Final Report from the
Vegetation Inventory Working Group
on a Proposed New Inventory

March 30, 1995

CIP

Preamble

The **R**esources **I**nventory **C**ommittee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments. First Nations peoples are represented in the Committee. **RIC** objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its 1991 report The Future of Our Forests.

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Table of Contents

Executive Summary

The design of the inventory has been finalized, tested, and is ready for the first full scale operational implementation in 1995. The design covers the entire land base of BC with a standard suite of measurements from the disciplines of timber, ecology, range and soils. The design is simple, reasonably efficient and is statistically and technical defensible. The results offer an excellent set of measurements for research, resource identification and large scale planning. In addition, it provides an unbiased basis in sampling for any future information needs.

An initial estimation of vegetation polygons provides location-specific information which also increases efficiency. Relocatable ground measurements will adjust these to form an unbiased set of estimates for vegetation and ecological characteristics in the province. To offer flexibility in scheduling and future reinventory, the units are inventoried separately until the province is covered. After each inventory is processed, adjusted information for every vegetation polygon will be individually available. The same sampling procedure can also be used to do a quick, less precise check of the province as a whole.

More information will be gathered than has ever been available previously, and the methods have been coordinated with several resource groups to ensure consistency of definition and procedure. The overall project is described generally in one video, and a second video for technical specialists covers the details of field measurements. Manuals have been written, tested and are now being prepared in their final draft.

Integration with other groups will use databases and Geographic Information Systems based on the TRIM mapping base. New features include a method to unbiasedly update the information based on local work, new decay procedures, direct growth information, statistics to indicate data reliability and an outside audit to add credibility to the system.

A wide variety of individuals and organizations has been involved, and the process has been worked out in considerable detail over several years. General recommendations are available in the full report, with technical details available in field manuals.

Discussions between Ministry, industrial and academic committee members has been frank, productive and remarkably successful. This report is the final set of recommendations of this committee, augmented by the field procedures and detailed processes developed by the committee.

Brief Description of the Inventory Design

In our opinion, the Vegetation Inventory has two major objectives.

First: **How much of a given characteristic is within British Columbia ?** For example, what is the volume of trees, the land coverage of Salal shrubs, or the volume of coarse woody debris? This answer requires an unbiased sampling scheme and careful measurements. We have, in addition, chosen to measure several types of information at the same sample points. This is partly to reduce cost, but it will also provide a rich and valuable set of data for future research. Two points are particularly important. This process is *statistically sound* and involves *actual measurements*. The field data is the source of the numbers which will eventually be produced to describe the vegetation in British Columbia.

At these common or "integrated" sample points we will measure biodiversity, plant species, tree volumes, growth capacity, range values, soil information and many other characteristics. Each of these may be measured with different sampling techniques, but whenever possible they will use the same definitions and measurement techniques. The whole province will be covered by this process, and the main purpose of this work is to get *overall totals* and to deduce some relationships. Experts from various disciplines have agreed upon the measurement procedures.

Second: Where, exactly, is this material ? The ground samples, by themselves, cannot be located in sufficient numbers to provide the locations of particular tree species, soil depths, etc. For this we need a separate process which will distribute this recognized sample total within the province. To accomplish this we will begin with an intensive process of drawing lines around similar vegetation groups on aerial photographs to form "vegetation polygons" and making an initial estimate of what is inside them. After the ground sampling process tells us the overall totals, these initial estimates will be adjusted. Instead of giving many polygons the same average number, as was done in the past, we will now adjust every initial estimate just enough to give a correct total. This is the mechanism we consider most practical for providing locally correct answers.

As an example, if the ground measurements show an average height in the province of 24 metres, while the estimates averaged 25 metres, we could correct the situation by reducing each of the estimates in the entire inventory unit. The seedling stands would still be virtually zero height, the 10 metre estimates are changed to 9.6 metres, and the 50 metre estimates to 48 metres.
If the estimates are well done, the issue of "where" the vegetation is will be solved. If the ground sampling is done correctly, then the total of the adjusted estimates will be correct. These two separate functions will tell us the vegetation characteristics throughout the province, and provide a valuable set of data for future research as a byproduct. The cooperation of different groups to provide common definitions, field procedures and codes will ensure a more cost-effective and rapid collection of vegetation information.

Then What ?

After these two basic problems are solved, the data will be maintained on a computer database so it can be reported, projected over time, and readjusted if that is necessary. Maps of the vegetation polygons and their information will become valuable products for other disciplines, and they can be combined with the work of other groups by computer mapping procedures (Geographic Information Systems) which are becoming common in British Columbia. This report suggests a fairly detailed process which would accomplish this, and gives a set of recommendations which will ensure a vegetation inventory that would accomplish the objectives given to this committee. For practical and statistical reasons it is desirable to do this process on individual "inventory units" which will eventually cover the entire province.

Major steps in the process :

1) Draw the lines around vegetation groups, and where possible make initial estimates.
2) Select a correct sample of these polygons (perhaps one in 2,000) to visit and sample in the field.
3) Inside that polygon establish sample plots to measure the following types of information:
    - Ecological classification, biodiversity, decayed vegetation and plant abundance.
    - Tree quantity and quality, growth rates, forest health information.
    - Soil characteristics as described from a soil pit.
    - Forage characteristics for domestic and wild animals.
    - Vegetation characteristics and structure.

(*Note: Field Manuals have been developed to do this in great detail, and it may take up to an entire day to sample a single polygon*).

4) Establish a relationship between the initial estimates and the field measurements.
5) <u>All</u> the original estimates are then adjusted by the minimal amount needed to ensure that the *totals* of all those adjusted polygons will be correct.
6) The adjusted data are stored in computer data bases and mapping systems which can report on any particular area within that inventory unit (one small watershed, for instance, where a plan is being studied).
7) Studies are done to specify how accurate the information will be for various purposes. The accuracy of the entire inventory unit, for instance, will be better than for an individual polygon.
8) Some data is supplied *by* other organizations, and some is forwarded *to* them (upon request).
9) The data is "projected" over time, to keep the information current.
10) Periodic checks or recompilations are done to assure the ministry and the public that the information is of sufficient quality.

The recommendations in this report, along with field procedures tested by the Vegetation Inventory Working Group through the Ministry of Forests sets out recommended procedures for this process in very specific detail.

Summary of Major Proposed Recommendations

Sampling Overview

01) The Vegetation Inventory should cover the entire provincial land base using a polygon-based design, with the same measurement process at each sample point.

02) The province should be divided into several areas, and each of these will be sampled separately. This will allow them to be recomputed or resampled individually.

03) The Ministry of Forests should conduct this entire Vegetation Inventory.

04) The Vegetation Inventory process should be a two-phase approach for some items.

05) The measurements from ground samples will be used in a regression to adjust the original polygon estimates.

06) The Vegetation Inventory measurements from ground samples should be the same regardless of the scale of the project.

07) The Vegetation Inventory process should allow for changes in timing and budget.

08) The adjusted polygon information should be available to other groups in the province from two main sources, the polygon attribute database and digitized (GIS) polygon transfer.

09) Polygon attribute data should be subject to quality control processes and statistical accuracy reporting.

10) The polygon attributes should allow future adjustments due to research results.

Procedures

Polygon Delineation & Map Base

11. Mid-scale photography (approximately 1:15,000) should ordinarily be used to assign boundaries to vegetation polygons.

Photo Estimation (Phase 1)

12. Photo-interpreters will estimate various polygon characteristics, where possible, in order to increase the efficiency of the Vegetation Inventory .

Ground Sampling (Phase 2)

13. The measurements from ground samples should be carried out with a standard set of consistent measurements throughout the province, with as few exceptions as possible.

14. A cluster of plots will be used, with the central point as the "integrated plot center" common to all resource data types.

15. Different measurements at ground sample locations may be used for collecting different resource data sets.

Sample Point Location

16) Once a polygon is chosen, the sample points within that polygon will be selected from a 100 metre grid permanently assigned, by UTM coordinates, to the maps used in the province.

17) Sample points will be relocatable.

Specific Attribute Groups

18) The intention should be to produce a standard set of data for several resource disciplines, each of which is matched to the others by physical location, and which form a valid sample of the BC land base.

Trees

19) "Top Height Trees" should be selected for site index determination using the 1990 definition proposed by the Productivity Council.

20) A Variable Plot should be used for obtaining information on larger trees, and a Fixed Plot for smaller trees. Both live and dead trees should be measured for diameters 2.0cm and larger.

21) Field crews should assign standardized grades and defect deductions.

22) "Old Growth Forest" status should be determined in the field.

Soils

23) The soil data recorded are meant to describe the point where the center of the integrated plot falls, making it a valid sample of the land base.

Ecological

24) The measurements from ground samples will verify the map information, and assign ecological "Site Series".

25) Woody Debris will be measured by two 24m line transects at right angles to each other, with the first one being oriented randomly.

26) "Wildlife tree codes" will be noted on all live and dead trees on the integrated Plot.

Smaller Vegetation & Biodiversity

27) It is impractical to inventory wildlife populations during this field work, so the emphasis will be on habitat and plant species.

Range

28) Range information should be gathered on parts of the province indicated by the map in the appendix of the field sampling procedures manual.

Other items

29) The Vegetation Inventory should be flexible enough to allow the collection of additional information as experience indicates.

30) Regions and Districts of the Ministry of Forests should be visited to explain the Vegetation Inventory as soon as possible.

Data Processing

31) Handheld recording devices should be used to gather information, when possible.

32) Data should be compiled in a standard format for inclusion in the database.

Data Storage & Documentation

33) Original data and accompanying documents should be carefully stored.

34) Locations of sample clusters, by geographic coordinates, should be available on the database and easily displayed on the standard maps used by the Ministry of Forests .

35) Photos at sampling locations should be readily available.

36) Supporting and training documents should be available in word processing format and as video footage.

Quality Control

37) The Ministry of Forests should have a consistent, continuing program of checking inventory work.

38) Standard procedures should be developed to supply information from GIS systems to the polygon attribute database.

39) A review of this entire Vegetation Inventory Design should be undertaken by outside inventory specialists, and repeated at 2-3 year intervals.

40) A standing committee should be established, with competent specialists from various organizations, to encourage further consistency of definitions and procedures among non-Ministry groups in BC.

41) These proposed Vegetation Inventory procedures should not be forced on groups who have historical data processes adequate to their own procedures for resource management.

42) Rounded numbers, data classes and cultural definitions should not be substituted for actual data.

43) Centralizing quality control, field work and data management should be encouraged.

44) Some form of overall direct check on the timber volumes and timber values of the vegetation inventory should be considered.

Reporting Systems

45) A polygon attribute database and a GIS system would be the main data source regarding the Vegetation Inventory. The custodian of the tree information should be the Resources Inventory Branch

46) A standard reporting system similar to "FIR" now in use at the Resources Inventory Branch should be continued.

47) Standard maps and reports should continue to be produced, and for the present these should be in traditional forms which users are accustomed to seeing.

48) The Ministry of Forests Resources Inventory Branch GIS system should allow users to use color and symbols of their own choosing to display data from the polygon attribute database onto custom maps.

49) Statistics for the Inventory Unit should be readily available to let the user know what accuracy to expect within the Vegetation Inventory Unit.

Integration with Other Inventories

50) The main integration and transfer of data with other groups will be based on Geographic Information Systems (GIS) Technology.

51) The members of this committee should visit other groups, and perhaps be integrated into them to encourage common approaches and principles.

"Localization" of the data

52) The inventory should be flexible enough to include additional information gathered at a later date.

53) Periodic recalibration should be done, as necessary.

54) "Operational Cruising" is not replaced by the overall Vegetation Inventory process.

55) Sampling and statistical expertise should continue to be available from the Ministry of Forests staff in Victoria.

"Update" of the information

56) Changing the inventory due to significant changes in individual polygon values or land base changes can be made at any time, since they will normally be a small part of the Vegetation Inventory .

Augmentation of particular data types

57) Specific disciplines which require more sampling should insure that the sample is unbiased over the whole Vegetation Inventory unit.

Projection of the Inventory

58) The adjusted inventory estimates should be modified over time by standard projection models.

59) Growth prediction and model building should be done as a process separate from the Vegetation Inventory.

Training

60) Training of field staff is a serious concern, and should be given high priority.

61) The committee recommends that a permanent group of 4-6 people be maintained within the MoF in Victoria who are fully experienced, and qualified to carry out Vegetation Inventory field work. In addition, we would recommend the development of a stable group of people within the contracting community to carry out the necessary field work.

62) The Ministry of Forests should insure permanent internal expertise in photo work, sampling, field measurements and data compilation within Resources Inventory Branch.

External Quality Control

63) To assure the public that the inventory is correct, the Province should employ an independent agency to do an audit.

Implementation of the Vegetation Inventory

64) The committee believes that the new procedures should be phased in at a rate consistent with the numbers of trained people available for this work.

65) The provincial commitment to this project should be clear.

66) A Provincial Inventory Technical Council should be established.

67) The value of information collected on the Vegetation Inventory should be periodically evaluated.

68) The province should continue to develop the Pre-Inventory Analysis (PIA).

Introduction & Overview

Purpose of the Committee

The report of The Forest Resources Commission, tabled April 1, 1991 made several recommendations in regard to the future resource inventories of the province. In order to develop the technical recommendations needed for such inventories, the Province brought together specialists from a variety of organizations and technical backgrounds.

Their task was to develop a resource inventory which was consistent, flexible, statistically correct and multi-disciplinary. Consistency of technique and definition, data sharing, and the production of data sets for both research use and as a base for future sampling were all addressed by this committee.

General Development of the Process

[TITF]
This process has taken over 3 years. At major points in the development the committee membership was changed to insure the appropriate specialists for each phase. Between November, 1991 and March, 1992 the committee was established as the "**T**imber **I**nventory **T**ask **F**orce" with the purpose of developing a design for a timber inventory. It did so, and produced a formal report in April, 1992.

[VIWG]
The scope was then widened to include other vegetation items which could be gathered at the same time and would be complimentary to timber data, and the committee was named the "**V**egetation **I**nventory **W**orking **G**roup".

Between July 1992 and March 1993 such an inventory design was developed. In some cases several alternatives were identified which the committee could recommend, and which would be chosen based on field efficiency and further testing.

Between May 1993 and March 1994 specialist teams were assembled and pilot projects were developed to test the details of the processes.

From April 1994 to March 1995 the group continued these pilot projects, improved the field techniques and processed some of the critical data. This report is the culmination of the Vegetation Inventory Working Group. The purpose of the pilot projects has been to develop procedures which could be implemented in the field with reasonable quality control and field efficiency. The lessons from these pilot projects are included with this report.

The committee has developed a sampling design which we consider adequate to produce an integrated Vegetation Inventory of British Columbia. If the sample size for some groups of data on particular resources are limited or increased (for efficiency purposes) it will not effect the general structure of these procedures. In all cases, the Ministry of Forests or a similar agency must ultimately determine whether the processes suggested by this committee are appropriate for implementation throughout British Columbia.

Background Discussions

The recommendations given here are necessarily brief. All of these points have been extensively discussed within the committee over the 3 year period. Many of them are the final choices from several alternatives and many of these have been field tested before the final choice has been made. Each recommendation represents the considered opinion of the committee, and each member has had the chance to review this report and prepare a minority opinion if they chose to do so.

Extensive work has been done on some recommendations by outside consultants, and background material is available to interested parties through the secretariat of the RIC process. Only a general discussion of the points is included in this document, but the reader can be assured that these points were thoroughly reviewed during the process, and represent the opinion of the committee in respect to technical correctness, credibility, flexibility and field efficiency.

The discussions presented with the recommendations will focus on the intent of the committee and on processes which are either new or very different from historical BC approaches to measurements. Many of the details are available in the field manuals or obvious from the field forms.

Committee structure

The Vegetation Inventory Working Group (VIWG) is one of many groups working under the Resource Inventory Committee (RIC). It is one of 3 groups that make up the Terrestrial Ecosystems Task Force, which is working to quantify the flora and fauna of the land surface of BC. A flowchart of the RIC groups is available in Appendix A. The general purpose of this process is to coordinate efforts, stabilize and agree upon definitions and procedures, then produce a procedure for gathering this information.

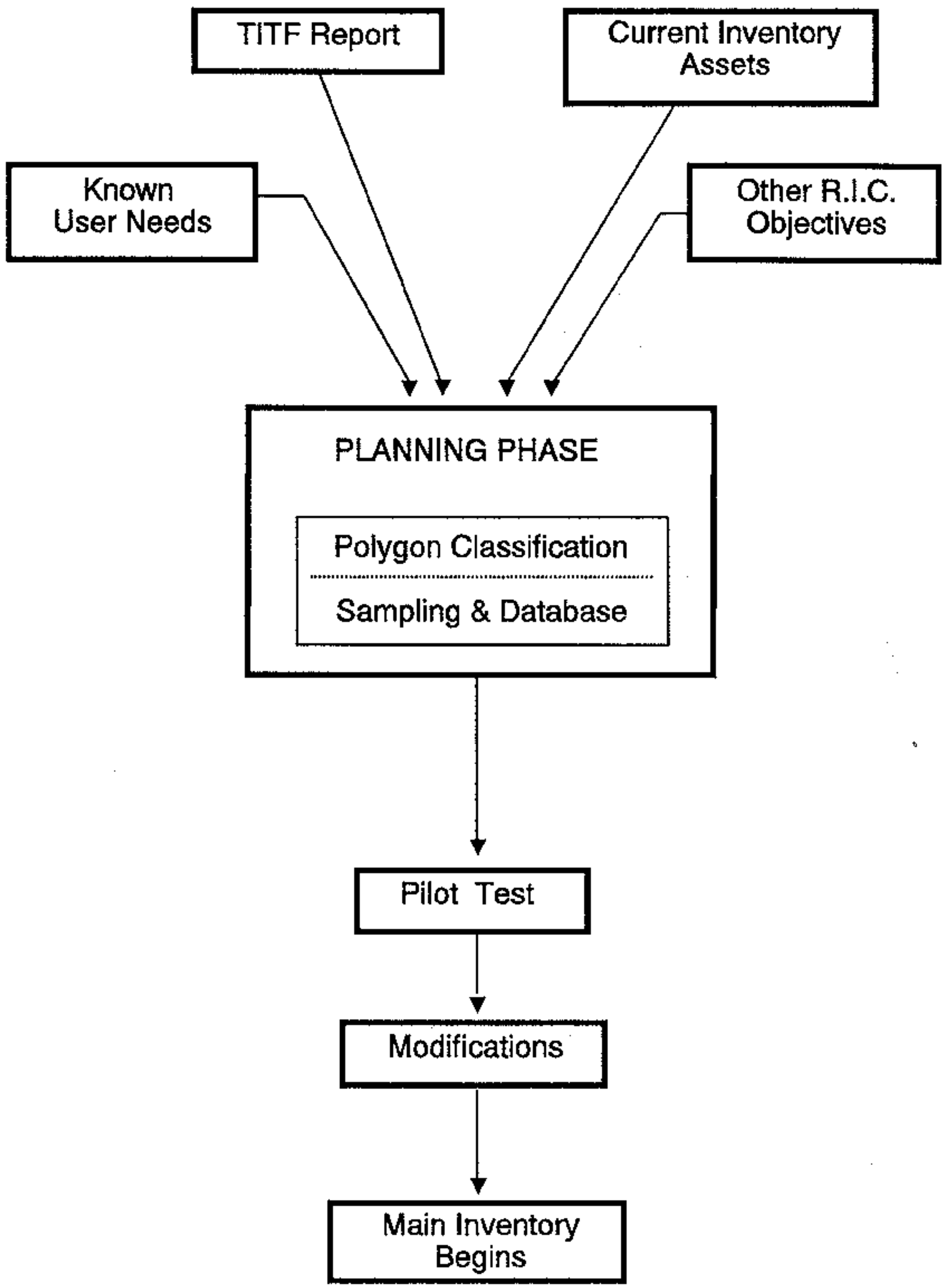
The list of members of the committee is included on another page of this report. In general, people were not chosen to represent any group or viewpoint. Membership was proposed strictly on technical expertise while seeking a variety of practical experience and current interests. As the work progressed the membership changed slightly to represent more specific technical fields in some cases, but several of the members have been through the entire 3 year process, and this has provided continuity of principle during that time.

