AQUATIC ENVIRONMENT PROTECTION IN PROTECTED AREAS: A COMPARATIVE STUDY

by

JOHN RANDALL SPYKSMA

B.S.F., The University of British Columbia, 1993

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE in THE FACULTY OF GRADUATE STUDIES (Faculty of Forestry)

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

April 1995

© John Randall Spyksma
In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Forestry

The University of British Columbia
Vancouver, Canada

Date April 27, 1995
ABSTRACT

Protected areas are established to preserve representative natural ecosystems and pristine environments and to provide opportunities for recreation. Water is critical to ecological processes and so must be an important factor in protected area management. Despite the importance of water to protected area integrity, the protection of the aquatic environment has been given very little consideration when compared to terrestrial environments.

This lack of consideration for the management and protection of the aquatic environment is evident in the protected areas of British Columbia and Thailand. Methods have been developed to help ensure the protection of the environments within protected areas. These methods fall short of giving the aquatic environment due consideration. In addition, managers have very little guidance or mandate to address external threats to the aquatic environment within protected areas. This deficiency is critical as external threats to protected areas will continue to intensify.

Recommendations are made to improve the protection of the aquatic environment within and entering protected areas. These recommendations include the improved use of present protection activities such as use permits, visitor management, and general management planning. In addition, more comprehensive land use planning, the use of public trust and instream flow legislation, and possible corridor protection programs are examined to improve the protection of the aquatic environment in protected areas.

Monitoring plays an important role in the protection of the aquatic environment in protected areas, but was lacking in Thailand. Monitoring efforts in B.C. protected areas could benefit from increased coordination. A framework is developed to guide protected area managers in the development of aquatic environment monitoring programs.
TABLE OF CONTENTS

ABSTRACT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACKNOWLEDGMENTS

CHAPTER I - INTRODUCTION
A. Introduction of the Problem
B. Study Purpose
C. Study Methods
   1. Aquatic Environment Protection
   2. Protection Methods
   3. Monitoring Framework
   4. Additional Monitoring Tools
D. Study Limitations

CHAPTER II - CASE STUDY DESCRIPTIONS - THAILAND
A. Introduction to Thailand
B. Protected Areas in Thailand
   1. National Parks
   2. Wildlife Sanctuaries
C. The Aquatic Environment in Thailand
D. Doi Inthanon National Park
   1. Park Resources
   2. Human Encroachment
   3. Land Zoning
   4. Agriculture/Aquaculture Activities
   5. Welfare Promoting Agencies
   6. Administrative Issues
E. Khao Sam Roi Yot National Park
   1. Park Resources
   2. Human Encroachments
   3. Water Developments to Facilitate Cultivation
   4. Aquaculture Activities
   5. Domestic/Industrial Activities
CHAPTER III - CASE STUDY DESCRIPTIONS - BRITISH COLUMBIA
A. Introduction to British Columbia 30
B. Protected Areas in British Columbia 31
1. National Parks 31
2. Provincial Parks 32
C. The Aquatic Environment in British Columbia 32
D. Banff National Park 34
1. Park Resources 34
2. Visitor Use 37
3. Townsite/Visitor Facility Development 39
4. Hydro-electric Development 42
5. Administrative Issues 45
E. Strathcona Provincial National Park 45
1. Park Resources 47
2. Visitor Use and Facility Development 49
3. Hydro-electric development 51
4. Mining 52
5. Administrative Issues 54

CHAPTER IV - CASE STUDY FINDINGS AND RECOMMENDATIONS 55
A. British Columbia/Thailand Comparisons 55
B. Protection Methods in Thailand 56
1. Legislation and policy 56
2. Consultation 60
3. Regulation/Enforcement 61
4. Environmental Impact Assessments 63
5. Public/International Awareness 64
6. Monitoring 66
C. Protection Methods in British Columbia 66
1. Planning 67
2. Legislation and policy 70
3. Licensing/EIAs 71
4. Zoning 74
5. Treatment/Restoration 74
6. Public Awareness/Stakeholder Consultation 75
7. Monitoring 79
D. Applicability 80
1. Policy Development 80
2. Licensing/EIAs 82
3. Working Groups 83
4. Public International Involvement 83
5. Monitoring 84
E. Discussion 85
CHAPTER V - DESIGN OF AN AQUATIC ENVIRONMENT MONITORING SYSTEM

A. Introduction 87

B. Developing an Aquatic Environment Monitoring Program 87
   1. Step 1 - Define information expectations 88
      1.1. Management and Monitoring Goals 88
      1.2. Defining "Aquatic Environment" for Design Purposes 89
      1.3. The Tiered Approach 89
      1.4. Identify Statistical Methods 91
      1.5. From Monitoring to Management 91
      1.6. Reporting Format 91
   2. Step 2 - Confirm Statistical Design Criteria 91
      2.1. Characterize Population 92
      2.2. Confirm Methodology 93
   3. Step 3 - Design Monitoring Network 93
      3.1. Where to Sample 94
         3.1.1. Representative Areas and Scale 94
         3.1.2. Statistical Considerations 95
         3.1.3. Environmental protection 95
      3.2. What to Sample 96
      3.3. When to Sample 97
         3.3.1. Sampling Frequency 97
         3.3.2. Cost-effectiveness 98
   4. Step 4 - Develop Operating Plans and Procedures 99
      4.1. Quality Assurance/Quality Control 99
      4.2. Sampling 100
      4.3. Data Analysis 101
      4.4. Data Storage and Retrieval Procedures/Processes 102
   5. Step 5 - Develop Information Reporting Procedure 102
      5.1. Means of Reporting 102
      5.2. Information in the Report 103
      5.3. Frequency and Distribution of Reporting 103
   6. Conclusions 103

C. Monitoring Framework Application 104
   1. Doi Inthanon National Park 105
   2. Khao Sam Roi Yot National Park 109
   3. Banff National Park 111
   4. Strathcona Provincial Park 116

D. Discussion 119
CHAPTER VI - DESIGN OF ADDITIONAL PROTECTION TOOLS
A. Comprehensive Planning 121
B. Public Trust Doctrine 123
C. Minimum Instream Flows 125
D. Corridor Protection Programs 128

CHAPTER VII CONCLUSIONS 132

REFERENCES 134

APPENDIX A 145
LIST OF TABLES

Table 1. Resource pressures and their sources in the protected areas of Thailand and British Columbia. 56
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The location of Thailand within South-east Asia</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>The location of Doi Inthanon National Park in Thailand</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Doi Inthanon National Park - note the park headquarters</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>A photo of the land adjacent to Khun Klang, taken from the banks of the Mae Klang River which runs past the village.</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>The IRP weir on the Mae Klang River, located approximately 3-4 km upstream from the village on Khun Klang.</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>Photo of the upper Mae Klang valley taken from just north of Khun Klang. Please note the many greenhouses. This view is typical of many of the valleys in the park.</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>The location of Khao Sam Roi Yot in Thailand (Conservation Data Centre, 1992).</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>A photo of the two main environments protected within KSRYNP. Please note the freshwater marsh (foreground) and the limestone mountains (background).</td>
<td>23</td>
</tr>
<tr>
<td>9</td>
<td>The general environments within Khao Sam Roi Yot National Park.</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>The extent of shrimp farming within and adjacent to KSRYNP. The photo was taken looking north from near the park headquarters. Due to boundary ambiguity, the extent of encroachment is unknown. Please note Khao Daeng, the canal in the bottom right hand corner of the photo.</td>
<td>27</td>
</tr>
<tr>
<td>11</td>
<td>An example of the machinery used to support the intensive culture of tiger prawns in and adjacent to KSRYNP.</td>
<td>28</td>
</tr>
<tr>
<td>12</td>
<td>The location of B.C in North America</td>
<td>30</td>
</tr>
<tr>
<td>13</td>
<td>The location of Banff adjacent to B.C. (Parks Canada, 1988)</td>
<td>35</td>
</tr>
<tr>
<td>14</td>
<td>The main aquatic environments in Banff National Park.</td>
<td>36</td>
</tr>
<tr>
<td>15</td>
<td>Photo of Banff Town from Sulphur Mountain. Please note the Bow River flowing through the town and the location of Lake Minnewanka in the upper right portion of the picture.</td>
<td>38</td>
</tr>
</tbody>
</table>
Figure 16. Bow Falls, on the Bow River within the town of Banff.  

Figure 17. The Bow Valley in Banff National Park just north of Banff town. Please note the travel corridors.  

Figure 18. The location of Strathcona in B.C. and on Vancouver Island  

Figure 19. The main rivers and waterbodies in Strathcona Provincial Park.  

Figure 20. The resort village of Mt. Washington, taken from the mountain. Please note the Forbidden Plateau areas of Strathcona Provincial Park in the background.  

Figure 21. Paradise Meadows in Strathcona Provincial Park just below the resort village of Mt. Washington.  

Figure 22. Buttle Lake just south of Buttle Narrows. Please note the drawdown zone.  

Figure 23. The active mine of Westmin Resources located at the southern tip of Buttle Lake.  

Figure 24. The proposed location of monitoring stations in Doi Inthanon National Park  

Figure 25. The proposed location of monitoring stations in Khao Sam Roi Yot National Park  

Figure 26. The proposed location of monitoring stations in Strathcona Provincial Park.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBVTF</td>
<td>Banff Bow Valley Task Force, Canada</td>
</tr>
<tr>
<td>B.C.</td>
<td>Province of British Columbia, Canada</td>
</tr>
<tr>
<td>BNP</td>
<td>Banff National Park, Canada</td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>BRWQC</td>
<td>Bow River Water Quality Council, Alberta</td>
</tr>
<tr>
<td>CHRS</td>
<td>Canadian Heritage Rivers System</td>
</tr>
<tr>
<td>CITES</td>
<td>Convention on International Trade of Endangered Species of Wild Flora and Fauna</td>
</tr>
<tr>
<td>CORE</td>
<td>Commission on Resources and the Environment, British Columbia</td>
</tr>
<tr>
<td>CPAWS</td>
<td>Canadian Parks and Wilderness Society</td>
</tr>
<tr>
<td>CPS</td>
<td>Canadian Parks Service</td>
</tr>
<tr>
<td>DFO</td>
<td>Department of Fisheries and Oceans, Environment Canada</td>
</tr>
<tr>
<td>DINP</td>
<td>Doi Inthanon National Park, Thailand</td>
</tr>
<tr>
<td>DLD</td>
<td>Department of Land Development, Thailand</td>
</tr>
<tr>
<td>DQOs</td>
<td>Data Quality Objectives</td>
</tr>
<tr>
<td>EARP</td>
<td>Environmental Assessment and Review Process, Canada</td>
</tr>
<tr>
<td>EGAT</td>
<td>Electricity Generating Authority of Thailand</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>FEARO</td>
<td>Federal Environmental Assessment and Review Office, Canada</td>
</tr>
<tr>
<td>IRP</td>
<td>Inthanon Royal Projects, Doi Inthanon National Park, Thailand</td>
</tr>
<tr>
<td>IUCN</td>
<td>International Union for the Conservation of Nature and Natural Resources</td>
</tr>
<tr>
<td>IWD</td>
<td>Inland Waters Directorate, Environment Canada</td>
</tr>
<tr>
<td>KSRY</td>
<td>Khao Sam Roi Yot National Park, Thailand</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>MIF</td>
<td>Minimum instream flows</td>
</tr>
<tr>
<td>MoELP</td>
<td>Ministry of Environment, Lands, and Parks; British Columbia</td>
</tr>
<tr>
<td>NCA</td>
<td>Nature Conservation Areas, in the provincial parks of British Columbian</td>
</tr>
<tr>
<td>NESDB</td>
<td>National Economic and Social Development Board, Thailand</td>
</tr>
<tr>
<td>NESDP</td>
<td>National Economic and Social Development Plan, Thailand</td>
</tr>
<tr>
<td>NP</td>
<td>National Park, in either Thailand or Canada</td>
</tr>
<tr>
<td>NPA</td>
<td>Thailand's National Parks Act, 1961</td>
</tr>
<tr>
<td>NPD</td>
<td>National Parks Division, Royal Forest Department, Thailand</td>
</tr>
<tr>
<td>NWT</td>
<td>Northwest Territories, Canada</td>
</tr>
<tr>
<td>ONEB</td>
<td>Office of the National Environment Board, Thailand</td>
</tr>
<tr>
<td>PP</td>
<td>Provincial Park, in British Columbia</td>
</tr>
<tr>
<td>PUP</td>
<td>Park Use Permit, used in the provincial parks of British Columbia</td>
</tr>
<tr>
<td>QA/QC</td>
<td>Quality Assurance/Quality Control</td>
</tr>
<tr>
<td>SPP</td>
<td>Strathcona Provincial Park, British Columbia</td>
</tr>
<tr>
<td>SWPP</td>
<td>Strathcona Westmin Provincial Park, British Columbia</td>
</tr>
<tr>
<td>RC</td>
<td>Ramsar Convention</td>
</tr>
<tr>
<td>RFD</td>
<td>Royal Forest Department, Thailand</td>
</tr>
<tr>
<td>RID</td>
<td>Royal Irrigation Department, Thailand</td>
</tr>
<tr>
<td>TAT</td>
<td>Tourism Authority of Thailand</td>
</tr>
<tr>
<td>TDRI</td>
<td>Thailand Development Research Institute, Bangkok, Thailand</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Association for International Development</td>
</tr>
<tr>
<td>WARPA</td>
<td>Thailand's Wild Animals Reservation and Protection Act, 1961</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>WCD</td>
<td>Wildlife Conservation Division, Royal Forest Department, Thailand</td>
</tr>
<tr>
<td>WHC</td>
<td>World Heritage Convention</td>
</tr>
<tr>
<td>WPA</td>
<td>Welfare Promoting Agencies</td>
</tr>
<tr>
<td>WSC</td>
<td>Watershed Classification, Thailand</td>
</tr>
<tr>
<td>WSRA</td>
<td>Wild and Scenic Rivers Act, 1968, U.S.A.</td>
</tr>
<tr>
<td>WWF</td>
<td>World Wildlife Fund</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

I would first like to thank the Lord as I have gained new meaning from the verse "I can do anything through Him who gives me strength" (Phil. 4:13, NIV).

I would like to thank the Canadian University Consortium - Asian Institute of Technology Partnership Project that facilitated my research in Thailand.

I would like to thank Dr. Peter Dooling, Professor, Natural Resources Conservation, Faculty of Forestry, for helping me during my research through his guidance. I also want to thank my fellow graduate students for acting as sounding boards and last but definitely not least, my wife, Shari, for standing beside me during the completion of my graduate work.
CHAPTER I - INTRODUCTION

A. Introduction of the Problem

Water is important to ecosystem functioning as all living things require water to survive. Protected areas are developed, in part, to protect the environment and its ecosystems in their natural state. Calls are being made for the use of ecosystem based management and protection of these areas (Brundtland, 1987 and IUCN, 1991). With a focus developing, for instance, on ecological integrity*, the protection of the aquatic environment is an important management consideration.

Methods to deal with impacts on or threats to the aquatic environment in protected areas must be provided. Despite the importance of the aquatic environment to ecosystem functioning, the protection of the aquatic environment is not always given due consideration within protected areas (Sewell and Yapp, 1986). As a result, many water development activities represent extreme threats to protected areas. This raises some important questions.

What considerations are given to the protection of the aquatic environment within or entering protected areas? Are managers given ample means to protect the aquatic environment? What improvements or changes can be made to provide for the necessary protection? How can an aquatic environment monitoring system be developed and how can it play a role in the protection of this environment?

B. Study Purpose

The questions voiced above are answered with respect to the national parks and wildlife sanctuaries in Thailand and provincial and national parks in British Columbia. Additional areas that protect the natural environment, do not have an ecosystem preservation focus, and permit industrial resource extraction activities are excluded from the study.

The study examines the methods that can be used to protect the aquatic environment within and entering protected areas. The applicability of these methods to other jurisdictions

*Parks Canada (1991) states that an ecosystem has integrity when its structure and function are 1) unimpaired by human-caused stresses and 2) likely to persist.
is assessed. The lack of aquatic environment protection in some protected area situations is noted and recommendations are made to address these deficiencies.

An aquatic environment monitoring system is an important step in the protection of this environment in protected areas. A well developed monitoring program can provide valuable information about the present state of the aquatic environment, the changes taking place within this environment, and in some cases, the source of these changes. The development of such a monitoring system is the first step in providing protection to the aquatic environment.

The number of protected areas is increasing significantly in British Columbia (B.C., 1991a) and in Thailand (Trisurat, 1994, Pers. com.). Both jurisdictions recognize the importance of developing an extensive protected areas system. If the adequate protection of their aquatic environments does not occur, the expansion of these protected area systems is made in vain.

The objectives of this study are as follows:

Objective 1 - To determine the level of protection given to the aquatic environment within and entering the protected areas of both Thailand and British Columbia.

Objective 2 - To examine and assess the methods used to protect the aquatic environments in the two jurisdictions.
- To determine if current protection methods can be applied in the protected areas in other jurisdictions.

Objective 3 - To develop a framework that guides protected area managers in the development of an aquatic environment monitoring system in support of protection efforts.

Objective 4 - To identify aquatic environment protection methods used in other jurisdictions that can address deficiencies in Thailand and British Columbia.

C. Study Methods

The procedures used to conduct this research project are outlined below based on the corresponding objective.
1. Aquatic Environment Protection (Objective 1)

To obtain background information on aquatic environment protection in the protected areas of both jurisdictions, a literature review was conducted. The review was conducted on literature on the protected area systems and the associated water development pressures in both Thailand and British Columbia: pertinent legislation and policy, protected area publications and research literature. The literature review was supplemented by interviewing government agents responsible for the management and protection of both protected areas and the water resource.

2. Protection Methods (Objective 2)

Case study protected areas were examined to determine the methods that are used in both jurisdictions to protect the aquatic environment. The case studies examined were Doi Inthanon and Khao Sam Roi Yot National Parks in Thailand, Strathcona Provincial Park in British Columbia, and Banff National Park in the adjacent province of Alberta.

The land use activities impacting the aquatic environment within the case studies are assessed and categorized. The methods that are used by protected area managers to address these land use categories are examined. Deficiencies that are present in the protection of the aquatic environment are noted.

A comparison between British Columbia and Thailand is conducted to assess the applicability of protection methods from one jurisdiction to the other. Included is the ability of methods from the other jurisdiction to adequately address deficiencies previously noted.

3. Monitoring Framework (Objective 3)

Guidance in the development of an aquatic environment monitoring system is provided through a framework. The framework notes many of the considerations that must be addressed in the development of an aquatic environment monitoring system within protected areas.

To develop the framework, the general nature of monitoring systems was reviewed and considerations pertaining to all aquatic environment monitoring systems were identified. This information was then tailored for use in protected areas. The framework also recognizes
the importance of present monitoring activities within protected areas and their value in supporting further monitoring.

Each case study area is then assessed in light of the monitoring framework. The past monitoring activities are reviewed, past and future monitoring activities are integrated, and general monitoring parameters and station locations are discussed.

4. Additional Protection Tools (Objective 4)

Protection methods used in jurisdictions other than Thailand and British Columbia are examined. The success of these methods to address deficiencies in British Columbia and/or Thailand is assessed. The additional protection tools examined are comprehensive planning, the public trust doctrine, minimum instream flows, and river corridor protection. Recommendations for their use are proposed.

D. Study Limitations

The scope of this study is limited in three ways. These limitations concern the nature of the aquatic environment studied, the number of case studies, and the implementation of the water monitoring system framework.

The importance of the aquatic environment to ecosystem functioning, and therefore protected area integrity, is clear. This study is, however, limited to the study of the surface freshwater environment. *Aquatic environment*, as used here, refers to water quality, water quantity, and biological components of this environment. Although precipitation, ground water, and estuarine/marine environments are not specifically addressed in this study, the importance of these aquatic environments to protected area integrity is understood.

Two case study areas are examined in each jurisdiction. It would be beneficial to examine a wider range of areas to obtain a more accurate depiction of the state of aquatic environment protection to and within these areas. The four case study areas were chosen, however, to best depict the conditions of aquatic environment protection in the protected areas of Thailand and British Columbia.

The monitoring framework developed to aid protected area managers would benefit from its implementation and resulting feedback. Time was not available for implementation.
To ensure the usefulness of the framework, however, the case study managers in Strathcona Provincial Park and Banff National Park have been consulted. Their comment and critique have been used to improve the framework and ensure its usefulness to protected area managers.
CHAPTER II - CASE STUDY DESCRIPTIONS - THAILAND

A. Introduction to Thailand

Thailand is a Pacific Rim nation located in the centre of South-east Asia (See Figure 1) at the junction of the Indo-Burmese, Indo-Chinese, and Indo-Malayan biogeographic sub-regions. It is for this reason that the country houses a very diverse assemblage of ecosystems and diverse populations of fauna and flora.

Accelerated alteration of the environment has taken place since the start of Thailand’s economic boom in the 1960s. The forest cover, for instance, has decreased from 60% in the 1960s, to less than 40 percent by 1980, and now to less than 28% of the country’s land base.

Figure 1. Regional location of Thailand in South-east Asia. Modified from C.I.A. (1986).
(TDRI, 1987). As more and more of the forests outside of designated protected areas become increasingly degraded, the forests protected in national parks and wildlife sanctuaries will become increasingly valuable (NPD, 1986).

B. Protected Areas in Thailand

Thailand boasts the largest protected areas system in South-east Asia (Parr et al., 1993, unpublished and MacKinnon and MacKinnon, 1986) with 74 national parks and 34 wildlife sanctuaries designated since 1960. Protected areas apart from the national parks and wildlife sanctuaries addressed in this study include forest parks and non-hunting areas. Although Thailand's protected areas cover over 13% of the country's land base, some of the country's natural environments are not well represented in the protected areas system, e.g., wetland and lowland forest environments (MacKinnon and MacKinnon, 1986). The under-representation of these types of environments within the protected area systems is due in part to the development pressures on Thailand's natural resources.

The integrity of many of the protected areas in Thailand is in question as the intensity of activities within and adjacent to protected areas continue to rise (Kasetsart University, 1987). A significant difference can be detected in the level of protection that is given to the main protected areas of the country such as Khao Yai National Park and those that are more remote and lower profile areas, commonly known as "paper parks" (MacKinnon et al., 1986). These protected areas of lower profile are bearing the brunt of many human-induced pressures.

1. National Parks

The designation of 14 areas started the national parks system in Thailand in 1958. The National Parks Act was established in 1961 to support the designation of these areas (Thailand, 1961a). Although many of the original 14 parks were "lost", twenty-three national parks were designated by 1980, 50 parks by 1985, 63 parks by 1990, and 74 parks by March, 1993 (Parr et al., 1993). Thirty nine additional parks are proposed (Smitinand, 1992). Despite the development of management planning for the national parks in 1986, less than ten parks have comprehensive management plans (Trisurat et al., 1991).
National parks are managed by the National Parks Division (NPD) in the Royal Forest Department (RFD). The national parks are defined as portions of land, which include the surface of the lands in general as well as mountains, streams, swamps, canals, marshes, basins, waterways, lakes, islands, and seashores that have been declared as a national park under the National Parks Act. The features of the land should be of national significance and must not be owned or legally possessed by any other party than the public body. This land is preserved in its natural state for the benefit of public education and enjoyment (Thailand, 1961a)

2. Wildlife Sanctuaries

The first initiative to directly protect wildlife in Thailand was the Wild Animals Reservation and Protection Act in 1961 (Thailand, 1961b). The Act places animals into two categories - reserved or protected - based on their abundance and level of endangerment in Thailand. The Act mandates the Wildlife Conservation Division (WCD) to manage wildlife sanctuaries and non-hunting areas for the purpose of protecting wildlife.

There are presently 34 wildlife sanctuaries, covering 25,559 square kilometres or 5% of the country (Smitinand, 1991). Five more areas are proposed in addition to the expansion of 10 present wildlife sanctuaries. One of the main concerns that has been raised by the management of the wildlife sanctuaries in Thailand is the lack of basic information on wildlife (Tunhikorn, 1991). Such information is very important and should be the basis for sanctuary establishment and management as well as long term wildlife protection initiatives.

It is important to note that there is little if any difference between the practice of management within the national parks and wildlife sanctuaries (TDRI, 1987). Although the different protected areas have different mandates in legislation, the actual management practices are not distinctive. This supports the selection of two national park case studies for this project. Due to this similarity in management focus, a proposal has been made to combine the two divisions and reclassify the protected areas according to their characteristics (Kasetsart University, 1987). This may help alleviate some duplication of effort in enforcement, management, and research.
C. The Aquatic Environment in Thailand

Thailand's water resources are both abundant and scarce due to their distribution over space and time. Rainfall is excessive during a few months of monsoon and minimal to non-existent the rest of the year. The distribution of Thailand's water, in combination with the country's fast rate of economic development, has resulted in water shortages in many areas. At the same time, due to the wet monsoon season, certain areas may regularly deal with flood events.

