Acres American, Inc. on behalf of the Alaska Power Authority. As part of these studies, Acres American recently contracted LGL Alaska Research Associates, Inc. to coordinate the terrestrial environmental studies being performed by the Alaska Department of Fish and Game and, as subcontractors to LGL, several University of Alaska research groups. LGL is responsible for further quantifying the potential impacts of the project on terrestrial wildlife and vegetation, and for developing a plan to mitigate adverse impacts on the terrestrial environment. The impact assessment and mitigation plan will be included as part of a license application to the Federal Energy Regulatory Commission (FERC) scheduled for the first quarter of 1983.

The quantification of impacts, mitigation planning, and design of future research is being organized using a computer simulation modelling approach. Through a series of workshops attended by researchers, resource managers, and policy-makers, a computer model is being developed and refined for use in the quantification of impacts on terrestrial wildlife and vegetation, and for evaluating different mitigation measures such as habitat enhancement and the designation of replacement lands to be managed by wildlife habitat. This report describes the preliminary model developed at the first workshop held August 23 - 27, 1982 in Anchorage.

1.1 Objectives

The ultimate purpose of the workshops and simulation modelling is to develop a framework that can be used as a basis for assessing impacts of and evaluating mitigation options for the effect of the Susitna Hydroelectric Project on the terrestrial environment in the Susitna Basin.

The specific objectives for achieving this purpose are to:

a) develop an understanding of the biophysical processes of the Susitna Basin with respect to wildlife and vegetation;

b) develop this understanding by integrating information on big game, furbearers, small mammals, birds, and plant ecology into a computer simulation model;

c) refine the model during a series of technical meetings;

d) update the model as new information becomes available from field studies; and

e) use the model as a framework and guide to assess terrestrial impacts of the Susitna Hydroelectric Project and to evaluate ways of mitigating impacts.

The workshops play a major role in attainment of these objectives. They provide a systematic approach to organizing information and people. As such, they are a major tool for consensus building and interdisciplinary coordination.

1.2 Relationship to Mitigation Planning

Many aspects of mitigation planning will be accomplished outside of the simulation modelling workshop process. Many mitigation measures, such as controlling dust along roads, leaving clumps of trees along the reservoir margin for eagle nesting, minimizing aircraft disturbance, locating recreation facilities away from critical wildlife areas, and deciding upon environmentally sound access road design criteria can easily be developed without a quantitative model. Most of these measures to be incorporated into engineering design and construction planning have been developed or will be developed prior to the submittal of the FERC application.

However, certain mitigation measures, such as habitat enhancement or compensation lands for habitat lost, may require several years of analysis and discussion. The primary purpose of the simulation modelling workshop process is to incorporate these more complex issues into the mitigation planning. Recognizing that these issues will not be resolved prior to the license application, the workshop process allows for an adaptive approach to planning. It provides a framework for increased communication, and a mechanism for designing and utilizing the results of future research and monitoring studies.

1.3 Simulation Modelling Workshops

There has been an enormous increase in public concern over environmental impacts of development projects in the past two decades. One consequence of this concern has been the use of detailed environmental impact assessments as an integral part of major resource development activities. These impact assessments are always multidisciplinary, but, in most cases, little effort is made to develop a coordinated, interdisciplinary approach. Consequently, vital information required to make predictions of impacts encompassing more than one discipline is often overlooked or not collected.

Over the past ten years a group of environmental scientists and systems analysts at the University of British Columbia and the International Institute for Applied Systems Analysis (IIASA) in Austria have developed a methodology to deal explicitly with interdisciplinary ecological problems (Holling, 1978). The core of the methodology is a five day workshop involving a team of four or five experienced simulation modellers and a group of fifteen to twenty specialists. The focus of the workshop is the construction of a quantitative simulation model of the system under study. The development of the simulation model forces specialists to view their area of interest in the context of the whole system. This promotes an interdisciplinary understanding of the system, and allows ecological and environmental knowledge to be integrated with economic and social concerns at the beginning, rather than at the end, of an impact assessment.

Simulation models require unambiguous information. In the workshop setting specialists are forced to be explicit about their assumptions. This objectivity exposes critical conceptual uncertainties about the behavior of the system, and identifies research needs.

1.3.1 Workshop Activities

The first step in the workshop is to clearly define and bound the problem. Bounding makes the modelling problem more explicit, thereby making it easier to decompose the system into manageable components or subsystems. In bounding, development actions (alternate controls available to management or development strategies) and indicators (those measures used by management in evaluating system performance in response to various combinations of actions) are generated. The model embodies the biophysical rules required to transform the actions into indicator time streams. Bounding also involves defining the spatial extent and resolution required to adequately represent the system, and by specifying the temporal extent or time horizon and an appropriate time step.

The final bounding exercise of the workshop is called "looking outward". It focuses attention on the subsystems defined by the actions and indicators and those variables required by each subsystem from the other subsystems. In looking outward, the standard question of analysis is recast. Instead of asking "what can you provide to the other subsystems from subsystem X?", the question "what do you need to know about all other subsystems in order to predict how subsystem X will behave?" is asked. This question demands a more dynamic view and forces one to describe a particular subsystem in the context of the entire system. The looking outward exercise generates, for each subsystem, a list of "inputs" it needs from the other subsystems and a list of "outputs" it must provide to the other subsystems.

The second step of the workshop is submodel construction. The workshop and each subgroup develops submodels for one of the subsystems. One workshop facilitator works within each subgroup and acts as the submodel programmer. The submodel must be able to generate the output variables required by oher submodels and the appropriate indicator variables identified earlier.

The final step of the workshop is to put each of the submodels into the computer and link them into the system model. The system model is run under a variety of development scenarios to explore the consequences of various actions and hypotheses about system structure. The principal objective of this exercise in an initial workshop is to point out model deficiences and identify areas requiring better understanding and information.

1.3.2 Beyond the Workshop

The first workshop can be followed by a period of independent work on identified research needs by collaborating individuals which will lead to a second workshop and possibly subsequent ones in a phased sequence. Early in the sequence, workshops concentrate on technical issues, but later, they focus more and more on communication to policy advisors and the affected constituencies. The emphasis on communication enables an effective and logical move to implementation, either in a pilot project or a full-scale program.

Throughout the workshop sequence, the simulation model is an expression and synthesis of new information and the changing mental models of scientists, managers and policy makers. The involvement and interaction of these groups means that learning becomes as much a product as does problem solving.

2. BOUNDING

All systems are hierarchial in nature; each is comprised of smaller parts, and is, in turn, embedded in, or part of larger systems. The most critical decisions that are made in planning research and analysis are the choice of components to be explicitly addressed. The same is true for modelling.

Within simulation modelling workshops, these choices are made during an exercise called bounding. Bounding forces the participants in the workshop to define lists of actions and indicators and places those in an appropriate spatial and temporal framework. Once this is accomplished, an exercise called "looking outward" defines the key interrelationships between components of the system under scrutiny.

2.1 Actions

Actions, in the context of modelling, are normally thought of as human intervention into the environment. With regard to the proposed developments on the Susitna, four major categories of actions (Table 2.1) were identified during the workshop. The first relates to the construction and operation of reservoirs; the second relates to recreational development, use, and control; the third relates to development other than hydroelectric; and the fourth corresponds to mitigation options.

Table 2.1: Actions Identified at Workshop

I. Reservoirs

a. Construction

- roads
- borrow pits
- transmission lines
- camp sites
- village sites
- temporary diversions
- river bed mining
- reservoir clearing
- soil disposal
- air strip construction
- aircraft use
- staging areas

b. Operation

- operating rule curves

II. Recreation/Access

- reservoir recreational development (access and facilities)
- recreational use (back packing, hunting, fishing)
- increased traffic on existing roads/railroads

III. General

- timber harvest
- changes in land use patterns (mining, oil and gas development)
- increased population in surrounding communities

IV. Mitigation

- habitat enhancement
- controlled burn
- replacement lands
- vegetation crushing
- flow regulation for fish and wildlife
- fire protection
- control of access
- hunting/fishing regulation
- scheduling of construction activities
- siting of roads
- reclamation/revegetation

2.2 Indicators

Indicators are those quantities which are used to evaluate the performance or health of a system in response to the defined actions. The set of indicators (Table 2.2) identified by participants in the workshop are primarily related to wildlife populations and wildlife habitat measures, although instream flows and indicators of recreational use are included.

The predicted changes in indicators are used to help determine the impacts of the actions over time, and in turn, evaluate the quantity, quality, and timing of mitigative actions.

2.3 Spatial Considerations

Defining the spatial extent and resolution of any research or analysis is a critical step. It determines the level of detail and places geographical limits on what is to be considered. Simulation models require an unambiguous definition of the spatial extent and resolution.

The spatial extent of the model was guided by estimated home ranges of brown bear and moose. An area corresponding to all of a home range was included. With this criterion, the Upper Susitna Basin, extended to include the Prairie Creek-Stephan Lakes region, was chosen as the area for assessing impacts upstream of the Devil Canyon Dam site. Within this upstream area, the Watana and Devil Canyon impoundments are considered separately and the remaining land is designated as a third spatial unit (Figure 2.1). Downstream, (Devil Canyon Dam site to Cook Inlet) an area corresponding to moose home range was defined using estimates

Table 2.2: Indicators Identified at Workshop

Hydrology

- instream flows

Vegetation

- acres of selected vegetation types

Wildlife

- populations of:

moose	raptors
black bear	caribou
brown bear	wolverine
sheep	small mammals
wolves	birds

- carrying capacity for the above populations
- numbers of animals harvested by hunters
- hunter success
- habitat quality

Recreation

- number of user days
- non-consumptive uses of wildlife

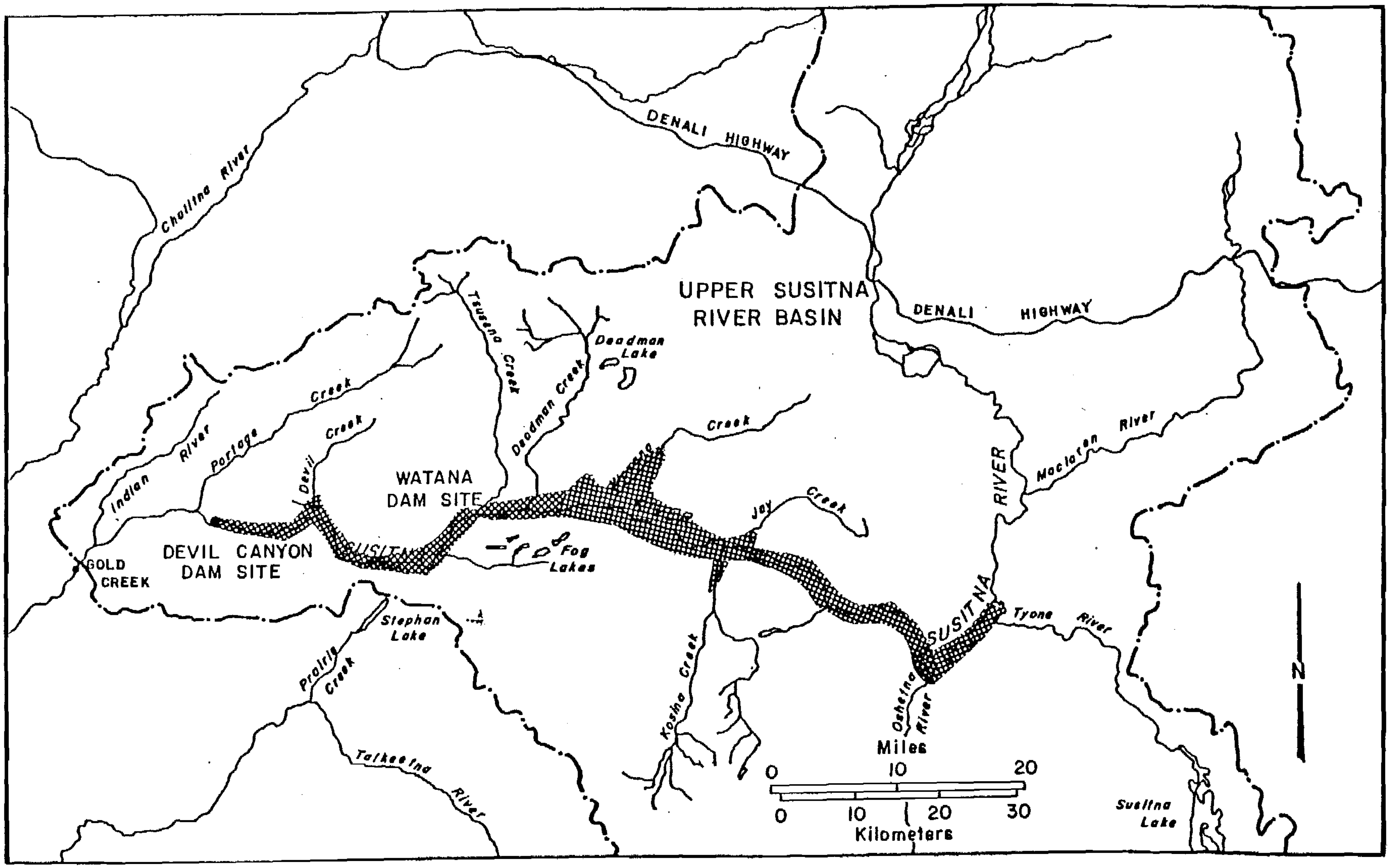


Figure 2.1a: Upper Susitna Basin showing the Devil Canyon and Watana impoundments (shaded area).

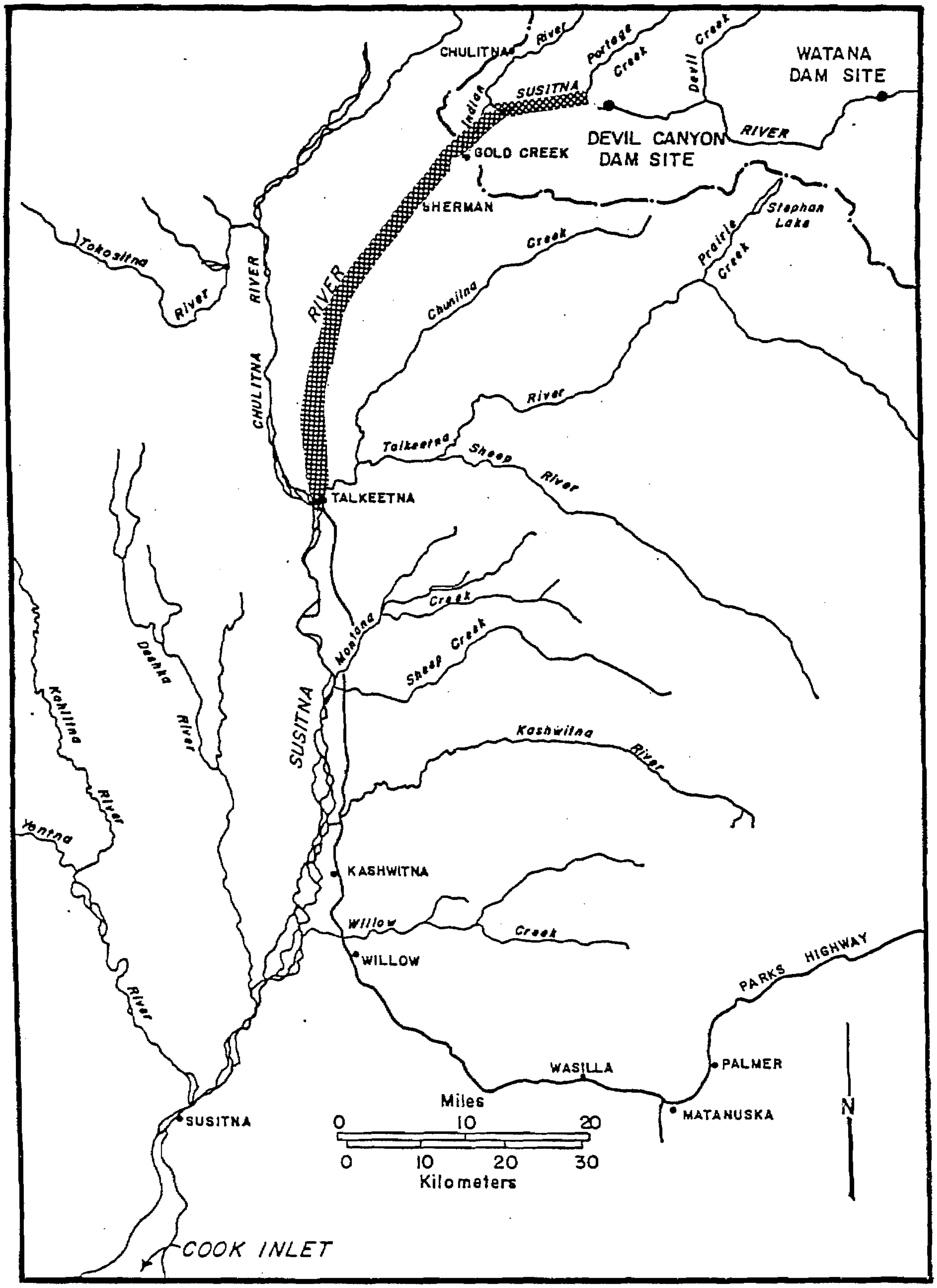


Figure 2.1b: Lower Susitna Basin showing Devil Canyon to Talkeetna riparian zone (shaded area) designated for the model.

from Modafferi (1982). Moose home range probably occurs in a band 60 km wide; 30 km on each side of the Susitna. The model simulates this band as far downstream as Talkeetna. The Susitna floodplain is considered separately within the downstream area. Areas downstream of Talkeetna were not included because the present and future hydrologic regime there, and its influence on vegetation dynamics, was considered too complex to construct an adequate predictive model.

Therefore, there are 5 spatial areas in the model:

a) the Watana impoundment;

b) the Devil Canyon impoundment;

c) the remainder of the Susitna Basin upstream of Gold Creek;

d) the floodplain from Devil Canyon Dam to Talkeetna; and

e) the remaining land in a 60 km strip from Devil Canyon Dam to Talkeetna.

Within each of the spatial areas, fourteen vegetation types (Table 2.3) were defined.

2.4 Temporal Considerations

The choice of the temporal resolution or time step for the model is always problematic because of widely different time scales of important processes. Many biological processes depend on water levels at critical times throughout the year requiring monthly, and sometimes daily, water level estimates. However, wildlife and waterfowl populations do not change substantially from one day to the next making daily population estimates unnecessary. These considerations, combined with the necessity of representing much slower

Table 2.3: Fourteen Vegetation Types Associated with the Spatial Areas

Conifer forest
- woodland
- open

Deciduous and Mixed Forest

Tundra

Tall shrub - alder

Medium shrub

Low shrub
- birch
- willow
- mixed

Unvegetated
- water
- rock/snow/ice

Disturbed
- temporary
- permanent

Pioneer

successional processes, led to a mixed temporal structure. Average and peak flows are available monthly from hydrology. All other submodels have a one year time step but may implicitly include seasonal dynamics when needed. A time horizon of 50 - 80 years was chosen (to capture the successional effects).

2.5 Submodel Definition

The breakdown of the system into component subsystems is reflected in the breakdown of the simulation model into the submodels:

a) physical processes/development/recreation;

b) vegetation;

c) furbearers/birds; and

d) large mammals.

The major components of each submodel (Table 2.4) were decided upon through discussion by workshop participants.

2.6 Looking Outward

The purpose of "looking outward" is to define the pieces of information that a particular subsystem requires from all other subsystems to predict its dynamic behavior. This is a qualitatively different question than the traditional one which generates lists of factors which affect a particular component of a system. The product of "looking outward" is an interaction matrix, with columns specifying what information a subsystem requires from each of the other subsystems (Table 2.5). The diagonals are blank because they represent the internal dynamics of each subsystem.

Table 2.4: Submodel Components Decided on by Workshop Participants

1. Physical Processes/Development/Recreation:

   - flows
   - stages
   - ice processes
   - reservoir elevations
   - aquatic furbearer habitat
   - hydroelectric development scenarios
   - other development scenarios
   - recreational use
   - recreational development

2. Vegetation:

   - areal extent of vegetation types
   - browse production
   - berry production
   - ecological succession
   - vegetation alienation

3. Furbearers/Birds:

   - beavers
   - golden eagles
   - passerine birds

4. Large Mammals:

   - moose
   - moose habitat
   - bears
   - bear habitat

Table 2.5: Looking Outward Matrix

	PHYSICAL PROCESSES/ DEVELOPMENT/RECREATION	VEGETATION	FURBEARERS/BIRDS	LARGE MAMMALS
PHYSICAL PROCESSES/ DEVELOPMENT/ RECREATION		- 3 day peak flows - location & areas (ha) of development activities - surface area exposed in floodplain (ha)	- date of break-up/freeze-up (lakes, ponds, streams) - date of first snow cover - minimum open water in river (km) - length of slough, side channels with >.5 m ice free water - reservoir elevations (ft) - human disturbance	- date of ice break-up (edge) - date of 'ice free' conditions - amount of ice shelving (March 15-June 15) - snow depths (elevation) in 150 m intervals, monthly - trips/day on access roads (seasonally) - trains/day (Nov-March) - recreational use days
VEGETATION			- areas of vegetation types (ha) - productivity (kg/ha) of: Paper Birch Balsam Poplar Birch shrubs Black Spruce White Spruce Willow shrub Aspen	- production of berries (kg/ha) - hectares of berries suitable for bear food - areas of vegetation types (ha) - standing crop (kg/ha) & areas of: Paper Birch Lowbush Cranberry Balsam Poplar Willow Shrub Aspen
FURBEARERS/ BIRDS		- areas (ha) of intensive beaver use by vegetation type		
LARGE MAMMALS		- consumption (kg/ha) of forage species by season & type		

Each piece of information listed in the matrix represents a specific hypothesis about system behavior. For example, the furbearers/birds submodel requires information on the length of sloughs and side channels that maintain at least .5 m of ice-free water throughout the winter from the physical processes/development submodel. The underlying hypothesis is that this represents potential overwintering habitat for beavers.

3.0 SUBMODEL DESCRIPTIONS

The four submodels, hydrology/development/recreation, vegetation, furbearers/birds, and large mammals, were then constructed in subgroup meetings of the participants using the model framework developed during bounding. This section describes the models conceptualized during subgroup meetings and during the computer programming phase of the workshop.

These models are the first interdisciplinary representation of the biophysical processes of the Susitna Basin. In some cases, the relationships described are based on good scientific evidence; in other cases, they are simply crude hypotheses or educated guesses. These models require considerable critique and refinement before a reasonable representation of important terrestrial processes is achieved.

3.1 Physical Processes/Development/Recreation

The Susitna hydroelectric development will impact the terrestrial environment directly through disturbance and vegetation loss on lands needed for project facilities, and indirectly through alteration of the hydrologic and ice regimes of the Susitna River. Another possible and perhaps major impact on the terrestrial environment will occur through increased recreational opportunities that may result from increased access and the development of recreational facilities at or near the reservoir. Also, while development associated directly with the hydroelectric project may have a substantial impact and is the primary focus of this project, it is important to place this development in the context of development activities that are indirectly related to the project, such as mining, oil and gas exploration and production, and new recreational facilities.

3.1.1 Physical Processes

Almost all the physical processes considered in the model are related to the flow regime or climate or the interaction of both factors. Currently, the model simulates the flow regime at three stations (Gold Creek, Sunshine, and Susitna) for three different cases:

a) preproject flows;

b) Case A, which corresponds to optimum power generation; and

c) Case D, which corresponds to the best development for meeting instream flow targets.

The flows are based on historical preproject flow data and estimates provided by Acres American Ltd. (pers. comm.) for past project flows under different operating conditions. Thirty years of data for each case are used and repeated. Figure 3.1 is a comparison among the three cases using the data used for simulation year 12. Average monthly flow is usually a poor indicator of the stress on an ecosystem and, in many cases, extreme flows (minima and maxima) are more important. The model makes daily and 3 day minimum and maximum flow estimates using data supplied by R & M Consultants (pers. comm.).

3.1.1.1 Reservoir Elevations

The operation of the dams causes the reservoirs to vary throughout the year as seen for the simulation year 12 in Figure 3.2. The model provides the reservoir elevations for Watana Reservoir based on monthly estimates provided by Acres American.

PREPROJECT FLOWS

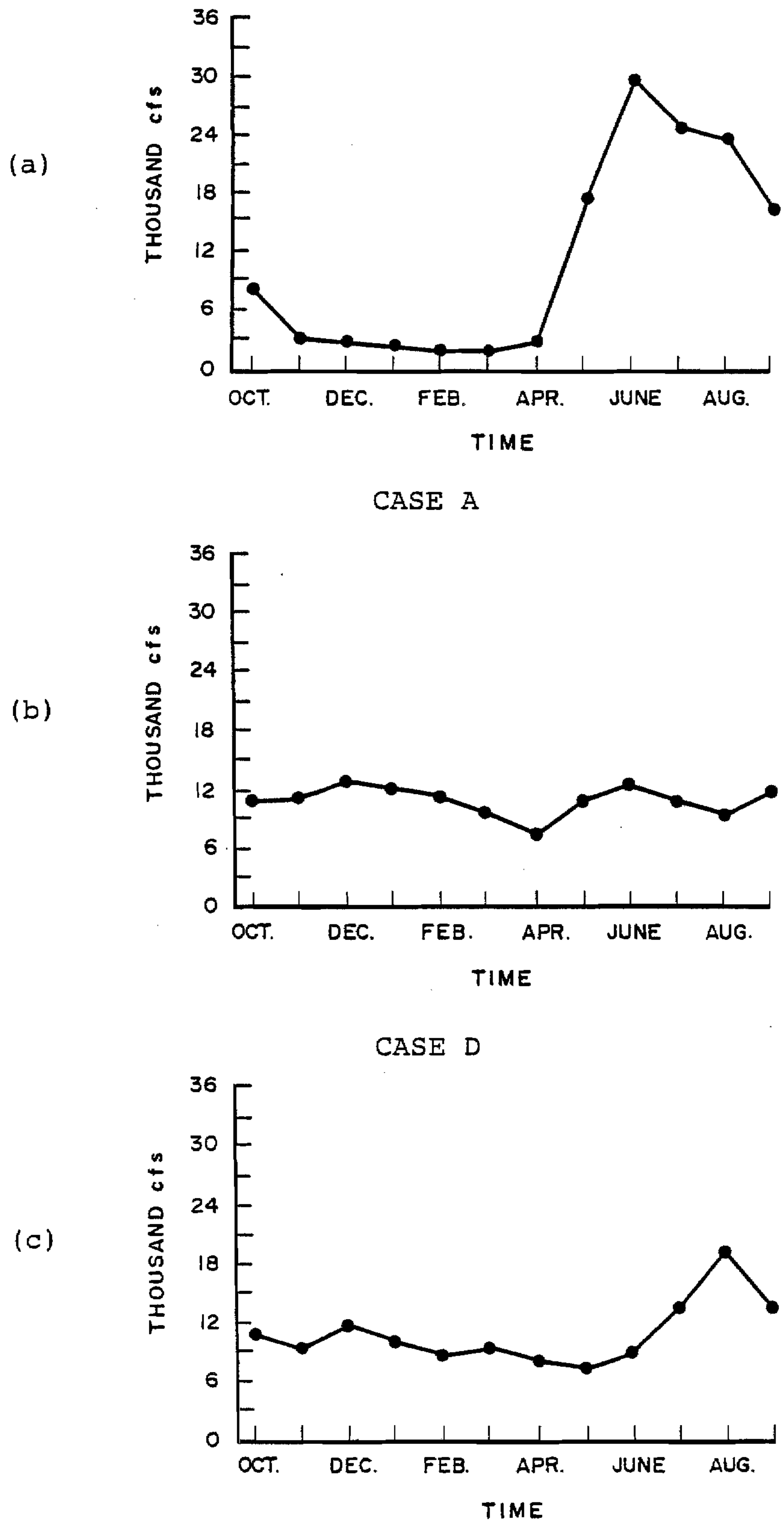


Figure 3.1: Gold Creek Flows for preproject (a), case A (b), and case D (c).