Initially, there were two "sub-committees" formed, one for sampling and one for photo-interpretation issues. These are also the two main parts of the inventory process itself.

Later, specialists were recruited into two "teams" under these sub-committees. The purpose of these teams was to work out the detailed processes involved in the techniques recommended by the main committee and both sub-committees. The members of the teams were experienced and well respected practitioners in the disciplines needed to carry out the proposed field work.

Flowchart Section 1

PLANNING



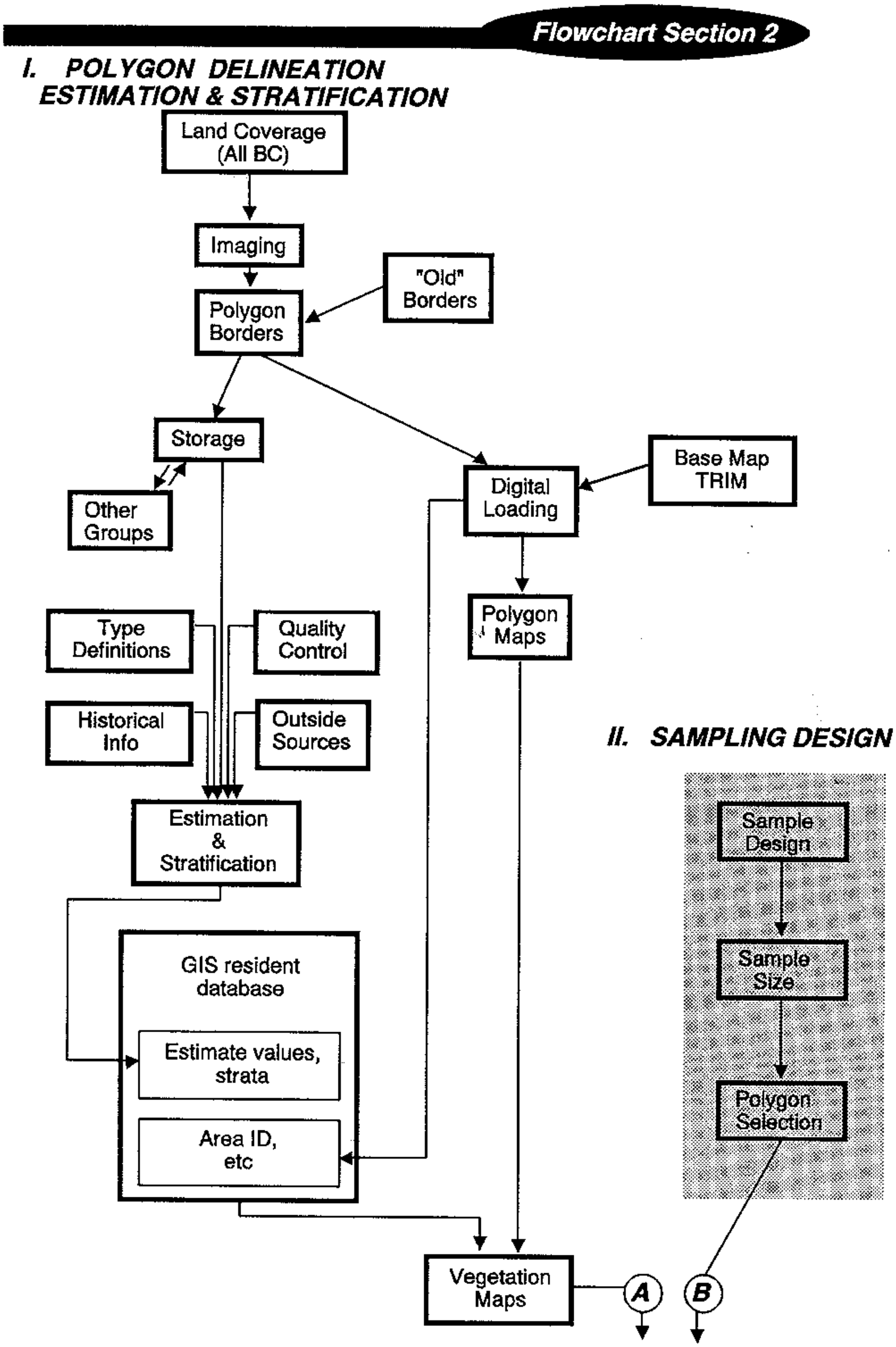
Inventory Flowchart and Overview

A proposed inventory process is illustrated on the following flowcharts. While a great many details are not included, it is meant to illustrate the design suggested by the Vegetation Inventory Working Group (VIWG). Most of the recommendations of that committee can be attached to one or more of the items shown on the flowchart.

Flowchart Section 1, Planning

Several pilot projects have provided basic "proof of concept" work for many of the specific techniques. Our intention is to provide fairly firm guidance for basic approaches, and allow as much flexibility as possible in the estimations, field procedures, recompilations, and subsequent updates and additions.

The firmest results have been in field processes, which is in keeping with the sequence in which the decisions need to be made as we prepare to put this design into practice during the next year. The data handling and GIS components need much more testing and development, and groups are being assigned to carry this out.


Flowchart Section 2
I. POLYGON DELINEATION
ESTIMATION & STRATIFICATION
Land Coverage (All BC)
Imaging
"Old" Borders
Polygon Borders
Storage
Other Groups
Digital Loading
Base Map TRIM
Polygon Maps
Type Definitions
Quality Control
Historical Info
Outside Sources
Estimation & Stratification
GIS resident database
Estimate values, strata
Area ID, etc
Vegetation Maps
II. SAMPLING DESIGN
Sample Design
Sample Size
Polygon Selection
A
B

Flowchart Section 2

I : Polygon Delineation, Estimation & Stratification

Polygon Work

In this section, photos are used to delineate boundaries of vegetation which appear to be consistent. The purpose is not only to identify consistent areas in the photo, but to anticipate differences (perhaps by topographic clues) which may not be verifiable until ground checks are made. Old polygon borders, if still appropriate, could be maintained.

Once polygons are drawn (and stored properly for future reference), they go two routes.

A) Digital loading for map production.

This produces the eventual map outline of the polygons, and will also provide certain information to the polygon attribute database.

For instance:

1) A unique polygon identifier, which will eventually be the link with the GIS system.
2) Area of the polygon.
3) Location of the polygon centroid (Latitude & Longitude, for instance).
4) "Neighborhood" information, such as bordering polygons or nearest watercourse.
5) Overlay information, such as administrative units to which the polygon belongs.

This processes is fairly well understood, and the MoF Resources Inventory Branch will develop many of the specific procedures in conjunction with committees of outside specialists. A test of processes for moving data, overlaying polygons, recovering data and using common polygon borders is recommended by the committee for the very near future. An initial small database may be kept on the GIS system itself for polygon information. This would then update the main inventory database whenever changes are made.

B) Estimation & Stratification prior to ground sampling.

Estimation of polygon parameters such as species percent, volumes, stand heights, ages and other items can be done using any information available to the photointerpreter. There is no chance of bias in this phase, since the polygons will be ground sampled later, and adjusted to insure that an unbiased mean is produced. These initial estimates will be recorded in a database.

Several estimation outcomes are desirable:

1) It is desirable, but not necessary, that estimations be as accurate as possible, since we will be visiting very few polygons, and it would be nice if the rough estimates are usable even without final adjustment. In addition, when all observers are reasonably accurate, they are automatically consistent.
2) Consistency is very important. Since all the estimates will all be adjusted later, any estimates that are inconsistent will lead to greater sampling errors after adjustment.

Stratification is the process of placing polygons into groups which have a different relationship of estimated vs. measured results. A "strata" will then be adjusted as a whole. An important point is to make sure that information which might be important for assignment to strata (or in reporting results for training, such as by photointerpreter ID) is maintained from this phase of the inventory process.

With the proposed inventory design, the use of stratification is of two types:

1) Stratification by anticipated differences in the relationship between estimates and measured values.
   It is no longer necessary to group data into the past "strata" which the inventory has traditionally used, but other groupings may be desirable. As an example, the volume may be adjusted differently by ecological zone, if the relationship between estimated volume and measured volume is different.

2) Stratification by value ranges when no initial estimate is available.
   In some cases the identical average value may be assigned to all the polygons within a grouping. This value will not be the center point of a value range, but the calculated mean of that group.
   If a historical "strata" designation is necessary to some user it should be assigned from the more exact polygon values stored in the database. This may be desirable from the point of view of map presentations, or to provide data in categories traditionally used by other groups.

A simple example of this process might be useful. 1,000 Polygons are classified by 2 photointerpreters, with the main species constant. They span two geographic regions. Volumes on polygons range from 30 to 1,200 cubic metres per hectare. Later sampling will be done for lichen biomass, using polygon volume as an initial estimate.

One stratification might be on the basis of the individuals doing the interpretation, since their relative estimates might be different for each other. Within this strata, we might feel that the species percent mixes are much more difficult to estimate in one of the two geographic areas, and therefore we might choose to make the two areas into strata. In addition, research indicates that the lowlands in area 2 will have a different relationship for polygon volume and lichen biomass, so we choose to make that a separate strata .

One potential stratification is therefore:

Strata:

1	Interpreter 1	Area 1	
2	Interpreter 1	Area 2	Lowland
3	Interpreter 1	Area 2	non-lowland
4	Interpreter 2	Area 1	
5	Interpreter 2	Area 2	Lowland
6	Interpreter 2	Area 2	non-lowland

A good deal of information on ground samples vs. photo estimates is available already, and might help to specify which kinds of strata would be useful. It is important to remember that stratification increases the efficiency of sampling and gives more confidence in individual polygons, but the process would be unbiased in any case.

The sets of estimates to be made have been identified by the classification group.

C) Map Preparation

Vegetation polygon maps can be produced after polygon loading, labeled after the estimations are made, and overlaid on TRIM maps for presentation. This map base can be used by field crews in the later sampling work. Color coding of maps should also provide considerable quality control advantages.

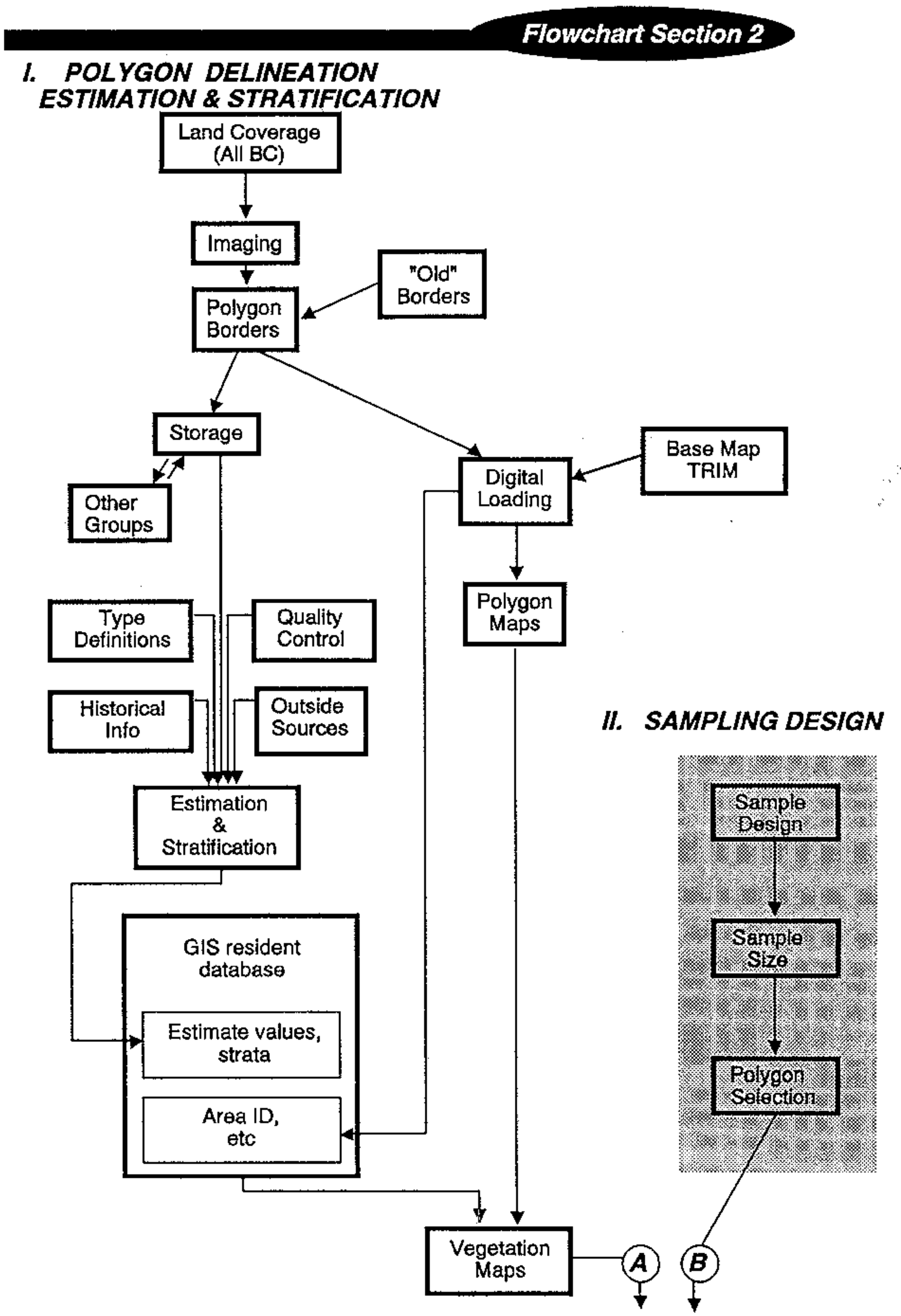
Later, standard final maps can be produced from these vegetation polygons with labels retrieved from the adjusted polygon attribute database. Special purpose maps will allow any labels desired, and the use of symbols derived from the database values.

II : Sample Design

The current plan is to use a basic standard sampling design, generally termed "two phase sampling", "Double Sampling", or some similar term. Adjustments are made to initial estimates by using ground sampling. Only a small percentage of the polygons will be visited. The ground sampling insures that the adjusted estimates inside each strata are unbiased. "Good" initial estimations insure that the adjustments are consistent throughout the strata, and therefore the final adjusted estimates should be close to the correct answers. The adjusted estimates might be better estimates of actual polygon values than would be given by field sample clusters that fall into that polygon, because the photointerpreter is observing the entire polygon while the sample falls into only a small area.

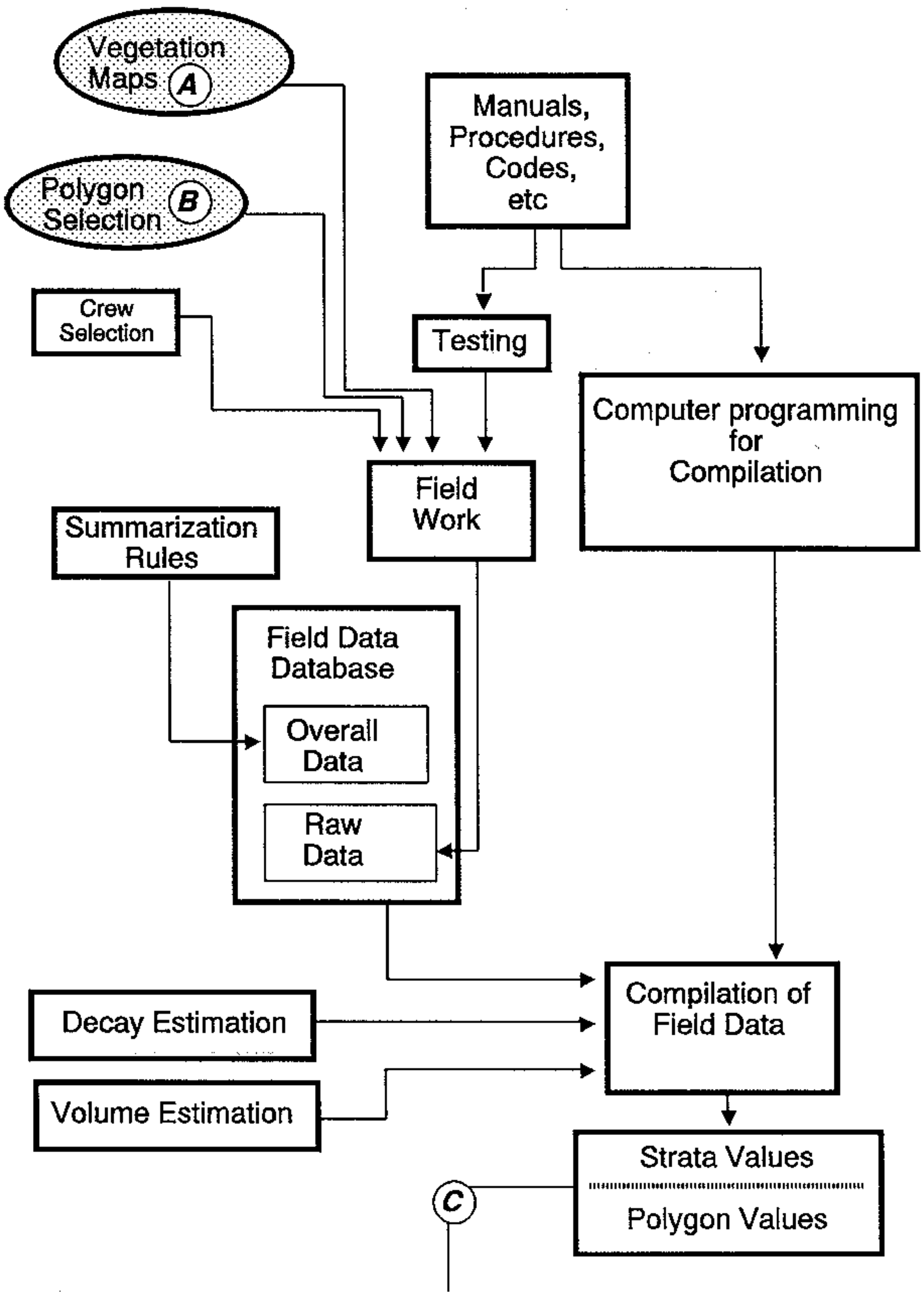
The actual form of the adjustment is flexible. For some items, a simple average will be given for the parameter (especially if it cannot be estimated from the photo). In other cases a ratio adjustment or a regression could be used. The sample design allows any of these choices.
Actual sampling will be done on a geographic area similar to a current Forest District boundary. This will insure that methods can be changed, based on experience, with each new project. Eventually this will cover the province. Estimation procedures can be modified after each of these projects is completed. Reinventory can be done without readjusting the rest of the province, since each project is designed to provide an unbiased stand-alone inventory.
The adjusted estimates will be stored in the polygon attribute database, and probably these values (perhaps rounded or put into classes) will appear on most of the maps which retrieve their labels from the database. In the case of "local available estimates" (which may or may not be well controlled and unbiased), this data can also be stored in a separate part of the database, with the source identified.

When sample size is chosen, the polygons to visit will be determined. The current sample plan is based on allocation proportional to area, using a sorted list of the polygon data. The question of sample size has not yet been finalized. Sample size is essentially a question of budget, available time, minimum accuracy and credibility, not a straight-forward mathematical calculation. The question need not be finalized before the first actual project, since the system is designed to work well with any level of samples.


