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ON-LINE (REAL TIME) HYDROLOGICAL FORECASTING SYSTEMS

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Note:

The sixth session of the Commission for Hydrology (Madrid, 1980) expressed its concern that many valuable reports prepared by its rapporteurs would not, for various reasons, be published in an established WMO series. While recognizing that WMO might not necessarily wish to endorse these reports since they frequently represented only preliminary drafts or working documents, the Commission nevertheless recommended that the reports be made available on request in their original language by means of simple photocopy or offset reproduction without extensive or even any editorial revision by the WMO Secretariat. The present report, falling into this category, is presented as indicated above.

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SUMMARY

This report contains a review of present status of automation of on-line /real-time/ hydrological forecasting systems in WMO Member countries, prepared according to the Resolution 10, Appendix, Part C, V Session of Comission for Hydrology, Ottawa, July 1976.

45 responses to the questionnaire on Operational Hydrological Forecasting were received from the WMO Members, of which 23 countries operate partially automated real-time forecasting systems. The development of a fully automated system is at present time /1979/ in experimental or pilot system stage in several countries, only a few fully automated flash flood warning systems are in operational stage.

The application of partially automated on-line systems to developing countries is considered as a feasible under certain conditions discussed in the reprot.

1. INTRODUCTION.

This report is prepared following the Resolution 10, Annex, Part C adopted by the V Session of Commision for Hydrology, /CHy-V/, WMO, Ottawa, 5-16 July 1978.

According to the terms of reference, the Rapporteur on On-Line Forecasting Systems had to:

/a/ collect information from Members on the status of automation in their operational hydrological forecasting systems;

/b/ asses the feasibility of applying fully automated on-line systems to developing countries;

/c/ submit a final report to the Comission.

To fulfil this task the Working Group on Hydrological Forecasting, CHy, has prepared a questionnaire on Operational Hydrological Forecasting of which Section 1 referred to on-line /real - time/ forecasting systems.

The questionnaire was sent to all Members and responses from 45 Members were collected by May 1978.

This report is based on the responses received together with some papers provided by or refferred to by the respondents as well as on the publication or information available to the Rapporteur, including information collected and reported by Dr H.J.Liebscher, Rapporteur, Working Group on Hydrology, RA-VI, WMO /Liebscher, 1978/.

The final draft of this report /Sept. 1979/ incorporates some suggestions made during the Working Goup on Hydrological Forecasting Meeting held in Geneva in October, 1978 **and comments on second draft /May,1979/.**

2. STATUS OF AUTOMATION IN OPERATIONAL HYDROLOGICAL FORECASTING SYSTEMS

2.1. Introductory remarks.

Replies on the questionnaires were received from 45 countries:
Australia, Austria, Belgium, Brasil, Bulgaria, Burma, Canada, Chile, Costa Rica, Cyprus, Czechoslovakia, German Democratic Republic, Guyana, Hungary, India, Indonesia, Iraq, Ireland, Israel, Italy, Japan, Jordan, Madagscar, Malaysia, Mauritius, Mexico, Netherlands, New Zealand, Norway, Pakistan, Philipines, Poland, Republic of Korea, Romania, Spain, Sweden, Switzerland, Syrian Arab Republic, Thailand, Tunisia, Turkey, USSR, United Kingdom of Great Britain and Northern Ireland, USA, Upper Volta.
Among these, 25 responded YES and 20 responded NO to the first question of Section 1, that is whether on-line /real-time/ hydrological forecasts and /on warnings are issued in the country. These figures probably do not represent fully a real situation.
Eight of the YES respondents described rather conventional forecasting systems without reference to a existence of automation of any forecasting procedure component.
On the other hand two of NO respondents descirbed some telemetering and computer processing operated in their countries.

Such an outcome resulted perhaps from a difference in understanding of the on-line /real-time/ forecasting system.

For the present report we define that as a system in which at least one component of an overall operation i.e. data collection, transmission, processing and forecast dissemination is automated, and the total cycle of operation is performed in real time.

This definition perhaps does not conform with a general idea of the on-line system, however for the moment a system in which a complete process from the sensoring till the forecast dissemination would be fully automated has not been found in the reviewed material.

According to the above definition 19 responses have been selected, 17 from the YES group and 2 from the NO group, for more detail consideration. To this number four informations selected from Dr Liebscher's material were added making total number equal to 23.

A general information on this group of 23 is assembled in the Table 1.

The replies on the questionnaire varied in the detalization. For this reason it is impossible to present now some statistics as to how many river basins, observing network posts etc. are automated, what is degree of automation in percents and so on.