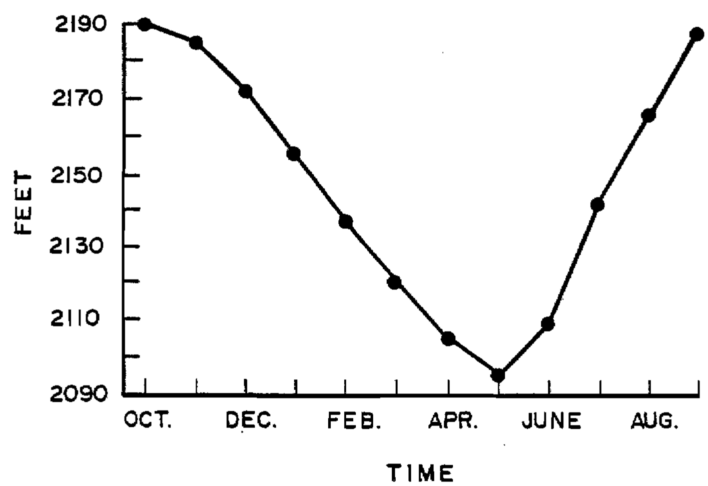


Figure 3.2: Watana Reservoir elevations throughout the year.

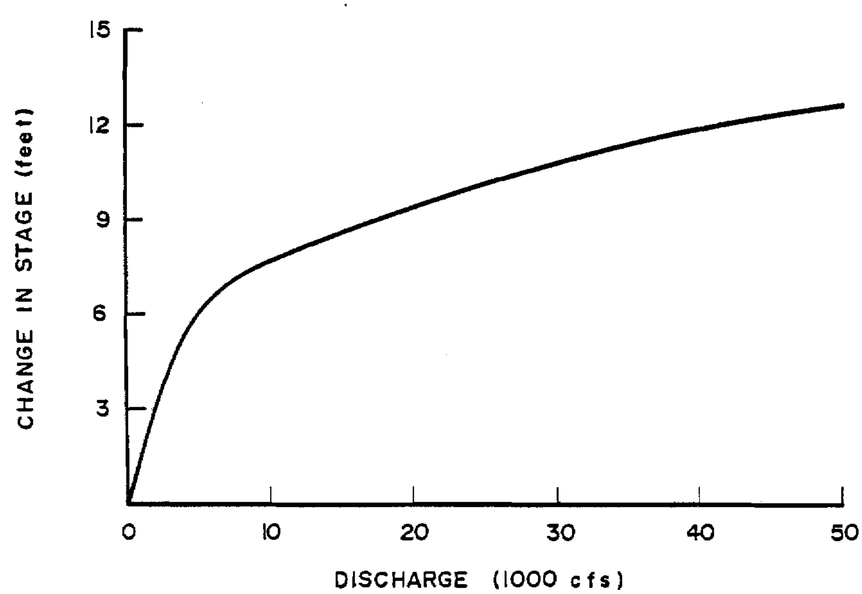


Figure 3.3: Stage - discharge rating curve for Gold Creek Station based on U.S.G.S. discharge data gathered since October 1, 1967.

3.1.1.2 Changes in Stage

The calculation of stage is based on stage-discharge rating curves like the one shown for Gold Creek (Figure 3.3). An estimate of stage variability for beaver dynamics is calculated as the difference of the stage in the maximum month, usually August, and the stage in the minimum month, usually March.

3.1.1.3 Side Channel and Slough Habitat for Beaver

Side channels and sloughs that retain greater than .5 m in depth of unfrozen water throughout the winter provide potential overwintering habitat for beaver. In the major area of concern, downstream of Devil Canyon Dam to Talkeetna, the amount of this habitat is directly related to water level (stage) and ice thickness. The stage depends on flow (Section 3.1.1.2), and the ice thickness depends on flow and the severity of the winter. In the model, the effect of the severity of winter was simulated as a random process that increased or decreased the amount of habitat from a mean value. The mean value was estimated visually from maps and reflects the fact that only 70% of the length of sloughs that are deep enough overall is suitable habitat due to the gradual decrease in depth at the end of sloughs. The relationship is expressed in the following equation:

$$\text{Shoreline Habitat} = \text{Mean Shoreline Habitat} * \text{Winter Severity Factor}$$

where shoreline habitat is defined as slough and side channels with greater than .5 m of ice-free water. The winter severity factor was constrained to take a value between .5 and 2.0, which limits the maximum effect to a doubling or halving of available habitat.

Currently, the model does not estimate flow effects on overwintering habitat. This is a major deficiency because of the year to year variation in flow and because of vast differences between flows throughout the winter that would occur with and without the project.

3.1.1.4 Scouring

The dynamics of ice scouring are imperfectly understood, but participants felt that scouring would be less prevalent after the project because of reduced flows during spring break-up.

At present, the model simulates ice scouring as a random process. The probability of significant ice scouring is .95 before the project and .05 after the project. A random number drawn from a uniform distribution determines whether scour occurs.

3.1.1.5 Water Surface Area in the Downstream Floodplain (Devil Canyon to Susitna-Chulitna Confluence)

Total area of water surface between Devil Canyon and Susitna-Chulitna confluence was estimated at various flow levels using the U.S. Corps of Engineers HEC-2 runs (dated February 2, 1982), (R & M Consultants, pers. comm.). Figures were computed by using the average width of adjacent cross sections and multiplying by the length between them. The steep slope around a flow of 20,000 cfs shown in Figure 3.4 exists due to the addition of sloughs to the flow regime of that level.

Knowledge of the water surface area and an estimate of the total area in the floodplain allows the vegetation

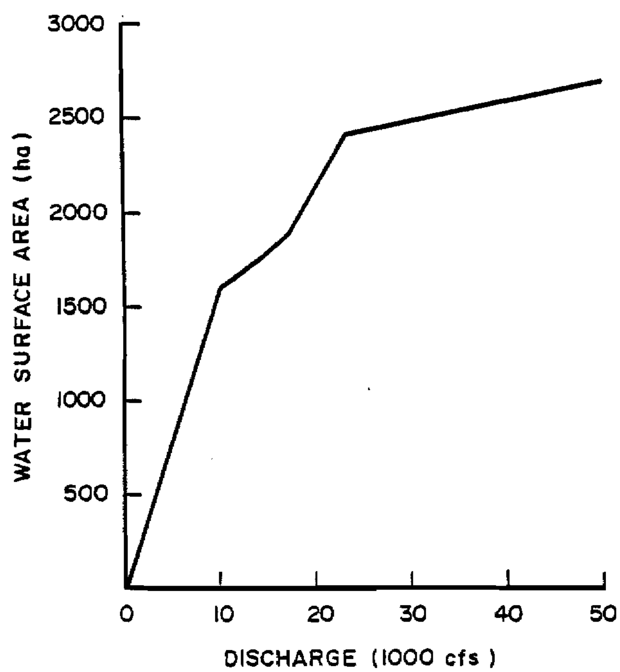


Figure 3.4: Water surface area in the downstream floodplain (Devil Canyon to Susitna-Chulitna confluence) as a function of discharge measured at Gold Creek Station.

submodel to estimate the total surface area exposed in the floodplain.

3.1.1.6 Snow

Snowfall is simply generated stochastically because there was insufficient conceptual understanding of snow dynamics. This is a major model deficiency because snow levels can seriously affect utililation of moose winter range.

3.1.2 Hydroelectric Development Activities

The timing, location, and areas affected by project activities considered by the model are listed in Table 3.1. At the appropriate time and location, the model alters the vegetation classification for the area associated with the site for the activity to the "disturbed" category (c.f. Table 2.3). The site may be permanently disturbed or may be reclaimed or revegetated at a later date.

3.1.3 Other Land Use Activities

There are a number of current and potential uses for the land with the geographic area being considered by the model. These include agriculture, forestry, recreation, settlement, coal development, mining development, oil and gas development, and transportation. There appears to be little potential for agriculture, coal development, and oil and gas development although lease sales have been proposed. Forestry and settlement may increase in the downstream portion of the Susitna. Perhaps the greatest potential is for increased mineral development and recreational opportunities.

Table 3.1: Hydroelectric Development Project Actions

ACTION	AREA AFFECTED	TIME	LOCATION
1. TRANSMISSION CORRIDORS (clearing)			
• Watana to Devil Canyon	41 mi x 400' = 1988 acres = 804 hectares	1989-1990	Watana to Devil Canyon
• Devil Canyon to Intertie	11 mi x 700' = 933 acres = 378 hectares	1989-1990	Devil Canyon to Chulitna Pass/Indian River
2. CAMPS			
• Watana	75 acres = 30 hectares 70 acres = 28 hectares Reclamation starts (No permanent structures)	1985-1994 1986-1995 1994	Between Tsusena & Deadman Creeks
• Devil Canyon	45 acres = 18 hectares 15 acres = 6 hectares Reclamation starts (No permanent structures)	1994-2002 1995-2002 2002	South of Susitna River on plateau opposite Portage Creek
3. VILLAGES			
• Watana (permanent)	31 acres = 13 hectares 35 acres = 14 hectares	1987- 1988-	Between Watana Camp site and Tsusena Creek, surrounding small lake
• Watana (temporary)	120 acres = 49 hectares		Adjacent to and south of permanent buildings
• Devil Canyon (no permanent buildings)	24 hectares	1995-2002	South of Susitna River on plateau opposite Portage Creek

Table 3.1 (cont'd)

ACTION	AREA AFFECTED	TIME	LOCATION
4. RESERVOIR CLEARING			
• Watana	1214 hectares	1989	Watana impoundment
	3642 hectares	1990	Watana impoundment
	3642 hectares	1991	Watana impoundment
	4047 hectares	1992	Watana impoundment
• Devil Canyon	607 hectares	1999	Devil Canyon impoundment
	729 hectares	2000	Devil Canyon impoundment
	607 hectares	2001	Devil Canyon impoundment
5. STAGING AREAS			
• Access Plan #13 (north)	61 hectares	1985-2002	Hurricane
• Access Plan #16 (south)	61 hectares	1985-2002	Hurricane
	61 hectares	1985-2002	Gold Creek
• Access Plan #17 (Denali)	61 hectares	1985-2002	Cantwell
	61 hectares	1994-2002	Gold Creek
6. CONTRACTOR WORK AREAS			
• Watana	77 hectares	1985-1995	Between Watana
	146 hectares	1986-1995	Camp and
	77 hectares	1987-1995	Dam Site
• Devil Canyon	61 hectares	1994-2002	Between Devil
(including batching plant)	61 hectares	1995-2002	Canyon Camp
	61 hectares	1996-2002	and
	12 hectares	1997-2002	dam site

Table 3.1 (cont'd)

ACTION	AREA AFFECTED	TIME	LOCATION
7. CONTAINMENT STRUCTURES			
• Watana	20 hectares 32 hectares 36 hectares 26 hectares 3 hectares 10 hectares 4 hectares	1985- 1986- 1987- 1988- 1989- 1990- 1991-	Watana Dam site including floodplain
• Devil Canyon	1 hectare 5 hectares 13 hectares 2 hectares	1996- 1997- 1998- 1999-	Devil Canyon Dam site including floodplain
8. AIRSTRIPS			
• Watana	47 hectares	1985-	Adjacent to Watana Camp
• Devil Canyon	9 hectares	1994-	Adjacent to Devil Canyon Camp
9. ACCESS ROADS (clearing)			
• # 13 (north)	59 mi x 60' width = 429 acres = 174 hectares	Construction: 1985 Intensive use: 1985-1995 Intensive use: 1994-2002	Hurricane to Watana Hurricane to Watana Hurricane to Devil Canyon
• # 16 (south)	69 mi x 60' width = 502 acres = 203 hectares	Construction: 1985 Intensive use: 1985-1995 Intensive use: 1994-2002	Hurricane & Gold Creek to Watana Hurricane & Gold Creek to Devil Canyon
• #17 (Denali)	40 mi x 60' width = 291 acres = 118 hectares 55 mi x 60' width = 400 acres* = 162 hectares	Construction: 1985 Intensive use: 1985-2002 Construction: 1991-1993* Intensive use: 1994-2002	Denali Hwy to Watana Denali Hwy to Watana Watana to Gold Creek* Watana to Gold Creek

Currently, the model only considers additional lands needed for settlement, mining development, and recreational development. Present use of the area is low, although substantial growth is expected if the Susitna project goes ahead. Estimates of current use are given in Table 3.2, are unsubstantiated, and must be revised when better estimates appear.

3.1.4 Disturbance to Wildlife

Associated with project activities and other land use activities is disturbance to wildlife as a result of the presence of humans. The model keeps track of three major classes of disturbance:

a) disturbance from recreational use;

b) disturbance due to the influx of construction workers; and

c) disturbance from vehicle and aircraft movements.

The disturbance from construction workers and vehicle traffic is provided in Table 3.3. Recreational disturbance is based on the use information in Table 2.2 and a small annual growth rate.

3.1.5 Access

The model allows for a choice of access route (Table 3.1). The choice of the access route will affect the amount and level of vegetation impacted and may impact critical wildlife areas. Another aspect is whether public access to the project area via the new access road is desirable. The model allows for completely open access or to restrict access in some manner.

Table 3.2: Estimates of Current Land Use and Recreational Use in Geographic Area Considered in the Model

	Upper Susitna Basin	Downstream (Devil Canyon-Talkeetna
Mining (hectares)	10,000	14,000
Recreation (user days)	13,000	--
Settlement (hectares)	2,021	6,064

Table 3.3: Disturbance Associated with Construction Workers and Vehicle Traffic

DISTURBANCE	LOCATION	TIME	MAGNITUDE
Construction workers	Watana Camp & Construction Area	1983	180 workers on site at one time
		84	192
		85	690
		86	780
		87	1,140
		88	1,500
		89	1,680
		90	2,070
		91	1,920
		92	1,500
		93	780
		94	360
		95	48
	Devil Canyon Camp & Construction Area	1994	60 workers on site at one time
		95	240
		96	480
		97	750
		98	990
		99	1,020
		2000	900
		01	540
		02	48
Vehicle traffic	To Watana	1985-1995	53 trucks per week each direction
	To Devil Canyon	1994-2002	92 trucks per week each direction
	Gold Creek to Devil Canyon	1994-2002	4 trains per week each direction (if Denali Route is chosen)
Big Game Harvests	Game Management Unit #13	Present	Caribou - 750/year Moose - 750/year Brown Bear - 100/year Black Bear - 60/year
Diversion Structures - Blasting -	Watana Dam site	1985-1987	Unknown
	Devil Canyon Dam site	1995-1996	Unknown

3.2 Vegetation

The vegetation submodel is a set of rules for simulating vegetation and land use processes in response to direct Susitna development activities and indirect changes of the hydrologic regime in the downstream floodplain. The model is based on a land classification system in which areas in each land class are updated annually in response to human activities and processes of natural vegetation change. The Looking Outward Matrix (Table 2.5) identifies the processes simulated by the vegetation submodel in terms of information required by other submodels. The information consists of area of various land classes for each spatial unit, berry production in each land class, the standing stock of potential browse for moose in each land class, and a measure of the proportion of both main channel and sloughs or side channels with associated vegetation preferred by beaver. The only actions for which the vegetation submodel is directly responsible are controlled burning and vegetation crushing.

3.2.1 Structure

The sequence of calculations for the vegetation submodel is outlined in Figure 3.5. Given current knowledge of vegetation dynamics in the area, constant conditions, or no net change, in the absence of development activities were assumed. Areas in the various land classes do not change in the model in the absence of development.

3.2.2 Classification System

The classification system was developed from work described in the Plant Ecology Phase I Final Report (McKendrick et al., 1982). The classification system in the model distinguishes 14 classes of land, primarily defined on the basis of vegetation type, in each spatial unit (see Section 2.3). Initial conditions (Table 3.4) were estimated for all spatial units, except the one representing moose range in the area downstream from Devil Canyon. The impoundment areas

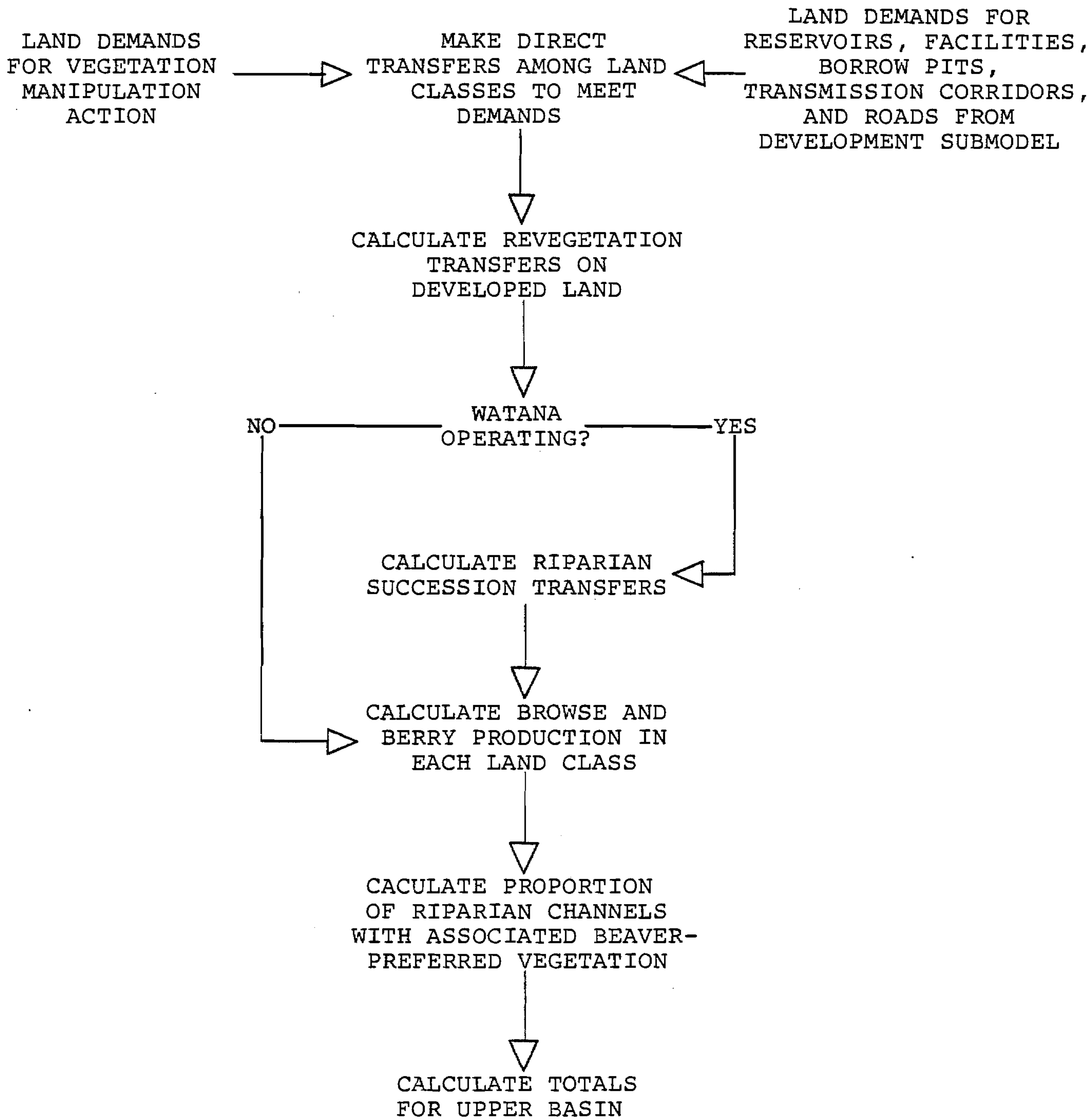


Figure 3.5: Calculation sequence for the vegetation submodel.

Table 3.4: Initial conditions for vegetation types estimated at workshop. All values are in hectares.

LAND CLASS	WATANA IMPOUNDMENT AREA	DEVIL CANYON IMPOUNDMENT AREA	REST OF UPPER SUSITNA BASIN	RIPARIAN ZONE TALKEETNA TO DEVIL CANYON
Coniferous Forest- woodland and closed	4275	153	183963	0
Coniferous Forest- open	3633	633	114607	0
Deciduous and Mixed Forest	2911	1516	36218	3500
Tundra	84	11	394590	0
Tall Shrub	537	3	128495	300
Medium Shrub	44	5	3306	0
Low Birch Shrub	400	44	29750	0
Low Willow Shrub	66	14	10565	0
Low Mixed Shrub	673	4	470784	400
Unvegetated-water	2060	813	36967	600
Unvegetated-rock, snow, ice	60	15	203478	0
Disturbed-temporary	0	0	0	0
Disturbed-permanent	1	1	1	0
Pioneer	1	1	1	200

estimated are slightly larger than the areas that would be cleared if the development proceeds. In addition to the spatial units described above, total areas in the upper Susitna Basin were calculated as the sum of the two impoundment areas and the rest of the upper Susitna unit.

The land classification was expanded. A medium shrub class was defined in order to calculate bird indicator variables. Two disturbed classes were defined to represent land disturbed by construction of permanent facilities or by temporary activities which would be followed by artificial or natural revegetation. A pioneer class was added to represent the initial stages of herbaceous vegetation in riparian areas and following temporary human disturbance.

3.2.3 Development Activities

The vegetation submodel responds to demands for land associated with reservoir development, road construction, transmission corridor construction, borrow pits, and construction of permanent facilities. These demands, calculated each year by the development submodel, result in transfers of land among various land classes within the respective spatial units. Generally, the development land demands in a given spatial unit are met from the various land classes in the spatial unit according to their relative proportions in that unit. However, land demands for roads are specified as proportions of various classes associated with specific routes.

Clearing for reservoirs is simulated by subtracting the appropriate proportions of the reservoir land demand from the respective land classes and adding the total to the inundated land class.

The development demand for facilities is met by transferring land to the permanently disturbed class.

Access road construction is simulated by taking land from various land classes according to development submodel demand and route-specific land class proportions. Land for roads is added to the low mixed shrub class under the assumption that the biggest areal change is in the associated right-of-way.

The demand for transmission corridors is met by initially transferring land to the low mixed shrub class. This land is then subject to succession to the medium shrub class at an annual proportional rate of 20%.

Borrow pits are developed by transferring land to the temporarily disturbed class. User specified fractions of the borrow pit land are then subject to either inundation or revegetation. Inundated borrow pits are transferred to the water class, while revegetation of borrow pits consists of an initial transfer to the pioneer land class followed by a transition to low mixed shrub at a proportional rate of 10% per year.

Finally, the action of vegetation manipulation (controlled burning and crushing) transfers land from the deciduous and mixed forest class to the low mixed shrub class. This land is then subject to succession to the medium mixed shrub class (at a rate of 20% of the low mixed shrub class per year), followed by transfer to the deciduous and mixed forest class (at a rate of 7% of the medium shrub class per year). The area of land transferred by vegetation manipulation is provided as an action to the model as a whole, rather than as a value calculated by the development submodel. This action is intended to roughly simulate controlled burning and vegetation crushing which were discussed as possible mitigation measures designed to increase wildlife habitat value. The land is transferred only from the deciduous and mixed forest land class. It was felt that this would be the preferred land for vegetation manipulation because of relative increase in habitat value resulting from converting this land class to earlier successional stages.

3.2.4 Riparian Succession

Under current hydrologic conditions, vegetation succession and disturbance in the riparian zone are assumed to be in equilibrium (i.e. no net change from the current land class composition). In the model, operation of the Watana Dam triggers two changes in the riparian zone from Talkeetna to Devil Canyon. First, initiation of the new hydrologic regime triggers a transfer of land from the water class to the pioneer class. Second, a process of net successional change is initiated because of stabilized flow patterns and lessened ice scouring causing a drastic reduction in disturbance intensity. This successional sequence is represented in Figure 3.6. The annual transfers among land classes (Figure 3.6) were estimated from a consideration of the observed ages of individual trees and shrubs within the various vegetation types. Operation of the Devil Canyon Dam has no additional effect because it was assumed that additional reductions in the intensity of disturbance would be small.

3.2.5 Wildlife Habitat

The wildlife submodels required a measure of browse, a measure of berry production, and an index of the suitability of vegetation along channels in the riparian zone (for beaver) as measures of habitat.