Common development pressures on the water resource include demands for hydro-electricity, irrigation, aqua-culture, industry, and domestic use. There is no statement within Thailand's resource or environmental legislation, much less the protected area legislation, that addresses the issue of villager's rights to water. As the country's population is increasing both within and outside protected areas, water is becoming more scarce. As water use conflicts increase, water rights will become more critical.

Jurisdiction over the water resource in Thailand involves 31 government agencies and 17 committees, including both development and protection advocates (NESDB, 1982). Which agency has what mandate depends on where the water is located, the nature of the development or water use, and the nature of activities in the surrounding area. The need for reform in water planning and management has been recognized (NESDB, 1982). The proposed water legislation is limited to addressing water development and use and does not address the protection of water for environmental quality or ecosystem protection, objectives of the country's protected areas (Thailand, 1993).

Two Thai development agencies, the Electricity Generating Authority of Thailand (EGAT) and the Royal Irrigation Department (RID), have the most significant impact on water resources in the country. EGAT is the primary agency in charge of providing the country with reliable electricity, the assumed prerequisite for the country's economic and social development (EGAT, 1990). The RID provides water for irrigation through a variety of water development activities (dams, canals, dikes, etc.).
Within the national parks and wildlife sanctuaries, the aquatic environment is under the jurisdiction of the NPD and WCD, respectively. Although the legislation governing protected areas states that no developments shall occur that impede instream water flows, a variety of internal threats including the use of the water by villagers occur within the protected areas.

D. Doi Inthanon National Park

Doi Inthanon National Park (DINP) is located in the northern province of Chiang Mai (See Figure 2). The park is representative of the mountainous regions of Thailand that are generally found in both the north and north-western portions of the country. The highest point in Thailand, Doi Inthanon at 2565 m, is protected in the park. Doi Inthanon National Park is Thailand's sixth national park, designated in 1972, with a present area of approximately 482 square kilometers. It was also the first national park in Thailand to have a formal comprehensive park management plan.

To facilitate the assessment of land use activities, their impacts, and the methods used to protect the park's aquatic environment, one village within the park was chosen as a focus area. Khun Klang is located in the centre of the park, next to park headquarters (See Figure 3). A review of the activities in and around Khun Klang (See Figure 4) provides an example of the pressures that are felt by the aquatic environments within DINP.

1. Park Resources

Doi Inthanon National Park encompasses a large mountainous area that is generally south-east facing. The park includes the headwaters of the Mae Ping (Ping River), one of the main tributaries to the Chao Phraya that drains much of northern and central Thailand.

The mountain slopes have historically been covered by a variety of vegetation communities. The rocky soils of the lower slopes are dominated by open dry dipterocarp forests. Riparian areas at this elevation support lowland evergreen forests. With increasing elevation from the foothills, a larger portion of the forests are evergreen. Where cooler and more moist conditions persist, the landscape supports hill evergreen or "sub-montane" forest. This transition is usually very abrupt - around 900-1100 m. These broadleaf evergreen
I—

National park boundary
River
District boundary line
Area not national park land

Figure 2. Location of Doi Inthanon National Park in Thailand. Modified from Emphandhu (1992).

Forests grow from this zone to the summit of 2565 m. Doi Inthanon is over 300 m higher than any other peak in Thailand and so this area resembles a unique montane vegetation community. Native pine can also be found at elevations between the lower slope dipterocarp forest and the mid-slope evergreen forest.

Doi Inthanon National Park has the country's most documented bird species. Bird watching is the primary focus of many Thai and foreign travelers entering the park. The mammal fauna of the park are not as well known. Confirmed records have been made for 77 species (of which 31 are bats). It is believed that most of the large mammals have been extirpated from the park due to hunting pressures. There have been some reports of the asiatic black bear and the barking deer although the tiger is most likely gone. Some small
Figure 3. Doi Inthanon National Park. Please note the location of the park headquarters. Modified from Conservation Data Center (1989)

Primates and small mammals (flying squirrels, shrews, and voles) may also be seen within the park.

Due to the extreme changes in elevation that can be found within the park (over 2100 m), the climate ranges from tropical in the lowland foothills to sub-temperate in the higher areas of the park. The climate can be generally divided into three seasons: cold from November to February, hot from February to May, and rainy from May to October. The rainy season is influenced by the monsoons and is characterized by usually short but heavy incidents of rainfall.

Within DINP, there are a number of land uses that put pressure on the park's aquatic environments. These have been categorized into 5 different types of threats to the park environments: human encroachment, land use zoning, agriculture/aquaculture activities,
Figure 4. A photo of the land adjacent to Khun Klang, taken from the banks of the Mae Klang River which runs past the village.

welfare-promoting agencies (WPAs), and administrative issues. These issues and activities have resulted in the damming and diversion of water ways, the alteration of riparian zones, the removal of forest cover, and the cultivation of valleys and hillsides.

2. Human Encroachment

The park has over 4,000 villagers of three tribal origins, Karen, Hmong, and Thai, living either on private holdings in the park or on park land. Although this may seem to represent a severe example of human presence within a national park, over twenty percent of Thailand's 56,000 villages are located within protected areas (Gray and Graham, 1991), e.g. Doi-Suthep, Tarutao, Mu Ko Phi Phi, and Had Noparanatara National Parks. Encroachment from the cultivation activities of local villagers is the main management issue in the protected areas of Thailand (RFD, 1993a). This issue of encroachment in protected areas is driven by poverty, the ever-increasing need for land, and development processes (Malik, 1984).
Khun Klang is a Hmong village of 750 people of 141 families (DINP, 1992). It is the largest village in DINP. In total there are 31 villages, 780 families, and 4,464 villagers within the park. The Hmong villages in DINP have an average growth rate of 6.77%, with the Karen at 1.9% (Emphandhu, 1992). Given the current average growth rate of the Hmong in DINP, the village of Khun Klang will double to 1500 people in just over ten years.

Although this population trend is not found throughout the park, an average park growth rate of 3.2 % gives additional evidence of the significance of the hilltribe villagers within DINP. With such a growth rate, due in part to in-migration to the park, the nature preservation goals of DINP are in jeopardy.

The Karen villagers colonized northern Thailand about 200 years ago. The first Hmong villagers entered the area approximately one hundred years ago, while most entered the park area since the end of the second world war. The Karen tend to focus their activities in the areas of gentler topography and lower elevation (1000-1500 m) where they cultivate rice and other staple crops. The Hmong have historically used swidden agriculture to grow crops, and are generally found at higher elevations. The slash and burn type of agriculture results in the clearing of large areas to grow crops. Swidden agriculture was sustainable in South-east Asia for over 10,000 years, due to the low population densities. Higher population densities result in a smaller time span between burning and cultivation which tends to degrade the soil in these areas. Due to the outlawing of opium cultivation and recent efforts of the WPAs, significant swidden agriculture has all but subsided in DINP. Many of the Hmong, as well as some of the Karen have started to grow cash crops of cabbage, flowers, and temperate fruits.

The difference in general philosophy of the two main tribes of people within DINP must be noted (Mischung, 1986). The Hmong are more forward and aggressive in nature. They feel that the world is a place in which they can make use of the resources to their own gain. No consideration is given to the conservation of long-term sustainability of the environment. The Karen on the other hand have historically had an attitude of stewardship toward the land. The environment is their lifeblood and is recognized as very fragile. The
tendency to exploit the environment would jeopardize future generations. Until recently, the Karen within DINP have only grown subsistence crops and have had no desire for involvement in market economies and the cultivation of cash crops. This desire has shifted recently, however, as the cultivation of exotic species of fruits and flowers has been adopted by both the Karen and Hmong.

With the increasing population and move to cash crop cultivation, the pressures on the park by the villagers is intensifying. The relations between park officials and the villagers is of increasing concern to managers. The enforcement of protected area legislation has resulted in many arrests as well as a number of clashes between armed villagers and the protected area officials. In addition, forty protected area guards and officials have been killed by villagers in the protected areas of Thailand in the 20 years ending in 1986 (TDRI, 1987).

3. Land Zoning

In 1972, the RFD assessed the land use activities within the park. The location of villages and intensive cultivation were excluded from the park boundaries (See Figure 2). This was done, it seems, in an attempt to minimize the critical issue of villagers inhabiting park land - contrary to the National Parks Act. As many of these villages were and are scattered throughout the park, these private holdings are "locked" within the overall park boundaries. Although, the activities within these plots are not of legal concern to the DINP park officials, the impacts from these activities are impacting the park's environment (Chantalamonkon, 1989). Since this enactment, the agricultural activity within the area has encroached on the surrounding parkland.

The area within DINP has been assessed by the Thailand Department of Land Development (DLD). A land use zoning system was developed. The area in and around Khun Klang has been designated, for example, for upland crops and orchards (DLD, 1985).

It is surprising that the development of a land use zoning system has occurred, however, within the national park. The involvement of the NPD or DINP staff in the development of this system was not evident. Beyond the designation of some areas free from
cultivation, no efforts have been made to address the conflicting objectives of agricultural development and protection.

4. Agriculture/Aquaculture Activities

Four percent of the park area, or 2050 ha, is used for agricultural activity within DINP (DINP, 1990). A majority of this area (75%) is used for the cultivation of a variety of dry land crops while the remainder is used for rice cultivation. Both types of agricultural activity are making use of increasing amounts of pesticides and fertilizers to maintain or increase yields. The park officials voice concern over the high use of chemicals in the park. There have been complaints made by the lowland farmers, downstream from DINP, about both the low water levels and poor water quality, caused by the activities within the park. The sheriff of ChomTong, the district downstream from the park, also voiced concern over the impacts that the villages within DINP have on the water resource that is used in the lowland areas (Waravudputapong, 1993, Pers. com.). Various studies conducted by the hospital in Chom Tong have identified the presence of abnormal levels of pesticide and herbicide residues in some of the vegetables in the lowland areas. These results are discussed in Chapter 5.

The cultivation of cabbage, which has decreased in recent years due to the crash of the cabbage market, carries the most significant erosion problems of all crops in the park (Sutsat, 1993 and DINP, 1993) as the soil is left bare. With the decrease in cabbage cultivation, additional cash crops are now being cultivated within the park. These crops, including flowers, grapes, and a variety of temperate fruits, tend to require more water than the traditional rain-fed crops. This increased use of water in addition to increased siltation problems have caused water shortages both within and downstream of the park.

Land use policy of the NPD in DINP to address excessive cultivation in the park has come in direct conflict with the historic cultivation patterns of many of the villagers. This policy does not allow the fallowing of cropland and then re-cultivation. After cropland is left for a short period of time, it is included in the park's reforestation program. The villagers claim that the policy results in more intensive cultivation on remaining land, increasing
impacts to water quality. No consultation has occurred between the villagers and park officials to address this issue.

The cultivation of parkland has undergone significant change since the construction of an asphalt road in 1973 from the nearby town of Chom Tong up to the summit of Doi Inthanon. The cultivation of cash crops has become more widespread as the road links farmers to lowland markets where fertilizer and pesticides can be purchased and their crops can be sold.

In addition to the cultivation of crops, additional agriculture activity includes an experimental dairy farm, developed by Inthanon Royal Projects (IRP). No information was available on the dairy farm except that it was conducted on a small scale, with only 10 - 15 head of cattle.

Fish pond development programs have been initiated in DINP. There are approximately 25 ponds in the Khun Klang area of Doi Inthanon. Ten of these aquaculture ponds are used for research trials to determine the species of fish that can produce well in the relatively cold temperatures in the park. The remainder provide food for the villagers. It is a plan of the IRP to develop ponds for each of the families within the town of Khun Klang.

No studies have been conducted to define the impacts that aquaculture activities may have on the ecosystems within DINP, despite the increasing concern from villagers downstream from the park.

5. Welfare-promoting Agencies

A number of welfare-promoting agencies have become involved in DINP. Much of this activity has taken place since the construction of the asphalt road into the park. The Thai-Norway Highland Development project has been working towards the sustainable cultivation of cash crops to improve the livelihood of the hill tribe villagers. U.S. A.I.D. has also sponsored the Mae Chaem Watershed Development Project that attempts to improve the productivity of rice and other non-opium crops in the area. These programs focus mainly on single villages within the park (Emphandhu, 1992).
Inthanon Royal Projects is a welfare-promoting project supported by His Majesty King Bhumibol Adulyadej of Thailand. Inthanon Royal Projects has outposts in 15 villages in the park (Royal Projects, 1988) and their impact can be seen throughout the park. A central IRP station is located in Khun Klang and is so examined in more detail here.

The objectives of the IRP are 1) eradicating the cultivation of the opium poppy, 2) providing a permanent productive system of agriculture, 3) improving the standard of living of the park's population, and 4) maintaining or improving the quality of the environment. IRP is the largest program in the system of royal projects scattered throughout Thailand's northern region.

Inthanon Royal Projects started work in DINP in the early 1980s. Initially, a weir (see Figure 5) and canal system were constructed on the hillside above Khun Klang. This facilitates the increased cultivation of crops in the valley surrounding the village. This irrigation system is one of seven systems that were constructed in DINP in 1983 to irrigate over 180 ha.

One focus of the IRP is research in the cultivation of exotic crops such as strawberries, apples, pomegranates, and flowers. Their extension activities support farmers throughout the park. Research findings from the station in DINP are also used in other royal projects areas in northern Thailand.

The use of fertilizers and pesticides within the royal project areas is under the supervision of the project personnel. Research findings and general agricultural expertise guide the farmers in their use of the chemicals. Outside the IRP stations, however, there is no regulation of either fertilizer or pesticide use. The number of greenhouses constructed is also unregulated (See Figure 6). Neither IRP or the park officials have made any efforts to determine the impacts of increased cultivation and development on the natural environment or have taken action to curtail this widespread change in DINP. Officials in the Royal Projects office in neighboring Chiang Mai did, however, voice concern over the unregulated widespread extension of activities initiated by IRP (Sutsat, 1993, Pers. com.). This concern
was supported, however, by stressing that this issue was under the jurisdiction of the DINP managers.

There are definite advantages to the development efforts of the royal projects in DINP. Their focus on intensive use of land removes the need to continue swidden agriculture techniques. The extension programs of the IRP include the provision of expertise as well as seed and funding to develop greenhouses and suitable cultivation spots. Terracing and drip irrigation systems are techniques used more and more in the Khun Klang area due to IRP influence. These techniques help to decrease erosion and loss of valuable topsoil. They also help to conserve water and decrease the likelihood of sedimentation in downstream aquatic environments.

Increased knowledge gained from research activities continues to enable villagers to make more money off smaller plots of land. The specific impacts of these activities on the
Figure 6. Photo of the upper Mae Klang valley taken from just north of Khun Klang. Please note the many greenhouses. This view is typical of many of the valleys in the park.

water resource within the parks and in downstream areas is not known. Preliminary monitoring, however, points to the need for further assessment and control over activities within the park (discussed further in Chapter 5).

6. Administrative Issues

Many of the issues and land use activities impacting park environments are caused or allowed to continue due to administrative deficiencies in DINP. Lack of adequate personnel and funding are closely linked to the lack of enforcement, e.g., although regulations prohibit hunting, cultivation, waterway alteration, or logging, they continue to occur. These
administrative issues factor into many of the management concerns in the protected areas of Thailand (Kasetsart University, 1987).

Although strengthening protected area legislation has been proposed to address management concerns, it is an increase in enforcement of present regulations that is necessary. The present lack of enforcement is due in part to the lack of funding and the remoteness of much of the illegal activity (Kasetsart University, 1987).

E. Khao Sam Roi Yot National Park

Khao Sam Roi Yot National Park (KSRYP) is located in the Pranburi and Kuiburi provinces, south west of Bangkok (Figure 7). The park was established in 1966 as the fourth park in Thailand’s national parks system. The conservation value of the park is significant as

![Figure 7. The location of Khao Sam Roi Yot in Thailand. Modified from Conservation Data Center (1992).](image)
it is the only national park in Thailand to protect lowland freshwater marsh habitat. In addition, the types of environments within the park are uniquely diverse.

The physical nature and geographic position make the park representative of the coastal environments of Thailand. The pressures that the park faces are also representative of the general pressures that comparable areas within the protected areas system in Thailand are facing. These include historic land rights of indigenous peoples, commercial development (shrimp farming), agriculture pressures (rice and fruit cultivation and grazing), and impacts from upland water developments (an irrigation dam).

The park was originally designated to protect the spectacular wooded limestone mountains and coastal scenery. It was further expanded in 1982 to include a significant area of the inland freshwater marsh (See Figure 8). The official size of the park is 98 square kilometers, although this is under dispute as its boundaries have never been well marked. If measured from some of the maps, the park appears to be as large as 162 square kilometers (Conservation Data Center, 1992).

Khao Sam Roi Yot National Park is located in one of the driest areas in Thailand with an average annual temperature of 27 degrees Celsius. A majority of the 1000 mm average annual rainfall falls during the south-west monsoon (May to October).

1. Park Resources

The environments or habitats within KSRYNP are quite diverse. These environments include:

1. Deciduous forest, secondary growth
2. Scrub, open areas, and cultivation
3. Paddies
4. Freshwater marshland
5. Mud flats
6. Brackish waters, prawn ponds
7. Mangroves
8. Sand beaches
9. Offshore islands
10. Open sea
The wetland or aquatic environments are of interest to this study. The freshwater marsh in KSRYNP is the largest of its kind in the country and is prime habitat for many species of birds and amphibians. Mud flats, brackish waters, and mangrove areas also play significant roles in the park as they provide additional habitat for many species of birds and small mammals.

The park still supports small populations of larger mammals due mainly to the inaccessible limestone mountains in the park's core. These mammals include leopards (*Panthera pardus*), serow (a deer like animal, *Capricornis sumatraensis*), and three or four species of primates. Due to the variety of habitats within the park, including wetland areas,
the park also supports many species of birds (296 species recorded to date). At least one hundred and fifty of these species are migratory.

The freshwater marsh is located on the west side of the limestone mountains. The mud flats, brackish water (and prawn ponds), and mangrove areas are located mainly east of the mountains near the coast. There is a small river or canal that drains the freshwater marsh west to the Gulf of Thailand. Historically, the canal and its path through the limestone ridges limited the infiltration of brackish water into the freshwater marshland. The freshwater marsh is fed by springs within the limestone mountains and, during the wet seasons, through runoff from the lowland areas west of the park. Please refer to Figure 9.

There are a number of land uses that impact the aquatic environment within KSRYNP. These have been categorized into 4 different types of threats to the park environment: human encroachment, water developments to facilitate cultivation, aquaculture activities, and domestic/industrial activities (Jintanugool and Round, 1989 and Bunpapong, 1993). Many of these land use activities occur both adjacent to and within the park boundaries. This is due in part to the inadequate demarcation of park boundaries and lack of park regulation enforcement. Along with the pressures on the park, the efforts of conservation groups are increasing the pressure on the Thai government to ensure the improved protection of KSRYNP (e.g. Usher, 1989).

2. Human Encroachments

The instances of human encroachment within KSRYNP involve both agriculture and aquaculture activities (both addressed in more detail below). Much of the encroachment is allowed due to improper demarcation of boundaries. In addition, many of the villagers within and adjacent to the park claim historic right and ownership to the land. Many of these plots of land have been sold to both local and out-of-town prospective shrimp farmers and business interests. It is uncertain whether these property claims are true or false. The policy of the local park management is to shy away from the investigation of these claims. This may be due in part to the shooting death of two wardens and threats to the upper management of the park during the last few years (1991-1993).
3. Water Developments to Facilitate Cultivation

The cultivation of crops takes place in much of the area surrounding KSRYNP. The cultivation also encroaches on parkland. Historically, the lowland areas within and adjacent to the park were not suitable for extensive agriculture activity due to the nature of the soils as
well as the relative dryness of the climate. To remedy this situation, the Pranburi Irrigation Dam was built in 1974. The dam, located west of the park in the Tenessarin Mountain range, is linked to an extensive concrete canal system (over 280 kilometers of primary and tertiary canals) that facilitates the irrigation of the lowland areas to the west of the park. More intensive cultivation has resulted in this area, all of which drains through the freshwater marsh in the park.

The lowlands west of the park are used in-part for rice cultivation. Due to the relative dryness of the area and in spite of the irrigation canal system, rice cultivation is limited to one crop of wet season rice (May - October). Coconuts, sugar cane, pineapple, and other fruits are also grown in the area.

Due to increased cultivation, the infiltration of residues from pesticides and herbicides into the marsh has become a park management issue. The water quality of the marsh was sampled, and although more monitoring is necessary to support the findings, pesticide and fertilizer residues were noted (Charoensiri, 1993, Pers. com.).

Cattle are also raised by many of the villagers that live within and adjacent to the park. These cattle are openly grazed on the dry rice paddies and mud flats within and adjacent to the park. Burning of the marsh edges (during the dry season) also takes place to increase forage for cattle. Due to boundary ambiguity, the extent of grazing and associated activities in the park is unknown and unregulated. The impacts of these activities (e.g. coliform levels, siltation, physical alteration of the environment) on aquatic environments within the park are unknown, but possibly significant.

4. Aquaculture Activities

The marshland and mud flats of KSRYNP have been historically used by local villagers. The scale of this activity was small, using small ponds and natural shrimp species. Over the last ten years, more intensive shrimp farming activities (See Figure 10) have caused land prices to rise which has lead to land speculation. Outside political and business interests have bought up property both within and adjacent to the park, areas in which the rightful
Figure 10. The extent of shrimp farming within and adjacent to KSRYNP. The photo was taken looking north from near the park headquarters. Due to boundary ambiguity, the extent of encroachment is unknown. Please note Khao Daeng, the canal in the bottom right hand corner of the photo.

Ownership to land is uncertain.

Intensive shrimp farming operations start with the construction of large ponds, 2-3 m deep, using heavy machinery. These ponds, with the help of large water pumps and other machinery (See Figure 11), are then used to grow tiger prawns, an exotic species that brings a good price. Large quantities of shrimp food and large amounts of shrimp waste causes pollution problems in the ponds and the surrounding aquatic environments. Although the shrimp farming business in and around KSRYNP peaked in 1992, there is still increasing pressure to develop more of the lowland area within the park.

The Khao Daeng canal (Figure 10) is the source of salt water for many of the shrimp ponds. To facilitate development of shrimp ponds, the canal has been dredged by the local irrigation department. This has caused the further infiltration of brackish water into the freshwater marsh. Such dredging, if it continues, could significantly impact the plants and
Figure 11. An example of the machinery used to support the intensive culture of tiger prawns in and adjacent to KSRYNP.

animals that rely on the marsh’s freshwater environment.

The construction and subsequent abandonment of shrimp ponds results in a drastic change in the topography of areas that used to be mud flats and marshland. Heavy machinery is used to construct these ponds which are abandoned once the pollution in the ponds is too great to warrant further prawn farming. The impacts of this activity on tidal flow patterns is
not known, although it is expected to cause significant change to the water balance in these wetland areas (Jintanugool and Round, 1989).

5. Domestic/Industrial Activities

A pineapple canning factory is located near the town of Rai Mai, west of the park. There has been some speculation as to the impacts that the factory is having on the nearby water source and in turn on the freshwater marsh and KSRYNP. Assessment by park officials in 1992 showed the water flowing from the factory to have abnormal color and smell. There was no subsequent confirmation of any polluting activity. There is concern over the possible impacts that the factory can have on the water system within KSRYNP and the wildlife within the marsh (Charoensiri, 1993, Pers. com.).

The park official also voiced concern over the lack of adequate garbage and human waste disposal in the villages around the park. As the populations continue to grow both within and adjacent to the park, the impacts that this has on the park and its water resources will also grow unless efforts are made to ensure the protection of the aquatic environment. In addition, the impacts of visitors must be addressed. Attendance has grown, for instance, in the national parks of Thailand from 1.9 million in 1980 to over 9.4 million in 1990 (Suckasaem, 1991). Adequate facilities for visitors are necessary to minimize their negative impact on the park’s aquatic environments.

Both within DINP and KSRYNP, there are a range of land use activities that are impacting the parks’ aquatic environments. Very little assessment of the extent of impacts has been made, although initial results shows significant change. The impacts to the aquatic environment within these parks needs to be assessed, and efforts taken to protect the aquatic environment from significant human induced change.
CHAPTER III - CASE STUDY DESCRIPTIONS - BRITISH COLUMBIA

A. Introduction to British Columbia

British Columbia (B.C.) is the western maritime province in Canada (See Figure 12). The province has a very diverse topography (mountains, valleys, plateaus, fjords, and coastline). The natural environments (flora and fauna) within the province are also diverse. The various environments within the province grow generally drier from west to east. The climate as well as the flora and fauna change with increasing continental influence.