Flowchart Section 2
I. POLYGON DELINEATION
ESTIMATION & STRATIFICATION
Land Coverage (All BC)
Imaging
"Old" Borders
Polygon Borders
Storage
Other Groups
Digital Loading
Base Map TRIM
Polygon Maps
Type Definitions
Quality Control
Historical Info
Outside Sources
Estimation & Stratification
GIS resident database
Estimate values, strata
Area ID, etc
Vegetation Maps
A
B
II. SAMPLING DESIGN
Sample Design
Sample Size
Polygon Selection

Flowchart Section 3

FIELD WORK TO CORRECT INITIAL ESTIMATES
INITIAL COMPILATION OF FIELD DATA



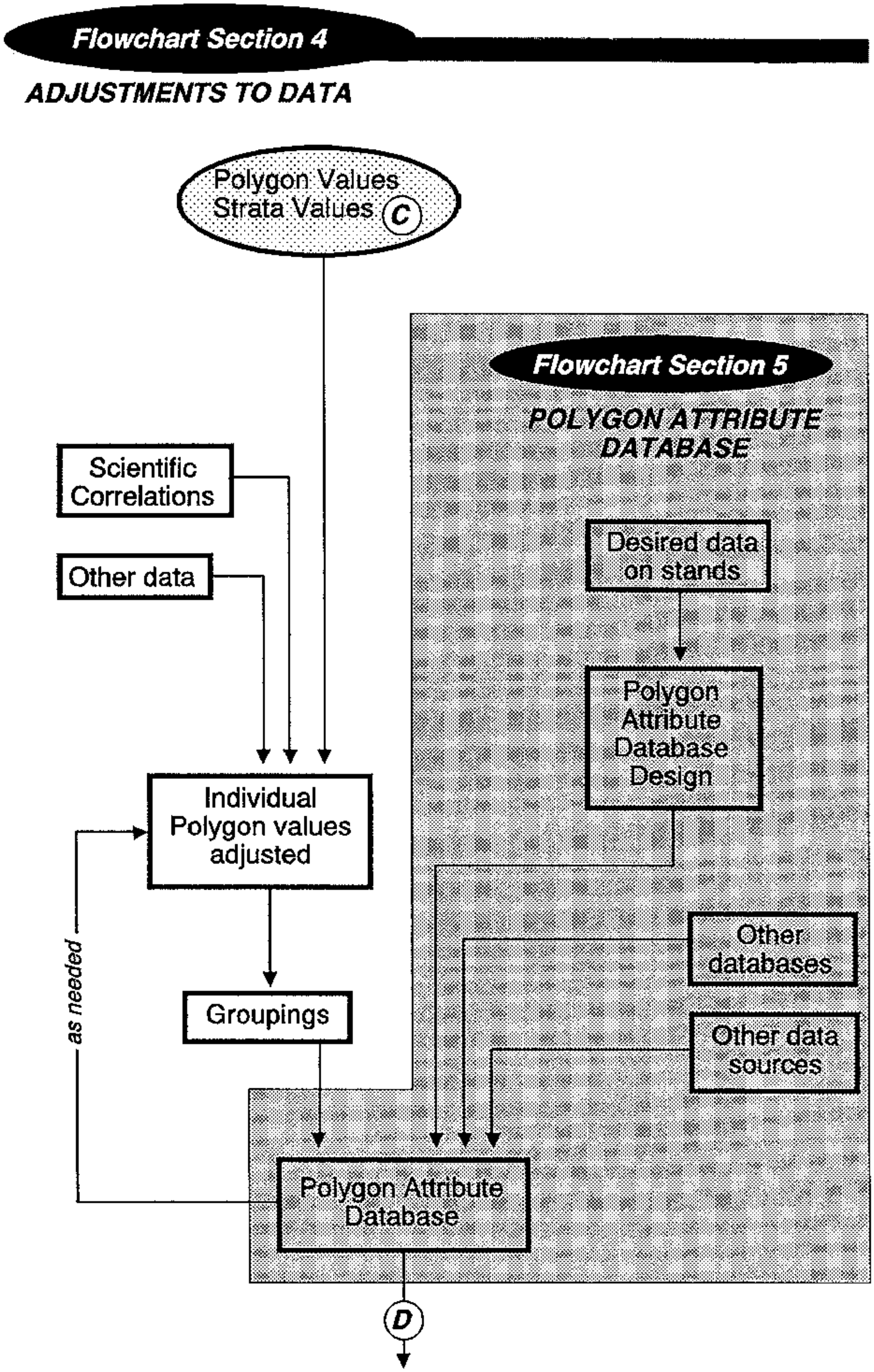
Flowchart Section 3 - Field Work to Adjust Initial Estimations,

& Initial Compilation of Sample Data

Field procedures have been worked out by the sampling team, who examined the issues of crew organization, training, standards & codes as well as computer compilation issues. Many of these issues were tested on the pilot project.

Sample data will eventually be of two types, raw (plot) and overall (polygon or strata). Raw data will be compiled to determine the eventual polygon adjustment, but retained in case re-summarization is needed. Overall data will be kept, and sometimes passed directly to the Polygon attribute database.

Summarized data can be average strata information or adjusted individual polygon estimates. Problems of decay reduction, volume calculation, etc. are being addressed by the appropriate experts in these matters, and will be incorporated into the compilation process.


Flowchart Section 4
ADJUSTMENTS TO DATA
Polygon Values
Strata Values
C
Scientific Correlations
Other data
Individual Polygon values adjusted
as needed
Groupings
Flowchart Section 5
POLYGON ATTRIBUTE DATABASE
Desired data on stands
Polygon Attribute Database Design
Other databases
Other data sources
Polygon Attribute Database
D

Flowchart Section 4

Adjustments to data

Initial estimates are made for the inventory unit using whatever source is available and useful. For polygon volume, the present VDYP stand model could provide very efficient volume estimates. For lichen volume, some other source might be used. Any estimates provided before field work can be adjusted during the main sampling effort. These adjusted estimates provide the initial Provincial Vegetation Inventory.

In the future, perhaps after the inventory is completed, new research may give us better estimates of the distribution of any parameter in the inventory. The purpose of this phase is to redistribute the values for the polygons, while maintaining the unbiased overall average. An example might be the estimation of volume using elevation. We might decide to shift volume from polygons at higher elevations to those at lower elevations, using the results from some study. While doing this, we would insure that the final sums would not vary greatly (or perhaps not at all) from the original sum. This phase would be performed whenever such an adjustment was needed.
The system would now have taken an initial estimate from section 1, adjusted it using direct ground measurements in sections 2&3 and perhaps at a later date shifted around that estimate based on some external information in section 4 while maintaining the original overall values.

In addition, the final information in these stands can be used to create groups useful to those who analyze the data, such as "managed stands" or "NSR". Such groupings can be more or less permanent, depending upon type.

Flowchart Section 5

"Polygon Attribute Database" for polygons

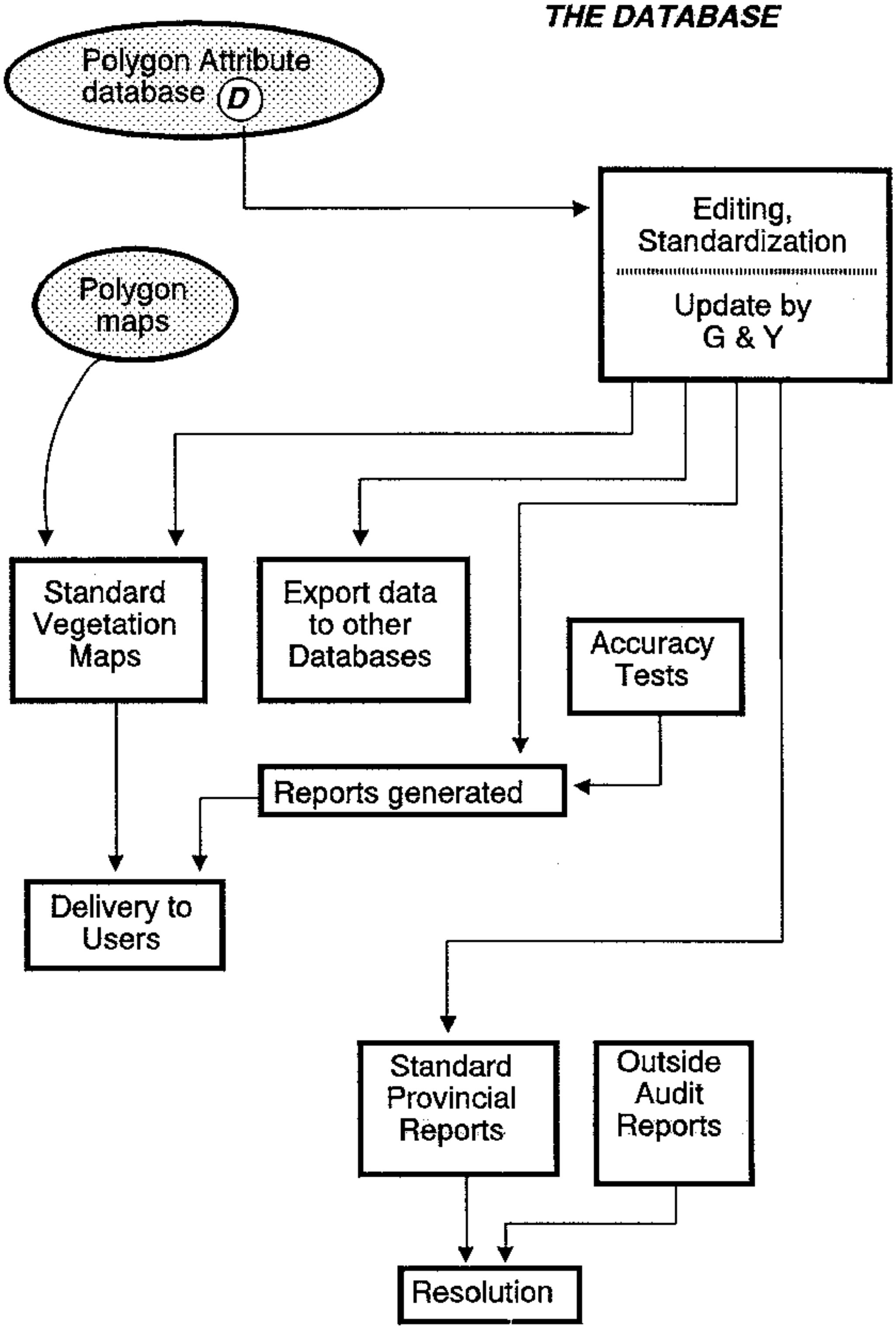
This will be the main source of information for forest inventory. It would be augmented in a number of ways from other sources, mostly by the method of overlaying other polygons and deducing the information. Examples would be Forest Regions, soil information, etc. This kind of information is available through GIS systems, and if judged to be helpful on a permanent basis would be stored directly in the database. Updates would be performed to insure compatibility, but the quality of the data would be the responsibility of the providing agency and simply transferred as needed rather than maintained by the Vegetation Inventory.

The reason to maintain this directly in the vegetation polygon database is to enable searches and comparisons on the database. For instance, we could determine what the average site index was on different soil types. Having the soil type on the database frees us from a direct connection to the GIS system, and enables this type of inquiry on a portable computer.

The design of the vegetation database is a major effort. The compilation and database group should take this project as far as possible to insure that none of the detailed decisions or definitions are overlooked. The MoF can then decide to accept, modify or replace the prototype database design.

Flowchart Section 6

REPORTING & MAINTAINING THE DATABASE



Flowchart Section 6

Reporting & Maintaining the Database

Standard maps are a traditional and useful product of the MoF Resources Inventory Branch, and are useful to other agencies as well. These require more time and preparation than "special order" maps which are generally for display and need less detail and precision.

Reporting the summary information, along the lines of the present Forest Information Reporting system will be possible with the full database or portions of it. In addition, estimates of the accuracy will be provided. Where necessary, any section of the inventory can be subsampled to determine accuracy by a valid sampling method produced by the MoF Resources Inventory Branch. Such a sample would provide adjustments within the local area sampled, but might not be applicable to the overall inventory.

General credibility for the inventory will also come from an independent audit by an outside agency. We have obtained guidance from a consultant on how to minimize conflict and resolve differences during this process.

Pilot Studies & Testing

The **V**egetation **I**nventory **W**orking **G**roup (VIWG) has spent a considerable amount of time discussing two inventory designs:
1) The polygon-based design
2) The mapless systematic grid-based design.

Throughout the design, development and testing of the new vegetation inventory, the VIWG concentrated time and effort on the finalization of the procedures for the polygon-based method of inventory. However, during operational testing in Chilliwack, both designs were tested with the overriding objective being to test and to develop sampling procedures for consistent use with both designs.

Planners and managers require the vegetation inventory to be responsive to local needs, accurate, consistent and statistically sound. The inventory must also provide descriptive statistics and spatial information

Testing of the Polygon-based Design

In the polygon-based design, relationships between phase two samples and phase one estimates are developed and applied to all vegetation polygons within the inventory. This multi-phased approach requires the mapping of the vegetation polygons as estimates in phase one and, afterwards, the sampling of some of these polygons as measurements in phase two.

Testing of the Grid-Based Design

In the mapless systematic grid-based design, a limited number of samples provides summary estimates for the inventory unit and the values sampled would also serve as an independent audit on the polygon-based provincial inventory. The application of the systematic grid-based sampling may expand as additional needs become apparent. The design requires the establishment of samples at systematic grid locations without reference to other available inventory information. The intensity of samples governs the practicality of generating spatial information together with summary statistics.

Pilot Test Recommendations

Through the careful evaluation of the planning and management requirements for the vegetation inventory, the VIWG determined that the polygon-based design best fulfills those future inventory needs for management units.

The VIWG recommends the polygon-based design for the provincial unit vegetation inventories. The VIWG also recognizes other inventory objectives, such as an independent and quick provincial audit. One way to achieve this objective is through the establishment of a limited number of samples using a systematic provincial grid-based design.

Detailed Recommendations of the Committee

(with additional minor items)

Sampling Overview

01) The Vegetation Inventory should cover the entire provincial land base using a polygon-based design, with the same measurement process at each sample point.
In the case of measurements which can only be done during part of the summer, the inventory should be designed to gather an unbiased subset of the eventual sample during that limited period to insure that all types of information can be unbiasedly estimated.
Parks, private land, urban areas, etc, will all be sampled, but in some cases there may be different methods of marking the sample locations to respect the use of the area.
If individual groups which are represented in the integrated sample point methodology want to supplement their data set, they should do it with a valid sample over the inventory area, and with the same field measurement techniques.

02) The province should be divided into several areas, and each of these will be sampled separately. This will allow them to be recomputed or resampled individually.
These areas would be over a geographic area similar to present Forest Districts. An initial example of such a map is included in appendix D.
A specific set of these should be developed on a map of the province in the near future and entered into the MoF Geographic Information System to insure that the province is completely covered.

03) The Ministry of Forests should conduct this entire Vegetation Inventory.
Where acceptable estimates for mapped polygons are already in place, the MoF should consider using these existing polygon estimates, but should conduct the field measurements on behalf of the province. Private companies should not be required to conduct the field work on areas under their own management.
The provincial estimates may be less precise than the private management inventories and might not replace these, but they will act as a rough check on this information.
In the case of large discrepancies the province should initiate a program much like the current "ratio adjustment" process now in use.

04) The Vegetation Inventory process should be a two-phase approach for some items.
Based on the test results from the Chilliwack pilot project, the VIWG at the time of this report is not prepared to recommend the grid based system.
Initial estimations will be followed by field measurements at locations chosen with a probability proportional to land area. This insures that each field measurement represents the same land area in the inventory.
The committee prefers a selection using a "sorted list" approach, partially for efficiency but mainly for the flexibility involved with this method. Other approaches are possible as well, but we feel that this is the best choice.
The field sampling should be conducted to describe the center sample point, and measurements should normally be located within the selected polygon.
The estimation approaches are being developed and tested by the Estimation Subcommittee, but may vary over time. It is not necessary that every possible estimation be made, and if some are quite variable they may be discontinued.
[A list of attributes being estimated for use in this two-phase approach is available in the draft procedure manuals now being prepared.]

05) The measurements from ground samples will be used in a regression to adjust the original polygon estimates.
Where initial estimates were not done, and no other estimate is well correlated with the measurements, those field measurements will be used as a simple direct sample.
An assignment should be made such that some polygons can be adjusted to a greater degree than others, since some estimates are more reliable than others.
Each polygon data set in the inventory should be adjusted individually, and the adjusted information stored for that polygon. At any future time this data can be recompiled. The unadjusted initial estimates should also be stored, where possible.

06) The Vegetation Inventory measurements from ground samples should be the same regardless of the scale of the project.
The system was designed so that sample size is completely variable. This sampling process works just as well at the provincial level as it does at the TSA level or the watershed level, with all the same procedures and definitions.
Sample polygons could be selected by a number of valid means, depending upon the operational constraints of the inventory, and the number of integrated plots per polygon may also vary. In any situation, however, the field procedures are the same.

07) The Vegetation Inventory process should allow for changes in timing and budget.
The current suggested process will accommodate a range of budget and time constraints, even though the plan calls for a long-range process involving TSA-size individual inventories which can be added for an overall answer.
For a quick provincial answer we could use the current maps as the first phase estimate, and take the number of plots which time and budget allow.
If first phase estimates are not available at all, the same field sampling process would still be used, and would produce an unbiased estimate.

08) The adjusted polygon information should be available to other groups in the province from two main sources, the polygon attribute database and digitized (GIS) polygon transfer.
The map base should be the TRIM project map base, even if this implies less detailed mapping. This is necessary to insure consistency and reliable transfer of data.
The polygon attribute database should be linked to the GIS by the use of a unique polygon identifier.
The GIS group in the Ministry of Forests should develop programs to feed GIS data into the polygon attribute database to insure consistency between the two sources.

09) Polygon attribute data should be subject to quality control processes and statistical accuracy reporting.
The MoF should develop processes to check field work during an inventory.
A separate audit should be developed for implementation by an outside agency.
A computerized sampling program should be developed to suggest a valid sample to any outside group which chooses to check the results of an inventory.
Statistical summaries should indicate the variability of the average of items reported by the inventory and also the variability for individual polygons.
A standing inventory review group should be formed to oversee additions and changes to the procedure over time. This group should be kept small and consistent.

10) The polygon attributes should allow future adjustments due to research results.
The overall totals should always be very stable if polygon values are ever readjusted by a different procedure (for instance, a different regression method shown by research to be more effective).
When a different procedure is used, a check should be made to determine the actual increase in accuracy (by polygon) due to that procedure, and the overall change in the attribute total.

Procedures

Polygon Delineation & Map Base

11) Mid-scale photography (approximately 1:15,000) should ordinarily be used to assign boundaries to vegetation polygons.
The expertise of BC in this field is considered one of the strengths of the contracting community, and this was central to our choice of sampling designs.
Polygons can also be divided along lines expected to have significance, such as at topographic breaks, even if the vegetation appears to be the same.
In addition, the field supervisor may choose to have several polygons (each with the same description) temporarily created from a larger one for sampling convenience.
Polygons should be individually identified, and quickly entered into a GIS to calculate area and prepare for field observations.
The GIS section should maintain quality control over the polygons created and their identification.

Photo Estimation (Phase 1)

12) Photo-interpreters will estimate various polygon characteristics, where possible, in order to increase the efficiency of the Vegetation Inventory .
This will insure not only a better average over the inventory, but better estimation of individual polygon values.
The measure of success for this photointerpretation will be the comparison of the variability after adjustment to the polygon sample data, not the accuracy of the initial estimate. If possible, more accurate estimates of actual polygon values will be obtained for this comparison.
The desirability of the "ground calls (field plots)" and "air calls (helicopter observations)" as currently used by the MoF for classification has not been confirmed as an advantage. If it is to be continued, the methodology and use should be shown to have a cost-effective role with the current sampling design.
In the case of recent logging the best source of data may be the "Silviculture Opening" information, and this might be retrieved and used directly, as a substitute for use of photointerpretation.

