AQUATIC SYSTEM INVENTORY

(BIOPHYSICAL STREAM SURVEYS)

APD Technical Paper 1

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AQUATIC SYSTEM INVENTORY
(Biophysical Stream Surveys)

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(Biophysical Stream Surveys)

CONTENTS

Page

5.0 DATA COMPILATION (GETTING IT TOGETHER)

6.0 DATA MANAGEMENT

7.0 INTERPRETATIONS

LIST OF RELATED PUBLICATIONS

A: Data Entry Procedures for Reach, Point and Fish Aquatic Data Cards
D. Belford and T.W. Chamberlin

B: A Hierarchical Watershed Coding System for British Columbia
W. Patrick Shera and Daniel J. Grant

C: Mapping Standards for 1:50 000 Aquatic Biophysical Maps
(In prep.)

D: Map and Card Edit Procedures
(In prep.)

E: Aquatic Survey Terminology
T.W. Chamberlin (ed.)

PURPOSE OF MANUAL

This manual and its related publications summarize the philosophy and procedures used in the systematic stream inventory program conducted by the Aquatic Unit of the British Columbia Ministry of Environment. It provides the documentation to accompany training courses for stream inventory, but does not stand alone; it is predicated on mandatory intensive field and classroom training.

The approach described in this manual is the result of much dedicated effort by all members of the Aquatics Unit over the last 5 years, and numerous hours of field application by literally hundreds of stream surveyors throughout British Columbia. Much work remains to be done in the area of stream inventory and classification and the author would greatly appreciate continued feedback and criticism towards the goal of truly integrated land and water resource management.

1.0 INTRODUCTION

1.1 Biophysical (Ecological) Survey

Resource surveys have traditionally been specific to single resources or products (e.g. forest inventory, mineral surveys, fish population surveys), and most commonly oriented to land based disciplines. The early explorers, such as David Thompson, were more ecologically minded, recording the salient aspects of almost everything they observed.

More recently, the Canadian Committee on Ecological (Biophysical) Land Classification has reviewed ecological approaches to mapping and classification in Canada in a series of publications dating from 1976 (Thie and Ironside). A review of these efforts clearly demonstrates that it is a difficult task to integrate both land and water resources in an ecological land classification scheme. Welch (1978) reviewed land/water classifications and pointed out some of the major reasons for this related to the scale of the processes and fluvial environments concerned. Table 1 is from his report. It is apparent that in describing fluvial environments, the purpose or objective of inventory must be very carefully matched to the scale or level of information gathered for the results to be meaningful.

Two specific problems emerge in stream (and lake) inventory which make compatibility with land system inventory difficult. The first is that whereas drainage basins, or watersheds, are the basic functional unit for water, they may not be relevant for the vegetation-soil-landform complexes mapped in land inventory. For example, both basin divides

TABLE 1: A HIERARCHY OF FLUVIAL ENVIRONMENTS[1]

FLUVIAL ENVIRONMENT	ECOLOGICAL LAND CLASSIFICATION LEVEL AND PRESENTATION SCALE	SUITABLE CLASSIFIERS	CONTROLS
RUNOFF RESPONSE	Facet 1:1000	Length of overland flow Drainage density Infiltration capacity Local relief	Physiography Soils Vegetation
HYDRAULICS	Type 1:10 000	Bedforms Roughness	Discharge Gradient Sediment Parent material
REACH HABITAT	System 1:50 000	Bank form Riverine vegetation Bedload Riffles, pools, falls, rapids Depth, width	Physiography Channel dynamics Debris load
CHANNEL PATTERN	System 1:50 000	Sinuosity index Pattern class	Debris load Energy relations
VALLEY FORM	System 1:50 000	Plan pattern Cross shape Terraces Under and over-fit	Tectonic history Geomorphic history Eustatic history Geology
DRAINAGE TOPOLOGY	System-District 1:50 000-1:250 000	Bifurcation Order Magnitude Basin shape	Growth Geology
DRAINAGE PATTERN	District-Region 1:250 000	Pattern River capture	Geology
RIVER REGIME	Region 1:500 000+	Lag time Basin size Precipitation Snow Base flow Etc.	Climate Physiograpy

[1] Adapted from Welch, 1978, p. 33.

(e.g. ridges) and valley bottoms may have a diversity of types of water bodies within fairly homogeneous land units. Rivers which derive their properties from outside the land unit through which they flow have been called "exotic" by some ecological land surveys. Similarly, rivers flowing at the edge of a valley bottom, for example, may have one bank in a hillside colluvial land unit while the other is an active floodplain.