Figure 12. The regional location of B.C. in North America. Modified from C.I.A. (1987).
B. Protected Areas in British Columbia

The national and provincial parks systems in B.C. work towards the goal of protecting the province’s representative natural environments. Additional areas that protect the natural environment in B.C. include 1) national wildlife areas (Canadian Wildlife Service), 2) provincial wildlife areas (B.C. Ministry of Environment, Lands, and Parks), 3) provincial recreation areas (B.C. Ministry of Environment, Lands, and Parks), 4) Ministry of Forests wilderness areas (B.C. Ministry of Forests), and 5) ecological reserves (B.C. Parks).

In support of the protected area legislation, policy has been developed for both the provincial and national protected area systems. Management plans are also developed to support management in the individual protected areas. Management plans and protected area policy aid planners and managers in fulfilling their mandate, that of the preservation of the natural environment and the provision of recreational opportunities.

1. National Parks

The national parks in Canada started in 1885 with the designation of a small area around the Sulphur Mountain hot springs in the Rocky Mountains. That area was later enlarged and became known as Banff National Park (BNP). Since that time, the national parks system has grown significantly to 36 national parks in 1995 (Parks Canada, 1995a).

The National Parks Act (Canada, 1985) mandates the control over the parks to the Parks Department, now in the Ministry of Canadian Heritage. For purposes of this report, this governing agency will be addressed as Parks Canada. Extensive policy development has also occurred to provide further guidance in both the national parks and the other protected areas managed by Parks Canada (Parks Canada, 1979).

The National Parks of Canada are hereby dedicated to the people of Canada for their benefit, education, and employment, subject to this Act and the regulations, and the National Parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations. (National Parks Act, Sec. 4)
In addition, "the maintenance of ecological integrity through the protection of natural resources shall be the first priority when considering park zoning and visitor use in a management plan" (National Parks Act, Sec 5.1.2).

2. Provincial Parks

The provincial parks in B.C. were started with the establishment of Strathcona Provincial Park in central Vancouver Island in 1911. Since that time, over 407 parks have been established and more are proposed (B.C. Parks, 1995). Presently, the provincial government is in an active program to significantly increase the areas protected in this system to 12% of the land base (from approximately 7% of the province's land base).

The Park Act (B.C., 1979a) mandates B.C. Parks, now in the Ministry of Environment, Lands, and Parks, to manage and protect the environments within the provincial parks. To further guide park planners and managers, a policy document for the protected area system was developed (B.C. Parks, 1990). The management of the provincial parks is dedicated to

"conserving and managing for future generations a wide variety of outstanding park lands which represent the best natural recreational features and diverse wilderness environments of the province" and "providing province-wide opportunities for a diversity of high quality and safe outdoor recreation, that is compatible with conserving the natural environment" (B.C. Parks, 1990, p.2).

C. The Aquatic Environment in British Columbia

With an increasing population and increased demands on the natural environment, water developments and other land use activities are placing increased pressure on the aquatic environment in British Columbia. In British Columbia these threats include timber harvesting, ranching and grazing, fishing and hunting, residential/commercial development, and mineral and hydro-electric development.

Much of the land and water of British Columbia is under crown (government) jurisdiction. The distribution of the rights is vaguely split between the federal and provincial governments. A majority of the management and protection of the water resource was given to the provincial governments. The federal government has jurisdiction over specific issues
or portions of water including navigable waters, marine environments, and water and habitat issues involving anadromous fish. The division of powers over the management and protection of the water resource has lead to conflict over who has jurisdiction, the duplication of management and monitoring efforts, and in some cases the inadequate and un-sustainable management and protection of the aquatic environment (Round Table, 1991a).

Both governments have explicitly stated that due to jurisdicitional uncertainty, it is important to develop new federal/provincial relationships in the management of water (Mitchell et al., 1994 and Environment Canada, 1987). Some efforts have been made to develop cost-sharing agreements to join forces in the management and the monitoring of aquatic environment and fisheries.

In general, the jurisdiction over the water resource is under the environment ministries of both provincial and federal governments. It is then licensed out, using various licensing or permitting procedures to interested users, e.g. domestic, hydro-electric, and mining activities (B.C., 1979b).

The original B.C. Water Act was passed in 1959 to provide water in support of mineral exploration and agricultural activities. Much has changed since that time and the values and pressures that are placed on the aquatic environment have also changed. The Act does not recognize in-stream uses including fishing, recreation, ecosystem protection, spiritual values etc. (Paisley and Solin, 1993; CORE, 1993; and B.C., 1991c). Presently, no license can be obtained that proposes an in-stream use of the water. A license can only be granted if actual power over the water, through construction or diversion, is exercised. Therefore, water can't be licensed or allocated for the downstream protection of a protected area.

A recent provincial initiative to review water legislation has recognized the need for maintaining instream flows and other natural aquatic environment characteristics (B.C., 1991c). Significant changes to water legislation and policy have not occurred. Although the improvement of the water licensing system in B.C. may not directly impact aquatic environment inside protected areas, the inclusion of environmental health and ecosystem integrity as legitimate water uses will help address external threats to protected areas.
Within the protected areas in B.C., the importance of water to the maintenance of the protected area has not been fully recognized. Evidence of this can be seen in the lack of policy that deals with water issues. In addition, the past practices of protected area boundary selection (e.g. in Strathcona Provincial Park) gives evidence of the lack of consideration given to aquatic environments. Because of this deficiency, the aquatic resources appear to be the most affected of all protected area resources (Parks Canada, 1991).

D. Banff National Park

Banff National Park represents the birthplace of the national parks system in Canada. The thermal springs at the Cave and Basin on Sulphur Mountain played an important role in the original establishment of the 26 square kilometre park in 1885. The park is now 6,641 square kilometres and is located 120 km east of Calgary, Alberta, on the B.C./Alberta border (See Figure 13). The park is bordered by Jasper National Park in the North and Yoho and Kootenay National Parks on the west. Together, the four national parks make up the protected area block known as the Rocky Mountain World Heritage Site. Additional lands around the park borders are generally crown lands administered by the respective provincial forest service and parks offices.

Although BNP is located in Alberta, the park provides an example of the water resource issues and protection methods in the Canadian national parks, including B.C. Land and water development activities as well as visitor use and facility development are the main categories of threats to BNP's aquatic environment. Despite extensive development and visitor use of its central corridor, the park has extensive areas of wilderness that have withstood significantly less visitor use. In all areas, the park is devoted to the "judicious stewardship" of the parks resources (Parks Canada, 1988).

1. Park Resources

The Canadian national parks system was developed to protect representative examples of a wide variety of environments and ecosystems throughout the country (39 natural regions). Banff National Park protects environments representative of the Main and Front Ranges of the Rocky Mountain natural region (Parks Canada, 1988). Both riverine eroded
V-shaped valleys and glacier eroded U-shaped valleys can be found in the park.

The vegetation communities in BNP are representative of the Main and Front Ranges and vary with elevation and climatic/micro-climatic conditions. The main eco-regions in the park include alpine tundra, sub-alpine forests, and montane forests. The sub-alpine forests are characterized mainly by sub-alpine fir and Engelmann spruce while the montane forests are characterized by white spruce, Douglas-fir, mixed forests, and grasslands. Due to past forest fires, significant stands of lodgepole pine can be found in both the sub-alpine and montane forest zones, many of which are now mature.

The wildlife present in BNP is representative of the eastern portion of the Rocky Mountain region. Many large species such as grizzly bear, mountain goat, bighorn sheep, mountain caribou, Rocky Mountain elk, cougar, and wolves can be found in the park. This
is due in part to the many large tracts of land within the park that have minimal and transitory human use.

The aquatic environments within BNP include a variety of streams and rivers as well as lake and wetland environments. The park also protects the headwaters of three main river systems - the Bow, Red Deer, and North Saskatchewan - that drain eastward out of the park (See Figure 14).

The park protects a number of historical and archeological resources that include both

Figure 14. The main aquatic environments within Banff National Park. Modified from Parks Canada (1988).
prehistoric use and more recent development that has taken place since the early 1880s. Both the Trans Canada Highway and the Canadian Pacific Railway go directly through the center of the park.

BNP has two townsites within its boundaries. Banff Town is an Alberta municipality, and Lake Louise townsite is run by Parks Canada. The townsites are the main areas of focus for visitor use and accommodation within the park. These areas have, in part, given BNP the name as a tourist destination. In recent years, there has been increasing concern over the impact that these centers have on the natural environments within the park.

A range of land use activities impact the aquatic environments within BNP. These land use activities have been categorized into 4 sources of threats to the park environments: visitor use impacts, townsite/visitor facility development, hydro-electric development, and administrative issues (See Figure 15). Although the park protects mountainous height of land, these threats involve threats both internal and external to the park.

2. Visitor Use

Eight and a half million people travel into Banff each year (BNP, 1995). Over half of these people pass through the park, while the remainder (approximately 3.3 million people in 1988) stop for a few hours to days or weeks (Parks Canada, 1988). Most visitor use takes place in the summer and winter months. In both seasons, there is a wide range of both backcountry and frontcountry visitor activities within the park. A consistent increase in visitor use is expected as the Canadian national park visitor levels have grown from 21.5 million visitors in 1992 to 25.5 million in 1993 (Parks Canada, 1995b).

As a majority of the visitor use and facilities are located in the Banff and Lake Louise townsites and along the Trans Canada and the Icefields Parkways, this area withstands heavy use. Most of the pressures on the aquatic environment are, therefore, found in these areas.

The pressures and impacts of townsites development on the aquatic environment in the park is addressed below. Additional developments along the travel corridors in the park range from the development of hotels (e.g. the Rimrock Hotel) to the picnic or sightseeing stops along the main roadways. Both can have significant impacts on the aquatic
The development of hotels, housing, and other visitor structures is regulated in Banff and Lake Louise townsites by the village boundaries. In the remainder of the park, there is concern over the development that is taking place. A moratorium was placed on all development in the Bow Valley in 1992 until an assessment of the current impacts of development on the natural environment within the valley can be conducted.

Although the visitor numbers and use of the frontcountry areas are increasing, the overnight use of the backcountry has declined an average of 4.6% per year since 1982 (Parks Canada, 1988). Presently 11,500 visitors overnight in the backcountry every year, while a large number of visitors make day use of the backcountry. This use is very unevenly distributed in the park. Even though the backcountry areas cover 93% of the park land, the visitor use of these areas tends to be to limited destinations on a limited number of weekends.
A variety of accommodations is available for backcountry hikers and trail riders: three trail shelters, seven alpine huts, four commercial lodges, and cabins. There are also a number of designated group camps and campgrounds in backcountry areas. Random camping is permitted in other areas.

The areas that tend to concentrate visitor use are the locations where significant impacts to the aquatic environment are more likely. There is some concern over the disposal of human waste at both backcountry and frontcountry lodges within the park as well as the other camping facilities (Parks Canada, 1988).

Some of the alpine huts have septic tank systems to address these issues. The solid wastes are transported, when required, to either the Banff or Lake Louise treatment plants. An alternative in lower use areas is the adequate location of the toilet facilities to minimize the impact or ensure no impact on the local aquatic environment.

Due in part to increased visitor use, the presence of *Giardia* is a concern in some backcountry and frontcountry areas. *Giardia* is a protozoan that can survive in waters with high levels of coliform. The protozoan can cause a very harsh illness to those who drink or use contaminated water. Boiling water that is used in all backcountry areas is recommended to visitors. The presence of *Giardia* in the water could be due to a variety of causes including the inadequate location of toilet facilities or the presence of increasing numbers of large mammals along the water courses. Efforts are being made to deal with situations where the location of facilities may be the cause (Pacas, 1993, Pers. com.).

3. Townsite/Visitor Facility Development

The town of Banff presently houses 7000 permanent residents with peak visitor levels of 25,000 people (Town of Banff, 1993). Future peak visitor levels are expected to reach over 42,000 people following the development of all town land.

The townsite of Banff became an Alberta municipality in 1990. At that time, town boundaries were designated by BNP. All the development activities of the town must be contained within this area. It is important to note, that although the municipality operates as
an entity, Parks Canada sits on the town council and has the final word on the approval of many developments within the town, e.g., subdivision construction.

The development that has taken place in Banff is placing increasing pressures on surrounding terrestrial and aquatic environments. The increasing use of Banff as a place of residence and a tourist destination has placed great pressure on the water resource, specifically the Bow River. A waste treatment plant was constructed in 1989 that has significantly lessened the impact that the town has on the water quality of the Bow River. The waste treatment plant includes coarse screens, comminution, primary clarification, activated sludge aeration, secondary clarification, ultraviolet disinfection, sludge thickening, thermophilic sludge digestion, sludge dewatering, and composting (Block et al., 1993).

The plant is owned by the municipality of Banff but privately run. The operators conduct regular monitoring of inputs and outputs and report to the municipality. Developments outside yet near the town of Banff also make use of the waste treatment plants. This use has placed unplanned pressure on the waste treatment plant. With increased development within and outside of the town of Banff, there is concern over the ability of the plant to treat all the waste.

The storm drains within the town of Banff have also been an area of concern to the BNP management (Tessolini, 1994, Pers. com.). Presently, the water that goes through the town's storm drains goes through an overground filtration system prior to going into the Bow River (See Figures 15 and 16). With an increase in development, the impact of these storm drains is a concern as the municipality does not treat the runoff. As the development in Banff causes increased development and construction of non-permeable surfaces, the presence of drainage bylaws may be necessary to address the concern over pollution from the storm drains (Leighton, 1994, Pers. com.).

The other main centre for visitor use in BNP is Lake Louise. As in Banff, boundaries have also been used to limit townsite growth. Lake Louise is significantly smaller than Banff with a current population of 1500. The increased development in Lake Louise has placed increased pressures on the aquatic environment. In the past, the planning and management of
Lake Louise did not significantly address the issue of water use or waste management (e.g. IBI Group, 1979). With increasing visitor use and development, water use and waste water treatment have become critical issues in the town.

The Lake Louise waste treatment plant was developed in 1983 in response to increased pollution of the Bow River and pressure from a multitude of downstream interests, including park users. Since that time, the plant has been used to support the increasing use and development in the Lake Louise area. The waste treatment plant is a second level treatment plant consisting of comminution, extended aeration in oxidation ditch basins, secondary clarification, chlorine disinfection, sludge digestion, and sludge storage in a large lagoon (Block et al., 1993). Operations of the plant during peak visitor use in 1994 were conducted at the designed maximum volume levels for the plant (Fitzpatrick, 1994, Pers. com.). As more development has been proposed for the Lake Louise area, the ability of the plant to process the corresponding increases in waste is uncertain.

Figure 16. Bow Falls, on the Bow River within the town of Banff.
Additional development in BNP focuses on the construction of visitor facilities. The park, for instance, has three commercial ski hill operations within the park. With such developments, the concentration of visitor use results in a concentration of pressure on the aquatic environment as well.

Sunshine Mountain, one of these ski hills, has its own on site aeration plant. The effluent from this plant is either ground injected or deposited into Sunshine Creek or ground injected. The solids are transported to the Banff waster treatment plant. The operation of the plant is conducted by the ski hill to the standards set out by BNP. Rigorous monitoring of the compliance of all the ski hills to environmental impact regulations must be maintained.

The impacts from the travel corridors on the park's aquatic environments is a concern to park managers (Parks Canada, 1988). The BNP Management Plan required the development of a contingency plan to deal with the possibility of chemical spills along the highway or the CPR rail line (See Figure 17). These corridors are used by trains and trucks that transport various chemicals and other materials that could prove harmful to the environment and visitors within BNP. The proposed plan is to address means to protect the environment by rapid notification and action following a spill.

In addition to the potential impact of chemical spills, the impacts of the salting of the roads on vegetation has been identified as a management issue. The impacts of salting on the aquatic environment in these areas is uncertain and should be examined.

4. Hydro-electric Development

There are a number of hydro-electric development projects in and around BNP. TransAlta is a regional electricity generating company that has present licenses to operate a number of projects within BNP: a dam on Minnewanka Lake (the Cascade operation) and the regulation of the Spray River.

A dam was constructed by Parks Canada to enlarge Minnewanka Lake in 1912. This facility was purchased by TransAlta Utilities in 1940. An additional dam, which incorporated the Cascade watershed area as well as the regular drainages in to Lake Minnewanka was constructed in 1941. The Cascade Dam stops the flow of the Minnewanka
Figure 17. The Bow Valley in Banff National Park just north of Banff town. Please note the travel corridors.

and Cascade watersheds as well as the majority of the Adjacent Ghost watershed (outside of BNP) that has been diverted into Minnewanka system (See Figure 15). This dam results in significantly lower flows in the summer months with increased flows in the winter months. For a few months in the summer, the Cascade river below the dam is dry as Minnewanka Lake is filled. During the operation of the Cascade dam for electricity generation, the primary flow of the systems is diverted via a canal to the Cascade plant. The water then re-enters the Cascade River just prior to its confluence with the Bow River. The federal water license that is held by TransAlta for their Cascade operations, was recently (1994) renewed for an additional fifty years.

There is concern over the impacts of the Cascade operations on the park's aquatic environments. Portions of the river below the dam can't support fish or other aquatic organisms due to the lack of water at certain times of the year. Changes to this operating
procedure are being negotiated between TransAlta and BNP to ensure flows in this reach of the Cascade during the summer months (Drury, 1994, Pers. com.). The aquatic communities in the river below the outflow from the Cascade plant also withstand abnormal flow conditions as the river withstands sharp increases in flow on a daily basis during the fall and winter months. A study is presently being conducted by a graduate student at the University of Montana that is looking at the impact of these flushing events on the benthic organisms in this reach of the Cascade River. No preliminary results are available.

The two main fish species in the lake are the Rocky Mountain Whitefish and Lake Trout. A study conducted after the construction of the second dam in 1941 found that there was a decrease in fish spawning on the banks of the lake (Rawson, 1942). This study also stated that, the lake would recover in 2-3 years if the water levels did not fluctuate significantly. Due to the commercial nature of the operation this has not occurred. Subsequent studies found significant decreases in the bottom organisms that live in the littoral zone although no changes could be verified in the fish populations (Rawson, 1945).

Research is now being conducted by a joint BNP TransAlta team on the impacts of fluctuating water levels on fish spawning (1994-1995). Results are not available as the research has not been concluded.

The Spray Operations of TransAlta impact the aquatic environment within the Spray River. A dam (Canyon Dam) is located just outside the park's south east corner. The development is outside of the park, and although it impacts the aquatic environment within the park, park managers have no legal standing in defining operating procedures. The license obtained by TransAlta from the Alberta government is in perpetuity, unless the requirements in the license are not fulfilled.

The Canyon Dam diverts and regulates the flow of the Spray River. Concern has been voiced by both BNP and TransAlta over the low temperature of the water released by the dam into the Spray River (MacFadden, 1994, Pers. com. and Cairns, 1994, Pers. com.). The water released from the dam is said to be significantly colder than pre-development
natural flows. No work or research has yet been conducted to address this concern (Cairns, 1993, Pers. com. and Drury, 1993, Pers. com.).

5. Administrative Issues

With increasing use of and pressures on the park, more effort must be made to manage and protect its environments. The opposite is actually happening. The 1995 federal budget in Canada, February 27th, 1995, cut the Parks Canada budget by 25% ($96 million) and 600-800 jobs will be lost over the next three years. The impact of these cuts on the protection of environments in BNP is uncertain. The cuts are due in part to Canada's economic situation. It must also be understood that with an increasing number of parks and their increased use, more management effort is needed to protect these areas. A dilemma ensues.

The land use activities and resulting pressures on the aquatic environments within BNP are quite diverse, from hydro-electric development both within and adjacent to the park to a range of visitor use and facilities. As the threats to the park's environments are quite diverse, a variety of methods to address these threats are required. The integrity of the park depends on it.

E. Strathcona Provincial Park

Strathcona Provincial Park (SPP), established in 1911, is B.C.'s first and Vancouver Island's largest provincial park. The park protects portions of the main mountain ranges and watersheds in the centre of Vancouver Island, off B.C.'s southern coast (See Figure 18). It is the only park that protects significant wilderness on Vancouver Island and so has an important role to play in the protection of natural ecosystems. Eighty percent of the park's approximately 220,000 hectares have been designated for wilderness conservation, where natural processes are to be permitted to continue without human interference.

As SPP was B.C.'s first provincial park, it provides a useful look into the management and protection efforts of B.C. Parks. The park protects both lake and river environments as well as mountainous wilderness areas, characteristics representative of many of the provincial parks in British Columbia. The park also provides prime opportunities for
both front and backcountry recreation and so provides an examination into the impacts and protection efforts associated with high use.

The planning and management of the park has gone through many changes in the last ten years. There was a move in the mid 1980s to remove over 30,000 ha from the park without public consultation. Public outcry stopped the process. The Strathcona Park
Advisory Committee was established to examine the situation and report to the government (B.C. Parks). The resulting report, "Restoring the Balance", made recommendations to B.C. Parks, many of which were addressed in the recent master plan for the park (B.C. Parks, 1993).

1. Park Resources

Strathcona Provincial Park protects the backbone of the Vancouver Island Mountain Range and four of the five biogeoclimatic zones are located within the park. Areas of interest in the park include the Golden Hinde (the highest peak on Vancouver Island at 2228 m), Della Falls (Canada's highest water fall), Comox Glacier, and Moyeha River. The Moyeha River valley is completely protected from its alpine headwaters to the ocean. The watershed drain both east and west of the parks central mountain range (See Figure 19)

The park is habitat for a variety of large bird and mammal species. These include cougar, elk, wolf, deer, black bear, migrating trumpeter swans, and the Vancouver Island marmot. The park is also habitat for a wide range of fish species including five species of salmon; pink, chum, coho, sockeye, and chinook; three species of trout and char; rainbow trout, cutthroat trout, and Dolly Varden; and two non-game species; sculpin and stickleback. Very little is known about the presence of other species of animals, e.g. small mammals, amphibians, reptiles, etc.

The resources within SPP have been impacted by various land use activities throughout the park's long history. A number of the valleys within the park have been logged in the past. Forest harvesting activities, no longer permitted in the park, continue to take place in the areas adjacent to the park. Although mining is no longer permitted in the provincial parks of B.C., historic mineral claims are still found within SPP. The management of SPP are attempting to negotiate with present holders of mineral claims and there is one active claim at the southern end of Buttle Lake operated by Westmin Resources.

This mine is operating in an administratively separate "Class B" park, Strathcona-Westmin Provincial Park (SWPP), that is in the middle of SPP (See Figure 18). Although
this area is technically a separate park, it is also administered by B.C. Parks. Both SPP and SWPP will be considered as one entity for the remainder of this paper.

The present threats to the park's aquatic environment can be categorized into 4 management issues or land uses: visitor use and facility development, hydro-electric
development, mining, and administrative issues. Although the park protects mainly mountainous height of land, both internal and external activities are impacting the park's resources.

2. Visitor Use and Facility Development

The recreational opportunities within SPP are quite wide ranging. The highway corridor in the centre of the park sustains a majority of the park use with campgrounds, hiking trails and swimming and boating opportunities. There are also many opportunities involving both summer and winter backcountry excursions. The park has approximately 16,000 day use visitors a year with over 4,000 parties registering at the campgrounds in August, the busiest month (B.C. Parks, 1993). The visitor use of SPP is expected to rise as visitor use in B.C. provincial parks (over 25.5 million campground, "boat in", and day use visitors in 1993) increased by over 10% from 1992 (B.C. Parks, 1994).

The backcountry use is concentrated in a number of areas within the park. The first is the Forbidden Plateau. This region is accessible west by road from Courtney, while the other backcountry areas are accessible west from Campbell River (See Figure 18). Certain trails in the plateau area undergo high use (B.C. Parks, 1993). There is concern over the amount of use and the impacts of this activity on the environment, including the water quality of the lakes and streams. Monitoring of some of the lakes (Battleship, Hairtrigger, and Kwai) has shown high levels of coliform and BOD. The coliform levels are more than likely due to heavy use by visitors. Inputs of organic matter due to vegetation degradation in high use areas have resulted in the high BOD levels. The second high use backcountry area is the Bedwell and Creme Lakes area. Although the lakes in this area are very deep, the same water quality concerns are found.

Adjacent to the Forbidden Plateau area of SPP is the resort town and ski hill of Mt. Washington (See Figure 20). The area is a fast growing resort village that is a base for year-round recreational activity with highest use in the winter. In recent years, there has been significant development in the area and evidence of this can be seen in the adjacent Paradise Meadows in SPP (See Figure 21). The meadows are a lowland, wetland area with some
Figure 20. The resort village of Mt. Washington, taken from the mountain. Please note the Forbidden Plateau area of Strathcona Provincial Park in the background.