Ground Sampling (Phase 2)

13) The measurements from ground samples should be carried out with a standard set of consistent measurements throughout the province, with as few exceptions as possible.
This will insure a consistent set of geographically matched data for research.
The field forms and procedures will remain more consistent, which will simplify training, compilation and quality control.
Any increase in efficiency by varying this consistent field process will probably increase cost in another part of the project, and we advise against it.

14) A cluster of plots will be used, with the central point as the "integrated plot center" common to all resource data types.
The intent of all the data gathered is to represent the point chosen as the center sampling point.
Some data may be gathered within the nearby area, but the intent is to describe the point where the central sample pin is driven.
Plots will not be moved to "more typical areas".
Dangerous plots will be omitted from the regular field work, rather than moved to a nearby location. A separate process will subsample them, if possible, or account for them in some appropriate statistical manner.

15) Different measurements at ground sample locations may be used for collecting different resource data sets.
All of the sampling methods, however, refer to the same central point. This insures a set of data which is useful for research purposes.
The pilot projects have developed a set of procedures which insure compatibility of timber, soils, range and ecological data at the same point.

Sample Point Location

16) Once a polygon is chosen, the sample points within that polygon will be selected from a 100 metre grid permanently assigned, by UTM coordinates, to the maps used in the province.
The selection will be made to separate the clusters inside a polygon in a statistically valid manner if more than one sample cluster is used.
At the discretion of the field supervisor, the polygon may be temporarily divided into parts to prevent large distances between sample clusters.

17) Sample points will be relocatable.
The intent is to facilitate quality control checks in the short run for sub-sampling, and allow for possible change detection in the long run.
The Global Positioning System will be used to record "ground" UTM coordinates, and the "map UTM" coordinates will also be retained.
Where plots are near polygon borders a "half plot" inside the polygon will be used for timber measurement and other resource measurements, if appropriate.

Specific Attribute Groups

18) The intention should be to produce a standard set of data for several resource disciplines, each of which is matched to the others by physical location, and which form a valid sample of the BC land base.
For specific field techniques and codes, the reader can refer to documentation currently being developed for field work.
This documentation should be available to users in word processing format and on video.

Trees

19) "Top Height Trees" should be selected for site index determination using the 1990 definition proposed by the Productivity Council.
A second species should be selected, at least at the integrated plot, for establishing the correlation between species site indexes.
The site indexes should be individually computed, then averaged.
The "site height" of the polygon should be computed from polygon age and polygon site index.
This will allow other site index calculations to be used, as required. This data is also available on individual trees, of course, in the "raw data" database.

20) A Variable Plot should be used for obtaining information on larger trees, and a Fixed Plot for smaller trees. Both live and dead trees should be measured for diameters 2.0cm and larger.
The standard volume summary, if only one is chosen (or one must be favored in the computational decisions) should be based on trees 2.0cm and larger.
On the fixed plot for small trees, only live trees will be considered.
A random tree will also be chosen on the integrated point Variable Plot for research and comparison purposes.

21) Field crews should assign standardized grades and defect deductions.
Standard deductions for various defects are being developed.
These can be changed in the future, since location and type of defect is also recorded.

22) "Old Growth Forest" status should be determined in the field.

A variety of other information can be used to establish this kind of status in the future as the definition changes. Since no adequate definition or sampling method is available at present this will ultimately be a judgment in the field, aided by a number of recorded ecological polygon characteristics.
This information, because it is a valid sample, can be used to check other estimates of old growth status, such as those produced from remote sensing.
Photos of the sample area will help determine borderline cases in the future.

Soils

23) The soil data recorded are meant to describe the point where the center of the integrated plot falls, making it a valid sample of the land base.
It may be necessary to dig the pit at a slightly different point, but one which represents the pin location. If this is not within the major ecosystem of the 10 metre fixed plot for vegetation sampling then a second soil pit will be dug.
The soil information is used for establishing the ecosystem descriptions, but will be gathered whenever possible - even where ecosystem is known already.
Texture and soil layer descriptions will be made by the field crew. Soil samples will also be collected for quality control in determining texture.
Chemical analysis is not recommended at this time.

Ecological

24) The measurements from ground samples will verify the map information, and assign ecological "Site Series".
Zone, Subzone and Variant will be determined at the sample points, to establish the error rate from existing ecological mapping of the province.
Moisture and Nutrient codes will be maintained in the data base. If Site Series definitions change, they might be deduced from this more basic information.

25) Woody Debris will be measured by two 24m line transects at right angles to each other, with the first one being oriented randomly.

26) "Wildlife tree codes" will be noted on all live and dead trees on the integrated Plot.
A standard 4 part code was developed to describe tree characteristics as they relate to wildlife use. These will be estimated on all sample trees on the variable plots. In addition, a fifth code was added for lichen volumes.
The actual use by some forms of wildlife will be recorded when this can be applied to specific trees in the sample.

Smaller Vegetation & Biodiversity

27) It is impractical to inventory wildlife populations during this field work, so the emphasis will be on habitat and plant species.
The plant list on a 10m radius plot will be recorded using standard botanical codes and coverage estimates.
This list will be used to produce a number quantifying biodiversity.
No specific attempt will be made to inventory rare species. This is not possible with an inventory of this scale.

Range

28) Range information should be gathered on parts of the province indicated by the map in the appendix of the field sampling procedures manual.
Utilization classes will be determined by standard estimation techniques.
Dry weight of Grasses and Forbs will be determined by clipping 4 micro-plots along the 24 metre woody debris transects.
Shrub coverage and average height will be determined by a line transect along the 24 metre coarse woody debris transects.

Other items

29) The Vegetation Inventory should be flexible enough to allow the collection of additional information as experience indicates.
Extra areas will be set up on the field cards in anticipation of additional data needs identified at a later date.
The sampling design has anticipated future sub-sampling, recalculation after changes in definitions, addition of new items, and separate sampling processes using the final data or adjusted polygons.

30) Regions and Districts of the Ministry of Forests should be visited to explain the Vegetation Inventory as soon as possible.
The process is overdue for exposure to the forestry staff. This has been neglected, but it should be done in early 1995. The video presentations will be a useful addition to any such presentation.
This should be extended to the consulting and industrial community as well.
The MoF should not press other organizations to accept procedures, definitions and standards until they have been successfully field tested.
Clarification of the relationship between the new Vegetation Inventory and TFL and Managed Forest inventories should be stressed.

Data Processing

31) Handheld recording devices should be used to gather information, when possible.
When field forms have proven stable and complete, then handheld recording devices will be considered for the inventory.
If possible, these should be used for data edit on the site, and perhaps as identification guides for plant species.
It is also possible to include field manual definitions and codes in such devices for instant reference in the field, and this should be considered.

32) Data should be compiled in a standard format for inclusion in the database.
Both a raw data and a polygon attribute database should be developed. The raw data format is necessary for recompilation and storage. The polygon attribute database would be the main vehicle for data distribution.
A "compilation and database group" should be formed to address these issues simultaneously. Much preliminary work has already been done for this.
This group should actually develop a working database, and the design for a program capable of handling the database in a format convenient to users.
The "FIP" files currently used in the Ministry of Forests are far too restrictive for future use, but perhaps the future databases should be able to produce them, since several users in the province are accustomed to this format and use it in their analysis.

Data Storage & Documentation

33) Original data and accompanying documents should be carefully stored.
Data should be stored in exactly the form it was taken in the field, or at least in a database capable of reproducing this form.
The data should be as readily available to users as possible, and this is especially the case with any centralized inventory group.
Some form of printed "hard copy" should be used for the storage of materials. In the future we would expect many of these forms to be scanned into databases and immediately available to users, but to insure against electronic disaster or technological incompatibility the MoF should also provide for a simple, permanent and safe storage format.

34) Locations of sample clusters, by geographic coordinates, should be available on the database and easily displayed on the standard maps used by the Ministry of Forests .
Locations for both "map" and "actual" locations should be kept.

35) Photos at sampling locations should be readily available.
These will be useful in deciding "borderline" cases for classifications from the data, and to do further interpretations not foreseen at the time of sampling.
Eventually, both overhead and ground-based photos should be scanned into the database so the user can call them up on demand.

36) Supporting and training documents should be available in word processing format and as video footage.
The use of word processors not only insures quick changes to errors, but allows a great deal of cross-referencing and word search capability. This is of use to outside groups as well as to the Ministry.
Word processing format can also be distributed quickly on the Internet and by other electronic means.
Videos will allow scientific staff interested in the data and contractors concerned with the procedures to view them in considerable detail and it will insure that the same message is repeated consistently.
Videos may also be useful in training.

Quality Control

37) The Ministry of Forests should have a consistent, continuing program of checking inventory work.
Final maps should be overlaid on original photos in such a way that boundary placement and line transfer procedures can be verified.
Field work needs to be checked consistently, and the effect of errors calculated, particularly in regards to volume, value and ecological classification.
This requires ministry staff to have field competence in all procedures involved with data gathering.

38) Standard procedures should be developed to supply information from GIS systems to the polygon attribute database.
Administrative boundaries, ecological zones, etc might all be read from the MoF GIS system into the polygon attribute database. A generalized set of programs should be developed immediately to do this, since many of these items would be helpful to the field supervisor.
The committee has serious concerns that the MoF GIS systems will not be up to the task of providing information and transferring data, and this capacity should be tested, just as the pilot project tested field processes.

39) A review of this entire Vegetation Inventory Design should be undertaken by outside inventory specialists, and repeated at 2-3 year intervals.
Such a review should be undertaken (1) prior to March 1995 concerning the overall design and field procedures and (2) after the first year of implementation of the inventory.

40) A standing committee should be established, with competent specialists from various organizations, to encourage further consistency of definitions and procedures among non-Ministry groups in BC.
Inventory specialists with the province and the contracting community who do this work should be invited to join such a group. This would serve to move users toward common standards at their own pace.
It should also be the mandate of this group to explore new and better ideas for inventory.

41) These proposed Vegetation Inventory procedures should not be forced on groups who have historical data processes adequate to their own procedures for resource management.
TFL holders, for instance, may have inventory systems which are well suited for their management purposes, and should be allowed to use them.
Such groups should, however, be encouraged to adopt the same definitions and methods (as a minimum) for any subset of data they choose to gather. For instance, a range group might use the range methodology, but not desire to measure trees, soils, etc.
The standing committee mentioned previously would help to introduce these procedures at an appropriate time frame and insure a benefit to all parties.

42) Rounded numbers, data classes and cultural definitions should not be substituted for actual data.
It is quite reasonable to have such definitions or classes <u>in addition</u> to the original data, but much harm has come from unnecessary summarization of data in the past.

43) Centralizing quality control, field work and data management should be encouraged.
Access to data, of course, should be as decentralized and direct as possible.
Decentralization of inventory planning, development of procedures and field work is almost always a bad idea, and the committee would discourage it.

44) Some form of overall direct check on the timber volumes and timber values of the vegetation inventory should be considered.
The committee is quite satisfied with the Resources Inventory Branch Decay Section approach toward a "location and type specific" decay reduction.
Most taper functions would be sufficient for practical work in inventory, provided that they are carefully checked before their introduction to insure that no species or size groups have unexpectedly large errors.
It would be useful to have at least some plots felled, in order to have a direct check on the final volume and value predictions. Perhaps these could be paired plots installed for the express purpose of destructive sampling so they did not interfere with other uses for the Vegetation inventory.

Reporting Systems

45) A polygon attribute database and a GIS system would be the main data source regarding the Vegetation Inventory. The custodian of the tree information should be the Resources Inventory Branch

The committee has no strong opinion about the major portion of the non-timber polygon attributes being held by others, but at least the major items for cross-referencing to timber information should be fed back into the Inventory database. "Ecological description" is one example of data which might be maintained by others but is constantly available on the Inventory database.

Standard copies of the database and GIS maps should be provided at intervals and fixed for those periods, even if the data is be constantly updated during those periods. Otherwise the summaries, plans, etc, will change every time they are run on this changing analysis base.

46) A standard reporting system similar to "FIR" now in use at the Resources Inventory Branch should be continued.

Such quick and responsive systems, available from terminals and PCs are very useful for the major questions asked by users.

Many of the questions and summary data can be anticipated, then provided on a limited size database of this sort. The major items, summarized over the usual administrative or ecological units serve the same purpose as standard maps - but with slightly more flexibility.

Users can go to the full database when questions are non-standard or require unusual area compilations.

47) Standard maps and reports should continue to be produced, and for the present these should be in traditional forms which users are accustomed to seeing.

Maps, for instance, might be produced with their current (or very similar) labels.

Reports using terms like "low site" should be available on demand for comparison purposes, but the database should be responsive to better choices for classes.

48) The Ministry of Forests Resources Inventory Branch GIS system should allow users to use color and symbols of their own choosing to display data from the polygon attribute database onto custom maps.

This would require the GIS group to set up user-friendly ways to display data from files provided by the user. This would allow many users to explore patterns of data, and to display relationships in the data.

49) Statistics for the Inventory Unit should be readily available to let the user know what accuracy to expect within the Vegetation Inventory Unit.

This should be stated in regards to the *average* value computed (technically, a "standard error"). In addition, an indication should be given about the variability between database values and specific polygon values (technically a "standard deviation around the estimated value"), and this display should probably be in terms of a histogram.

In the case of data which is not continuous, such as "leading species", the types and frequency of errors should be stated in an "error matrix".

Integration with Other Inventories

50) The main integration and transfer of data with other groups will be based on Geographic Information Systems (GIS) Technology.
The transfer and provision of georeferenced information by the MoF has been very limited. The committee is very concerned that this will be the weak link in sharing data.
Many of the simple tasks needed for the Vegetation Inventory have not been tested on GIS systems. This needs to be done as quickly as possible.

51) The members of this committee should visit other groups, and perhaps be integrated into them to encourage common approaches and principles.
The VIWG committee has already adopted standard coding and field techniques where possible. Use of "Describing Ecosystems in the Field" has been one example. Many of the coding schemes for these procedures need improvement, but this is less important with computer technology which can display an explanation along with the codes.
Few of the other groups would naturally share the sample locations used by the Vegetation Inventory, but the principles of sampling, data recording and information sharing and summarization would apply to other groups. Many of these groups are less advanced in their planning process than the VIWG, and there is presently little communication between these groups.

"Localization" of the data

52) The inventory should be flexible enough to include additional information gathered at a later date.
The problem of substituting new cruises and other sampling processes directly into the inventory is simply too technically difficult, but their use as estimates is far less likely to introduce statistical problems or bias.
The committee believes that the solution of this technical problem is to recalibrate the inventory, using any "new and better" information as a better estimate than the one previously used.
Where information is available from very reliable sampling, these polygons should be designated as "minimum change" items. This will maintain the overall unbiasedness of the inventory while improving the localized precision.

53) Periodic recalibration should be done, as necessary.
At intervals, all of the intermediate changes should be updated as a group. This involves including the "newer" information (as estimates) to all of the initial estimates, then recalibrating and reapplying the adjustment process.

54) "Operational Cruising" is not replaced by the overall Vegetation Inventory process.
Operational cruising is appropriate for the need to determine appraisal values on areas which might be harvested in the near future, and the Vegetation Inventory is not.
The Operational Cruises (and their data collection and analysis requirements) are governed by the needs of the Valuation Branch, and these needs are clearly beyond the mandate of the Vegetation Inventory carried out by Resources Inventory Branch.

It would be highly desirable if the field measurements and definitions used for operational cruising were identical to those of the proposed vegetation inventory process. Valuation Branch seems inclined to accept this approach, and it would solve many nagging small differences in comparisons of field data.

55) Sampling and statistical expertise should continue to be available from the Ministry of Forests staff in Victoria.

Recent acquisition of staff with a strong technical background in biometrics by the MoF Resources Inventory Branch is to be commended. This will continue to be an asset as the inventory is developed, modified and integrated into other parts of the Ministry of Forests and other provincial agencies.

It is essential that this staff have as much exposure to field work and professional contacts as time will allow. It is an essential part of their professional training.

"Update" of the information

56) Changing the inventory due to significant changes in individual polygon values or land base changes can be made at any time, since they will normally be a small part of the Vegetation Inventory .

Update of the vegetation inventory, as related to forest management activities (such as harvesting and silviculture) and catastrophic events (such as fire and pest infestation) will be addressed periodically to standards determined by the MoF.

Existing regression (or average) adjustments might be used, if appropriate.

Large changes, such as a massive fire, might trigger a recalibration effort for the inventory unit, at the discretion of the MoF.

Augmentation of particular data types

57) Specific disciplines which require more sampling should insure that the sample is unbiased over the whole Vegetation Inventory unit.

It is very tempting to apply special sampling projects against the entire inventory. This should be avoided, since the technical problems are difficult, subtle and could very well detract from the credibility of the inventory.

In some cases the solution will be to accept the polygon chosen already, and simply to add more sample clusters inside that polygon. Range, for instance, may require a higher precision in the "measured" weight of forage in a polygon and can get this by doing more clipping plots. This enhanced answer would then be applied to the standard plot data. If they only sampled "areas that looked too low", however, they would have a biased sample.

It is therefore very important that external data and procedures get careful review before the inventory database is modified by them.

Projection of the Inventory

58) The adjusted inventory estimates should be modified over time by standard projection models.

The inventory provides the "starting point" for forest growth models and other projections of vegetation. In addition, it provides decay and insect attack information which has not previously been available.

In addition to the volume, basal area, species percent, age, etc, the database has information on tree growth items such as site index and past growth (5,10,20 yr) which should be helpful for growth models.

59) Growth prediction and model building should be done as a process separate from the Vegetation Inventory.

While the sample locations do provide the opportunity to directly check growth over time, the production of growth models is best done from data specially provided for that purpose. The inventory does provide an unbiased sample for weighting the application of any research data. It may be easy for researchers to know the growth rate of a particular stand condition, but the inventory may be their only source of an estimate for how often that condition exists.

The Productivity Council should continue to acquire growth data. This work will not be strongly affected by the Vegetation Inventory.

Training

60) Training of field staff is a serious concern, and should be given high priority.
If adequate numbers of trained field staff are not provided, this could jeopardize the Vegetation Inventory. In the immediate future only enough people are needed for a few projects, but within 2 years we will need many trained people who could bid on the projects undertaken.
The training efforts are close to adequate for the estimation phase, but need considerable work for the field sampling.
Only trained people should be employed in the Vegetation Inventory process. Specialized training programs should be developed at Ministry expense. To insure that training is effective, the Ministry should require minimum qualifications to apply for the program or for placement on the waiting list.
Thought should be given to developing some sort of cooperative agreement with the contracting community along the lines pursued when the TRIM project was begun. This could guarantee a certain amount of work to groups which establish crews trained to do the new inventory processes.
Where possible, the Ministry should consider payment on the basis of a daily rate, experience and adequate check cruises. This would minimize initial quality control problems, especially at the start of the process.

61) The committee recommends that a permanent group of 4-6 people be maintained within the MoF in Victoria who are fully experienced, and qualified to carry out Vegetation Inventory field work. In addition, we would recommend the development of a stable group of people within the contracting community to carry out the necessary field work.
Large stable crews were used in past inventory processes, and it minimized the concerns with staff, timing, cost and quality control.
The Ministry simply cannot be without internal expertise for this project, unless it contracts virtually the entire process to a large external contractor which would serve as the contact with all other contractors employing photointerpretation and field measurements staff, and the committee would advise against this.

62) The Ministry of Forests should insure permanent internal expertise in photo work, sampling, field measurements and data compilation within Resources Inventory Branch.
To motivate qualified people to stay with the program for a long period, some thought must be given to a career path within forest inventory.
At the very least, there should be a 4-6 person group within inventory branch which can train staff, perform quality control, test procedures and establish standards. This requires a minimum of about 4 months of continuous field work in the Vegetation Inventory as a background. The preliminary field experience cannot be skipped, and the preferable method is to have MoF staff do the actual field work for the first few inventories, perhaps with a few contractors to increase the work force.
To maintain this size core group may require more positions, since changes of staff must be assumed over time.

External Quality Control

63) To assure the public that the inventory is correct, the Province should employ an independent agency to do an audit.