A second difference between aquatic inventory and terrestrial inventory is derived from the fact that streams respond at much more rapid time scales than do most soils or vegetation. Both the water and channel environment may change radically over a few hours or days, whereas some species of fish may occupy their habitat for only a few days in a year. Adequate stream classifications must allow for both of these factors.

These considerations have led to a biophysical stream survey procedure in British Columbia which concentrates on the channel enviroment, but which also relates that channel to the land system through which it flows. The survey is biophysical (ecological) in that it considers both physical and biological characteristics of rivers, and is conducted relatively independently of related land surveys (soil, geology, etc.). Despite this independence, strong correlations are apparent between river reaches (sec. 2.2) and surrounding landscapes, and a competent stream surveyor must have an excellent appreciation of the manner in which climate, geology and vegetation shape the hydraulic geometry of the river environment. Only through this integrated approach can aquatic ecosystems be understood.

1.2 Uses and Users

An inventory must be designed in the context of intended applications. Forest inventories are traditionally oriented to predicting merchantable wood volumes; soil surveys follow a well established soil classification. And yet ecological research such as Holling's (1978) has adamantly pointed out that what we do know about social, economic and environmental behaviour is much less than what we do not know. The frequent, and sometimes radical, changes in program goals and environmental assessment procedures reflect this uncertainly and suggest that systematic resource inventory must be designed to maximize its applicability to future unknown as well as the presently known applications.

Aquatic system surveys have historically collected information for two rather different interests, the manipulators of water or channels (e.g., irrigation, power, navigation), and the biological inhabitants of rivers and lakes (e.g., fish). Increasingly these areas are converging as local and regional land planners, foresters, recreationalists and others are putting heavy demands on the extractive as well as in-stream values of water bodies. The systematic aquatic survey described here is designed to provide a basic core of data from which inferences can be made about the dominant physical and biological processes in a river. Intensive single purpose surveys complement this basic biophysical description by providing specific details, but without the basic ecological framework it is difficult to accommodate new users' needs or to develop comparisons between areas.

1.3 Products

The standard reconnaissance level survey procedure described here produces data stored in a computerized data base, several standard summaries of that data, and maps of some selected data elements (the Aquatic Biophysical Map). From these products, analyses can be made of relevance to specific resource problems, but a strong distinction must be maintained between basic data and the subsequent interpretations. A wide variety of reports can be constructed from a given data set, but user requirements in a particular region will dictate which are most appropriate. Sections 6 and 7 discuss data management and interpretations in more detail.

Although this survey procedure is theoretically applicable to a variety of applications, the anticipated product design should be a part of survey pre-planning. A serious investment of planning time with intended recipients of survey information will frequently permit a focusing of inventory effort in areas of most immediate application, and will often suggest modifications of procedures which will benefit both surveyors and users, while maintaining the integrity of the basic biophysical data.

2.0 SAMPLING DESIGN

2.1 Scale and Sample Density

The objectives of a survey must be closely related to the scale at which information is gathered. Information useful for comparing major basin properties will be quite different than that required for locating a bridge crossing. Table 2 summarizes some of the characteristics of four arbitrary levels of survey scale.

TABLE 2: LEVELS OF AQUATIC SURVEY

LEVEL	OBJECTIVES	SAMPLING	NO. OF SAMPLES
I Broad Overview	REGIONAL Comparisons 1:100 000 to 1:500 000 Provincial planning	REMOTE Sensing Existing data only 80 ch. to ERTS imagery	NONE
II Reconnaissance	BASIN comparisons 1:50 000 Reaches defined obstructions located Fish sp. presence/absence Regional or strategic planning	AERIAL observation Reach parameter estimates Few point samples 20 - 80 ch. aerial photos	FEW
III Detailed Inventory	MANAGEMENT 1:10 000 - 1:20 000 Habitat types described Population sizes measured Sub-regional or Operational planning	GROUND transects Reaches subsampled Detailed aerial photos	MANY
IV Intensive Studies	SITE SPECIFIC Engineering design Population ecology Time functions established Productivity estimates Project design	REPETITIVE sampling Experimental work	MANY

It is important to note that scale, which normally refers to map presentation scale, also implies information density and hence reliability. Information gathered at a general level can not be "blown up" to a more detailed level without serious distortion of its meaning.