The total number of respondents is less than one half of the total WMO Membership so it is one more reason to refrain from such a statistics.

A discussion of the subject under present conditions is of a general character. It reflects some experience of the Members in the on-line forecasting systems development which in all cases is not completed and for this reason is considered as a preliminary one.

The following main aspects of the subject are considered: status of automation, time for the system development and implementation, system structure and reliability.

2.2. Status of automation.

It seems that none of the questionnaire respondents has at present an operational on-line system in which the whole process from the measurement /sensoring/ until the forecast dissemination is fully automated.

In the systems of 23 selected Members /see Table 1/ automated are:

/a/ data collection and transmission to the central/local collecting station;

/b/ data processing including data control, record summaries, analysis, forecast computation and printout;

/c/ simple flood warnings, including those concerning flash floods, that is indication of a critical value exceeding, either water level or precipitation.

These operations are automated either separately or there are combinations: /a/, /b/ and /c/; /a/ and /b/; /a/ and /c/; /b/ and /c/. In each of existing systems there are some manual operations, human control and interaction. In most cases information disseminated to users is formulated in the final shape by professionals although the computer is an essential tool in generating forecast information. In some cases data collection and transmission is manual but data processing and forecast computation is done by computer. In other cases only data collection and transmission is automated providing virtual instant access to current data together with concise summaries of preceding trends and eventually alarms.

In several systems in UK, USA, Malaysia and other countries a weather radar is a helpful source of a rainfal and snowfall amount information.

The satellite information is also of great value, although, so far, it is not used directly in the on-line hydrological systems but rather as a source of information for the forecaster on duty concerning snow and ice cover, flooded area extent, soil moisture and a source of information for meteorological analyses and forecasts input to the hydrological forecast computation.

In the countries where the hydrological and meteorological services are combined they use the component subsystems which are or are to be common for both weather and hydrological forecasting.

A great diversity of the equipment is applied in all operations. After initial prototype/pilot systems have been installed and operated the next step is to unify the system equipment within a country /UK,USA,Australia/.One of the most difficult system element to obtain is perphaps a reliable communication.Land lines are unreliable and expensive,land radio has a limited range beyound which it requires the use of realy towers which makes the system expensive.The most promising seems to be satellite radio system,however for the moment only a few countries can afford it.Another radio communication technique, Meteor Burst,is in operation for a data collection system in Alaska by several agencies and in Western United States by the Soil Conservation Service for a network of several hundred stations at high elevations.The latter data are collected at 3 locations and transmitted automatically to a computer system in Portland, Oregon.

Some other techniques like Chirpsounders is now under investigation and,possibly,will be available in the near future /Shiesl, 1975/.

The actual state of the on-line forecasting systems development coincides with the rapid advancement in sensing,communication and computer technology and it is obvious that the suitable and available hardware has to be applied in the systems.

A solid state electronic package provides for a capability for economical automating much of hydrologic equipment.

From the present review one can draw a conclusion that by the 1978 a number of countries where the on-line /real-time/ hydrological forecasting systems exist /with partical automation of the whole forecasting procedure/is of range ______ of 20. In most of these countries the systems are in a stage of development which can be considered as an experimental, prototype or a pilot system stage. Only a few countries, perhaps Japan, UK, USA and Australia, have passed this stage and are implementing an unified, routine operation systems. France, UK and Denmark within the European Economic Community are developing the European Hydrologic System /SHE/ which seems suitable for application to the on-line forecasting systems /Abbott, 1978/.

Several developing countries as one can see from the Table 1 have implemented real-time systems in routine forecasting service and proved the feasibility of such an enterprise.

Despite many difficulties and rather slow progress in comparison with the needs - a development of the on-line /real-time/ systems represents a considerable achievment which improves an overall standard of the hydrological forecasting service.

Even partial automation of any part of a forecasting process increases the amount of available information, speeds up the data processing and makes the forecasts more timely and accurate.

2.3. Time for the system development and implementation.

Information on this subject is rather sparce in the reviewed material. In advanced already countries hydrological forecasting real-time system development started in the sixties, while in most countries - in seventies.

In all cases it takes several years before the system can be considered as reliable and operational. Research and development works, prototype and pilot system operation, testing several options of the hardware and software as well as organizational arrangements and gathering of experience by the personnel engaged - all of this needs a considerable time.

