AQUATIC HABITAT MAPPING OF THE AOSERP STUDY AREA (1978): ASSESSMENT AND RECOMMENDATIONS

by

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1. INTRODUCTION

During 1978, a number of aquatic projects were funded by Alberta Oil Sands Environmental Research Program (AOSERP) using a habitat inventory and mapping approach. Initially, preliminary recommendations were sought for the mapping of aquatic habitat parameters for the AOSERP study area (Figure 1). A data gathering method and map preparation procedure was recommended (Brown et al. 1978) closely following procedures developed by the Resource Analysis Branch (RAB) of the British Columbia Ministry of the Environment (Chamberlin and Humphries 1977).

Initial field work using such an inventory procedure was carried out by biologists from the Freshwater Institute (FWI), Winnipeg, Aquatic Environments Limited (AEL), Calgary, and Renewable Resources Consulting Services Limited (RRCS), Edmonton, in three study locations within the AOSERP study area. Both FWI and AEL carried out the inventory as part of more intensive fisheries investigations whereas the primary thrust of the RRCS investigation was the inventory itself. FWI biologists were responsible for the Muskeg and MacKay rivers, while AEL biologists worked mainly on the Hangingstone and Horse rivers and the portions of the Clearwater and Christina rivers within the AOSERP study area. RRCS biologists studied the lower portions of the Firebag, Marguerite, Ells and Steepbank rivers within the AOSERP study area.

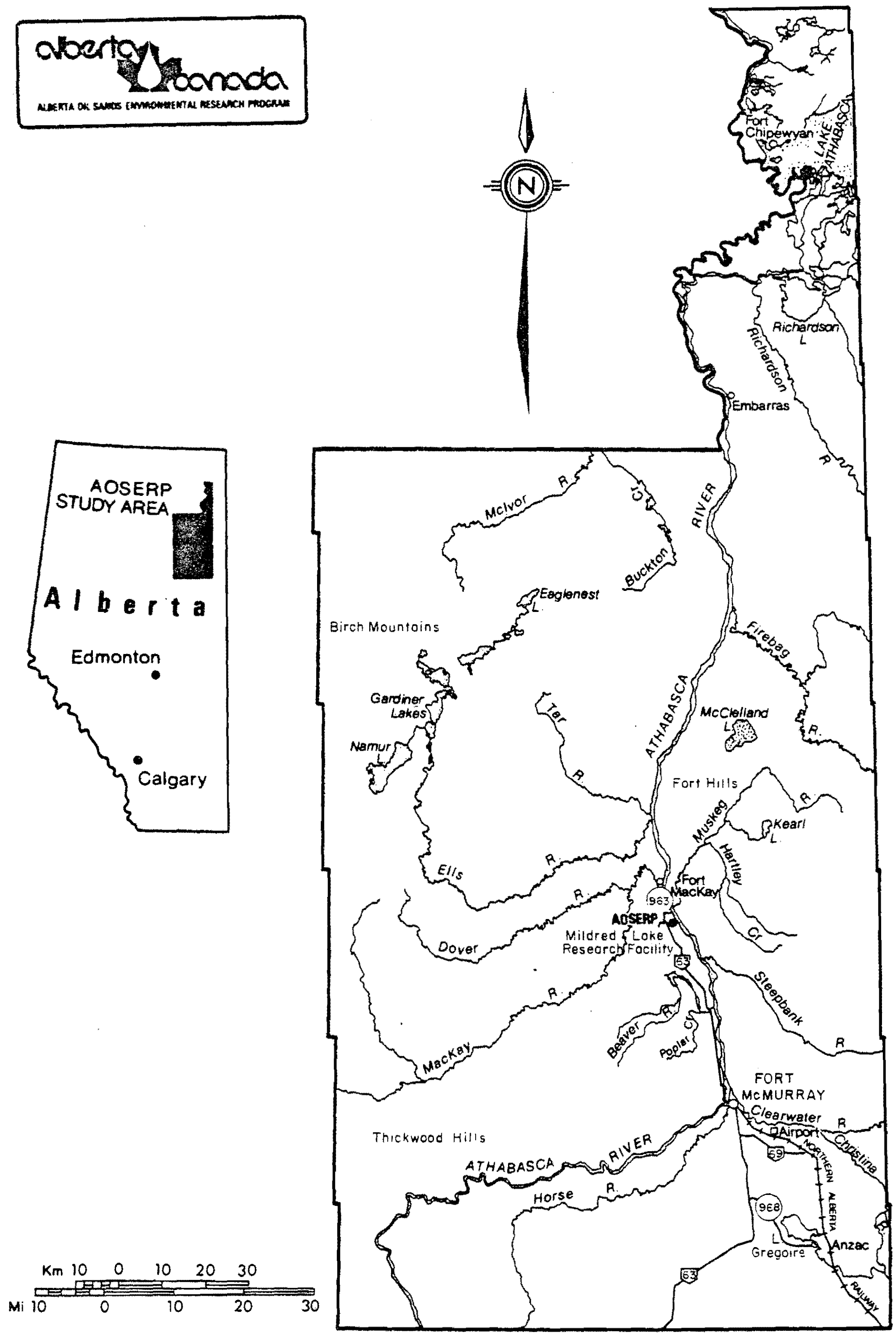


Figure 1. The AOSERP study area.

2. REPORT OBJECTIVES

In order to acquaint AOSERP contractors with the philosophy and structure of aquatic inventory as conducted by the Resource Analysis Branch, a workshop was held on the 20, 21 September 1978 (Wrangler and Seidner 1979). At this workshop the rapid evolution of the RAB system was discussed and the incompatibility of the Brown et al. (1978) recommendations with the present RAB format was highlighted. This report was commissioned by AOSERP in order to review the present status of the RAB system and to recommend a suitable approach for the ongoing AOSERP aquatics inventory program.

The objectives of this report are:

1. To assess the work carried out in 1978 for completeness and to determine if this material is compatible with the procedures developed by the RAB;
2. To recommend procedures for adoption by AOSERP to set up an adequate biophysical mapping base including:
   a. the geographical extent of the study area,
   b. training of an inventory staff,
   c. the availability of 1:50,000 NTS base maps and recent aerial photography; and
3. To advise AOSERP of the methods and costs of the RAB aquatic habitat inventory procedures.

Throughout this report I have assumed that the reader is familiar with the objectives and methods of the RAB aquatic habitat inventory. The reader should also note that a critical review of the various management applications of the RAB is not part of this report.

3. ASSESSMENT OF THE 1978 AOSERP AQUATIC HABITAT INVENTORY STUDIES

A comprehensive assessment of the work carried out in 1978 is not possible at this time since reports by FWI and AEL are not yet available. However, a general assessment of the approach, field procedures, and adaptation of the RAB techniques has been conducted.

The report entitled "Preliminary Recommendations for Mapping of Aquatic Parameters for the AOSERP Study Area" (Brown et al. 1978) was completed in March 1978. Part of this report provided recommendations on the inventory of the aquatic systems in the AOSERP area. These recommendations were adapted from the RAB system (Chamberlin and Humphries 1977). Unfortunately, most information provided in the report is outdated due to the rapid inhouse development of the RAB system. Also, many of the adaptations and modifications of the RAB system suggested by Brown et al. tend to confuse or complicate the mapping of aquatic data and are functionally questionable. For example, the reach cards, point cards, and list of major aquatic habitat parameters for mapping are not acceptable if AOSERP plans to use the RAB system for computer storage, mapping, or digitizing in the future. The development of the reach code by Brown et al. (1978:14) is also questionable. They have unduly complicated the function of the mapping procedure and have included many parameters that are impossible to obtain during a rapid inventory. For example, parameters such as maximum seasonal stream temperature (± 1°C) or minimum dissolved oxygen (mg/l) are impossible to obtain unless the survey is done repeatedly (seasonally). Other parameters such as velocity, depth, and turbidity fluctuate widely and are meaningless except as a description of the conditions on the date of the survey.

To summarize, the recommendations of Brown et. al (1978) should not be followed by AOSERP if they intend to proceed with mapping, computerization, and interpretative research using the RAB system. I would recommend the use of the most recent RAB aquatic inventory techniques.

As I have already mentioned, the 1978 field-inventory program was carried out in three study areas. Each area was studied by an independent organization. This approach has resulted in the following drawbacks.

1. Comprehensive training of crews in the airphoto interpretation, field work, and compilation of maps was not undertaken before the programs were carried out. RAB personnel undergo training in a one-week workshop prior to field work. All crew chiefs (reconnaissance observers) have a minimum of one year of experience.
2. Since the habitat analyses were carried out by three independent organizations, the results will be variable. Much of the data gathered during the aquatic survey is based on interpretations or judgements by field personnel. Because of the number of individuals involved and the lack of a common training program, it is highly unlikely that the results (especially with respect to the physical parameters) will be comparable.
3. Because FWI and AEL did the aquatic habitat inventory as a small part of larger fisheries studies, the aquatic habitat inventory possibly suffered as a result of time constraints, budget contraints, or low priority within the study design.

Table 1 indicates the areas studied in 1978 along with comments on potential problems with the data base obtained. This table shows clearly that the 1978 work is incomplete. The reasons for the incompleteness include:

1. Field crews were not familiar with RAB procedures;
2. Air photo interpretation of background research on survey areas prior to field work was not carried out;
3. High water conditions (flood level) reduced the quality and completeness of data during some surveys;
4. There was incomplete watershed coverage in almost all cases;

5. Use of the Brown et al. (1978) report caused confusion about techniques, symbols, etc.; and
6. The AOSERP aquatic workshop was held after field work was completed (i.e., 20 to 21 September 1978).

Although these field studies have not conformed to the proper RAB format, a great deal of valuable information has been gathered on the fish, benthos, and on many physical and chemical parameters. This information should provide a substantial base for the 1979 program and that work in the study area can be reduced greatly by incorporating this information into the 1979 survey. Cross checks should be made on all streams to ensure that the existing information can be adapted into the final product with a high degree of consistency and compatibility. Further work is necessary for all watersheds. Previously collected biological data can always be added to the data base and should be examined in detail preceding field studies. However, rather than relying on physical descriptions of dubious quality, it would be better to reinventory the whole study area.

Table 1. Aquatic habitat analysis carried out during the 1978 field season.

Research Organization	Watershed Surveyed	Coverage	Problems Encountered	Comments
Renewable Resources Consulting Services Ltd. (contract transferred to LGL Ltd.)	Firebag River	The mainstem of the river from its confluence to the AOSERP boundary.	High water conditions during the fall survey Base map coverage incomplete (1:50,000 scale).	Inventory of the watershed is incomplete. Except for the Marguerite River no tributary rivers were surveyed. Mapping at 1:50,000 is incomplete. Airphoto interpretation and initial survey prior to AOSERP aquatic system workshop.
	Marguerite River	The mainstem of the river from its confluence with the Firebag River to km 75.	as above	as above
	Ells River	The mainstem of the river from its confluence to Gardiner Lake.	High water conditions were not as severe as in other rivers. Turbidity was still high.	as above
	Steepbank River	The mainstem of the river from its confluence to the AOSERP boundary.	High water conditions during the fall survey.	as above

continued ...

Table 1. Continued.

Research Organization	Watershed Surveyed	Coverage	Problems Encountered	Comments
Freshwater Institute[a]	MacKay River	Six points were surveyed from the confluence to the Dunkirk River.	AOSERP aquatic system workshop was not held until after field work was completed.	Information gathered for the survey was generally obtained from study sites established for the intensive fish program. Point samples were not chosen to be representative of the various reaches.
		Two points were surveyed on the Dunkirk River.	Brown et al. (1978) reach and point cards used for survey.	
		Two points were surveyed on the Dover River.	Inefficient use of helicopter using a two man crew. Helicopter not at the disposal of the survey crew.	Mapping will not be undertaken following the Resource Analysis Branch format.
				No air photo interpretation prior to field work.
	Muskeg River	Seven sites were surveyed on Muskeg River.	as above	as above
		Three sites were surveyed on Hartley Creek.		
		Two sites were surveyed on the unnamed creek flowing out of Kearl Lake.		

continued ...

Table 1. Continued.

Research Organization	Watershed Surveyed	Coverage	Problems Encountered	Comments
Aquatic Environments Limited[b]	Hangingstone River	Nine points surveyed	High water conditions during part of the survey. Budget constraints for completion.	No airphoto interpretation was undertaken in advance for any of the areas surveyed. Reaches were not designated. Mapping incomplete.
	Horse River	Four points surveyed along the mainstem of the river.	as above	as above
	Gregoire River	as above	as above	as above
	Christina River	The mainstem of the river from its confluence to the Gregoire River.	as above	Most of this watershed has not been inventoried. Mapping very incomplete. Many of the physical measurements were not done at points that were sampled. No air photo interpretation prior to field work.

continued ...

Table 1. Concluded.

