A CENTRALIZED FORECASTING SYSTEM FOR THE WESTERN UNITED STATES

by

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INTRODUCTION

The Soil Conservation Service (SCS) conducts a cooperative snow survey and water supply forecasting program in the Western United States and Alaska. The primary mission of this program is to supply accurate and timely predictions of anticipated runoff to water managers in the agricultural sector and to other interested users based upon analysis of current hydrometeorological conditions. During the past decade, the program has undergone rapid evolutionary change in response to the expressed need for more frequent data and improved forecast services from the user community. Installation of SCS's SNOTEL system (Barton & Burke, 1977) and reorganization of the Snow Survey Program in 1983 (Barton, 1983) clearly evidenced the agency's commitment to meet these needs. Increased use of automation in all facets of the program from initial data collection to analysis to information dissemination were required.

As a result of the reorganization in 1983, a number of functions including streamflow forecasting, data base management, report generation, applications development, and hydrologic modeling were assigned to the West National Technical Center (WNTC) in Portland, Oregon. A staff was assembled to fulfill these responsibilities and develop the necessary hardware and software systems to support program activities in 11 western states. Partial implementation was scheduled for fiscal year 1985 with full implementation projected for fiscal 1986.

A conceptual design called the Centralized Forecasting System (CFS) was formulated to accomplish all of the assigned tasks. This system was envisioned to be the primary focal point for snow survey data collection, streamflow forecasting, data exchange, and product dissemination for the foreseeable future. Its main function was to serve as the integration mechanism and delivery system to make planning information available at local SCS offices where it could be incorporated into ongoing conservation applications programs. This report describes the principle features of CFS, current status, and accessibility to the user community.

FUNCTIONAL REQUIREMENTS

The design of CFS demanded consideration be given to accommodating a number of functional requirements including rapid data processing, ease of use, and online accessibility by over 300 SCS offices and numerous other cooperators. It was also necessary to insure its compatibility with SCS's field office communication and automation system (FOCAS), a project aimed at providing microcomputer facilities at all local offices over a 5-year period. These requirements dictated a multi-user, multitasking computer facility capable of supporting as many as 60 simultaneous users operating in an interactive mode. A menu driven user interface was necessary to facilitate ease of use and minimize training requirements.

CFS also had to be capable of storing current and historical hydrometeorological data for the entire West in several different data base structures. Storage capacity was needed

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to manage monthly data for 1700 snow courses, 600 stream gauges, 300 reservoirs, and 1200 precipitation station as well as daily data from 550 SNOTEL sites and 1,000 climatological stations. Data access, editing, and report retrieval routines were required for all data held in storage.

It was imperative that CFS contain a forecast component that would permit assimilation of a diverse set of existing forecasting procedures for over 500 forecast points obtained as a consequence of the snow survey program reorganization. An ability to exchange data and coordinate forecast information with 5 National Weather Service (NWS) River Forecast Centers and snow survey program personnel at SCS state offices was a necessity. Software to automate production of monthly state water supply outlook reports containing runoff predictions and summarized data was mandatory. In addition, users required access to a variety of data summaries and forecast products stored in an updatable directory.

A number of applications programs and data analysis utilities were necessary to insure quality control and enable hydrologists to update forecast procedures. File maintenance and electronic mail capabilities were requisites to manage data exchange and communicate with a wide variety of users. A security system was needed to restrict write access to sensitive files according to predefined authorization levels.

CFS SYSTEM CONFIGURATION

Hardware

The requirements analysis showed that CFS would function best in a minicomputer environment. A Data General MV 8000 computer was acquired and installed in April 1984 to support CFS as well as other WNTC applications. The hardware configuration in which CFS resides currently consists of the following:

1 CPU with 8MB main memory
1.5 GB of peripheral disk storage
72 user ports (40 dial-up, 32 hardwired)
2 tape drives (1600 and 6250 bpi)
2 printers

Two operating systems run concurrently. They are Data General's AOS/VS operating system and Data General's implementation of the UNIX operating system. The UNIX operating system runs as a sub-environment of AOS/VS. CFS was designed to coexist in both operating environments depending on the application being run by a user.