The most difficult problem is probably to put all the system components together and get the system operational as a whole. Experience shows that even when all the components taken separately show a perfect performance, still it doesn't mean that put together they would produce a desirable outcome of a system. A teething troubles period is in most cases a rather extended one. It is worth nothing that the meaningful results in the system operation were obtained in most cases after several years of the pilot system tests and trial operation, since almost impossible is to get an operational system just by passing such a stage of development.
An "armchair approach" like "the data are being collected, the personnel have been trained, the computers and equipment have been installed and therefore there should be no difficulties" - leads to nowhere. When all above conditions have been fulfilled it is just the beginning and not a completion of the task. Several papers /Askew, 1978; Dee Weather Radar Report, 1977; Porter et al, 1975; Schiesl, 1975/ show convincing examples to challenge an "armchair approach".

From this general rule there exist a few encouraging exceptions when a system was made operational within a relatively short period of time. One such an example is the Soil Conservation Service Meteor Burst system /USA/ of data collection and transmission.

Besides of the proper hardware installation the main condition seems to be to gather a staff which is willing to do a job, is adequately trained, is well motivated and has enough endurance to promote the job to the successful completion. This again needs several years to arrive at.

2.4. System structure and reliability.

A system reliability seems to be the most important criterion to satisfy. A real-time system should be operational at any time, in all weather conditions, especially during floods, storms, tornadoes, droughts and other extreme events. It should supply information when telephone and telegraph land lines as well as power supply lines are broken, when a human access to the observation post is impossible due to flooding or due to the road or the bridge failure, traffic disturbance and other similar reasons.

The system should be robust enough to resist to a damage originated either from natural or human action. It should be as stable as possible to keep all the technical parameters within the established limits. The maintenance and control operations performed manually should be as simple as possible and preferably should be performed by the local staff.

The system should have a high flexibility of the hardware and software structure enabling easy replacement, expansion or updating of any component to adapt a system to changes in technology, in environment or in user demands. This can be achieved by a modular structure of hardware and software.

The postulate of flexibility is stressed in several papers and it seems quite obvious.

The reliability postulate is reflected in the following solutions:

/a/ Each outstation should be robust,selfcontained and utilize the simplest available technology.On the other hand all the sensitive and sophisticated equipment for receiving and processing network data should be housed secure from environmental stress and vandalism and provided with proper supervision.The transfer of the record-keeping function from the field unit to a more secure site allows a substantial reduction in the complexity of the field unit./Burnash, Twedt, 1978/

/b/ Outstations connected to the power supply lines have to be eqipped with batteries providing a reserve power for at least 10 days in the event of prolonged mains failure. Stations having only battery power available should have a capacity sufficient for six to twelve month continuous operation./ Bureau of Meteorology,1973/

/c/ Telecommunication should be preferably based on radio links or should have at least reserve radio option in addition to hard line operated under normal conditions.The radio equipment should have a self-contained /battery/ power supply making it independent on the public power network.

/d/ All hardware should have reserve options in a case of a failure of any component of equipment,power supply or communication .The reserve facilities should ensure a flow and dissemination of information to interested users under the likely unfavourable conditions during extreme events.

/e/ A loss of data from outstations is often very disruptive to a forecast system. To help overcome part of this problem the number of stations that are installed is generally greater than the minimum number needed for successful operation.

/f/ The system as a whole, that is the equipment and the personnell should undergo several tests under initial operation for at least a year or longer during which extreme events should be observed or simulated - before it can be considered operational - provided that all the tests will show satisfactory results.

/g/ A permanent staff and necessary facilities have to be provided for the repair and maintenance works all year around. This should be preferably a local personnel equipped with the means of transportation for an easy access to any post of the system.

/h/ It is desirable to include in the system all available relevant facilities of meteorological service for data collection, transmission, processing and the forecast dissemination.

Experience shows that the effort required for automation is often underestimated and it may be difficult to keep such an advanced system in operation with sufficient reliability.

3. FEASIBILITY OF APPLYING ON-LINE HYDROLOGICAL FORECASTING SYSTEMS TO DEVELOPING COUNTRIES.

As is seen from Table 1 among 23 countries operating real-time systems some 6 can be considered as developing ones. This countries operate all necessary sophisticated components of on-line systems including telemetering posts, computers and in some cases - weather radars. This proves a feasibility of applying such systems to developing countries.

From rather brief responses provided by these 6 countries it is difficult to draw an information on how the present state of development has been achieved, how long time it needed, what kind of outside assistance, if any, have been provided, how local personnel have been trained and so on. This information, perhaps, can be obtained later on.

