METRIC CONVERSION IN CANADA

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A poor man once asked a sage, "Why am I in such need?" The sage broke off a willow twig and cut notches on it at equal intervals. Then he gave it to the poor man, saying, "I give thee this sceptre of success - a stick for measuring. Remember, all things are made to measure - sandals for thy feet, the sheath for thy sword. Drive the stick straight into the ground and according to its shadow, which follows the sun, thou shalt measure time and arrange thy life. In the spring, when the shadow shortens, sow thy grain; in autumn when it lengthens, gather in thy crops. Measure thy share and thy neighbour's share; do it honestly and thou shalt fare well."

- anon

INTRODUCTION

The origin of the metric system of measurement can be traced to Gabriel Mouton, the vicar of St. Paul's Church in Lyon, France, who, in 1670 proposed a decimal system of weights and measures. The concept was revived in 1790, was approved by Louis XVI and, despite the French Revolution, final standards for the metre and the kilogram were completed in 1799. The metric system gained acceptance throughout the 1800s and was made legal in the United States in 1866 by an Act of Congress and in Canada in 1873 by the Weights and Measures Act.

In 1875 the Treaty of the Metre was signed by 17 nations including the United States establishing, among other things, a General Conference of Weights and Measures (CGPM) to deliberate on international weights and measures. (Canada signed the Treaty in 1907 - most countries are now signatories including all major nations and 95% of the world's population). In 1960, *Le Système International d'Unites* (abbreviated internationally as SI) was established as a practical and logical system of units.

This paper will describe the SI briefly, discuss the Canadian conversion program and outline activities in the Water Resources Branch.

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SI UNITS

SI units are divided into three categories namely, base units, supplementary units and derived units. The selection of base units is somewhat arbitrary, the main criterion being that other units in the system can be derived from base units by multiplication or division with unity as the only factor. Such a system is know as a "coherent" system. For example, the unit of area is obtained when unit length is multiplied by unit length. The SI base units are shown in Table 1.

Table 1

SI BASE UNITS

Quantity	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

The CGPM recognizes two units as supplementary units. These are the measure of plane angles namely the radian (symbol rad) and the measure of solid angles namely the steradian (sr). The radian and steradian may be used as base units or as derived units.

By using the seven base units and two supplementary units, it is possible to obtain a number of derived units. For example, the SI unit of density is kilogram per cubic metre (kg/m^3) and that for angular velocity is radian per second (rad/s). Some derived units have been given special names and symbols. These are shown in Table 2.

TABLE 2

SI DERIVED UNITS WITH SPECIAL NAMES

Quantity	SI UNIT Name	SI UNIT Symbol	Expressed in Terms of Other SI Units	Expressed Terms of Base and Supplementary Units
frequency	hertz	Hz	s^{-1}	s^{-1}
force	newton	N	$m \cdot kg/s^2$	$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
quantity of electricity, electric charge	coulomb	C	$s \cdot A$	$s \cdot A$
electric potential, potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm		V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	$V \cdot s$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
luminous flux	lumen	lm	$cd \cdot sr$	$cd \cdot sr$
illuminance	lux	lx	lm/m^2	$m^{-2} \cdot cd \cdot sr$
activity of radionuclides	becquerel	Bq	s^{-1}	s^{-1}
absorbed dose of ionizing radiation	gray	Gy	J/kg	$m^2 \cdot s^{-2}$

There are some units that are in widespread use that, while not SI units, are retained because of their importance or because of their specialized use. The units used to measure time (years, days, hours and minutes) and temperatures (^{o}C) are examples of the first category while astronomical distances (astronomical units and parsecs) are examples of the latter.

IMPLEMENTATION OF SI UNITS IN CANADA

Although the metric system has been legal in Canada since 1873, Canada like most english speaking countries, did not take major steps towards adopting the system until relatively recently. In 1970, the Canadian Parliament endorsed a White Paper on Metric Conversion. One key phrase in the White Paper stated, "If the inevitability of eventual change is accepted, then the need to begin the process of change as soon as possible is obvious." As a result the Metric Commission was established in June, 1971.

The aims of the Commission are to develop an overall metric conversion plan for Canada, to help each economic sector to make its own conversion plans, to monitor progress towards conversion and to, disseminate information concerning conversion. The Commission has no power to force conversion but can only persuade. Unlike some nations, Canada has not made use of yard-pound units illegal. It is hoped that conversion will be largely completed by 1980.

A series of 10 Steering Committees and about 60 Sector Committees were set up in order to co-ordinate conversion in various sectors. Each Steering Committee draws its membership from the appropriate national associations, manufacturers, businesses and so on. In the federal government, the Inter-departmental Committee for Metric Conversion acts as a Steering Committee.