Figure 21. Paradise Meadows in Strathcona Provincial Park just below the resort village of Mt. Washington.
areas of standing water. Visual assessment of this area shows siltation and sediment in these wetland areas, most likely from the development taking place in the village area, outside and upstream from the park.

3. Hydro-electric Development

B.C. Hydro, the British Columbian crown corporation in charge of providing the province with electricity, has a series of dams on the Campbell River downstream from SPP. The closest one to the park is the Strathcona Dam that regulates the level of the Upper Campell and Buttle Lakes (See Figure 22), the later being within SPP. The Strathcona Dam was constructed in 1940, when the area to be inundated was logged and the stumps left. The level of Buttle Lake was raised to a maximum of 728 m above mean sea level. Most of the spawning areas in the rivers flowing into Buttle Lake were inundated.

Figure 22. Buttle Lake just south of Buttle Narrows. Please note the drawdown zone.
The operations of the dam result in low water levels in the winter and spring that make the lake less accessible from campgrounds and boat launch sites. This decreased accessibility is due mainly to the presence of large areas of mud flats in the drawdown zone that occurs at low water levels. These water levels also make boating more dangerous as more stumps are either exposed or closer to the lake surface. Due to significant water level fluctuations, up to a maximum of 9 metres, plant species are unable to colonize the drawdown zone (See Figure 22).

B.C. Hydro also operates the Heber River Diversion. Located in the north-western portion of the park, this operation diverts water from the westward flowing Heber River into Drum Lakes, part of a tributary system of the Elk River which then flows into Buttle Lake. There is some contention as to the impact of this operation on the Elk River. B.C. Parks would like to remove the diversion (B.C. Parks, 1993) as it claims that the increased flows of this operation have resulted in the scouring and dynamic nature of the Elk River. Extensive gravel bars are present throughout the valley, especially at the mouth of the river at Buttle Lake. B.C. Hydro claims that the Elk River is naturally dynamic and that it is the impacts of historic logging in the valley that has de-stabilized the river banks and resulted in excessive erosion. The diversion is closed during peak flow events. B.C. Hydro is presently studying the situation.

Westmin Resources, the only mining company active in the park, operates two hydro-electric developments within the park to support the Myra Creek operations. There are small dams on both Thelwood Creek and Tennant Creek (within the designated SWPP). It is claimed that these developments do not, however, significantly alter the aquatic environments in these waterways (Quilter, 1993, Pers. com.).

4. Mining

Numerous mining claims have been staked in SPP, although only one mine is presently active. This mine, administered by Westmin Resources, is located at the southern tip of Buttle Lake (See Figure 23). Past mining activity can also be seen in a few areas of the park. The Drinkwater Creek, Della Falls, and Creme Lake areas in the southern portion of
the park have a number of small abandoned mines. Both the Bedwell River and Moyeha Bay areas have past producing mines that have been out of operation for many years. There is no knowledge of the possible impacts of the past producing mines on the aquatic environment in these areas. The possibility of acid mine drainage at the old mine sites is uncertain.

The remaining mine site in the park is the Myra Creek operation of Westmin Resources. The claim for this mining site was made in 1918, although the mining activity did not start until 1965. The initial operation of Westmin was an open pit mine just north of Myra Creek. That was followed by two separate underground mining operations. The mining activity of Westmin Resources around Myra Creek has been an issue of concern for environmental and conservation efforts within the government and the private sector for many years. Water quality monitoring by B.C. Environment in the late 1970s identified some water quality problems in Buttle Lake. This was due mainly to the dumping of tailings from the Myra Creek mines into Buttle Lake. The dumping of tailings into the lake was halted in

Figure 23. The active mine of Westmin Resources located at the southern tip of Buttle Lake.
1982, as the first series of settling ponds was constructed to intercept the drainage from the new on-site tailing dumping area. Since that time, the infiltration of aluminum and zinc into Myra Creek and Buttle Lake have continued to be of concern. Efforts were made to deal with these problems and in 1987, a new settling pond system and increased treatment of the mine drainage has significantly improved the water quality in Myra Creek and in Buttle Lake. In turn, the zoo- and phyto-plankton communities have returned to more natural states and a majority of the metal concentrations in fish tissues have decreased significantly. There is generally less biological stress on the fish in the lake system (lower hepatic metallothionein levels) (Deniseger and Erickson, 1991).

5. Administrative Issues

As in the Canadian national parks, the funding for the management and protection of park resources is expected to decrease. Despite this, the provincial government is in the process of significantly increasing the provincial protected area system from approximately 7% (B.C. Parks, 1994) to 12 % of the province's land base (B.C., 1991a). With both an increased number of parks, and significantly more use of these areas, more effort to protect park environments is necessary. If adequate protection isn't given to park environments, the expansion of the protected area system is made in vain.

Threats to the park environments in SPP are evident from both internal and external sources. Protection methods that recognize the source of the threats will more likely be successful in protecting park environments.
CHAPTER IV - CASE STUDY FINDINGS AND RECOMMENDATIONS

A. British Columbia/Thailand Comparisons

The case studies examined represent a range of protected areas in Thailand and British Columbia. Doi Inthanon National Park, BNP, and SPP all have characteristically mountainous terrain. They illustrate the aquatic environment issues that are felt by mountainous protected areas. Khao Sam Roi Yot National Park, on the other hand, is a lowland park, with a mountainous core. All case studies have wetland environments, e.g. lakes, rivers, streams, and/or wetlands in which similar aquatic environment issues emerge.

In B.C., the jurisdiction over water outside of protected areas is given to the Hydrology and Water Quality Branches of the Ministry of Environment, Lands, and Parks. Water rights are then given through a system of licenses or permits to users or development interests through provisions in the B.C. Water Act. These development interests that obtain permits may be government agencies or private organizations. Within Thailand, however, EGAT and the RID, two water development agencies in Thailand, have significant control over the water resources in the country.

Both Thailand and B.C. have similar objectives in the protection of the environment within protected areas. A comparison of the legislation governing the respective protected areas shows very little difference in the power that is given to the agencies administering these areas: total jurisdiction over the land, water, and all activities within the areas. The differences between the protected area systems arise in the planning and management activities. These differences are caused in part by the nature of the resource issues/pressures, the amount of funding, and the level of management. Table 1 compares the general resource pressures and their sources that are evident in the protected areas of Thailand and Western Canada (B.C./Alberta).

The land use issues outlined above fall into two categories based on their sources: external and internal to the protected areas. The protected area legislation addresses internal threats to the protected area environments by giving full jurisdiction to the managers of these
Table 1. Resource pressures and their sources in the protected areas of Thailand and Western Canada (B.C./Alberta)

<table>
<thead>
<tr>
<th></th>
<th>Thailand</th>
<th>Western Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- hydro-electric development within and adjacent to parks - Electricity</td>
<td>- same - B.C.Hydro and private interests - e.g. Strathcona PP</td>
</tr>
<tr>
<td></td>
<td>Generating Authority and Royal Irrigation Department - e.g. Khao Sam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roi Yot NP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- additional adjacent developments - e.g. aquaculture near Khao Sam Roi</td>
<td>- additional adjacent development - e.g. resort village near Strathcona PP</td>
</tr>
<tr>
<td></td>
<td>Yot NP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- hill tribe villagers living within northern parks - e.g. the Hmong and</td>
<td>- people living within the parks - &quot;townsite development&quot; - e.g. those in</td>
</tr>
<tr>
<td></td>
<td>Karen in Doi Inthanon NP</td>
<td>the Town of Banff in Banff NP</td>
</tr>
<tr>
<td></td>
<td>- internal development of visitor services - e.g. Khao Sam Roi Yot NP</td>
<td>- same - e.g. Banff NP</td>
</tr>
<tr>
<td></td>
<td>- land and resource claims by historical users - e.g. Khao Sam Roi Yot and</td>
<td>- land and resource claims by native peoples and long-term inhabitants -</td>
</tr>
<tr>
<td></td>
<td>Doi Inthanon NPs</td>
<td>e.g. Banff NP</td>
</tr>
<tr>
<td></td>
<td>- administrative issues - lack of funding - e.g. general</td>
<td>- same - e.g. general</td>
</tr>
<tr>
<td></td>
<td>- increasing visitor levels and resulting pressures - e.g. many of the</td>
<td>- same - e.g. many of the areas</td>
</tr>
<tr>
<td></td>
<td>areas</td>
<td></td>
</tr>
</tbody>
</table>

areas. External threats, however, are not addressed within protected area legislation or policy in Thailand or British Columbia. This can be seen in the lack of options that protected area managers have in dealing with external threats.

B. Protection Methods in Thailand

Means to address both internal and external threats to the protected areas of Thailand are discussed below based on the methods that can be used to address the threats: legislation and policy, planning and consultation, regulation/enforcement, environmental impact assessments, public/international awareness, and monitoring. This discussion includes an assessment of present methods used and recommendations to address deficiencies.

1. Legislation and policy

Thai legislation and policy provide avenues to protect the aquatic environment within protected areas; deficiencies are evident, however. The legislation and policy issues
discussed here involve recent changes in policy, the use of zoning, watershed classification, wetland conservation, and coastal development planning.

The legislation that mandates protected areas gives the management agencies the jurisdiction over all activities within the protected area boundaries. This includes activities that impact the aquatic environment. Beyond that point, it is the lack of funding and enforcement combined with the lack of political/administrative support for protected area objectives that has resulted in the inadequate protection of the aquatic environment. In addition, the complex legislation and multi-agency jurisdiction over the water resource in Thailand has failed to give adequate recognition to the aquatic environment in protected areas.

To address many of the threats to protected areas and guide the activities of the protected area agencies, a management planning framework has been established. The development of management plans is an important step in the improved protection of area resources. There is, however, a lack of support for implementation of the planning process as very few protected areas in Thailand have official management plans.

The seventh (1992-1996) Thai National Economic and Social Development Plan (NESDP), which guides all Thai government agencies, has addressed a number of natural resource issues including the need for management plan implementation (NESDB, 1991). The guidelines include 1) the implementation of present protected area management plans (that although previously developed, many have not been implemented), 2) the rapid enactment of laws for natural resource conservation (of which a water resource law will be first), and 3) the development of land use plans to decrease conflict. The last two outlined above deal with general resource issues in the country. They can, however, have significant impacts on the protection of the aquatic environment in protected areas.

One recent NPD policy change has directly increased protection to the aquatic environment within the Thai national parks. A decision was made in 1991 that prohibits the Tourism Authority of Thailand (TAT) from constructing and operating facilities within the national parks. This decision addresses the extreme development pressures on the aquatic
environment that the TAT has historically supported within the national parks (Trisurat, 1994).

There has also been progress in the development of an official watershed conservation program in Thailand. A watershed classification system (WCS) has been developed to aid in the management of these lands. The class structure ranges from WCS 1-5, WCS 1 being sensitive, with no inhabitation and very limited activity to WCS 5 being high use with high levels of inhabitation.

The issue of tenure to ensure wise use of lands is being examined by the RFD and is being used, in part, in the less sensitive watershed areas (RFD, 1993b). Possible program initiatives involve the provision of credit for good practices and market support for crops that promote soil and water conservation.

The WCS may prove to be a valuable tool for protected area managers. The reason for this is the overriding power the system has over the protected areas. Activities within a WCS 1 area, for instance, whether inside or outside of a protected area, must abide by the respective WCS regulations. In addition, the WCS represents a more holistic view of the natural landscape, and has the potential to play an important role in the wise management of the aquatic environment.

In addition to the zoning used in the WCS, a zone system has been developed for the protected areas in Thailand. This system can play an important role in the protection of the aquatic environment within protected areas. It is important to use it as a tool, supplemented by zone regulations and adequate enforcement.

Pirawat (1986) has proposed, for instance, the land use zoning of KSRYNP to address the land use conflicts. Such a zoning program would help to both assess the present state of the park landscape and guide management activities in the park. In the case of KSRYNP, proper boundary demarcation would be a necessary precursor to the zoning program. In support of park management and park integrity, the extension of the boundaries to include the whole of the freshwater marsh should be considered.
In DINP, the land zoning of the DLD is used by park managers to address land use activities. As DINP has its own zoning scheme, both systems should be integrated to ensure that the preservation objectives of the park are adequately addressed.

An important deficiency in conservation legislation and policy in Thailand is in the area of wetlands. Thailand does not have a nationally recognized definition of wetlands. National legislation or policy regarding wetlands is needed. Lack of guidance on wetland management and the adequate enforcement of regulations make it very awkward for managers of protected areas that house wetlands to properly manage and protect these areas. The lack of awareness of the complexity and value of wetlands has also been recognized as an important issue in wetland conservation that must be addressed (Bunpapong, 1993).

Wetland environments can have significant impacts on surrounding conditions: ground water recharge and discharge, flood control, shoreline stabilization, and sediment/nutrient retention. Wetlands can also provide important sources for forest, wildlife, fisheries, and water resource use (Dugan, 1990). Over a quarter of all threatened birds in Thailand, in addition to many of the threatened mammals, inhabit wetlands (Collins et al., 1991). These characteristics of wetlands underline the need to increase wetland protection efforts both within and outside of protected areas. The protection or preservation of wetlands within a protected area is one method that can be used to address wetland deterioration. It should be realized, however, that this designation does not guarantee adequate management and protection.

Coastal environments, although adequately protected in theory, are experiencing the same fate as the wetlands in Thailand. Development pressures are having drastic effects on many of the coastal protected areas. Such is evident in the discussion of Khao Sam Roi Yot National Park above.

There have been some efforts in other areas of Thailand to address coastal development pressures. Integrated coastal resource management initiatives have been developed for some of the other coastal national parks in Thailand (e.g. Mu Ko Phi Phi and Tarutao National Parks) (Polsi, 1991). As a multitude of resource pressures are felt in
KSRYNP, such a program may prove valuable in addressing the resource issues and conflicts in and around the park.

2. Consultation

Consultation based working groups are being used to a small degree to increase the protection of the aquatic environment in protected areas. Stakeholders, be they government agencies, organizations, or local people, with interests in and around the protected areas, must come together to develop agreements. Such a process is being used in KSRYNP. Local business interests, environmental conservation interests, park managers, and local people have come together to address the issues of land and water rights, boundaries, and the development of land and water within and impacting the park. If such a settlement can be developed, it is more likely to be successful than one that is enforced by the park management. In addition, a settlement may expand the impact of managers to the land use activities outside of the protected areas. It must be noted, however, that the success of working groups rests on the willingness of the participants to come to an agreement and the outside support for the agreements once reached.

Doi Inthanon National Park has become the focus of a number of welfare promoting agencies (WPAs), concerned with the welfare of the hilltribe villagers in the park. There is, however, a lack of consultation and coordination between the welfare promoting agencies and the DINP officials. Due in part to this lack of consultation, a bad rapport has developed between the park officials and hill tribe villagers. The park officials are perceived by the villagers as primarily strict regulators, opposing their livelihood, in the manager's attempts to enforce the National Parks Act and prohibit cultivation.

Any planning or management activities within DINP should involve consultation with the WPAs and the villagers within the park. Such consultation will help work towards a balance between the protection of park resources and agricultural development that is taking place within the park. Through all these activites, however, the NPD must ensure the protection of the natural environments within the park.
3. Regulation/Enforcement

The enforcement of regulations is an important part of ensuring adequate protection to the protected area environments. The main enforcement issues in the protected areas of Thailand revolve around human encroachment, including the enforcement of boundaries and cultivation regulations.

The enforcement of boundaries is an important protection issue in KSRYNP. Addressing many of the issues and resource pressures in KSRYNP is hindered by the lack of adequate park boundary demarcation. Action required to deal with this situation is lacking. The boundaries were originally designed to protect the limestone outcrops and that is the reason for their undulating nature in the eastern portion of the park. The boundaries drawn in the western portion of the park were changed in 1982 to include about half of the marshland. The reasoning at the time for the inclusion of only half of this wetland environment was to cut down on the opposition against the removal of this area from both agriculture and aquaculture activities (Charoensiri, 1993, Pers. com.).

There was some progress regarding boundary demarcation in 1991. The Bangkok Post and The Nation, two Bangkok newspapers reported that the land title documents of 165 people living in and around KSRYNP would be investigated (July 7, 1991). This action to investigate land title documents was taken following reports from park officials that identified widespread encroachment into the park wetlands by both villagers and investors. Since that time, however, no action has been taken (Parr, 1993, Pers. com.).

Khao Yai National Park in central Thailand has initiated a program to plant a 20 metre strip of trees of the same species to mark the park boundaries (Vejaboosakorn, 1991). This will aid in enforcement of park regulations and also show the local villagers the exact extent of park land. Again, enforcement is necessary to make such a program effective.

In many cases, the strict enforcement of regulations, e.g. the prohibition of cultivation in parks, is not an option in the protected areas of Thailand. In many instances, hilltribe villagers inhabit protected areas and rely on cultivation for their livelihood. In these instances, a number of issues need to be addressed. These issues include the amount and
nature of the cultivation permitted, methods to enforce the accepted level of cultivation, and addressing the needs of villagers if cultivation is not permitted.

The **National Parks Act** states that there shall be no inhabitants of the national parks. Cultivation in protected areas is also illegal in Thailand. The presence of thousands of hilltribe villagers, however, has resulted in a change in policy regarding human presence in protected areas.

Doi Inthanon National Park is a prime example. Although not officially voiced, it is assumed that inhabitation and cultivation within DINP will continue. In addition to the conflicts between the legislation and what is actually occurring in the park, the managers have not been given any guidance in addressing inhabitation and cultivation issues. This uncertainty and lack of guidance may be the cause for very inconsistent enforcement of cultivation in the park (Emphandhu, 1992). Sporadic arrests and confiscation of cultivation machinery has left the villagers within the park uncertain as to what is permitted. The result is a bad relationship between the park officials and the local people, a relationship that is a detriment to the protection of park resources.

Similar enforcement issues arise in KSRYNP. The same issues of customary or historical rights to the land and water are present. As in DINP, the park area has historically supported agricultural activity at a smaller scale. In KSRYNP, it is the pressures from both increased agriculture activity and the relatively new tiger-prawn farming operations that are threatening the marshland. In this case, management plan development should take into consideration the historical presence of small scale sustainable agriculture. Any planning efforts should also identify and address legitimate claims to the land (Parr et al., 1993, Unpublished).

The draft **Thailand Forestry Sector Master Plan** recognizes the need to develop policies to deal with conservation/local people conflicts and interactions and the role of local peoples within protected areas (RFD, 1993a). One such program is proposed to address the economic needs of the villagers in or adjacent to the protected areas (Vejaboosakorn, 1991). If their needs can be met through
external activities or non-destructive internal activities, the pressure on the protected area resources can be minimized. Such programs, although very complicated, can play an important role in the protection of the aquatic environment within the protected areas. There are also situations where hilltribe villagers, supported by programs, have become more in tune with the environmental implications of their activities, e.g. Doi Luang National Park and Doi Chiang Dao Wildlife Sanctuary (Smitinand, 1992).

4. Environmental Impact Assessments

The EGAT has developed environmental protection policy for their water development projects. Environmental impact assessments (EIAs) must be conducted for large hydro-electric development projects. These assessments are usually conducted by outside research groups hired by EGAT. A similar situation is found with large projects of the RID.

The validity of these assessments has been questioned, however, after a recent incident. An EIA was conducted by Chiang Mai University for the proposed Khaeng Sua Ten Dam in northern Thailand. The dam is to be constructed within Mae Yom National Park, inundating 66.6 square km (15% of the parkland).

The RID sent the report back to the university requesting undisclosed changes. The resulting report was seen by some local conservation academics as biased and inadequately simple. In addition, the dam proposal has been altered since the early planning stages although the environmental assessments had not been expanded accordingly.

The Center for Conservation Biology at Mahidol University in Bangkok, one of the agencies which voiced concern over the original assessment, was then requested by the World Bank (a supporter of the dam project) to conduct a rapid assessment of the area to be inundated by the dam. The resulting report (Mahidol University, 1992) commented on the limited assessments made by the Chiang Mai University team and also provided findings of the assessment. The World Bank is presently reassessing its support of the project.

This situation is an example of the pressures of large scale developments on protected areas in Thailand. The prioritizing procedure for large projects does recognize the location of the projects within or impacting protected areas, giving slightly less priority to the projects...
within "wildlife conservation boundaries" or protected areas. An example of the seeming insignificance of protected areas in project planning is, however, the original EIA on the Kaeng Sua Ten Dam proposal (Royal Irrigation Department, 1991). The document states that the presence of the national park was not a significant concern. The report voiced the three reasons for this insignificance: 1) there are many developments within other protected areas in the past, 2) the villagers within the park were illegally logging the area, and 3) that the NPD wanted to relocate the villagers within the park anyway.

EIAs, if conducted properly, can be used to help regulate activities that are detrimental to protected areas. To ensure the EIAs usefulness, the results of the assessments should be integrated into either the management of the protected areas, or the land use planning of surrounding areas.

5. Public/International Awareness

Public awareness and the involvement of the international community can play an important role in the protection of aquatic environments in protected areas.

Improved public education, for those in proximity to a protected area and elsewhere, can benefit the protection of their aquatic environments. With increased education, the local people may hold a more open view to the importance of the protected area and its aquatic environment. Their resulting actions, although voluntary, can directly decrease the threats to the aquatic environment in protected areas. In turn, an enlightened public will most likely result in an increased political lobby for protected areas. The main limitation of public awareness in this role is that it is based on the voluntary openness and involvement of the public and is, therefore, susceptible to the shifting views held by the public.

In KSRYNP, a second of visitor and education centre is being developed to increase awareness of the importance and sensitive nature of the marshland environments within and adjacent to the park. The royal projects in DINP are teaching local farmers the impacts of cultivation on the environment as well as how to cultivate crops using more environmentally friendly methods - terracing, drip irrigation, etc. Both approaches will help increase local
awareness of the protected area environment. This understanding may result in less villager induced threats, furthering the protection of the aquatic environment.

International conservation interests and the international community can also provide avenues for increasing the protection of the aquatic environment within protected areas. Through lobbying of conservation organizations, international pressure can be placed on governments to improve the protection of these environments. An example of this can be found in Khao Sam Roi Yot National Park. Conservation efforts in Thailand are lobbying the World Wildlife Fund (WWF) to call for the increased protection of the freshwater marsh in the park. The WWF, Siam Society of Thailand, and the Bangkok Birdwatchers Club are also lobbying the Thai government for action. Although some action has been taken, it is too early to tell if the marsh will be saved from further degradation.

International conventions are additional avenues that can help improve the protection in protected areas. Thailand acceded to CITES, the Convention on International Trade of Endangered Species of Wild Flora and Fauna, in 1984. CITES remains the only conservation convention of which Thailand is a member. Other conventions that could significantly improve the protection of Thailand's protected areas and their aquatic environment are the World Heritage Convention (WHC) and the Ramsar Convention (RC) (Kasetsart University, 1987). The WHC was adopted by UNESCO in 1972 and provides an avenue to identify areas of global natural and cultural importance. Such places obtain the World Heritage Site label. The convention provides an avenue for international cooperation in the protection of universally important sites. A proposal has been made to UNESCO to include Khao Yai National Park in central Thailand as a possible world heritage site. This designation would bring in funding and protection support for the park and further ensure its protection (Vejaboosakorn, 1991). Benefit from Thailand's involvement in the WHC would be limited, however, as protection and integrity requirements for sites are very stringent.

The RC, or the "Convention on Wetlands of International Importance, Especially as Waterfowl Habitat", requires member countries to include wetland concerns and protection in national planning and management procedures. Thailand has a number of wetland
environments that would benefit from these changes in land planning and management. This convention, unlike the WHC, specifically addresses wetland environments, and can help improve aquatic environment protection directly.

6. Monitoring

The assessment of the impacts on the aquatic environment through monitoring is an important step in detecting the need for more protection of these environments. The information provided by monitoring will guide management in addressing threats to the park's aquatic environment.

No policy on monitoring has been developed for either the national parks or wildlife sanctuaries in Thailand and so guidance in this matter must come directly from legislation. The legislation does not, however, propose any aquatic environment monitoring within protected areas. The natural environment protection that is required by this legislation, however, requires an understanding of the state of the resources, and so monitoring should be used.

Although not required some monitoring does take place within the protected areas. This monitoring has been conducted by protected area officials as well as outside organizations, universities, hospitals, etc. These monitoring activities tend to be very limited in scope and inadequate in the protection of protected area environments.

It is very evident that monitoring is necessary in the protected areas in Thailand. The many threats to the aquatic environments in these areas, and limited surveys that show significant change in the aquatic environment, point to the need for long term reliable monitoring activities.