Neither of these systems is fully automated as it is in most developed countries for the moment too. So, an answer to the question concerning fully automated system feasibility cited at the beginning of this report is for the moment negative.

Partially automated systems, however, exist in developing countries and the development and implementation of these systems seems quite feasible. A general approach to the on-line /real-time/ system development may be presented in a simplified sketch flow chart as in Figure 1. The scope of each activity may be different, some operations i.e. R&D works on hardware or software development, may be performed outside the system in question.

Essential features of such an approach seem to be the following:

/a/ The parallel, interrelated works on system planning, personnel training, software development, hardware R&D works and hardware acquisition, installation and testing and, afterward, integration of all above branches in system testing, implementation and operation.

Needless to say that all these activities should be well coordinated by an efficient management.

/b/ Several loops have to be expected and performed after each evaluation of the hardware, software and the whole system performance. These loops can be repeated several times, and an extended time may be spent on them. Not all of the possible loops are presented at the Figure 1, but the idea seems to be clear.

A decision to develop an on-line system should follow from a general plan of the hydrological service and water resource development. It is obvious that such a decision should result from studies whether an on-line system is really needed and whether it is feasible.

This question needs a comment. There exists an opinion that the fully automated on-line forecasting systems can help developing countries to bypass well known troubles with a lack of skilled personnel, inadequate infrastucture etc. In other words it is hoped that the on-line systems would produce necessary hydrological forecasts/warnings and this may substitute or diminish an effort needed for an overall development of the hydrological service including an improvement of network, telecommunication, data processing and personnel training. Such a hope is rather an illusion in the light of collected information and experience discssed above. This experience shows that a certain standard of hydrológical/hydrometeorological service should be achieved to make installation of an on-line / real-time / forecasting system feasible, the key conditions being a sufficient number of skilled professionals and the facilities necessary for the system operation and maintenance.

An automated on-line forecasting system cannot be a goal for itself. It is always a component of the water resources management and/or flood protection system. So, the feasibility studies of the on-line system, its design, implementation and operation have to be considered in close connection with the task and performance of the main system. When considering a degree of automation in the system design one may point out that an automation is desirable for the flash flood and dam-break flood warning systems, for collection of observation data from remote, uninhabited and/or inaccessible areas, for routine data processing, computation and dissemination of forecasts and warnings. The faster and the more surprise is the natural process in question / i.e. flash flood / the more automation is needed. On the other hand the more time for an event monitoring is available / i.e. a flood wave travel along major river / the more human control and intervention in a forecast computation should be contributed. In any case, however, the human control in the real-time system is indispensable since, for many well known reasons, an automated system may produce unacceptable outputs, make false alarms etc. It is also desirable to have a reserve option for issuing forecast/warning using conventional methods in a case of an automated system failure.

The discussed studies have to show how high degree of automation would be optimal for a planned system, what system output and benefit can be expected and what resources: human, finance, physical and a time as well are needed for system development and operation.

When taking decision it is important to know whether there will be just one or several on-line systems, where and when. If several systems are planned then the selected solution should have the greatest possible range of application to the present and prospective requirements of engineering practice throghout the 80's and 90's: it should have outstanding development potential.

A few obvious conditions should exist for the system development as adequate funds, personnel, organizational arrangements, logistic support etc. The most important condition seems to be the existence or the establishment of the system development team consisting of competent specialists or the existence of the training facilities for the able people promotion.

Wellknown is the lack of trained personnel in developing countries and this problem is perhaps the most difficult to solve. The problem can be overcome by calling on the services of overseas experts, but in the long-term it is necessary to rely on local expertize for the operation and improvement of the on-line forecasting systems.

Another problem is lack and poor quality of observational data. However, the system development group cannot just wait for suitable data to appear for their system or model but

must take the initiative of making system / model / available that will justify the collection of siutable data.
A WMO HOMS / Hydrological Operational Multipurpose Subprogram / Project which has been approved by the VIII Congress among its purposes has to integrate the already acquired experience of WMO Members and transfer it to any user at need of a similar to HOMS system.

It seems that the HOMS Project outputs will be helpful for developing countries interested in establishment of an operational on-line / real-time / hydrological forecasting system.

4. CONCLUSIONS.

The on-line / real-time / hydrological forecasting systems with a various degree of automation are operated in 23 WMO Members among them 6 are developing countries /1978/. At this time fully automated are only few flash-flood warning systems.