Research Organization	Watershed Surveyed	Coverage	Problems Encountered	Comments
Aquatic Environments Limited	Saline Creek	Two points were surveyed along the mainstem of the creek.	Much of the area was difficult to land in with helicopter. Fort McMurray airport control limited flights in this area thereby negating proper inventory procedure.	No air photo interpretation was undertaken in advance for any of the areas surveyed. Reaches were not designated. Mapping incomplete.
	Saprae Creek	Three points were surveyed along the mainstem of the creek	as above	as above

[a] Personnel communication from Bill Bond (Freshwater Institute, Winnipeg; letter dated 21 December 1978)

[b] Personnel communication from Derek Tripp (Aquatic Environment Limited, Calgary; verbal communication January 1979)

4. ADAPTATION OF THE RAB METHODS TO THE AOSERP STUDY AREA

4.1 PROPOSED STUDY AREA

The watershed has generally been recognized as the basic ecosystem unit involved in lake and stream inventory (Mullan 1978). The RAB has designed the organization and interpretation of data on a hierarchical basis with this concept in mind. Watersheds have been chosen as the basic ecosystem unit for management of lotic waters because of the dependence of each component on all other components of the watersheds. Any changes in the characteristics of headwater streams or channels may ultimately be reflected throughout downstream reaches. The converse relationship is also often true (e.g., the blockage of fish migrations).

Because the boundaries of the AOSERP study area do not follow the watershed boundaries, the AOSERP study area cannot be used for a properly conducted aquatic habitat inventory. In 1978 many of the studies were confined by the AOSERP study area (see Table 1). This has definitely restricted the applicability of the data for future impact analysis and management.

The possible exceptions to the study of watersheds will of necessity be the Athabasca and Clearwater rivers. The large size of these watersheds precludes complete study by AOSERP. Within the boundaries of the study area these rivers should be divided into reaches and mapped. However, comparative studies using the RAB interpretative techniques cannot be applied.

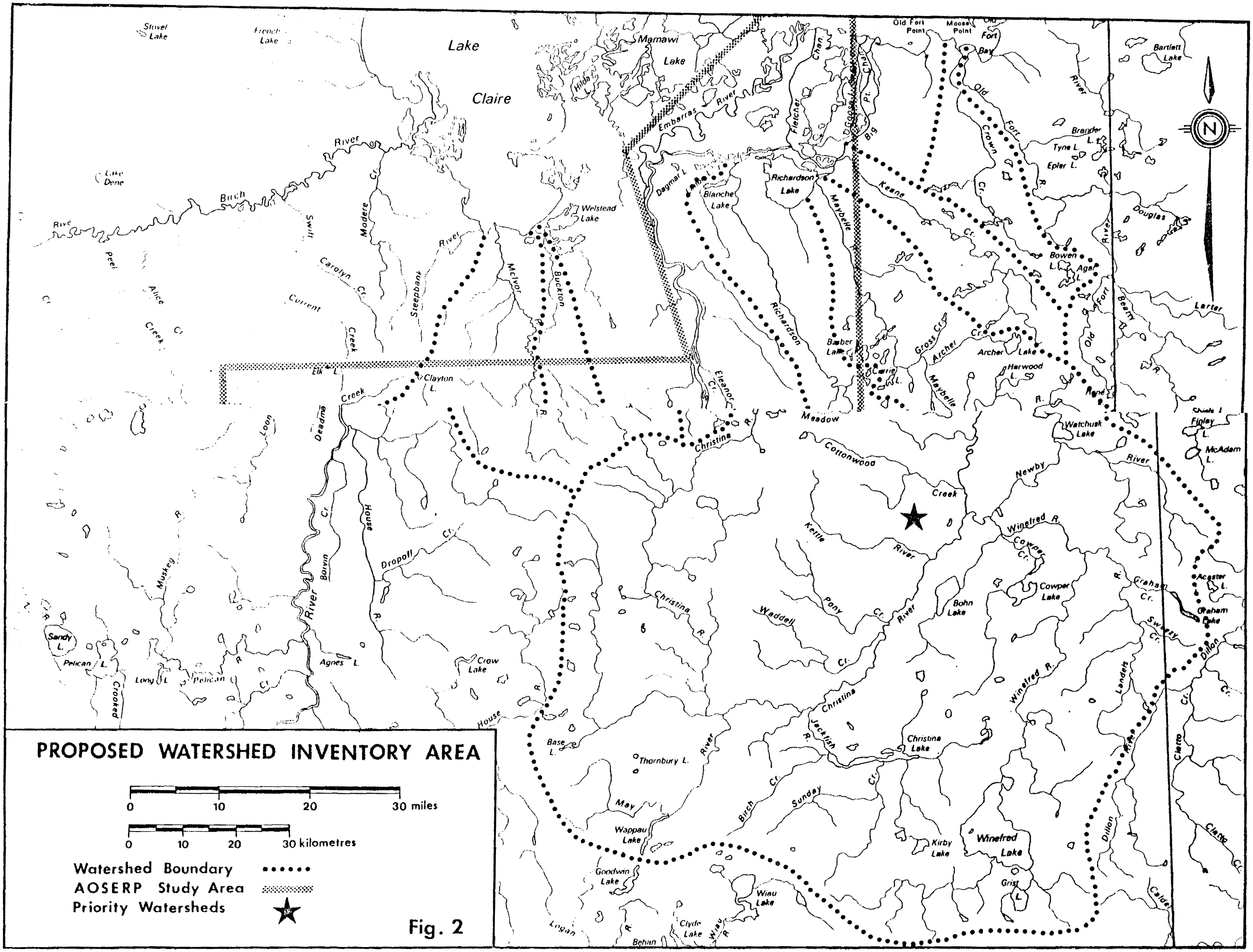
The geographical extent of the proposed study area for the 1979 field season should take into consideration both the watershed concept and the future extent of development. All possible development sites and townsites should be considered, but more important is the assessment of all possible corridor routes which includes roads, rail, pipelines, and hydro lines. Since developers usually have a wide range of options open to them it will be essential to have data available to analyse all of these possible options.
A number of *in situ* recovery techniques, both thermal (steam injection, combustion, electrical, nuclear) and non-thermal (dilutents,

emulsification, bacterial) are under consideration at the present time (Humphreys in review). The data base generated by the inventory procedure should extend over a wide enough area to ensure that the effects of future developments can be assessed without additional field work. All watersheds are considered important but those of highest priority have been identified and are indicated in the map of the proposed study area (Figure 2). However, new developments may require extensions of these boundaries or may change the watershed priorities considerably. The proposed study area should be reviewed before the 1979 program commences to ensure that all anticipated future developments have been taken into consideration.

4.2 WATERSHED CODING

In an aquatic system workshop (20 to 21 September 1978) presented by T.W. Chamberlin and E.A. Harding of the RAB, the importance of the hierarchical coding of watersheds was stressed. The major objectives of the watershed coding system are to prevent the loss of data and to organize the data for retrieval. A coding system (based on the system used by the RAB) was developed for the AOSERP study area by Brown et al. (1978). However, it did not extend beyond the boundaries of the AOSERP study area and did not take into consideration the watershed concept as developed by the RAB. (The AOSERP code does not include the entire Athabasca River watershed.)

Since watersheds are hierarchically related, a coding system should be developed for all of Alberta. The master dictionary of watershed codes should be maintained by one of the government line agencies (i.e., Alberta Environment or Alberta Recreation, Parks and Wildlife). If other government agencies are to successfully use the information generated by the AOSERP aquatic survey it must provide a logical structure for "collating data within larger systems, providing comparison of properties between systems, and facilitating upstream-downstream analysis" (Chamberlin 1977).



PROPOSED WATERSHED INVENTORY AREA

Fig. 2

In order to establish a provincial watershed coding system, a workshop should be held and representatives from Alberta Environment, Alberta Recreation, Parks and Wildlife, AOSERP, and AOSERP contractors should attend. Although it would not be necessary to code the entire province in detail, an agreement on the numerical codes for the major drainages should be established (see Section 8.1 for one possible coding system). One of the key areas for agreement by the provincial agencies will be in the Peace-Athabasca Delta region. The rivers in the Peace-Athabasca Delta form a complex of channels and lakes that must be logically coded in order to establish a system for all of the watersheds draining into the Mackenzie River.

4.3 MAPPING

Standard reconnaissance surveys following the RAB procedures are mapped at 1:50,000. "The map base will normally be the 1:50,000 NTS series, with topography screened to 60% and other information (stream lines) screened to 80%" (Chamberlin and Humphries 1977). After compilation of the field data onto working maps, information such as stream line features lists, area and perimeter of watershed, and stream profiles are digitized. Map digitizing organizes mapped data into a computer-compatible form convenient for summary and analysis within watershed systems or between watershed systems.

One of the problems identified during the 1978 field program was the incomplete coverage of the AOSERP study area by the 1:50,000 NTS map series. One of the objectives of this report is to assess this deficiency and to recommend alternatives. The present status of 1:50,000 maps is as follows:

1. Published maps (1:50,000 NTS) are available for part of the proposed study area. Following is a list of available map sheets which can be obtained from Alberta Energy and Natural Resources (see list of contacts: Section 8.2, No. 1).

73M	1 to 16
74D	6, 11 to 14
74E	3 to 6, 11 to 14
74L	1 to 8, 11 to 14
84A	1, 2, 7 to 10, 15, 16
84H	1, 2

2. Preliminary maps (1:50,000) are available for some map sheets. These show the basic drainage patterns and contour lines; however, they cannot be screened to stress various features. Following is a list of available map sheets which can be obtained from Ottawa (see list of contacts: Section 8.2, No. 2).

74 D	5, 10
84H	7 to 10, 15, 16

3. A number of map sheets cannot be obtained at a scale of 1:50,000. They are the following:

74D	1 to 4, 7 to 9, 15, 16
74E	1, 2, 7 to 10, 15, 16
74L	9, 10

In order to provide base maps in areas where either published or preliminary maps cannot be obtained, a number of alternatives could be followed.

1. Planimetric basis 1:63,360 (1" = 1 mi) can be obtained (dated 1950 to 1951). Contours from a 1:250,000 scale map would have to be superimposed on the planimetric map bases and both reduced to a 1:50,000 mylar base map (see lists of contacts: Section 8.2, No. 3).
2. Aerial mosaic coverage (1:63,360) can be obtained from Alberta Energy and Natural Resources. These maps provide suitable coverage of drainage patterns; however, contour lines are not shown. Digitizing using these bases is not possible.
3. Orthophoto mosaics, at 1:25,000 with contours, can be obtained for a small part of the AOSERP study area. The contour lines for the 1:25,000 mapping are at 500 ft

intervals and are not suitable for calculating average stream gradients. Therefore actual elevation measurements at reach breaks, for these map sheets, would be necessary (T. Chamberlin, pers. comm.). The following map sheets may be useful:

74D	7, 15
74E	2, 7, 10

None of these alternatives will provide a fully satisfactory map base for aquatic habitat mapping. Mr. T. Chamberlin of the RAB has indicated that aerial mosaics have been used by them where published maps are not available. This map base provides a fairly accurate picture of the drainage patterns and has been found to be the most acceptable alternative.

4.4 AERIAL PHOTOGRAPHS

Overall, the aerial photography that can be obtained for the biophysical mapping of aquatic resources is fully adequate. Most of the proposed study area is covered by aerial photography taken for project VE 2.3 (Thompson et al. 1978). False colour infrared photographs (Kodak 2443 film, Wild RC-10 camera, 152 mm lens) in 23 cm positive transparency format (1:60,000 scale) were obtained for most of the AOSERP study area. This photography should be excellent for reach designation and for the identification of channel patterns and form. Detailed information on available false colour infrared photographs provided by Thompson et al. (1978) and consequently has not been repeated here.

In addition, panchromatic photography is available over all of the proposed study area from the Alberta Aerial Photo Branch. It varies in coverage, date, and scale. Aerial photography taken in 1949 to 1951 (1:40,000) is available for the entire study area; 1:31,680 (2" = 1 mi) photographs are available for 50 to 60% of the proposed study area. These photographs were taken in 1960 to 1969 and are concentrated in a corridor along the Athabasca River. Other areas of individual interest have been photographed from low altitudes over the years and are available at different scales.

Additional low altitude photography may be of value in the future in order to document changes in the lotic environment due to development. Low level large scale (70 mm) aerial photographs have been used by the RAB to provide detailed descriptions of selected small tributary streams. Simultaneous exposure (two cameras with fixed camera separation) provides stereo viewing and is excellent for documentation of instream and riparian features (see list of contacts: Section 8.2, No. 4).

4.5 STAFF TRAINING

One of the most obvious deficiencies in the 1978 aquatic inventory program was the lack of specific training of the personnel working on this project. Because of the subjective interpretative nature of many of the parameters gathered during the aquatic habitat analysis, specific training and experience is necessary to ensure consistently compatible results. Participants must be familiar with all aspects of the philosophy and structure of the aquatic inventory as conducted by the RAB. Additional training is also required to provide field technicians with a working knowledge of aerial photograph interpretation and field procedures. The RAB holds a training camp (5 days) for technicians each spring. Senior field personnel usually have a minimum of one year's experience.