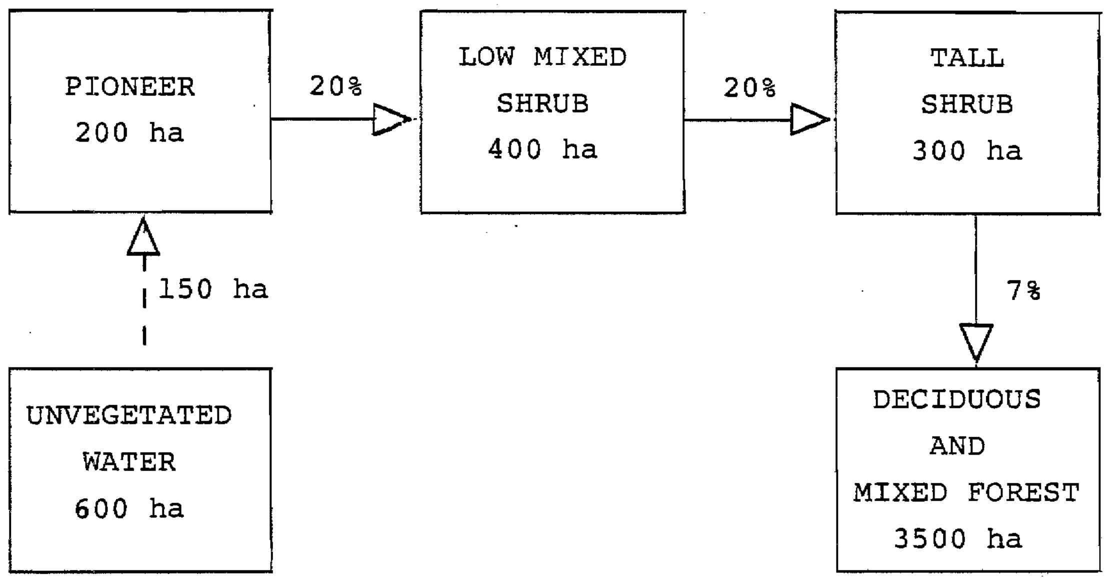


Figure 3.6: Successional sequence in the Talkeetna to Devil Canyon Riparian Zone. Numbers within each compartment are the estimated initial conditions. Numbers on the solid arrows represent the annual percentage transfer under post-Watana dam conditions. The dashed arrow represents a single addition of land to the sequence in the year Watana operations commence.

An estimate of potential browse (kg dry weight/ha) is obtained for each land class by multiplying the relative cover of the primary browse species in each of the land classes by the quantity (kg/ha) of browse associated with each species (Table 3.5). Random variation (standard deviation of 10%) is applied to these estimates to yield annual values. Annual berry production (kg dry weight/ha) is calculated in a similar fashion by applying the same random annual variation to an average production estimate (Table 3.5) based on production of berry species and their relative cover in the various land classes.

The suitability of channel vegetation in the riparian zone for beaver was difficult to calculate given the available information and the spatial scale of the model. The furbearer/bird submodel requires the proportion of both main channel and sloughs/side channels, with certain substrate conditions, which have willow or balsam poplar in close proximity to the channel. While it was not possible to make distinctions between main and sloughs/side channels or substrate conditions, an examination of aerial photographs indicated approximately 25% of the channels in the riparian spatial unit (Talkeetna to Devil Canyon) currently have willow or balsam poplar vegetation in close proximity to the banks. Initially, it was assumed that this proportion will change in relation to the fraction of the riparian zone in the low mixed shrub land class.

A more reasonable, although still crude, assumption based on cover has since been incorporated. Cover values for willow and balsam poplar in each of the land classes in the riparian zone as estimated from data in McKendrick et al. (1982) are combined to yield a total cover value for the vegetation preferred by beaver for each land class. These cover values are then averaged across the various land classes, weighting each value by the relative area in that land class:

Table 3.5: Estimates of average values for potentially available browse standing crop and annual berry production in each land class. Average values are modified in the model by a random variation.

LAND CLASS	POTENTIALLY AVAILABLE BROWSE (kg dry weight/ha)	BERRY PRODUCTION (kg dry weight/ha)
Coniferous Forest-woodland and closed	570	60
Coniferous Forest-open	570	20
Deciduous and Mixed Forest	329	70
Tundra	120	2
Tall Shrub	0	0
Medium Shrub	2395	15
Low Birch Shrub	1975	20
Low Willow Shrub	600	0
Low Mixed Shrub	1410	20
Unvegetated-water	0	0
Unvegetated-rock, snow, ice	0	0
Disturbed-temporary	0	0
Disturbed-permanent	0	0
Pioneer	0	0

$$TBC = \left[\sum_{t=1}^{14} BC_t HA_t \right] / THA \qquad (6)$$

where,

TBC = total cover value (percent) of beaver preferred species;

BC_t = cover value (percent) of species preferred by beaver in each land class;

HA_t = area of each land class (hectares);

THA = total non-water area in riparian zone (hectares); and

t = land class type (1 through 14).

TBC increases if vegetation changes increase the proportions of riparian area in land classes with high cover values for willow and balsam poplar and decreases if vegetation changes result in proportionally more areas with low cover values for willow and balsam poplar. Encouragingly, the value of TBC calculated from the initial areas in each land class is within 0.5% of the independently estimated 25% of channel currently having willow or balsam poplar in close proximity. Since a value of 0 for TBC would also imply that 0 percent of the channels had willow or balsam poplar in close proximity, TBC was assumed to be a reasonable, direct indicator of the percent of channels in the riparian zone which had associated vegetation characteristics suitable for beaver.

3.3 Furbearers and Birds

The Susitna hydroelectric development will impact furbearers and birds primarily through habitat changes, although increased access may cause increase trapping intensity on furbearers. Habitat changes will result from habitat losses due to impoundments and to alteration of the downstream hydrologic and ice regimes.

Participants decided early in the development of the furbearer/bird submodel to concentrate on the population dynamics of one furbearer, the beaver, and to utilize a habitat approach for birds.

3.3.1 Beaver

The major sources of impact on beaver were hypothesized to be:

1) a change in the amount of appropriate habitat for food and denning sites; and

2) an increase in beaver trapping intensity due to improved access to the region.

A simple beaver population model was built to simulate the effects of these two sources of impact. A simple but rigorous approach, neglecting some detailed biology (i.e. ingestion rates, growth rates, fat content, fecundity, etc.), is appropriate given the current state of knowledge. A more detailed representation of beaver may be needed when more data and understanding are available.

The model chosen is commonly used in biology - the logistic growth model with an additional mortality term:

$$\frac{dB}{dt} = rB(1 - \frac{B}{K}) - M$$

where,

B = number of beaver colonies;

r = intrinsic growth rate (yr^{-1});

K = carrying capacity (number of beaver colonies); and

M = mortality term.

The group chose the number of beaver colonies (also called dens or lodges) as the measure of population because the number of beaver in a colony is extremely variable. The population time trajectory is easily predicted (Figure 3.7) if the carrying capacity, intrinsic growth rate, and mortality are constant over time. However, the trajectory is more complex if the parameters change with time. The remainder of this section describes how the subgroup chose to represent the variation of these parameters as a function of the information available from the other subsystems.

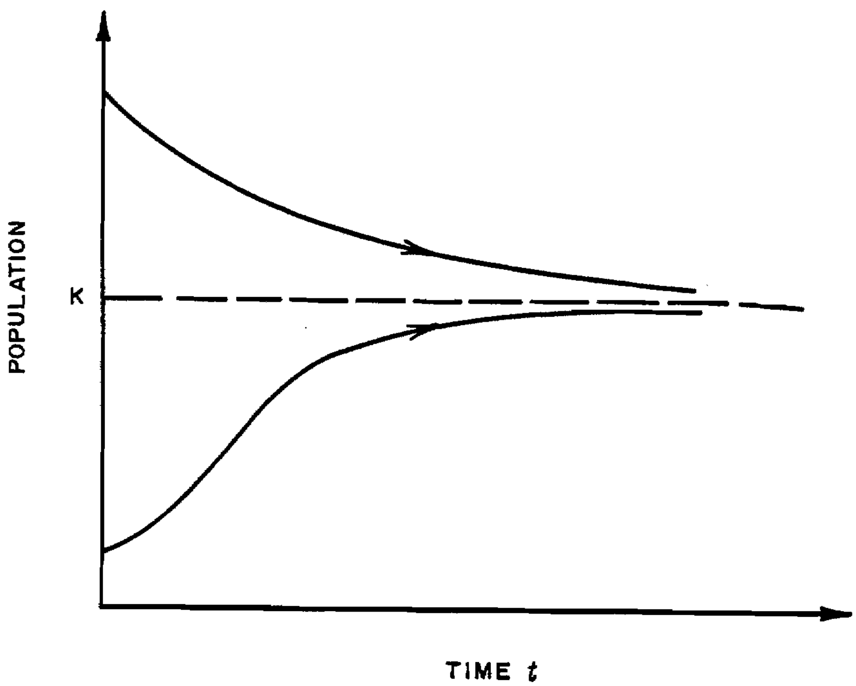


Figure 3.7: Time dynamics of a population based on the logistic growth model. A population that starts above its carrying capacity (K) will decline to its carrying capacity. A population that starts below its carrying capacity will increase towards its carrying capacity.

3.3.1.1 Beaver Carrying Capacity

In the context of this model, carrying capacity is the maximum number of beaver colonies that can be supported within each spatial unit. To determine this number, it is necessary to first define good beaver habitat and second, to estimate the maximum number of colonies that can successfully use that habitat.

Beaver habitat was defined as kilometers of shoreline satisfying the following conditions:

a) willow and balsam poplar are the dominant vegetation adjacent to the shoreline which has a bank composed primarily of silt (from the vegetation submodel); and

b) the water adjacent to the bank is sufficiently deep that there is at least .5 m of unfrozen water below the maximum ice cover (from the physical processes/ development/recreation submodel).

The willow and balsam poplar vegetation is required by beaver both as a source of food as well as lodge construction material. Only vegetation in the riparian zone on either side of the river is of interest because beaver rarely travel more than 100 m from their lodge location. The silty bank is hypothesized to be an indicator of suitable slope for den construction and lack of ice scouring.

The severe annual ice scour under the present flow and ice regimes prohibits development of suitable habitat along the main channel, and beaver habitat is only associated with the proper vegetation in sloughs and side channels. However, severe ice scour will likely be a rare event after impoundment. This will probably result in more willow and balsam poplar stands along the main channel which, given the predicted stabilization of water levels between Devil Canyon and Talkeetna, could result in beaver establishing colonies on or near the main channel.

To capture this effect, the length of potential main channel shoreline that does not freeze to within .5 m of the bottom is assumed to be double the length of the stream reach in each spatial unit. This is probably an underestimate because it ignores small bays and secondary channels currently exposed to ice scouring. It does, however, provide an indicator of positive habitat changes along the main channel. A proportion factor for willow and balsam poplar along the main channel provided by the vegetation submodel is used to convert shoreline length to appropriate habitat.

Ice-free water is a critical condition to the definition of habitat. Because a beaver den entrance is below the water line, ice-free water is the route by which the beaver leave their den in the winter to feed. The hypothesis is that the beaver will not survive the winter if there is less than .5 m of ice-free water.

To arrive at an actual carrying capacity for beaver colonies, it was assumed that the maximum colony density is 1 colony/2 km of habitat. Therefore, the total carrying capacity for beaver in each spatial unit is:

$$K = ((S_s * V_s) + (2 * S_m * V_m))/2$$

where,

K = carrying capacity;

S_s = km of suitable sloughs and side channels;

V_s = proportion of willow and balsam poplar with silty banks associated with S_s;

S_m = km of suitable main channel; and

V_m = proportion of willow and balsam poplar associated with S_m.

3.3.1.2 Intrinsic Growth Rate (r)

The intrinsic growth rate is the maximum rate at which the population can increase. It assumes ideal conditions (i.e. plentiful resources, no competition for habitat, etc.). This growth rate is only realized in the logistic model when the population is very much smaller than the carrying capacity (i.e. when B is much less than K in the logistic equation, page 44). The intrinsic growth rate (r) can be estimated as the exponential growth rate in the equation:

$$N_t = N_o e^{rt}$$

where,

N_t = number beaver colonies after t years;

N_o = number initial beaver colonies; and

r = exponential growth rate.

Participants hypothesized one beaver colony would spawn a second colony in a minimum of two years if there was a great deal of appropriate habitat and no other beaver colonies competing for space. Therefore, a doubling of colony size in 2 years means:

$$N_2 = N_o * e^{r*2} = 2N_o$$

and $$r = \frac{\ln 2}{2}$$

$$\simeq .3$$

The intrinsic growth rate was assumed constant for this model.

3.3.1.3 Mortality

Water Levels

Beaver colonies are vulnerable to changes in water level within the year. Increases in water level on the order of a few meters can result in the flooding of a den (in summer) or the freezing of a food cache (in winter). Similarly, a drop in water level will expose the colony to increased predation or, even more likely, severe winter temperatures if the water level falls below the den entrance. This is likely not a problem in the sloughs and side channels but is definitely a major factor (along with ice scouring) currently preventing establishment of beaver colonies along the main channel. Since decreased fluctuations in water level are predicted after impoundment, the simulated beaver colonies which may have established themselves in available habitat along the main channel are subjected to a mortality factor from water level changes (Figure 3.8). Total mortality of main channel colonies is possible with sufficiently extreme water level fluctuations.

Predation

After some discussion, the subgroup felt that predation on beaver probably is insignificant. Beaver is

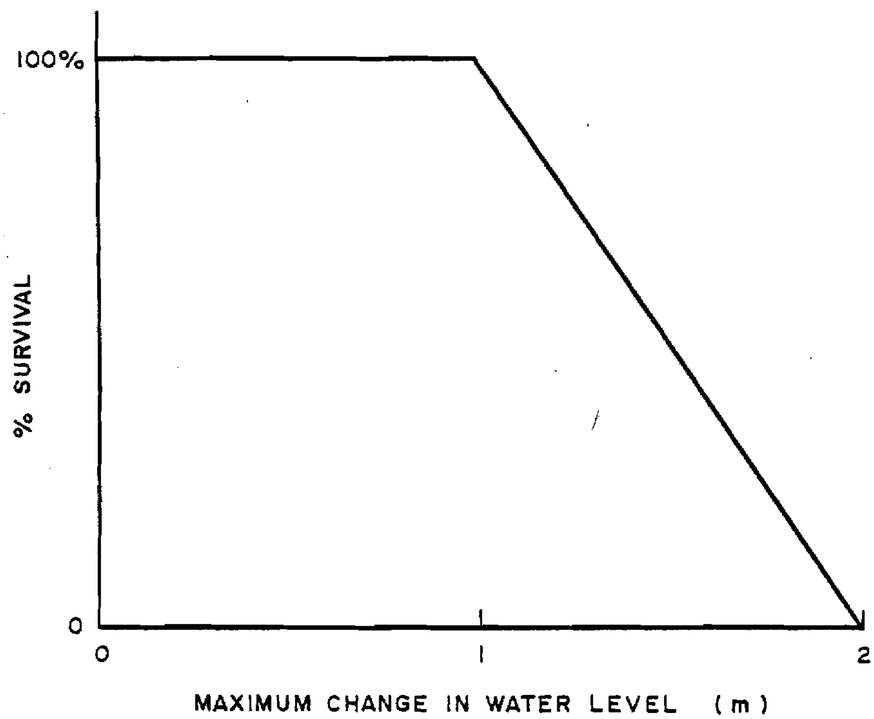


Figure 3.8: Percent survival of beaver colonies on main channel as a function of maximum change in water level from summer to winter.

a minor food item for both wolves and bear. Therefore, predation is not presently included in the model.

Trapping

Trapping is certainly one of the major potential sources of beaver mortality. Beaver are especially vulnerable to trapping during the winter when traps can be set over the beaver's access hole in the ice. The rapid decline of beaver populations in the lower 48 states when beaver trapping was a viable occupation is evidence of high vulnerability to trapping. Three factors were hypothesized to influence trapping effort:

1) beaver pelt prices;

2) knowledge about the location of beaver colonies; and

3) the number of other trappers in the area.

Price is certainly a key factor. Participants suggested that the beaver population in the Susitna Basin would probably be decimated within one year if beaver pelts were suddenly worth 5 to 10 times their current price (given the trappers knew where to go).

A maximum trapping mortality is calculated (Figure 3.9) using a price factor between 0 and 1. The price factor is model input and can be changed to explore the effect of a sudden price shift. This maximum mortality is modified by an access factor (Figure 3.10) expressed as a function of the number of people using the spatial area (i.e. construction workers plus public). For any given population, the access factor will change as a function of

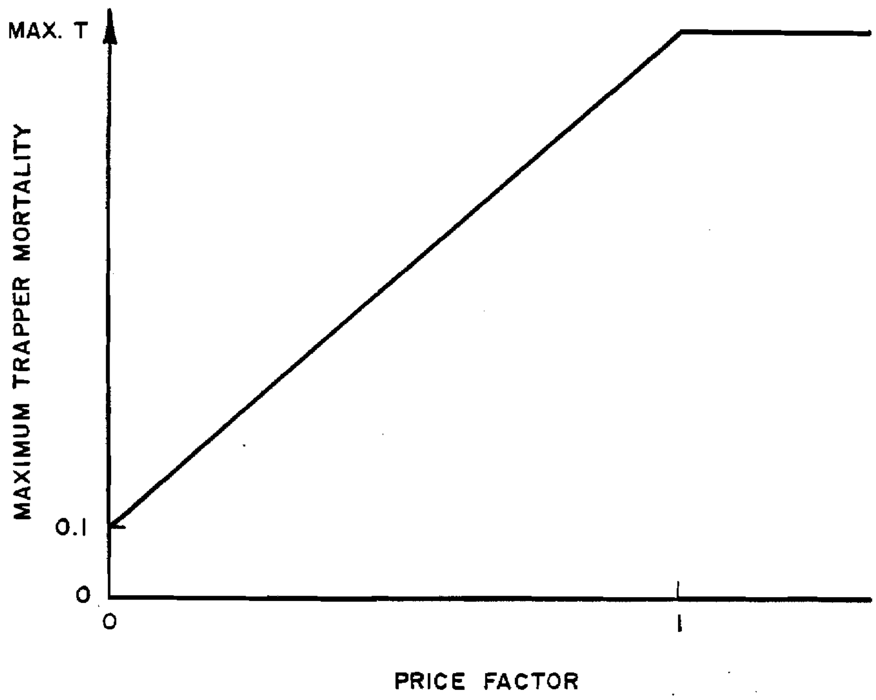


Figure 3.9: Maximum beaver trapping mortality as a function of a user specified price factor.

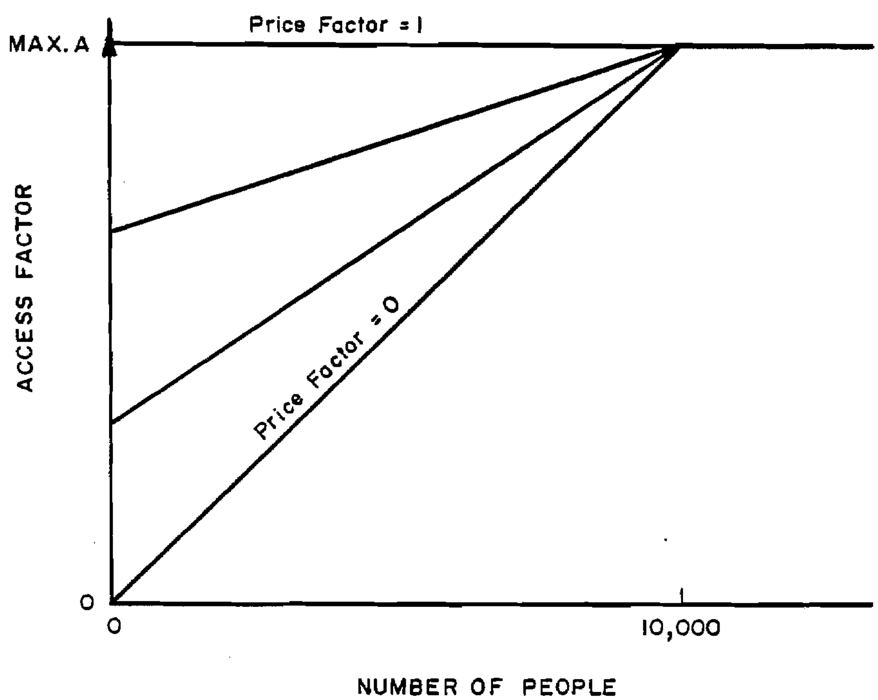


Figure 3.10: Trapper access factor as a function of the number of people using the area.

the user-specified price factor. The assumption is that access becomes less important as the relative price for beaver increases. Therefore, if the price factor reaches 1, then the beaver will experience the maximum trapping mortality (i.e. max_T). At present, max_T is equal to .9 and max_A is equal to 1. To limit access, an identified mitigation possibility, the user must specify a lower value for max_A.

3.3.1.4 Initiation of Main Channel Population

Since the water level changes are large before impoundment, the main channel population invariably suffers total mortality each year. However, the model does assume that a certain fraction (i.e. 10%) of the surviving beaver (in the side channels) will attempt to colonize under utilized habitat along the main channel in the spring.

The number of these migrants that succeed in establishing main channel colonies is reduced in direct proportion to the difference between the carrying capacity and the spring population along the main channel. Therefore, if the main channel population is zero (which it is prior to impoundment) then all of the migrants will establish a colony and their survival will depend on the simulated changes in water level and the degree of ice scouring during the following winter.

3.3.2 Birds

Participants identified the golden eagle, yellow-rumped warbler, tree sparrow, fox sparrow, and the trumpeter swan as key bird species for discussion. However, after considerable discussion, participants concluded that the limited state of knowledge about these birds precluded a species by species description of how they might be impacted by the project. Also, many critical survival processes for these species are controlled by events and conditions external to the model because they are migratory. Therefore, impacts were simulated as changes in habitat.

3.3.2.1 Passerine Birds

The approach used for this group was the Habitat Evaluation Procedure (HEP). The number of species and bird density were identified as important to establishing the value of any particular habitat. Average magnitudes for these two criteria were specified for each vegetation type (Table 3.6) using data from field studies in 1980 and 1981 in the upper basin.

A per hectare suitability index is calculated for each vegetation type by taking the sum of 1/3 of the species number value from Figure 3.11 and 2/3 of the bird density value from Figure 3.12.

The relative weights for each criterion selected by the subgroup indicate that bird density is somewhat more important than number of species.

A total number of habitat units is then calculated within each spatial unit:

$$\text{Habitat Units} = \sum_i TU_i * \text{Area}_i$$

where,

TU_i = suitability index for a given hectare of habitat i (from Figures 3.11, 3.12); and

Area_i = area of habitat i in spatial unit.

This representation assumes the birds, on average, will use land of any given vegetation type in exactly the same way each year. Although this is probably not a reasonable assumption, there is not enough information to take the model much further at this time.

3.3.2.2 Trumpeter Swan

Trumpeter swans are very sensitive to human disturbance.

Table 3.6: Passerine bird density and number of species associated with different vegetation types.

VEGETATION TYPE	DENSITY #/10 ha	SPECIES #/10 ha
Coniferous Forest		
Open	15.7	8
Woodland	34.3	17
Deciduous and Mixed Forest	43.9	22
Tundra	3.9	7
Tall Shrub	12.5	10
Medium Shrub	39.	6
Low Shrub		
Birch	10.6	6
Willow	(10.6)	
Mixed	(10.6)	

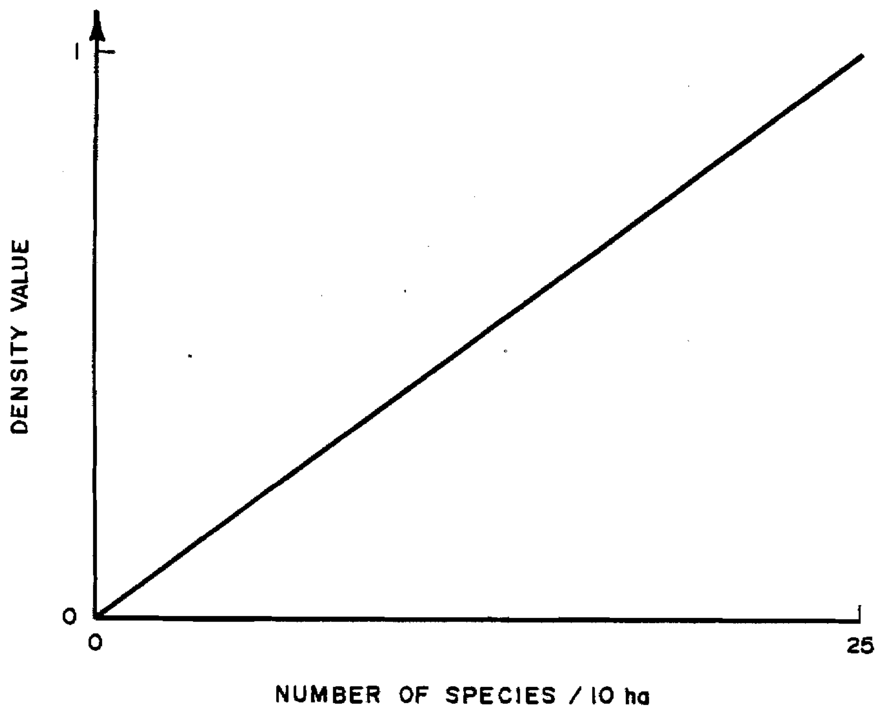


Figure 3.11: The relative value of species in any given vegetation type.

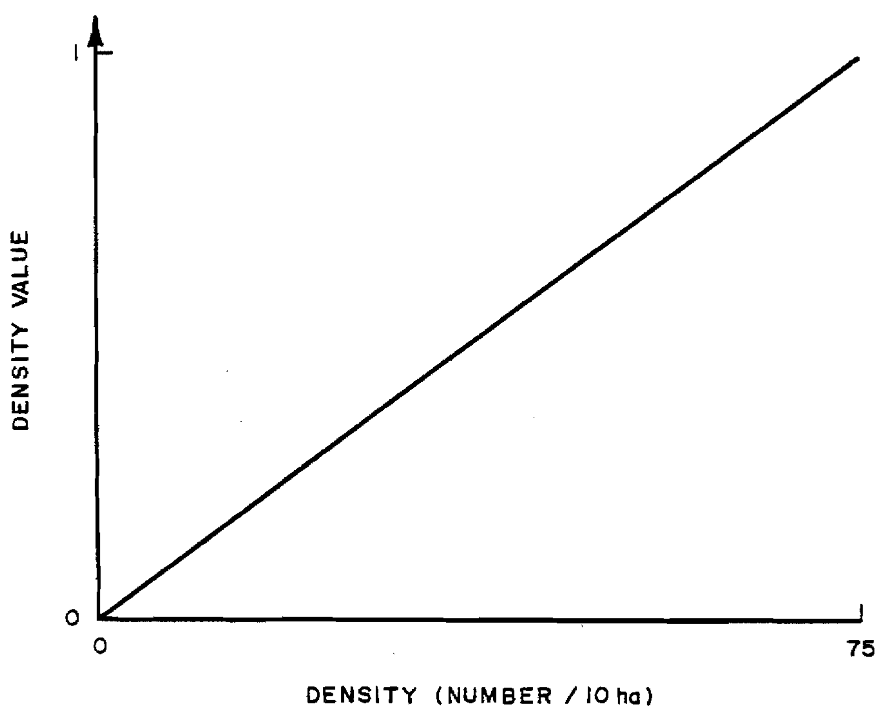


Figure 3.12: Relative value of bird density in any given vegetation type.