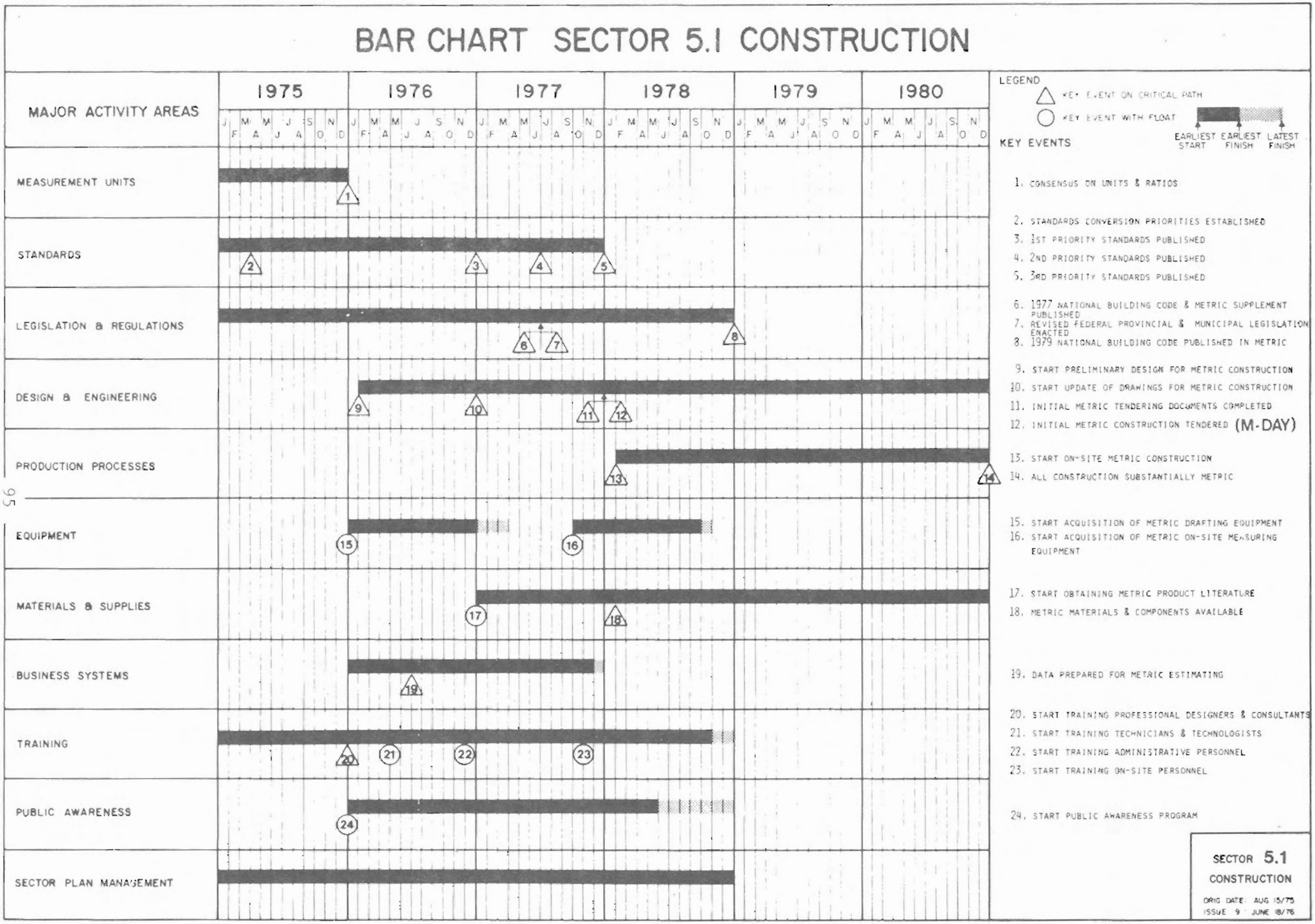
A listing of the various committees is as follows:

Steering Committee	Sector Committees
No. 1	Transportation, Communications, Electric Power
No. 2	Iron and Steel Mills, Metal Fabricating, Machinery, Shipbuilding, Boatbuilding, Motor Vehicle, Truck, Trailer and Motor Vehicle Parts Industries
No. 3	Electrical, Electronics, Aircraft and Aircraft Parts Manufacturers
No. 4	Mining and Metallurgy, Non-Ferrous Metals, Non-metallic Minerals, Oil, Natural Gas, Chemicals, Rubber and Plastics Products Industries
No. 5	Construction, Engineers, Architects, Surveyors, Real Estate
No. 6	Food, Beverages, Tobacco, Packaging, Agriculture, Grain Handling, Fishing, Trade (Grocery).
No. 7	Textiles, Clothing, Leather Industries, Trade (Hard and Soft Goods) and Miscellaneous Manufacturing Industries.
No. 8	Forestry, Wood, Furniture, Paper and Allied Manufacturing, Printing and Publishing
No. 9	Consumers, Services, Labour Organizations
No. 10	Information, Education, Training
ICMC	Federal Government Departments

These committees are responsible for preparation of conversion plans, monitoring progress and co-ordinating with related programs. Generally the preparation of a plan for a given sector of the economy follows an Investigation phase, a Planning phase, a Scheduling phase and an Implementation phase. As part of the plan, it may be necessary to develop new standards for an activity. Also, it may be necessary to have legislation passed to permit the use of metric units in an industry.

The end result of this work is a sector plan that is approved by members of the appropriate industrial association. These plans may be summarized in the form of a chart; a typical one for sector 5.1 - construction is shown in Figure 1. At the end of December, 1976, 24 such sector plans had been approved.

FIGURE I


BAR CHART SECTOR 5.1 CONSTRUCTION
MAJOR ACTIVITY AREAS
1975
1976
1977
1978
1979
1980
J F M A M J J A S O N D
MEASUREMENT UNITS
STANDARDS
LEGISLATION & REGULATIONS
DESIGN & ENGINEERING
PRODUCTION PROCESSES
EQUIPMENT
MATERIALS & SUPPLIES
BUSINESS SYSTEMS
TRAINING
PUBLIC AWARENESS
SECTOR PLAN MANAGEMENT
LEGEND
KEY EVENT ON CRITICAL PATH
KEY EVENT WITH FLOAT
EARLIEST START
EARLIEST FINISH
LATEST FINISH
KEY EVENTS
1. CONSENSUS ON UNITS & RATIOS
2. STANDARDS CONVERSION PRIORITIES ESTABLISHED
3. 1ST PRIORITY STANDARDS PUBLISHED
4. 2ND PRIORITY STANDARDS PUBLISHED
5. 3RD PRIORITY STANDARDS PUBLISHED
6. 1977 NATIONAL BUILDING CODE & METRIC SUPPLEMENT PUBLISHED
7. REVISED FEDERAL PROVINCIAL & MUNICIPAL LEGISLATION ENACTED
8. 1979 NATIONAL BUILDING CODE PUBLISHED IN METRIC
9. START PRELIMINARY DESIGN FOR METRIC CONSTRUCTION
10. START UPDATE OF DRAWINGS FOR METRIC CONSTRUCTION
11. INITIAL METRIC TENDERING DOCUMENTS COMPLETED
12. INITIAL METRIC CONSTRUCTION TENDERED (M-DAY)
13. START ON-SITE METRIC CONSTRUCTION
14. ALL CONSTRUCTION SUBSTANTIALLY METRIC
15. START ACQUISITION OF METRIC DRAFTING EQUIPMENT
16. START ACQUISITION OF METRIC ON-SITE MEASURING EQUIPMENT
17. START OBTAINING METRIC PRODUCT LITERATURE
18. METRIC MATERIALS & COMPONENTS AVAILABLE
19. DATA PREPARED FOR METRIC ESTIMATING
20. START TRAINING PROFESSIONAL DESIGNERS & CONSULTANTS
21. START TRAINING TECHNICIANS & TECHNOLOGISTS
22. START TRAINING ADMINISTRATIVE PERSONNEL
23. START TRAINING ON-SITE PERSONNEL
24. START PUBLIC AWARENESS PROGRAM
SECTOR 5.1
CONSTRUCTION
ORIG DATE: AUG 15/75
ISSUE 9 JUNE 18/76

While much of the metric conversion activity has taken place behind the scenes, the Canadian public seems to have accepted the changes fairly well. However as the system impinges more and more on persons' daily lives, some resistance could be anticipated.

As part of the metric conversion process is the development of new standards, many opportunities exist for reducing the proliferation of sizes of various products. For example, in Australia, 11 sizes of door hinges have replaced 93 and now all screw holes are in the same location. An American study has shown that fresh fruits and vegetables could be packed in four basic metric cartons. These cartons can be adapted to modular pallets thus reducing handling and warehousing costs.

The Canadian government has adopted the philosophy that metric conversion costs should stay where they are incurred. That is, there will be no grants to industries or individuals for metric conversion. This factor generally will mean that industries must incur a large initial expense that in most cases will be made up over a period of years by greater operating efficiency, for example, in larger production runs.