AOSERP must ensure that adequate training is received by field crews for the proposed program. Since complete familiarity with all of the procedures (pre-typing, aerial photo interpretation, field work, mapping, digitizing, and computerization) requires experience, I would recommend that an experienced biologist and/or technician be hired from the RAB. This person could act as project co-ordinator.

Responsibilities of the co-ordinator should include:

1. Evaluation of the adequacy of the existing data and estimation of the cost of the proposed 1979 survey;
2. Training of personnel in both field and office procedures;
3. Crew supervision during field operations;

4. Co-ordination of coding, mapping, and digitizing of field information; and
5. Liaison with RAB regarding new techniques and computerization of the data base.

Mr. T. Chamberlin, Head of the Aquatic Section, Resource Analysis Branch, has provided a list of suitable people (see list of contacts: Section 8.2, No. 5 to 7). Training of additional staff should be undertaken in Alberta using material (i.e., aerial photographs, substrate samples, etc.) from the study area. Field training and orientation could be held at the AOSERP Mildred Lake Research Facility.

At the present time the RAB uses an eight-man crew during field inventory (two three-man point sample crews and two air observers, with one person from each point sample crew wearing a wet suit for observation of fish by floating). This crew size optimizes helicopter utilization (a Bell 206B is the most suitable) and ensures that survey members (especially air observers) are rotated frequently to overcome fatigue. In the AOSERP area a six-man field crew may be adequate (reduction of each point sample crew to two men) since floating may not prove to be very beneficial in highly stained (humic) water, because of the reduced visibility.

4.6 INTERDISCIPLINARY COORDINATION

Prior to the 1979 program all aspects of interdisciplinary co-ordination should be considered by AOSERP. If this is done at an early stage a great deal of valuable data could be gathered during the normal aquatic survey with little additional cost. For example, the proposed stream survey program could readily include an evaluation of aquatic furbearer habitat if one or two of the field crew are familiar with both fisheries and wildlife techniques. Routine recording of habitat parameters that are thought to influence local distribution of furbearing mammals (e.g., stream depth and velocity, bank type, riparian vegetation) are already documented by the resource analysis procedure. By spending a few extra minutes at each site, furbearer activity (tracks, otter slides and latrines, beaver lodges and dams, muskrat bank dens) could be recorded. Discussion with Mr. Gary Searing (LGL Ltd., Principal Investigator, AOSERP Semi-Aquatic Mammals Project LS 23.1) has indicated that this information would be a valuable addition to the AOSERP data base on aquatic furbearers, which at present consists primarily of aerial and track surveys along selected streams. Records of furbearer activity gathered during the stream surveys would provide specific information on habitat structure and extensive information on distribution.

5. UPDATE ON RAB METHODS AND COSTS

5.1 ACTIVITY FLOW FOR THE AQUATIC SECTION

At present the RAB is adapting their data base and aquatic analysis procedure to computer storage and handling. In order to do this efficiently and in a cost effective manner they have developed an activity flow chart to describe their present work program. At present their manual capability to produce summary reports and interpretations from their data base is considered to be "severely limited" (T. Chamberlin, 16 to 17 January 1979, verbal comm.) and it will remain limited until the data can be handled by computer. Section 8.3 provides a brief review of the aquatic system activity flow, and describes a proposed system flow that incorporates computer use. Standard reports that will be part of normal computer output include dictionary listing, system survey history summary report, system aggregate fish summary report, and system reach, point and fish listings (selected by attribute criteria).

If the results of an aquatic survey of the AOSERP study area are to be used effectively, computer storage and handling must be incorporated into the program. This capability does not have to be in place prior to the field program. In fact, a delay in the adoption of a computer system approach may be advisable in order to ensure that the RAB has overcome problems that will no doubt be encountered. However, the use of a suitable survey format must be incorporated into the field program. In order to facilitate key punching operations the RAB is changing the design of their reach, point, and fish cards. The new cards should be available for use by May 1979. A new manual is also planned in order to clarify glossary terms and field procedures (perhaps by late spring 1979). AOSERP should ensure that these updated procedures and documents are obtained and used so that the field data are suitable for computer storage and retrieval.

5.2 COMPUTER SYSTEM DESIGN

Mr. M. Isaacs of the British Columbia Systems Corporation has documented the requirements and the alternatives for computer systems design for the RAB aquatic inventory system (Section 8.4). Eight major points were considered in order to compare the system alternatives and to evaluate costs. They include system design costs, operating and maintenance costs, cost of converting existing data, timing, risk of error, ease of use, flexibility, and reporting capability. Mr. T. Chamberlin has indicated that present RAB plans are to adopt a batch system using Mark IV language. It should be pointed out, however, that the system chosen by RAB should not preclude the choice of a different system by AOSERP that is better suited to available facilities and user requirements. The adaptation of the RAB programs would no doubt be possible (although perhaps time consuming).

5.3 INVENTORY COSTS

It is not possible to define the cost of the proposed aquatic habitat analysis project until the 1978 reports have been submitted and assessed for completeness and compatibility with the RAB procedures. As suggested in Section 4.5, the first role of a co-ordinator would be to assess the existing data in order to provide cost estimates to AOSERP. AOSERP will then be able to set priorities in view of their 1979 budget commitments.

Recent estimates by the RAB from a study of the North East Coal Area of British Columbia, showed a cost of $\$10.81/km^2$ or 1.6¢/ha (Mr. T. Chamberlin, 16 to 17 January 1979, verbal comm.). This cost included salaries and disbursements, but did not include overhead items such as building rental, administration costs, etc. If all of the "proposed" aquatic study areas (see Section 4.1) were surveyed (approximately 580 townships) at a cost of $\$10.81/km^2$, the total cost would be \$584,640.00.

However, it is not realistic to apply this cost factor to the areas proposed for the AOSERP aquatic habitat study. Different drainage densities, different sampling requirements, and the existence of an already large body of fisheries information will substantially reduce the final cost per kilometre in the AOSERP area.

When the 1978 reports are completed, an assessment should be made that includes the following factors:

1. Knowledge gaps in the existing data base (from an aquatic habitat perspective);
2. The number of kilometres (linear) of re-inventory or partial inventory that is required;
3. The number of kilometres of new inventory that is required;
4. Sample density requirements;
5. Number of field days required; and
6. Staff requirements for both field and office work.

Because of budget constraints and/or the time constraints of AOSERP's mandate, it may be important to develop a set of priorities for the aquatic habitat analysis project and to develop a sequential transfer of responsibility (to other government agencies) to ensure that the project does not suffer from a lack of continuity. A number of logical breaks are apparent within the overall aquatic habitat project (Figure 3). These may aid in the transfer of responsibility and in the continuity of funding for the project in the future. However, continuity will suffer unless key personnel are maintained throughout all phases of the project.

The strategy (contract or line agency) that should be chosen to ensure continuity of personnel is not clear. It is clear, however, that the long-term benefit of the aquatic habitat project will not be realized if the project is done on a short-term contract. In order for the data base to develop to a point where it is routinely used in management and assessment activities, a longer-term commitment (either by contract or within a line agency) must be undertaken.

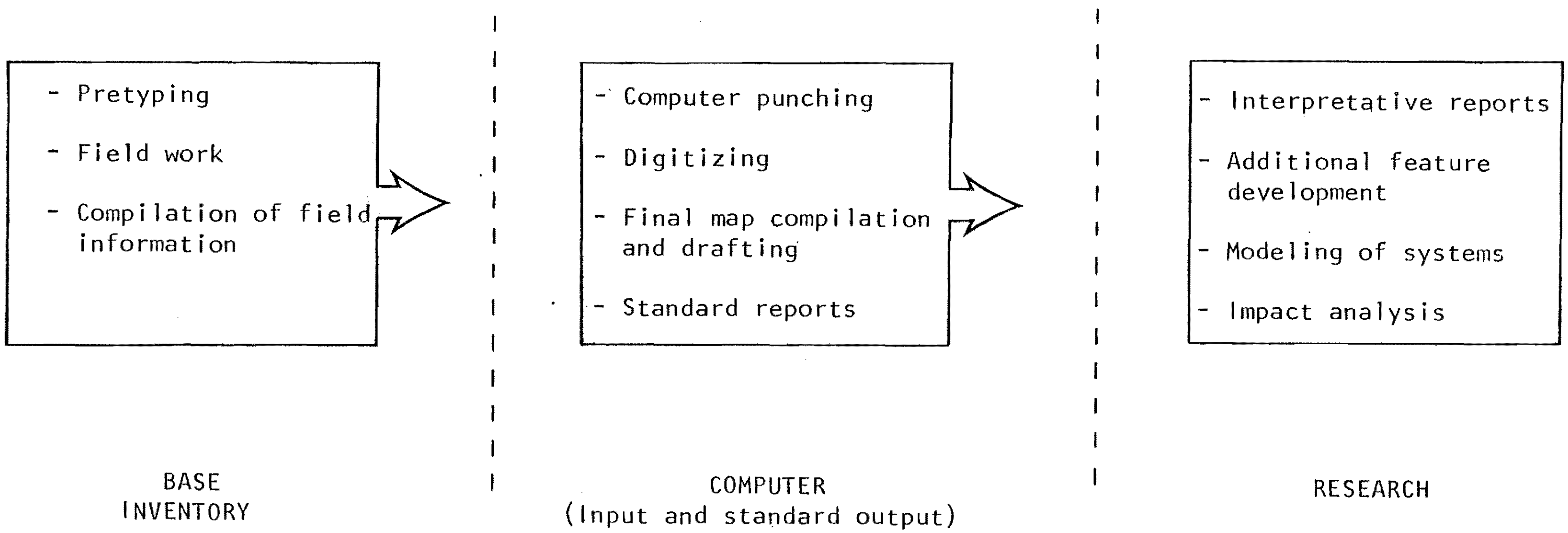


Figure 3. Optimal development of the aquatic habitat analysis project (assuming that the system is computerized).

6. SUMMARY OF RECOMMENDATIONS

1. The recommendations of the Brown et al. (1978) report should not be followed if AOSERP intends to proceed with mapping, computerization, and interpretative research using the framework provided by the RAB system.
2. Existing aquatic habitat analysis information conducted by AOSERP researchers should be further assessed for specific knowledge gaps, consistency, and compatibility with the evolving RAB system. (This would include the reports from the 1978 studies that have not been completed at this time.) Areas that are found deficient should be partially re-surveyed during 1979.
3. The 1979 study area should extend over a wide enough area to ensure that probable future developments can be assessed without additional field work. Figure 2 indicates the extent of the proposed study area.
4. A provincial watershed coding system should be developed and the master dictionary of codes should be maintained by a government line agency.
5. The use of planimetric bases and superimposed 1:250,000 scale maps should be used to produce 1:50,000 mylar base maps, in areas where 1:50,000 NTS or preliminary maps are unavailable. This method is suitable for digitizing and thus has been found to be the most acceptable alternative. These maps should be used in the AOSERP study area where required.
6. If possible, an experienced biologist and/or technician should be hired from the RAB to co-ordinate the 1979 field program. The co-ordinator should be responsible for the training of field and office staff and should act as a supervisor during the entire project.
7. Interdisciplinary co-ordination with AOSERP contractors working on semi-aquatic mammals should be considered. AOSERP should review its 1979/80 work

program to determine if other programs could be co-ordinated with the aquatic habitat program. This will maximize the usefulness of the aquatic data base at little additional cost.

8. If the results of an aquatic survey of the AOSERP study area are to be used effectively during final analyses, a computer storage and handling system must be incorporated into the program.
9. AOSERP should, in co-operation with users in government and industry, be continually updating the program to accommodate new requirements, thereby ensuring continuity and maximum long-term benefits.

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8. APPENDICES

8.1 EXAMPLE OF A POSSIBLE WATERSHED CODE FOR THE PROVINCE OF ALBERTA. (From D. Berry, Fisheries Biologist, Fish and Wildlife Division, Alberta Recreation, Parks and Wildlife.)

Major Watersheds in Alberta

00 - Mackenzie - Slave River
10 - Mackenzie - Peace River
20 - Mackenzie - Athabasca River
30 - Beaver River
40 - North Saskatchewan River
50 - South Saskatchewan - Red Deer River
60 - South Saskatchewan - Bow River
70 - South Saskatchewan - Oldman River
80 - Milk River
90 - Minor watersheds crossing Alberta-Saskatchewan border

Athabasca Watershed

20 - Mackenzie - Athabasca River
21 - Richardson River
22 - Firebag River
23 - MacKay River
24 - Clearwater River
25 - La Biche River
26 - Lesser Slave River
27 - Pembina River
28 - McLeod River
29 - Berland River

23	1000	060	050	010	000	000
Athabasca R. MacKay R.	Dunkirk R.	Snipe Cr.	Unnamed Cr.	Unnamed Cr.		

20	1200	260	080	010	010	000
Athabasca R.	Ellis R.	Namur R.	Unnamed Cr.	Unnamed Cr.	Unnamed Cr.	