The final results of the inventory should be directly checked, not just the field processes. Measurements may or may not be on the same sample locations used in the inventory. Procedures should be reviewed with the Province before the work is done so that differences are not because of field procedure. Calculation procedures should be applied to some past data or past sample sites to insure that the results would change only from data differences, not processing differences.

Any processes that the reviewing agency considers flawed, inefficient or unwise will be reported as additional items.

The auditing agency should be connected with a forestry consulting group in order to ensure that field work is done correctly, and the results are interpreted in a standard and compatible way. Differences should be discussed before the results are released to insure that errors of procedure or interpretation are not involved, but the auditors should not be reporting directly to Resources Inventory Branch, since this would diminish the credibility which is the point of the exercise.

Implementation of the Vegetation Inventory

64) The committee believes that the new procedures should be phased in at a rate consistent with the numbers of trained people available for this work.

It is important not to disrupt the ability of the contracting community to continue to train and employ photointerpreters who will eventually be used to implement this new inventory

The current contracting community must be trained for the additional field work skills without losing their cruising skills which take considerable time to develop. There is already a critical shortage of cruising staff in BC, and it is important that the transition to the new inventory will not make the situation worse.

65) The provincial commitment to this project should be clear.

The significant resources needed for staff, training and facilities to complete a major vegetation inventory for BC suggests the need for a continuous 3 to 5 year funding commitment. A definitive project schedule, linked to the budget and resources available to that commitment is essential.

66) A Provincial Inventory Technical Council should be established.

The MoF should establish a joint Provincial Inventory Technical Council (PITC) to provide technical guidance and to oversee the implementation of the new Vegetation Inventory.

Members of the PITC should be selected on technical merit, not as representatives of particular groups.

To insure a variety of backgrounds and experience the Membership should consider the MoF, MoELP, the private sector, Universities, Technical Schools and inventory specialists.

67) The value of information collected on the Vegetation Inventory should be periodically evaluated.

Many potential users have identified types of information for collection during the Vegetation Inventory. However, the use of the information collected from the Vegetation Inventory should be evaluated after implementation. Deficiencies (with respect to users' needs) should be addressed during these periodic reviews.

Users of the Vegetation Inventory should be routinely identified and their uses documented. This information will assist the standing committees previously mentioned (recommendations 40 & 66) in evaluating the Vegetation Inventory.

68) The province should continue to develop the Pre-Inventory Analysis (PIA).

The PIA must evaluate the existing inventory attributes in view of current standards and management objectives, and provide recommendations for the new inventory.

The PIA should be applied to the total area of a recommended Inventory unit.

The PIA should estimate the advantages to be gained by changing the current polygon borders and their estimated attributes.

Appendix A

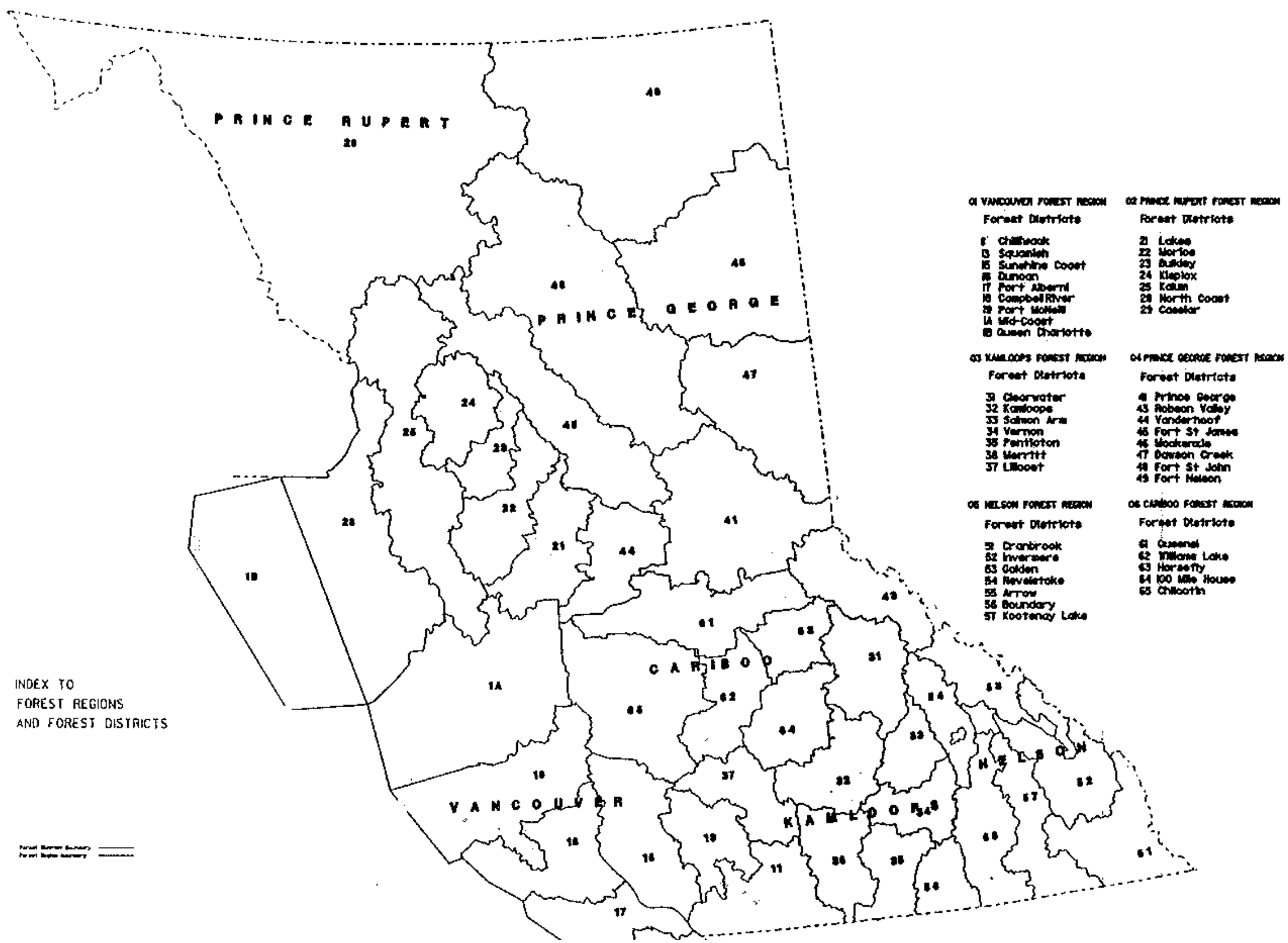
Glossary of terms used in this report

BC British Columbia
FIP Forest Inventory Protocol
FIR Forest Inventory Reporting (system)
FRC The Forest Resources Commission
FRDA Forest Resources Development Agreement
G & Y Growth and Yield
GIS Geographic Information System
GPS Global Positioning System
MoELP Ministry of Environment, Lands and Parks
MoF Ministry of Forests
NSR Not Satisfactorily Restocked
PC Personal Computer
PHSP Pre-Harvesting Silvicultural Prescriptions
(or simply called "Silvicultural Prescription")
PIA Pre-Inventory Analysis
PITC Provincial Inventory Technical Council
RIC Resources Inventory Committee
RPF Registered Professional Forester
TETF Terrestrial Ecosystems Task Force
TFL Tree Farm License
TITF Timber Inventory Task Force
TRIM Terrain Resource Information Management
TSA Timber Supply Area
UBC University of British Columbia
UTM Universal Transverse Mercator
VDYP Variable Density Yield Projection
VIWG Vegetation Inventory Working Group

Appendix B

Example map of potential inventory units

RECOMMENDED ADMINISTRATIVE UNITS FOR THE VEGETATION INVENTORY



Appendix C

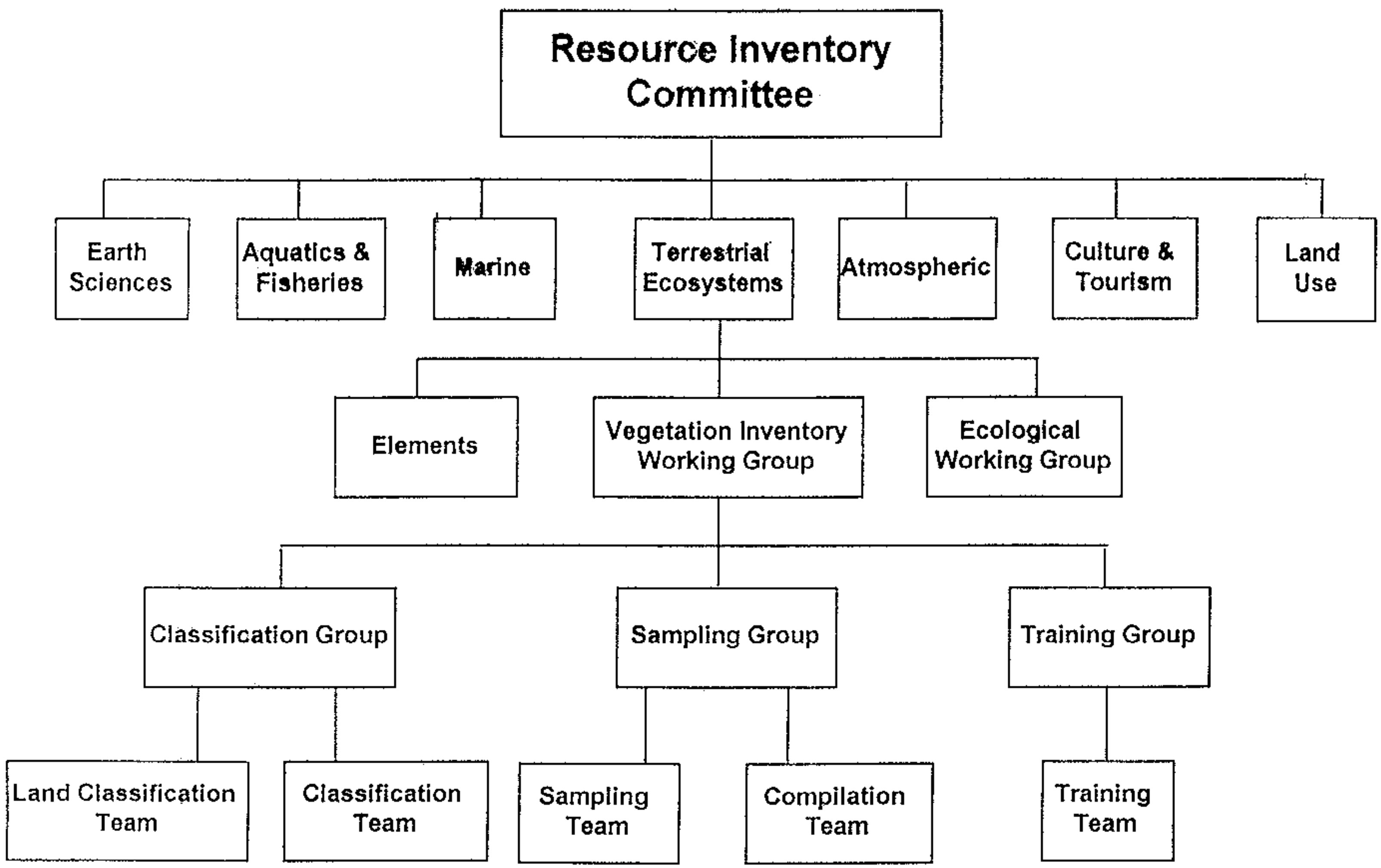
Current Structure

1) Flowchart of the **R**esources **I**nventory **C**ommittee structure.

2) Terms of Reference for the **T**errestrial **E**cosystem **T**ask **F**orce.

3) Terms of Reference for the **V**egetation **I**nventory **W**orking **G**roup.

General Scheme of Vegetation Inventory Committee Format



TERRESTRIAL ECOSYSTEMS TASK FORCE

Terms of Reference, Work Plan and Budget

Co-Chairs: B. Pendergast and S. Omule

June 25, 1992

Draft 2.0

1 Introduction

The Terrestrial Ecosystems Task Force (TETF) represents the renewable (predominantly living) resources group resulting from the consensus of a workshop of the Resources Inventory Committee
(RIC) held at Mesachie Lake May 27-28, 1992. TETF represents the following interests, most which
were represented at the Mesachie Lake workshop:

Biodiversity;

Ecological classification;

Range inventory (ecological and cultural)

Soils;

Vegetation mapping (forest cover, including timber inventory and silviculture surveys);

Wildlife biophysical mapping;

Wildlife population inventory.

Reporting to RIC, TETF will develop common standards and procedures for the collection, storage, analysis, interpretation and reporting of inventory data for the terrestrial ecosystems.

TETF: Draft 2.0

2 Terms of Reference

2.1 Vision

The vision for the TETF is as follows:

CLASSIFICATION: Single, integrated ecological classification.

MAPPING: Permanent ecological units mapped at small and medium scales, with full provincial coverage, providing a single set of polygons for all resource agencies.

VALUES: Common standards and procedures for resource evaluation. Each advocate agency provides interpretations for resources within its mandate, including soils.

SAMPLING: Ecological classification and mapping provides a framework for detailed stratification and sampling of vegetation (for, e.g., range utilization, habitat monitoring, silviculture surveys, and timber inventories). The site-specific information collected confirms or refines the ecological mapping. Mapping of present vegetation at larger scales must be periodically updated, but map units should stay nested within the permanent ecological units.

Notes:

Medium scale ecological mapping can be at scales of between 1:250 000 and 1:50 000, depending on the resource values.

Detailed mapping will be on a TRIM base, to facilitate data sharing.

Ecological classification and mapping also provides a framework for inventory of animal populations and monitoring of habitat use and biodiversity.

2.2 Objectives

1. To develop methodologies for integrating inventories of renewable (pre-dominantly living) terrestrial resources, as well as inventories of other resources, as fully as is practical within the constraints of economic and resources management needs and consistent with the objectives of RIC.

2. To recommend ways of capturing historical terrestrial ecosystems inventory information

3. To effectively communicate the methodologies developed to achieve a common land resource inventory.

3 Process

- TETF will establish mechanisms for consulting with other task forces within RIC, government agencies, industry, First Nations Peoples, and other non-government agencies.

- TETF will set up several working groups to carry out the various assignments, assisted by consultants as required.

- Work will be conducted through projects, as described in the work plan and timetable below.

- TETF will coordinate and integrate the work of the working groups.

4 Work Plan and Timetable

Project 1: Revise and summarize the current needs and inventory requirements to satisfy them
August 31, 1992

Project 2: Examine issues and principles common to terrestrial ecosystems inventories
October 30, 1992

Project 3: Design a strategy for integration of common inventory needs and communication of results. As agreed with other task forces

Project 4: Design inventories to meet the common and specific needs for timber, range (ecological), wildlife and soils; and provide for a system to accommodate biodiversity inventory
February 28, 1993

Project 5: Prepare manuals and documentation for RIC
March 31, 1993

5 Membership

Membership of the TETF and its working groups will consist of technical specialists chosen as individuals (not representatives) from the federal and provincial government staff, industry, the consulting community, universities, technical institutions, First Nations People and other non-government agencies.

6 Structure and Responsibilities

The task force itself will consist of 7-10 technically qualified individuals form each discipline (wildlife, biodiversity, timber, silviculture, range, and soils), plus an expert in database design and a biometrician as required.

Working groups will be composed of varying numbers of technically qualified specialists in vegetation, wildlife, range, and soils inventories. [The basis for structuring the working groups has not been agreed upon: one option is to base them on the type of inventory (e.g. vegetation; range; soils); another option is to base them on the inventory process components (e.g. sampling; classification; mapping; databases].

The task force will make sure that common problems related to classification, sampling, mapping and databases are addressed. Some of the issues to be addressed include: procedures for polygon-line information transfer and overlay; procedures for database information transfer; compatible definitions, codes, and procedures; valid statistical or sampling procedures for polygon description (if appropriate); accommodation of biodiversity inventory; and field-data capture that minimize duplication.

The working groups, who will eventually overlay their information and share data, will work out:

methods to sample polygons for specific resources, as well as techniques to infer information about the unsampled polygons;
procedures and standards to collect, analyze, report and interpret data.

VEGETATION INVENTORY WORKING GROUP

(TERRESTIRAL ECOSYSTEMS TASK FORCE)

TERMS OF REFERENCE

Reporting to the Terrestrial Ecosystems Task Force, the Vegetation Inventory Working Group (VIWG) shall make recommendations pertaining to the vegetation inventory which includes timber and silviculture. The focus will emphasize process, methodology, standards and procedures for the vegetation inventory of the Province of British Columbia.

The working group will recommend standards and procedures for an accurate, flexible, and stand-specific inventory process. The recommendations will apply to all provincial Crown land regardless of tenure.

Specifically the Terms of Reference are:

1. Design and plan the development of an accurate vegetation inventory process, as follows:

a) Requirements definition;

b) Develop and recommend pre-inventory analysis procedures;

c) Design and recommend flexible, but statistically sound inventory methods to provide an accurate vegetation inventory to meet client needs for site-specific and broader planning; the need to integrate the vegetation inventory with inventories for other resources vales will be fully recognized in the design;

d) Recommend size of inventory units;

e) Develop and recommend technical standards for an inventory program;

f) Address the issue of using silviculture information (PHSP’s, etc.), cruise, scale and other data to support the inventory process;

g) Develop and recommend decision support tools to generate client-defined inventory reports, to assess statistical accuracy of a client-defined unit inventory, and to determine appropriate sampling methods to improve the accuracy of the unit inventory;

h) Recommend the appropriateness of the application of the inventory information for a given standard of accuracy, complete with examples of what it can and cannot be used for;

i) Pilot test the recommended standard and procedures for field application in 1992-1993;

j) Recommend processes for larger scale field testing and demonstration in 1993-1994, including integration, technology, staffing and training requirements for implementing the recommendations.

Appendix D

Previous work & Historical summary

1. Terms of Reference for the **T**imber **I**nventory **T**ask **F**orce (it preceded the VIWG)

Background papers

2. Paper: Some Characteristics of a good inventory, K Iles & Associates Ltd., 1992
   (This was a guiding reference in the TITF committee)

3. Paper: An Historical Summary of Forest Inventory Sampling Designs in British Columbia, J.S. Thrower & Associates Ltd., 1992
   (This is a good summary of previous BC Inventory efforts)

NOTE: A list of reports and discussion papers (some are simply in draft or discussion format) is available from the RIC Secretariat.

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The Executive Secretariat
Resources Inventory Committee
840 Cormorant Street
Victoria, BC, CANADA
V8W 1R1

Phone: (604) 920-0661
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Timber Inventory Task Force

Terms of Reference

Ministry of Forests

Inventory Branch

November 1, 1991

Draft 3.1

1 Introduction

The forest Resources Commission (FRC) in its report *The Future of our Forests* recommended that a Timber Inventory Task Force be set up to "design and plan the development of an accurate timber inventory". Included in the report was a further recommendation to "conduct a critical review of the present Ministry Forests' Reinventory Program and to report within the next 12 months". The Provincial Forest Resources Inventory Committee (FRIC) will establish a Timber Inventory Task Force (TITF) to implement the FRC recommendations.

2 Task Force Terms of Reference

2.1 Terms of Reference

Reporting to FRIC, the Task Force shall make recommendation to the Ministry of Forests on matters pertaining to timber inventory, which includes forest classification, growth and yield, and loss factors. The focus will emphasize purpose, methodology, and standards and procedures of timber inventory in the province of British Columbia.
The Task Force will review the current inventory program and recommend standards and procedures for an accurate, flexible, and stand-specific timber inventory process. The review and recommendations will apply to all provincial Crown land regardless of tenure. Specifically, the terms of reference are:

1. Review the current Ministry of Forests' Inventory Program. The review shall address:
a) Design requirements;
b) Inventory methodology;
c) Growth and yield;
d) Site productivity;
e) Decay, waste and breakage (loss factors);
f) Forest classification procedures, standards, cultural definitions such as NSR (not satisfactorily restocked) and "operable" forest land, and site attributes such as old-growth characteristics and biodiversity;
g) Database and data standards.