Although there are only a few breeding pairs in the area, it is known that Stephan Lake is a favored staging area during the spring and fall migraiton. Participants felt that the construction and use of roads and the transmission line would cause the major impacts. It was concluded that because potential impacts are known and predictable, the concern involved proper siting of roads and transmission lines to ensure minimum interference with nesting/staging areas. This was not included in the model.

3.3.2.3 Golden Eagle

The major impact of the Susitna project on the golden eagle will probably be the destruction of their traditional cliff nesting sites due to inundation.

Most of the good eagle nesting sites that may be affected have been found in the Watana impoundment area. Representation of this imapct in the model is done by comparing the elevation of each active site to the maximum elevation of the reservoir. If the nest elevation is less than the maximum reservoir level, then the nest site is counted as flooded. No attempt was made to determine just which sites had an active nest in any given year, nor what effect an inundated nest might have on the young. Instead, this indicator shows the potential reduction in existing eagle nest carrying capacity as a consequence of impoundment.

3.4 Moose

Discussions in the moose subgroup focused on alternative approaches to constructing a generalized population dynamics model that could later be refined to examine questions concerning the probable impacts of the Susitna hydroelectric development and the effectiveness of various mitigation measures. Subgroup participants stated clearly that having a model running at the end of the workshop was not their principal goal. Rather, they chose to concentrate on the development of a conceptual framework suitable for later refinement.

Neverless, it seemed desirable to have some form of moose model operating at the workshop simply for the purposes of demonstration. The remainder of this section, therefore, describes an attempt on the part of the workshop programmer to illustrate some of the kinds of relationships that might eventually be incorporated in the model. The specifics of the relationships should in no way be attributed to any of the workshop participants. Hopefully, however, the example does capture in a crude way some of the processes that were discussed and will serve as a stimulus for further thought.

3.4.1 Structure

Development of the moose submodel was guided by the need to produce indicators for evaluating both the impacts of Susitna hydroelectric development on moose and the potential effectiveness of various mitigation measures. The bounding exercise (Table 2.2) identified three general types of indicators:

1) measures of numbers of animals (total population size, harvest, numbers of animals dispersing out of the Susitna Basin);

2) indices or measures of habitat quality; and

3) indices or measures of habitat carrying capacity.

The structure of the moose submodel combines a simple model of winter carrying capacity and a generalized population dynamics model that can later be refined for the Susitna project as additional information and understanding become available. The computational sequence for the model is illustrated in Figure 3.13.

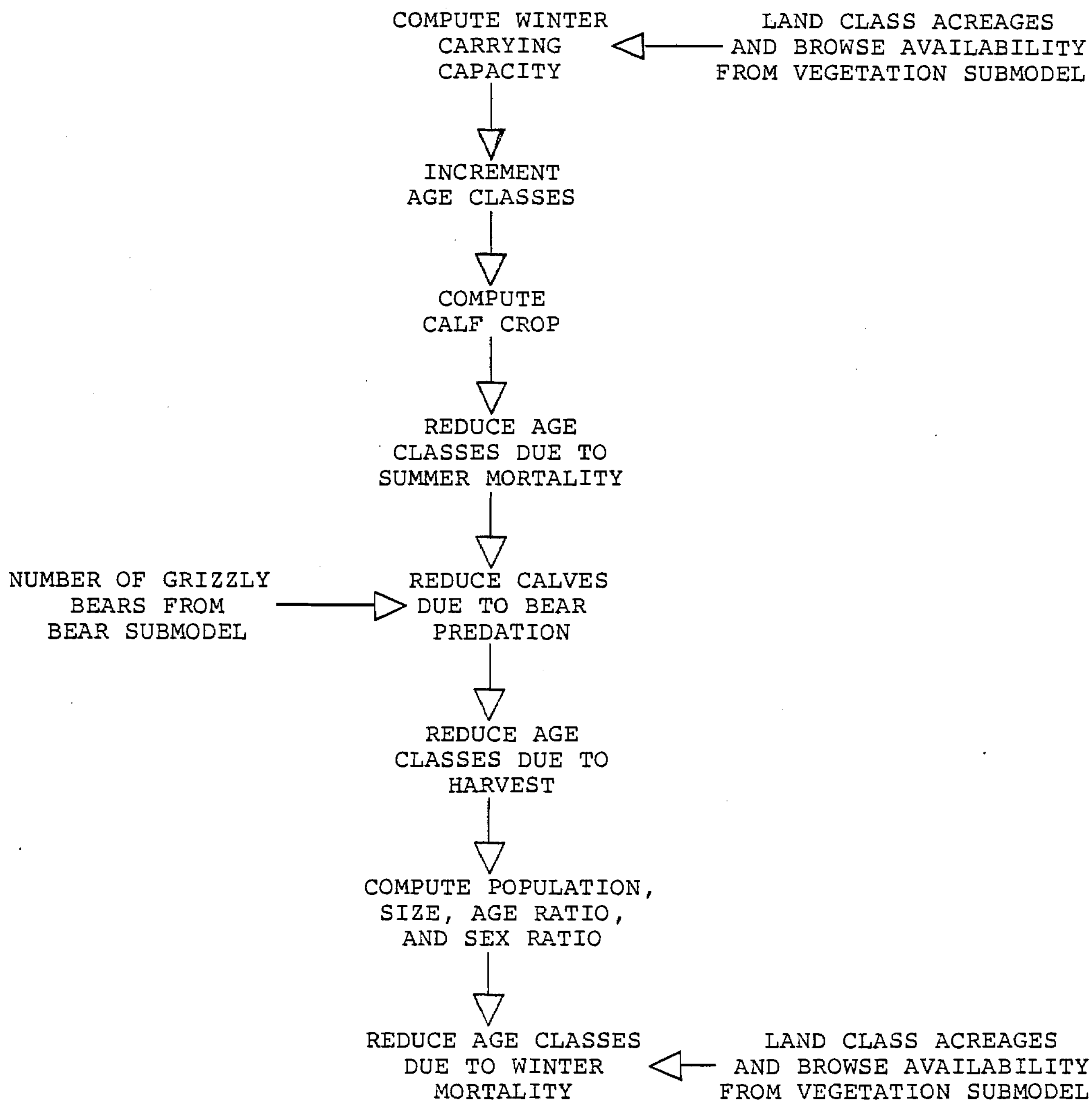


Figure 3.13: Calculation sequence for the moose submodel.

3.4.2 Winter Carrying Capacity

The winter carrying capacity for each spatial unit is calculated as the number of moose-days of browse available:

$$U = \sum_{j=1}^{14} A_j B_j (1 - L)/F$$

where,

U = moose-days of browse available;

A_j = area in land class j (ha);

B_j = available browse in land class j (kg dry weight/ha);

L = proportion of available browse at end of summer lost due to leaf fall; and

F = individual moose forage requirement (kg dry weight/day).

The vegetation submodel provides the area (A_j) and amount of browse available at the end of the summer (B_j) for each land class. Available browse is defined as the standing crop of plant material of species, size, and height suitable for moose forage. The amount of browse available in the winter is the amount available at the end of the summer reduced by a proportion representing leaf fall. Division by a daily forage requirement produces the number of moose-days of winter forage available.

3.4.3 Population Dynamics

The basis of the population dynamics model is a simple life table model that represents the birth and death processes for 20 age classes of moose for each sex. The biological year for the model begins with calving. Animals surviving from the previous year are first advanced to the next age class. Calf production is then calculated based on the number of females of reproductive age in the herd. The remainder of the year is divided into three periods for the calculation of various forms of mortality:

a) a summer period representing the time from calving to the start of the harvest;

b) the harvest period itself; and

c) a winter period representing the time from the end of harvest to calving the next year.

The number of animals in each population class is reduced by an age- and sex-specific mortality rate during each of these periods.

The utility of this model for assessing impacts and mitigation success is strongly dependent on the extent to which the reproductive and mortality rates incorporated in the model can be functionally related to factors influencing moose dynamics that may change with hydroelectric development. Much of the discussion in the subgroup focused on which of these factors might be important and how they might be quantified for representation in a simulation model. While a variety of interesting ideas emerged, there was not sufficient time or information at the workshop to begin to quantify such relationships.

3.4.3.1 Reproduction

Reproduction is calculated separately for yearlings (those 2 years old at the time calves are dropped) and adults (those 3 years or older at the time calves are dropped). Each of these groups has a fixed pregnancy rate (currently set at 0.85 for adults and 0.80 for yearlings) and a density-dependent ovulation rate per pregnant female (Figure 3.14). Ovulation rates are presently the same for both groups of females though the rate in yearlings should probably be somewhat lower. Pregnancy rates and ovulation rates are multiplied by the number of females to arrive at the number of calves born. The calf sex ratio is assumed to be 50%.

3.4.3.2 Summer

The population classes are first reduced by an age-specific mortality rate (presently 0.35 for calves, 0.01 for adults) during the summer period.

An additional mortality rate for calves is then calculated from the number of grizzly bears present (provided by the bear submodel) and the density of moose calves:

$$P = B * ((C * M)/(C + H))$$

where,

P = number of moose calves killed by bears;

B = number of bears;

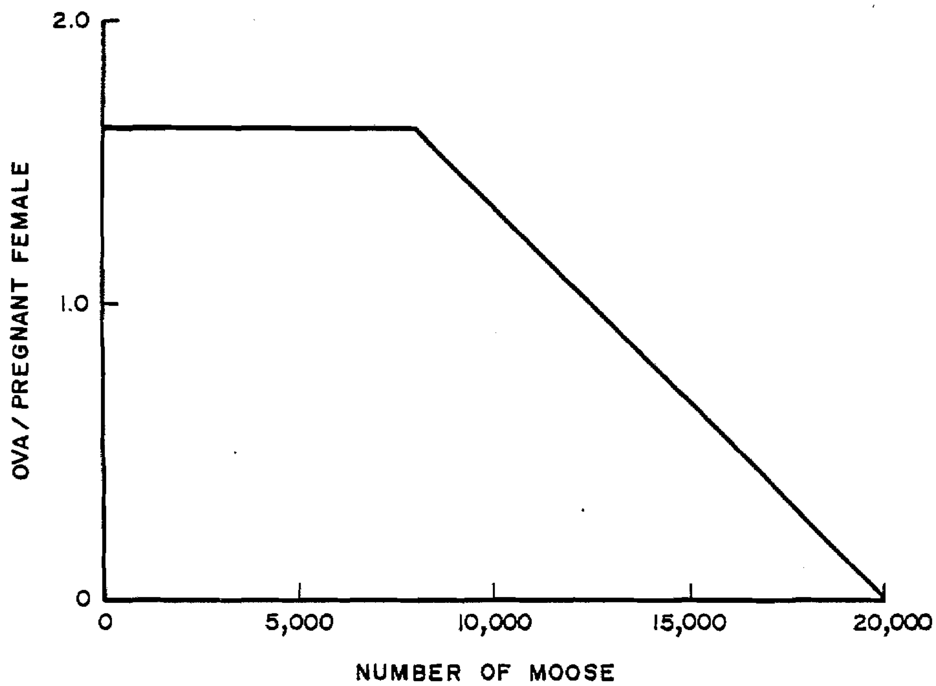


Figure 3.14: Relationship between moose density and ovulation rate.

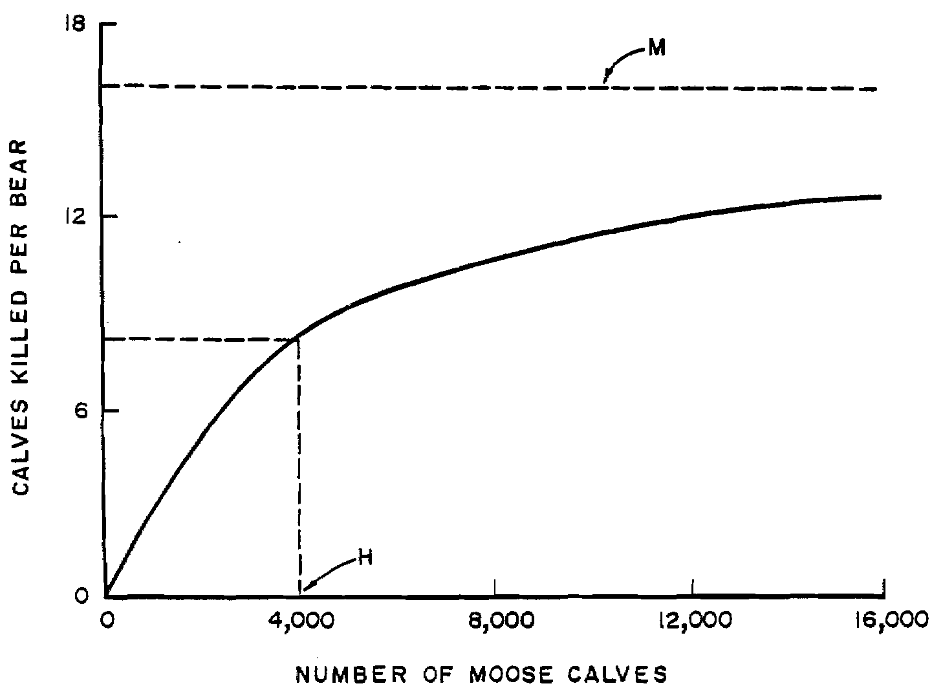


Figure 3.15: Relationship between moose calf density and bear predation rate with a half-saturation constant (H) of 4,000.

C = number of moose calves;

M = maximum number of calves that would be killed by a single bear in one summer; and

H = calf density at which a single bear can kill half of the maximum (M).

Bear predation on calves is assumed to be equally distributed between males and females. The form of this relationship (Figure 3.15) assumes that:

1) an individual bear finds it more difficult to locate and kill calves as calf density declines; and

2) bear predation saturates at some maximum level.

The half-saturation constant (H) varies in response to the randomly generated snowfall pattern as shown in Figure 3.16. This assumes that predation is heavier in years following heavy snowfall because calves are less healthy and therefore more vulnerable to bears. Figures 3.15 and 3.16 suggest an individual bear will find it easier to find and kill calves at low calf density in years following heavy snowfall.

3.4.3.3 Harvest

Harvest is assumed to be a constant rate (currently set at 40%) that is applied to a user-specified range of male age classes (presently males 3 years of age and older). The age ratio, sex ratio, and size of the herd are calculated following the harvest calculation. The age ratio is obtained by dividing the number of surviving calves by the number of cows 2 years of age or older and the sex ratio is obtained by dividing the number of bulls

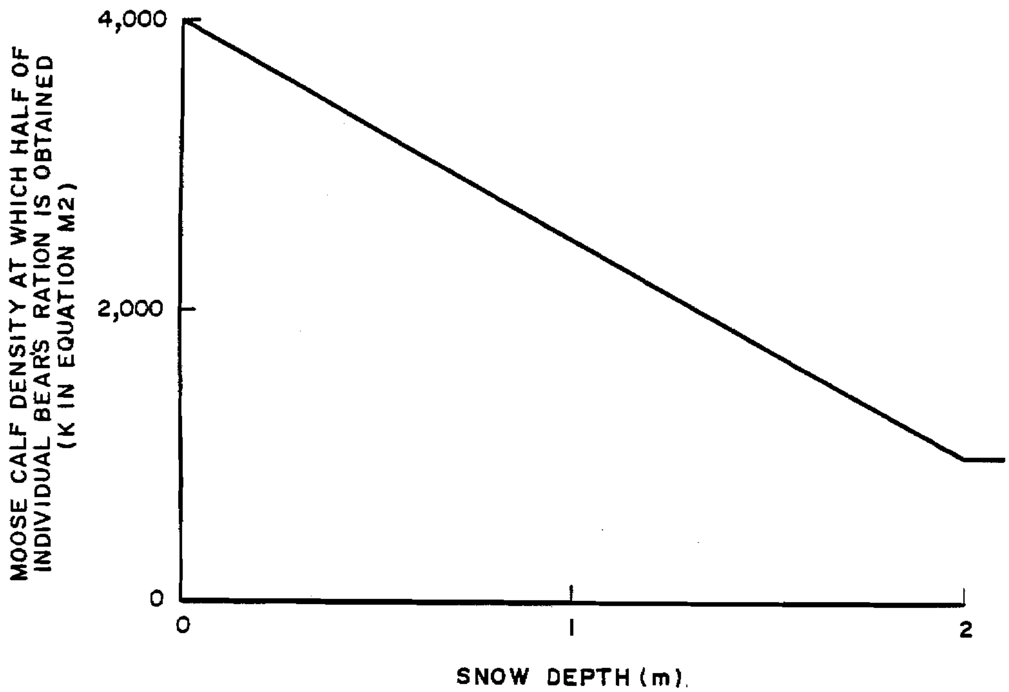


Figure 3.16: Relationship between snow depth and half-saturation constant for bear predation function.

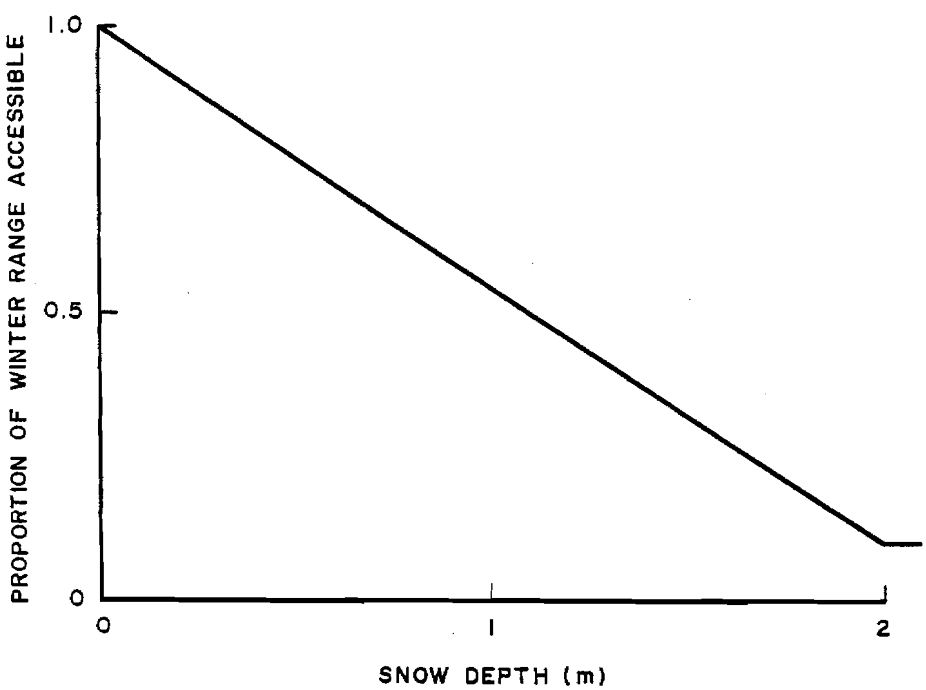


Figure 3.17: Relationship between snow depth and proportion of winter range accessible to moose.

2 years of age or older by the number of cows 2 years of age or older. These ratios are expressed as calves/100 cows and bulls/100 cows, respectively. The simulated age ratio, sex ratio, and population size calculated after the harvest thus correspond roughly in time to composition counts actually done in the field.

3.4.3.4 Overwinter Mortality

The final part of the example moose submodel calculates calf and adult winter mortality rates based on food availability. The area of winter range potentially available in any simulation year is first calculated by:

$$\left[\begin{array}{c}\text{preproject}\\ \text{winter range}\\ \text{area}\end{array} - \begin{array}{c}\text{area of}\\ \text{Watana}\\ \text{impoundment}\end{array}\right] * \begin{array}{c}\text{proportion of winter}\\ \text{range accessible}\end{array}$$

The randomly generated snowfall pattern affects the proportion of winter range accessible (Figure 3.17). The total amount of forage available on the winter range is then calculated using an equation similar to that for winter carrying capacity (page), but assuming that all of the winter range is in the conifer woodland class. The amount of food available per moose per day is computed as the total amount of available forage divided by the total number of moose present and the average number of days spent on the winter range. Forage available per individual is used to calculate calf and adult survival rates (Figure 3.18).

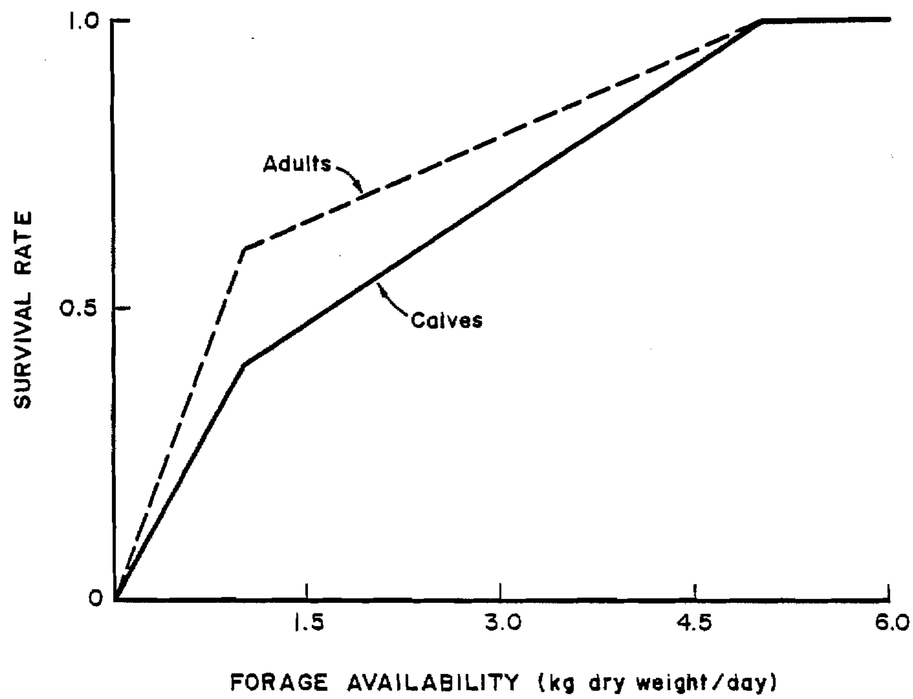


Figure 3.18: Relationship between forage availability and moose winter survival rate.

3.5 Bears

The bear submodel relates population response of black and brown bears to changes in habitat structure and to more direct human influences (hunting, disturbance from construction activity, etc.). The model contains two major simplifications. First, only female bears are considered. Mature males are assumed to always be sufficiently numerous to mate the reproductively active females. Second, hunting is not included because the kill of bears is heavily biased towards males due to hunting regulations and the desire of hunters to take large males as trophy animals.

The structure of the model is a simple life table that represents the birth and death processes for various age classes of black and brown bears. The population dynamics of bears in the study area are assumed to be controlled by reproduction, mortality, and dispersal.

3.5.1 Structure

The life history structures used for brown and black bears are portrayed in Figures 3.19 and 3.20 respectively. Mature females are partitioned into groups based on the presence or absence of offspring (two groups for black bears (Figure 3.20); three groups for brown bears (Figure 3.19)). Immature female black bears are partitioned into four age classes and immature female brown bears are partitioned into six age classes.

The proportions of females in a given age class that have reached maturity (Table 3.7) are assumed constant. For example (in Figure 3.19), a three year old immature brown bear that survives the year must become either a

Table 3.7: Proportion of females reaching maturity by age.

AGE	PROPORTION REACHING MATURITY BLACK	BROWN
2	0.5	--
3	0.75	0.44
4	1.0	0.76
5	--	0.9
6	--	1.0

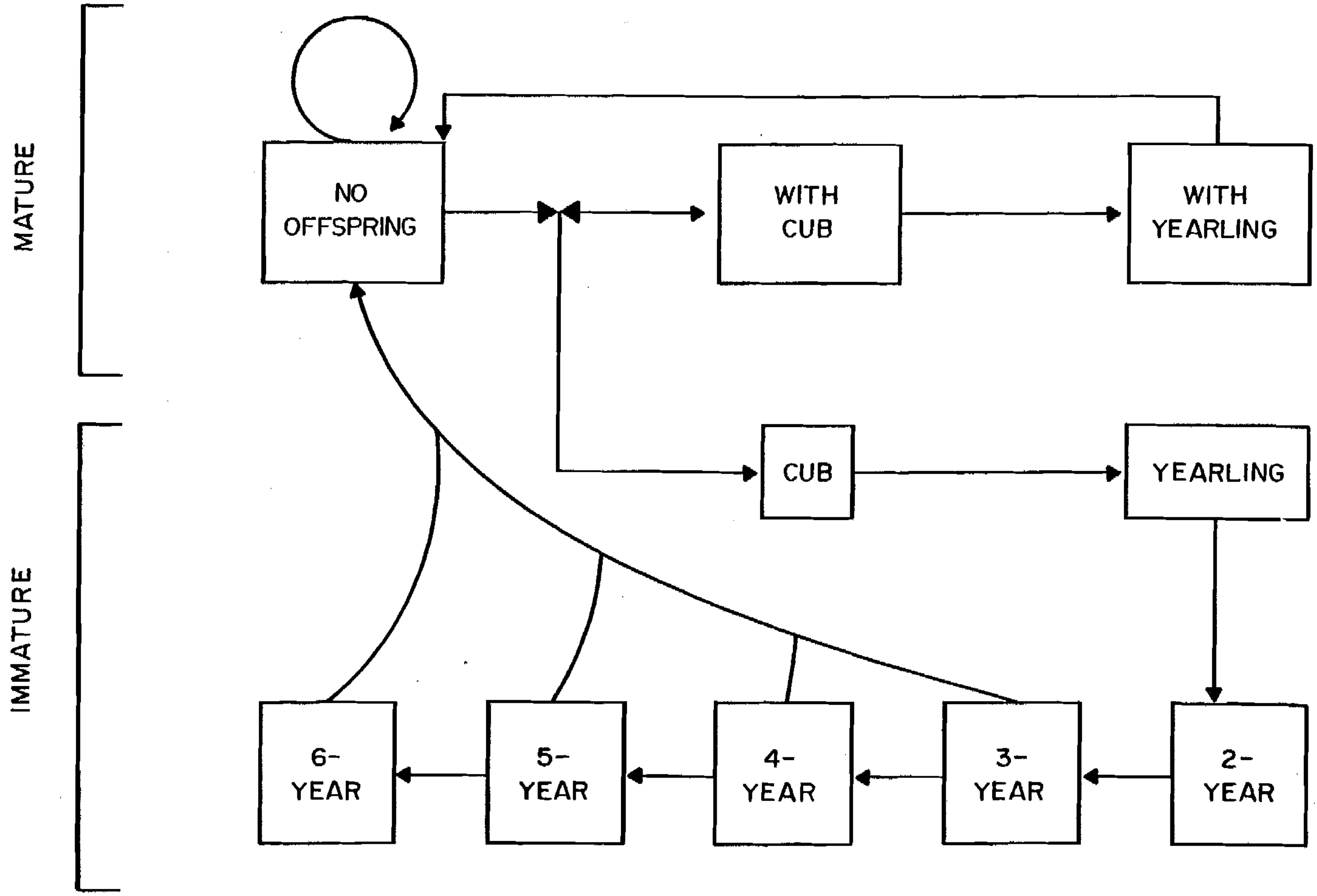


Figure 3.19: Life structure of brown bear. Each arrow represents a time step of one year.