26	1300	090	100	080	010	000	000
Athabasca R. Lesser Slave R.	Swan R.	Inverness R.	Sutherland Cr.	Murray Cr.	Unnamed Cr.		

The Peace-Athabasca Delta is very complex and would require considerable examination to decide how this area should best be handled. The above is rough and may contain errors concerning the accuracy of the numbers applied.

8.2 LIST OF CONTACTS

Mapping

1. Mr. Bruce Mackenzie, Head of Photogrammetric Services, Mapping Section, Resource Evaluation and Planning Division, #107, 9810 - 111 Street, Edmonton, Alberta. Telephone: 427-7195.
2. Mr. Keith Hodgins, Topographic Survey, Survey and Mapping Branch, Energy, Mines and Resources, Government of Canada, Ottawa, Ontario. Telephone: (613) 955-4629.
3. Mr. Ed Kennedy, Mapping Office, Surveys and Mapping Branch, Alberta Transport, Transportation Building, 9630 - 106 Street, Edmonton, Alberta. Telephone; 427-6467.
4. Integrated Resource Photography Ltd., 310 Water Street, P.O. Box 2278, Vancouver, British Columbia. Telephone: (604) 681-3181.

Personnel

5. Mr. Ted Harding, 516 Harbinger Street, Victoria, British Columbia. Telephone: (604) 385-2651 (home), 387-3473 (office).
6. Mr. Paul Harder, 10 Glenmore Drive, West Vancouver, British Columbia, V7S 1A4. Telephone: (604) 926-0387 (home), 687-7588 (office).
7. Mr. Dan Davies, #312, 161 W 4th Street, North Vancouver, British Columbia, V7M 1H6. Telephone: (604) 988-8324 (home), 666-2153 (office).

8.3 COMPUTER SYSTEM DATA FLOW OF RAB. (From C. Grant, Resource Analysis Branch, Ministry of the Environment, British Columbia.)

Aquatics Inventory System

The Aquatics Inventory System can be viewed as four phases for discussion: input, edit, storage, and reports.

Input will be entered as transactions. A transaction is a data record identified by a key (that which makes the data unique--i.e., reach number) that specifies actions to be taken. It can add new data or it can change or delete existing data in the data base depending on the action specified by the user.

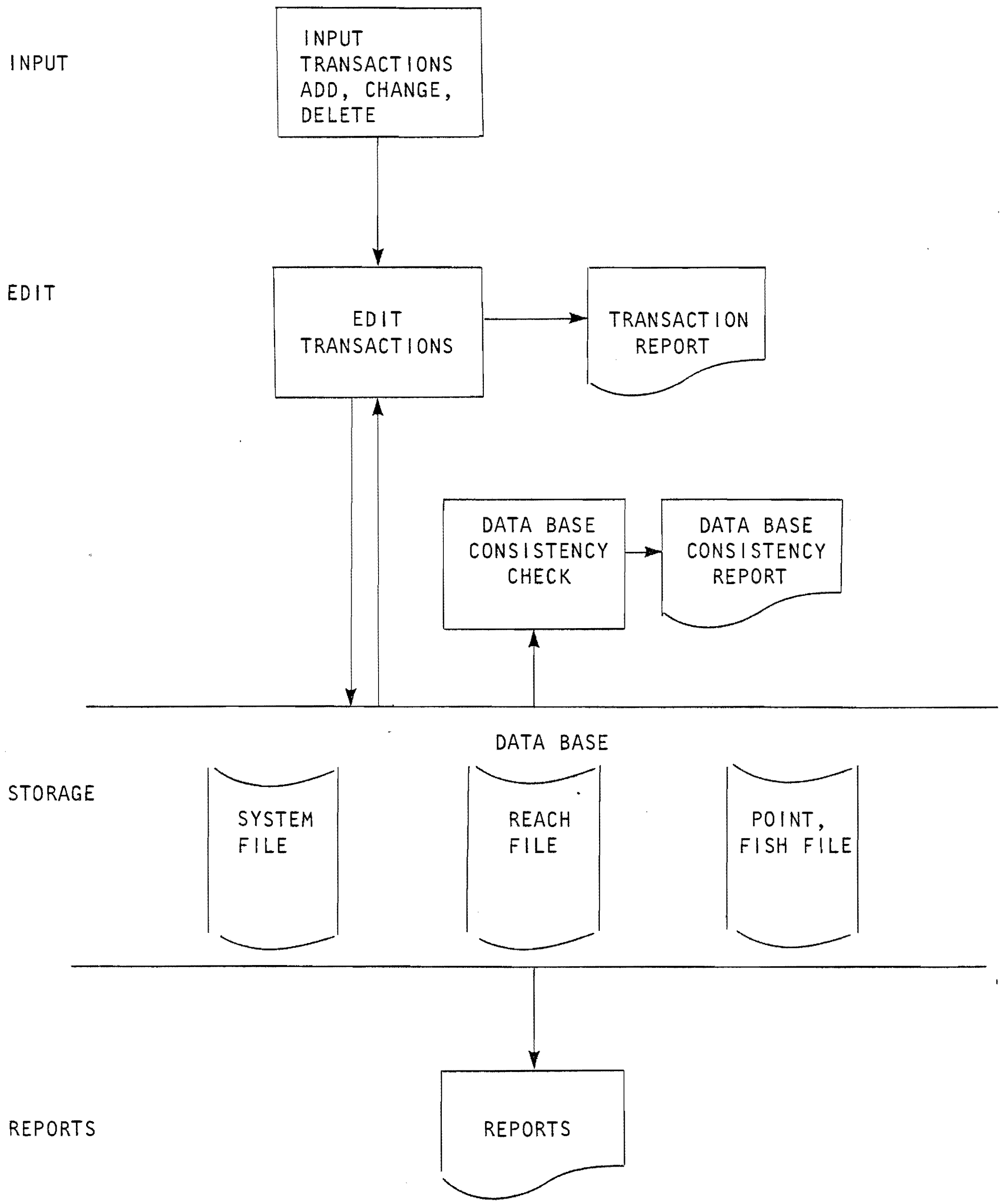
The add criteria is used for data entering the system whose key has not been previously defined (i.e., new watershed identified). Due to the hierarchical nature of the data, the input must be entered and exist in the data base in the following order: watershed code, reach, point, fish, and digitizing data (watershed aggregate physical properties and features listings). From the input add transaction records will be key punched onto tape or cards, depending on the type, and entered at the user's request. When reaches or points are added, the system file is automatically updated (i.e., number of reaches, points, etc.)

The change action allows the user to change records already in the data base. This provides the user with the ability to make spelling corrections that cannot be detected by machine, but may be detected as a result of a visual edit.

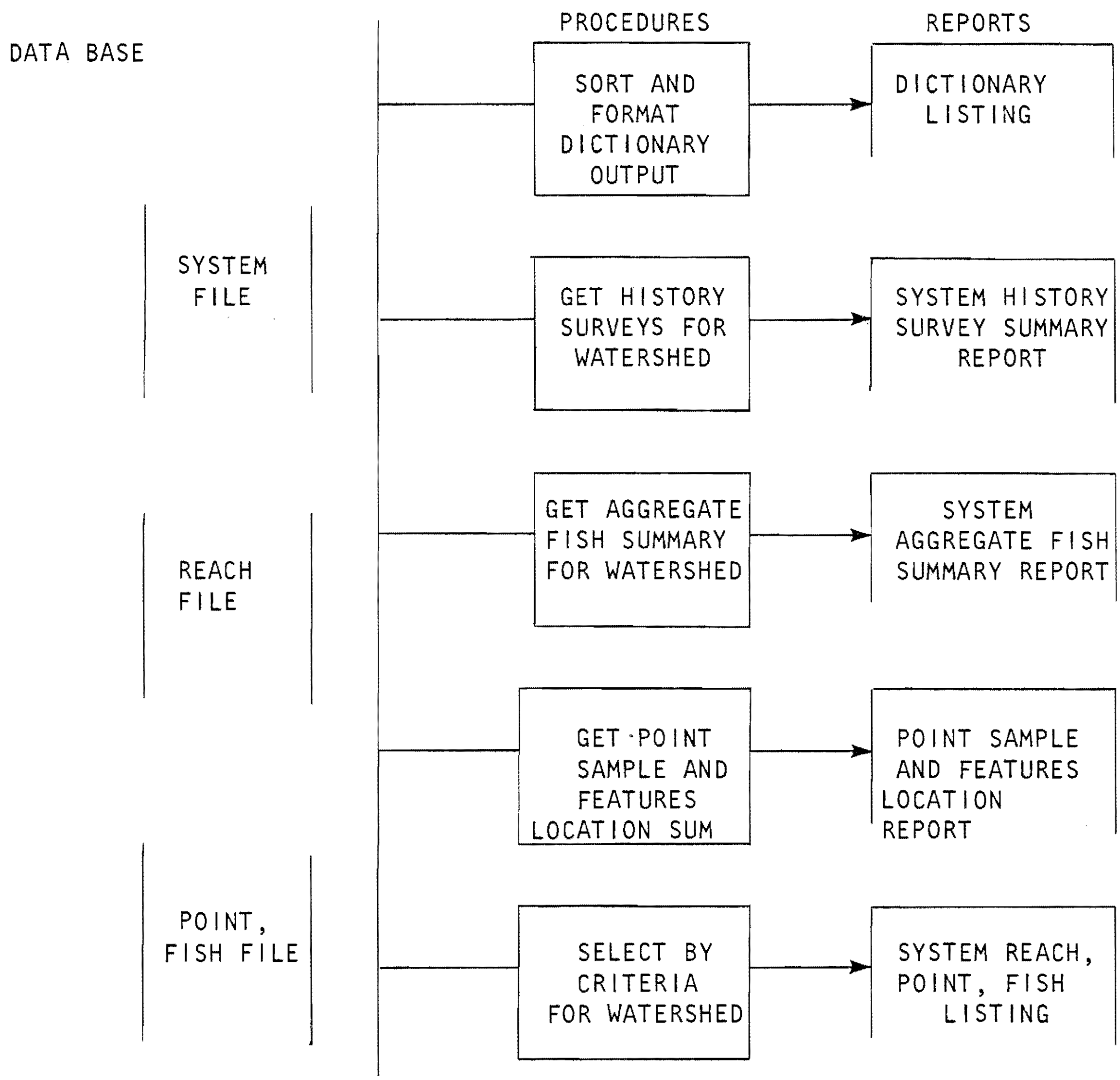
Through the delete action the user may delete records or segments (see file structure) from the system or correct any key errors that were not detected (i.e., reach associated with wrong watershed as a result of a coding or key punching error). To correct a key error the user must delete the record or segment and re-enter the record or segment as an add action with the correct key.

The edit phase consists of an edit procedure which edits the transactions and provides a transaction report and a consistency procedure which edits the data base and provides a consistency report.

PROPOSED SYSTEM FLOWCHART



continued ...


DATA BASE
PROCEDURES
REPORTS
SORT AND FORMAT DICTIONARY OUTPUT
DICTIONARY LISTING
SYSTEM FILE
GET HISTORY SURVEYS FOR WATERSHED
SYSTEM HISTORY SURVEY SUMMARY REPORT
REACH FILE
GET AGGREGATE FISH SUMMARY FOR WATERSHED
SYSTEM AGGREGATE FISH SUMMARY REPORT
GET POINT SAMPLE AND FEATURES LOCATION SUM
POINT SAMPLE AND FEATURES LOCATION REPORT
POINT, FISH FILE
SELECT BY CRITERIA FOR WATERSHED
SYSTEM REACH, POINT, FISH LISTING

When a transaction is entered, various field value and field checks are performed. Transactions failing these checks are rejected and must be re-submitted. If the transaction passes the edit check, the action (add, delete, or change) is processed.

A transaction report is always generated when transactions are entered. An image of each transaction is outputted, providing the means for a visual edit by the user, along with the status of the transaction followed by any value or a key error message that may have been detected. This report should be saved until the next transaction report is generated or until all rejected transactions have been re-submitted.

The user has the option of requesting a consistency report at any time. This will provide a list of any inter-record or inter-file inconsistencies which the user may or may not take action on.

Storage of the data in the data base will consist of three files: system file, reach file, and point fish file. These files contain variable length hierarchical records. These records provide an efficient means of storing the data due to the variability in frequency of some attributes (i.e., fish summary, stream features, history surveys, comments) and the hierarchical nature of the data (i.e., fish data related to point data). These structures also provide for easy incorporation of new data types (i.e., sub-reaches) or attributes. Sub-files and new reports may be generated with ease from these files.

Five reports have been identified by the user to meet present user demands. They are: dictionary listings; system survey history summary; system aggregate fish summary; point sample and features location list; and system reach, point, and fish listings selected by attribute criteria. These reports may be generated by the user as needed.

In summary, because the Aquatics Inventory System is relatively new, with a small volume of data records, the system has been designed to give the user maximum data entry flexibility, ability to incorporate new data types with a minimal amount of programming, and provide new reports in a relatively short time.