2. Design and plan the development of an accurate timber inventory process, as follows:
a) Requirements definition;
b) Develop and recommend pre-inventory analysis procedures;
c) Develop and recommend flexible, but statistically sound inventory methods to provide an accurate timber inventory to meet client needs for site-specific planning; The need to integrate the timber inventory with inventories for other resource values will be fully recognized in the design;

d) Recommend size of inventory units;
e) Develop and recommend technical standards for an inventory program;

f) Address the issue of using cruise, scale and other data to support the inventory process;
g) Develop and recommend decision support tools to generate client-defined inventory reports, to assess statistical accuracy of a client-defined unit inventory, and to determine appropriate sampling methods to improve the accuracy of the unit inventory;
h) Recommend the appropriateness of the application of the inventory information of a given standard of accuracy, complete with examples of what it can and cannot be used for;
i) Test the recommended standards and procedures for field application;
j) Provide demonstrations to ensure the recommended inventory standards and procedures are interpreted correctly;
k) Suggest options for appropriate technology, staffing and training requirements for implementing the recommendations.

The Ministry of Forests will evaluate the TITF recommendations for implementation within the Inventory Program.

2.2 Process

The Task Force will coordinate its work with FRIC to ensure that FRIC's standards are incorporated into the TITF recommendations.
The process will be modular in nature and will fit in with the development of other resource inventories under the review of FRIC. It should be considered as the first of two phases of developing multi-resource inventories. The second phase will be to integrate the various resource inventories. The Task Force will consult with the staff of the Ministry of Forests and other government ministries and agencies (such as lands, parks, and tourism) to ensure proper linkage and integration of the timber inventory with other resource inventories.

2.3 Work Plan and Timelines

The Task Force will proceed in order as follows:

1. Inventory Program Review — 5 months

a) Review

- Characteristics of a good inventory design.
- Overview of current inventory process.
- Past inventory techniques and problems.
- General shortcomings of past inventory.
- Report on the current inventory process.

b) Determine information about Inventory clients

- Who are the clients?
- What are the client needs?
- Are client needs being met?
- How do the clients use the products?
    - How much are the clients willing to pay for products?
    - What demands are placed on the inventory program?
    - On what areas of the inventory program are the demands placed?

2. Design and test timber inventory process 12 months

- General principles and philosophy of inventory design.
- Future needs.
- Present assets and limitations.
- Linkages to other inventories.
- Overall approach to new inventory.
- Field testing.
- Report and produce documentation on the new inventory process.

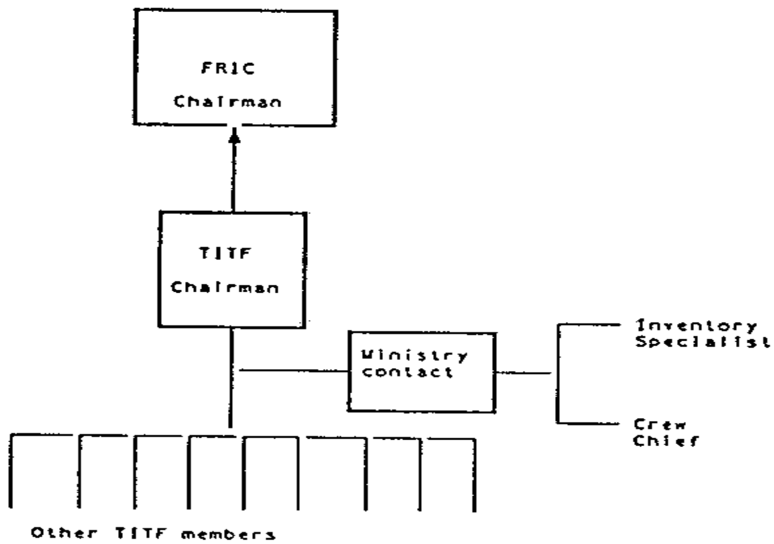
Item 1 can be started immediately, but item 2 will not be started until the other Task Forces addressing cultural/amenities inventories (e.g. recreation, tourism, archeology, wildlife, watershed, and geological) and the FRIC master plan are in place.

3 Task Force Program

3.1 Members

TITF will consist of a total of 12-14 technical experts chosen as individuals (not representatives) from the Ministry of Environment, Lands and Parks; the Ministry of Forests; the forest industry; forestry consulting firms and individuals; and the University of British Columbia. In addition, a 3-person field crew will be established to test and demonstrate the recommended procedures.

3.2 Structure and Responsibilities



Responsibilities are as follows:

- Chairperson: sets agenda; controls time allocated to discussion topics; calls for opinions or concesus as required; insures that minority opinions are expressed.

- Members: review, discuss and recommend current methods and field applications; consult with their peers.

- Inventory Specialist: summarize discussions; prepare technical reviews and initiatives for discussion; analyze field trials; arrange for experts to advise the Task Force.

- Ministry Interface: Ministry of Forests project leader and contact on technical matters.

3.3 Meetings

The Task Force will meet for 1 day every 2 weeks or as required

Budget

An appropriate budget will be provided by the Ministry of Forests to cover meeting costs, all out-of-pocket expenses and fees for non-government members and invited experts.

Some Characteristics of a Good Inventory

A Discussion Paper

prepared for the

Timber Inventory Task Force

April 1992

by

Dr. Kim Iles

Kim Iles & Associates Ltd.
Nanaimo, BC

Introduction

The following principles of design are some that should be considered when reviewing a previous timber inventory or designing a new one. They apply to other types of natural resource inventories as well.

In some cases it will be true that cost, time restrictions or other factors will intervene and prevent some of these general principles from being used with a particular inventory. Still, these ideas in principle should be considered.

The precise method of their execution will depend upon the specific requirements of the inventory, and these methods must be designed and reviewed by specialists who have a clear appreciation of the field work, maintenance of the data and reporting requirements.

(1) Simple (Robust)

The design should be a simple as possible for purposes of credibility and generality.

The design must allow for wrong assumptions, missing data, redesign during the main execution, and updating at a later date.

All these considerations call for the simplest practical design, all other things being equal.

(2) All of the BC land base is accounted for and sampled.

While current forest type definitions must guide the work, it should be assumed that questions about "uneconomic", "low volume", "unmerchantable" (etc.) timber will be of increasing interest in the future.

It is wise to have at least minimal information on each category of land, even non-forest land. It is certainly wise to have minimal estimates for all ownership categories of forest land, if only to independently verify more complete data from other sources.

(3) Current complaints are acknowledged and considered.

It is not clear what all the alleged "problems" are with the current inventory, at least from the technical point of view. The Timber Inventory Task Force should verify the problems as far as possible, and be seen by the inventory users to do so.

(4) Stand-specific data.

We should be able to give individual labels to all forest (stand) polygons, even if the initial estimated values are all identical averages from a strata.

The database structure should therefore be set up for individual stand attributes on a "seamless" map base.

We should consider some form of "post-processing" to spread out the individual polygon values within a class, while maintaining the overall unbiased nature of the inventory. This allows the maximum flexibility for "post-processing" the data in a variety of ways.

(5) A core INVENTORY STAFF has been through the design and execution of this inventory, and is ready to change it as needed.

The training of key inventory people is essential. It is highly desirable for the Inventory Branch to retain experts in this field. This helps with setting standards, quick modifications, future planning and general credibility. Contractors are very useful, but not a complete substitute for "in-house" expertise.

It is important, 5-10 years after the inventory has been taken, that there are a number of people who can update, defend, explain and modernize this inventory.

One of the key ingredients of such a team is that they get the experience of planning and executing the current inventory, including field experience.

They should have the benefit of listening to visiting speakers, watching the decision process, and knowing the reasons why particular techniques were (or were not) adopted.

A number of key inventory people should therefore be included in the work of the committee for training purposes. It may be, of course, that these people move on to other positions not involved with inventory. Still, an attempt should be made to give this experience to a group of people inside the Branch. Having people who have been through this process is a major advantage, to be sought where possible.

(6) "Overdesign" is desirable.

Future changes will require finer categories and, if anything, tighter sampling errors. Minimal sampling at the start will mean undersampling later on, when divisions are finer.

One alternative is to design for very simple, valid and cheap additions of additional plots at a later date, but this will require more elapsed time than will normally be available.

(7) Statistical accuracy is known.

An attempt should be made to clearly portray:

- The Accuracy of the raw data, perhaps from an independent quality control procedure and by quick access to definitions and standards.
- The Statistical precision of the data for the summarized (average) units.
- An indication of the precision expected from an individual polygon estimate.

Some of this can be done by making this information easily available from the database information system where the summary data is stored. In some cases it should be provided along with summary reports.

The "worst case (95%)" Sampling Error should be avoided as the sole error indication, in favor of some more helpful set of indicators, such as the minimum (5%), maximum (95%) and probable (50%) error estimates.

The intent here is to limit the expectation of the user, and the subsequent complaints when they feel that the data is "not accurate enough".

(8) Statistics are unbiased (or bias is known to be small).

Biased estimators, such as Baysian estimates, are known to be very efficient in many situations, but are a sure bet to increase anxiety and credibility problems.

Where possible, unbiased statistical estimators should be used.

Where real advantages are seen, overall parameters should be kept unbiased, while localized ones may incorporate bias which is statistically reasonable. In these cases, a study should be provided to show the upper limits and average amounts of the bias incurred.

If a set of watersheds, for instance, used individual corrections (which involve a statistical bias on each of the individual watersheds) then the overall average of all watersheds should be controlled to give the same total as a simple unbiased average would have indicated initially. Individual differences from the unbiased estimate should also be stated.

(9) Multiple stages are used.

Certainly a 2-stage sample is called for, and perhaps a 3-stage sample procedure. This offers the opportunity to use the rough estimates (from "higher" stages) for other inventories or future additions and special projects.

The ability to estimate species groups and rough volumes from the present inventory is a powerful opportunity to improve sampling precision in the next inventory.

At the same time, too many levels would probably lead to a problem with summarizing various land groupings.

The use of many levels is not called for, unless the inventory needs are extremely precise and unlikely to change with time. This is not the case with the BC timber inventory.

(10) Categories are flexible.

We should be able to "Lump" or "Split" the land base <u>after</u> the field work is done. Enough data points must be available to recalculate on smaller units than are anticipated initially.

The units we anticipate for summarization will undoubtedly change at a later date, and usually into finer designations. This will require gathering descriptive data beyond the stand category initially used, in order to put the plots or stands into different groupings at a later date.

(11) Recalculation of the raw data is possible.

The data should be kept in such a state that recalculation on a partial or whole basis can be accomplished. For auditing and quality control purposes alone, this would be highly desirable.

When particular portions of the land base are used for planning purposes, it will often be required that data within that area be reprocessed (and perhaps in the complementary area as well). Otherwise, considerable biases should be expected in those selected areas.

(12) We can "Update" with new or redefined parameters.

We must assume that the inventory definitions, items of interest and measurement schemes will all change over a period of years, and design the inventory to be recalculated and updated with these new items and definitions.

In many cases, the most practical quick response will be to determine a regression between new and former standards.

In some cases, research will provide the relationships.

(13) Ancillary data can be used in the future to adjust stand data in an unbiased way.

Individual stand information may be changed by ancillary data at a later stage, or grown differently into the future.

A case in point might be the use of Empirical Bayes estimates, or different growth patterns for ecological types with the same stand description.

When such changes are made, they should be constrained to give the same overall estimate as would be chosen by a simpler unbiased method.

(14) Further (and perhaps more specific) samples can be taken from the inventory, and the data from the inventory can be used to facilitate such studies.

The ability to provide a properly chosen subsample from the land base or the set of plots used from the inventory would be very desirable. Map output of sample locations should be easily and quickly available at any scale.

We should provide a valid approach to [random, systematic and list] samples taken from the actual land base, the map base, the past samples, or the database itself.

This would encourage valid sampling approaches by others, while serving as an excellent quality control and research tool for inventory purposes.

This also offers the ability to specify a more precise sample in a local area in order to get a highly accurate local answer.

Computer programs for this purpose can be written at reasonable cost for use with the GIS system.

(15) Available on a database.

Modern databases are of sufficient quality to hold both raw and summarized data. In most cases, they can be used with a personal computer to view a selected subset of the Provincial database.

Both types should be available :

- RAW DATA for purposes of recalculation when only part of the land base forest types are selected for use or when techniques change, as well as the location of trees with particular research interest. This would probably not be widely available for use, and controlled by a central group--probably in Victoria.
- SUMMARY DATA for planning and reporting purposes, and to allow searching for stands with particular characteristics. This would be much more widely available, in whole or in part, in an "official" version released by Inventory Branch at intervals.

It is important that such a database be able to transfer its contents to another database of a different format or in another language.

(16) Good quality control procedures, well documented.

Quality control processes will be important throughout, both for training and to control error and bias (as well as to establish credibility).

This will require good procedure documentation, which will also be useful in training field crews. The use of video systems should be encouraged for training and documentation purposes. Manuals should also be available in word processor format.

Some attempt to "reconcile" the amounts harvested with the inventory estimates is very desirable, but the limits to any traditional "cut vs. cruise" comparison must be made clear.

(17) "Ground Truth" can be verified over time and by outside groups.

For purposes of outside auditing, technical questions about procedure, or for any other valid reasons, the "ground-truth field work" should be available for checking by outside parties. Plot locations stored on paper maps or air photos are the preferable (minimum) source of plot locations. It is also highly desirable for plot locations to be on a GIS.

(18) Major conclusions reinforced by inexpensive separate system.

If possible, it should be "audited" by an outside agency.

A large and complex inventory system cannot be completely checked for accuracy, and projecting such an inventory adds to the problem.

For credibility purposes, at least one outside check on the items which are important in decision making (overall volumes, growth rates, field work accuracy, etc.) would be very desirable. If such a simple outside check could be done be a separate agency, so much the better.

This is the best defense for the credibility issue. A completely outside audit, which comes to approximately the same conclusion, is a powerful argument that the errors which might have caused errors and bias did not in fact do so.

(19) Stand polygons compatible with other GIS systems.

The location of particular stands must be known, both in "inventory map location" for the maps used with inventory and in "real terms", perhaps with the "Global Positioning System" as a standard for accuracy.

"Location" in this sense would mean that the stand centroid was known, and perhaps that the polygon was described in a way which could be overlaid on any other GIS system available.

(20) Can be related to other inventories.

By matching ground points with each system:

With ground points well documented, any new measurements or sampling processes can be directly matched with the nearest inventory points. There are many advantages to directly matching the locations sampled by different sampling systems.

Subsampling and double sampling matched to the inventory sample locations would offer real statistical advantages. Direct comparisons of data are often useful for quality control and research purposes.

By GIS systems:

When sample points are referenced with UTM coordinates, they can draw a great amount of information from other sources.

This requires that not only that GIS systems be compatible, but the map bases must also be reasonably compatible--not a small problem. The use of the TRIM database would solve many of these problems.

(21) Projectable through time by Growth & Yield techniques.

The inventory will have to be updated not only for 5-15 years, as "the present" changes, but for one or more rotations.

While any inventory would likely be adequate for most simple projections, we should consider the provision of sample points for more sophisticated model projections, perhaps choosing these points after the fact because they were typical (or extreme). These sample points could be "upgraded" to whatever extent needed for model projections to be applied. They may eventually be used as permanent sample plots.

Site index (or some similar attempt to describe growth potential) will be particularly important for very long-run growth estimation.

(22) Historical data should not be deleted without due consideration.

When an area is logged, the previous data describing that area should continue to be available.

Questions such as "are we logging a representative set of stands from the land base" are frequent, and will become more so in the future. A knowledge of the attributes from stands now harvested should be retained. This is no small task for the database or GIS functions, but would be of real value.

(23) Quick, overall reporting systems are in place.

The need for many types of summaries are quite predictable, and should not require the use of a complicated database.

A personal computer system which quickly and easily reports summary data should be in place for simple inquiries, and should be available at the District level.

An Historical Summary of Forest Inventory

Samplings Designs in British Columbia

A Report to the B.C. Ministry of Forests
Inventory Branch
Timber Inventory Task Force

James S. Thrower, Ph.D., R.P.F.

February 3, 1992

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I gratefully acknowledge the contributions of several individuals and thank them for their assistance in this project. Much of the historical information of what actually happened is not documented and without the help of these persons I could not have determined the circumstances of these events. Mr. Jerry Jelinek and Mr. George Allison (both retired from Inventory Branch) were very helpful in describing the methods used in the first major inventory from 1951-1957. Mr. Imre Spandli (Inventory Branch) was very helpful in describing in detail the methods and procedures of the most recent inventory from 1961 to 1977. Mr. Jack McLellan (Inventory Branch) was very helpful in describing all the events from the end of the first major inventory to the present and also spent a great deal of time reviewing this manuscript.

Table of Contents

INTRODUCTION

Forest inventory sampling methods have changes dramatically in British Columbia since the first attempts to quantify the timber resources in the early 1900's. Initially, inventories did not involve sampling in the usual sense but were compilations of any available information including rough guesses of volumes and areas. Often surveys of many become broader in scope and increased requirements of statistical reliability, improved aerial photography and computer technology, and improved aerial and ground access.

The Province is now preparing to re-design and undertake another inventory of the forest resources. Undoubtedly this inventory will be more intensive and more sophisticated than former ones and include factors that were not of concern in the past. More emphasis will likely be placed on non-timber resources. The Timber Inventory Task Force has been formed to advise on the technical aspects of the new inventory. Part of the process is to review the former inventories. This report is presented as part of this review and is concerned only with the sampling designs used in the previous forest inventories.

This report was prepared from discussions with individuals who were involved in the last two major inventories starting in 1951, and from a wide variety of published and unpublished historical and technical documents. The scope of this report is limited to the sampling designs used for estimating volume and does not consider sampling for decay or growth and yield. Include are various notes and comments that relate to general factors and conditions that may have affected what actually occurred. Unfortunately, this report was prepared under severe time limitations and thus not all possible sources of information were reviewed. However, this report should contain the major components of the sampling designs of the previous inventories. Hopefully, this is sufficient information for the Task Force to interpret the objectives of the previous inventories and the sampling designs used in attempts to achieve them

The history of inventory sampling in the Province is not always entirely straightforward. Often many programs were conducted simultaneously at various stages of development. I have tried to simplify the situation by discussing the sampling designs and other events in specific time periods. Sometime this is appropriate and other times it might result in slight confusion of misrepresentation of the events.

The body of this report contains two major sections. The first gives an overview of four major periods in the history of inventory in the Province. The second discusses the historical trends in the inventories, and possible affects of future developments on inventory sampling designs. This is followed three appendices. Appendix I is a table showing some important characteristics of the sampling designs by time period. This should facilitate comparison among the various inventories. Appendix II gives a more detailed point-form listing of the major items of the sampling designs that were summarized in the first section of the report and in Appendix I. Appendix III is a histogram showing the number of inventory plots established by year, inventory period, and type of sample plot.

SUMMARY OF INVENTORY PERIODS

Many events have occured since the first inventory near the turn of the century and often the timing and sequence overlaps and is confusing. This section summarizes the major events in four subsections. These subsections are named by major events that occurred in the time period. The following list shows the specific events (given in Appendix II) that are covered in these subsections.

Compilation Inventories (1910-1950)

up to 1910	The First Compilation Inventory
1911-1918	The Second Compilation Inventory
1919-1937	The Last Compilation Inventory
1938-1950	Maintenance Surveys

The First Complete Inventory (1951-1960)

1951-1957	The First Complete Inventory
1958-1960	Maintenance Surveys

The Second Complete Inventory (1978-Present)

1978	Sub-Unit Surveys
1979-1981	Inventory Update Program
1982-1987	History Update Program
1988-1991	Re-Inventory Program

Compilation Inventories (1910-1950)

Prior to 1951, inventories were merely compilations of existing information. Of these three inventories in this period, and especially in the first (Fulton 1910), volume was estimated by guessing for many large areas. The next two inventories (Whitford and Craig1918, Mulholland 1937) used an increasing amount of information from surveys, but sampling was not done specifically of either. Where surveys were available, they were often done to different standards and thus were very difficult to summarize on a common basis. Sampling was really only done in the last inventory starting in 1927 and only for some areas of the Province. The sampling used in the 1927 inventory was strip cruising at various intervals, widths, and lengths. Estimates were given volume by drainage basin and Forest Districts (roughly equivalent to the present Forest Regions).