Applying of on-line / real-time / systems with partial automation to the developing countries seems feasible under conditions discussed in the present report, see Chapter 3. The automation of any part of a forecasting procedure increases amount of the available information, speeds up the data collection and/or processing and makes the forecasts more timely and accurate.

A development of an on-line / real-time / hydrological forecasting system requires considerable funds and efforts for the personnel training, software development and hardware purchase and installation and an extended period of time to spend before a system becames operational. Moreover, it requires substantial funds and efforts to keep the system operational with adequate reliability in extreme conditions like floods, storms, droughts etc. An automated on-line forecasting and warning system certainly can not be imagined as a wonderful tool which itself would perform all the tasks without any effort from its user.

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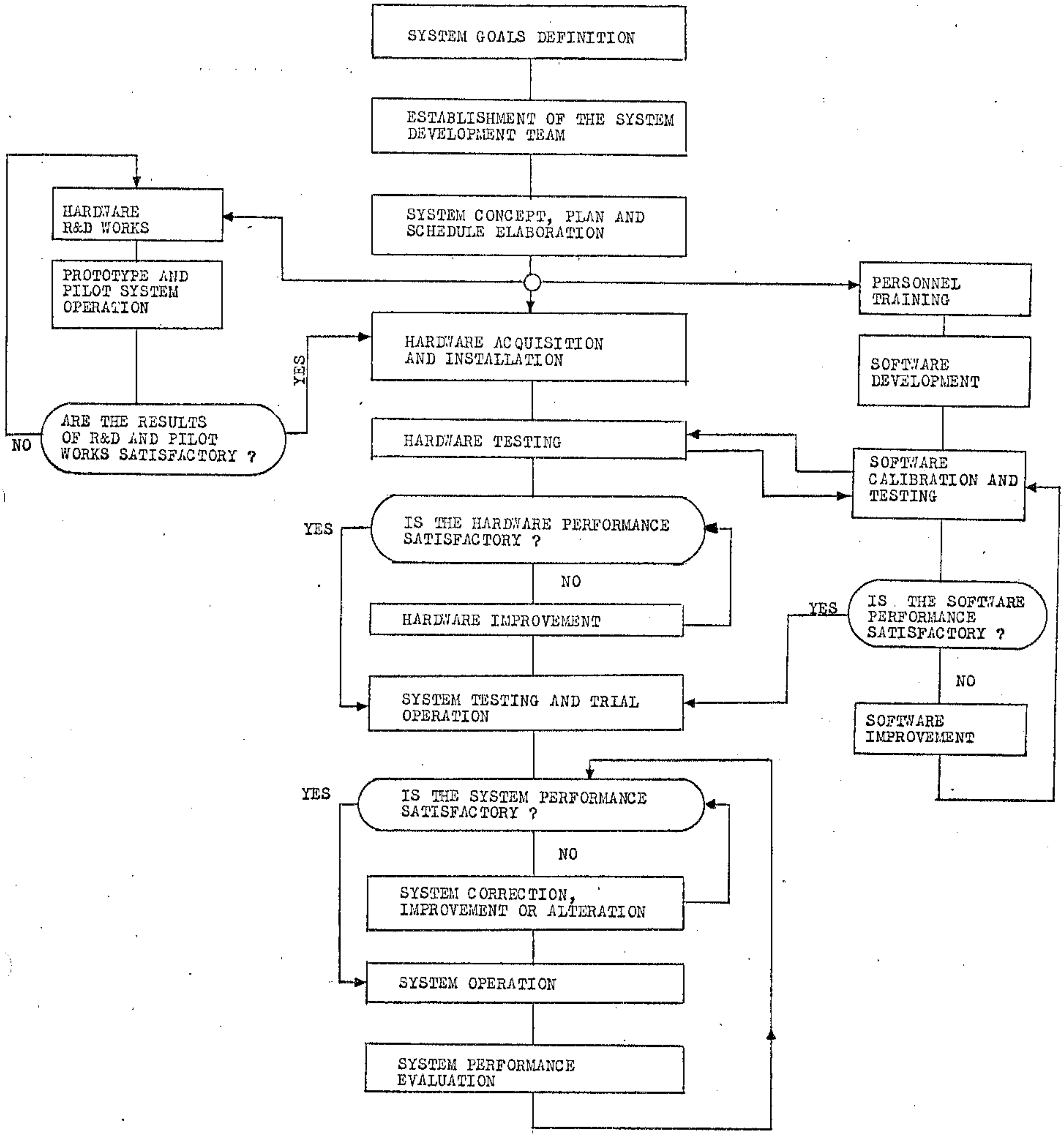

FIGURE 1. A FLOW CHART SKETCH OF THE ON-LINE /REAL-TIME/ HYDROLOGICAL FORECASTING SYSTEM DEVELOPMENT.