List of Files and Record Descriptions

1. System File
   - system file records will be defined as 2 level variable length hierarchical records keyed by a watershed code
   - the record will contain dictionary information, the aggregate physical properties of the watershed, and any known surveys related to the watershed and its mainstem

2. Reach File
   - reach file records will be defined as 3 level variable length hierarchical records keyed by watershed code and reach number (and date for re-surveys)
   - the record will contain reach documentation, stream attributes, fish summary data, and stream features data all related to the watershed's mainstem

3. Point Fish File
   - point fish file records will be defined as 3 level variable length hierarchical records keyed by watershed code, reach number (zeroes bb if unknown), point number, date, and time
   - the record will contain point documentation, point attributes, fish documentation, fish data summary, and individual fish data for a particular point and time

Data Conversion

All data, with the exception of the Aquatic Directory file, exist on paper.

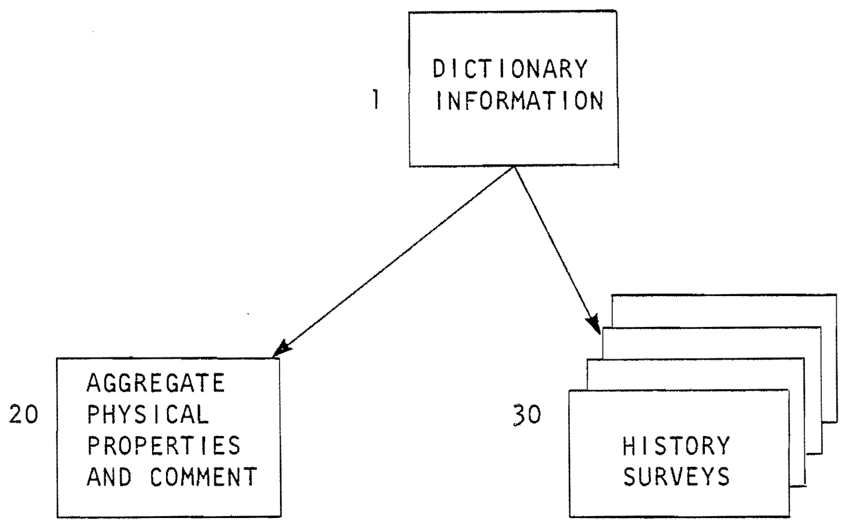
The Aquatic Directory file presently resides on a Honeywell disk file. This will be copied to an IBM tape and a small conversion program will be required to build the system file. This will be done before the system can become operational.

APPROXIMATE SPACE ALLOCATION

	# OF RECORDS		# OF BYTES		TRACKS	
	CURRENT	YEARLY	AVERAGE	MAXIMUM	AVG. CURRENT	YEARLY
1. SYSTEM FILE						
Dictionary Information	14,000	------	70	70	52	------
Aggregate Physical Program	1,800	600	59	1,059 (1000 comments)	6	2
History Survey	2,100	700	28 (1 survey)	30,800 (1100 surveys)	3	1
					61	3
2. REACH FILE						
Documentation and Attributes	6,800	2,250	166 fixed	166		
Fish Summary	6,800	2,250	20 (5 species)	140 (28 species)		
Stream Features	6,800	2,250	52 (2 features)	560 (20 features)		
			50 comments	2,000 comments		
	6,800	2,250	288	2,866	105	35
3. POINT FISH FILE						
Point Documentation and Attributes	3,300	1,100	200 fixed	200		
Fish Documentation	3,300	1,100	50	50		
Fish Data Summary	3,300	1,100	22 (x4)	22 (x48)		
Individual Fish Data	3,300	1,100	19 (x4)	19 (x50)		
			20 comments	2,000 comments		
			434	4,206	78	26
4. BAD TRANSACTION FILE		400	400	30,800	10	10
TOTAL					254	74

PROPOSED RECORD STRUCTURES FOR FILES

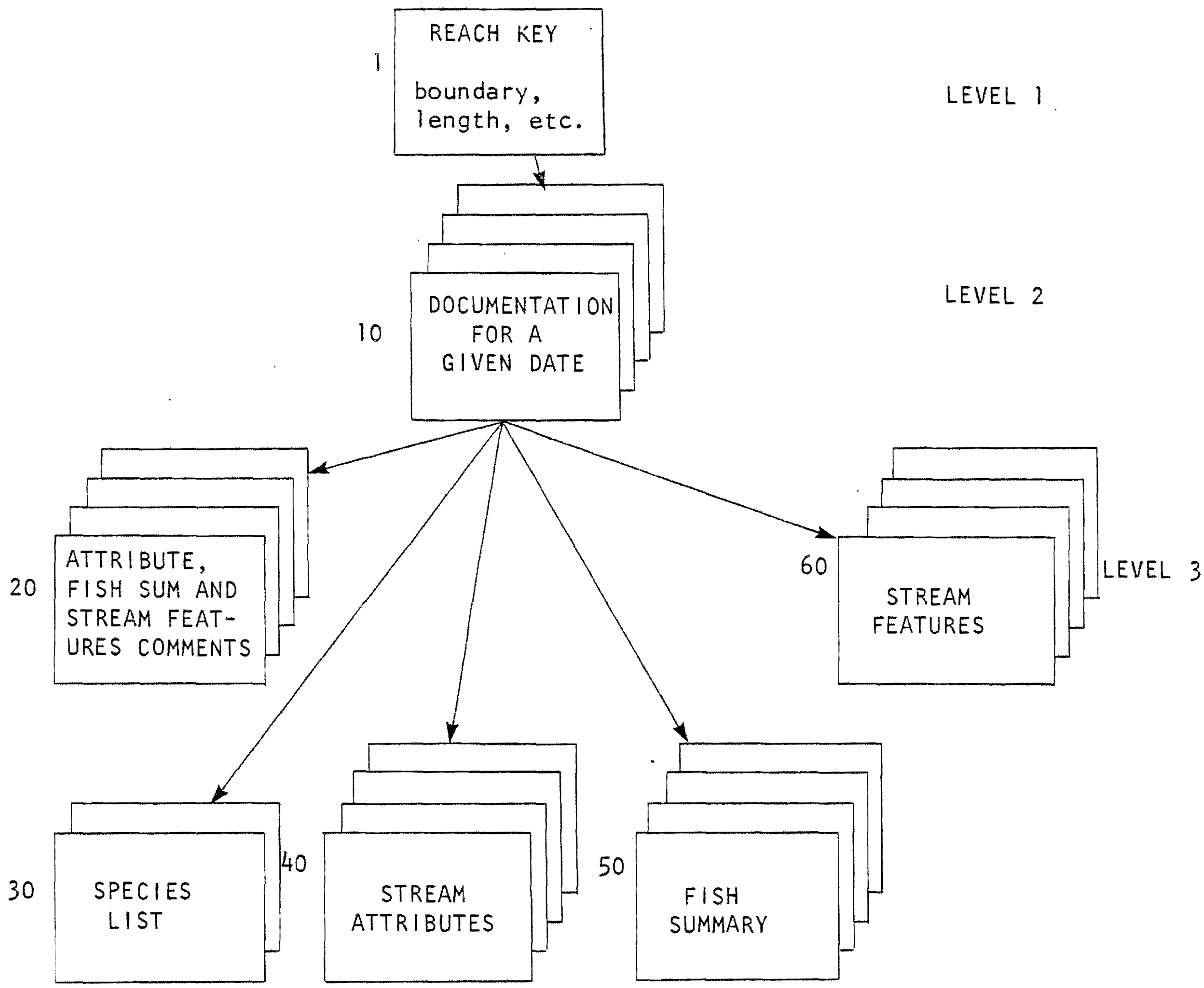
1. SYSTEM FILE



SEGMENT KEY:

1 - WATERSHED CODE
20 - AGGREGATE PHYSICAL PROPERTIES FLAG
30 - AGENCY FROM TO, DATE

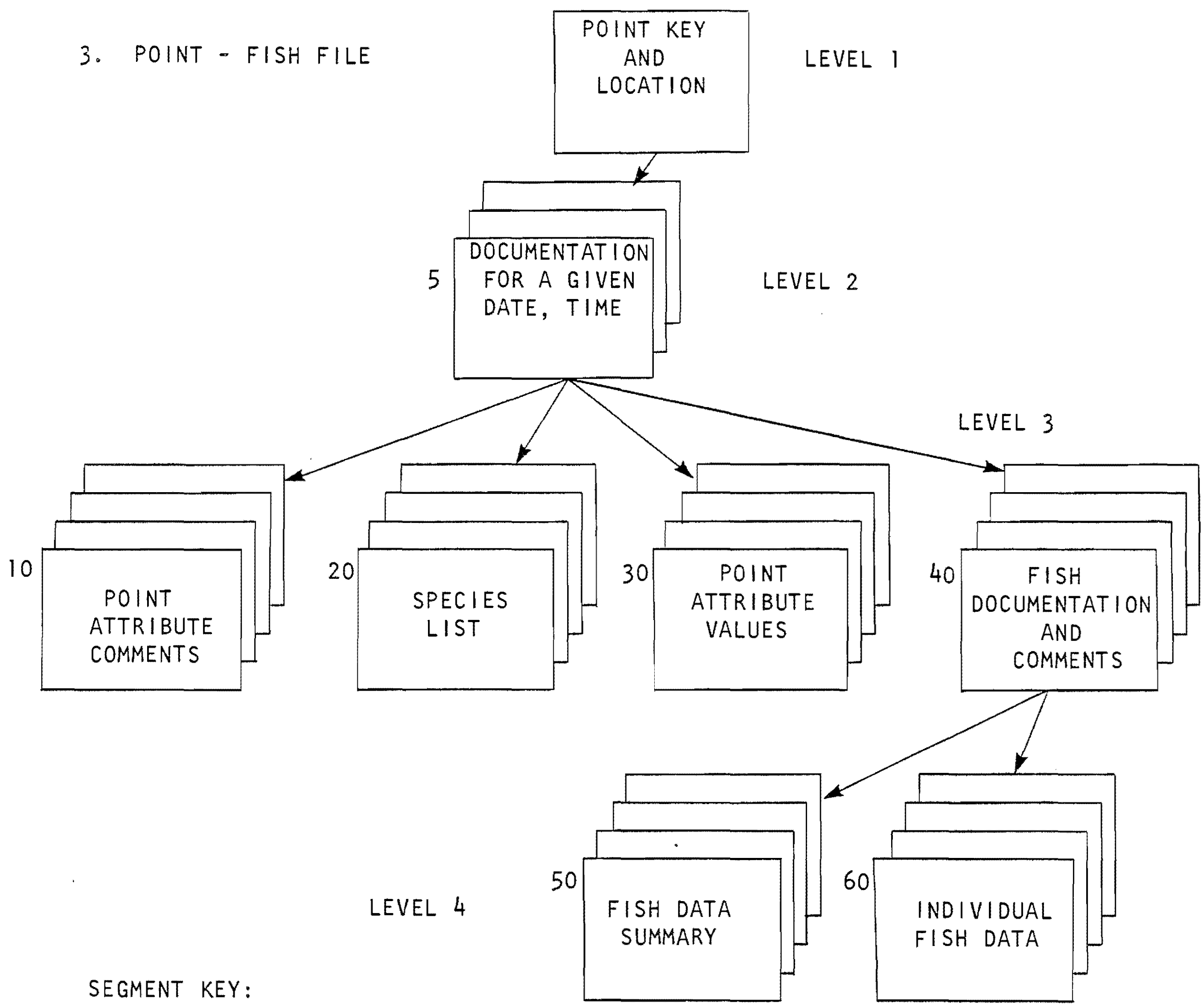
2. REACH FILE RECORD



SEGMENT KEY:

1 - WATERSHED CODE REACH NUMBER
10 - DATE
20 - COMMENT CODE (i.e. C1)
30 - SPECIES LIST CODE (i.e. S1)
40 - STREAM ATTRIBUTE CODE
50 - FISH SPECIE CODE
60 - STREAM FEATURES CODE

3. POINT - FISH FILE



SEGMENT KEY:

1 - WATERSHED CODE, REACH NUMBER, POINT NUMBER
5 - DATE, TIME
10 - COMMENT CODE (i.e. C1)
20 - SPECIES LIST CODE (i.e. S1)
30 - ATTRIBUTE CODE
40 - FISH CARD NUMBER
50 - SPECIES
60 - FISH NO.

The survey history data can be inputted through the new system as soon as the dictionary data have been converted.

Over the past three years there have been four reach formats, two point formats, and two fish data formats. The latest cards may be entered via the new system. There are two options concerning old data formats:

1. Key punch instructions for each format can be defined so that the data can be key punched and stored on tape. A conversion program can then be written converting the old format to the new format, and the data may then be entered via the present system. Since the writing on the old cards is not very distinguishable, there will be many key punching errors and a great deal of time will be required to edit the records.
2. All old data can be edited and transcribed onto the new cards. This would be especially useful where comments on old cards refer to attributes on new cards. This method would result in the cleanest data in that the data would get a second edit by the proposed system.