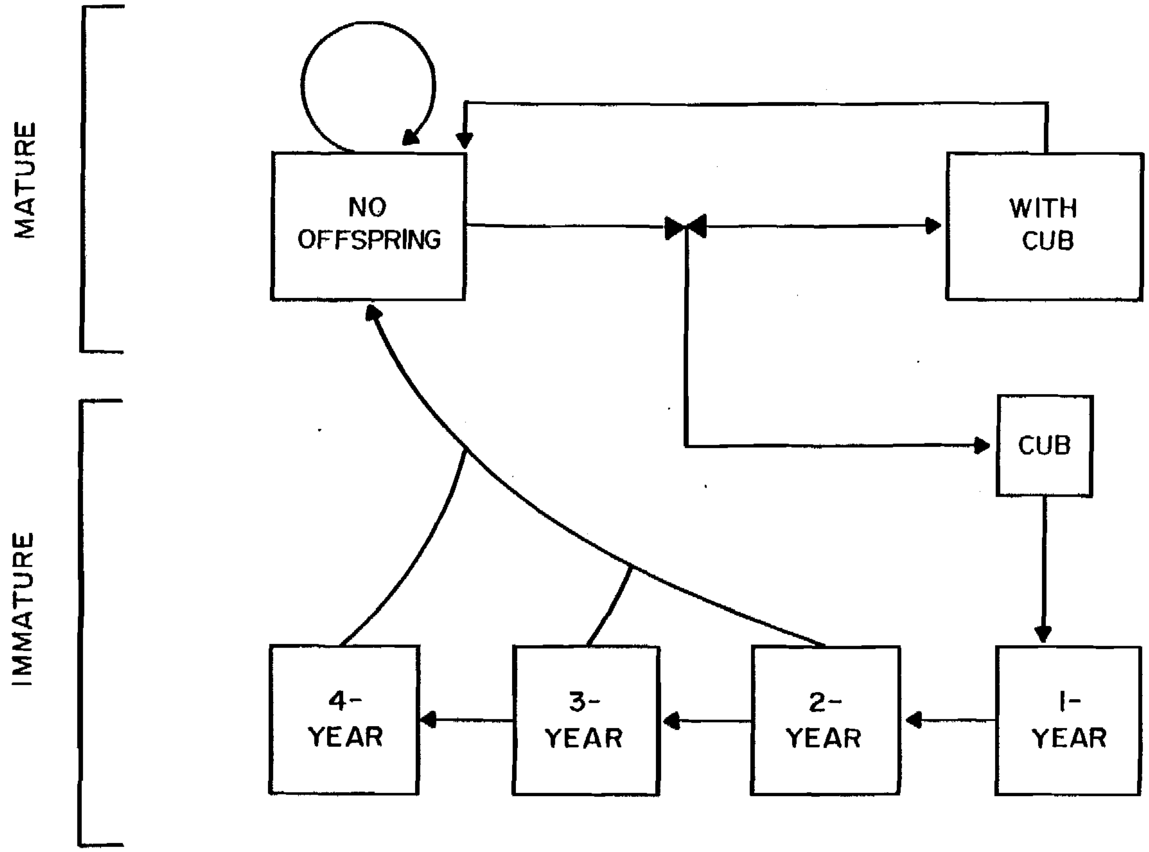


Figure 3.20: Life structure of black bear. Each arrow represents a time step of one year.

mature animal with no offspring or a four year old immature animal. Mature animals without offspring either remain in that condition or produce cubs.

3.5.2 Reproduction

The proportion of females emerging with cubs and litter size is a function of the previous summer's food availability (primarily blueberries). The model uses an index of summer food availability because little is known about the levels of berry production (biomass) that constitute a good or bad year for bears. The index of summer food (I_{SF}) is defined as:

$$I_{SF} = \frac{\text{total berry production in year t}}{\text{total berry production in 1980}}$$

The total berry production for a given year is a sum of the total berry production in each vegetation type. The vegetation submodel provides berry production per hectare for each vegetation type and the area in each vegetation type to calculate total production. The summer food index is modified by use of the salmon resource from Prairie Creek. Twenty five percent of brown bears in the study area are assumed to use this resource during one third of their summer feeding periods. It is assumed that future recreational developments or material sites in the area will preclude bear use of this resource. Because the level of disturbance (number of recreational use days per year) necessary to preclude use could not be determined, it was arbitrarily assumed that this resource would be lost if recreational use becomes double the 1980 level. If this recreational use level is reached, the summer food index is reduced by 8%.

The proportion of females emerging with cubs as a function of the index of summer food availability is shown in Figure 3.21. Fifty percent of the females emerge with cubs when the food index is 1.0, representing an average berry crop. The α parameter governs the sensitivity of pregnancy rate to food availability. When the food index (in Figure 3.21a) is near $1 - \alpha$, the proportion with cubs is near 0; when it is near $1 + \alpha$, the proportion is close to 1.0. In the current version of the model, α is 0.2 for black bears and 0.5 for brown bears; black bears are assumed more sensitive to changes in berry production.

Mean litter size is a linear function of the summer food index (Figure 3.21b). The maximum mean litter size is 2.5 for brown bears and 2.7 for black bears. The number of cubs is the product of the number of females emerging with cubs and the mean litter size. It is assumed that 50% of the cubs are males and 50% are females.

3.5.3 Mortality

Animals two years of age or greater are assumed to have a constant mortality rate (.05 for brown and .08 for black bears).

Mortality of cubs and yearlings is assumed to be a function of spring food availability. Spring food, which includes such items as equisetum, moose calves, small mammals, skunk cabbage, roots, and cottonwood buds, is more vulnerable to inundation than summer food. Because of the lack of understanding of the relationship between cub and yearling mortalities and spring food availability, an index of spring food availability is used. The index

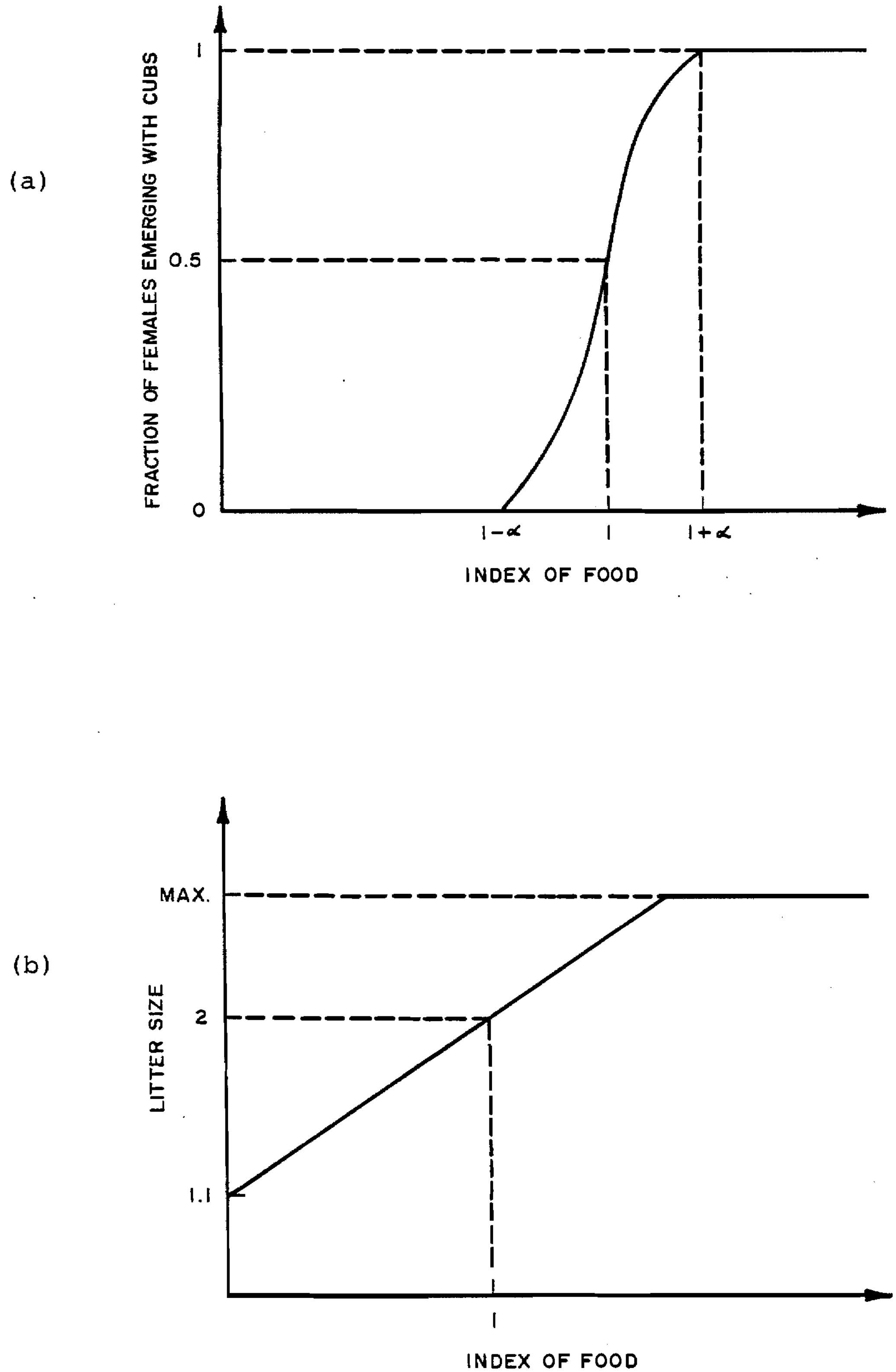


Figure 3.21: Reproduction relationships as a function of the previous year's food: (a) proportion of females emerging with cubs; (b) mean litter size.

(I_{WF}) relates vegetation types utilized by bears (open conifer forest, medium shrubs, and all low shrub types) to the base year 1980 and is calculated as:

$$I_{WF} = \frac{\text{total area of suitable bear habitat in year t}}{\text{total area of suitable bear habitat in 1980}}$$

In any given year, the total area of suitable habitat is found by summing the vegetation types utilized by bears. Mortality is linearly related to the spring food index (I_{WF}) (Figure 3.22).

3.5.4 Dispersal

Dispersal to and from the study area by subadult brown bears is probably common while black bears in the study area may contribute to bear populations in other areas. Dispersal is thought to be controlled by the density of one year or older black bears and two years or older brown bears. Therefore, the base year (1980) was assumed to have no net dispersal. Dispersal from the study area in subsequent years is directly proportional to any increase in density; however, only immature animals (one year or older for black bears and two years or older for brown bears) disperse. The total density of bears can exceed the density set in the base year because mature animals are included in the calculation of dispersal rates but only applied to immature animals.

3.6 Model Results

During the workshop, the participants constructed a number of relationships to functionally relate the biophysical processes operating in the Susitna Basin. Lack of data and understanding forced an overly simplistic representation of many of these processes. As a result, great care must be taken in evaluating the results presented in this section.

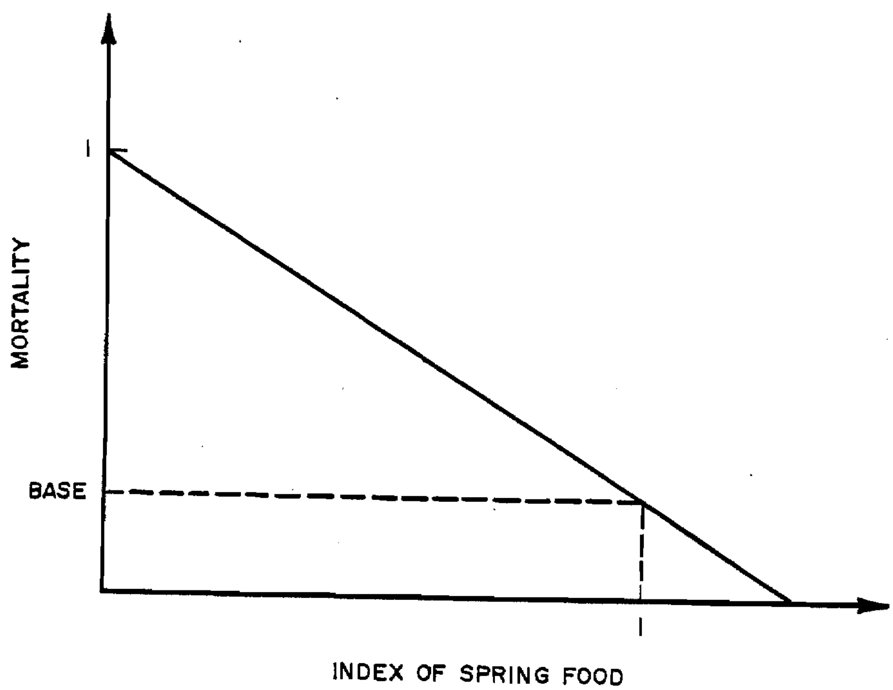


Figure 3.22: Mortality of cubs and yearlings. Base mortality for black bears is 0.2 for cubs; 0.2 for yearlings. Base mortality for brown bears is .15 for cubs; .10 for yearlings.

We caution against considering the results to be valid projections of what might happen in the Susitna Basin. In particular, the moose submodel and the bear submodel results are examples of how the important processes affecting moose and bear can be incorporated into a simulation model. They are not intended to represent the moose and bear populations of the Susitna Basin.

Three scenarios (sets of actions) to be simulated were developed at the workshop:

a) a baseline or no project scenario;

b) an optimum power generation scenario with little mitigation; and

c) a Watana only scenario with a hydrologic regime based on instream flow targets.

The major differences between scenarios (Table 3.8) relate to flow regime, number of dams constructed, choice of access route, and control of access.

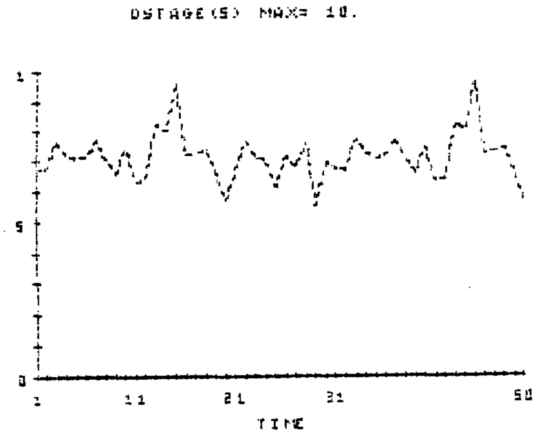
The following figures compare indicators for the three scenarios. It may ultimately be desirable to compare the quantitative results but, at present, only the qualitative results should be considered. It is more appropriate to examine the general temporal differences in the indicators among the scenarios, rather than to focus on their actual values.

3.6.1 Physical Processes/Development/Recreation

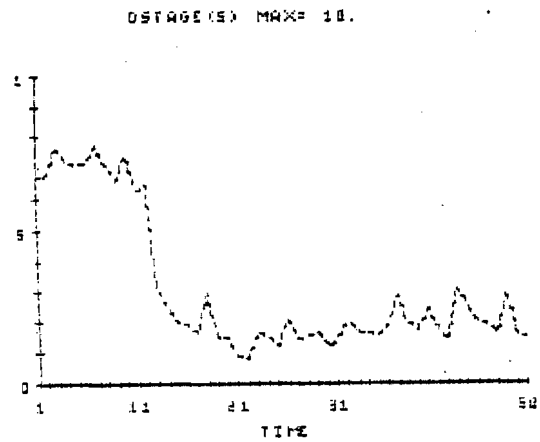
The maximum annual change in stage measured at Gold Creek Station (Figure 3.23) is considerably less under the

Table 3.8: Scenarios Used in the Simulations

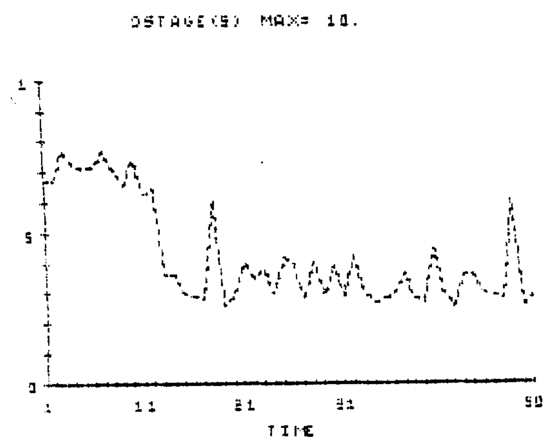
	No Project	Full Project	Watana Only
Flow Regime	preproject	case A (optimum power generation)	case D (best for fish)
Access Route	none	plan 17	plan 13
Access Control	no increased access	open access	no increased public access
Dams Constructed	none	Watana, Devil Canyon	Watana



a) No Project



b) Full Project



c) Watana Only

Figure 3.23: Maximum annual change in stage at Gold Creek Station. The maximum value on y-axis is 10 feet.

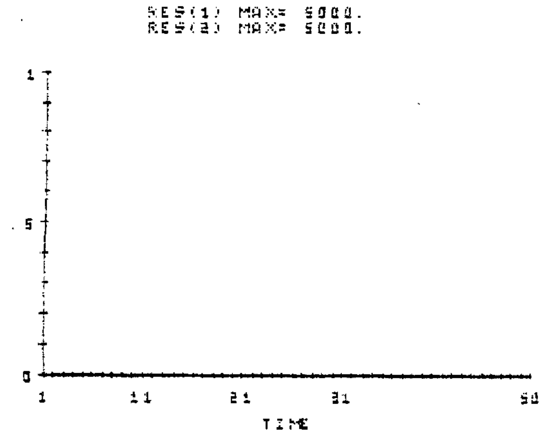
regulated scenarios (Figures 3.23b and 3.23c). The drop that occurs at simulation year 12 is associated with the commencement of the operation of the dams. The average change in stage with dam operation is about twice as high under the hydrologic regime based on instream flow targets (Figure 3.23c) than it is under the hydrologic regime that is optimum for power generation (Figure 3.23b).

The amount of reservoir clearing in a year (Figure 3.24) follows the schedules outlined in Table 3.1. The large jump in reservoir claring in both development scenarios (Figures 3.24b and 3.24c) is associated with the clearing for Watana; the smaller jump later in time in the optimum power generation scenario (Figure 3.24b) is associated with clearing for Devil Canyon.

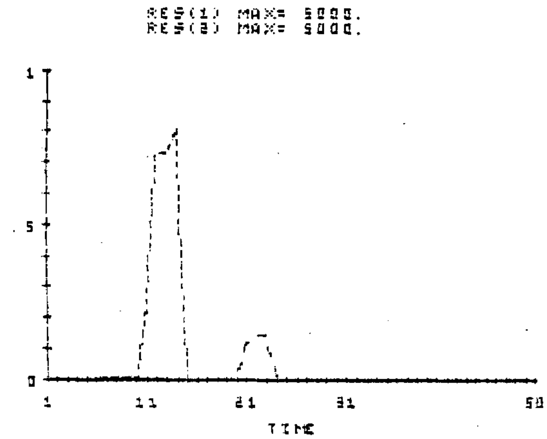
Influx of construction personnel is associated with dam construction (Figure 3.25). In the model, this influx is simulated using the schedule outlined in Table 3.3. The large peaks are associated with the construction of Watana (Figures 3.25b and 3.25c); the lesser peak is associated with the construction of Devil Canyon (Figure 3.25b).

Recreational use of the area is assumed to increase gradually without the project (Figure 3.26a). There is a steeper increase for ten years after Watana is completed under the full project scenario with no restriction on access (Figure 3.26b). The Watana only scenario with restricted access (Figure 3.26c) has the same gradual increase in use as the no project scenario.

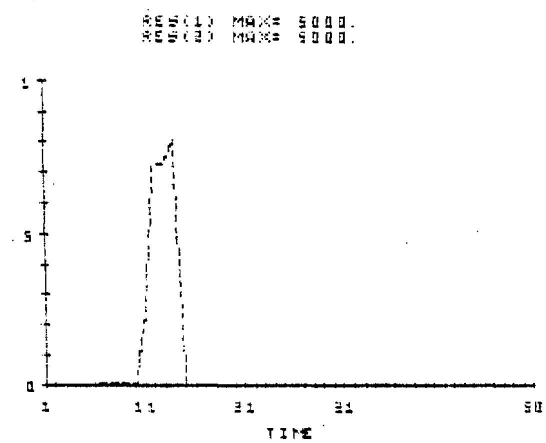
Potential overwintering habitat for beaver in sloughs and side channels (Figure 3.27) is unaffected by the introduction of the projects. This is because the changes in the availability of habitat are assumed to be based only on changes in winter severity and not on the flow regime.



a) No Project

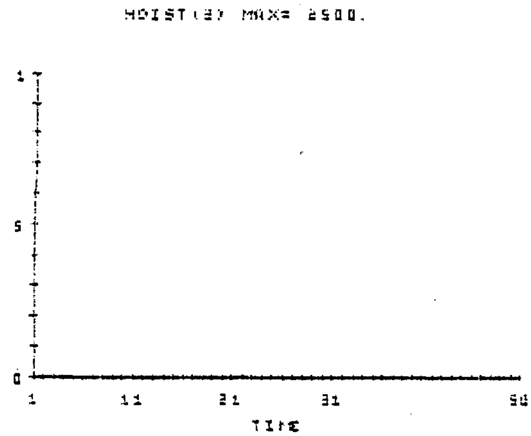


b) Full Project

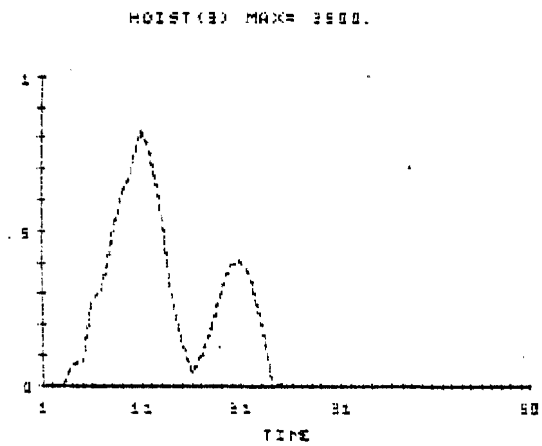


c) Watana Only

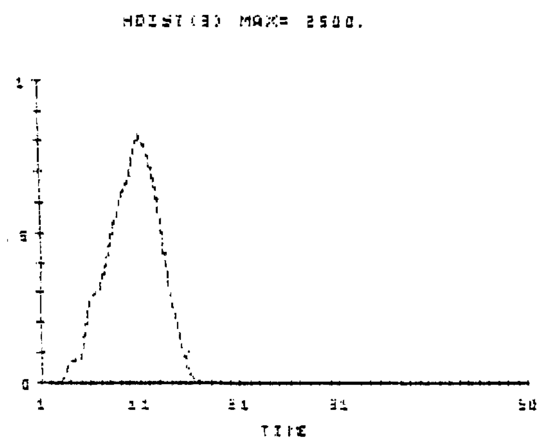
Figure 3.24: Amount of reservoir clearing (ha) per year. The maximum value on the y-axis is 5000 ha.



a) No Project

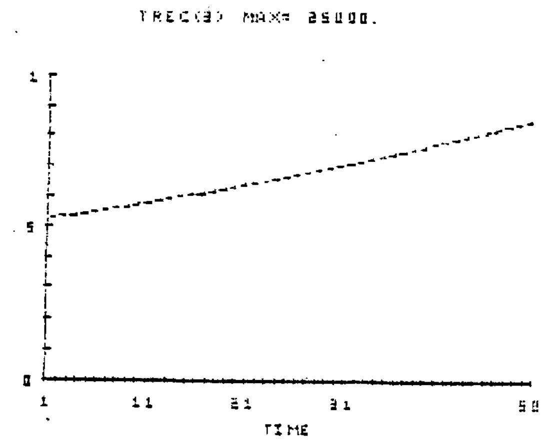


b) Full Project

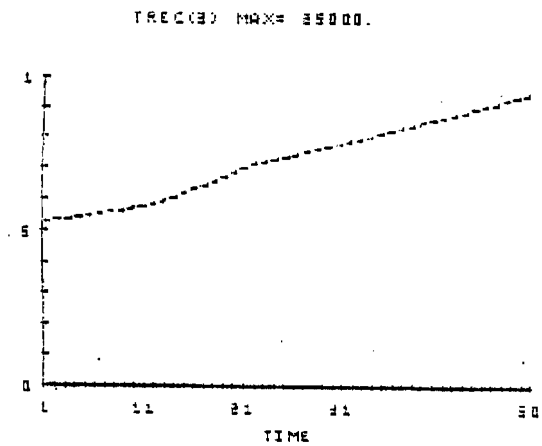


c) Watana Only

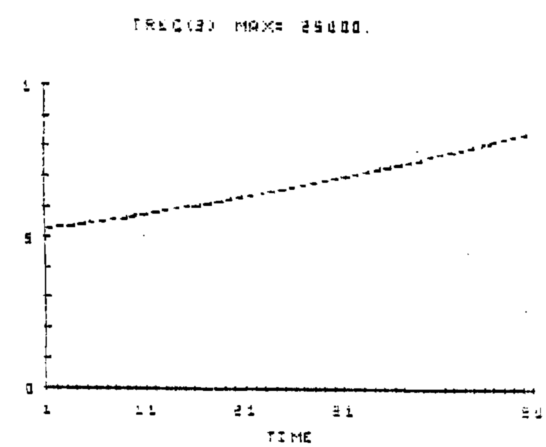
Figure 3.25: Construction personnel on site at any one time. The maximum on the y-axis is 2500 workers.



a) No Project

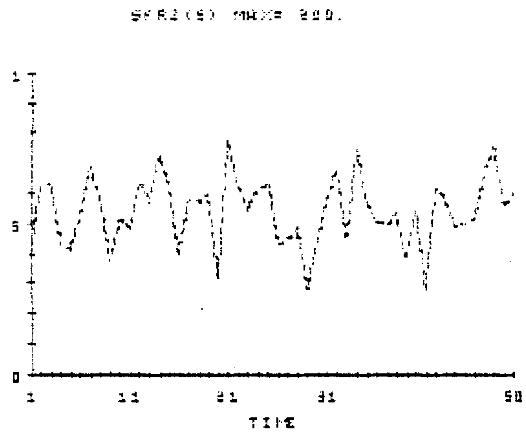


b) Full Project

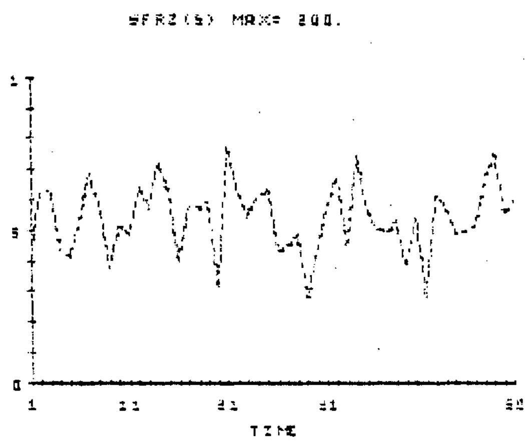


c) Watana Only

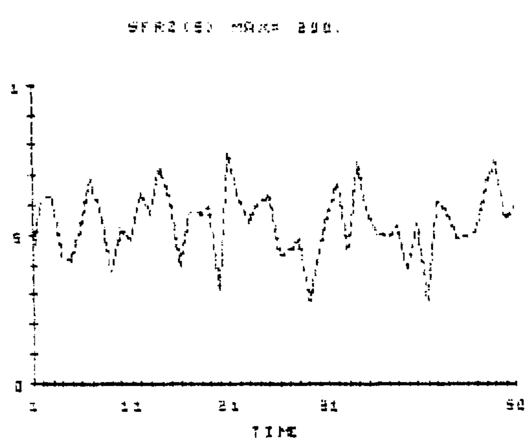
Figure 3.26: Recreational use days in the Upper Susitna Basin. The maximum on the y-axis is 25000 use days.



a) No Project



b) Full Project



c) Watana Only

Figure 3.27: Potential overwintering habitat for beaver in sloughs and side channels. The maximum on the y-axis is 200 km.