APPENDIX

TABLE 1: REAL-TIME HYDROLOGICAL FORECASTING SYSTEMS, MAY,1978, REVISED, SEPTEMBER,1979

COUNTRY	OPERATING AGENCY	NAMES OF RIVER BASINS AND/OR R.REACHES	DATA COLLECTION	DATA TRANSMISSION	DATA PROCESSING: input	DATA PROCESSING: model/software structure	DATA PROCESSING: computer hardware	DATA PROCESSING: output	FORECAST USERS, FORECAST DISSEMINATION
1	2	3	4	5	6	7	8	9	10
AUSTRALIA	Bureau of Meteorology	Brisbane R.	20 automat. TM outstations	UHF radio	P,H Δt=20s to 24 hrs	Time schedule and data reading function	Micro - processor	Observed records; alarms; system status	Flood forecasting; water supply
	"	Macleay R.	5 automat. TM outstations	VHF radio	P,H Δt=2min to 3 hrs	"	hardware control	"	Flood forecasting
	Melbourne and Metropolitan Board of Works	12 rivers and creeks catchments in Melbourne Metropolitan area	66 automat. TM outstations, Interrogation time 9 s	Telephone lines	P,H Δt=6 min 5 words of 8 bits one station message	"	PDP-11/40 128K words 6 discs storage	observed records; alarms; telemetry failure indication	data collection; flood protection
AUSTRIA	Hydrographisches Zentralbüro Wien	Danube,Linz Danube,Vienna ; Salzach, Enns, Saalach-Salzburg Drau,Klagenfurt; Mur,Gräz	18 RL recording.g. 8 " 10 " 10 " 10 "	Telephone lines " " " radio	H,Q, travel time	regression	Siemens 4004	riv.level forecasts for Linz /12 hrs/ and Vienna /24 hrs/; forecast errors 4s≤10cm 85%	Inland Navigation, hydropower
BELGIUM	Institut Royal Meteorologique; Several Hydrological Services	Dyle R. and others	Several TM networks consisting of RL,raingauges, piezometers, up to 100 posts for one collecting stn. /L.G.M.system/	public telephone networks	P,H Δt:from 1/4 up to few hours	time schedule and data reading functions	Micro-processor	Record summaries, alarms, flood forecasts, data files for year books	Water MNGMT, Flood Control
BRAZIL	Dept.Nacional de Obras de Saneamento,Rio de Janeiro	Upper Paraguay R. Basin	16 automat. TM outstations trigered by clocks	radio, short wave		SSARR		forecast of water-level 4 weeks ahead	ranchers /cattle production/ inl.navigtn.

1	2	3	4	5	6	7	8	9	10
CANADA	Flood Forecast Centre Fredericton, N.B.	St.John R. Basin	Operation: March-May full time, weekly updating, readiness, frequent, use during hurricane seasons.	radio via satellite	Δt=1 day	SSARR		forecast 3 and 5 days ahead	power; emergency measures organization
	Conservation Authorities Toronto	Ontario Province				API-UH		flood warn. and forecast	
	Inland Waters Directorate	Gr.Lakes St.Lawrence R.			H	probabilist.		6 month forecast month. mean lev. of each of G.L.	inland nav.; fisheries
	Inland Waters Directorate	British Columbia			Snow, Q. meteorolog. forecast	Simpak UBC Water-Shed Model	hand calculators	worst likely expected flow fore-casts	