C. Protection Methods in British Columbia

As in Thailand, the managers have total jurisdiction over protected area environments. If adequate protection does not occur, it is generally a lack of application or enforcement of protected area regulations. There are some instances, however, where issues such as historical rights to resources influence the ability of management to protect the aquatic
environment. These include instances where historical land and resource rights have been provided to historic inhabitants.

Protected area managers do not have jurisdiction over any of the external threats to protected area resources. Due to the objectives of the protected areas, however, the managers may have a mandate to address these external threats.

The following discussion examines the methods used to protect the aquatic environment within protected areas in B.C. Seven different categories of protection methods are used to facilitate the discussion: planning, legislation and policy, licensing/ EIAs, zoning, treatment/restoration, public awareness/stakeholder consultation, and monitoring.

1. Planning

Management plans are required for both provincial and national parks in B.C. These management plans, in conjunction with park zoning policy, attempt to deal with threats to the protected areas and prevent future changes in the natural environments. This management planning process guides managers in the fulfillment of the protected area objectives.

The management plans for protected areas in B.C. recommended certain management actions. The lack of prioritization and the lack of support (administrative, political, or monetary) may leave these actions in jeopardy. All efforts should be made to obtain long term support for management plan recommendations.

The following discussion examines how both the BNP and SPP management plans address the protection of the aquatic environment.

The BNP management plan states that Parks Canada "will ensure that the natural flow patterns of these rivers are protected and that manipulation of the stream bed is minimized." The plan also mentions work that has been conducted in conjunction with other government agencies (Environmental Protection Service and the Inland Waters Directorate) to develop water quality standards and minimize pollution. The plan guidelines regarding the aquatic environment within the park are as follows:
1. The assurance that sound effluent management occurs at all facilities.

2. The monitoring of water quality and where necessary, all measures will be taken to eliminate or prevent pollution.

3. The development of standards to minimize siltation, loss of habitat and changes to natural flow patterns caused by necessary modifications of the stream channel.

4. The removal of abandoned dams (at Duthil and Spray Eight Mile) and the restoration of natural flow patterns.

5. The maintenance of heritage values of the North Saskatchewan that led to its nomination as a Canadian Heritage River.

6. The management of aquatic resources on an ecological basis, through the development of an aquatic resources management plan

In addition to these recommended actions, there are portions of the plan that address specific aquatic environments within the frontcountry of BNP. The first is the Vermillion Lakes area. This area is an important wetland and is located in proximity to Banff Town. Due to its sensitive nature, the wetland area will be included in a Banff vicinity plan that will address management issues including the needed levels of protection and adequate visitor levels. The plan is to address local protection issues and will help ensure the protection of the Vermillion Lakes environment in its natural state.

An aquatic environment management plan has been proposed for BNP (Parks Canada, 1988). The plan has presently being developed and is not expected to be completed before the spring of 1996 (Pacas, 1993, Pers. com.).

The list of aquatic resource guidelines, consideration given to specific water protection areas, and the work towards an aquatic resources management plan all show that the management within BNP is dedicated to the sound ecosystem based management of the aquatic resources within the park.

The SPP master plan (B.C. Parks, 1993) follows a similar format as the plan for BNP and outlines a number of issues and management actions that will help protect the aquatic environment:
1. Monitor and protect lakes, streams, and rivers, from interference.

2. Prohibit water impoundments, diversions, and future domestic use projects.

3. Ensure proper design and location of sanitary facilities.

4. Develop contingency plans for toxic spills along the Strathcona and Buttle Lake Parkways.

5. Continuance of monitoring of Westmin Resources run-off to ensure proper water treatment and the fulfillment of water quality standards

6. Work with B.C.Hydro to develop a reservoir management plan which accommodates the recreational and environmental interests of SPP.

This list of priority management actions outline ways to improve the protection of the aquatic environment in SPP.

One important issue that has been addressed through management action is high visitor use. Regulations have been developed that prohibit camping in backcountry areas that do not have toilet facilities. In addition, revegetation programs are being used to address water quality concerns in the high use backcountry areas.

The development of a management plan for SWPP, located inside SPP, has been initiated by B.C. Parks. The management of this area, with the mine and a number of other developments, is very complex and will require effort from all involved organizations: B.C. Parks, Westmin Resources, Ministry of Energy, Mines, and Petroleum Resources, B.C. Environment (Environmental Protection, Water Management, and Fish and Wildlife Habitat Branches), Department of Fisheries and Oceans, and Environment Canada (Environmental Protection). A draft plan is being developed and rests on the willingness of these agencies and groups to consult and work together.

Due to the importance of the aquatic environments to the park and the range of activities impacting these environments, an aquatic environment management plan is recommended. The plan could outline the present state of the environment, outline short and long term goals for the aquatic environment, and management actions to reach those goals.
The plan could be developed for both SPP and SWPP, addressing all the threats to the aquatic environment in these areas.

2. Legislation and policy

There has been a variety of legislation and policy changes in the protected area systems in B.C. in the last decade. Within the Canadian national parks, one of the changes that has occurred is the prohibition of new townsite development and logging activity in the national parks. The 1993 decision to stop logging activity was a result of court action taken by the Canadian Parks and Wilderness Society against Wood Buffalo National Park for allowing timber harvesting in the national park (CPAWS, 1995).

Another change to the national park legislation addresses the apparent dichotomy within protected areas between environment protection and recreation. The legislation now states that the national parks primary focus should be the maintenance of ecological integrity within the parks. This decision came at a time when increasing tourism related development was taking its toll in the national parks. The practical definition of ecosystem integrity and ecosystem management is still in the process of being interpreted by park managers (e.g. Woodley, 1993).

Within the B.C. provincial parks, a 1991 policy decision was made to prohibit mining activity in the parks. Negotiations are taking place with the mineral claim holders, in Strathcona Provincial Park for instance. What the results will be, along with the compensation that may be necessary, is uncertain.

Native land claims are also a policy and management issue facing protected areas in B.C. The provincial government is presently conducting negotiations with a variety of bands to address the claims. What impact the settlements will have on protected area management is not known. The possibility of cooperative management between the protected area agencies and the native bands may be an avenue that will be used to ensure both the protection of protected areas and the fulfillment of native rights.

In BNP, the claims to the land are within the townsites. Due to the nature of the leases, Parks Canada must permit the land holders to remain. Consultation should occur
between the townsites and the park management to ensure adequate environmental protection. As Lake Louise townsite is under Parks Canada jurisdiction and Banff town is an Alberta municipality, the nature of consultation with the land holders will take on different forms. The end result should be agreements that ensure the protection of the park's natural environments.

3. Licensing/Environmental Impact Assessments

The licensing of use and the assessment of environmental impacts are two methods used to ensure the protection of the aquatic environment in B.C. protected areas.

Water Licenses are used in both BNP and SPP to guide the use of water within the parks. The nature of the licenses varies slightly due to the different jurisdictions that administer them: on provincial land in B.C., it is the Ministry of Environment, Lands, and Parks, and on federal land in national parks it is Parks Canada. Requirements for environmental protection or monitoring can be stipulated in the license: e.g. TransAlta was required to undertake research on the fish populations in Lake Minnewanka and Westmin Resources was required to conduct monitoring activities.

An application for a provincial water license is examined by the Ministry of Environment, Lands, and Parks by assessing the presence of previous water licensees, the availability of water, and the environmental impacts of the proposed water use. One of the drawbacks of the provincial water licensing system in B.C. is the limited water uses that can support a water license. Water licenses can not be acquired for instream uses such as recreation, fisheries, aesthetics, etc. The licenses are limited to mainly out-of-stream uses, e.g. domestic use, mining, agriculture, etc. where the construction of facilities to somehow regulate the water is required. This prohibits the issuance of a water license for reasons of ecosystem or protected area integrity.

As evident in both BNP and SPP, water licenses can be valuable tools to ensure that proper consideration is given to natural water processes within protected areas. It is also understood that some long-term commitment to the license is required. Some degree of adaptability is needed, however, to deal with new information and to address changing
concerns for the environment. The need for this adaptability in water licensing is important in any situation, and more so in a protected area.

In addition to the provincial water licenses, waste permits must also be obtained by those who deposit waste into the environment. Westmin Resources, for instance, must have a waste permit to allow for the runoff from the mine tailings site. These permits have a similar function to the water licenses and can limit impacts through requiring both environmental protection efforts and/or monitoring activities. Although the deposition of "waste" within protected areas is counter to the preservation efforts of these areas, such a permitting system is valuable when this deposition is necessary (e.g. based on historic rights to resources).

Within the provincial parks in B.C., park use permits (PUPs) must be obtained for any development, facility construction, or commercial activity. The issuance of PUPs is based on the assessment of the proposal's environmental impacts as well as the placement of the activity in the overall purpose of the park. Although PUPs are examined on a case to case basis, consideration is given during each review to the cumulative impacts of proposed activities. As with the other licenses outlined above, the permits are issued with stipulations requiring certain activities to be carried out. This will ensure, for instance, mitigation of impacts or the monitoring of the aquatic environment. The permits are issued generally on a ten year basis (renewable) and can be deemed invalid if permittees do not conform to the requirements of the permit.

The final issuance of PUPs is at the discretion of the park managers in determining if the requested activities are consistent with the park's objectives. In addition, a PUP must be obtained prior to any other provincial licenses or permits, e.g. water licenses or waste permits. In this way, B.C. Parks has an overriding authority within the protected areas in determining the necessity and use of the aquatic environment.

An environmental impact assessment is included in the issuance of a PUP. All activities that involve federal lands or federal funds, e.g. national parks, must also undergo environmental impact assessments. The nature of the federal assessment procedure has recently changed (December, 1994). Historically, proposals for activities on federal lands
involved the Environmental Assessment and Review Process or EARP. This environmental assessment attempted to examine the possible impacts to the natural environment within the park and was successful in doing so (Tessolini, 1994, Pers. com.). The EARP could reject a proposal for development or certain activities within the park for four reasons:

1. if the mitigation of environmental impacts are minimal (or not identified)
2. if the environmental impacts are too great
3. if the developer has failed to recognize possible or certain impacts
4. if public concern has increased over the issue, and then it may go to a public hearing.

There are two main drawbacks of the process that were identified by the BNP wardens. These are lack of consideration of cumulative effects and the overriding effect of political clout and lack of political support for the system. The program examines each development proposal on its own and does not examine the cumulative effects of all development activities. In addition, even though the EARP may point out areas of concern or environmental impacts that are unacceptable, political lobbying or political clout may result in the approval of these developments.

The Federal Environmental Assessment and Review Office (FEARO) in conjunction with the Canadian Environmental Assessment Act have replaced EARP and have improved environmental impact assessment procedures for federal activities in Canada. The new program addresses the past problems of cost, delays, and uncertainty for industrial interests. The new program also ensures participant funding of the assessment, the one proposal/one assessment policy, the involvement of the public, and the need for a Cabinet decision to respond to the decisions or recommendations of an independent environmental assessment panel (Canada, 1994).

To supplement the federal environmental impact assessment processes, a BNP directive was developed to provide further guidance of activities during the construction or development of houses, buildings, etc. This directive gives strict guidelines as to the protection of the aquatic environment during construction and development activities (BNP, 1988).
Despite the relatively stringent requirements of the federal EIA procedures, and despite the prohibition of additional construction as stated in the BNP management plan, there has been increasing concern over the development activities in BNP. As a result, a moratorium has been placed on development in the Bow Valley until a study of the impacts of development is concluded (proposed for 1996). More information on the moratorium is given below.

4. Zoning

Both the national and provincial parks in B.C. have zoning systems. For the national parks, the zoning system is used to "establish the extent of protection and use of specific park lands . . . and [is] applied on the basis of goals, objectives, resource analyses, and potential uses of the park" (Parks Canada, 1988, p.23). A similar zoning system is used by B.C. Parks to guide both visitor use and management activities in the parks (B.C. Parks, 1990).

In addition to the general zoning in SPP, the wilderness zone designation of nature conservation areas (NCAs) has been proposed for large tracts of wilderness in SPP. The designation of park land as NCAs under the Park Act gives added protection to these areas as roadless wilderness areas within provincial parks retained in a natural condition for the preservation of their ecological and scenic features. All commercial activities based on motorized use, hunting, or resource use are prohibited (B.C. Parks, 1993).

5. Treatment/Restoration

Actions are being taken in both SPP and BNP to restore altered environments and treat sources of environmental change. Both actions will help restore aquatic environments and maintain them in their natural state.

Waste treatment facilities have been developed in Banff and Lake Louise townsites and at Sunshine Mountain in BNP. The impacts that these visitor centres have on the aquatic environment of BNP have been significantly decreased. The plants were constructed for both the improvement of the natural environment within the park as well as in response to complaints from downstream users of the water. Monitoring of these facilities is carried out
to ensure the success of the plants in improving water quality and minimizing impacts on the natural environment in BNP.

Individual septic systems have been developed for areas in the backcountry that concentrate use (e.g. lodges). Although no routine monitoring of water quality is presently conducted at these sites, monitoring by lodge owners should be required. This will help ensure the protection of the aquatic environment and other resources in these areas. The exact frequency of sampling, position of the stations, and the parameters measured should be determined through consultation between lodge owners and Parks Canada.

Restoration of aquatic environments has been identified as an important priority in the management plans of both BNP and SPP. All abandoned dams in BNP, except one, are being removed and the stream channels returned as much as possible to their natural state. The one dam that will remain is on Johnstone Creek. The small reservoir it creates is used heavily by recreationists, removing pressure from more sensitive areas of the park.

Restoration activities are also being proposed for the draw-down zone of Buttle Lake in SPP (See Figure 18). Vegetation trials have been initiated to examine the success of planting water tolerant species.

6. Public Awareness/Stakeholder Consultation

Public awareness can be a very valuable tool in the protection of aquatic environment in protected areas. Through increasing public knowledge of the threats to protected area resources, the public may in turn lobby for change. This is evident in BNP, as public pressure over the development in the park played a role in the moratorium placed on development. The use of public awareness to increase protection is limited, however, in that it relies on the ability of protected area issues to be shared with the public, the ability of the public to voice concern, and the impact that this concern can have on activities outside of protected areas.

Visitor education can also be used to directly decrease impacts to the aquatic environment. Providing information about 1) the importance of the water to natural processes, 2) the ways in which visitor use impacts the aquatic environment, 3) the impacts
of aquatic environment change on the overall environment, and 4) environmentally friendly visitor use techniques can improve the consideration given to the aquatic environment.

This approach has been adopted by both Banff National Park and Strathcona Provincial Park and recreation organizations through the development of backcountry use guidelines and etiquette. This approach can prove very valuable as many visitors recognize the importance of protecting the environment that they themselves enjoy.

Increased awareness and consultation is being used to address a number of issues within SPP. One issue is the concern over impacts from Mt. Washington Resort expansion on the park environments. The park managers have sent letters to all the development interests in the Mt. Washington area to request their cooperation in minimizing the impacts of development on the lower Paradise Meadows area (Quilter, 1993, Pers. com.). As this development area is outside of the park, park management has no legislated mandate. Improvements in environmental protection will rely on the willingness of developers and the ability of the MoELP, the government agency with the corresponding mandate, to help ensure the protection of the park's environments.

As in Thailand, international conventions and organizations can improve support for protection efforts. BNP is part of the Canadian Rocky Mountain Heritage Site under the conservation program of the IUCN (UNESCO). Increased publicity is gained from this designation as well as an increased awareness of the importance of the park's natural environments.

Although not evident with BNP or SPP, the biosphere reserve program is also used in Canada to increase protection to protected area environments. Waterton Lakes National Park in Alberta is such a reserve. The reserve program was iniated by UNESCO and the United Nations Environment Program to 1) conserve biological diversity, 2) establish biological baselines, and 3) integrate the impacts of human activites on biological systems (Poore, 1983).

Non-governmental organizations (NGOs), at all levels, can play an important role in increasing protection efforts within protected areas. They can, for instance, place pressure on
governments to increase protection efforts. Such is the case with Canadian Parks and Wilderness Society vs. Wood Buffalo National Park. In SPP as well, groups such as Friends of Strathcona Park can lobby the protected area managers and the government to increase protection of the aquatic environment within these areas.

In addition to increased public awareness on the local, national, and international scale, consultation based working groups can play an important role in protected area activities. A number of these groups, all different in form and function, are being used in the protected areas of B.C.

The Federal Minister of Canadian Heritage, Michel Dupuy, established the Banff Bow Valley Task Force (BBVTF) to study the pressures and issues in the Bow Valley and make recommendations to the government. A moratorium was placed on all development in the Bow Valley corridor during the study. Such a stop to development, and the current study should provide a more sophisticated way of looking at the development pressures in the Bow Valley. The task force was established because the importance of the Bow Valley and its montane environment as a critical ecosystem for BNP was recognized. The task force is examining the ecological, economic, and social considerations or issues regarding the development that has taken place within this corridor. A report is expected from the task force in April of 1996 that will outline long term management and land use recommendations that will be consistent with the objectives of the Canadian National Parks Act.

The Banff Bow Valley Task Force (BBVTF) is a multi-disciplinary group of professionals that must assess the present state of development in the Bow Valley and make long-term recommendations for development and/or protection of the valley. This program is different from a standard stakeholder consultation group as the members are employed by the government to make an assessment and are not advocates for a certain interest group. The group does however, represent a team approach that consults with the public over the development in BNP.

The Bow River Water Quality Task Force was established in May of 1990 in response to concerns over the quality of the Bow River, specifically below Calgary, a main urban
centre east of the park. The task force acquired much information on the uses, abuses, and state of the river. Its first recommendation was to develop a permanent council to address the water quality issue in the Bow River basin.

In response, the Bow River Water Quality Council (BRWQC) was established in 1992. The council acts as a means by which stakeholders of the Bow River can communicate directly with the government as well as with each other. There are 17 stakeholder groups represented on the council. They range from representatives from rural and urban communities, fisheries and recreation interests, first nations, industry and additional interest groups. The mandate of the council includes 1) the advising of the Alberta Environment Minister on policy regarding the river basin, 2) the promotion of awareness, 3) the improvement and protection of the water quality of the river basin, and 4) the fostering of cooperation between the government, the public, and other stakeholders.

The development of the BRWQC helps to raise awareness over the importance of the river and the need to protect it. With regards to BNP, the program helps to identify and stress the importance the park plays in the provision of a viable and safe water source. It also enables the managers within the park to increase awareness of the threats to the aquatic environment and the protection measures taken.

Working groups and stakeholder groups are starting to be used in SPP. B.C.Hydro has initiated a stakeholder group to examine how their operations impact other interests in the Buttle Lake area. B.C. Parks is also working towards a reservoir management plan developed through consultation with B.C.Hydro. The plan is to address the operational levels of Buttle Lake as well as the restoration programs for degraded environments in and around the reservoir. These examples show the range of protected area situations in which stakeholder consultation may prove valuable in addressing complex land use situations.

As in public education and awareness, using working groups to improve protection of the aquatic environment is generally based on voluntary involvement. This leaves the success of these methods for protection in jeopardy. Although some recognition has been made for
the use of working groups to address external threats (Parks Canada, 1991), no support has been provided to guide protected area managers in this direction.

7. Monitoring

Aquatic environment monitoring is conducted within protected areas in B.C. In many situations, the monitoring is conducted when a critical issue or situation dictates the need. When such specific monitoring is conducted, the results may provide the information to guide protected area managers to conduct remedial or preventative management actions. In some cases this information is not enough.

Long-term monitoring is also very important as it will provide the baseline information that allows managers to understand and identify the nature of the aquatic environment. Such a system, if developed properly, will provide an assessment of the aquatic environment, an identification of trends in that environment, and the identification of environmental change that warrants further study and/or management action.

Some protected areas have long-term aquatic environment monitoring systems in place to provide baseline data and regular "state of the environment" information. BNP has such a program. When routine monitoring is conducted, it is important to have a program for more intensive spot surveys to fill all the information requirements. In BNP, a comprehensive aquatic environment monitoring system is needed to tie together the monitoring that has occurred and point out areas that need additional monitoring. The development of such a system may be conducted along with the proposed aquatic environment management plan.

A similar comprehensive monitoring system is needed in Strathcona. A wide range of monitoring is conducted in the park by many different operators (outlined in Chapter 5). A comprehensive monitoring plan could help to coordinate these activities, pool results, and make all monitoring more useful to all those involved.

Although monitoring does occur in protected areas in B.C., examination of the case study areas points to the need for more coordination and the development of a comprehensive monitoring system.
D. Applicability

Deficiencies were noted in the protection of the aquatic environment in each of the jurisdictions. The following discussion examines how protection methods from one jurisdiction can address aquatic environment protection in other jurisdictions. The discussion examines policy development, licensing and EIAs, working groups, public awareness/international involvement, and the use of monitoring.

1. Policy Development

The protected area systems in B.C. have developed policy documents that provide varying degrees of guidance to managers. The policy developed by Parks Canada provides an example of the detail and guidance that can prove valuable in the protection of all environments within protected areas.

The avenues to ensure protection, or means to address the threats to the aquatic environment, can be provided in part through policy development. The national parks and wildlife sanctuaries in Thailand have very little policy to support management and protection efforts. In many instances, as in the case study areas examined, the managers are not given the guidance to protect the environment, aquatic or otherwise, through addressing the threats to protected area resources.

The development of aquatic environment protection policy must be an evolving process. The process should involve regular evaluation and adaptation (Radosevich, 1991). This evaluation and adaptation should be based on how the policy relates to current resource threats and the different methods that can be used to protect the aquatic environment.

Policy development is required for the protected area system in Thailand. More guidance is required for the managers of these areas, as the threats to protected area resources are becoming more complex. Improved policy development should also be considered for the provincial parks in B.C. Present policy (B.C. Parks, 1990) is very limited in its guidance to protected area managers. This is especially the case with the protection of the aquatic environment.
A protected area zoning system has been developed for the protected area systems in both jurisdictions. Although the zoning system was applied in all the management plans or maps of the case study areas, its success relies also on the involvement of management in using and enforcing the zoning. Zoning with the use of the NCA designation in B.C., for instance, will improved the protection of park land in SPP due to its legislated backing. The NCA designation will help to protect the aquatic environment along with other resources in this area over the long term.

It is important to outline that zoning is a tool in the management and conservation of protected area resources. Enforcement of regulations, an area of deficiency in Thailand, must play an important role if a zoning system is to succeed. In addition, a program to educate visitors and protected area inhabitants as to the regulations and permitted activities within each zone will also aid in ensuring its success.

Rights to land and water have been recognized in the townsites within BNP. Parks Canada is now working with the inhabitants to minimize the impacts to the park's natural environments. Such is also the case with the mine in SPP. The park managers are working with Westmin Resources to address threats to the aquatic environments within the park.

The recognition of historic rights to land and water in Thailand is still at large. No decisions have been made on how to address the presence of inhabitants in DINP, for instance. Recognition of rights should involve cooperative management and protection of the park's resources, including the aquatic environment.

Along with the recognition of land ownership and water use in KSRYNP, efforts must be made to determine legitimate ownership of land. This will help to address the environmental impacts of increasing populations. Programs, involving the local villagers, must be developed to address the unnecessary and excessive impacts of cultivation on the park's aquatic environment. These activities will help to sustain the natural wetland environments within the park.
2. Licensing/EIAs

The procedures to develop provincial park use permits, water licenses, and waste permits in B.C. provincial parks provide a valuable way to control activities within protected areas and stipulate conditions for the activities that are permitted. The individual procedures differ slightly, although the general principles are the same. The environmental impacts of proposals are determined, and conditions are placed on the licensees to minimize the environmental impacts, undertake remediation activities, conduct monitoring, etc. The park use permit process can also refuse a proposal if it does not conform to the objectives of the protected area. Similar considerations and principles are involved in the environmental impact studies and water licensing procedures within the national parks in B.C.

There are presently no procedures to provide licenses or permits for activities in the protected areas of Thailand. There are also no environmental impact assessment procedures to determine the impacts of activities sponsored by either the protected area agencies or other organizations. It would be of value to the protected areas in Thailand to develop such a system. Take for instance the construction of additional visitor centres near the marsh in Khao Sam Roi Yot National Park. An environmental impact assessment would provide information to minimize the impacts to the marsh. Another example is the activities of the welfare promoting agencies in Doi Inthanon National Park. The impacts of the resulting intensive cultivation on the aquatic environment and other environments within the park are not known.

A licensing system for the protected areas of Thailand would have to include procedures that will ensure the fulfillment of protected area objectives. This will prevent the licensing system from merely legitimizing pollution from development within the protected areas. The issues of enforcement and political/administrative support would also have to be addressed. These factors are presently lacking in present protected area planning and management activities (Kasetsart University, 1987).
3. Working Groups

Consultation-based working groups have been used in the protected areas of both jurisdictions. Groups have been developed, for instance, to address issues of reservoir operation procedures in Strathcona Provincial Park and to address boundary and encroachment issues in Khao Sam Roi Yot National Park. In both instances, the groups are coming together to resolve external threats to protected areas. This approach should be considered for use in addressing a wide spectrum of threats to the protected areas in B.C. and Thailand.