In British Columbia we have chosen 1:50 000 (Level II) as a reconnaissance scale from which both upward generalization and downward refinements (with additional sampling) are possible. This corresponds to the "Land System" level of mapping in ecological land classifiction terminology (Lacate, 1969) and could probably be mapped at 1:125 000 in regions of more homogeneous terrain such as the Arctic and prairie provinces (see Fig. 1).

2.2 The Reach

The aquatic survey utilizes a stratified sampling procedure in which "reaches" are the sampling unit. A reach is defined as a relatively homogeneous section of river whose properties reflect a <u>repetitious sequence of physical processes and habitat types</u>. Reaches are initially delineated on air photos on the basis of uniform channel patterns and channel to valley relationships. It is assumed that these channel forms are a reflection of the overall balance (or lack of balance) between materials, energy and time. Hence a long pool-riffle sequence or a sequence of regular meanders would be delineated as a reach even though the exact location of pools or meander curves might vary from year to year.

From this definition it can be seen that reach properties are parameter averages (e.g. width) or percentages (e.g. pool), and can hence be combined from reach to reach to allow aggregate system properties to be estimated. The accuracy of reach parameter estimates will be a function of variability within the reach, number of ground (point) subsamples, and reliability of air photo interpretations. Again, the relationship between scale, information density and survey objectives is apparent.

Sub-reaches may also be identified which more closely represent individual habitat elements such as pools or riffles, but these will still be in the context of the basic reach whose boundaries reflect hydraulic processes and materials constraints.

Reach data is entered onto a standard data card from which it is placed into computer storage. It should be noted that reach information is accumulated from a variety of sources other than measurements, and should be updated as new information becomes available. General procedures related to reach property estimation are discussed in Section 4.2. Data entry instructions for reach data cards are summarized separately in a companion publication ("Data Entry Procedures").

2.3 The Point

The point sample in a stream survey describes a specific location at a specific time. In reconnaissance level survey the point location is frequently opportunistic due to access limitations, such as helicopter landing sites or road crossings, and will not normally be representative of the reach in all its particulars. Preselection of the point sample site on the basis of prior reach stratification is therefore mandatory to avoid misleading data.

When ground access permits additional sampling, further measurements should be made to better reflect the range of variability found in a given reach. Systematic line transect techniques have been described (Duff and Cooper, 1976; Dunham and Collotzi, 1975) which provide guidance for very detailed surveys, and adaptations for the evaluation of limiting factors have been developed by the Habitat Improvement Section of the B.C. Fish and Wildlife Branch (Wightman, J.C., 1979; Tredger, 1980). Even with very detailed survey, however, the objective is to describe the characteristics of the reach or sub-reach as the basic stream units.

The principal objective of point samples in reconnaissance level survey, therefore, are to support the reach descriptors by:

1. Establishing fish species distribution and the relative amount of other biota.
2. Providing a flow and water quality measurement for the particular time of survey.
3. Providing ground truth for aerial observations and air photo interpretations and of bed material, bank forms and related channel and valley properties.
4. To provide a point of comparison, against which the rest of a reach can be described.

The repetition of point samples through time is highly desirable, as both the biotic and hydrologic properties of river reaches may vary with the seasons even though valley and channel physical properties are relatively constant. Repetitive point samples are seldom done, however, in Level II surveys.

The discussion of scale and information density in Section 2.1 should be emphasized here. Without systematic line transects or an equivalent stratified sampling design, information cannot be applied below the level of average reach properties.

3.0 PREPARATION FOR A SURVEY

3.1 Bases and Airphotos

Several steps of preparation are required prior to field activity. Map bases usually require special preparation and should be ordered several months before drafting will take place. Although the field map is normally the standard published 1:50 000 NTS sheet, the mylar upon which information is eventually plotted must have contour lines and cultural information screened by about 60% to emphasize the drafted thematic data (i.e., stream lines and reach features).

When special bases, such as orthophoto mosaics and planimetric maps are used, they should be carefully examined to ensure that stream lines are present and that adequate topographic information is present to accurately locate reach boundaries and sample locations. Users should be aware that map bases at smaller scales (e.g. 1:250 000) are frequently generalized with respect to the location and detail of stream lines. Minor meander curves for example, may be "smoothed out".

Two sets of pre-drafting maps are used in 1:50 000 surveys: field (working) maps, and a master. Irrespective of the abuse heaped upon the field maps, masters should remain dry, unfolded, clean and neat. Masters will be used later for digitizing, a process which assumes accuracy of ± 0.25 mm, and will provide the basis for final drafting onto mylar or other stable material.