Cost estimates of both these options will be estimated in the detailed design.

All digitized data will be entered through the proposed system but may not be entered until all related keys (i.e., reach, etc.) have been created.

8.4 COMPUTER SYSTEM DESIGN OPTIONS AND COSTS FOR RAB. (From M. Isaacs, British Columbia Systems Corporation.)

USER REQUIREMENTS

1. (Data) Timing Considerations

In general the timing constraints are not important. The overall data collection process is a lengthy one. Several months can elapse between the assignment of a region for data collection and the completion of the point and reach cards for its watersheds. Thus, it is reasonable that there is not any critical rush to have the data added to the computer files. Rather, staff timings and the smoothing out of the data coding will be the deciding factors for determining when new data are entered into the computer system.

For standard reports, output received within a few hours would be perfectly acceptable. It is expected that standard reports kept in the Aquatics Section would be capable of answering any questions requiring a more immediate response.

Non-standard reporting and data manipulation of modelling purposes can be expected to take longer, as technical assistance from programming support staff will no doubt be needed. However, this type of data processing would only be required for special studies, which are generally of a medium to long-term nature. Thus the system response time should not be a problem; as long as the necessary information is contained in the files, the system will be capable of meeting the needs of the Aquatics Section.

2. Completeness

The data collected in the system are quite varied in nature. Some, such as watershed areas or obstruction locations, are numeric and quite accurate. Other data, such as substrate compositions or bank vegetations, are numeric and estimated. Much of the data are nominal, such as channel forms (straight, irregular, or meander) or cross sections (confined, bounded, or unconfined).

Literal data (i.e., comments) are also an important part of the data and must be included in any computer system that may be developed.

Aquatics Section spends a great deal of time tracking down available data from other sources. Many agencies in both the federal and provincial governments, as well as private sources (such as consultants) collect data that are useful to this section.

They are extremely concerned about the loss of data, both from a physical and a logical standpoint.

Physical loss, from fire or mismanagement of physical records, is always an important consideration.

The logical loss of information is often not as apparent as its physical loss. When "contact" with data is lost, however, considerable effort is often required to re-establish sources. This generally occurs over a period of time as staff leave and take their knowledge and sources with them.

The capability of preventing such losses is considered to be a prime requirement of any computer system design. It must be capable of acting as a bibliographical cross reference.

3. Accuracy

Along with completeness, accuracy is an important user concern. This is reflected in the detailed edits that are performed during the map production phase. Although much of the data collected is (by necessity) "soft", it sill reflects the judgement of skilled and experienced staff.

Unlike many systems, it is not possible to check for validity by batch or hash totals. Thus great care must be taken to edit the data as carefully as possible to prevent transcription and omission errors. This might require, for example, that checks for reasonableness be included in the edit phase.

4. Accessibility

There is no point in the Aquatics Section having a computer system if they cannot access the data any differently than with the present manual system.

They have already specified a number of standard reports that they feel should be available within a few hours. These reports must be flexible in the sense that various parameters can be changed for a given run.

Examples of the standard reports needed are:

4.1 Aggregate fish species list for a given stream;

4.2 Limits of upstream downstream distribution by fish species and reach boundary location;

4.3 Survey listing for a given system;

4.4 Total lineal distance of mapped and digitized features within a given system;

4.5 Spawning zones by species;

4.6 Flood and side channel location;

4.7 Listing of location, type, and height of obstructions;

4.8 Listing of arbitrary subsets of reach attributes (by reach); and

4.9 Listing of the location of specified types of sample points.

5. Flexibility

Although not explicity stated by the users, overall system flexibility is probably the most important single criteria for evaluating alternative system design. This is apparent when the present system is looked at in historical perspective.

The need for the creation of a separate section for water/fish was recognized in 1974, and the first full summer of field work did not take place until 1975. Since then, the branch has undergone various reorganizations, to the point where there is now an Aquatics Section with the Biological Systems group.

Data have thus been collected for three years. Six regions in the province have been surveyed:

1. N.E. area,
2. S.E. area,
3. N.W. area,
4. Quadra Region,

5. Chilliwack Region, and
6. Keogh River (northern Vancouver Island).

All data collection is a result of external requests for analyses and impact studies. The N.E. and S.E. areas were surveyed because of coal mining potential; the N.W. because of logging; the Chilliwack region because of agricultural land use; and the Quadra and the Keogh River because of urban suitability studies. This illustrates the variety of requests received by the section, and by inference the variety of analyses required. To date, all data processing to support such analyses has been done manually.

Problems inherent with a relatively new organization trying to satisfy a wide variety of needs is reflected in the data collection methodology itself. The point and sample cards have undergone several revisions, a new fish sample form is being developed, and field procedures have been altered.

Although the users have specified a number of standard reports that are needed, they have not yet had any experience with a computer system. Once such a system is set up and reports can be produced automatically, it is very likely that they will request additional reporting capabilities.

Any computer system that is developed must have the flexibility of coping with such changes. There is no reason to believe that procedures and requirements have now stabilized. New interpretation requests may require that new data be collected or currently recorded observations be modified.

6. Integrateability (sic)

A prime factor in the organization of the RAB is the recognition of the interdisciplinary nature of proper resource analyses. To this end, consideration must be given to how an aquatics system can integrate with existing and planned systems or data sources in other sections of the branch, or other government agencies.

Examples of these are EQUIS (maintained by the Pollution Control Branch), Fish and Wildlife Surveys, and work done by outside consultants. In addition, there is the possibility of the development of a ministry wide data base to incorporate all environmental data.

7. Staff Efficiency

All procedures in the current system are manual. They are:

1. Gather working documents,
2. Pretype the watershed regions,
3. Field work,
4. Map compilation,
5. Card/map edit,
6. Outside edit,
7. List features,
8. Digitize map,
9. Transfer slopes to each card,
10. Transfer slopes to map,
11. Transfer system data to features list,
12. Map to drafting, and
13. Post-drafting edit.

It is clearly desirable to reduce the time required for as many of these steps as is possible. A computer system could help achieve this in almost every phase of the operation. Ideally such a system would not require any additional time from the Aquatics Section staff. In practice, however, some staff time will be required. The alternative computer systems that can be designed will have different impacts on the staff time requirements.

8. Forms

The reach and point cards have been designed with field operations in mind. The users would rather transcribe data from these cards onto coding sheets for the computer system than have these source documents redesigned, if the redesign adversely affects the field use of the cards.

9. Transcription

Transcription of data from one form to another should be kept to a minimum. Unlike key punching errors, which are almost always detected during verification, transcription errors tend to go undetected as the operation is performed only once. As mentioned above under the section on accuracy, it is very difficult to detect errors once they have entered the system.

STANDARD SYSTEMS REPORTS

The users have expressed a strong desire that certain standard reports be produced in any computer system that may be developed. As this phrase is so frequently used and by so many different people, it is advisable to clarify what is meant by the phrase "standard system report" in order to avoid any possible problems at the time of the detailed systems design.

Standard system reports can be defined as those reports which have an established output format. For each run of such a report generation program, certain variables will have to be specified as parameters which will then be used to determine which records will be included in that particular run of the report generation program.

Three distinct phases can then be isolated:

1. Record selection--
   The input parameters are edited, and if no errors are detected, are then used to determine which records on the file are pertinent for this run. The selected records are then passed on to the second phase.
2. Record sort (optional)--
   For some reports it will be necessary to sort the selected records in some order other than that in which they are stored. This would be specified in the parameter list, and the sort would be done in phase 2. The sorted records are then passed on to the third phase.

3. Record report--
   In the third phase the actual report is printed. This phase does not change for each run. Rather, this phase merely reports on whatever records were selected in the first phase. This separation of selection and report printing simplifies things for both the programmers and the users.

ALTERNATE SYSTEM DESIGNS

The basic system design is quite straightforward, as the logical flow of the data is completely sequential. The basic records now used (system, reach, and point cards) are the result of considerable thought and experience (although changes are still being made to the actual card layouts, the system reach and point concepts have remained constant), and will clearly be the basis for any chosen computer system.

A variety of detailed designs are possible. The actual hardware used can be either IBM or Honeywell; the file structure used can be sequential, indexed, or integrated (i.e., a data base); the digitizer procedures can be enhanced; the data entry can be batch or online; and plotted output can be added.

Three different designs will be described in the following sections. They vary considerably in complexity, capability, and cost. With each, variations in the digitizer procedures can be incorporated. However, these variations are the same for all three alternatives, and are thus discussed separately in a section on the implications of digitizer enhancements.

Briefly, the three possibilities are:

1. A completely batch system using sequential master file(s). All data are transcribed from reach, point, and features listings onto coding sheets which are then key punched by clerical staff and batched for processing.
2. A combination batch/online system with sequential or indexed/sequential master file(s). Data are entered

online through an interactive program. The reach, point, and system cards are still maintained however. All report production is by batch.

3. An online system using sophisticated data management techniques, which include a data base structure for the master file, transaction processing, and a user oriented enquiry language for ad hoc report production.

The following sections describe each alternative in greater detail. Each system is described from both the user's and a technical point of view. The relative advantages and disadvantages of each are discussed, along with estimates of the design, operating and maintenance costs.

The three alternatives are then summarized against a list of decision criteria. As there are several subjective aspects to these alternatives, they are included with the summary statement to assist in the selection of the best system design to meet the user's needs.

ENHANCED USE OF THE DIGITIZER

As mentioned in the section "Alternate System Designs", digitizing enhancements can be added to any of the three alternate systems. The enhancements are:

1. Eliminate the transcription of digitized data (latitudes, longitudes, reach slopes, and features distances) onto the features listing sheet. This can be accomplished by recording the digitizer output on cassettes available with the HP9825A calculator and then copying them onto the IBM compatible 9 track tape.
2. Eliminate the transcription of watershed area and perimeter calculations by the same process as described in (1) above.
3. Save the co-ordinates of the perimeter points when the watershed area/perimeter program is run. This would allow the automatic plotting of watershed

region plots. Because of the large number of points involved, a thinning algorithm will be required to reduce the number of points saved to a manageable level.

4. Save the co-ordinates of the points where contour lines cross the stream. This would allow the automatic plotting of stream profiles and accompanying features.

The first two options would eliminate transcription errors as well as save clerical time. The third and fourth enhancements would provide extensions to the system's reporting capabilities.

The third enhancement overlaps with other broad plans of the RAB with respect to geographical information storage and retrieval, and hence should be held in limbo pending the outcome of studies in this area.

The fourth enhancement can be easily implemented during the digitizing of the features listing for the stream.

The results achieved by implementing the first, second, and fourth enhancements are:

1. A saving in clerical time from not having to transcribe digitizer output;
2. The elimination of possible errors during the transcription process; and
3. The storing of data which will allow enhanced output formats in the form of automatically produced stream profile plots.

Approximately $450 will be saved annually by elimination of the clerical transcription. This is based on an effective rate of 8 features listing sheets processed per hour, 500 sheets produced annually, and an annual salary of $13,000.

The operational requirements at the digitizer will be the same regardless of which computer system is used for the aquatics inventory system. However, if the Honeywell is used, there is a physical transportation problem in that tapes may have to be sent to Vancouver.

One additional program on the HP9825A will be required if the three recommended enhancements are added to the system.

The storing of the watershed area and perimeter can be done in one program, which should be straightfoward to set up. The saving of the counter line crossing points can be achieved by modifying the features listing program. This will also satisfy the requirements for option (1).

It is estimated that these programs will take about two weeks, and will cost about $2,500. The batch programs needed on the IBM or Honeywell will be quite basic and should also require about two weeks to write, also for $2,500. Thus the total programming costs are about $5,000.

Note that this does not include the cost of producing any plotted output. Further investigation of plot requirements, both in terms of type of output and size and frequency is needed before cost estimates can be prepared.

The additional staff time required to incorporate these additional features is quite minimal, as the relevant regions of the mapsheets are currently being passed over already. Some additional time will be required of the tehnicians when making up the features listing to include the contour crossing points. General administration will also be required to co-ordinate the processing of tapes and cassettes and to ensure that the data are properly added to the master file for the aquatics inventory system. This time requirement would be about one man month per year, and would therefore cost approximately $1,000.

Thus total annual costs for adding the enhanced digitizer capabilities to any of the three alternate designs are approximately $1,550.

ALTERNATE SYSTEM DESIGNS - BATCH SYSTEMS

This is the first of three alternate system designs that are described for the aquatics inventory system. This design is the slowest (in terms of response time) as all processing is done by batch.

1. User's Point of View

1.1 Data entry and edit

The reach tally and point sample cards would continue to be used as at present. The features listing sheet may require some minor changes to enhance the watershed system data section. All data (including comments) will be transcribed onto coding sheets which will then be key punched by clerical staff. Whenever desired, the key punched data would be processed through an edit routine. This will check for valid syntax and logical relationships in the data, and will print out appropriate error and warning messages. For data control purposes, it is recommended that the master file not be updated at all if any records are flagged as errors during the edit run. However, this restriction can easily be removed if it is found to be more of a problem than an aid once the users are familiar with the system's operation.