The Data General minicomputer supports both asynchronous and synchronous communications. Asynchronous communication is possible at data rates of 300, 1200, and 2400 bps. MNP error checking protocol is available at all these speeds. Synchronous communication takes place at 4800 bps using either IBM 3780 or HASP protocol. The WNTC computer is a designated node on the U.S. Department of Agriculture's DEPNET telecommunication system and is therefore accessible via GTE's TELENET network.

Software

CFS is a logical framework composed of many applications programs, data bases, and utility routines connected by a series of macro commands that are transparent to the user. Figure 1 shows the 7 major functional software components as viewed by a dial-in user. Each component is composed of multiple programs and/or data bases. Software source code is written primarily in FORTRAN 77, but there are also programs in BASIC and C.

Access to all components of CFS is controlled by a menu system that grants permission according to authorization levels established by logon identifiers. Three classes of logon ID's are defined. Menu screens and options displayed to the user are different for each ID class. This feature was incorporated to reduce the likelihood of inadvertent file deletion or modification. Each dial-in user is granted a temporary directory or workspace for storing output files that may be downloaded at the end of each work session. The <clear screen> and <end of line> delimiter characters are passed to CFS via the first menu encountered by a dial-in user to facilitate exchange of data and command entries.

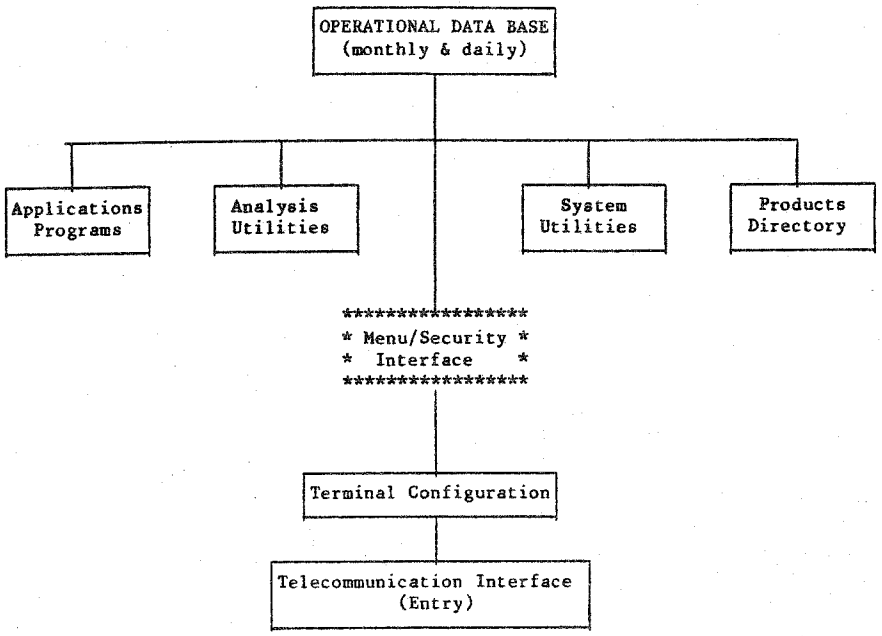

Figure 1. Block diagram of the major functional components comprising CFS as viewed by a dial-in user.

CFS is a menu driven system designed to accommodate novice users; however, experienced users have the flexibility to operate in command mode by stringing together successive menu item selections on a single line separated by spaces. All major menu commands are acronyms, mnemonics or full English words that are designed to convey the meaning of what the command does. Help options are found in most applications programs to explain the meaning of queries to users for input. Figure 2 is a block diagram of the menu system structure showing major elements that an ordinary interactive user would encounter. Menu commands are shown in bold print. All the commands in figure 2 are available to dial-in users except for MODELS. Execution of the various hydrologic models is presently limited to hydrologists on the Water Supply Forecasting Staff at the WNTC.