Air photos, for both pre-typing of reaches and field mapping, may require 1 - 8 weeks for delivery in British Columbia. For reach delineation, 1 inch = 80 chains or about 1:50 000 scale photos are appropriate, although for very large river systems LANDSAT imagery has been useful. Larger scale photos (1:20 000 or 1 inch = 20 chains) are useful for channel property estimates in selected areas, but are too small for reach delineation and too numerous to be viewed for every km of large surveys. Very large scale photos (1:10 000 - 1:1000) are very useful for experimental or specific design applications such as highway design or habitat improvement projects, but would not normally be used in systematic inventory.

The air photo record may extend back through time, and surveyors should consider using sequential photos of the same location to document time trends in channel stability, vegetation regrowth, and changes associated with major runoff events. This is not normally done in a Level II survey, but is frequently appropriate for special studies.

In situations where adequate bases are not available for mapping, it is suggested that stream symbols be plotted directly on suitable air photos. The zoom transferscope or epidiascope may be useful at this stage. The location of sample points or features can then be referred to a clear grid overlay with standard cm-mm line spacing. The photo number and x-y coordinate provide precise georeferencing on the photos to ± 0.5 mm. Distortion is minimized by plotting only in the central portion of photos in the flight line (60% overlap).

In British Columbia, air photos are ordered from:

Provincial Map and Air Photo Sales,
Ministry of Environment,
Parliament Buildings,
Victoria, B.C. (with a 1 - 8 week delivery time).

or

federal photos (labelled A or RSA) from:

National Airphoto Library,
615 Booth Street,
Ottawa, Ontario. K1A 0E9. (with a 4 - 6 week delivery time).

All photos should be previewed if possible; federal photos are available on microfilm at Map and Air Photo Sales in Victoria and the Terrestrial Studies Branch has a specialist in remote sensing who can provide advice when required (Mary Redmond 387-1834).

3.2 Watershed Code Numbers

A hierarchical numerical coding system for stream systems in British Columbia (and the Yukon) has been developed by the Aquatics Unit. It is described fully in the companion publication by Shera and Grant (1980), and provides a means for assigning a unique numerical identifier for up to 8 levels of stream hierarchy.

All data elements are accessed by the watershed code number, which should be obtained from the Ministry prior to survey. A dictionary of all codes is available for extensive users in both numerical and alphabetical order. The code number has been found useful for organizing a number of non-computer applications also, such as accessing slides, samples and miscellaneous information which cannot easily be computerized.

3.3 Reach Pre-typing

Reaches have been defined as the basic sample stratification device for river survey. Pre-typing of reaches using air photographs provides a valuable framework for focusing the inventory effort. In addition to determining where reach boundaries will occur (enabling new reach property estimates to be started) point sample locations can frequently be located, significant features identified and problems of logistics anticipated. When possible, systems should also be flown by fixed wing aircraft to confirm proposed reach boundaries and sample points before helicopter sampling begins.

Reach pre-typing for most streams will require small scale photos (1:50 000 ±) so that transitions between river segments are clear. In any event, a large number of photos must usually be viewed, and the use of a high quality scanning stereoscope (e.g. Old Delft; Zeiss) will greatly improve performance efficiency. The appropriate scale of photography will, as usual, be related to the objective of the survey.

Tentative reach boundaries and feature locations (e.g. bridges, obvious falls and the location of any features requiring field checking) should be transferred to working maps in anticipation of refinement in the field and to facilitate the location of representative point sample locations.

3.4 Logistics and Planning

Actual field survey time occupies less than 30% of the inventory effort. Nevertheless, well organized logistics and cost estimates are vital for success and require a number of decisions related primarily to scale and access.

Scale of inventory is the single most important factor affecting time and costs. A 1:20 000 scale survey, for example, will cost 5 - 10 times more than a 1:50 000 survey, the difference related primarily to sampling density. Ground access costs per unit area for reconnaissance survey can be much higher than helicopter access when time and salary are considered, and would normally be warranted only where detailed photographic records or systematic sub-sampling is desirable. When helicopters cannot be used, intensive air photo interpretation is mandatory to minimize ground sampling time.

The value of training cannot be over-emphasized. A poorly trained crew will not only perform much more hesitantly in the field, but will produce questionable data which may require more time to decipher (by other people) than was spent gathering it (see Section 6).

A rough rule of thumb in estimating helicopter flying time for stream surveys is to measure the line distance of all streams to be flown, assume a survey speed of 80 km/hr., and then triple the estimate to include fuel stops, ferrying, and crew pickup and drops. In mountainous terrain, adequate fuel reserves for longer low level return routes must be maintained because of unpredictable weather.