The objectives of these early inventories was to estimate how much wood was available for harvest. This was the level of information needed by the expanding industry at the time. Utilization standards changed dramatically in this time period in terms of the size and species that were considered merchantable. Estimates quickly became outdated because of rapid expansion of the industry, the ability to utilize new species and smaller trees, and increasingly intensive management. Two World Wars and the depression of the 1930's had a dramatic affect on field operations for these inventories (Sloan 1956).

The First Complete Inventory (1951-1960)

The second major period in the history of inventory sampling started in 1951 with the creation of the Forest Surveys and Inventory Division of the Forest Service and the signing of Federal-Provincial agreement for a new inventory of the Province. This first complete inventory of the Province from 1951 to 1957 took seven years from planning through to compilation. At the time, preliminary information from former inventories was not available for much of the area for designing the sampling plan. Also much of the area was not classifies prior to sampling and the two functions were done simultaneously. Only sparse sampling was done for much of the northern region of the Province. Aerial photographs were available for most of the Province the first time. Initially they were 40 chain photos taken by the military for reconnaissance of major topographic features, and did not give the desired resolution for a timber inventory. These were gradually replaced by higher resolution 20 and 40 chain photos taken specifically for the inventory.

The stated objective of the inventory was to provide estimates of total volume to a precision of +/- 10% (at 2 standard errors (se)) for major species in each Forest Inventory Zone (FIZ), and for all species at the subzone level. FIZ zones were similar but nut the same as the current zones. Estimates of average and total volumes were given by what were called Summary Types by FIZ and subzone. The Summary Types were groups of related forest types delineated from the aerial photos.

Access was very poor for many regions of the Province compared with today and this severely limited sampling operations. The emphasis of the inventory was on mature timber and older age classes. Attempts were not made to implement a statistically valid traditional stratified random design because budgetary and logistic constraints made this infeasible. The strata subjectively chosen for sampling were based largely on mature timber and available access. Random location of sample plots was used in the initial phases of the inventory, however, this was quickly replaced with subjective location of sample plots in "*representative*" areas of stands indentified from aerial photographs. The number of samples was not determined based on desired sampling precision because of the budgetary limitations. Practical and logistical restrictions were major factors affecting the sampling plan.

Activities in the last three years of this period (1958-1960) involved primarily maintenance surveys. Theses used the same methodology as the recent completed inventory and were designed primarily to enhance classification and to supplement the inventory. New 20 chain photos were used almost exclusively and sampling and classification were undertaken as separate functions.

The Second Complete Inventory (1961-1977)

The third major period in the history of inventory sampling brought the second complete inventory of the Province done between 1961-1977. The surveys done in this inventory are often referred to as *Unit Surveys* because the major sampling units were management units (Public Sustained Yield Units - PSYU's). Most of the volume data currently in the inventory data base (approx 77% of the sample plot clusters) were collected in this period. The emphasis was also on mature timber and used a similar approach as the 1951-1957 inventory. Major differences were: more samples taken; more refined strata definitions; new management units; more refined classification variables of age, height, site, and stoking; sampling and classification were combined; and higher resolution, larger scale (20 chain) aerial photos.

The objective of this inventory was to estimate total volume for each unit (PSYU) to +/- 10% (at 2 SE). The principles of stratified sampling were used, but logistic, budgetary, and administrative difficulties prevented the random selection of strata, stands, and samples (clusters of plots). The resulting design was termed "*modified stratified random sampling*". The strata were defined as age, height, and stoking classes within a given Inventory Type Group (ITG). ITG's were groups of forest types related by species composition.

Strata were subjectively chosen such that sampling was concentrated in older age classes of the larger types. Often most of the area in a PSYU was contained in a small number of the strata, thus strata with proportionately small areas were usually not sampled. Stands within strata were chosen to avoid sampling areas where samples already existed, and with the objective of ensuring a geographic distribution of samples throughout the PSYU. Access was also a major consideration in stand selection and often was possible only by boat, float plane, helicopter, or on foot. Thus stands from several strata were often selected to be near each other to facilitate access.

Samples were sometimes randomly located in the target stands by using a grid overlay on aerial photos. However, many samples were subjectively located in areas considered to be representative of the stand. In mountainous areas, samples were often located on lower slope positions accessed by vehicle or boat, and on upper slope positions accessed by helicopter. The number of samples actually located was determined by the number that could be established by the crews in a field season. Rules of thumb were used for estimating the number of samples to be established, but budgetary constraints were usually an over-riding factor. The number of samples established by strata was monitored during the field season to check that strata were not over-sampled. However, this was not always achieved and some major types contained many samples while others contained very few. The achieved sampling precision was not monitored during the field season which resulted in varying sampling errors among strata.

Despite practical limitations, some attempts were made to implement a statistically valid sampling plan using randomly located samples. Sample size was computed from a rule of thumb indicating 150 samples per 500,000,000 cubic feet (approx 14,000,000 m3) and also considered impractical to implement under current limitations, primarily because accessing the randomly chosen samples was extremely difficult and was taking double and triple the time needed to establish the subjectively located samples.

The departure from the principles of traditional stratified sampling were necessary because of the limitations and conditions of the time. This has probably had two major results. First, the inventory was probably more efficient in that it gave more information for the limited financial resources. The subjective selection of strata with the highest per unit area volumes (the older age classes) and the highest total volumes (strata with the largest areas) ensured that theses important strata were included in the samples. However, the subjective selection of strata , stands within strata, and samples within stands has magnitude of the bias is not known and probably small, but samples were often subjectively located in stands to favour what was likely a higher than average conditions in terms of volume. Also the non-random sampling methods makes the interpretation of the calculated sampling errors difficult and inference based on traditional probability theory cannot be made in the usual sense.

History and Inventory Updates (1978-Present)

The most recent major period in the history of inventory sampling contains several significant changes. These were precipitated largely from a need for more detailed information about the forest resources. However, a major factor in the development of the inventory methods in this period was a change in philosophy in the Forest Service of what was needed from the inventory and how the information was to be used. There was a desire to provide estimate averages of groupings of similar forest types, thus could not provide estimates at the stand level. Consequently , a new sampling methodology was required to supply the information for the more stringent demands. This motivated significant changes in classification, sampling, data storage, compilation, and the method of estimating volumes for individual stands.

The Sub-Unit survey system developed and tested in 1977 was introduced in 1978. This sampling method was designed to provide more detailed estimates on much smaller areas. The sub-units were usually individual drainages as small as 5,000 ha. The sampling method was a multi-phase system using a linear cluster of 6 variable-radius plots and low-level aerial photographs. The sub-unit survey program was replaced with management unit surveys based on Timber Supply Areas (TSAs) in 1979 to reflect the new administrative boundaries.

The multi-phase sampling design used 70mm aerial photo plots as the first phase and ground based prism plots as the second phase. The intent was to define a relationship between estimated volumes of fixed-area plots from photo measurements and the actual volume measured from ground based variable-radius prism plots established in exactly the same place as the photo plots. This relationship could then be used to adjust a large number of other photo plots that could be taken less expensively. The multi-phase sampling methodology was the most statistically rigorous sampling design to date, but the system was difficult to implement and had many technical problems. There was also a lack of experience and expertise to operate the very sophisticated system at the Forest Region level where the cameras were based. Camera failures occurred frequently and were not detected until after the pictures were developed. Photo processing was done in Ontario which caused additional delays. Also it was very difficult to match the ground and photo plots. The multi-phase sampling system was unsuccessful because of a lack of funding and many practical problems. However, the opinion of those familiar with the process is that with modern technology and geographic conditions and the short-commings of previous attempts can be rectified.

A re-inventory program was initiated in 1998. However, this was really only a reclassification program because field sampling for volume was not undertaken. Other major changes in this period include converting the inventory data base to continuous variable instead of the formerly used classes. This was a significant change in the data base and allowed for the storage of actual values taken from samples and other measurements. Data previously collected and recorded as classes were either reinterpreted to a higher resolution or converted to class midpoints. The change to continuous variables was also accompanied by a change in the way in which volume were assigned to forest cover polygons. The formerly used Average Volume Line (AVL) approach where all stands in a given strata were assigned the average volume was replaced by predicting volumes for individual stands from a regression function using the polygon attributes expressed as continuous variables.

DISCUSSION OF HISTORICAL AND FUTURE TRENDS

Sampling designs used in forest inventories in British Columbia have changes from a mere compilation of available information or "*stock taking*" of timber to sophisticated multiphase sampling designs. Prior to 1951, the areas of interest were those under current exploitation or planned for development in the near future. Samples were not needed for inaccessible areas and those that did not have timber that was considered merchantable with technology of the day. Surveys reflected current utilization standards in species and size of trees. As a result, these inventories quickly became outdated as standards changed. Practitioners of the time realized that technology would change and allow utilization of currently non-merchantable timber, but priorities were on providing information for current management. Inventory sampling methodology has now changed to be more rigorous and covers the entire Province, involves much lower merchantability limits, and includes species that were formerly omitted. Despite differences of former inventories and advancements in sampling techniques that have paralleled advances in technology, there are several trends that emerge over the various periods of inventory that have profound affects on sampling designs. There are factors in large-scale inventories that are the same today as the turn of the century. Many of these factors will probably be the same in the next inventory. A review of historical trends and consideration of future possibilities may help to identify some areas that warrant special consideration.

Information Needs

Sampling systems are usually designed to provide only the type and resolution of information that is needed about the population being surveyed. Sampling systems used in former inventories were designed to provide the information needed at the current time under the current limitations. This was especially true of the first inventories. Forests are dynamic systems, and thus it is often said that inventories are outdated the minute the information is published. This is true and probably cannot be avoided. However, a major factor leading to the apparent lack of longevity of these inventories to provide information for management was that they often were designed to provide information to a standard that was very quickly as the forest grew and changed, but became outdated much faster because of changing requirements for information. This was certainly the case in the early years with merchantability standards of size and species of trees.

Some examples of changing standards are that in early years, surveys were done on the coast to 24 inch diameter limits and excluded hemlock and balsam. This information soon became inadequate when markets and technology changed to allow the utilization of other species and smaller trees. Also lodgepole pine was considered a non-merchantable species for most of the Province until the 1950's and 1960's, much of the central interior was classified as pine-scrub and led to thoughts that available mechantable timber volumes would soon be depleted. Deciduous species were considered non-merchantable until recently and were not intensively sampled in the last inventory between 1961 and 1977. In the previous inventories it was recognized that more of the resource would be merchantable as markets and technology changed, but sampling was usually designed to meet immediate needs only. It is likely that in many cases these anticipated changes occurred much faster than anticipated.

From a sampling perspective, these changes in utilization standards are simply changes in the type of information needed from the sample. Sampling systems were designed at the time to provide the needed information. Statistical reliability was not needed in the early part of the century because cut control and availability of timber was not a major consideration and survey methods were designed accordingly. Some changes in information needs are brought about by changes in technology to utilize different types and sizes of wood and the ability to sample and process data. However, others are brought about by changes in the public need for information about the forest. Future inventories must not only consider present and future utilization of timber, but also the need for information about the many other components of the forest. This type of information has not played a large role in the design of former inventories but will surely be a major component of future information needs. This will surely affect the sampling designs of future inventories.

Presently more detailed information is needed from the forest than ever before and from a myriad of forest resources other then timber. From the timber perspective, more detailed information is needed than has been collected in the past including information at the individual tree level. The current information needs are not only for an inventory in the traditional sense of what is out there, but also needed is information about the forest, trees, and ecosystems that will allow the detailed modeling of tree and stand growth and yield. Furthermore, the method in which growth and yield is modeled dictates the type of information that is needed. An example of the type of information that will probably be needed is spatial and temporal distributions of trees, information on crown characteristics, and information about the ecological characteristics of the forest. Information requirements will become more demanding as modeling techniques become more sophisticated.

Use of Information

Another trend that is apparent from previous inventories is that the information has been used, without exception, for purposes other than which the sampling plan was designed to provide. This has lead to dissatisfaction with previous inventories because the information was expected to provide answers that were not considered when the sampling system was designed or the questions had not been asked. For example, strata averages from the 1951-1957 inventory were sometimes used to estimate volumes of individual timer sales. It was not the objective of the inventory to estimate the volumes of individual stands, but the inventory information was used for this purpose and it created a perception that it did not adequately represent the forest. The likelihood of using information from the next inventory for purposes other than it is designed is almost assured. The challenge is to provide a sampling design that provides information for current as well as future information needs. Of course there is a trade-off between utilizing finite resources to obtain currently needed information against future information needs. It is impossible to know exactly what information will be required of the next inventory into the future. However, trends in timber utilization, public opinion and use of the forest, and forest management can be used to help identify the type of information that might be needed in the future.

Statistical Requirements

Despite attempts of former inventories to adhere to the statistical principles of sampling, it was not possible. Practical, logistical, administrative, and budgetary limitations were always over-riding factors. There were not enough resources to sample all strata and access was limited. Random location of samples in stands was achieved in some cases, but subjective location was favored because of simplicity. The result is the inventories may have been more efficient in providing more information with finite financial resources than a strict random sampling procedure, but this deviation from statistical principles has probably introduced a bias (probably small but of unknown magnitude). Furthermore, interpretation of the sampling error and confidence intervals cannot be made from probability theory in the usual sense.

Implementation of forest inventory sampling based on strict random requirements is very difficult. The amount of additional confidence in the estimate in terms of unbiasedness may not be worth the large additional expense required to achieve the randomness. This was the finding of the practitioners who attempted to establish completely random samples in the 1961-77 inventory. However, it is highly desirable to have unbiased estimates unless the amount of bias is known to be small. Other sampling systems can be combined with random sampling to increase efficiency. Multi-phase and multi-stage designs combined with selecting units with probability proportional to size (PPS) and systematic sampling can greatly increase sampling efficiency. Multi-phase and multi-stage designs combined with selecting units with probability proportional to size (PPS) and systematic sampling can greatly increase sampling efficiency and reduce the amount of randomness needed at the ground level.

Technological Advancement

Technology has also been a major factor in the design of forest inventory sampling systems. Initially the ability to sample the forest was very limited by ground and air access. The advancement of aerial photography has probably been the most significant technological development aiding forest inventory. The sampling system used in all the inventories after 1950 have been made possible by the ability to identify and map homogenous portions of the forest from aerial photos. Now high, medium, and low-level photography are all used to some extent in forest inventory sampling.

Another major technological advancement that has affected forest inventory sampling designs is the ability to store and manipulate virtually unlimited amounts of data with computers. The class-based inventories prior to 1977 were the result of the inability to annually deal with large amount of data expressed as continuous variables Now the difference in the amount of computer memory needed to store a class variable as opposed to a continuous variable is not important. The cost of mass storage of data is now so inexpensive that it is of little concern.

Technological advances of the future will undoubtedly have an equally or even more profound affect on the forest inventory sampling designs. The ability to manipulate and store data has far exceeded our ability to collect the data. The next major development in technology affecting forest inventory will probably be made in use of digital image analysis of aerially captured data. This will affect sampling designs in that large amounts of data will be captured quickly and easily at relatively low cost. These data can then be combined with relatively few very intensive sample points in a multi-phase sampling design similar in concept to that developed using 70mm photography. This type of data capture and analysis could also be used to sample for other types of attributes that have not traditionally been measured in forest inventories such as the spatial distribution of trees.

Also measurement techniques for ground sampling have changed little since the first inventory in the province. The enhanced ability to collect large amounts of precise data from ground measurements of trees will surely affect sampling designs. For example, upper stem diameters are almost never collected except under research conditions. The number of trees measured at a given plot is a function of the amount of time taken and the amount of information obtained. As with aerial technology, the next major advancement in ground sampling will probably be in digital image analysis of data captured at the plot level. Also the use in which information is collected at the plot and higher levels. These technological advancements will surely require changes in the sampling designs used to obtain the information.

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Appendix I - Some Important Characteristics of Major Inventory Periods in British Columbia.

Period	Objective	Sampling Design	Strata Definition
1910	Quantity forest resources in B.C.	No sampling. Compilation of existing information. Much guessing.	NA
1911-18	Estimate available merchantable timber supply in the Province	No Sampling. Compilation of available information. Took three years to compile information.	Province divided into 66 drainage basins
1919-37	New Inventory in 1927 to more accurately reflect the current state of the of forests and new merchantability standards	Some Area's surveyed, but there was a compilation of surveys, cruises, and other available information	Estimates given for the new 5 Forest Districts (somewhat similar to current Forest Regions) by drainage basin.
1938-50	Maintenance surveys only. Update function. No new inventory	Strip cruises.	NA
1951-57	The first complete inventory of the Province. Objective to estimate total volume for strata	Intent was modified stratified random sampling at the FIZ subzone level (not current FIZ)	Summary Types (groups of related forest types) by age, height, and stoking class.
1958-60	Maintenance surveys for the enhancement of classification	As above	As above
1961-77	Unit Survey's. Second complete inventory of B.C. Objective to estimate total volume by strata for aggregate forest types in each PSYU.	Intent was modified stratified random sampling at the PSYU level.	The 42 inventory type groups by age, height, and stoking class.
1978	Sub-Unit surveys. Objective to estimate detailed stand characteristics for smaller land units (usually for individual drainages)	Multi-phase stratified random sampling using 70mm low level photography and ground samples	Individual stands for sampling. Aggregated forest types for compilation and precision control.
1979-81	Re-inventory and update functions decentralized to Regions	As above.	As above
1982-87	History update program for major depletions from harvesting, fire, insects	NA	NA
1988-91	Re-inventory Program. Objective to re-classify TSAs on a 10 year cycle.	NA	NA

Precision Objectives	No. and Type of Plots	Location of Plots
NA	None	NA
NA	None	NA
NA	27 000 km of strips and 4 800 km of aerial photo strips. Reconnaissance surveys done were not available	Systematically located strips.
+/- 10 % of merchantable volume/acre	Strip cruises	Systematic strips at intervals of 1/2-one mile and 1/2-one chain in width.
+/- 10 % of total volume for: species by Province; major species by zone; and all species by subzones.	7 057 clusters of 4 fixed-radius sample plots	Subjective location in representative areas of stands. Random location of plots attempted but considered infeasible.
NA	2 824 clusters of 4 fixed-radius sample plots.	Subjective location in representative areas of stands
+/- 10 % of total volume for each PSYU	37 963 clusters of 2 fixed-radius sample plots.	Subjective location in representative areas of stands. Random location of plots attempted but considered infeasible
+/- 10 % of total volume for aggregated forest types	612 6-prism plot sample clusters. Phase 1:4-8 fixed area photo plots along a strip. Phase 2: 6 prism plot sample clusters	Phase 1: random strip in stand. Phase 2: plots selected randomly or in a restricted random manner to represent full range of variation
As above	1502 6-prism plots sample clusters	As Above
NA	278 6-prism plot sample clusters	None
NA	None	NA

Comments
First attempt at any inventory in B.C. (Fulton 1910)
Second attempt at an inventory (Whitford & Craig 1918) Much of the Province was unexplored. WW1 interrupted sampling
Third attempt at an inventory (Mulholland 1937). Depression of 1930's affected sampling. No new estimates for northern part of Province.
Sampling suspended in 1942 because of WWII
First complete inventory in Province took 7 years.
New aerial photos available at 1 : 15,840
Class-based inventory. About 77% of current data base from this period.
Concept developed and tested in 1977.
Program initiated but unsuccessful because of practical problems. Photo plots were used for classification
Field sampling ended in 1984. Monitoring from satellite imagery and silvicultural records
No file sampling (except for classification).