3.6.2 Vegetation

Only a few selected vegetation types are presented. The major changes in vegetation in the Upper Susitna Basin are assumed to occur in the impoundment areas. It is important to remember that perpetuation of present conditions is assumed without project development (Section 3.2.1). In the model, the vegetation in the impoundment zone decreases and the area of water increases as the reservoirs are cleared and filled. With the project, the vegetation in the Watana impoundment is cleared and the area inundated, hence, the coniferous and mixed and deciduous types decline (Figure 3.28). A similar pattern is observed in the Devil Canyon impoundment area (Figure 3.29). The model currently assumes that vegetation in Devil Canyon impoundment will be unaffected if only Watana is constructed (Figure 3.29c). Although the changes in vegetation in the impoundment areas (Figures 3.28 and 3.29) appear dramatic, they actually represent a small proportion of the total vegetation in the Upper Susitna Basin. The proportional changes in vegetation are small when viewing the entire upper basin as a unit (Figure 3.30).

It is assumed that changes in the downstream riparian zone will be identical whether both dams or only Watana is constructed. The area of deciduous and mixed forest increases with the project (Figure 3.31).

In the model, the tall shrub community first increases and then decreases as the later successional stages become dominant and the low mixed shrubs decline after the project begins operation (Figure 3.32b, c). The mechanisms underlying these changes are depicted in Figure 3.6 (page 39). It is assumed that after the project, the low mixed shrub will succeed rapidly to the tall shrub which in turn succeeds

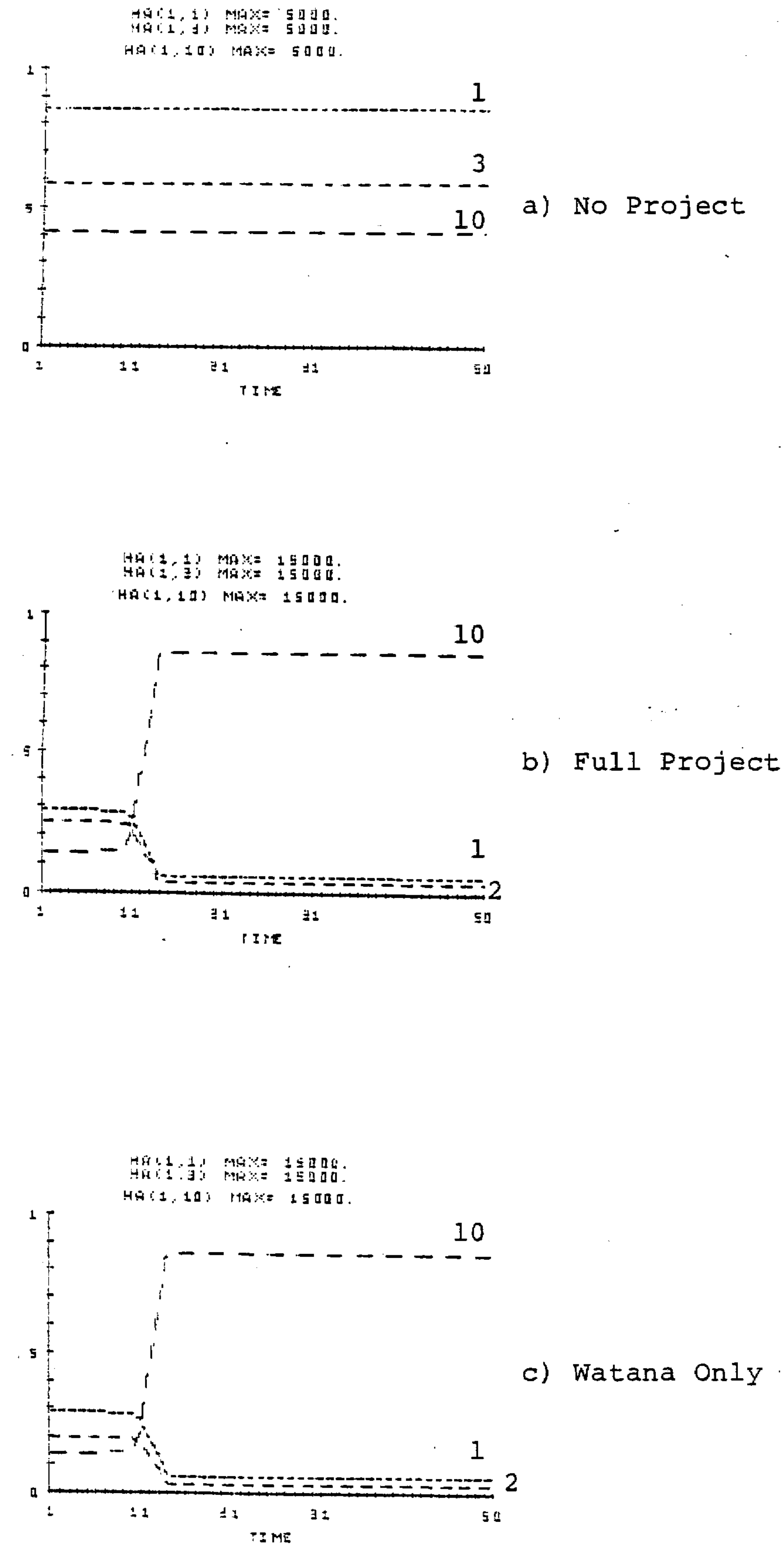
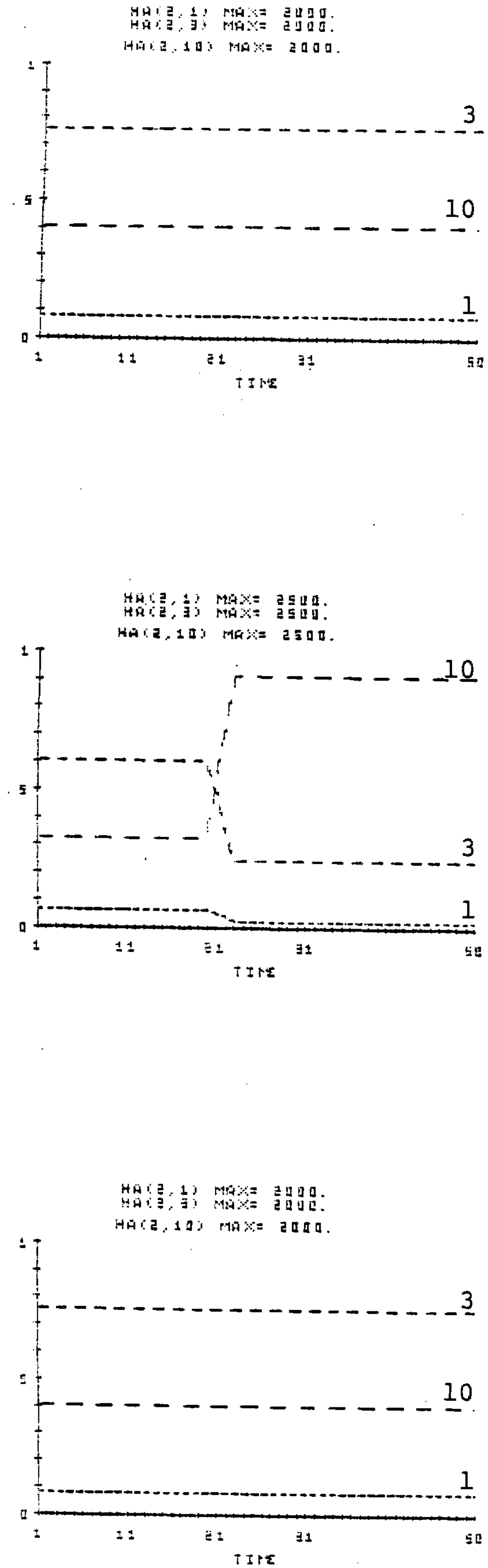


Figure 3.28: Changes in areas of selected vegetation types in Watana impoundment area: closed coniferous forest (1), deciduous and mixed forest (3), and water (10). The maximum value on y-axis is 15,000 ha in (b) and (c); 5,000 ha in (a).



a) No Project

b) Full Project

c) Watana Only

Figure 3.29: Change in areas of selected vegetation types in Devil Canyon impoundment area: closed coniferous forest (1), deciduous and mixed forest (3), and water (10). The maximum value on the y-axis is 2000 ha in (a) and (c); 2500 in (b).

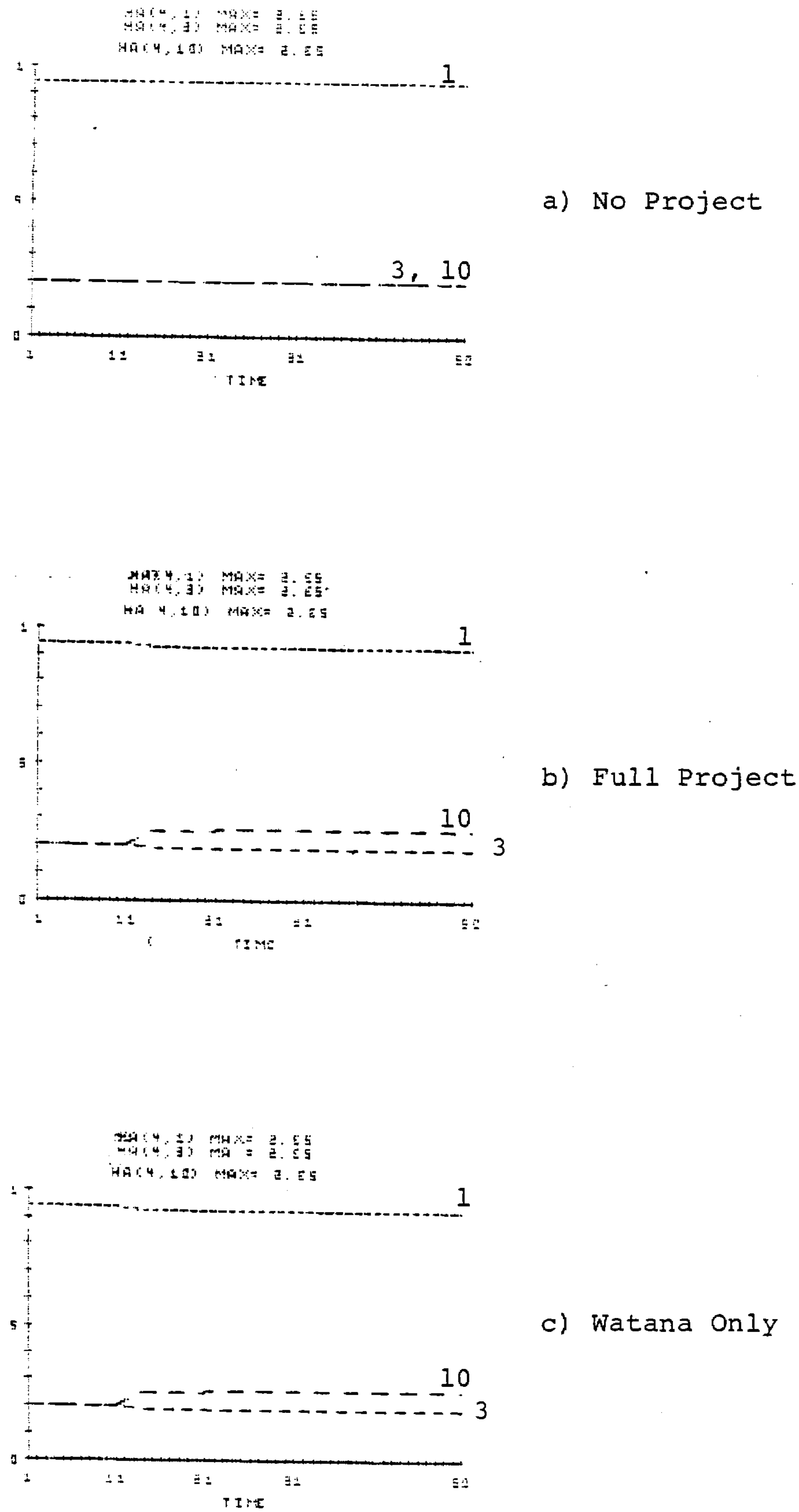


Figure 3.30: Changes in areas of selected vegetation types in the Upper Susitna Basin: closed coniferous forest (1), deciduous and mixed forest (3), and water (10). The maximum on the y-axis is 200,000 ha.

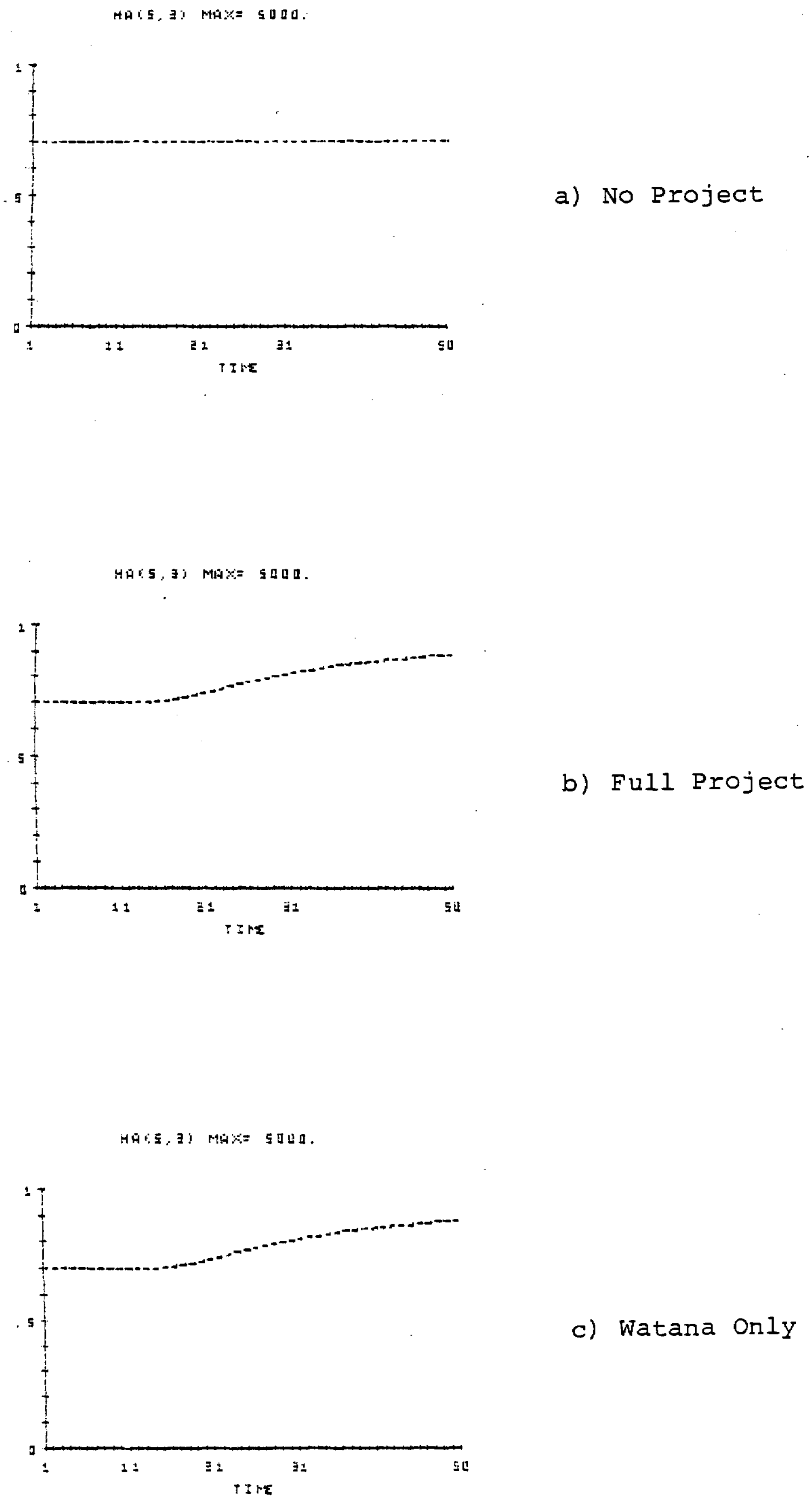
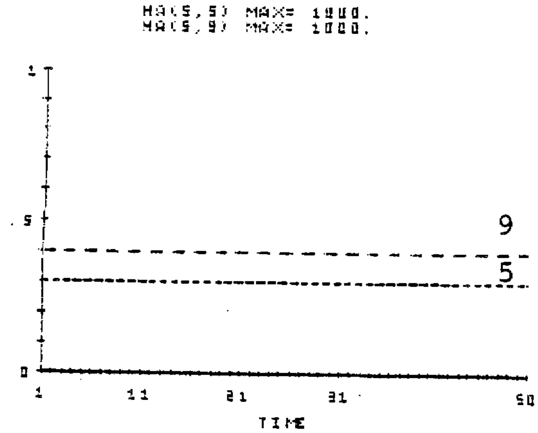
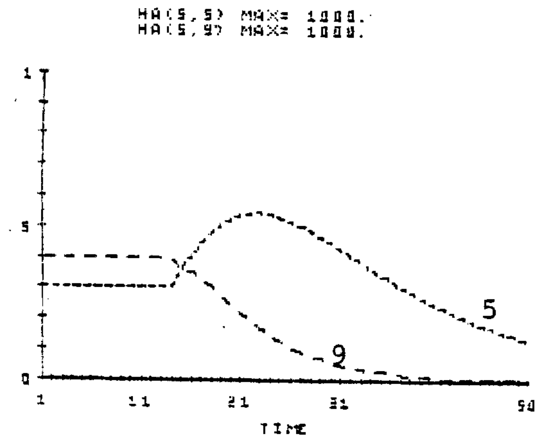


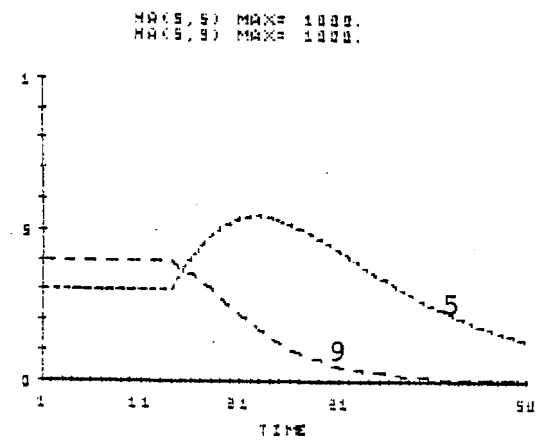
Figure 3.31: Area of deciduous and mixed forest in the downstream riparian zone. Maximum on the y-axis is 5000 ha.



a) No Project



b) Full Project



c) Watana Only

Figure 3.32: Areas of tall shrub (5) and low mixed shrub (9) in the downstream riparian zone. The maximum value on the y-axis is 1000 ha.

more slowly to the mixed and deciduous forest. The difference in conversion rates gives rise to the initial increase and eventual decline of the tall shrubs.

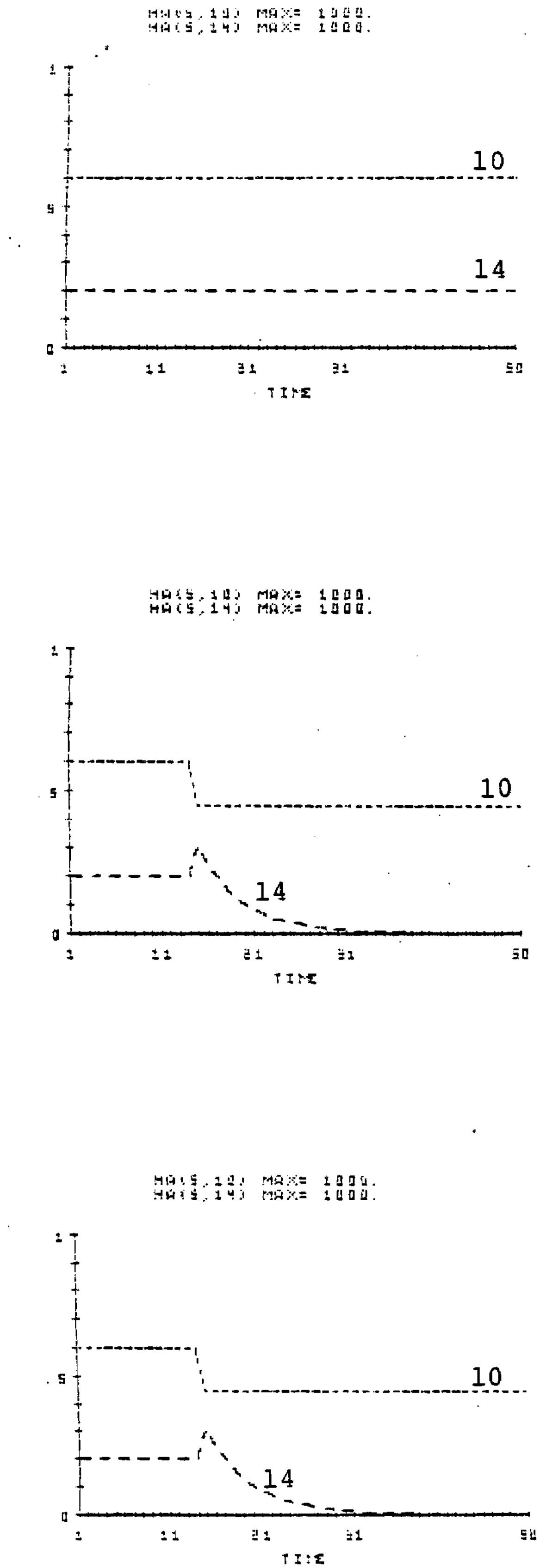
The model projects that the surface area of water in the floodplain will decline with development and pioneer species will increase immediately after impoundment then gradually decrease (Figure 3.33). The decrease in surface area of water is assumed to occur because of the reduction in peak flows; the dynamics of the pioneer species are described in Figure 3.6 (page 39).

3.6.3 Furbearers and Birds

Under the current assumptions in the model, the beaver colonies and carrying capacity associated with sloughs and side channels in the downstream riparian zone are similar for all three scenarios (Figure 3.34). Beaver populations are at or near their carrying capacity through the 50 year time horizon in all three scenarios. One possible explanation is absence of direct linkages between the hydrologic regime and beaver, and between the vegetation and beaver.

Main channel colonies and their carrying capacities exhibit a more interesting behavior (Figure 3.35). Without the project (Figure 3.35a), there are no main channel beavers although there is ample carrying capacity. Under the project scenarios (Figure 3.35 b, c), the carrying capacity increases slightly. Main channel beaver colonies appear after the project begins operation but are kept at a level well below their carrying capacity by periodic severe ice scouring events and years of unusually high stage fluctuations.