The principles of Murphy should always be observed.

4.0 FIELD OPERATIONS

4.1 Aerial and Ground Procedures

Aerial stream observation is done at 30 to 200 m in elevation (depending on river size and tree height) at about 80 - 100 km/hr., while closely following the river to allow the observer a clear view of both bed and banks. This is not normal flying behaviour for most pilots, and explicit communication between pilot and observer and some practise will be necessary before efficient observations can be made.

Information is recorded on tape during flights, the observer commenting on all relevant reach card parameters while traversing the reach. The value of knowing approximate reach boundaries (from pre-typing) is obvious. Representative photographs are taken and their location noted verbally. Correlation between tape and ground locations requires frequent verbal references to identifiable ground points and to locations marked on the observer's field map. The observer should not hesitate to slow down, circle, hover or otherwise use the helicopter; it is an observation tool, not just a transport vehicle. To prevent ambiguities, the observer must concentrate fully on correct and complete terminology, and hence must have memorized all codes applicable to stream parameters. A check list conveniently located is useful.

Information collected on tape should be compiled on reach cards and the "master" map as soon as possible following flying since memory quickly fades. Whenever possible, this compilation should be carried out the same or following day.

Specific attention must be given to the tape recorder during and before flights to ensure that batteries are fresh for each flight and that the machine is running. If possible, new batteries should be used for each day's flying and a spare tape recorder carried. "For the want of a nail, the kingdom was lost".

Equipment for ground crews should be well organized in a container suitable for the helicopter's cargo hatch. Drop off points may require careful maneuvering, so the process of unloading and loading must be efficiently done. It is the observer's responsibility to brief the ground crew on their location, expected time of pick-up, and the relevant codes and names for data cards. When possible, this should be done before takeoff.

Ground crews, working as a team, will be able to complete their non-fish sampling observations and measurements within about 30 minutes. With efficient flight time planning and the use of 2 ground sample teams, 6 - 8 sample points can be completed in a day. The limiting factor in aerial survey will normally be observer fatigue due to the physical and mental stress of continuous concentration on stream features. Experience shows that observer performance deteriorates rapidly after 3 to 4 hours flying time. We strongly recommend rotating observers on alternate days to allow tape transcription and reach card compilation in the day immediately following flying observations.

4.2 Reach Property Estimation

Aerial procedures have been discussed. The accuracy of observations can be improved by cross checking with air photo measurements (e.g. channel width, valley flat width) and with ground data from point cards and at landings. Momentary hovering over bars helps calibrate the eye for bed material size. As the end of a reach is approached (on the ground or in the air) a quick summary of parameters and impressions should be made on the tape, remembering that general comments can also be preserved.

The most important principle in gathering data from aerial observations is to avoid misleading information. If verbal comments contradict themselves within a reach without some explanation, then the data may have to be rejected. Remembering that the objective is to determine an average parameter value for the reach (while noting exceptions) the observer must continuously review what has been and will be seen in the context of the current observation.

Reach property estimation from aerial observations is a difficult skill, analogous to air photo interpretation, and requires both training and practice for accuracy and consistency. Observers should not fly unless all phases of preparation have been completed and they are in excellent physical and mental condition.

4.3 Point Samples

The point sample data card contains real numbers, derived mostly from measurements. Yet the sample is but one point within a reach. Since point sample data cards can be used to record information from a variety of types of samples (plots, single banks, complete transects) both the location of the sample and its relationship to the reach must be clearly stated. For example, a side channel description adjacent to a larger river will be extremely useful in understanding fish rearing habitat, but will be quite confusing if the reader thinks it describes the main channel.

Standard methods (see also Section 6.6, data entry) should always be followed, and unavoidable departures noted as a comment. Considerable flexibility will be required to adapt some standard methods to the peculiarities of small and large rivers, but for example, distances measured by tape, rangefinder or visual estimate should be clearly differentiated.

Some point properties (e.g. bank material texture) are relatively constant whereas others (e.g. water depths, velocity) will be a function of the time of survey. In repetitive sampling, all should be repeated, both as a measure of channel stability and as a check on observer consistency. This is particularly important when repetitive fish sampling is done to document relationships between changes in fish habitat and their utilization of that habitat.