The working group approach can also be used to address internal threats to protected area environments. Within Doi Inthanon National Park, there is a present lack of communication between the welfare promoting agencies, the local villagers, and the park officials. This has resulted in hostile encounters and a lack of communication between the groups. This situation works against the efforts to improve the protection of the aquatic environment in the park.

The development of a working group in DINP should include representatives from the Royal Projects and other welfare promoting organizations, all three tribal peoples, and the park management. The initial objectives of this group could involve the joint control of agricultural expansion, the minimization of impacts to the aquatic environment, and the continuation of consultation based activities to address concerns or issues as they occur.

4. Public Awareness/International Involvement

The improvement of information transfer to and education of 1) the public, 2) visitors in the protected areas, and 3) development interests in and around these areas can improve the protection of the aquatic environment. This avenue is being used in all of the protected area case studies: the contact with the adjacent resort development in SPP, public awareness of excessive development in BNP, the rallying of water users below DINP, and the local, countrywide, and worldwide media coverage over the impacts to a globally significant marshland in KSRYNP.
Such efforts can improve the awareness of the impacts of various activities on the aquatic environment. This increased awareness may then translate into increased pressure and lobbying of governments to improve the protection of the aquatic environments.

Increasing public awareness of conservation and protected area issues is also being used in both jurisdictions to improve protection. Groups such as the "Friends of Strathcona Park" show the interest of the public in the protection of local protected areas. On a larger scale, environmental groups are becoming more involved in ensuring the proper protection of the natural environment within protected areas (e.g. CPAWS). The public, through various organizations or groups, are playing more of a role.

Similar environmental groups are becoming active in Thailand as environmental awareness is increasing (Parr, 1993, Pers. com.). Protected area managers in Thailand must make use of this support for the protection of the country’s natural environments. This can be done through the education of the local public as well as lobbying at the national and international level.

The involvement of Canada in a number of conservation and protection based international conventions extends increased protection to a number of different environments. Thailand’s involvement in these conventions (World Heritage, Ramsar, Biosphere Reserves, etc.) could bring increased protection to a number of protected areas. Thailand's involvement in the Ramsar Convention would help increase the protection given to the country's remaining wetlands both within and outside of protected areas.

5. Monitoring

The impacts of activities that jeopardize the integrity of protected area environments can usually be detected within the aquatic environment. In this way, the monitoring of the aquatic environment can play a very important role in the protection and management of a protected area as a whole.

Very little monitoring was noted in the case studies in Thailand. The protected areas in B.C., however, have extensive, though uncoordinated aquatic environment monitoring taking place. This monitoring is conducted by a variety of agencies and organizations. The
specific monitoring programs of the case studies are discussed in Chapter 5. In addition, the improvement of present monitoring is recommended with guidelines as to the parameters to be measured and the location of monitoring stations.

E. Discussion

The examination of present protection methods and the applicability of methods across jurisdictions sheds some light on the state of the aquatic environment within the protected areas of British Columbia and Thailand. Internal threats to the protected areas of both jurisdictions can be generally addressed through the use of methods outlined above, e.g. enforcement, boundary demarcation, management planning, zoning, and visitor awareness.

In Thailand, there are additional issues that will have to be addressed before the protection of the aquatic environment can be ensured. These issues include human encroachment, inhabitation of protected areas, and rights to the land/water. After protected area legislation and policy has outlined guidance for managers in these areas, many of the internal threats could be addressed through proper funding and political/administrative support.

External threats, on the other hand, have not been recognized to the same extent in either British Columbia or Thailand. Further work is necessary to provide guidance in dealing with external threats. Additional methods or tools must be developed to address the range of external threats, from development activities immediately adjacent to the protected areas to the distant sources of water pollution flowing into these areas. This guidance may be obtained through an assessment of other protected area systems and jurisdictions and the methods used to address external threats to protected areas.

One important step in addressing both internal and external threats to the aquatic environment is the development of a monitoring system. A monitoring system can provide evidence of the success or failure of protection efforts and therefore point to areas where increased protection is necessary.

The case studies showed a range of monitoring activities within protected areas. In Thailand, the development of routine monitoring by park management is a necessary first
step. In British Columbia, the integration of monitoring activities and the development of a comprehensive monitoring program is important. In both cases, guidance is required to develop a monitoring program that will provide managers with the information needed to help ensure the protection of protected area aquatic environments.
CHAPTER V - DESIGN OF AN AQUATIC ENVIRONMENT MONITORING SYSTEM

A. Introduction

A well developed monitoring system will accurately define the condition of the aquatic environment within a protected area, and identify alterations or impacts that this environment is experiencing. Management based on monitoring results then addresses land use activities that are linked to the environment change.

The aquatic environment as well as its monitoring are quite complex. The aquatic environment is always in a state of flux, over time and space. A monitoring system must distinguish between the natural flux of the environment and human induced change. It is the human induced change that must be accurately defined, its source identified, and measures taken to suspend or minimize impacts.

The remainder of this section consists of an aquatic environment monitoring framework. The framework outlines considerations that must be made when developing a monitoring system. There may be a variety of monitoring activities presently conducted by different agencies or organizations within a protected area. The presence of such programs can be incorporated into an overall monitoring system.

B. Developing an Aquatic Environment Monitoring Program

Many monitoring systems, when considering their size and longevity, may involve much funding. Initial preparation work is therefore important to help ensure the longterm success of a monitoring system. Such work will help ensure that the monitoring results are reliable and consistent with system objectives (Ward and Loftis, 1986).

The framework outlined below builds on work done by Ward and Loftis (1989). The procedure is then tailored to the monitoring of the aquatic environment in protected areas. A similar framework is used by the Inland Waters Directorate of Environment Canada to guide general monitoring system development (Haffner, 1986).
1. Step 1 - Define Information Expectations

Defining information expectations is one of the most critical steps in obtaining a reliable and successful monitoring system. This step provides written evidence that outlines the purposes and limitations of the monitoring system prior to the initiation of any sampling activities (Ward and Loftis, 1989). The reliability of information from an aquatic environment monitoring system depends in part on the conformity of the system to its predetermined objectives and expectations (Kimstach, 1992).

Sampling techniques as well as data analysis and reporting procedures must also be reviewed at this stage. This will help ensure that the usefulness of the sampling results (Ward and Loftis, 1986). A monitoring system will fail if the information obtained is not given to those who are to use the information.

1.1. Management and Monitoring Goals

Monitoring and management goals must be defined at an early stage in monitoring system development. It is important to describe the monitoring system goals and objectives and how the results will be used in management activities - a mission statement.

Monitoring systems may be based on a range of objectives. These objectives may include 1) the measure of incurred damage, 2) the establishment of baseline data, 3) the verification of standards, and 4) the comparison of impacts (Mount, 1976). All four of these objectives may apply to aquatic environment monitoring systems in protected areas.

Guidance in identifying goals can be found in many government sources including B.C. provincial and Canadian federal legislation and policy. In many cases, monitoring systems are developed to meet requirements outlined in legislation or policy. If a monitoring system is required through legislation, the reasoning and objectives of the monitoring system are usually outlined. In many protected area systems, although reference to monitoring is not explicitly referred to in the legislation or policy, the management requirements and goals of protected areas require monitoring activities. It is then the job of the protected area manager to determine the corresponding aquatic environment monitoring system goals and objectives.
1.2. Defining "Aquatic Environment" for Design Purposes

Depending on the context of a monitoring system and what results are expected, the focus of the system will change. At this stage, the focus of the monitoring system must be identified. "Aquatic environment" must be defined with respect to an aquatic environment monitoring system.

The aquatic environment has been generally defined above. At this stage, however, more detail should be given to that definition. This detail will help to focus the monitoring efforts and should include the aquatic environment parameters that are of concern. The characteristics of those parameters e.g. average, maximum, minimum, or trend measurements, are also important.

1.3. The Tiered Approach

The following overview of the Tiered Approach to monitoring should also be considered at the preliminary development stages of the aquatic environment monitoring system (see Appendix A). This tiered approach attempts to deal with the questions of limited time and resources (funding) as well as monitoring system efficiency, while obtaining reliable and useful information. Although this system was originally developed for sediment assessments (Adams et al., 1992), it is applicable to general aquatic environmental monitoring. The use of this tiered approach to monitoring will influence many of the different aspects in the further development of the monitoring system.

This approach allows for a periodic evaluation of the results to determine whether further sampling and monitoring is necessary. Such an approach will identify areas where there may be a breaching of threshold values or where there may be a question or uncertainty over the results. These instances warrant additional sampling to develop conclusive data.

**Tier I** - The first tier is the screening stage. At this point, aquatic environment assessment values are determined. These values, acting as threshold levels, can be seen as standards to which further monitoring results can be compared. The values are determined through preliminary monitoring and assessment of the aquatic environment (the development of baseline information). In some instances, control stations or the development of baseline
information may not be possible within the protected area. In this instance, comparison studies or control stations outside of protected areas may be required.

If further monitoring shows that the threshold values have been breached (e.g. results of the second tier), then more sampling and monitoring is necessary. If not, the environment is not significantly altered and immediate intensive monitoring is not necessary. The development of assessment values or standards may be the biggest task in the development stages of an aquatic environment monitoring system.

**Tier II** - The second tier is the *investigative* stage. At this level, two factors are determined. First, the level of contamination is examined through the monitoring of the aquatic environment. Both chronic and bio-accumulation factors must be addressed if applicable. Second, the zone of influence is determined. This involves identifying the spatial and temporal distribution of the contaminated environment. If this area seems to be quite large, additional sampling may be necessary to delineate the area (see the next tier). If the area is small, the sampling already conducted may be sufficient to spatially define the area of environmental alteration.

**Tier III** - The third tier is the *confirmatory* stage and outlines the in-depth aquatic environment sampling that is necessary to obtain a reliable description of the altered environment. This process will attempt to confirm the suspicions that were developed in Tier II by conclusively identifying the contaminants, their levels, and their specific spatial and temporal distributions.

This tiered monitoring system is meant to be an integrated approach in using existing tools to assess the aquatic environment (Adams et al., 1992). The remainder of the aquatic environment monitoring framework deals with specific steps that are followed in the development of an aquatic environment monitoring system. These steps and actions should be considered and carried out within this tiered approach to monitoring. This will ensure that while making the most efficient use of resources, a reliable environmental assessment is conducted.
1.4. Identify Statistical Methods

The general statistical methods that will be used in the monitoring system must be identified at this early stage. This does not include the actual statistical design. This does include the general statistical methods that will be used to provide the information that is required. The methods chosen will be based in part on the parameters outlined previously (section 1.2.).

The outline of the statistical framework will act as a base for the development of monitoring activities and will influence any further design of the monitoring system. Further delineation is conducted in step two of the overall monitoring framework.

1.5. From Monitoring to Management

Direct reference must be made at this initial stage as to how the results will influence protected area management activities. The monitoring results may shed light on the state of the environment. The results may elicit more monitoring or identify aquatic environment conditions that warrant remedial management activities. The monitoring results that trigger or warrant such activities (e.g. threshold levels) must be outlined prior to the commencement of sampling. This will help to ensure that the monitoring results will be put to their intended use.

In protected areas, monitoring activities may provide baseline information, examine trends in the aquatic environment, or deal with specific pollution concerns. In each of these cases, certain environmental thresholds will warrant management action. The extent of management action and the monitoring results that would trigger this action should be outlined at this stage.

1.6. Reporting Format

The reporting of monitoring results is critical to the success of the monitoring system. The reporting format and the extent of report dispersal are important factors to define prior to monitoring. In addition, the type of information that must be included in the report is important. For instance, different personnel at different protected area planning and
management levels may require different information. The reporting format should provide the data that is expected by the users along with associated data analysis and interpretation.

Further definition of the reporting format can be addressed at the completion of the monitoring system or at predetermined reporting intervals. Reporting intervals, if used, must be defined at this stage, prior to the initiation of monitoring activities. This will help ensure commitment to the adopted reporting system.

2. Step 2 - Confirm Statistical Design Criteria

The use of statistics will be briefly addressed in this report. It must be understood that this discipline is critical to the functioning and success of a monitoring system. Sources for additional information are provided.

In a monitoring program, statistics can play a very important role in three areas: 1) identifying background population characteristics prior to full fledged sampling (pilot studies), 2) detecting changes in the quality of the environment, and 3) quality control (Ward and Loftis, 1986). Population, as used here, refers to certain aquatic environment parameters.

Defining the characteristics of aquatic environment parameters is important. The characteristics of the population will influence the sampling network and the analysis of the data. The second area is the main portion of the monitoring system and involves the assessment of the environment. Statistics must be used as a tool to ensure reliable assessment (Ward and Loftis, 1986). The third area, quality control, is a concept that must be considered throughout the whole monitoring system and is addressed in section 4.1.

Step 2 builds on the outline of statistical methods produced in Step 1. Many assumptions were made in that step about the populations of the aquatic environment characteristics (Ward and Loftis, 1989). This step involves addressing the populations' characteristics and assumptions to ensure reliable and unbiased results.

2.1. Characterize Population

Information on aquatic environment parameters can be obtained from many sources. Previous studies that have been conducted may shed some light on the nature of certain
parameter populations. Previously obtained information in database form can be used in some cases to identify population characteristics (Loftis and Ward, 1981). If so, pilot studies may not be necessary.

If this information is not available and little work has been done on a certain parameter, pilot studies may be required. These studies will help identify characteristics of the parameter population that may influence the development of sampling and analysis procedures.

The statistical methods outlined in this section must take into consideration certain population characteristics. These characteristics or assumptions may include independence of the parameters (in time and space), presence of a normal distribution, and a constant sample variance. These assumptions can be tested, if necessary, in a pilot study.

Aquatic environment characteristics do not tend to follow the assumptions that many statistical tests require for optimum results (Ward and Loftis, 1989). When this is the case, the system designers must use their judgment in identifying the influence these conditions have on the results and make appropriate changes to the sampling and analysis procedures.

In overview, when the characteristics of the population have been identified, the statistical design and analysis is developed so as to guarantee reliable results. The monitoring results look beyond natural variations and accurately assess the "real" variations or characteristics that are the focus of the monitoring system.

2.2. Confirm Methodology

Once population characteristics have been identified and needed remedial action taken, a statement and outline of the ability of the proposed statistical methods to provide the required information is developed. This gives further recognition of the objectives of the monitoring systems and the ability of the chosen statistical methods to meet these objectives.

3. Step 3 - Design Monitoring Network

In the design of the monitoring network, the location of the monitoring stations, the aquatic environment parameters sampled, and the frequency of sampling is determined (Ward
and Loftis, 1989). These three considerations involve the where, what, and when of the monitoring system.

3.1. Where to Sample

When dealing with the spatial distribution of the sampling network, consideration is given to varying spatial scales. Both the "macro" and "micro" scales must be considered (Ward and Loftis, 1989) e.g. from the specific watershed or representative stream to the stream reach and position within the stream.

3.1.1. Representative Areas and Scale

The main principle behind a monitoring system is to determine the present state of the aquatic environment - to sample a certain parameter to determine the average, maximum or minimum value that represents that portion of the aquatic environment watershed. In this sense, the parameter measure should be representative of the aquatic environment in that area.

Past research has examined how to determine the representative nature of a water body or aquatic environment. Beginning with a larger scale, Warry and Hanau (1993) advocates that the selection of representative watersheds (representative of terrestrial eco-regions and relatively untouched areas), can be aided by the use of previously existing land classification systems.

The act of locating stations for sampling involves the consideration of representativeness, although at a smaller scale. Sampling a lake, for instance, may be conducted in a variety of ways. Considerations must include the depth of sampling, the distance from shores, and the distance from outlet and inlet streams and specific point pollution sources. These placement considerations as well as the type of sampling devices must be custom tailored to the specific lake and influenced by the characteristics of the desired information (Hilton et al., 1989).

There are many different aquatic environments that will be included in a monitoring system. The lake environment that was referred to above is one of them. It is important to understand the wide range of aquatic environments: e.g. rivers and streams, lakes, bogs,
swamps, other wetlands, and sediment environments. Each different aquatic environment has
different sampling issues that must be addressed, the specifics of which are not dealt with in
this thesis.

In ensuring accurate monitoring results, scale must be addressed at both the temporal
and spatial levels to ensure reliable measurements (Loftis et al., 1991). Temporal scale
involves, in part, the examination of observations over time and will help addresses seasonal
and diurnal parameter fluctuations. Spatial scale deals more with the adequate placement of
monitoring stations.

3.1.2. Statistical Considerations

Spatial correlation may be evident with some aquatic environment parameters. A
common statistical assumption that must be met is that the sampling measurements must be
independent. This effect of station placement on the interdependence of measurements must
be recognized.

The placement of sampling stations may also be influenced by the need for a
minimum number of stations. This requirement may be based on population characteristics -
again, a statistical consideration on the spatial distribution of sampling stations.

The characteristics of the measured population may also influence the sampling
network. The network must be designed to take into consideration these characteristics so
that the resulting information is unbiased and reliable, fulfilling the preset objectives. An
example of this is the characteristics of lake water quality that was outlined above. The
natural variances that may be found in the population must be identified and procedural
changes made and precautions taken where necessary.

In addition, when biological parameters are considered, life history information and
seasonal distribution and movement information are very important.

3.1.3. Environmental protection

The placement of sampling stations and some sampling techniques may result in
degradation of the environment. Considerations must be made to address possible impacts of
1) initiating the sampling program, 2) routine measurement collection, 3) the removal of sampling stations, and 4) the long-term effects of monitoring stations.

In some protected areas, efforts have been made to deal with these impacts through environmental impact assessments. These assessments must be conducted prior to any activity within the protected areas. Such assessments may be necessary for a variety of monitoring activities including the placement of monitoring stations or for the capture of organisms when biological monitoring techniques are used.

3.2. What to Sample

The aquatic environment parameters selected in Step 1 are given further definition at this stage. The further definition of the parameters is directed by the desired results of the monitoring system and the predicted changes that are expected in the aquatic environment. These considerations help narrow down the parameters and parameter characteristics that must be sampled.

If sufficient correlation can be found between parameters, the sampling of one of the parameters may be reduced or eliminated and identified through regression relationships (Sanders et al., 1983). This may cut down on the number of parameters that must be measured. An example of correlation between parameters is with metalethionien and a variety of heavy metals. Metalethionien is an enzyme produced by fish when they are under stress induced by heavy metals. The presence of metalethionien may identify certain levels of metals in the aquatic environment.

Aquatic environment indices may also be used. Indices can be developed for specific water uses in specific areas. They can be very valuable tools in linking many water parameters to a certain aquatic environment index. Indices can also be used to bridge the gap between those who collect the data and the managers who must understand its implications (Ott, 1978). A word of caution is necessary, however, regarding the impacts that the associated assumptions may have on the accuracy of the indices.
3.3. When to Sample

Monitoring systems may focus on one or two sampling categories. These categories are long term monitoring and single event monitoring. The focus of a specific monitoring system must be the first consideration in determining the timing of the sampling program.

In many cases, long term monitoring involves a program that has a more long term focus. In this case, the sampling mechanisms may be placed within the environment in the long term. This type of monitoring is generally used to either measure trends or determine impacts on an environment due to chronic exposure to pollution.

Single event monitoring, also known as intensive survey monitoring, is the type of monitoring used by regulatory agencies. It can be used to conduct rapid surveys to determine the compliance of the water users to pre-defined guidelines and objectives or to assess specific pollution events. If objectives have been set up for various aquatic environment parameters, such monitoring activities may provide the necessary information.

In protected areas, both types of monitoring programs are necessary. It is important to determine the long term trends within these areas, as their focus for management is the long term sustainability of the natural environment. It is also important to monitor the effects of activities within the protected areas. This may be best met by select intensive monitoring surveys in combination with longer term monitoring activities.

The desired information or the objectives of the monitoring system should guide this decision. In many cases, monetary support may also be a critical factor that determines which type of monitoring is used.

Both types of monitoring involve similar considerations when dealing with sampling frequency. The single event monitoring focus may require more stringent consideration of detail as such monitoring events are more prone to bias and distortion of results.

3.3.1. Sampling Frequency

The consideration of sampling frequency is critical to ensure reliable and conclusive data. The determination of sampling frequency is therefore very important in the design of a
monitoring program and must be directly linked to the statistical methods that were identified in Step 2.

Once standards have been developed for certain parameters, the knowledge of population distributions and characteristics can be used to develop sampling frequencies. All sampling parameters have a certain degree of natural variability. It is this variability that must be identified (long term trend analysis) and addressed through the sampling program.

In general, the population characteristics, combined with the objectives of the monitoring system, influence the sampling frequency. Knowledge and expertise is needed in statistics and aquatic environment populations to determine accurate sampling frequency. The main issues that must be addressed are dealt with in brief here. The following is a list of references for more information on sampling frequency (Butt, 1985; El-Shaarawi and Kwintkowski, 1985; Green, 1979, and Sanders et al., 1983).

3.3.2. Cost-effectiveness

The cost of monitoring plays an important role in determining sampling frequency. Cost effectiveness must be addressed throughout monitoring system design, although it tends to play a critical role in the development of sampling frequency (McEwen, 1993).

The general process of cost effective sampling frequency involves the level of data accuracy. The relationship between sampling frequency and accuracy of data can be determined for an aquatic environment parameter. The changes in accuracy can then be related to changes in sampling frequency (and therefore cost). This relationship can then be used to define the accuracy and corresponding sampling frequency desired.

Please refer to Beckers and Chamberlain (1974) for further discussion of cost-effectiveness.

In overview, Step 3 involves the delineation of the sampling locations and the measurements that must be made at each station. This section provides the necessary information for subsequent steps, the next being the development of operating procedures.
4. Step 4 - Develop Operating Plans and Procedures

As with many of the other steps in this monitoring framework, this step is very important in obtaining reliable and unbiased monitoring results. It involves the delineation of routine operating procedures. These operating procedures must be defined so that it is possible for different people to work on the various monitoring activities and generate consistent results (Ward and Loftis, 1986). The objective of consistent operating activities must be the focus of this step.

4.1. Quality Assurance/Quality Control

During the development of a monitoring network, much consideration must be given to quality assurance/quality control (QA/QC). This issue, although important throughout monitoring system development, comes to light here as consideration is given to the actual sampling activities.

Both sampling and non-sampling errors must be addressed in a QA/QC program (Montgomery and Sanders, 1985). Sampling errors may be incurred through the sampling network design. Non-sampling errors may be realized in the sampling collection and lab analysis procedures. Because quality control is an issue that must be addressed throughout the development of a monitoring system, it is critical to have the support and understanding of quality control issues from the top supervisory positions of the monitoring system, in both field and laboratory situations (Kimstach, 1992). This will allow the importance for QA/QC to be realized throughout the process.

When developing quality control, all the possible sources of unnatural variation must be identified. Actions should be taken to deal with these sources so the reliability of the data is consistent with predetermined objectives.

Conceptually, quality control must be separated from acts of inspection. Inspection involves the acceptance or rejection of an output due to its comparison with accepted standards. Quality control involves the determination of the capability of the processes to meet the predetermined standards (Fetter, 1967).
Another way to deal with quality control has been proposed by Hall (1986). This process involves the use of *data quality objectives* (DQOs). DQOs outline the required data accuracy that is needed to support specific decisions or actions. The development of DQOs must involve both the technical staff as well as the decision makers. This will provide both a broad perspective of general needs and objectives as well as the expertise of technical personnel to provide means to meet these objectives. The work by Hall (1986) is valuable as it explicitly outlines both the procedures and the persons involved in the use of quality control in a water monitoring system. This ensures the consideration of quality control throughout monitoring activities.

For further information on quality control and corresponding procedures please refer to Fetter (1967) and Hansen (1963).

4.2. Sampling

There are four main areas for which operating procedures must be outlined. These are the collection, preservation, transportation, and preparation/analysis of the samples/data. Of these four areas, not all must be addressed for all aquatic environment parameters. The measurement of water volume or velocity, for instance, requires operating procedures for collection and analysis of the data while the sampling of heavy metals requires operating procedures that include all four considerations.

The type of sample collected depends on three factors (Environment Canada, 1983): the objectives of the program, the characteristics of the environment being sampled, and the resources that are available. First, the objectives of the program, including certain aquatic environment parameters as well as their accuracy and precision, will influence the type and magnitude of the collection. Second, the characteristics of the environment will influence collection activities. For instance, the flow regime in a stream or the mixing occurring within a lake will influence the collection of samples. Third, the availability of equipment, materials and collectors will influence the collection procedures.