1.2 File updating

Batches that successfully pass through the edit phase will then be processed through the file update routine. This will reformat the new records and take the indicated edit action (add, delete, or modify). Appropriate file control data will be printed out to verify that the file has been successfully updated. This will include before and after record counts, counts of the number of additions, deletions, and changes, and before and after record images (for changes) and before images (for deletions).

1.3 System reports

Standard system reports (as described in the section "Standard Systems Reports") will be produced by batch processing. The necessary selection parameters will be punched on cards and submitted through the card reader with the selected JCL deck.

Nonstandard data reporting and manipulations can be performed by either the Aquatics Section data base co-ordinator or by B.C.S.C. support staff upon receipt of a work request.

1.4 Advantages

There are three advantages of this system over the third alternative.

1.4.1 Implementation time--This system is easier to design than the third alternative, and hence can be implemented more quickly.

1.4.2 Cost--Because this system is easier to design than the third alternative, its design costs are correspondingly less. In addition, its operating and maintenance costs are less than both alternatives, as no line charges or online file space costs are incurred. Although this alternative does have key punching costs, they are more than offset by these savings. Maintenance costs are lower than with the third alternative as the programming techniques used are more basic.

1.4.3 File integrity--With a batch system, there is no problem with file recovery if either a program or system crash occurs. With the second alternative, it may be necessary to re-enter all data processed since the last file save (which is usually the previous evening), depending upon the nature of the problem and the level of precautionary action taken in designing the interactive program. The same is true of the third alternative, although journalization utilities exist to simplify the recovery procedure.

2. Technical Description

2.1 Computer system

This system can be implemented on either the Honeywell or the IBM hardware. It will run only in batch.

2.2 Files

The master file for this system will only be accessed sequentially. Whether all data should be kept in one file, or should be logically separated into multiple smaller files can be decided at the time of the detailed system design.

The master file for this system will contain all of the data from the system, reach, and point records (including fish records). All comments will also be maintained on this file.. No additional master files are needed unless the enhanced digitizer option is included. In that case, an additional file will be necessary to record the thinned perimeter point co-ordinates and stream/contour crossing points, if the third digitizing enhancement is incorporated into the system.

As only sequential files are used, and all processing is by batch, there is no need for any online storage. Variable length records will be used in this system because of the varying size of some of the repeating groups and the length of the comments fields.

2.3 Programs

2.3.1 Programming language--If the Honeywell system is used the language must be either FORTRAN or COBOL74. As the application is scientific, and it is expected that the system will eventually be used with packages such as SPSS, FORTRAN is the recommended language.
If the IBM system is used, the language would be either PL/1 or FORTRAN. In this case, PL/1 is recommended over FORTRAN due to its more powerful string manipulation features.

2.3.2 Required programs--This system will require one edit program, one update program, and approximately 10 standard report programs.
The edit program must be extremely comprehensive, and should include checks for "reasonableness" of the data which would flag certain data elements but would not consider them to be errors.
The update program will be relatively straightfoward, as it essentially just reformats the update detail, takes the indicated action, and writes out a new master file.
The standard system reports will have to allow for complex record selection criteria. However, the same record selection phase could be used for most of the programs, thus reducing program development time.

2.4 Operational procedures

Batch editing and updating would be run no more than a few times a week; in practice, one could expect two or three edit runs and one update run a week. The number and size of the standard system report runs will vary during the year, and the frequency of such runs can be expected to increase in time as familiarity with the system grows and the size of the master file increases. If the size of the file ever becomes cumbersome in relation to the frequency and type of these production runs, it can be segmented, thus reducing execution times and costs.

All editing, updating, and report generation will be handled by the Aquatics Section staff. The necessary JCL for each type of run will be kept as card decks in their office.

3. Costs

3.1 System design, programming, and implementation

The following phases are in accordance with the small project file cycle of the SPECTRUM project management system.

Phase	Description	Hours	Cost
2.1	preliminary design	44	1,760
2.2	detailed design	175	7,000
2.3	program design	189	7,560
2.4	programming	473	16,555
3.1	implementation planning	39	1,560
3.2	system test	47	1,880
3.3	operations turnover	17	680
3.4	training/startup	17	680
3.5	wrapup	8	320
		1,009	37,995

For the approximately 10 programs required, the cost per program for machine time is estimated at $150. Thus, overall machine costs will be approximately $1,500.

The total system development cost is therefore estimated at $39,500.

3.2 Operating and maintenance

The annual run requirements are estimated as follows:

edit runs	- 150 runs at $10 per run
update runs	- 50 runs at $10 per run
standard report runs	- 200 runs at $25 per run

The total annual run costs are therefore approximately $7,000.

Any additional computer costs, such as forms, temporary file space, etc. will be minor in comparison and should not exceed $1,500.

The annual rate of record generation is estimated at 3,500, including system, reach, and point records. Assuming 400 characters each (which includes comments) and a key punching rate of $12 per hour, 10,000 keystrokes per hour, and verification, the estimated key punching costs would be $3,360. Aquatics staff time requirements are based on a data transcription rate of 5 minutes per record and an annual salary rate of $17,000. For the 3,000 point and reach records (the system records are already being completed by clerical staff with the output from the digitizer) the annual estimated staff cost is $2,400. This does not include any of the costs of work on the features listings, as this is already being done by the staff. Administration of the system, co-ordination with B.C.S.C. and others who request reports, etc. is estimated at three man months per year, or an additional $4,250. Thus, operating costs are estimated at $18,500. Maintenance requirements will be approximately three man weeks per year. At the rate of $35 per hour, this is roughly $3,700.

The total annual maintenance and operating costs are therefore estimated to be $22,200.

ALTERNATE SYSTEM DESIGNS - INTERACTIVE (INDEXED)

This is the second of three alternate system designs that are described for the Aquatics Inventory System. This design combines batch processing for report generation with online data entry through an interactive program.

1. User's Point of View

1.1 Data entry and edit

The reach tally and point sample cards will continue to be used at present. The features listing sheet may require some minor modifications to complete the watershed system data section.

All data will be entered into the system by the Aquatics Section staff by means of an interactive program. This includes the digitizer output, unless the enhanced digitizer option is added to the system.

The data can be entered into the system through either a hard copy terminal (such as the Decwriter) or at a CRT. The hard copy has the advantage of providing an immediate log of the entire terminal session. The CRT, on the other hand, is quieter, generally capable of much faster operation and is easier to use for extended periods of time.

When data are ready to be entered, the user will log onto the system with a standard sign on procedure. The interactive program will then query him as to what data manipulations are to be performed (add new records, modify existing records, verify the records inserted by someone else, etc.), and will lead him through the required steps, editing his data line by line. A "HELP" routine will allow him to obtain additional information from the system when he encounters a situation that is not clear; the system will describe why it did not accept the data or

expand on its query, and then return to its previous position. For those already familiar with the system's operation, a "terse" form of all system messages can be used to reduce unnecessary delays while the system is communicating with the user.
This form of data entry is ideally suited to checking for reasonableness of the data being entered. If the system suspects that something may not be correct, it need only put out a message to that effect. The user then has the opportunity to either ignore the message, or to correct the error immediately.
It may appear at times that this form of data entry takes longer than merely filling out a coding sheet. However, there are no error lists to process at a later date, and the input error rate is generally lower as this procedure is not as tedious as straight transcription of data.

1.2 <u>File updating</u>

There is no need for any update routine to be run after the data are entered through the edit program. The master file is updated as soon as a valid record is completely entered.

1.3 <u>System reports</u>

Standard system reports (as described in the section "Standard System Reports") will be produced by batch processing. There are two ways that these reports can be generated. They can be punched on cards and submitted through the card reader with the appropriate JCL (exactly as in the first alternative), or they can be "spawned" by an interactive program that queries the user as to which records he wishes to select and which standard report he wants to run. Regardless of which procedure is used to initiate the report generation program, it will execute in batch mode. Under normal conditions the output should be available within a few hours.

1.4 Advantages

There are several advantages with this system in comparison with the other two alternatives.

1.4.1 Implementation time--This system is easier to design than the third alternative, and hence can be implemented more quickly. The design time requirements are very similar to those of the first alternative.

1.4.2 Cost--Because this system is easier to design than the third alternative, its design costs are less. In addition, its operating and maintenance costs are less than those of the third alternative, as less online file space is needed and the programming techniques used are more basic.

1.4.3 Accuracy--The accuracy of the data can be expected to be better than the first alternative. The online data entry by technical staff will trap errors or inconsistencies that might otherwise go undetected, regardless of the sophistication of the program edits.

1.5 Disadvantages

There are few disadvantages with this system in comparison with the other two alternatives.

1.5.1 Cost--There are additional operational costs for line connect charges and file space usage. However, there are no key punching costs. These two factors come very close to cancelling one another, and the true net effect cannot be determined until the system has been in operation for some period of time.

1.5.2 Batch reporting--The production of batch reports automatically involves some delay in obtaining output. The third alternative would generally not have this form of delay. However, this is quite a minor point, and can in fact be partially overcome through an interactive reporting program that can be added to the system at a future date.

1.5.3 File integrity--As discussed in Section 1.4.3 of the discussion of a purely batch system there is a greater chance of running into difficulties with this system in the event of a system or program crash. However, the impact of this potential problem can be minimized with careful program design.

2. Technical Description

2.1 Computer system

This system can be implemented on the Honeywell computer system. In theory, it can also be implemented on the IBM hardware, but there are unresolved policy issues outstanding at B.C.S.C. with regards to the use of TSO. In addition, the pending replacement of the IBM 158 leaves several issues unresolved at this time.

2.2 Files

The master file for this system will be an indexed sequential file. Although it is possible to design the system using only sequential files, it is faster and more convenient to use the indexing capability. A key for each record can be easily constructed from the watershed code, the record type, record sequence number, and data date (needed for repeated point sampling at the same location).

Records will be variable in length. Although comments can be extracted and filed separately offline (for savings in file space charges), it would complicate the entry phase considerably.

File space savings can be achieved by recognizing that it is not necessary to have the full master file online at any one time. The only data that need to be kept online are those which relate to projects currently in progress. Since all report production is by batch, there is no problem in keeping the data for completed projects on tape. Intelligent juggling of the online data could reduce the file space charges quite significantly.

2.3 Programs

2.3.1 Programming language--If the Honeywell computer is used (which appears to be almost a necessity), the language can be either FORTRAN or COBOL74. If FORTRAN is used, the HLSUA interactive ISP must be used to access the indexed file. This is not a Honeywell supported product, but it has been used quite successfully in the past. If COBOL74 is used, the new Honeywell file system UFAS must be used. Of the two languages, FORTRAN is favoured for the following reasons:

1. An interactive FORTRAN compiler is available, which dramatically speeds up program development time.
2. The string handling capability of FORTRAN is not much worse than that of COBOL74.

3. The aquatics system is much more "scientific" than "business" in its use and needs; traditionally FORTRAN has been used for scientific applications and COBOL for business applications.
4. The staff most likely to be assigned the programming task are already familiar with FORTRAN; many of the RAB programs currently in use have been written in this language.
5. There does not appear to be much concern over the lack of official technical support for interactive ISP; it is in fact already in at least one RAB program without any problems. Also, a new version of FORTRAN is to be released this fall which eliminates this problem. It will handle UFAS files, which are compatible with the time sharing system.

If the IBM system is used, PL/1 is preferred over FORTRAN as VSAM would be used. Also, its string handling is better than that of FORTRAN.

2.3.2 Required programs--This system will require one combined edit/update program, approximately 10 standard report programs, and one master file load/unload utility to selectively put certain watershed regions online and maintain others on tape.

The edit/update program will be completely interactive. Successfully edited records will be immediately added to the index master file. The program should have both regular and terse forms of each command or comment to expedite the throughput of those familiar with the operation of the system. This is particularly important if the users do not get a high speed modem and CRT for their data entry.

The editing should not be only on a field by field basis, but should also be done between records, so that possible inconsistencies can be pointed out to the user immediately, and appropriate action taken if he feels it necessary.

A "HELP" subsystem should be included to provide additional explanatory information to the user when he encounters a situation with which he is not familiar. This should be designed in such a manner that the "HELP" response by the user is acceptable to the program at any time it is expecting input from the user. This is an easily added "human" element which helps greatly in establishing user confidence and independence. The standard system report programs will be exactly the same as in the pure batch option (alternative 1). Only the master file structure will be different; the types of requests and the output layout are the same. The user may opt for an interactive program to structure and spawn the batch report generation program. This program would query the user as to the type of standard report desired and which records should be included. The load/unload utility is a straightfoward routine for putting the selected records onto the indexed file from tape, while all other records are put onto a second tape. Detailed record count and size statistics should be provided to assist the user in minimizing his file space use.