The point card permits considerable flexibility in defining a sample's domain. As an operating convention, however, the riparian zone is extended about 20 m back from the bank, and averaged values, such as bed material composition or debris loading should represent average characteristics up and down stream for 1 - 2 stream widths. In this sense the point approximates the "plot" of vegetation sampling, but without a rigorous spatial limit. More detailed sampling would require discrete samples at multiple points across a series of cross sections to establish the spatial distribution of properties within the river bed. But remember that scale and sample density must be related to survey objectives. The companion publication "Aquatic Survey Terminology" provides some examples of point parameter estimations.

4.4 Fish Sampling

Fish sampling methods to establish species presence and distribution must be sufficiently flexible to handle all types of water. Electrofishing alone will produce poor results in a turbid river, but with a stop seine downstream it may be effective. Visual observation, angling and swimming may be the only means of sampling deeper water. On larger rivers, boat mounted boom shockers and nets may be necessary. Methods of sampling appropriate to the expected river types must be determined during the planning phase, and the required variety of equipment carried during the survey.

Comments on fish behaviour are valuable adjuncts to later data interpretion, especially in conjunction with the stream cross-section on the point card. "Gut feelings" should always be preserved as "comments", but compared wherever possible to subsequent sampling. This is particularly important where expected population densities are not found. Although fish population estimates are not made during reconnaissance level surveys, the data may suggest areas of higher or lower priority for future detailed studies.

Species identification should be absolute. The ground crew is responsible for the veracity of all species names, and in the case of doubt or unusual findings, samples should always be taken for outside verification. The B.C. Provincial museum will verify any questionable samples free of charge.

4.5 Sample Management

In this section, sampling means bringing something back. Whether a fish, a plant, bed material or water, the decision to sample assumes that the additional information will contribute to the more accurate characterization of the reach. All samples must be correlated with point sample locations and completed point cards. Without the physical point data, the interpretive value of samples is considerably reduced.

Fish are normally preserved in 10% formalin solution in a plastic twirl-pac prior to transfer to glass bottles. Ional solution may be added if colour stability is required. Waterproof labels in the container must be used.

Water samples taken for ad hoc sediment concentrations should be preserved with about 1 cc per l of $CuSO_4$ solution mixed at 0.45 g/l concentration and stored in refrigeration until analysis. Water samples for standard chemical analyses must be collected in standard bottles and sizes prescribed by the Ministry of Environment's Laboratory (3650 Westbrook Cres., Vancouver, B.C. V6S 2L2; 228-9766). All water sample bottles must be clearly labelled with sample location, date and time and initialed by the sampler. Location in systematic survey should include watershed code and point number.

Bed material and invertebrate sampling are not done as part of standard reconnaissance survey, but standard methods are available. Both require careful sampling design and technique and should not be undertaken without full support facilities for both sampling and subsequent analysis. Consult the Aquatic Studies Branch for information.

5.0 DATA COMPILATION (GETTING IT TOGETHER)

5.1 Watershed Boundaries

The delineation of watershed boundary lines on master map bases prior to drafting is a first step in the compilation process. In regions of low relief and extensive wetlands it may not be a simple task, but will always follow a set of rules which presume that water flows downhill. These assumptions are:

1. All watershed boundary lines intersect all contour lines at right angles;
2. Ridges divide watersheds;
3. Shallow depressions, wetlands and some lakes may drain both ways;
4. Distributaries at a river mouth are within the river's basin;
5. Diversions are mapped (and numbered) as part of their receiving basin, although their channel may originate within another basin.

All watersheds for which information has been compiled must have watershed code numbers. Consult section 3.2 and the companion publication "A Hierarchical Watershed Coding System for British Columbia", available from the Aquatics Unit, for details.

5.2 Field Data

We heavily stress the principle of minimizing the number of data transfers from one piece of paper to another. With few exceptions, tapes or their transcripts should be compiled directly on to reach cards and working maps. Point sample data should be written only once on point cards, and all fish information should be compiled in the field on fish sample cards. Not only does this procedure reduce the probability of error, but it also ensures that information is recorded in the correct formats for data entry (see also section 6.3).

5.3 Data From Other Sources

Information about reaches, especially fish species distributions, is frequently available in the files and reports of other agencies, universities and private firms. Such data or studies should be referenced in the Survey History file for each basin and those portions which apply to card formats recorded thereon. Interviews with local resource managers, sporting or environmental groups, and residents often turn up unexpected data. Verification (e.g. of species names) is always required before accepting such information, and a qualification of the reference source may be necessary (e.g., anecdotal).

Close communication between related survey teams (e.g. terrain and aquatic) will frequently improve the biophysical basis for reach boundaries and clarify the geological context in which the stream lies.