Appendix II - Point-Form of Summary of Significant Inventory Periods

1910: The First Compilation Inventory

- Fulton (1910) reported on his Royal Commission on Forestry on the general state of the forest industry
- This was the first attempt to quantify the forest resources in British Columbia.
- No sampling was done and very little information was available.
- Had information on some tenures but broad based estimates were from guessed averages per unit area multiplied by estimated total areas.
- A major difficulty in estimating timber volumes was in defining merchantability limits because "the standard of timber that can be profitably cut is being lowered every year" (Fulton 1910)
- No effort was made to estimate the volume of immature, non-commercial, not restocked forest land, or rate of growth.

1911-1918: The Second Compilation Inventory

- Increased awareness of natural resources resulting from activities in WWI.
- Recognized the need for an inventory of forest resources.
- Whitford and Craig (1918) reported on the Forest of British Columbia.
- This was the second attempt at an inventory in British Columbia but was only a compilation of other surveys.
- The objective was to secure an estimate of the available supply of merchantable timber in the

Province.

- No sampling was done.
- No air photos were available
- Took three years to compile report.
- Estimates of merchantable timber by species given for the 66 drainage basins covering the Province.
- Estimates based on available information from reports provided by the newly created B.C. Forest Branch (in 1912), timber owners, surveyors and others.
- Compilations were for minimum stump diameter of 10 inches (which was considerably below utilization standards of the time (Sloan 1945. P. 199)).
- At the time much of the area of the Province remained unexplored.
- At best only reconnaissance surveys had been done in undeveloped areas.
- Had problems defining what was merchantable timber and land, e.g., older cruises were designed to estimate only amount of timber that was economical to cut, and Balsam and Hemlock were omitted from cruises as well as timber less than 24 inches in diameter.

1919-1937:The Last Compilation Inventory

- The previous inventory was still a good source of information for many resources, but became increasing inadequate for timber.
- Required a new inventory to meet current demands of industry and for administration of the forest resources
- Forest Service began a new inventory in 1927.

- Mulholland (1937) reported on the Forest Resources of British Columbia.
- This was the third attempt at an inventory in British Columbia, but as with the 1918 inventory, was only a compilation of many other smaller surveys
- The objective of new inventory was to provide more detailed estimates and to give as accurate a description of forest conditions as possible from available information.
- Province divided into 5 administrative Forest Districts (what now fairly well resemble our Forest Regions).
- Preliminary estimates were completed and published in Forest Service annual reports for individual Districts between 1928 and 1935
- The Mulholland report presented a complete inventory for the Province including updates for the Vancouver and Prince Rupert Forest Districts

- Emphasis of inventory was on volumes of mature timber and some description of the growing stock for future estimates of growth.
- No volume estimated for immature stands or trees that were considered to be wasted in the logging of mature stands.
- Intent was to continuously update the inventory as required to reflect change.
- The inventory was made mostly during the depression years of the 1930's and the poor market conditions and low profits were reflected in its assessment of merchantability (Sloan 1956,

p.203)

- Surveys done for some areas and overall inventory was a compilation of all known cruises from private owners and the Forest Service.
- Field reconnaissance was done for areas not covered by surveys.
- Attempts were made to adjust different cruises to a common standard.
- Forest surveys covered 4,000,000 ha of productive forest, about 13% of the estimated total area in the Province capable of timber production.
- 27,000 km of surveys strips were done recording age, height, dbh, and volume.
- 4,800 km of aerial photos was stereoscopically plotted.
- Estimates of volume for the 27,000,000 ha "*unorganized northern territory*" were based on estimates from Whitford and Craig (1918) because at the time Mulholland (1937 p. 151) stated that " the forest resources of that bleak country are not of commercial importance and are entirely inaccessible at present".
- Maps showed volume per acre and percent species composition for mature stands, and composition, comparative density, and height of immature stands.
- Statistics were compiled from the summation of volume estimates from minor watersheds, blocks of timber, and individual surveyed lots and timber licenses.
- Published figures were by drainage basins and Forest District.

1938-1950: Maintenance Surveys

- Subsequent dissatisfaction of the maps created in the previous inventory for the unsurveyed areas were encountered because they were begin used for purposes other than for which they were designed (BCFS 1947).
- Maps were continually updated as new surveys of areas were completed.
- Sampling methods involved strip cruising at various widths and intervals, depending on the purpose of the specific survey.
- Strip intervals usually varied from one-half to one mile, and samples were from one-half to one chain wide and up to 20 chains in length.
- Precision of specific surveys continued until 1942 when operations were suspended because of WWII (Sloan 1956, p.203).
- The first Sloan (1945) report used the 1937 inventory with some amendments made from the surveys conducted in the intervening years.

1951-1957: The First Complete Provincial Inventory

- The first complete inventory began in 1951 after the creation of a new Forest Surveys and Inventory Division of the Forest Service.
- The inventory was funded through a Federal-Provincial agreement to collect information to a standard for inclusion in national statistics.
- Planning began in 1951 and sampling started in 1952.
- The inventory took seven years and was complete in 1957 (B.C. Dept. Lds. For. 1957).

- The second Sloan (1956) Commission report used the inventory published in the 1954 Annual Report. This was an interim report as field sampling was not yet complete.
- Malcolm (1957) described the sampling procedures for this inventory.

Classification

- Province divided into 7 inventory zones ranging from 1.6 to 16 million ha (not the current Forest Inventory Zones) and subzones of about 400,000 to 800,000 ha.
- Initially only old air force photos available, but new 20 and 40 chain photos were flown for the entire Province.
- Forest types delineated on photos from stereoscopic interpretation aided by ground and air observations.
- Forest types delineated by:
  1. Stand structure (e.g., mature, immature, etc)
  2. Species composition
  3. Age class (3 to 5 classes depending on structure)
  4. Height class (4 for mature timber)
  5. Stoking class (3 classes based on no./acre)
- Minimum forest type size was 16 ha and at the outset of the inventory was much larger.
- Classification and sampling procedures occurred simultaneously because did not have previously delineated photos.

Sampling Overview

- Intent was to use stratified random sampling at the FIZ subzone level, but was not achieved because of practical and logistical limitations.
- The resulting sampling design was termed "*modified stratified random sampling*".
- Strata were called Summary Types and were groups of one or more of the 11 related forest types (groupings of related species) recognized in classification falling within a wide range of species composition, age, height, and stocking.
- 264 possible Summary Type combination.
- Stated precision objectives were to estimate total volume to within +/0 10% (at 2 SE):
  1. By species in the Province as a whole.
  2. For major species in FIZ zones.
  3. Collectively for all species in FIZ subzones
- Number of samples required to meet stated precision requirements not calculated or controlled until late in the inventory.

- Sample plots were fixed-radius circular plots, with size ranging from 0.0004 to 0.2 ha depending on species composition, stoking, and age class.
- Samples were clusters of 4 plots for mature stands and 2 plots for immature stands.
- Attempts in the initial phases of the inventory to randomly locate samples (plot clusters) within stands using grid overlays on photos, however, this was soon replaced with subjective location of samples in "*representative*" areas of stands

- Average volume per acre was computed by species and forest type from the various sampling strata.
- Total volume was computed as the product of these averages multiplied by the areas computed for each areas from the forest cover maps.

1958-1960: Maintenance Surveys

- Maintenance surveys conducted for the enhancement of classification.
- Had some crews supplementing the sampling from the 1951-1957 inventory.
- Larger scale 1:15,840 photos allowed more refined classification.
- Sampling and classification were separate field functions.

1961-1977: The Second Complete Provincial Inventory (Unit Surveys)

- Initiated the second complete inventory (Unit Survey) of the Province.
- Objective was to estimate average volume by strata for groupings of related forest types for each sampling Unit (Public Sustained Yield Units -PSYUs).
- Volumes for individual stands were assigned the average of the stratum, known as the Average Volume Line (AVL) approach (as with the previous inventory).
- Most of the current volume data base (approx 77% of sample plot clusters) was collected in this period.
- Sampling and classification functions were combined.

Classification

- Air photos delineated by species, age, height, stocking, and site for productive forest land.
- Forest types (stands) classified into 42 Inventory Types Groups (ITG) by species for mature and the 17 Growth Types Groups for immature, and by 9 age classes, 8 height class, 4 stocking class, and 4 site classes.
- Samples were summarized during the field season to ensure that target types were actually sampled.

Sampling Overview

- Survey projects were undertaken separately for each Unit (PSYU) which ranged in size from 140,000 to 5,500,000 ha.
- Each PSYU was sampled in a single season and was not revisited until a re-inventory was scheduled, thus additional samples were not located in strata determined to be sparsely sampled after compilation of the data.
- Sampling design based on principles of stratified random sampling but were not achieved because of practical and logistical limitations.
- Resulting sampling design was termed "*modified stratified random sampling*".
- Strata were ITGs by age, height, stoking, and sometimes site class or disturbance class.
- Precision requirements were to estimate total volume of the PSYU to +/- 10% (at 2 SE).
- Ground sample information was collected as continuous variables but was recorded in the data

base only as classes.

- The resulting inventory was class-based.
- Data base only included: species to the nearest 10%; age in 20 year classes up to 140, then 141-250, and 250 and older; height in 30 foot (9 m) classes; and stocking into 5 broad classes.
- Original data for the exact measurements were kept only on the field sheets.

Sample Size Calculation and Allocation

- All stands in PSYUs were summarized by strata (ITG by age, height, and stoking class) from the previous inventory noting area, number of existing samples, and an estimate of the desired number of additional required samples.
- Strata were subjectively selected from each ITG to favour older age classes with proportionately large areas.
- Strata were selected such that their area would comprise about 80% for the ITG.
- Initial sampling plan developed from estimated total number of samples needed in the Unit (PSYU)
- Initially estimated as a rule of thumb that about 16 samples per major stratum were needed to achieve the desired precision of +/- 10% at 2 SE
- After 1963, the estimated number of samples needed for a given grouping of types of a major species was determined from experiences in similar PSYUs.
- The actual number of samples was limited by the annual budget.
- Sample compilation occurred at the end of season, thus desired control over sampling size and precision was not closely controlled.
- A tally of the number of samples established in each stratum was made during the field season to help guard against over-sampling. However, some projects contained from 2 up to 100 samples in the major types (Hegyi 1990).

Sample Location

- Stands were chosen for sampling to ensure geographic distribution throughout the PSYU, and to avoid areas where previous sampling had occurred.
- Access and terrain were also major considerations and most stands were selected to facilitate access.
- Samples were changed to a cluster of 2 fixed-area plots of varying size that roughly equalled the total area of the 4-plot clusters used in the previous inventory.
- Some samples were randomly located in the subjectively chosen strata and stands by selection of random coordinates from a transparent grid overlay on photos.
- However, many other samples were subjectively located directly from aerial photos to be representative of the stand
- Subjectively located plots were often established close to roads, rivers, lakes, and on lower slope positions.
- Attempts were made at using truly randomly located plots and a rigorous stratified random sampling design adhering to statistical principles, however, this doubled and tripled the time required to establish samples and was abandoned for the subjective location of samples.

Theoretical Comments on the Sampling Design

- Sampling design based on statistical principles, but deviations from theoretical statistical assumptions were necessary because of administrative, practical, logistical, and budgetary limitations.
- The intended stratified random sampling design deviated from theoretical statistical principles in that:
  1. Not all strata were sampled and those chosen were not always chosen at random.
  2. Selection of stands within strata was not always random.
  3. Selection of sample plot locations within stands was not always random.
  4. Plot sizes were changed depending on stand conditions.
  5. Samples were not allocated proportionately among strata and estimates were not weighted appropriately for the unequal sample size and unequal area.
- Deviations from the theoretical statistical sampling assumptions probably had several affects:
  1. Generally, this may have resulted in a more efficient survey for estimating total volume of the PSYUs in that sampling was concentrated in the large and higher volume types.
  2. Estimates of average volumes were probably biased based because:
     - Some strata were not considered for sampling in the subjective selection.
     - Some stands were not considered for sampling in the subjective selection.
     - Samples (plot clusters) were not always randomly located in stands and in some cases may have been located in such a manner as to favour higher productivity areas such as lower slopes and areas of better than average stocking.
     - Samples were not weighted by the area from which they were taken.
     - Plots of varying sizes were weighted equally in the estimates.

- Sampling concentrated on the older stands thus only poor representation from younger age classes (some units had very little immature, especially on the coast), however, more emphasis was put on immature after 1973.
- Deciduous forest types and much lodgepole pine was considered to be non-commercial at the beginning of the survey and was poorly sampled (Forest Resources Commission 1990)

1978: Sub-Unit Surveys

- Sub-unit Survey methodology replaced the class-based Unit surveys and was used only in 1978.
- This was in response to the need for more detailed estimates including stand level parameters at the sub-unit level (individual drainages as small as 5,000 ha).
- This change to Sub-unit Surveys was also accompanied by major changes in classification, sampling, volume calculation, and the way that inventory data were collected and stored in the data base.
- The class-based system was replaced with a system that recorded the classification attributes as continuous variables in the data base.
- Volume calculation was changed from the AVL method to a regression approach where the

predictor variables were the classification parameters expressed in continuous units.

- Sampling methedology changed to a multi-phase design.
- The first phase was low-level 70 mm air photo fixed-area plots and the second phase was variable-radius ground plots for double sampling (Hegyi 1985, 1990).
- The intent was to define relationships between photo plots and ground plots to adjust other photo measurements where ground plots were not established.
- Sample plots were changed from the previously used cluster of 2 fixed-area plots to a linear cluster of 6 variable-radius (prism) plots to facilitate the new sampling methodology.
- Only cursory testing of the new sampling method.
- The multi-phase sampling design was not successful because of poor funding and many practical problems.

1979-1981: Inventory Update

- In 1979 the Forest Service reorganized, decentralized many function to the regions, and created the new management units called Timber Supply Areas (TSAs).
- Sub-unit Survey system replaced by a Management Unit (TSA) type of inventory implemented using the sub-unit classification and survey methodology.
- 70 mm photo booms developed earlier were sent to each Region.
- Intent was to provide capability for re-inventory and updating in each Region.
- Program was not successful because the practical aspects of the sampling methodology were not perfected, and operation of the camera booms required a high level expertise and training that was not available in the Regions.
- First and second phase samples were established using the multi-phase sampling system but relationships between photo volume and plot volumes were never successfully established for assigning stand volumes on an operational basis.
- The 70 mm photographs were used mainly for classification purposes.

1982-1987: History Update

- Funding constraints reduced the inventory program to a maintenance mode but facilitated conversion and placement of data base to digital format and re-compililation of existing data to new Timber Supply Area (TSA) management units.
- No major operational field sampling was undertaken.
- A program was introduced to monitor depletions such as harvesting, insects damage, and fires. This was done through silvicultural records and high level satellite imagery.

1988-1991: Re-inventory Program (Re-classification only)

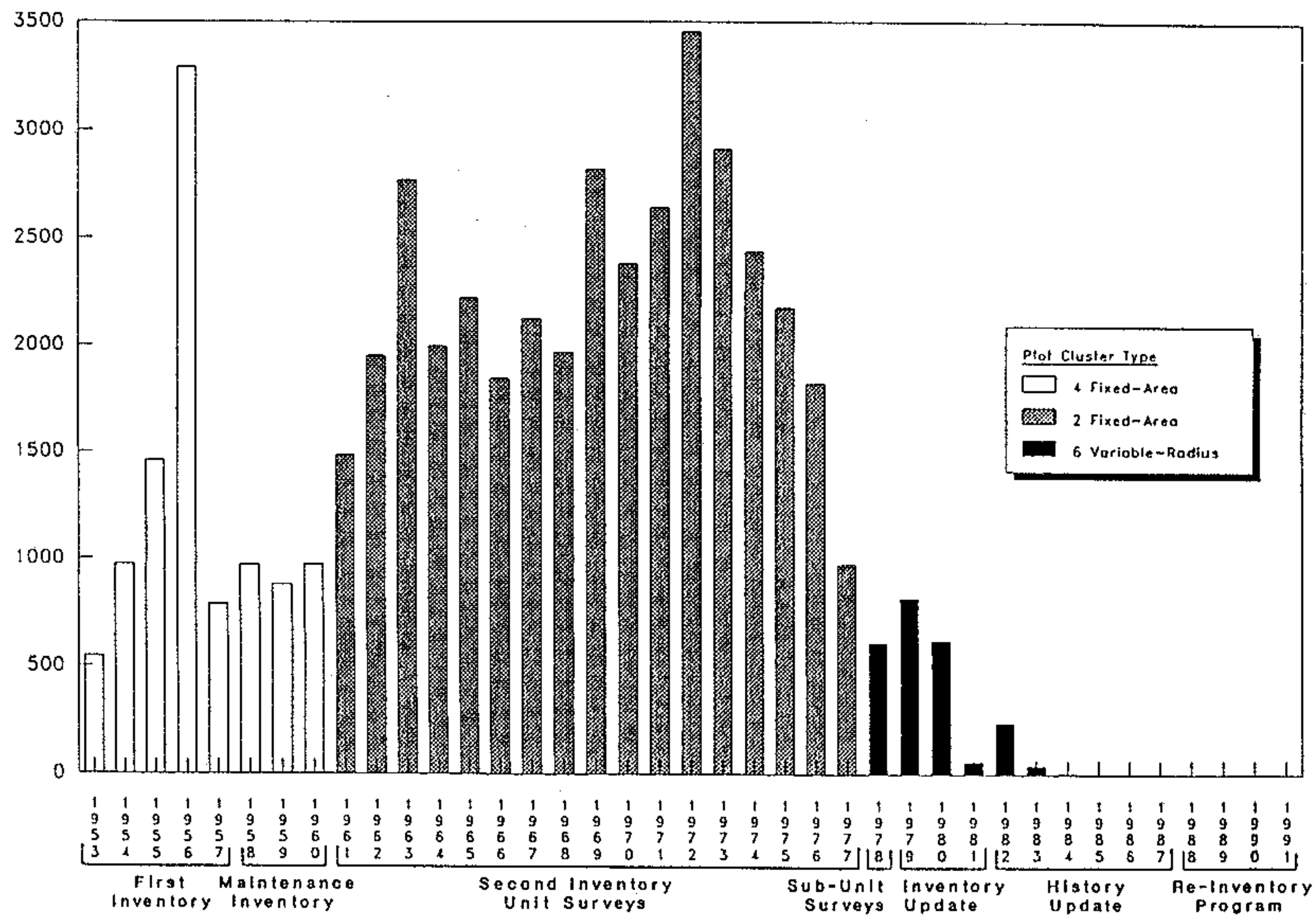
- In 1988, a program introduced to re-inventory TSAs on a 10 year cycle.
- Funding increased to complete conversion of forest cover maps to digital format, to begin inventory of management units (TSAs), and to improve the image analysis system used in the inventory update program (Ministry of Forests 1991).

- This initiative was not a re-inventory in the usual sense in that only re-classification of new photos was undertaken with supporting air and ground calls.
- No field sampling undertaken.
- Volumes assigned to polygons from prediction equations (VDYP) developed primarily from samples collected between 1961 and 1977.

1991-Present (from Ministry of Forests 1991)

- A major increase in funding through the Forest Renewal Program (FRP) covering a five year period provided for Timber resource inventory, inventory update, forest resource geographic information systems, statistical analysis and summaries, growth and yield, and remote sensing.
- FRP funding is tied to specific inventory program goals, with little being allocated to improving current inventory systems.
- FRP funding enabling hiring of additional staff, completion of the second growth inventory; improvement of accuracy of the inventory through the installation of additional ground samples of growth and yield; possibly of integrating cruising data into the inventory; and update of all active forest cover maps on a 2 year cycle, and inactive maps on a 5 year cycle.

APPENDIX III - Number of Sample Plots by Year of Establishment



Source: Personal communication from Jack McLellan, January 1992.