2.4 Operational procedures

The user would sign on to the system at any time he chooses. It is his responsibility to ensure that the section of the master file that he needs is online. Automatic system saves performed each evening ensure that in the event of a catastrophic program or system crash the worst possible case would involve restoring the file to its status the previous night and re-entering that day's data.

The user would have complete control of the system, both for data entry and for report generation. The reports would be generated either through card decks as in alternative one, or by having the batch jobs spawned by an interactive program.

3. Costs

3.1 System design, programming, and implementation

The following phases are in accordance with the small project life cycle of the SPECTRUM project management system.

Phase	Description	Hours	Cost
2.1	preliminary design	44	1,760
2.2	detailed design	200	8,000
2.3	program design	189	7,560
2.4	programming	473	16,555
3.1	implementation planning	39	1,560
3.2	system test	47	1,880
3.3	operations turnover	17	680
3.4	training/startup	25	1,000
3.5	wrapup	8	320
		1,042	39,315

For the approximately 11 batch programs required, the cost per program for machine time is estimated at $150. Comprehensive testing of the interactive data entry program is estimated at $500. Thus, overall machine costs will be about $2,150.

The total system development cost is therefore estimated at $41,500. This does not include a second interactive program for spawning the batch standard report runs.

3.2 Operating and maintenance

As with the first alternative, it is estimated that there will be 200 standard report runs per year at a total cost of $5,000.

Assuming that records can be added to the system at the rate of 10 per hour, and that 3,500 records will be generated annually, the total cost for line connect charges (at $9 per hour) is $3,200. It is difficult to estimate the cost of the interactive program's execution, but based on test runs of sample programs, it should not exceed $10 per hour, or $3,500 per year. The online storage requirements can vary considerably, but if it is assumed that not more than 5,000 records need be kept online at any one time, then the file space charges (based on 400 characters per record) would be approximately $500. Thus the total computer charges are about $12,200. Although there are no key punching charges, there is a staff cost involved in having the data entered by the technicians. Based on an annual salary of $18,000, the cost for the 350 hours of data entry is about $3,500. In addition, there are administration and co-ordination expenses which are to be included. Using the same estimate as with alternative 1, these amount to $4,250 per year. Thus the overall operating costs of this system are approximately $20,000.

The maintenance estimates are the same as those for alternative 1. This is three weeks per year of programmer support from B.C.S.C. which (at $35 per hour) amounts to roughly $3,700.

Thus the total annual operating and maintenance costs are estimated to be $23,700.

ALTERNATE SYSTEM DESIGNS - (DATA BASE SYSTEM)

This is the third of three alternate system designs that are described for the aquatics inventory system. This design uses "state of the art" data management techniques, with all processing being online. However, its extremely high design and maintenance costs almost surely make it infeasible as a realistic alternative: for this particular application much of the power of the data management system is in effect wasted. Thus this system is described only briefly in order to complete the discussion on the range of possibilities.

1. User's Point of View

1.1 Data entry and edit

The data entry and edit is completely online. After the initial sign on procedure, the user would notice very little difference between this data entry and that of the second alternative. All edit checks and messages would be exactly as in that alternative. However, the entire master file would be kept online rather than just the active portion as is the case in the second alternative.

1.2 File updating

The master file is immediately updated, just as in alternative 2.

1.3 System reports

It is in this area that the major difference between this design and the second alternative becomes noticeable to the user. The data management system includes a user oriented query language that enables him to write (in simple language) his own report routines. These can be kept in a library for future use, and can be easily modified. This frees the user somewhat from the need for programming assistance every time a new report type is needed. However, the capabilities of these report writer routines are limited. Complex reports will still require "proper" programs be written.

1.4 Advantages

There are several advantages to this system in comparison to the first and second alternative. However, in comparison to the second, almost all are very minor (because of the particular application, not because the data base management approach is not truly powerful) and can be almost completely overcome through some added sophistication to the second alternative.

1.4.1 File security and integrity--It is possible to selectively apply passwords to some of the data to prevent its unauthorized access or modification. This is an important consideration in many business systems. The system is well protected in the event of a system crash, as all file changes are logged on journalization files. However, this is not as critical a factor in this particular application as in some others.

1.4.2 Availability of data--The entire data base is kept online, and hence all data are immediately available for online reporting or editing. However, as it is possible to in fact index every record in the file, the same possibility exists with just an indexed file approach.

Moreover, the file space charges will be much higher as allowance has to be made for all records that will eventually be on the file, thus initially wasting a lot of file space.

1.4.3 Multiple users--The data management approach allows multiple users to simultaneously access the data base and simultaneously update records. This is an important consideration for distributed data entry systems, but is not a critical factor in this application.

1.4.4 Reporting capabilities--The user oriented query processor is good for basic report production. Higher level languages (such as PLP - Procedural Language Processor on the Honeywell system) enable programmers to write more complex report generation routines more quickly than with standard languages such as COBOL74. However, when the timing needs of this system are taken into account and the standard system report package is properly designed, these advantages are not that much better than the capabilities of the second alternative.

1.5 Disadvantages

There are several disadvantages with this system in comparison with the first and second alternatives.

1.5.1 State of the art software--Any new software is bound to have problems that have not been completely ironed out. The DM IV package on the Honeywell system is "just off the shelf". There are no users at this time on the B.C.S.C. Honeywell system, although it is expected to be used in the near future for some large systems. However, the first users can expect to encounter many problems about which little is known.

1.5.2 Cost--The design and operating costs are much higher than with either alternatives one or two. The assistance of the B.C.S.C. data base administrator (DBA) is required to set up the file structure on the computer system. The programming costs will be higher because of the new techniques used in the programming languages. There is a significant training period required to learn how to write the report generation routines in the user oriented language.

The operating costs will be significantly higher as all file space must be initially allocated, whether it is used or not. Although some ways can be found to reduce this allocation, it will still be significantly higher than with the second alternative. Programming support costs will be dramatically higher as well, as the techniques used are new and complicated.

Data base management systems are essentially intended for large scale systems with transaction processing requirements. They are generally used in business applications with several terminals signed onto the system simultaneously. The important characteristics in these types of applications are the security and safety of the data, the lack of redundancy, the control of simultaneous access, and the online availability of all data. These are not critical issues for the aquatics inventory system.

2. Technical Description

2.1 Computer system

The IBM systems have IMS (Information Management System) available, while the Honeywell system has DM IV (Data Management IV). Both software packages support a data base design that is suitable for this application.

2.2 Files

All data are integrated in one large file termed a data base. This file is online and all data in the system are immediately available. Several different record types can exist within the one file, and logically related records (such as all reach records for a given stream) are internally connected via pointers. The particular structure of this data base would be hierarchical, with point samples within reaches within streams within larger streams being the basic tree structure.

2.3 Programs

2.3.1 Programming language--If the IBM IMS is used, the programs would be written in PL/1. If the Honeywell DM IV is used, the language at this time would have to COBOL74. A new version of FORTRAN is to be released sometime this fall that has IDS II (Integrated Data Store II - the name of the Honeywell data base file structure) features, but their exact capabilities are not known at this time.

Many of the standard reporting requirements could be handled through the user language QRP (Query Report Processor) if the DM IV system is used.

2.3.2 Required programs--An edit/update routine is the basic requirement of the system. The need for special report generation programs would have to be examined on a case by case basis to determine whether a program is required, or if the need can be handled through QRP.

2.4 Operational considerations

The data entry and edit features would be almost identifical to those for the second alternative. Extensive user training will be required to teach them how to use QRP.

3. Costs

It is extremely difficult to accurately estimate the costs involved with this type of system, other than the fact that they are extremely high. The following figures are extremely rough; costs could in fact go much higher. However, they do illustrate that in comparison to the other two alternatives, this system is almost out of the question.

3.1 The following phases are in accordance with the small project life cycle of the SPECTRUM project management system.

Phase	Description	Hours	Cost
2.1	preliminary design	98	3,920
2.2	detailed design	273	10,920
2.3	program design	420	16,800
2.4	programming	560	19,600
3.1	implementation planning	84	3,360
3.2	system test	105	4,200

Phase	Description	Hours	Cost
3.3	operations turnover	42	1,680
3.4	training/startup	91	3,640
3.5	wrapup	9	360
		1,682	

Computer costs are a large unknown due to the lack of knowledge about either IMS or DM IV within the corporation at the present time. However, it would not be unreasonable for these costs to be at least twice what they are for the second alternative, and are thus estimated at $4,000+. Thus the total system development costs are at least $68,500.

3.2 Operating and maintenance

These costs are also extremely difficult to estimate with any degree of accuracy. They will be higher than with the second alternative, however, for at least two reasons. The file space requirements will be much higher than with the indexed file approach, since the entire file must be kept online and space allocated for future record additions. It is possible to allow for only a set amount of file expansion, and when this is utilized, the system can be reconfigured. However, no data are available on the cost of this reconfiguration, so it is not possible to determine the most economical reconfiguration/file space combination. Operating costs will also be higher due to the use of QRP (assuming the Honeywell system is used) by the users. Because it is a new feature and the users are not experienced with it, it would not be unreasonable to see the costs for production reports double over the second alternative. Therefore, overall operating costs will be at least $5,000 more than with the second alternative.

Program maintenance costs can be expected to increase dramatically over the requirements of the other two alternatives. The techniques used are complex, and all of the software is new. Again, it would not be unreasonable to expect maintenance costs to at least double over those of the other two alternatives to about $7,300 per year.

Therefore, total annual operating and maintenance costs are estimated to be at least $32,000, and could go considerably higher.

CONVERSION OF EXISTING DATA

The conversion of the existing data cards to system computer records is considered as a separate cost factor from the system design, programming, and implementation costs. This is done for two reasons:

1. It is not in fact necessary to convert the existing data to implement a computer system design. Rather, the existing data can be converted after implementation as time, resource, and reporting requirements permit.
2. Since the existing data can be converted over a period of time, the costs associated with this conversion can be spread over two or more fiscal years.

The following table is based on current (i.e., fall/77) record counts of 1,200 watershed system records, 2,200 point records, and 4,500 reach records. This total is approximately double the expected annual record production rate, and consequently the entries in the following table are obtained by doubling the data entry costs detailed within each system description's operating cost calculations.

Cost Factor	Batch System	Batch/Online System	Data Base System
machine costs	$ 5,500	$13,400	$13,400
staff time	4,800	7,000	7,000
administration	4,250	4,250	4,250
key punching	6,720	-	-
Total	$21,270	$24,650	$24,650

LIST OF CRITERIA

1. System Design Costs

   This includes staff and machine costs for system design, programming and implementation.

2. Operating and Maintenance Costs

   This includes all costs for program execution, file space and line connect charges, B.C.S.C. programmer support, and staff time costs for data processing and administration over and above what is now being done in the branch.

3. Convert Existing Data

   This is the cost of converting the existing data, which amounts to (fall/77) about two full years worth of data generation.

4. Timing

   This is the number of weeks until the system can be implemented. For the first two alternatives it is the total number of man weeks required. For the third alternative, it is slightly less than the total number of man weeks required as there is some overlap between program design and the support services of the Data Base Administrator setting up the data base.

5. Risk of Error

   This is the likelihood of erroneous data being added to the master file through transcription or key punching error. It is also the difficulty in file recovery should the computer system or the updating program crash.

6. Ease of Use

   This reflects the amount of training that staff will required in order to successfully use the system.

7. Flexibility

   This is the ability of the system to "adapt" to changes in record structure or the addition of new record types. All systems require some program modifications in these situations; this is an indication of the relative ease and speed with which these changes can be incorporated.

8. Reporting Capability

   This is the speed with which the system can produce a requested report.

COMPARISON OF SYSTEM ALTERNATIVES

CRITERIA	PURE BATCH SYSTEM	COMBINED BATCH/ONLINE SYSTEM	DATA BASE SYSTEM
1. System development costs	$39,500	$41,500 (not including interactive batch report generator)	$68,500+
2. Annual operating and maintenance costs	$22,200	$23,700	$32,000+
3. Convert existing data	$21,270	$24,650	$24,650
4. Installation time	29 weeks	30 weeks	44+ weeks
5. Risk of error (both data and system failure)	data error - medium system error - low	data error - low system error - medium	data error - low system error - low
6. Ease of use (training requirements)	data entry - easy ad hoc reports - difficult standard reports - easy	data entry - easy ad hoc reports - difficult standard reports - easy	data entry - easy ad hoc reports - medium standard reports - easy
7. Flexibility (ease with which programs can be modified to cope with system changes)	straightforward	straightforward; slightly easier than pure batch system	not as easy as the other two; requires assistance from B.C.S.C. DBA
8. Reporting capability (speed of response)	slow (minutes to hours)	medium (seconds to hours)	fast (seconds to minutes)
9. Additional cost of digitizing enhancements (initial cost)	$ 5,000	$ 5,000	$ 5,000
10. Annual cost of additional digitizer features	$ 1,500	$ 1,550	$ 1,550
11. Additional annual cost for high speed modem and CRT terminal	not applicable	$ 3,800	$ 3,800