5.4 Map Compilation Principles

Mapping standards for standard 1:50 000 Aquatic Biophysical Maps have been established by the Terrestrial and Aquatic Studies Branches. In general the standards include conformance to a standard legend (the application of which is, however, quite flexible), the separation of inference and certainty in symbols, and the avoidance of information which although correct, could be misleading.

The scale of map dictates what degree of information generalization is appropriate. At 1:50 000 a fairly wide range of variability may (and should) be "lumped" within a reach, and hence the information characterizing that reach on a map will only indicate broad averages. Likewise "zonal" information about sections of stream (e.g. a zone used for intensive spawning) will be generalized about that zone, and detailed surveys would be required to evaluate site specific impact or habitat improvement measures.

The "master" map is compiled either in the field (for large integrated surveys) or in the office. It must accumulate in a neat and orderly fashion, all data plotted on "field" or "working" maps as well as that being compiled on point and reach cards. It will be the final document submitted for draughting and used in the digitizing procedure and hence should contain no ambiguity.

5.5 Map and Card Edits

All samples, data cards and maps must have their numerical codings cross-indexed correctly or they cannot be found. Similarly they must all convey the same information, and use the proper allowable data entry codes. The "Map and Card Edit Procedures" ensure that these objectives are met.

Editing procedures, in addition to providing correlation between data elements, also provide the last opportunity for data to be compared with common sense. For this reason, the "outside edit" finally applied to a map should be done by a person not connected with the project area, and allows inferences and assumptions to be questioned from a fresh viewpoint.

Map and card edit procedures have been documented and are available from the Aquatics Unit, Ministry of Environment.

6.0 DATA MANAGEMENT

6.1 Objectives of Data Management

The Aquatic Data Base has three principal objectives:

1. To ensure that inventory data is not lost.
2. To ensure that data is organized so that it is easy to retrieve.
3. To ensure that data is available and useful for resource decision making.

These objectives presume that inaccessible data _will_ be lost; that unorganized data _will_ _not_ be used; and that incomplete or inappropriate data _is useless_ for decision making.

Clearly data management must start with sample design. Hence the system, reach, point hierarchy of the aquatic inventory with their associated data cards and forms. Unfortunately, data management requires time and energy (as do all measures which reduce the entropy of a system) so that a commitment to the steps which _follow_ field work is the first requirement for a successful inventory program.

6.2 Source Documents

A source document is the document from which data are entered into the data base. Since recoding is not done, the field cards (Point, Reach, Fish) are original source documents, along with the "master" map and digitizing coding form. Source documents are created during the inventory process as observers, ground crews and compilers complete their tasks.

To avoid loss and maintain organization of source documents, they are collated and maintained by the observer, who collects point cards from all ground crews at the end of each day's sampling. Following compilation, all field cards and maps are maintained centrally at the Aquatic Studies Branch, Victoria, B.C., under the supervision of the Aquatic Data Analyst. A copy of all source documents should be maintained in a separate storage location (e.g. from a systematic microfilming program). Groups conducting inventory from regional centers should consider fireproof vault storage and Xerox copies of all source documents.

6.3 Handwriting, Punctuation and Codes

Both keypunchers and computers are programmed to accept only previously defined and admissible codes. They can not decipher ambiguous numbers or letters, insert missing commas or colons, or translate words into codes.

The first rule then is to print clear characters with a sharp black erasible pencil. Thick pencils produce illegible characters. An HB hardness is suggested.

Some of the more common oversights and conventions include the following:

1. Ditto marks may not be used for repeats. Use arrows.
2. "+" is allowable only with the fields "TOTAL NO" "Fish Age" (Fish Card) and "Turbidity" (Point Card).
3. Greater than ">" and less than "<" may not be used.
4. Numbers with a decimal must have a digit to the right of the decimal.
5. Field limits (number of digits allowed) may not be exceeded. A decimal point occupies a digit position. Consult specific data entry instructions in the companion publication "Data Entry Procedures".
6. Information must be consistent between data cards and maps (e.g. the inferred brackets for fish species).
7. All comments must be labelled with either C#, S#, F#, or CX. The number must be included with C, S and F on the reverse side.
8. The system name must be either "unnamed" or the dictionary name and the spelling (and punctuation if applicable) must be correct.
9. The "key" data must be entered on all cards.
    - 9.1 Reach: System No; Date; Reach No.
    - 9.2 Point: System No, Date; Time; Reach No., Point No. and, if applicable Fish Sample No.
    - 9.3 Fish: System No; Date; Reach No; Point No; Fish Sample No.
        - 9.3.1 Fish Summary: Species and method.
        - 9 3.2 Individual Fish: Fish No.
10. The "approximately" symbol "∼" is not allowed.