Large companies can absorb the initial conversion cost however small business will have problems. Also, in many trades it is customary for workers to own their own tools thus presenting a problem. In order to resolve some of these situations, some Steering Committees have set up working groups such as ones on "employees privately-owned tools" and "scales in the retail food industry".

METRIC CONVERSION IN THE WATER RESOURCES BRANCH

The Water Resources Branch of the Department of Fisheries and the Environment consists of four divisions: a Hydrology Research Division which conducts ground water research, a Glaciology Division which conducts glacier research, a Water Survey of Canada Division which gathers streamflow data from some 2400 sites and an Applied Hydrology Division, essentially the headquarters arm of the Water Survey, which establishes standards and conducts experimental work.

The principal task of metric conversion of the Branch became that of converting Water Survey activities because of the large numbers of sites involved and the number of capital items. Also many activities of the two research divisions were already conducted in metric units although some changes were required to conform to SI practises. Some glacier surveys had been carried out in SI units since 1968. Serious consideration of the overall conversion program began in 1973.

There is probably no "best" time to start a conversion program. If an agency is among the first to convert there are some false starts while other fields of influence work out their standards. For example, the lengthy delay in deciding whether or not Canada would use international (series A) paper sizes held up decisions concerning Water Resources Branch metric forms. However, authorities claim that each year adds about 8% to the total cost of eventually converting to metric.

During the investigation phase several basic principles were followed, namely:

1. Dual units would not be used. Authorities say that dual units are a crutch that prevents persons from "thinking metric".

2. "Hard conversions" would be used whenever feasible rather than "soft conversions". This would save the trouble of having to make another conversion at some future date.

3. Accuracy standards would remain the same whenever feasible. A change in measuring systems should not imply a change in accuracy.

4. SI units and practises would be used whenever feasible. Here again this would save changing to SI units at some future date.

5. Existing Canadian Standards Association (CSA) and International Organization for Standardization (ISO) standards would be used whenever possible. This would save "reinventing the wheel".

6. European practises and those of nations that have recently "gone metric" would be examined to see how relevant they were to the Canadian situation. Here again the object was to avoid reinventing the wheel and to avoid awkward metric practices evolved over long periods.

Eventually a set of standards for conduct of Water Survey work evolved as personnel learned more about SI and exchanged information and comments. These are summarized in the Appendix; some examples of the decision making process are:

1. Although most metric countries observe water levels to 0.1 m, it was felt that this would be too radical a departure from the existing Water Survey standard of 0.01 ft. A precision of 0.002 m was selected although, for ease of computations by computer a resolution of 0.001 will be used in publications.

2. It was decided that all discharges would be expressed in cubic metres per second (m^3/s) to 3 significant figures but no more than 3 decimal places. Since 0.001 m^3/s is more than 0.01 ft^3/s there will be some lost precision at extremely low flows. The only alternative was to use litres per second (ℓ/s) for low flows but this was considered as unweildly and potentially confusing. Also the litre is not an SI unit.

3. It was decided that recorder time scales should be changed from 0.1 in/hr. to 2.5 mm/hr. The former scale is actually 2.54 mm/hr. and since hard conversion was feasible, a scale of 2.5 mm/hr. was adopted.

4. One departure from SI practise that was adopted was the use of the cubic decametre (dam^3) as a replacement for an acre-foot. The SI units of cubic metres or cubic kilometres resulted either in large numbers of zeros or numerous decimal places for many stations.

5. It was found that metric stock of many materials was not available or, as in the case of fasteners, no decisions had been made as to the system that would be used in Canada. Therefore equipment conversions proceeded on the basis of making the equipment function in metric, perhaps changing non-critical dimensions to even metres or fractions of metres, but using non-metric materials.

During this decision making process personnel from the USGS, Water Resources Division and other US agencies were consulted to ensure that Canadian and US metric practises would be in agreement as much as possible. Provincial water resources agencies were also consulted.

The investigation and planning phases were complete in 1975 and a schedule for conversion was developed. According to this schedule, the conversion of Water Resources Branch activities would have been complete by the end of 1977. Unfortunately, at this time, the Department's proposal for additional funds for conversion was turned down and agencies were advised to convert to metric using their normal budget allocations.

This led to a number of decisions. First it was decided to continue the metric conversion program since some momentum had been built up. Also all new field equipment would be purchased whenever possible in metric units and computer programs would be developed for processing metric streamflow data. Data, however, would not be published in metric as, before this is done, all past data (about 52 000 station-years) should be converted to metric. The $400 000 cost of doing this is prohibitive unless new funding is provided.