1	2	3	4	5	6	7	8	9	10
CANADA /contd/.	Water Survey of Canada Direction de l'Hydrometrie Quebec	North Saskatchewan South " " Ottawa				SSARR	computer programs and data files on disk	runoff simulation and river routing, snow-melt flow forecast	
FEDERAL REPUBLIC OF GERMANY	Bundesanstalt für GerÄsserkunde, Koblenz	Major River Basins	RL recording STNS, Automated D. Acquisition	Public telephone network	H,Q	Time schedul. &data reading functions, flood forecast model	micro-processors, small computers	record summaries flood forecasts& warnings, data files for year books	water MNGMt, flood protection
FRANCE	Service Central de l'Hydrologie et de l'Environnement du Ministère de l'Equipement	DORDOGNE Upper Garonné, Gardons and Vidourle, Catchments of East Pyrenees	RL&RAIN Recording Gages	radio, mostrly 80 MHz frequency band	P,H,Q	Time schedul. & data reading functions		Record summaries Alarms	Water MNGMT, flood control
GDR	Institut für Wasserwirtschaft Berlin	Saale R.basin 12.000 km²	Raing.RL water quality, all TM Δt = 15 min.		P/snowmenlt/. Q;salt concentr. Δt = 2 hrs; initial values of reservoir releases; QPF,snowmelt forecast for 1 day, estmn. for 5 days; moving data window: 5 days past, 5 days ahead.	rainf-runoff; channel routing nonlinear threshhold salt transport recursive regression for updating procedure.		hydrograph of all interested state variables /5 days past, 5 days ahead/ a/for the initial regime; b/for the optimal regime; data lists; calculated reserv.oper.rules; computns 1-4 times daily	Water MNGMT, Water Quality Control.
HUNGARY	National Water Authority	Zagyva-Tarna 5676 km²	18 STNS: RL,Rain&Snow, Air&Soil temperature, Soil Moisture	telex,	P/rain and snow/ H,Q, air&soil temperature & moisture	Time schedul., &data reading, rainfall-runoff; Channel routing, reservoir control	HP desk computer, TRA computer	Record summaries, alarms,flow forecast, reservoir operation rules	Water MNGMT, flood control

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ITALY	Service Hydrographique Central	PO, Adige Tagliamento Arno, Cabrone, Tevere, Reno, Lacone, Fiumi, Uniti, Savio	12 river level TM posts						
JAPAN	River Department	large rivers; information system			rainfall, water stage		central computer plus terminals	forecasts of low flow or flood issued by person	
REP.OF KOREA	Han River Flood Control Office	Han R. basin 26.000 km^2	TM Rainf. G:38 RLG:12 reserv.lev.G: 5		rainfall observed & forecasted; water level	storage function method		forecasts of Q&H	5 TM warning STNS TV, radio
Forecast procedure: 1/ rainf forecast; 2/ runoff forec.; 3/ forec.dissimination; 4/ replacement forec. dissimntd by observed; 5/ go to 1/ and repeat.									
MALAYSIA	Drainage and Irrigation Department	Kelantan R.basin Trengganu " Pahang "	TM rding, RL collected during north - east monsoon season /OCT - JAN/, Δt = 6 hrs, radar data /Aerial coverage & Direction of Storm Movement/	telex		Sacramento UH	NOVA 1220 mini comp.	Q, issued once daily or every 6 hrs /flood/	
MEXICO	Direccion General de Control de Rios e Ingenieria de Seguridad Hidraulica	Balsas Grijalva	Raingauge, RLg.			UH		short range flood forec.	
PHILIPPINES	National Flood Forecasting Office Pagasa	Pampanga R. basin	TM.			two series tank model; crest stage relations		flood forecasts and warnings	
POLAND	Institute of Meteorology and Water Management	Soła River basin, Dunajec R. basin, Lower Vistula	14 rain.g.+ 1 RLg: 17 rain.g.+ 2 RLg. 4 RL.g	radio telex	P,Q, Δt = 3 hrs Q,H, Δt = 15 min, and 1 hr QTF met.forecast air temperature, air humid.def. wind speed, total radiation	modified SSARR version; Dooge type nonlinear dynamic system	ODRA 1305 64K core	Q hydrogr. flow volume Δt = 1 hr, 48 hrs ahead H hydrograph Δt = 1 hr 24 hrs ahead	telex telephone reservoir managers; Inland navigation