Preservation of the sample may require refrigeration to slow decomposition processes (organics) or the precipitation of the water quality parameter from the water. This will
prevent any breakdown of the sample that may occur outside of the natural aquatic
environment.

Transportation of samples may also require refrigeration. Rapid transportation and
analysis may also be required due to the degradation of the sample soon after its removal
from the natural environment. This issue is one that may be difficult to fulfill when
monitoring within a protected area. The remoteness of the sampling site may require more
planning and coordination to protect the viability of samples.

The preparation of aquatic environment samples is defined in part by the type of
analysis procedures that will be used. The viability of the sample may also rest on the
preparation procedures. In turn, the analysis of the samples is most dependent on the type of
parameter being considered. The type of parameter will determine the materials and
equipment that are needed as well as the timing that must be followed.

This is a very brief outline of the collection, preservation, transportation, and
preparation/analysis of aquatic environment parameters. Please refer to the specific
references noted above for additional concerns. There are many technical documents that
prove helpful when considering these procedures. Although most of these publications deal
with water quality sampling (e.g. Environment Canada, 1983) the principles can be applied to
many aquatic environment characteristics.

4.3. Data Analysis

Data analysis, in contrast to sample analysis, involves the interpretation of the data to
provide useful information to protected area planners and managers. Depending on the use of
the monitoring system results, the analysis procedures may involve a focus on the central
tendency (or mean) of the data for a given time period. Other situations may warrant the
examination of trends that involve a focus on the distribution of results over space or time
(Ward and Loftis, 1986).

Data analysis must be consistent with the objectives of the monitoring system. The
analysis conducted must provide the information that is required from the system in the form
and format that is required.
When routine data analysis is required, it is important to define the role that it will play in the overall aquatic environment monitoring and management activities within the protected area. Due to the routine nature of this analysis, the findings may not always be analyzed and reviewed. This may result in the loss of information that could prove valuable to protected area managers.

4.4. Data Storage and Retrieval Procedures/Processes

The data storage and retrieval processes must be explicitly defined. This includes defining the computer programs and data format that will be used. This will provide ease of access for reporting purposes. The development of consistent data format and storage will also help ensure the usefulness of the data.

5. Step 5 - Develop Information Reporting Procedure

The general reporting procedures were outlined in Step 1 of this process. It is these statements that are now expanded to provide a detailed explanation of the reporting procedures. The main objective of this reporting section is to fulfill the information expectations also outlined in Step 1.

5.1. Means of Reporting

The use of computing for this process can be very beneficial: from data acquisition or data entry and analysis to database management and automated reporting. If the data has a consistent and accepted format, the manipulation of the data into report form may then be conducted with ease. It is also important to identify the proper use of figures, tables, and text to supplement the data.

Where necessary, the reporting format and style should be consistent with that of other aquatic environment monitoring and management agencies or groups. This allows for the widespread use of the information with the possibility of reducing duplication. This is especially important for many protected areas so that information from protected area monitoring systems is useful for outside interests, both public and private. The value of province- or country-wide aquatic environment monitoring/survey databases is an issue that
has been noted by many government agencies. Such a system would allow for streamlined access to valuable and consistent data, furthering its use and value.

5.2. Information in the Report

The information that must be included in the report must follow the defined objectives outlined in the previous steps. Any superfluous data and information must be excluded from reports (in a valid and organized manner) so as to make the resulting document succinct yet inclusive of all requested information and analysis.

The analysis of data is a very important part of a report. For some protected area planners and managers, the interpretation of the data must be included so that the results can be used to influence further planning and management activities. It is this objective, of linking the monitoring system and its results to subsequent management activities, that is critical to both the success of the monitoring system and the improved ecosystem protection within protected areas.

5.3. Frequency and Distribution of Reporting

Depending on the nature of the aquatic environment monitoring system, the frequency of reporting may be important to consider, e.g. in a long-term trend analysis monitoring system. In this case, the frequency of reporting must fulfill the information objectives that have been defined.

Apart from report frequency, different types of reports may be necessary, depending on their audience or user distribution. The information obtained may be useful for a wide variety of users and their respective needs.

6. Conclusion

As water is critical to the functioning of protected area ecosystems, the development of a water and aquatic environment monitoring program is a task critical to the successful protection and management of protected areas. The framework for the development of such a system was outlined above. This framework can be used as a guide for protected area managers.
It is very important, that throughout the development and implementation of the monitoring program, a link must be made between the monitoring system and management activities, between monitoring results and future management within the protected area. This will ensure that the information obtained from the monitoring program will influence, where necessary, management practices. The result is a protected area management program that is directed by the findings of aquatic environment research and monitoring. Such a protected area is more likely to fulfill its primary mandate that calls for the protection of the natural environment.

C. Monitoring Framework Application and Recommendations

The following is a general application of the monitoring framework to the case study protected areas addressed in Chapters 2 and 3. This application of the framework includes a number of the basic concerns:

1) the extent of present monitoring activities,
2) the integration of past, present, and future monitoring activities,
3) the general location of main monitoring stations, and
4) the type of aquatic environment parameters to be considered.

This brief outline for each protected area is to initiate the application of the framework. The considerations and discussion voiced here must be combined with the intimate knowledge of the protected area environments to produce a successful monitoring program.

This section does not deal with the issues of funding, experimental design, or the exact location of stations. These issues and many of the specifics of developing a monitoring system must be considered by managers that are aware of the resources and resource pressures within the protected areas.

To guide the following discussion, the general mission statement or objectives that will be assumed is the identification of aquatic environment change. The writer assumes that baseline information on the state of the aquatic environment is available, and that limits of acceptable change have been developed for the aquatic environment characteristics of interest. As this may not be the case in the specific protected areas, a separate monitoring program
may need to be developed to obtain baseline information and aid in the development of measures of acceptable change.

1. Doi Inthanon National Park

There is presently very little aquatic environment monitoring being conducted in DINP. No past monitoring projects conducted by the park agency have been identified. The extent of monitoring is limited to a few water quality projects developed by the Chiang Mai University (Chantalamonkon, 1989 and Liawruangrath et al., 1989) and the infrequent monitoring of water quality in the lowland areas downstream of the park by the local hospital (Chom Tong, 1991).

One of the Chiang Mai University studies (Pontip, 1989) took complete water quality parameter measurements in 9 stations along Mae Klang, the main river that drains DINP. The study found that although no heavy metal pollution was evident, the dissolved oxygen, biological oxygen demand, chemical oxygen demand, and coliform levels made the water unfit for drinking. This study, because it examined the Mae Klang at various intervals along the river, should be adopted and continued by the NPD. Due to the placement of stations, it would provide information on the source of pollutants as well as the nature of environmental change.

An additional study (Liawruangrath et al., 1989) conducted similar parameter measurements in the Mae Klang and found that pesticide residues were very high in the agricultural areas within the park especially during the rainy season.

The hospital in Chom Tong district has conducted studies of vegetable crops in the lowland areas below DINP and found conflicting results. One of the four studies conducted in 1991 and 1992 found significant levels of residues from common pesticides and fertilizers. The hospital did take samples of water from four stations along the Mae Klang in 1992 and the analysis showed no significant presence of common pesticide residue. It must be realized that both of these studies were very limited spot surveys and further work is necessary to determine the actual levels of residues in the waters of DINP. Until more information can be
obtained, conclusions can't be determined on the exact impacts of aquatic environment changes.

The results of these projects show some alteration of the water quality. This change is noted by the presence of pesticide and fertilizer residues in the water. Some of the reports were not conclusive, although others have found significant levels of contaminants. The latter found the water unfit for domestic use.

No monitoring has been conducted by the park managers to determine the impacts of land use activities on water quantity or the riparian environment, or whether these changes threaten the park and its resources. Downstream of the park, however, there have been rallies and group meetings held by the farmers to protest both the water quality and low water quantity levels.

With this limited monitoring in mind and the realization of some change in the aquatic environment of DINP, the development of a monitoring system for the park is very important. As populations grow and land use activities continue to intensify within the park, the impacts to the aquatic environment will also rise.

Future monitoring activity within the park should be initiated and maintained by both government agencies involved in the park, the NPD and IRP. It would be beneficial to develop a joint program as both agencies have interests in the park, its resources, and the impacts of cultivation activities on the aquatic environment.

At the time that DINP was visited, there seemed to be an animosity between the organizations which may come in the way of developing a joint monitoring program. The reason for this relationship was not made known, but may be due in part to the sponsorship of IRP by the King of Thailand. Any contact with or comments on the activities of the IRP by other groups (e.g. NPD) may seem disrespectful to the king. In support of the environments within DINP, however, a joint project between the organizations is important for both water management and aquatic environment monitoring activities.

The monitoring activities conducted by Chantalmonkon (1989) can be used as an example of the positioning of monitoring stations within the park (See Figure 24). The
project outlined nine stations along the Mae Klang, the major river draining DINP. The stations, located from its headwaters to the park boundary develop a good backbone to a detailed monitoring program. The maintenance of this system would correspond to the first Tier outlined in the monitoring framework above. Additional monitoring stations may also be necessary throughout the park. The placement of these stations could be downstream of areas of intensive use (e.g. the villages). In this way, any change in the aquatic environment will be attributed to a fairly specific source.

The monitoring conducted within this network must consider the seasonal fluctuations in the aquatic environment that are based on both the monsoon and the nature of the seasonal cultivation of the crops (and application of fertilizer and pesticides).

Funding and logistics may dictate the placement of these stations. If strategically placed, however, the stations will provide an adequate assessment of the aquatic environment that will point to further monitoring or management action if necessary.

The parameters to be considered in the monitoring program within DINP should take into account the range of agricultural activities and their impacts. The parameters considered in the minimal monitoring that has taken place provide this information: dissolved oxygen, biological oxygen demand, chemical oxygen demand, and coliform levels in addition to pesticide and fertilizer residues (depending on the nature of the chemicals used). The regular yet less frequent measurement of heavy metals should be considered as the use of a variety of chemicals, automobiles, and gasolines by villagers and park staff is becoming more prevalent within the park. The monitoring of sediment may also prove valuable in identifying pesticide residue.

In addition to these parameters, the development of biological monitoring techniques could prove valuable. Invertebrates or vertebrates could be used for this purpose. As the funding support for monitoring with DINP is minimal, the initial focus should be on abiotic monitoring, as biological monitoring activities can be quite expensive and may not receive support.
Figure 24. The proposed location of monitoring stations in Doi Inthanon National Park. Modified from the Conservation Data Center (1989).
2. Khao Sam Roi Yot National Park

Khao Sam Roi Yot National Park is a park that is not very conducive to a strict park monitoring plan. Both activities within and adjacent to the park and the inadequate park boundary layout, provide a situation where a more comprehensive monitoring program would be valuable. The following discussion will focus however on the aquatic environment within the park, and assumes that park boundaries and the prohibition of illegal activities are enforced.

There is record of only one monitoring action within KSRY. This was conducted by the park assistant-superintendent and a U.S. Peace Corp volunteer that was working at the park. The monitoring measured the water quality of the freshwater marsh in the park, identifying the presence of pesticide/fertilizer residues in the marsh. Although monitoring was limited in time and space, the results, showing detectable levels of chemical residues, identify the need for further monitoring.

Monitoring stations must be located in both the marshland areas as well as the main canals draining the park (e.g. Khao Daeng). Please refer to Figure 21. The marshland samples must be taken from a range of positions, consistent from one sampling period to the next. The depth of sampling and proximity to outflows/inflows and shorelines must be considered. The significant inflows of the marsh should be identified and used as locations for the monitoring stations.

The season of sampling within the marsh and main streams in the park is important. An adequate range of sampling times must be developed to address the fluctuating levels in the marsh, and the seasonal nature of the cultivation activities within and adjacent to the park.

As the whole marsh is not located within the park, monitoring activities outside of the park may be necessary, and the logistics for this type of activity addressed. In addition, the impact of ground water on the marsh may be very significant. Although the protection of ground water in protected areas is not directly addressed in this paper, its inclusion in the aquatic environment monitoring of a marsh/wetland complex is critical.
Figure 25. The proposed location of monitoring stations in Khao Sam Roi Yot National Park. Modified from Conservation Data Center (1992).
The parameters to be measured within KSRY should take into consideration the nature of the land use adjacent to the park: chemicals used (pesticides, fertilizer, shrimp farm feed), waste from intensive shrimp production and cattle grazing, sedimentation, and the level of brackish water infiltration (due to dredging) to name the major parameters of interest. The use of biological monitoring (plants, invertebrates, and vertebrates) may provide very valuable, especially within the marsh environment.

3. Banff National Park

Extensive water quality monitoring has been conducted within BNP. This monitoring has been limited to the chemical and physical characteristics of the water. Further monitoring of biological characteristics of the aquatic environment - aquatic organisms and populations - has only recently been initiated and water volume levels have not been the focus of any monitoring activities.

The management of BNP (park wardens) conduct routine monitoring exercises along the main use corridors of the park. Nineteen monitoring stations have been identified along the main water courses in the park. Water quality samples are taken from these locations twice a year, at the summer and winter high use periods. Any additional monitoring, including back country monitoring activities, is conducted on a need basis and is usually a one time event unless further work is necessary.

The nineteen stations are located in strategic positions to provide the most efficient and valuable information regarding the nature of the water quality. The location of the monitoring stations also enables fairly accurate determination of possible pollution sources. Further proposals for monitoring station locations are not necessary.

A joint effort by the Inland Waters Directorate (IWD) and Parks Canada conducted monitoring in BNP from 1973 to 1991. The program was developed to provide an overview of water quality changes occurring in the major watersheds within the park and to provide a record of water quality at the downstream boundaries of the park (Block et al., 1993).

The Parks Canada/IWD monitoring started with an intensive inventory monitoring program that helped to define baseline information and values. The program was then
reduced to a "watchdog" type program with three monitoring stations in BNP. These were 1) on the Bow River above Lake Louise, 2) on the Bow River at the park border, and 3) on the North Saskatchewan river at the park border. The program has developed a series of guidelines and site specific objectives for water quality in BNP (Block et al., 1993).

Apart from the monitoring conducted by Parks Canada and IWD, there have been a number of additional monitoring efforts in BNP. These include the monitoring of park lakes (zooplankton, fish populations, and water quality) by the Canadian Wildlife Service (1960s-1980s).

Monitoring occurs at the outflows of all waste treatment plants throughout the park (Banff and Lake Louise townsites and Sunshine Village). The back country lodges in the park are required to monitor water quality below septic treatment areas when a problem is noted. The need for monitoring of water quality at the back country lodges, however, is conducted when advised by park managers, who may not be present when the pollution events may occur.

Presently, monitoring is conducted throughout the park by a number of agencies/organizations (Parks Canada, IWD, Town of Banff, Sunshine village). The coordination or integration of these different groups is important, as common databases of information and common approaches to monitoring will prove useful to all parties involved. The integration of activities must include the timing of sampling, the parameters measured, as well as the nature of reporting procedures.

When one of the groups is planning or conducting monitoring activities, the input from other agencies or organizations may prove valuable. The adoption of common monitoring techniques and reporting procedures/formatting will also improve the usefulness of results to all groups.

The timing of reports and interpretation of results is an area that could be improved in BNP. The IWD, for instance, has conducted monitoring efforts in BNP for over twenty years. The interpretation of results from the last twenty years was made in 1993 (Block et al., 1993). The results, interpretation, and recommendations made in the report are very
important and valuable to the management of BNP. Considerations as to more frequent intervals, or the identification of pollution events as they occur may prove valuable in protecting the aquatic environment.

The extent of IWD involvement in BNP is being reassessed at present, as funding for monitoring is being cut. The maintenance of the current monitoring activities is important. More frequent reports are needed however (Cairns, 1994, Pers. com.).

The presence of the BVWQC provides a very important link between the monitoring of the many groups and the integration of results. The group is calling for the increased monitoring of water quality on the Bow River and is developing a library that includes the reports on past and present monitoring activities. The efforts of the council are resulting in a more holistic view of the issue of water quality, through the involvement of all interest groups and agencies that impact the water. The development of such a group is one way in which to integrate monitoring programs and their results.

In addition, the monitoring that is presently being conducted by IWD (two sites in BNP) should be maintained, be it by IWD or Parks Canada directly, as results will support over 25 years of monitoring initiated by the IWD. In turn, this program can support the Parks Canada monitoring activities.

The present system of monitoring conducted by Parks Canada in BNP provides a more in-depth assessment of the Bow and North Saskatchewan Rivers. The placement of sampling points divides the park into sections that can be more intensively monitored if necessary. If one of the Bow River water samples, for instance, points out certain pollution, possible sources can be identified somewhere between that sampling station and the next upstream station. This present system is valuable and well developed and represents Tier 1 as outlined in the framework above.

The Parks Canada stations are monitored twice a year during high use periods of the summer and winter. Consideration as to increasing the frequency of monitoring must be made. As resource pressure due to development and visitor use continue to increase, there is a need for more frequent monitoring. The system should consider monitoring once a month
for three month periods at high use times. This would provide more detailed information on the water quality of the rivers during high use periods, the time at which significant environmental change may be more likely. Determining the exact timing of sampling should involve an assessment of the water quality parameters in question and the population dynamics of those parameters.

Monitoring of many water quality parameters is being conducted at the three sewage treatment plants in the park (Banff, Lake Louise, and Sunshine). This should continue, as it supports the Parks Canada system in the identification of possible sources of pollution.

Present business licenses for the backcountry lodges require monitoring when it is deemed necessary or required by park officials. As the park officials are not always on site to identify aquatic environment concerns, the business licenses of these operators should be altered to include routine monitoring of the aquatic environment – specifically water quality. Requirements for monitoring and reporting of water quality could include bi-weekly or monthly sampling during high use periods. This monitoring would provide Parks Canada with an ongoing record of water quality at these lodges, to ensure compliance with park objectives. The exact number and location of sampling sites would have to be determined by the operator and park officials.

In addition to the lodges in the backcountry, the monitoring of water quality in the rest of the backcountry areas of the park is also important. Monitoring of the lakes in the high use backcountry, both day use and long trip areas, during high use periods will provide a look into the state of visitor impacts on the aquatic environment in the backcountry. Water quality and, where possible, fish should be monitored for organo-chlorine pesticides and PCBs as atmospheric transportation of these chemicals may be an issue of increasing concern in the park (Block et al., 1993).

The parameters measured by Parks Canada (twice annually) focus on coliform levels. Consideration should also be made to include the water quality impacts of the increased development in the park: e.g. chemicals in storm drain runoff, impacts of chemicals used on the transportation corridors. Although the environmental impacts of these developments
should have been identified and mitigated through the environmental assessment and review process, subtle yet significant impacts to water quality could be occurring. A pilot study may be necessary to identify what parameters should be considered and if such an issue is causing significant change to the BNP aquatic environment.

The monitoring at back country lodges and lakes should focus on coliform levels and the presence of resulting parasites (e.g. *Giardia*). The presence of the protozoan is of increasing concern in BNP's back country (Pacas, 1993, Pers. com.). Such monitoring can help identify areas in which the water is unsafe to drink or use and also guide visitor management activities in these areas.

The monitoring that has been identified above, focuses only on the water itself and not other components of the aquatic environment (Block et al., 1993). Only minor research programs have examined other aspects of the aquatic environment. A graduate student from the University of Montana is studying the impacts of flush events from the Cascade Dam at Minnewanka Lake on the invertebrate communities in the downstream reaches of Cascade Creek. Parks Canada is also working with TransAlta in studying the impacts of fluctuating lake levels on fish spawning in Minnewanka Lake.

Additional aquatic environments that could be considered for Parks Canada monitoring include sediments (bottom and suspended) as well as populations and community structure of a variety of aquatic species, both vertebrate and invertebrate. The use of certain species as indicators of the state of the aquatic environment can prove useful to park managers.

To support both the monitoring efforts outlined and proposed above, and the increased protection of the aquatic environment in BNP, an aquatic environment assessment is required. This assessment should include physical, chemical and biological components (invertebrate and fish communities) (Block et al., 1993).

An aquatic environment management plan was proposed for BNP in the last park management plan (Parks Canada, 1988) but has yet to have been developed. An assessment of the aquatic environment should be a prerequisite to such a plan. Both aquatic environment assessments and management plans, as they have been proposed for BNP, would be very
beneficial developments for all of the case study areas outlined and discussed in this thesis. A plan, following an accurate assessment, would guide the managers in the protection of the aquatic environment.

4. Strathcona Provincial Park

Water monitoring has been conducted in Strathcona for approximately 25 years. Initially, the monitoring had a regulatory nature and was focused around the mining and hydroelectric development activities in the area.

Present monitoring has expanded beyond this primary focus to include visitor use and certain environment characteristics (invertebrate communities and fish species/population levels). The agencies and organizations that are conducting aquatic environment monitoring include B.C.Parks, B.C.Environment, IWD, B.C.Hydro, and Westmin Resources.

B.C.Parks has conducted only limited monitoring activities within the park. One of the programs involves the monitoring of the backcountry lakes within the park. This was conducted about ten years ago to obtain baseline information for the lakes. The lakes are presently monitored for coliform and BOD during high use periods (July/August). This monitoring has outlined the need for visitor caution as high levels of coliform have been identified. The water at the frontcountry campsites is also monitored to ensure its potability.

The findings of the backcountry monitoring, which is focused in the Bedwell/Creme and Forbidden Plateau areas has shown a general decline in water quality over the last five years (Quilter, 1993, Pers. com.). Visitor and resource management actions (strict camping regulations and revegetation programs) are being used to address this water quality concern.

B.C.Hydro conducts monitoring within the Campbell River watershed to support the hydro-electric operations that they have developed. This includes the monitoring of snowpack to predict water supply, the monitoring of flow levels in some of the rivers of the system, and the monitoring of water quality in the reservoirs. IWD plays a minor role in the monitoring of the volume outflow as they have one station on the Elk River.

Westmin Resources have a number of Water Licenses and Waste Permits to authorize their operations within SPP. These permits have stipulations that require them to conduct
monitoring of water quality both in Myra Creek (the watershed in which present operations occur) and in a number of downstream stations within the Campbell River watershed.

One monitoring station is located at the on-land mine tailings dumps site, three along Myra Creek, and three along the length of Buttle Lake. The frequency of monitoring required in the licenses ranges from continuously (e.g. pH at the tailings dump) through to every three months (e.g. many of the chemical measures)(B.C., 1992). The parameters that are to be measured include heavy metals and other chemicals as well as nitrogen, phosphorus and coliform.

This monitoring of Buttle lake was initiated in the early 1980s. This was due to concerns over water quality caused by the dumping of the tailings from the Westmin mines into the lake. The tailings are no longer dumped in the lake, although sampling is continued to monitor the effects of Westmin's activities on the aquatic environment.

In addition to the monitoring conducted by Westmin, B.C. Environment has also historically monitored the water quality in the Buttle Lake watersheds in response to the resource development activities in the area.

The monitoring of Buttle Lake, the focus of B.C. Environment's activities, gave evidence of a declining quality of the lake water. The heavy metal concentrations had significant impacts on the fish and plankton communities in Buttle Lake (Nordin et al., 1985). The metal concentrations peaked in 1980/81. Since that time, improved collection facilities and treatment procedures at the Westmin mine have been successful in causing the heavy metal levels to decline. With this decline, changes have also occurred in the biological communities within the lake. A number of metal sensitive zooplankton and phytoplankton communities have returned to the lake. In addition, the levels of metal-ethiothionein, an indicator of metal induced biological stress in fish, have been decreased to what is said to be normal levels (Deniseger and Erickson, 1991). The health of the lake environment is also shown through the increase in angler success and the large increases found in fish numbers in many of the feeder streams of Buttle Lake.
The absence of some sensitive phytoplankton species does, however, show the environment has not yet fully recovered from its altered state.

This discussion has shown that much monitoring has occurred and is occurring within SPP. There does, however, seem to be very little integration of the monitoring efforts or an active sharing of results. As visitor use increases and the use of park resources continues, the monitoring of the aquatic environment will continue to be very important. Steps must be taken to make use of past results and coordinate future efforts. In some instances, however, duplication of monitoring is necessary for regulatory reasons.

The integration of monitoring efforts can play an important part in the usefulness of the information gained from monitoring in SPP. The actual monitoring of the aquatic environment, due to the different requirements of the organizations, may not prove conducive to integration through joint activities. The methods used to monitor as well as similar data forms and reporting procedures may prove useful, however. With such consistency in form and format, the data would be usable by the different organizations and outside interests as well. Reports, organized in a similar format will make both the information and interpretation common and therefore easier to understand.

Some effort has been made to develop a collection of monitoring studies and reports that have taken place in the SPP area. The present collection is held by a B.C.Environment employee at the regional office in Naniamo, B.C. (Erickson, 1993). Although this limited collection is held in the office, its presence should be more widely displayed to Westmin, B.C.Hydro, and B.C.Parks. With a larger number of parties aware of the collection, increased support and input into the collection could be facilitated and more value given to the collection.