The change in the number of habitat units for passerines is small in relation to the total for the Upper

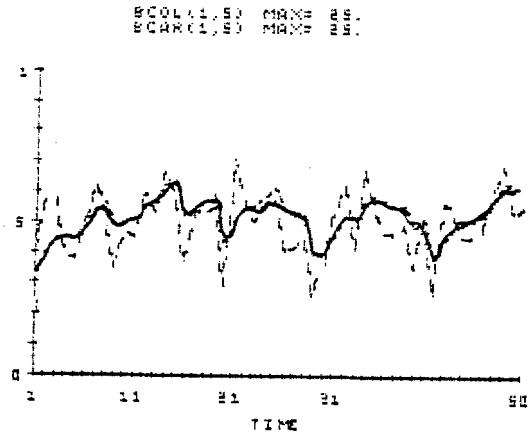


a) No Project

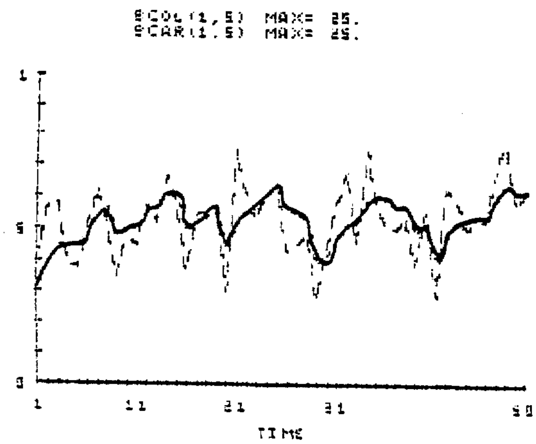
b) Full Project

c) Watana Only

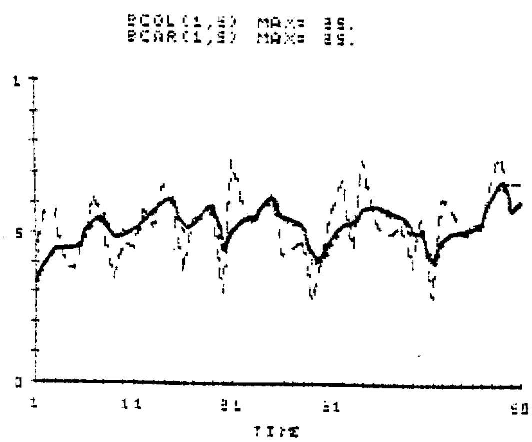
Figure 3.33: Areas of water (10) and pioneer species (14) in the downstream riparian zone. The maximum value on the y-axis is 1000 ha.



a) No Project



b) Full Project



c) Watana Only

Figure 3.34: Beaver colonies utilizing sloughs and side channels (solid line) and their carrying capacity (broken line) in the downstream riparian zone. The maximum on the y-axis is 25 colonies.

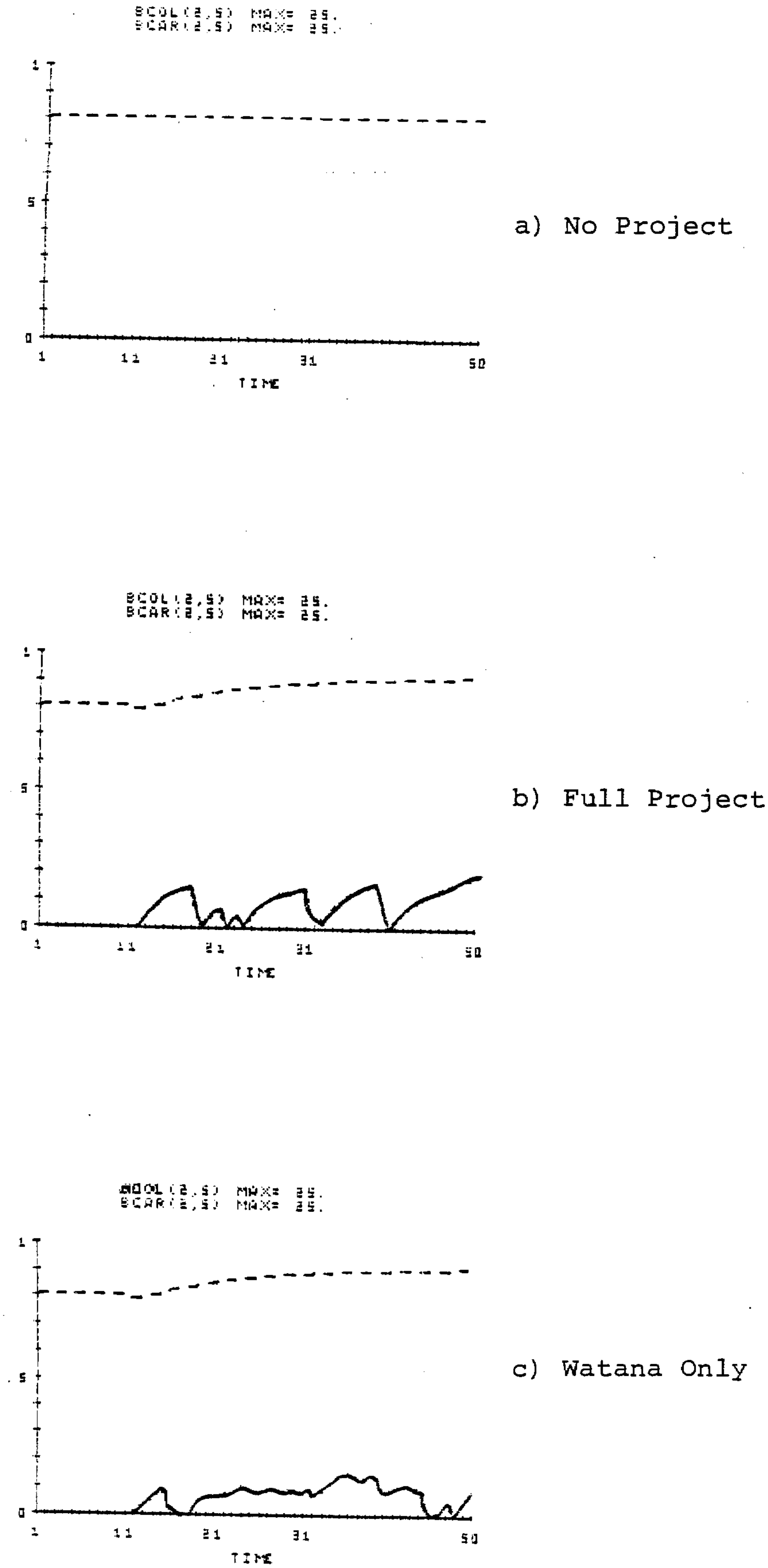


Figure 3.35: Main channel beaver colonies (solid line) and carrying capacity (broken line). The maximum on the y-axis is 25 colonies.

Susitna Basin (Figure 3.36). A slight decrease in the total number of units can be observed for the project scenarios (Figure 3.36b, c).

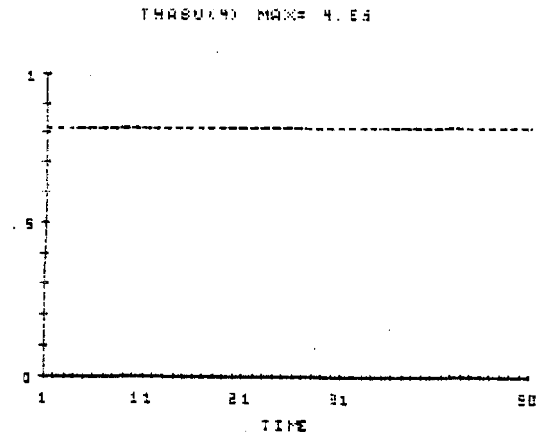
3.6.4 Moose

The projections for moose should be regarded as being for a hypothetical population in an area similar to the Upper Susitna Basin. The fall post harvest moose population exhibits considerable year to year variation (Figure 3.37). There is a severe winter in year 10 that causes a severe drop in the population in all scenarios. The population then gradually recovers in the no project scenario (Figure 3.37a), but, with the project (Figure 3.37b, c), the population fails to recover as rapidly and fails to reach as high a level as without the project. The reason for the lower population appears to be the loss of home range associated with the clearing and filling of the impoundments.

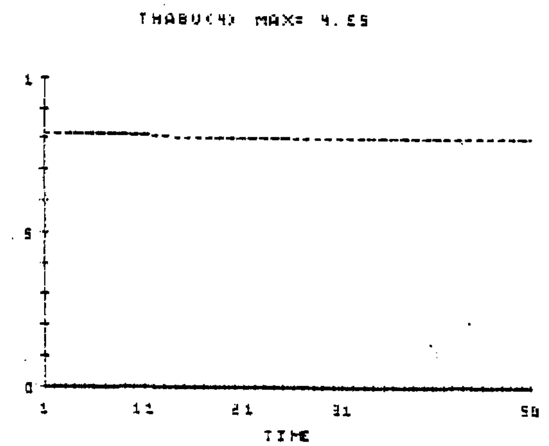
The number of animals lost to bear predation (Figure 3.38) is slightly less with the project than without. The harvest (Figure 3.38) declines proportionally with the population due to the assumed constant harvest rate.

3.6.5 Bears

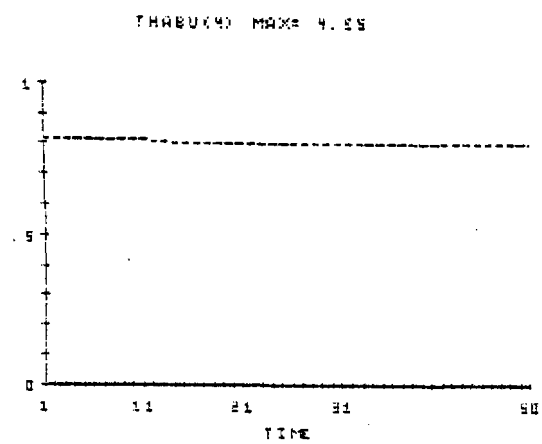
The grizzly or brown bear is not affected by the projects (Figure 3.39). The black bear (Figure 3.40) declines rapidly after the project in response to loss of habitat within the impoundment areas.



a) No Project



b) Full Project



c) Watana Only

Figure 3.36: Habitat units for passerines in the Upper Susitna Basin. The maximum on the y-axis is 400,000 units.

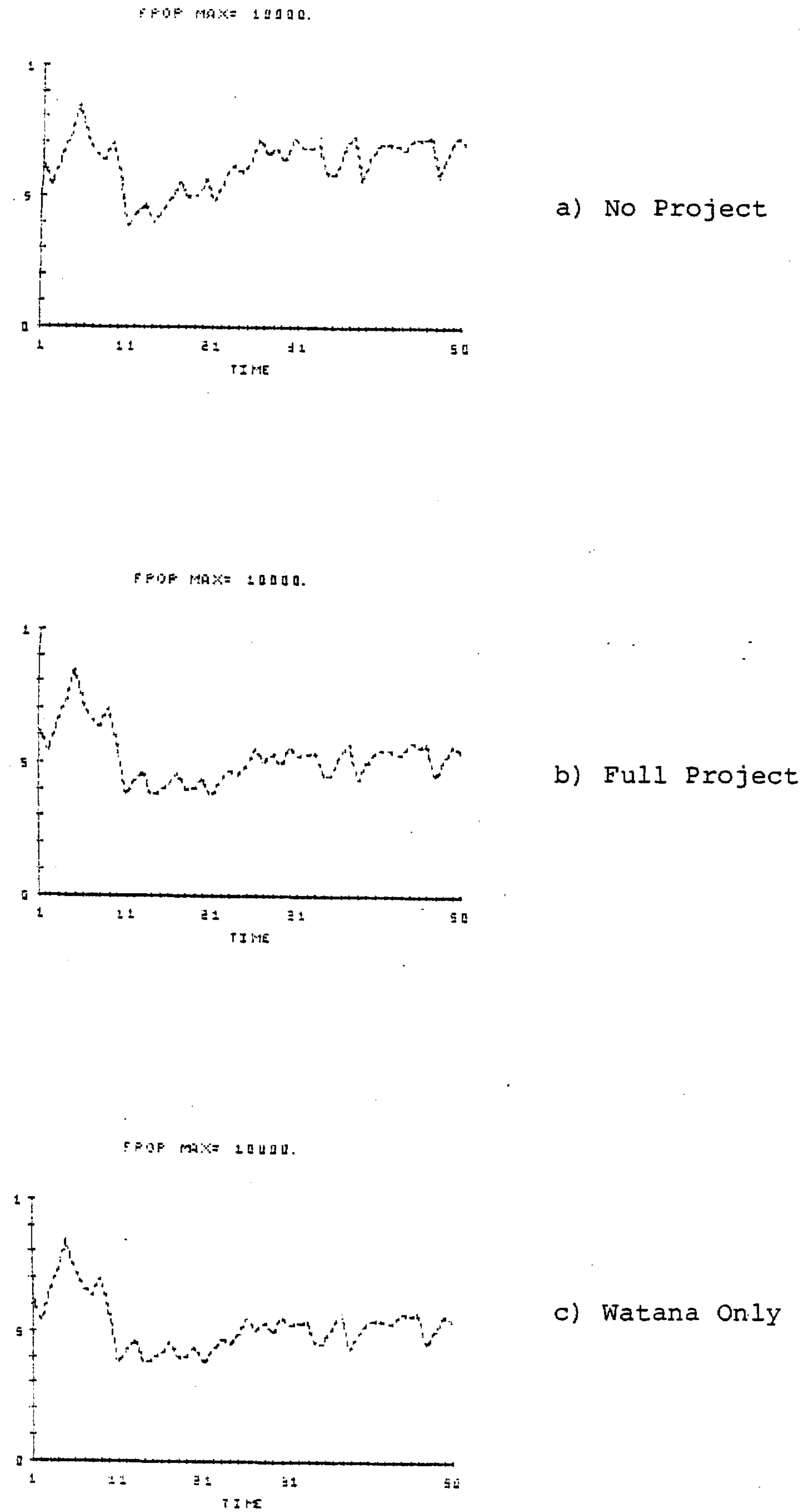
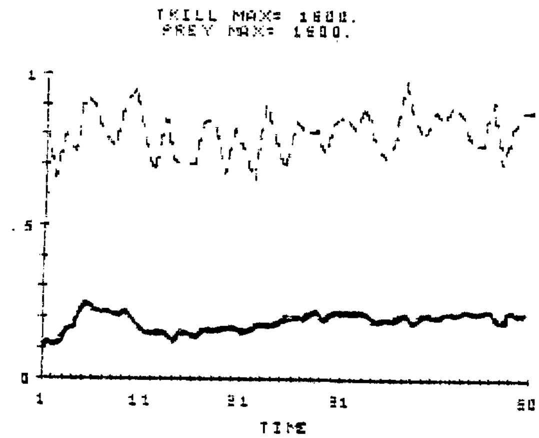
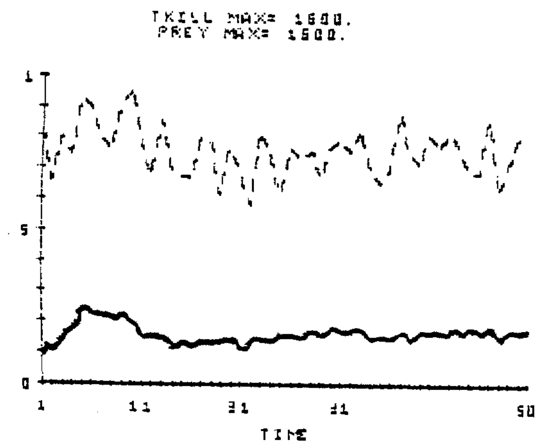


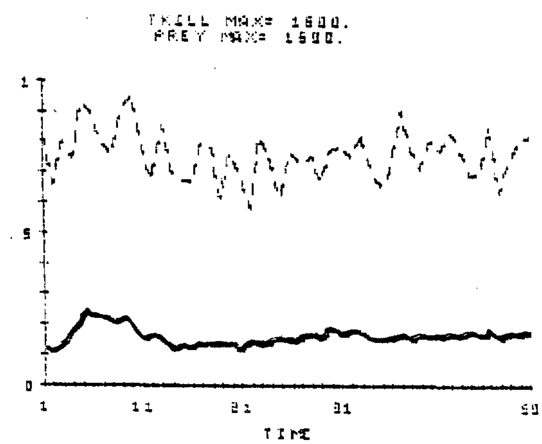
Figure 3.37: Fall post-harvest moose population. The maximum value on the y-axis is 10,000 animals.



a) No Project

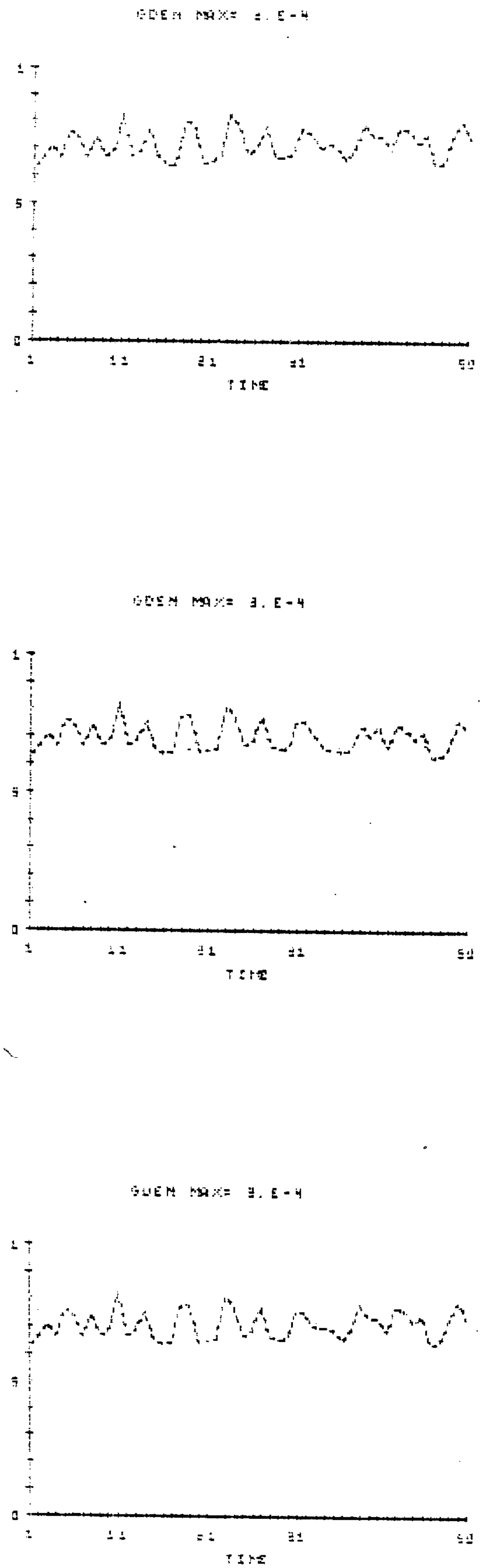


b) Full Project



c) Watana Only

Figure 3.38: Moose lost to bear predation (broken line) and through hunting (solid line). Maximum value on y-axis is 1,600 animals.

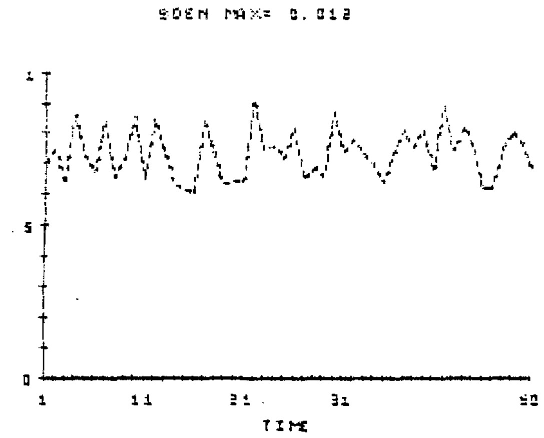


a) No Project

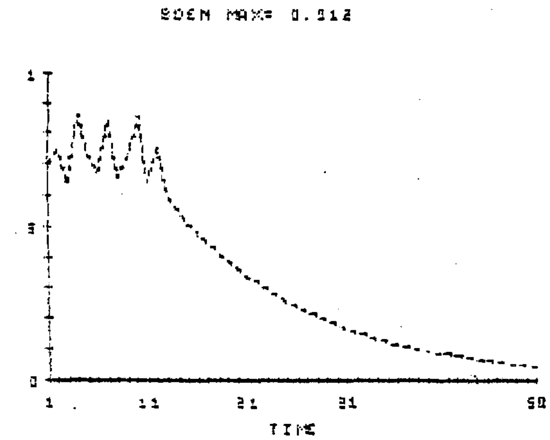
b) Full Project

c) Watana Only

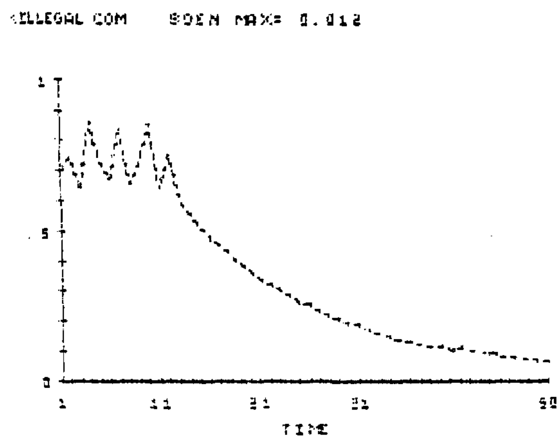
Figure 3.39: Brown bear density (animals/ha). The maximum value on the y-axis is .0003 animals/ha.



a) No Project



b) Full Project



c) Watana Only

Figure 3.40: Black bear density (animals/ha). The maximum value on the y-axis is .012 animals/ha.

4.0 PRODUCTS

The most highly visible product, the working simulation model, is given a conceptual treatment in Section 4.1. While the preliminary model is important, the process of building the model within the workshop process has generated two additional and perhaps more valuable products: a synthesis of gaps in our understanding and data (Section 4.2), and an analysis of how model refinements can direct efforts into filling these gaps (Section 4.3).

4.1 Conceptual Model

The looking outward matrix (Table 2.5) provided the framework for linking the component submodels. The completely integrated model is a complex set of numerous relationships within and between submodels. To gain a broad understanding of the major processes included in the model, the simulation model has been translated through a process of simplification and compression into a conceptual model of the terrestrial environment in the Susitna Basin (Figure 4.1).

In the conceptual model, the major components (boxes) and the major linkages (arrows) represent the processes and information transfers considered to be imporant to understanding the biophysical system in the Susitna Basin. In the diagram (Figure 4.1), solid lines represent linkages that are included in the numerical simulation model; broken lines represent critical linkages that could not be conceptualized during the workshop and were not included into the numerical simulation model.

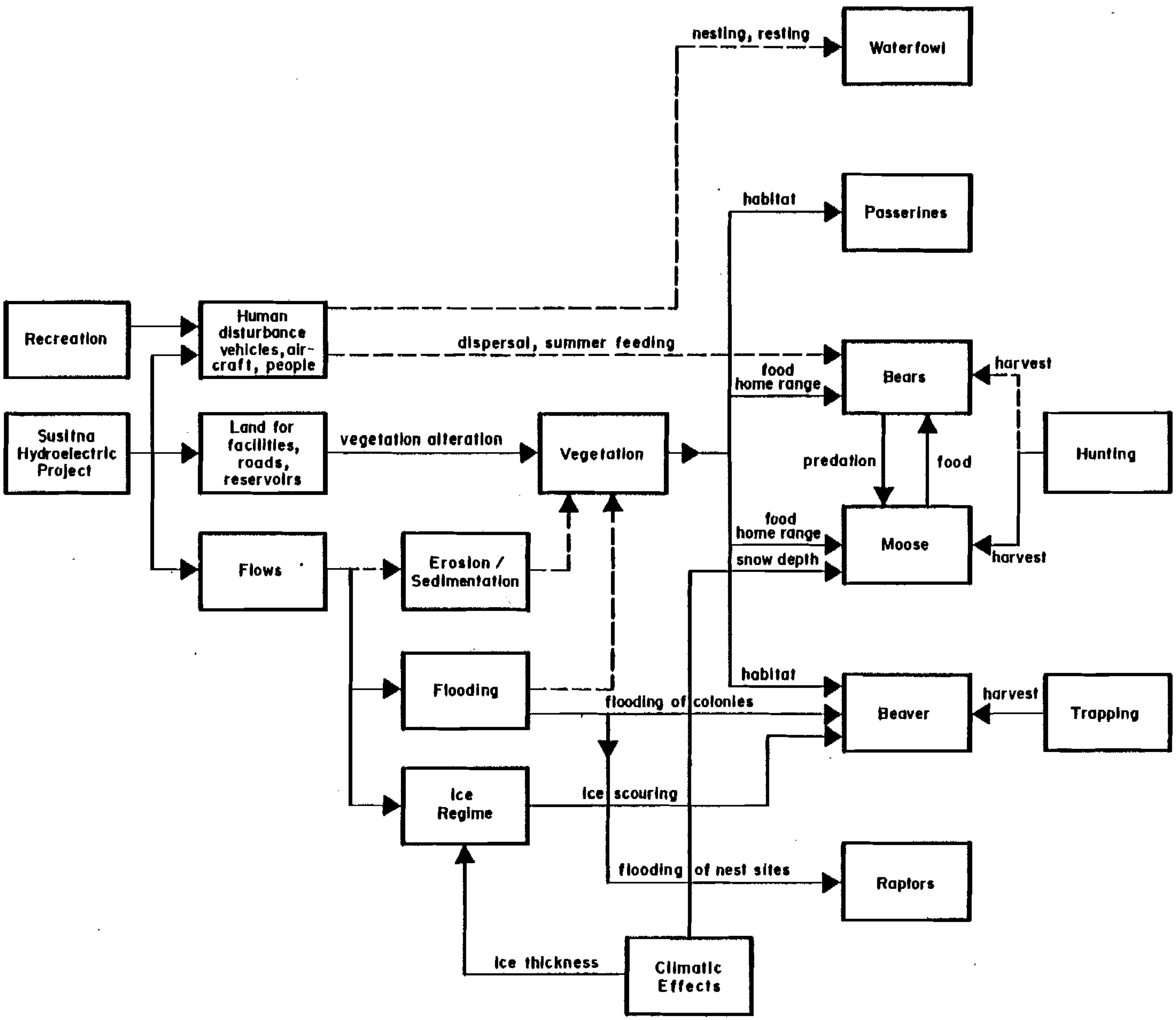


Figure 4.1: Conceptual model of major components and linkages included in the model of the terrestrial environment in the Susitna Basin.

The model depicted in Figure 4.1 represents the first interdisciplinary perspective of the potential impact of the Susitna Hydroelectric Project on the terrestrial environment in the Susitna Basin. As such, it provides an overall framework for assessing deficiencies in our current understanding.