FORECAST COMPONENT

The operational forecasting program for seasonal volumes is known as WYFOR (for Water Year FORcasting). WYFOR is a data management and runoff prediction system designed for interactive access and execution. It is the principle tool in CFS for generating streamflow predictions and exchanging hydrologic data within the snow survey program. WYFOR is the vehicle for storing monthly hydrologic data for the current water year and producing numerous data listings, summary tables and forecasts used to create state water supply outlook reports. Current year, preceeding year, and average values are stored in WYFOR for approximately 3000 stations. These data are used in some 3500 forecast equations and cross basin comparisons to produce forecasts at 533 locations in cooperation with NWS forecast centers.

Snow course, precipitation, reservoir contents, and in some cases, streamflow data are readily available to cooperators for the current and previous year. Comparisons are made to the previous year and average values for individual stations and are summarized by watershed and major river basin for each state. The contents of WYFOR data files are updated monthly during Winter and Spring. Throughout the current year, data contained in WYFOR are considered provisional. At the end of each water year, current year data undergo a quality review and are offloaded into the CFS operational data base and to archival files at the USDA Fort Collins Computer Center in Colorado for subsequent access.

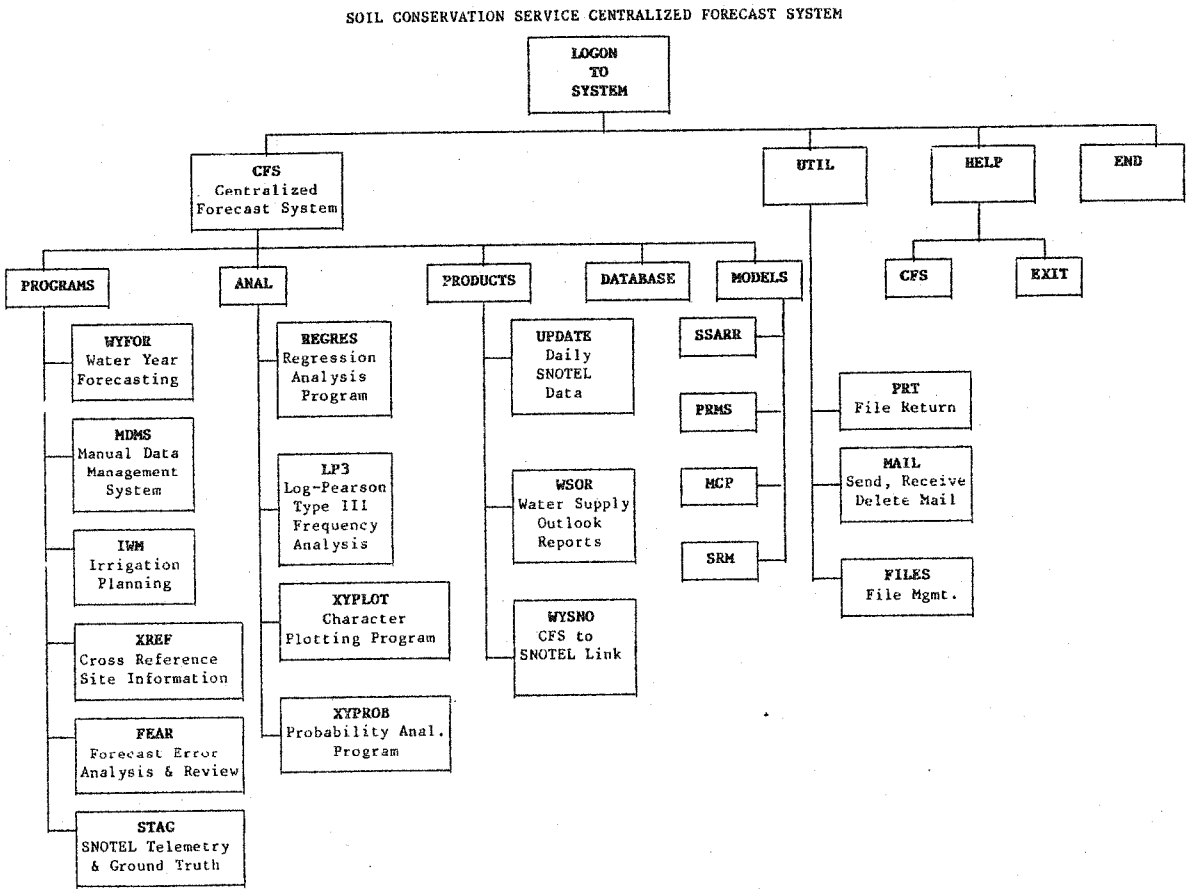

Figure 2. Block diagram of the CFS menu structure. Words in bold face are menu commands.

The forecast component also contains a simple line editor to enable state snow survey personnel to compose narratives describing current hydrologic conditions across their state and within river basins they have delineated. The text files they create are combined with output files from WYFOR and reformatted to produce the monthly water supply outlook reports (WSOR's). The monthly reports are stored in a products directory that is accessible through the CFS menu.

Several hydrologic simulation models have been ported to CFS to provide the capability to make short and midterm forecasts on the order of days rather than months. The models available within CFS include the U.S. Geological Survey's (USGS) Precipitation Runoff Modeling System (PRMS), NWS' Manual Calibration Program (MCP), Agricultural Research Service's Snowmelt Runoff Model (SRM) and the U.S. Army Corps of Engineers Streamflow Synthesis and Reservoir Regulation Model (SSARR). These models are not being used for actual operational forecasting yet. Rather, work to date has focused on adapting them to use daily SNOTEL data from 5 test watersheds scattered across the West. Model performance and suitability of SNOTEL data as input are being evaluated.