11. Use capital letters for coding all fish species.
12. NTS map numbers are separated by commas, not semicolons or slashes.
13. The field observers are separated by a slash.
14. All mapped and non-mapped fish species must be recorded in the reach "Fish Summary" section, as well as on Fish Cards (if sampled). OS is only permitted in the reach symbol on Aquatic Biophysical Maps.
15. "$" may be used only in header fields, and only where allowed.
16. Methods should be given for all hydraulic fields but see specific instructions for possible exceptions.
17. Units, where optional, must be noted (Turbidity, Fish Sampling Time).
18. "T" may not be used except for bed or bank material categories.
19. "271R" as a map symbol indicates a trace of bedrock, whereas "R" on the data card or map means 100% bedrock only when it stands alone.
20. Texture codes must sum to 100, and detailed texture categories must be less than or equal to the general category.

6.4 Data Entry and Edit

Detailed instructions for each data field are given in a separate publication ("Data Entry Procedures"). Although data cards are designed for field use, they will be entered (keypunched) directly by people not familiar with their content. It should be clear, therefore, that an appreciation of precise and careful coding and writing is a necessary part of field activity.

Some general aspects of the data entry process should be understood. First error checks are made in the compilation process when cards and maps are cross-checked. Second level checks are made internally during the keypunching process and during the initial "consistency check run". It is nevertheless extremely easy for errors to slip by undetected in the computer if no pre-defined "rules" have been violated. Only care will prevent these errors.

The editing process to correct computer identified errors is tedious, time consuming and expensive. As an example, if errors run relatively high, a week or more of editing time may be required for every two weeks of keypunching (representing about 500 cards). Careful adherence to data entry procedures can reduce this error rate by at least a factor of ten.

6.5 Digitizing Mapped Information

Following compilation and final edit, the "master" Aquatics Biophysical Map is digitized. This process measures the latitude and longitude and distance upstream of all stream features or sample points, the length and slope of each reach, and the area and perimeter of each watershed. A computerized (Hewlett Packard 9825) digitizing system with a position accuracy of ± 0.01 in. is used, emphasizing the need for very precise location of all data on the map. It should be remembered, however, that map accuracy (e.g. elevations ± 0.5x contour interval) will limit output accuracy.

Data from the digitizing process is stored in the Aquatic Data Base and is also organized by watershed code, reach and point number. This allows synthesis and comparison of mapped information across several map sheets or basins without having to refer to the physical map sheets. A variety of standard output reports are available, depending upon users' needs.

7.0 INTERPRETATIONS

7.1 Numbers and Experience

The purpose of attempting to quantify data is to improve the quality of conclusions, to more easily communicate those conclusions and to permit their testing and evalution by others. In the interpretation of data, there is no substitute for experienced intuition, but professional "judgement" must always be supported by all relevant measurable parameters. A conclusion supported by an explicit paradigm or procedure will always be more credible than one resting solely on an observer's opinion.

7.2 Capability and Other Models

Capability, productivity, sensitivity and suitability are interpretations frequently applied to streams and other resources. In general they must be based on defined criteria and be specific to well defined referent items. For example, a "Fish Capability" model is quite general (perhaps absurd), whereas a "juvenile coho salmon rearing capability" model is considerably more meaningful.

Another factor which must always be specified in an interpretation model is the level of expected management intensity. For example, a stream may have an important limiting factor which can be overcome by an appropriate action (e.g. obstruction removal, cover enhancement). The capability assessment is then conditional upon the required management activities.

7.3 Derivative vs. Interpretive Maps

A distinction is made between maps or models which are based <u>only</u> on source document data in an untransformed or uncombined form (e.g. stream widths, gravel size) and those in which the data have been evaluted, lumped, assessed etc., such as spawning gravel quality. The former are called <u>derivative</u> maps since the information is derived directly from survey data, whereas <u>interpretive</u> maps invoke additional knowledge and assumptions, and frequently combine information from various sources.

For management purposes, interpretations will almost always be required to transform the raw inventory data to a form which can be used by non-specialist planners and administrators. Even low, medium and high categories, however, must be based on some data. The objective of systematic inventory is to reduce to a minimum the uncertainties of those things which <u>can</u> be measured so that controversy and discussion is centered on those vaues and attitudes which presently elude measurement but which pertain to our proper and informed relationship to the natural environment.

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