4.2 Summary of Conceptual and Information Needs

Numerous gaps in data and understanding became apparent during the workshop. Throughout the workshop, notes were made as these gaps arose during discussion and a formal session was conducted toward the end of the workshop to pull together the many thoughts and ideas on future research.

The information needs discussed at the workshop (Table 4.1) are divided into two categories: conceptual and data. Conceptual needs are those requiring the development and/or testing of relationships. Data needs, for the most part, can be satisfied through data collection and searches of existing information sources.

4.3 Model Refinements

The more detailed discussion of conceptual and information needs presented in this section is based on analysis of what information is required to refine the model. A refined model implies an increase in understanding, for the model represents a synthesis of our current understanding. Judging from the long list of conceptual and data needs presented in Table 4.1, our current understanding is far from adequate. By critically examining the components and linkages depicted in Figure 4.1, this analysis addresses most of the information needs (Table 4.1) and illustrates how refinements to the model can focus efforts directed towards satisfying them.

Table 4.1: Information Needs

	CONCEPTUAL	DATA
Physical Processes/ Development/Recreation	- relationship of riparian surface areas to flow in the reach Devil Canyon to Talkeetna - relationship of ice scouring to flow in downstream area - relationship of stage to flow in downstream area - ice hazard index for reservoir (March 15 - June 15) - model for predicting monthly snow depth in elevation ranges - relationship between over-wintering habitat for beaver and flow	- location, size, and structural characteristics of material mining sites - access roads routing and design - extent and nature of non-project development expected to impinge on the area within the next 50-75 years - estimates of current and projected recreational use in the area from both project and non-project sources - vehicle traffic along roads - location, timing, and areas of planned activities - expected impoundment water levels (seasonal) - estimates of mean monthly snow depths in 200 m elevation ranges
Vegetation	- better understanding of successional dynamics of all vegetation types in both upland and riparian areas - relationship of successional dynamics to changes in flow in the downstream area - annual variation in productivity of forage in selected vegetation types - seasonal variation in crude protein content and digestability of forage species - the role of fire in upland succession	- areas of balsam poplar and willow dominant vegetation types currently available as riparian habitat for beaver - estimates of current productivities of forage in selected vegetation types - estimates of current productivities of berries - stream bank characteristics - length of side channels and sloughs in the downstream area - estimates of crude protein content and disgestability for forage species in mid-summer and mid-winter

Table 4.1 (cont'd)

	CONCEPTUAL	DATA
Furbearers/Birds	- clear definition of beaver habitat - relationship of trapping effort to trapping mortality - relationship between beaver utilization of vegetation and succession - relationship between stage fluctuation in main channels and suitability of banks as habitat - relationship between ice scouring in main channels and suitability of banks as habitat - horizontal measure of cliff nesting habitat available - relationship of the logistic growth rate (r) and habitat quality, winter weather, and interference from other colonies and man - colonization of main channel habitat - measures for comparing loss of passerine habitat due to the impoundment	- areas of intensive beaver use by vegetation type - data on current beaver trapping mortality - data on size and composition of food caches - proportion of cliff nesting habitat that will be inundated at high water in the reservoir
Moose	- clear definition of home range - behavioral reactions of moose to human disturbance caused by the project - a definition of winter carrying capacity that considers: 1) species composition at browse; 2) protein content of each species; 3) digestability of each species; 4) moose requirements for protein and digestable energy - reexamination of the density dependent reproduction (Figure 3.14)	- estimates of summer mortality by age and sex - estimates for the parameter values in the predation relationships (Figures 3.15 and 3.16) - estimates of available winter range

Table 4.1 (cont'd)

	CONCEPTUAL	DATA
Moose (cont'd)	- inclusion of black bear and wolf predation on moose calves - inclusion of grizzly bear predation on older moose - relationship between harvest rate and numbers of hunters - relationship between snow depth and usable winter range	
Bear	- habitat classification system sensitive to quantity of summer berry production - relationship of bear dispersal and feeding to disturbances caused by development activities - relationship between food availability and bear survival - relationship of harvest to population size and hunting effort - inclusion of interspecific and intraspecific bear predation on cubs	- data on bear utilization of salmon population in the Prairie Creek-Stephan Lake area, and also in downstream sloughs and side channels - data on bear diet in the spring
Spatial	- reexamining of the spatial resolution of the model - a more detailed representation of vertical stratification in vegetation classification systems - a more detailed representation of vegetation in areas close to channels and sloughs	

4.3.1 Physical Processes/Development/Recreation

4.3.1.1 Recreation

Currently, the model contains little credible information with respect to recreation. Little or no information was available on existing or future recreational use in terms of numbers of use days or amounts of land needed. Data on current use and credible projections of future use and need are critical to better understanding of the impact of recreation on wildlife in the Susitna Basin.

4.3.1.2 Land Use

At present, the model contains only scanty information about current land use patterns in the study area. Because of the dynamic nature of land ownership in the area brought about primarily by the Alaska Native Claims Settlement Act, it is extremely difficult to make projections about future land use patterns. However, a credible development scenario requires that the model make projections about changing land use patterns with and without the project. This is inadequately represented in the present model.

4.3.1.3 Physical Processes

Flooding and Ice Scouring - Downstream Floodplain

The mechanisms that cause ice scouring are not clearly understood; therefore, it is difficult to develop a model for this phenomenon. A better understanding of the changes in frequency and duration of flooding caused by alteration of the flow regime and changes in the amount and degree of ice scouring is needed before reasonable predictions of the potential impacts of the project can be made.

Overwintering Habitat for Beaver

At present, the suitability of overwintering habitat for beaver is not directly related to flow regime in the downstream floodplain. The habitat in side channels and sloughs is suitable if at least .5 m in depth of unfrozen water is available throughout the winter. The model currently assumes that the severity of winter, which determines the ice thickness, is the only determinant of the amount of habitat. This is overly simplistic, and it is likely that the increased winter flows brought about by the project will have a major effect on the amount of suitable habitat. A better conceptual understanding of the relationship between the amount of suitable habitat and the flow regime must be developed.

Climatic Effects

The importance of climatic effects to understanding processes that might be affected by the project can not be overstated. The most important climatic influences are snow and ice. The interrelationship between the ice regime, flow, and vegetation has been discussed earlier.

Snow, or rather the amount of snow on the ground, affects the ability of moose and caribou to utilize winter range. In the model, the amount of snow on the ground is stochastically generated and does not provide a realistic representation of what actually occurs. An alternate approach is to use a more robust snow model similar to one developed by McNamee (1982) for simulating the effect of snow in elk dynamics. Such a model consists of three components: snowfall, snowmelt, and snow interception. In the simplest version of the model, snow is assumed to be general in nature, such that snow depth (not density, crusting, etc.) would be the only influence on ungulate dynamics. The general model would be:

$$SN_{s,t} = SN_{s,t-1} - MR * SR * f(CC_s) + SO_t * f(CC_s)$$

where,

$SN_{s,t}$ = snow depth on site s in time step t;

MR = maximum snowmelt;

SR = snowmelt factor specific to site characteristics (e.g. elevation);

SO_t = snowfall; and

CC_s = crown closure.

In simple terms, the model suggests that the snow depth in a given time step is equal to what was there the time step before less what has melted plus what has fallen through to the ground. Both snowmelt and snow interception are functions of stand openness. Work of Harestad and Bunnell (1981) relates the level of snow interception to snowfall and canopy closure; the work of Haverly et al. (1978) and Leaf and Brink (1973) can provide guides for defining snowmelt. A similar model needs to be developed to better understand how moose and caribou will adapt to the loss of winter range as a result of the impoundments.

4.3.2 Vegetation

Each spatial unit contains a large number of attributes (e.g. initial areas in various land classes, average annual berry production). The land classification system, the spatial scale, and the associated estimates of initial conditions are structural hypotheses about what is an appropriate representation of the system. Although they are subject to more precise quantification based on current and future data, many values were estimated quickly and roughly at the workshop. Consequently, they should be considered as very preliminary estimates.

4.3.2.1 Spatial Resolution

The spatial units and land classification system in the model are compromises. Clear suggestions for improvement emerged at the workshop with respect to birds (more detailed resolution of vertical stratification in the land classification system) and beaver (more detailed spatial resolution of vegetation in areas close to channels and sloughs). The need for spatial units more appropriate for moose (e.g. winter range) was also discussed at the workshop. These issues must be resolved before proceeding to a more precise estimate of variables within various spatial units and vegetation types.

4.3.2.2 Resolution of Development Activities

Land is removed for development activities from various land classes based on the relative proportions in the respective spatial units or, in the case of roads, based on proportions specific to a given route. The model could be refined to provide additional activities or to provide a finer resolution of the land class changes associated with an activity given its specific location within a spatial unit.

An example is the transfer of land in the impoundment spatial areas to the water class. This transfer is currently based on the development submodel's calculation of land cleared for vegetation, rather than on a calculation of the amount of area actually covered by water.

4.3.2.3 Wildlife Food

Currently, the model simulates the variation in browse standing crop and berry production as a random process. This simple representation could be improved by adding mechanisms that incorporate the effects of consumption of vegetation by wildlife. This is particularly true in the case of moose consumption of browse and to some extent, beaver alteration of habitat in the riparian zone. Further improvements in the model would result if the productivity of browse and berries can be functionally related to climatic variables such as temperature, snowfall, or total precipitation. However, current understanding of the determinants of productivity in the area may not be sufficient to fully develop these relationships.

4.3.2.4 Riparian Succession

The model currently assumes that transitions among land classes in the riparian zone are in equilibrium before the Watana Dam. It also assumes that the project will eliminate disturbance-caused transitions which set vegetation back to earlier successional stages. This hypothesis is not completely unreasonable in the Talkeetna to Devil Canyon riparian zone where postproject flows will be highly regulated and relatively ice-free. The assumption is clearly not applicable to riparian areas below Talkeetna where postproject unregulated flow will be a much higher proportion of total Susitna flow because of the inflow from major tributaries.

The representation of riparian succession could be dramatically improved by including all the transitions (which would presumably be approximately balanced under current conditions). The disturbance-related transitions could then be functionally related to the hydrologic regime through variables such as peak flows and ice presence. Hydraulic simulation models and the supporting channel cross section data being considered in the instream flow studies of the aquatic assessment could be very useful in developing such a representation of the effects of river flow on vegetation transitions.

4.3.2.5 Dynamics of Upland Vegetation

The current hypothesis is that the areas in various upland land classes are constant except for changes associated with specific development activities or vegetation manipulation actions. While this is a weak assumption, current understanding of upland successional processes is not sufficient to suggest a more dynamic approach.

The most serious drawback of this approach may be an underestimate of the importance of natural fire in the area along with its consequent effects on the natural variability of wildlife habitat. Van Cleve and Viereck (1981) have stated that:

> "The taiga of interior Alaska is dominated by young stands in various stages of succession - mature stands of over 200 years in age are rare. Fire is the main cause of the young ages of the stands - in some areas fire that kills all of the above ground vegetation can be expected every 50 - 100 years."

If this is the situation in the study area, the natural fire regime needs to be represented in a 50 year simulation.

The long-term habitat value of inundated areas may not be fairly represented by their current species composition if fire periodically converts them to earlier successional stages in the absence of inundation.

4.3.3 Furbearers/Birds

4.3.3.1 Beaver Model

Given the minimal understanding of beaver physiology and population parameters, the logistic equation is an appropriate model for describing the beaver population. Although structurally simple, its versatility regarding parameter specification ensures that it is responsive to the major impacts of the project. As a consequence, the model dynamics are transparent to the user without losing sensitivity to the major issues. Therefore, it is recommended that the logistic structure be maintained until new information dictates the need for a more detailed approach.

Refinements to the beaver model should concentrate on specification of the carrying capacity and intrinsic growth rate.

Carrying Capacity

Obviously, the definition of carrying capacity is critically dependent on how beaver habitat is defined. From the perspective of the furbearers subgroup, the definition present in Section 3.3.1.1 was an acceptable compromise given the relatively coarse spatial representation of the riparian zone. However, this definition requires information not easily obtained from the vegetation and hydrology submodels. Consequently, more effort is required to better establish how these information needs can be satisfied. This will require a meeting between the furbearer subgroup and the vegetation and hydrology groups. The discussion should focus on defining beaver habitat and its compatibility with the kinds of information that can realistically be supplied by the other subsystems.

Related to the discussion of habitat is the carrying capacity of any given section of habitat. The present estimate of 1 colony/2 km seems too small especially given the hypothesis that beaver rarely wander more than 100 meters from their den site. This may require specification of more than one kind of habitat with varying levels of beaver utilization.

Intrinsic Growth Rate

Currently the beaver model assumes the intrinsic annual population growth rate is constant at .33. The validity of this assumption should be challenged. Growth rates could be a function of habitat quality, severity of winter weather, and interference from other colonies or man. Discussion of these effects and comparison of the projected population rates of increase to a natural situation may indicate a need for refinement.

Movement of Beaver Between Side and Main Channels

Currently the model's characterization of cross fertilization of beaver colonies between the side and main channels is based very much on fiction. It was structured following the workshop and purely serves as a mechanism to ensure main channel habitat is colonized. Just how reasonable a process that is requires discussion.

Mortality

Currently, the beaver populations are subject to three sources of mortality: changes in water level, ice scouring, and trapping. Although all three of these mortality processes require some refinement, the most critical one is likely the rate of trapping. As described in the text, trapping is difficult to structure in the model since the driving forces are the price for beaver pelts and the attitude of the trappers. Both are unpredictable at the best of times.

4.3.3.2 Passerine Birds

Using a habitat oriented procedure certainly seems to be the best way to deal with the migratory passerine birds, given the model is spatially restricted to the Susitna Basin. Currently, the model "habitat unit" indicators show little sensitivity to the impoundment due to the large area of the region included in the calculation. This region was chosen somewhat arbitrarily and it may be profitable to discuss other suitable ways of comparing the loss of habitat due to impoundments.

4.3.4 Moose

4.3.4.1 Winter Carrying Capacity

The computation of winter carrying capacity assumes that average browse availability for each land class is an adequate measure of winter habitat. A better estimate of the carrying capacity would consider:

1) the species composition of the available browse;

2) the protein content of each species;

3) the digestible energy content of each species; and

4) the daily moose requirement for protein and digestible energy.

4.3.4.2 Reproduction

The reproductive function (Figure 3.14) is a density-dependent relationship in which population density is a surrogate for food consumption. The hypothesis is that, at higher population densities, less food is available per individual and females are less successful in bringing their calves to term. Participants indicated that this phenomenon has never been observed in the Susitna herd, but that it does occur in other ungulate herds. The density-dependent reproductive function was incorporated in the example model largely as a means of preventing unlimited exponential growth. The density-dependent portion of the curve in Figure 3.14 is rarely operative with the winter population sizes (i.e. usually under 8,000 animals) generated from the parameter set currently being used.

4.3.4.3 Summer Mortality

Summer mortality is currently hypothesized to be a constant fraction of each age and sex class. While this is probably not the case, there is little understanding of factors that affect these rates.

4.3.4.4 Predation

There are two principal hypotheses incorporated in the bear predation portion of the example moose model. First, the rate of predation by an individual bear is assumed to be a function of moose calf density as shown in Figure 3.15. Second, vulnerability of moose calves to bear predation is assumed to be related to snowfall in the previous winter. The combination of these two assumptions results in a steeper slope on Figure 3.15 in years of heavy snowfall and thus more effective predation by bears at lower calf densities.

The stimulus for this information was a series of observations indicating lower calf/cow ratios in the Susitna moose herd in years following heavy snowfall. The relationship seems to be fairly consistent except in one year during which there was a bear removal program. In that year, the fall calf/cow ratio was high despite a hard previous winter. Biologists hypothesize that these data indicate a relationship between winter severity and vulnerability of moose calves to bear predation.

The model formulation probably captures the qualitative aspects of this hypothesis quite well. However, the parameter values currently used in Figures 3.15 and 3.16 are merely guesses and obtaining actual estimates for them may be very difficult. If reasonable data cannot be obtained, other formulations for the predation function may prove more useful. The present model is also deficient in that it:

1) considers predation only by grizzly bears. Black bears and wolves are also known to prey on moose;

2) considers predation only by the female cohort of the bear population (the only cohort incorporated in the bear submodel); and

3) considers only predation on calves. Grizzly bears are also known to take older moose.

4.3.4.5 Harvest

The model assumes that male moose between some minimum and maximum age set by the user are subjected to a harvest rate that does not vary from year to year. While this is probably not an accurate assumption, no clear hypotheses emerged at the workshop concerning how the actual harvest rate might be related to factors such as level of hunter activity, moose population size, or weather. For example, the relationship between number of hunters and harvest rate should be explored more thoroughly if the hydroelectric project results in greater hunter activity. The impact of a larger number of hunters can probably be mitigated through more stringent permit and harvest quota systems, but such systems will undoubtedly require more intensive effort by management agencies.

4.3.4.6 Winter Mortality

The basic hypothesis articulated at the workshop concerning winter mortality has two distinct parts. First, biologists feel that in severe winters a larger proportion of the moose herd in the Upper Susitna Basin depends on the area surrounding the proposed hydroelectric project for winter forage. Second, they believe that more severe winters restrict the proportion of the area surrounding the proposed project that is actually usable by moose. If this hypothesis is true, the proposed project can be expected to impact moose to the extent that it will destroy or alter winter range. This may occur through a variety of mechanisms including direct inundation, facilities construction, frosting of vegetation, and drifing of snow blown off the surface of the impoundment.

Unfortunately, the two mild winters so far encountered in the moose study have not produced a great deal of information useful in examining this hypothesis. The moose model is therefore deficient in a number of respects. First, it assumes that the entire moose herd in the Upper Susitna Basin winters in the area surrounding the proposed project. Second, the estimate of the total amount of winter range available before the project is crude; it is simply the length of the Watana impoundment (about 50 miles) multiplied by an average width of 5 miles. Third, the relationship between snow depth and proportion of winter range usable by moose (Figure 3.17) is arbitrary, as are the relationships between forage availability and survival (Figure 3.18). Finally, the assumption that all of the winter range is in a single land class is clearly erroneous.

Nevertheless, much of the necessary data to test these hypotheses could probably be obtained from existing land class and contour maps, a stratified sampling program for browse production, snow course surveys, and the existing radio-telemetry program. The existing maps could be used to determine how much land in each vegetation type exists in various elevational bands. The browse sampling program could then provide estimates of forage availability in those bands. Snow course and radio-telemetry data could be used to ascertain which elevations are used by moose under what snow conditions, and thus, how much forage is available. The final step, relating forage availability to moose survival, would likely be the most difficult and would probably have to be based on studies of penned animals.

4.3.5 Bear

There are a number of conceptual and data deficiencies within the bear model. Many of the functional relationships need to be reexamined and their parameters reestimated or, in some cases, completely restructured.

4.3.5.1 Spring Food

The current spring food index does not take account of the quality, quantity, and desirability of the food resource associated with different vegetation types. Also, moose calf predation, a food resource critical to the spring survival of immature bears, must be explicitly included in the model.

4.3.5.2 Mortality

Harvest and predation on cubs are two major sources of mortality not included in the current version of the model. Relationships needs to be developed to estimate harvests as a function of population size and hunting effort, and interspecific and intraspecific predation on cubs by both brown and black bears need to be included in the model.

4.3.5.3 Dispersal

Currently, dispersal is based on density only and is not restricted to immature animals. Older animals probably disperse as well, and a more realistic dispersal mechanism should be included. Also, the impact of human disturbance on dispersal and the degree to which human disturbance acts as impediments to movement to and from forage areas has been neglected and should be examined.

5.0 FUTURE WORK

Much work is required before the model will be a valuable aid in mitigation planning. This work has already begun. Subsequent to the workshop, a meeting to refine the vegetation and big game studies to better assess the impacts of habitat loss on big game was held September 28, 1982 at the Fairbanks Alaska Department of Fish and Game office. While the meeting was not directly related to model refinement, the discussion focused on many aspects of moose habitat utilization that were considered problem areas during the workshop. Meetings specifically designed to focus on model refinements have been tentatively scheduled for the week of November 15 - 19. These technical meetings, to be attended by the participants of the August workshop, will focus on detailed questions in each of the submodels. Current planning has one technical meeting for each of the submodels.

After the technical meetings, work will begin on revising the existing model by including better data and, where necessary, restructuring of the functional relationships.

At the workshop tentatively scheduled for late February or early March, the refined verison of the model will be presented for critique. That workshop will deal with two other major questions: a review of research planned in the terrestrial environmental studies associated with phase II of the Susitna Hydroelectric Project, and alternative ways of valuing changes in habitat based on model projections.

Early in November, 1982 the Alaska Department of Fish and Game staff in Anchorage will begin taking responsibility for the moose and bear submodels. They will work closely with the modelling team to refine the model to a state that it provides a framework for evaluating the impacts of the project.

While the focus of the technical meetings and workshop will be model refinement, they will also serve as a forum for discussing issues and information needs related to comprehensive mitigation planning. This next series of meetings and workshops are designed to improve our collective understanding and to clarify the process that will be used to examine the complex issues of habitat enhancement and compensation lands.

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7.0 LIST OF PARTICIPANTS

Attending the Susitna Terrestrial Modelling Workshop
August 23-27, 1982

NAME	AFFILIATION	ADDRESS
Tom Arminski	Alaska Power Authority	344 West 5th Avenue Anchorage, Alaska 99501 (907) 277-7641
Greg Auble	USFWS - Welut	2625 Redwing Road Fort Collins, Colorado 80526 (303) 226-9431
Warren Ballard	Alaska Dept. of Fish & Game	P.O. Box 47 Glennallen, Alaska 99588 (907) 822-3461
Keith Bayha	USFWS	1011 East Tudor Road Anchorage, Alaska 99507 (907) 276-3800
Bruce R. Bedard	Alaska Power Authority	334 West 5th Avenue Anchorage, Alaska 99501 (907) 277-7641
Steve Bredthauer	R & M Consultants	P.O. Box 6087 5024 Cordova Anchorage, Alaska 99503 (907) 279-0483
Leonard P. Corin	USFWS	605 West 4th, #G-81 Anchorage, Alaska 99501 (907) 271-4575
Ike Ellison	USFWS - Welut	2625 Redwing Road Fort Collins, Colorado 80526 (303) 226-9431
John Ernst	LGL	1577 "C" Street, Suite 305 Anchorage, Alaska 99501 (907) 274-5714
Bob Everitt	ESSA Ltd.	678 West Broadway Vancouver, B.C. (604) 872-0691
Steve Fancy	LGL	P.O. Box 80607 Fairbanks, Alaska 99708 (907) 479-6519

NAME	AFFILIATION	ADDRESS
Richard Fleming	Alaska Power Authority	334 West 5th Avenue Anchorage, Alaska 99501 (907) 277-7641
Bill Gazey	LGL	1410 Cavitt Street Bryan, Texas 77801 (713) 775-2000
Philip S. Gipson	Alaska Cooperative Wild- life Research Unit	University of Alaska Fairbanks, Alaska 99701 (907) 474-7673
George Gleason	Alaska Power Authority	334 West 5th Avenue Anchorage, Alaska 99501 (907) 277-7641
Michael Grubb	Acres American	900 Liberty Bank Building Buffalo, New York 14202 (716) 853-7525
John Hayden	Acres American	1577 "C" Street Anchorage, Alaska 99501 (907) 276-4888
Dot Helm	University of Alaska Ag. Experiment Station	P.O. Box AE Palmer, Alaska 99645 (907) 745-3257
Brina Kessel	University of Alaska Museum	P.O. Box 80211 College, Alaska 99708 (907) 474-7359
Sterling Miller	Alaska Dept. of Fish & Game	333 Raspberry Road Anchorage, Alaska 99502 (907) 344-0541
Suzanne Miller	Alaska Dept. of Fish & Game	333 Raspberry Road Anchorage, Alaska 99502 (907) 344-0541
Ron Modafferi	Alaska Dept. of Fish & Game	333 Raspberry Road Anchorage, Alaska 99502 (907) 344-0541
Robert Mohn	Alaska Power Authority	334 West 5th Avenue Anchorage, Alaska 99501 (907) 277-7641

NAME	AFFILIATION	ADDRESS
Carl Neufelder	Bureau of Land Management	4700 East 72nd Avenue Anchorage, Alaska 99501 (907) 267-1200
Ann Rappoport	USFWS	605 West 4th, #G-81 Anchorage, Alaska 99501 (907) 271-4575
Wayne Regelin	Alaska Dept. of Fish & Game	1300 College Road Fairbanks, Alaska 99701 (907) 452-1531
Butch Roelle	USFWS - Welut	2625 Redwing Road Ft. Collins, Colorado 80526 (303) 226-9431
David G. Roseneau	LGL	P.O. Box 80607 Fairbanks, Alaska 99708 (907) 479-6519
Karl Schneider	Alaska Dept. of Fish & Game	333 Raspberry Road Anchorage, Alaska 99502 (907) 344-0541
Robin Sener	LGL	1577 "C" Street, Suite 305 Anchorage, Alaska 99501 (907) 274-5714
Nicholas Sonntag	ESSA Ltd.	678 West Broadway Vancouver, B.C. (604) 872-0691
Robert N. Starling	NORTEC	750 West 2nd Avenue, #100 Anchorage, Alaska 99501 (907) 276-4302
Gary Stackhouse	USFWS	1011 East Tudor Road Anchorage, Alaska 99507 (907) 276-3800
Bill Steigers	University of Alaska Ag. Experiment Station	P.O. Box AE Palmer, Alaska 99645 (907) 745-3257
Nancy Tankersley	Alaska Dept. of Fish & Game	333 Raspberry Road Anchorage, Alaska 99502 (907) 344-0541

NAME	AFFILIATION	ADDRESS
Thomas W. Trent	Alaska Dept of Fish & Game, SU Hydro Aquatic	2207 Spenard Road Anchorage, Alaska 99503 (907) 274-7583
Joe Truett	LGL	Rural Route 1, Box 1-A Flagstaff, Arizona 86001
Larry Underwood	AEIDC	707 "A" Street Anchorage, Alaska 99501 (907) 279-4523
Jack Whitman	Alaska Dept. of Fish & Game	P.O. Box 47 Glennallen, Alaska 99588 (907) 822-3461
Marjorie Willits	Alaska Dept. of Natural Resources	555 Cordova Street Anchorage, Alaska 99510 (907) 276-2653