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SPAIN	Comisarias de Aguas	Rio Sil, Guadalmedina, Campanilos, Guadalorce, Eastern Pyrenees	10 pluviogr. TM 10 " " Semi Automatic system Automatic "	radio radio low freqency	QPF for 24, 48, 72 hrs, long rivers Δ t=3,6,12 hrs	rainfall-runoff model /TEMEZ		Forecasts of H,Q, crest height and time	Flood protection telex, telepnone
SWEDEN	Swedish Met.and Hydrological Institute /SMHI/	F=1109 - - 5860 km^2 10 catchments	Manual operated rain 3-7 STNS; air temp. 1-6 STNS for one catchm. partly autom. TM	telephone	P,t^o,Q daily totals or means	HBV model with updating procedure; 1/ snow melt-degree day; 2/ soil moist-potent.evaporn; 3/ response function 3 nearlinear components, time-area transformation; alternative simulation	SAAB-D22 SAAB-D23 UNIVAC 1100-2 desk calcul. Hewlett-Pack. 9821 with plotter	flood forec. & warnings short range; spring flood bolume	
SWITZERLAND	Laboratoires de Recherches Hydrauliques Hydrologiques et Glaciologiques, Ecole Politechnique Zürich	Rhine at Basel	18 RL gauges 15 automated		H,P snowmelt	autoregressive-regressive, or linear transfer functn.		Q hydrograph; Δt = 1 hr, for 2 days; Q for third day	Inland navigation, flood protection
THAILAND	Mekong Committee	Lower Mekong	raing., radar, RL & discharge		H,Q,P QPF	SSARR	IBM 360/40	H, 5 days ahead for 10 cross sectns	National Mekong Committees of Kampuchea, Laos, Viet-Nam, Thailand
USSR	Hydromet Service	Volga, Kama, Viatka, Gorki, Kuybyshev reservoirs, with adjacent small watersheds	39 meteo stns 89 RL posts	telephon telex	H,Q,P/rain and snowmelt/ t^o, meteorol. forecast Δt=1 day	water balance, convolution integral routing; snowmelt runoff with a routing procedure		forecast of the daily inflow into reservoirs, 5 days in advance; snowmelt runoff	Gorki and Kuybyshev reservoirs operators
UNITED KINGDOM	Wessex, South West and Welsh Water Authorities		raingauges - and in one case radar; river flows and levels	telephone and radio	P,H,Q meteorologic forecasts and warnings			forecasting peak flows, times of peak and areas liable to be flooded	
		parts of the country are covered by automatic T.M. systems monitoring river level; forecasts and warnings are provided by use of models on line and off line and by manual systems							

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UK /contd/	Welsh Water Authorities	Tee R. basin	14 RL STNS 4 Reserv.L.STNS 5 Raingauges All TM Δt = 30 min. D.commanded and stored by computer	Land lines, UHF radio	P,H,Q Δt =30 min. QPF	Real-time systems executive RSX-11; ISO model /Lambert/; UH/losses M; Variable Parameter Diffusion M; continuous d. analyses	PDP 11/35 56K core, back-up disc 1,2 M words; Texas 700 ASR; colour TV to display hydrographs	Flow/RL hydrograph forecast; telemetry failure indication; observed d. records	Water Mngmt
USA	National Weather Service /NWS/	National Scale	Flow forecasts issued daily for some 2500 locations; 6700 raing. 3100 RLg; 10% collection automated; many systems with automated d. collection, transmission and/or d. processing; weather radar network	telex, phone, radio - satellite, /AFOS-system/, meteor burst	P,H,Q Δt =24 hrs Δt = 6hrs /flood/	NWSRFS concept.models snow, soil moist., streamflow routing; unsteady channel flow; programs& proced.for mod. calibr.and verification: 1971-Stanford IV, 1974-Sacramento /soil moisture accounting components/	three IBM 360/195 operated from remote terminals; under development disk oriented system direct access disk files /AHOS system, 5000 STNS automated/	NWS-data files; actual forecasts are made by professionals, the computer is an essential tool in generating forecasting information	Newspapers, radio, TV water MNGMT power production, irrigation; flood protectn.
	US Army Corps of Engineers /COENG/	Columbia R.	automated data collection system /CROHMS/ 120 fully autom. stns	radio microwave, telex		SSARR			
	COENG	New England	41 posts. computer control. interrogation, processing and printout	VHF: sensor-relay; UHF: between relays; SHF multiplex: main collect. terminal-operational headquarters					
	NWS, California - Nevada River Forecast Center	California rivers	23 stations	high speed radio netw.		Sacramento			
		Flash-Flood Warning System	Event-reporting, automated, TM - precip.gauges, RL gauges, radars	radio, telephone, radio via satellite /AFOS system/	P, AP, QPF; Δt from several min up to 6 hrs		minicomputers at local d. collect.site; IBM 360 at RFC	flash-floods forecasts/warnings	flash-flood protection

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USA /contd/	NWS	Potomac R.	20 stations,TM /AHOS/	hard wire telephone					

LEGEND: D- data; P- precipitation; H- water stage /level/; Q- water discharge /flow/; Δt- time step /resolution/ of input and/or output data; QPF- quantitative precipitation forecast; MT- magnetic tape; TM- telemetering post; t°- air temperature; RL- river level; L- level; UH- unit hydrograph; MNGMT- management; STNS- stations; M- model.

NOTE:A number of other smaller automatic data collection systems exists in Australia and in some other countries.