The present monitoring of the aquatic environment has identified numerous sampling sites that ensure an adequate description of the aquatic environment. The monitoring locations in Buttle Lake, as used by B.C.Environment and Westmin, should be continued. Past monitoring included water quality measures at some of the inflow streams to Buttle Lake. These stations should be considered for future monitoring as these locations will
provide evidence of the source of aquatic environment changes. The streams to be monitored at their outflow may include the Elk (into Upper Campbell Lake), Wolf, Phillips, Henshaw, and Ralph Rivers. The monitoring of these rivers include the higher use areas draining into Buttle Lake. This monitoring could be conducted by B.C.Parks or B.C.Environment, or by joint agreement between the two agencies.

Additional river monitoring should include the areas draining the remainder of the park: the Salmon, Moyeha, Drinkwater, Bedwell, Ash, and Puntledge Rivers. The monitoring of these streams should focus on the impacts of high visitor use in both the parameters measured and the timing of sampling.

In addition, the monitoring of the lakes within the park should be continued. Many of the lakes should be monitored frequently during high use periods (July-August). The results of this monitoring should continue to guide the management of visitor use in the back country. Please refer to Figure 22 for the additional monitoring stations proposed.

Parameters to be considered in the river and backcountry lake monitoring should focus on BOD, coliform, and suspended sediments, all possible impacts of visitor use activities. Parameters to be considered in Buttle Lake monitoring should continue to follow the programs of B.C.Environment and those outlined in the Westmin waste/water permits.

D. Discussion

The monitoring framework provides managers with guidance in the development of a monitoring system for the aquatic environments within a protected area. Many of the specifics that play important roles in a successful monitoring system are not, however, addressed in the framework. The framework stresses the need for further expertise in a number of areas, e.g. statistics, sampling design, monitoring techniques.

Because of this lack of specifics, the framework must be used in conjunction with additional understanding of monitoring systems. This may be provided through either experience or through guidance from papers that address these more specific issues. Some of these manuals or sources for guidance have been outlined within the framework.
Figure 26. The proposed location of monitoring stations in Strathcona Provincial Park. Modified from B.C. Parks (1993).

The framework does, however, provide a thorough investigation of the issues and considerations that must be made when developing a monitoring system, whether for aquatic environments or other measures. The framework is a starting point for protected area managers and should supplement their understanding of the aquatic environment within the protected area.
CHAPTER VI - DESIGN OF ADDITIONAL PROTECTION TOOLS

An overview of the protection methods presently used was conducted above, with recommendations to improve their use. Despite the improvement of present protection methods, there are still gaps in ensuring the adequate protection of the aquatic environment. Many of these gaps occur in addressing external threats. External threats, due in part to the lack of applicable protection methods or tools, have been recognized as significant within many protected areas systems (Dooling, 1987, Parks Canada, 1991, and Stottlemeyer, 1987).

The following discussion examines a number of protection approaches that have been used in other jurisdictions. A few of the methods have been or are being used in B.C. In this case, the following discussion makes recommendations to improve their present use.

A. Comprehensive Planning

If the concerns of protected areas were adequately addressed at local and regional planning scales, the protection of the environments within these areas could be improved.

An example of this is in the Northwest Territories of Canada, in and around Nahanni National Park. The park protects the mid-sections of both the Nahanni and Flat Rivers. Present mining activities, along with mineral exploration and proposals for hydro-electric development have caused some concern to park managers. The Nahanni National Park Management Plan attempts to partially address the external threats to the park.

The management plan recognizes the importance of regional planning, water use licensing, and overall development on the park. The plan outlines that through inter-agency cooperation, Parks Canada will ensure that the water quality and ecosystem integrity of the park will be maintained (Parks Canada, 1987). To fulfill this objective the plan outlines cooperation with the Inland Waters Directorate of Environment Canada to determine baseline water quality conditions of the Nahanni and Flat Rivers. In addition, the plan called for the need for regional planning in the areas upstream from the park with the governing agency of the NWT and the representation of the parks interests with the Territorial Water Board for projects affecting the park's aquatic environment.
The political situation within the NWT supports the involvement of the protected area managers in regional planning. The federal government has total jurisdiction over the land and water in NWT. In this way, consultation between the Department of Indian and Northern Affairs and Parks Canada is within the federal government and there is no concern over constitutional jurisdiction issues. This aside, such coordination is important in the protection of protected area aquatic environments from external threats.

With the national parks in B.C., inter-governmental coordination and cooperation is required to address external threats to the protected areas. To fulfill this need, the inclusion of Parks Canada staff in land planning activities would be an important step. More efforts must be made to give such involvement official recognition. Such would improve the consideration given to national park concerns.

In the provincial parks of B.C., the inclusion of B.C. Parks and the concerns of the provincial parks in land use planning is critical. Recent developments in land use planning in the province have attempted to take a more comprehensive view of land use planning at a regional scale (CORE, 1993). Despite this new development, the official inclusion of protected area concerns in land use planning has not yet occurred. Present protected area concerns are voiced through an inter-agency referral process. If other land management agencies have concerns regarding the parks, or B.C. Parks with the activities of other land management agencies, the plans or proposals are referred for comment. Such a situation improves the standing of protected area concerns in general land management. Because the referral takes place one incident or issue at a time, the overall protected area mandate may not be addressed in general land planning and management. In addition, although the referral process does allow the concerns of B.C. Parks to be voiced, the use of either the information provided or the concern voiced by B.C. Parks is not required.

Efforts must be made to improve the inter-agency cooperation in addressing and solving concerns over external threats to protected areas. This can be conducted in part through the involvement of B.C. Parks in all regional and local planning activities.
In Thailand, the land planning mandate is split between many different agencies. The simplification of this situation is critical before any meaningful interagency cooperation can take place. Prior to this change, the protected area concerns must be addressed on a protected area specific basis. Each management team must become involved in local and regional planning activities that affect the protected area. In addition, the park management should also become involved on a project specific basis, e.g. dam development, agricultural development, etc. In support of these protected area specific activities, the NPD and the WCD headquarters should be in contact with the many land planning and management agencies to advocate general protected area concerns.

B. Public Trust doctrine

The public trust doctrine is a concept that can be found in legislation governing public land and water. The doctrine, in essence, holds that "the public, or all individuals in common, have a right to certain natural conditions - in this case instream flows - that supersedes any private rights in the use of the natural resources" (Huffman, 1983, p259) and that the government has the fiduciary duty to hold natural resources in trust for the public (Westwater, 1993). The inclusion of language that infers the public trust, or the explicit statement of public trust has had great impact on the management and protection of the environment in the United States (Ingram and Oggins, 1992). Many of the western states, for instance, have had to include the issue of public trust in the management and allocation of water flows. The doctrine has been used to provide the public, as users or stakeholders, with legal standing and clout in demanding the use and protection of the aquatic environment. The presence of the public trust doctrine has been used to increase the protection of instream water flows to the extent of the nullification of historically approved water rights (e.g. National Audubon Society v. Superior Court of Alpine County in 1983).

The increased use of public trust application can be explained in part by the changing views of the public with regards to the environment. As the population grows and the further appropriation of the limited water resources continues, the importance of reserving water flows for fish, wildlife, scenic value/aesthetics, recreation and water quality is being
recognized. As society's views are changing, the courts are interpreting the public trust to apply to a far broader spectrum of resource issues (Ingram and Oggins, 1992).

A similar doctrine of public trust is found in Section 38 of the Yukon's Environment Act: where it states that the government of the Yukon shall conserve the natural environment in accordance with the public trust. The doctrine of public trust is not addressed directly in the protected area legislation in B.C. The National Park Act, for instance, refers to the duty of the government to preserve the natural environment for the enjoyment of the citizens of Canada but does not address that duty as the public trust. The reference in this legislation to the duty of the government does not explicitly include the concept of "public trust." Whether or not the protected areas legislation implies the public trust will be determined by the courts.

The public trust doctrine can play an important role in the protection of the aquatic environment. Through its use in the U.S.A., the doctrine recognizes the non-traditional values of the aquatic environment and protects corresponding uses of water, e.g. recreation, fish survival, etc. Depending on the way in which the public trust doctrine is stated, the protection that it can offer may differ. The doctrine may for instance protect the recreational and fishery values of a river, but protection for environmental or ecological integrity may be beyond its scope. The delineation of uses covered by the public trust are determined by the way in which it is included in the legislation and the interpretation of the law by the courts.

One important use of the public trust that may develop in the future is with regards to public access to "navigable" waters. Study of the common law of England and a few cases in Canadian law, demonstrates that the principles that support the public trust in this manner are present in Canadian Law. In The Queen v. Meyers (1852). It was ruled that "the great lakes and streams which are in fact navigable...must be regarded as vested in the Crown in trust for the public uses for which nature intended them..." (Mr Justice Field in The Queen v. Meyers in Routhwaite, 1981).

The use of the public trust doctrine as it relates to navigability has the potential to change the protection of instream flows and the public right to waterbodies. If this public trust can be enforced, as it has in the United States, it will require the provinces in Canada to
maintain the public rights to use the waters. The impact of this public trust enforcement on protecting the aquatic environment within and entering protected areas is uncertain. Its success in this manner relies on how public "use" and "navigability" are defined.

C. Minimum Instream Flows

Minimum instream flows (MIF) refer to minimal aquatic environment requirements, beyond merely water volume, for certain values and/or uses associated with water. Certain water uses require certain aquatic environment characteristics to be preserved, e.g. water-based recreation requires certain water flows (water volume, water quality, etc) to enable the safe use of the water. For this example, MIFs can be developed to identify the minimum flows that are required for various types of recreation activities.

MIFs may also be used to protect certain values that are placed in the aquatic environment, values that do not necessarily include uses of the water. These may include the minimum flows that are required for the preservation of fish habitat or minimum flows to ensure the maintainance of ecological integrity.

The concept of MIF and the use of MIF protection of the aquatic environment is an issue that has been discussed and used much in the U.S.A. One avenue where legislated MIFs are used to protect the aquatic environment is in conjunction with the Wild and Scenic Rivers Act (WSRA) passed in the U.S. in 1968 (discussed below). The legislation supporting this river protection system requires the assessment of the instream flows that are required to protect the significant values of the river, e.g. its wildness, aesthetic quality, or potential for recreation.

The instream flow protection mechanism in the WSRA has been used to increase the protection of aquatic environments within the national parks of the U.S. (Gray, 1988). Under the WSRA, the National Parks Service must manage the designated rivers for the purpose of preservation rather than for multiple use, a common consideration within the U.S. national parks. The inclusion of rivers under the Act will help address external threats to the park's aquatic environment. If a national park river is designated under the WSRA, no federal government agencies will conduct or support activities outside of the national parks.
that will detract from the river characteristics that were the focus of its designation. This can help protect the river and the aquatic environment within the national parks from external threats. Due to present deficiencies in the WSRA, however, the ability of the Parks Service to regulate private activities from significantly impacting the instream flows of the rivers is minimal.

Individual states have also made use of MIFs to protect water flow. The approaches taken differ from one state to the next. California case law, for instance, does not recognize instream use without some type of diversion or control over the water. Despite this, instream uses have been recognized as important and future appropriations must consider these instream flows (Colby, 1990). Recent (1983) recognition of the public trust doctrine in California law has provided additional protection to the aquatic environment.

Another approach to instream flows is used in Montana. Montana passed legislation in 1983 that allowed the state government to appropriate instream flows in the interest of the public. Appropriations have been made in the Yellowstone River basin and efforts are also being made to protect instream flows in a number of other important river basins (McKinney et al., 1988).

The first stage of considering MIFs in the management and protection of the aquatic environment is the assessment of the flow requirements attributed to certain uses or values. This can be done using a variety of methods, one being the U.S. Fish and Wildlife Service's Instream Flow Incremental Method. This method determines the MIF for fish through predicting the potential fish habitat available for each life stage of a species as a function of flow. This method was used in support of efforts to obtain water rights to the Red River for instream uses and values.

Requirements for recreation is another issue that is considered in many MIF studies. In some cases, e.g. when recreation use is based on fish presence, the MIF for the preservation of fish habitat can be used as a measure of MIF for recreation use. In other cases, the direct requirements of recreation use must be determined. Water quality may also be an issue of consideration in MIF requirements. The presence of toxic chemicals at safe
ambient levels can be used to represent the minimum instream water quality required (Garn, 1986).

As the use of MIF has been entertained in the U.S. for over 20 years, methods have been developed to link aquatic environment characteristics with uses of and values placed on the water. Much work would be necessary in B.C., perhaps building on the efforts in the U.S., to determine the water flow requirements for different uses of, or values placed on, the aquatic environment (Anderson, 1982).

Due to the provincial jurisdiction over most water issues and situations, the development of instream flow legislation is best left to the B.C. government. Although the federal government has jurisdiction over a number of water issues (outlined in Chapter 3), the jurisdiction of the provincial government over water is far more reaching.

As there is presently no consideration of instream flows in provincial legislation and only minimal consideration in federal legislation in Canada, effort must be undertaken to remedy the situation. Some effort was initiated by the B.C. provincial government in recent years to address minimum instream flows, amongst other issues (B.C., 1991c). It is yet to be determined if anything will come of that program, or if other provincial initiatives will address the lack of recognition given to instream flows.

One area where the development of provincial minimum instream flow legislation would come into direct conflict with the federal government's mandate is in fish habitat. The federal government has jurisdiction over the protection of anadromous fish and their habitat. As fish and fish habitat are an important part of many minimum instream flow situations, this issue is sure to come to light if the province were to develop such legislation.

A strong recommendation is voiced here for the development of instream use legislation. Passing instream flow legislation would most likely be difficult and the jurisdiction of both the federal and provincial governments in the protection of instream flows will have to be defined. Despite uncertainty and difficulty, the passage of such legislation has the potential to provide unprecedented ecosystem based consideration of instream values such as fisheries, aesthetics, ecological integrity and environmental protection.
The presence of MIF legislation would improve the consideration that these values have in land use and resource use planning activities. MIF legislation will also help protect water flows entering protected areas. It would provide an avenue by which managers can address external upstream threats to the protected area environments.

D. Corridor Protection Programs

Corridor protection programs are programs initiated or run most commonly by governments to protect the values attributed to certain corridors. "Corridors" refers loosely to rivers, trails, roads, or travel routes. The values protected in a corridor protection program can vary significantly, including scenic/aesthetic, historic/cultural, recreation, wildlife/fisheries, and ecosystem protection values. The corridor programs reviewed here focus on those that protect river or waterbody corridors. This discussion will focus on the ability of corridor protection programs to aid in the protection of the aquatic environment in its natural state as it enters protected areas.

Although no corridor protection programs have been adopted in Thailand, a number of programs have been developed in B.C. (provincial programs) and in Canada (federal programs). The Canadian Heritage Rivers System (CHRS) is a program that was initiated by the federal government of Canada in 1984 to ensure the management of significant Canadian rivers. The rivers were deemed significant on the basis of their natural heritage, human heritage, and recreational use or potential. B.C. was the latest province to become a part of the program (1993). The main drawbacks that kept the province from joining included the lack of funding and federal support to the process, the stringent integrity guidelines that must be met before a river could become a part of the CHRS, and the concerns over sovereignty issues. The latter concern over sovereignty is the main reason why both Alberta and Quebec have not yet joined the CHRS.

The CHRS is a program sponsored by the federal government, and yet relies on the initiative and political will of the provinces. A management plan, developed by the government agencies that have jurisdiction over the river, guides the management of the river
after designation (Parks Canada, 1984). The lack of funding and legislative backing for the project causes the program to fall short of increasing the protection that is given to the rivers.

In B.C., the only rivers designated under the CHRS are within protected areas, and the CHRS does little to add to their protection. It is yet to be tested whether the CHRS will help improve the management and possible protection of the aquatic environment outside of a protected area. Efforts should be made in B.C. to use the CHRS to protect rivers that, although outside of protected areas, are critical to the integrity of these areas. If this does occur, this national program has the possibility of improving the protection of the aquatic environment (river) entering a protected area. Present use of the CHRS shows that the program adds more to the publicity of the river than to its improved protection.

The corridor programs initiated in B.C. by the provincial government have focused on protecting recreation values of rivers and other recreation corridors. Many of the initiatives were developed with no legislative support and no official advocate within government, and so remain incomplete. Throughout the rise and fall of corridor programs, the call was made for the provincial government to join the CHRS and provide a provincial program that could carry on where the CHRS left off. Such a corridor program has not yet been developed.

In 1985, the Recreation Corridor program was adopted by the B.C. provincial government to identify, protect, and provide for the recreation use of corridors that are of provincial and regional significance (B.C., 1985). The program was developed to facilitate cooperative interagency and public action. Although the guidelines for designation were outlined in the program, they were never officially established. The program was also misinterpreted as a strict protection effort rather than a unique means to establish recreation corridors (Westwater, 1993). Due to the lack of guidance for and acceptance of the program, it was abandoned shortly after its inception.

The draft B.C. Rivers and Trails Program was developed in 1991 to provide a framework to identify and manage significant rivers and trails for recreation in an integrated land use setting (BC, 1991b). Although this program seems to address the misconception of the preceding Recreation Corridor program, critics were quick to point out that it had
similar deficiencies as its predecessor. The criteria for designating corridors are vague and the management planning framework is fraught with inconsistancies. In addition, even though the program uses an integrated land use setting, there are no procedures to deal with disputes or determine tradeoffs (Paisley and Solin, 1993). The program, not yet implemented, is also very complex and prone to political interference (Westwater, 1993).

This overview of the corridor protection initiatives of the provincial and federal governments shows the present void of adequate corridor protection in B.C. Work is needed to provide a program that will be successful in protecting corridors for recreation and other uses. Its use in protecting aquatic environments entering protected areas must also be recognized. Corridor programs will help address many external upstream threats to the aquatic environment in protected areas.

The examination of corridor programs used outside of B.C. can provide insight into the eventual development of a successful program in the province. The Wild and Scenic Rivers Act (U.S.A., 1968) was developed to protect rivers in the U.S.A. The program makes use of the concept of minimum instream flows, outlined earlier, and so has much more depth and weight in protecting river corridors that any of the programs in B.C. The Act was passed in the U.S.A. in 1968 to address the issue of minimum instream flows and non-traditional values (recreation, environmental protection, scenic/aesthetic) placed on the water resource. The Act outlines three classification schemes for wild and scenic rivers: wild rivers which are generally free from impoundments and generally inaccessible except by trail, and with watersheds or shorelines essentially primitive; scenic rivers which are free from impoundment with shorelines or watersheds still largely primitive and shorelines largely undeveloped but accessible in places by road; and recreational rivers that are readily accessible and may have some development (Utter and Schultz, 1976).

The development of wild and scenic river legislation in the U.S.A. provides a good example, and a first step in the improved protection of instream flows within rivers. Due to the program's limited scope (stringent requirements) and the lack of regulatory power by the managing agency, its ability to adequately protect instream flows is hampered (Gray, 1988).
As the WSRA falls short in this respect, more effort is needed to increase the protection of instream flows (Grady, 1975). The success that the WSRA does provide, is due mainly to its support through legislation.

In addition to the WSRA, individual states have developed programs, many of them legislated, that have similar objectives as does the federal counterpart (e.g. California, 1972). In this way, additional protection can be given to rivers that may not exactly fit the federal requirements for designation but are still recognized as significant.

An assessment of past corridor protection programs in B.C. was conducted by Westwater Research at the University of British Columbia. They proposed, among other things, the support of a corridor program through legislation (Paisley and Solin, 1993). It was also recognized that although use of legislation to support such a program may take time and may cause some difficulty in the passage, it would aid in ensuring the ultimate success of the program.

The development of a corridor protection system may also prove valuable in conjunction with the instream flow legislation. Such legislation would support a corridor protection system that is based on the nature of the values placed on the corridor.

The protection tools outlined above should be considered in both Thailand and B.C. to address the many external threats to the protected areas. The application of these four protection tools occurs beyond the individual protected area scale as the sources to the threats go beyond protected area boundaries. Action must be taken, therefore, by the governments of the jurisdictions (Thailand, British Columbia, and Canada) to ensure, within protected areas, the protection of aquatic environments from external threats.
CHAPTER 7 - CONCLUSIONS

What considerations are given to the protection of the aquatic environment within or entering protected areas? Are managers given ample means to protect the aquatic environment? These were two of the questions that were posed at the start of this paper. The review of aquatic environment protection in the protected areas of B.C. and Thailand gave evidence to address these questions.

Many land use activities place pressures on the aquatic environment within the protected areas of Thailand. From the siltation and high water use from villagers within the protected areas to the water quality impacts from intensive external development, the aquatic environment is influenced by a range of land use activities. The protected areas in B.C. showed a less intensive yet significant presence of aquatic environment threats, from the impacts of fluctuating water levels and mining activity to water quality concerns over high visitor use and facility development. Although the water resource was addressed in the management plans of these areas (except KSRYNP as it did not have a plan), significant threats and impacts to the aquatic environment were still at large in these protected areas.

Improvement was evident in some instances as efforts were made to address the aquatic environment as a whole (Parks Canada, 1988). The need for an aquatic environment monitoring system has also being recognized (Cairns, 1994, Pers. com. and Charoensiri, 1993, Pers. com.). Concrete evidence of change that will increase the protection of the aquatic environment has not yet developed as increasing pressures are placed on the aquatic environment in these areas.

The examination of protection methods showed a variety of approaches to address internal threats to the aquatic environment - from the increased awareness of protected area visitors to licensing of development activities. Although deficiencies were noted in each of the case studies, many of the issues could be dealt with through either proper enforcement and regulation or the use of internal protection methods being used in the other areas. These methods include the use of licensing activities, zoning, and consistent enforcement.
Successful protection methods to address external threats were all together lacking, however. From vague consideration in land use planning activities to the use of public awareness and lobbying, the methods were generally dependent on the willingness of those involved and not required or backed by legislation.

Recommendations were made to improve the protection of the aquatic environment from both internal and external threats. In addressing external threats, the discussion examined the use of legislated instream flows, the public trust doctrine, and corridor protection programs. All recommendations attempt to give the aquatic environment concerns of protected areas more clout in the planning and management of surrounding lands.

One issue that was strongly evident, more in the Thai protected areas than in B.C., was the lack of aquatic environment monitoring activities. Where monitoring programs did exist, the managers would benefit from more coordination and integration of the monitoring activities.

Aquatic environment monitoring represents the first step in the adequate protection of this environment. The development of an aquatic environment monitoring system within or outside of a protected area is quite complex. Developing a monitoring system within a protected area also warrants the recognition of specific issues and considerations. These issues have been addressed in the framework above and their consideration helps to ensure the development of an accurate and efficient monitoring system.

If a monitoring system is developed properly, it will provide both state of the environment information and evidence of environmental change. When significant change has been detected through a monitoring system, managers can call for increased protection efforts. These may include protection methods presently used, but if addressing external threats, additional methods are needed.
REFERENCES


Conservation Data Center. 1989. The Birds of Doi Inthanon National Park. Department of Biology, Faculty of Science, Mahidol University, Bangkok. 55p

Conservation Data Center. 1992. The Birds of Khao Sam Roi Yot National Park. Department of Biology, Faculty of Science, Mahidol University, Bangkok. 62p.


Mischung, Roland. (1986). *Environmental Adaption Among Upland People of Northern Thailand: a Karen Case Study*. Frobenius Institute, University of Frankfurt, West Germany.


Parks Canada. 1995a. Data received from the National Parks Systems Branch, Park Canada, Hull, Quebec.


RFD. 1993a. Forestry Sector Master Plan. Section on the Conservation of Ecosystems and Biodiversity. Thai Royal Forest Department.

RFD. 1993b. Forestry Sector Master Plan. Section on Watershed Management. Thai Royal Forest Department.


*Prepared by* Associated Engineering Alberta, Ltd.

Trisurat, Yongyut. 1994. Personal Communication. Former park official - National Parks Department, Royal Thai Forest Department, Bangkok, Thailand.


APPENDIX A

A visual guide to the tiered approach within the aquatic environment monitoring framework of Chapter 5. Modified from Adams et al. (1992).

Are threshold values or standards available

No —> Develop threshold values

Yes

TIER 1
SCREENING

Conduct Monitoring (general and non-intensive)

Threshold values not exceeded

No further immediate monitoring necessary

Threshold values exceeded

TIER 2
INVESTIGATIVE

Addition monitoring necessary (to define zone of impact)

Zone small (can define area of influence and source of change)*

Zone size large (additional definition required)

TIER 3
CONFIRMATORY

Additional monitoring necessary (to give required definition to zone of impact)

Zone small (can define area of influence and source of change)*

* When a specific zone of influence and source of environmental change is determined, management action can be recommended