At the present time fewer than 5% of the Water Survey's 2400 gauging stations are operated in metric. Some minor problems have occurred but generally it can be said that personnel have adapted to the system well and that the cost of converting a gauging station has been a little lower than anticipated. It has been noticed that, the first year that the streamflow data for a given site has been worked up, the computations generally take much longer. This is because part of the year's record is in yard-pound units and the other part is in SI units. Also all station documentation must be changed to the new system.

It is expected that conversion in the Water Resources Branch will be completed in the early 1980s, but it will be many years before all equipment is constructed in SI units as many items of Water Survey equipment and instrumentation have life expectancies of 20 to 30 years. Major benefits of the Water Survey's conversion program have not been identified although design calculations for gauging structures are noticeably easier in SI units. Perhaps in a few years a more definitive statement can be made. There would be decided disadvantages eventually in not changing as all commercial and manufacturing sectors are changing.

CONCLUSIONS

The metric system of units, in particular SI units, provides a logical, coherent system for performing measurements. Use of the system has spread throughout the world until now only a few non-metric countries remain.

Canada has made a commitment to be largely converted by 1980 Plans for conversion in each sector of the Canadian economy have been or are being formulated. Conversion in some areas such as hospitals and consumer products is well advanced.

The Water Resources Branch of the Department of Fisheries and the Environment has also developed a plan for conversion. The work of the Branch should be conducted in SI units in the early 1980s if present progress continues. No major technical problems have arisen but, at the same time, no striking benefits have been identified.

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DECISIONS CONCERNING METRIC CONVERSION IN THE WATER RESOURCES BRANCH, ENVIRONMENT CANADA

General: The following standards are for the normal case. Deviations are expected for unusual circumstances. For example, gauge heights may be observed to 0.001 m at accurate weirs or increments of stream widths may be smaller than 0.1 m on very small streams.

(1)	Water discharges	- Cubic metres per second Three significant figures but not more than three decimal places
(2)	Water levels	- Observations: 0.002 m Publications and computations: 0.001 m
(3)	Water depths	- 0.01 m. May change with varying conditions
(4)	Water temperatures	- Observations: 0.5°C Some observations and conversion of past data will be to 0.1°C
(5)	Water velocities	- Metres per second Three significant figures but not more than three decimal places
(6)	Stream widths	- A sliding scale so as to have a minimum of 20 observation positions but not closer than 0.1 m. Cableway markings should be in increments of 1 m, 2 m, 5 m, 10 m and 20 m with an unambiguous marking code to designate 10-metre marks and 100-metre marks, etc. The increment should be painted on the A frame cable support.
(7)	Level rod readings	- Have suggested 0.002 m in order to be the same as observation of water levels and divisions on the staff gauge. May eventually use 0.001 m. Either figure requires an interpolation of the 0.01 m divisions on standard survey level rods.
(8)	Conversion equations	- Five significant figures (Using four figures to convert as compared to five figures causes differences in the answers when rounded to three significant figures)

cfs x 0.028317 = m^3/s
feet x 0.30480 = m
mile x 1.6093 = km
square mile x 2.5900 = km^2
acre-feet x 1.2335 = dam^3

(9) Recorder chart scales

(a) rectilinear grid:

gauge height;	1:5	standard
	1:10	optional
	1:1	optional (weirs and flumes)
time;	60 mm/day (2.50 mm/hr)	standard
	30 120 180 240	optional (where warranted)

(b) curvilinear grid (equal increments along arc):

gauge height;	0 - 3 m range 0 - 6 m range	25 cm wide paper

time scale same as for rectilinear

(10) Computation procedures - Sequence and rules of rounding same as at present (see manuals)

(11) Snow depths - 0.01 m (rain will be reported in millimetres)

(12) Snow water equivalent - 0.001 m

(13) Sediment concentration - mg/ℓ or g/m^3 (The values would be identical)

(14) Sediment load - Tonnes (1000 kg) per day

(15) Sample volume (of water plus sediment) - cm^3

(16) Drainage areas - Square kilometres
Three significant figures but not more than two decimal places

(17) Volume of water - Cubic decametres
Three significant figures but not more than two decimal places

(18) Notation - In published tables of data use neither commas nor blanks to separate the thousands e.g. 12450 not 12,450 or 12 450
Symbols for computer use will be of the form M3/S (for cubic metres per second) and DAM3 (for cubic decametres) etc. as described in ISO Standard 2955. Symbols otherwise will be of the form m^3/s, dam^3 etc. as in the Canadian Metric Practice Guide