OPERATIONAL DATA BASE

The primary online repository for hydrologic data in CFS is its operational data base (ODB). It holds all the requisite historical hydrometeorological data from active stations that are necessary for water supply forecasting and conservation planning activities. All data are stored in a water year format. It is comprised of two major sections that are integrated through a common relational data base architecture. These sections are defined by the time steps of their data--daily and monthly.

The daily data section holds data for 5 data types. These include SNOTEL, NWS climatological, streamflow, reservoir, and radiation data. In the case of SNOTEL, only the morning poll is stored regardless of how many other responses might have been received. Not all SNOTEL data are stored in the ODB. Although SNOTEL sites can transmit up to 16 parameters, only snow water equivalent, precipitation, maximum temperature, minimum temperature, and average temperature are stored because they are the most useful operationally. Similarly, only daily maximum and minimum temperatures and precipitation are stored for climatological stations. When fully loaded, the ODB will contain data for 550 SNOTEL sites and about 1000 climatological stations. Significantly less data will be stored for streamflow, reservoir, and radiation data types. Only those stations required for hydrologic or conservation applications assessment modeling will be stored.

The monthly data portion of ODB also stores information for 5 data types: snow course, precipitation, streamflow, reservoir, and miscellaneous. These monthly data have been assembled to support seasonal volume forecasting and conservation planning activities by SCS personnel. When all monthly data have been loaded, the ODB will contain historic monthly information for 1700 snow courses, 1200 precipitation stations, 550 stream gauges, and 300 reservoirs from 12 western states and 3 Canadian provinces.

A custom relational data base written in C and running under UNIX was designed to manage insertion, updating, and reporting of the data described. Data base loading and editing routines were developed to permit efficient data management. Most users, however, are primarily interested in data retrieval and report generation to address a specific problem. This task is accomplished by invoking a query language that locates and retrieves data matching key attributes and outputs it in predefined formats.

Each station loaded into the ODB is characterized by 11 key attributes that are used to locate data. These attributes are:

1. state (name or FIPS ID)
2. latitude
3. longitude
4. elevation
5. site name
6. station ID
7. datatype
8. region
9. subregion
10. accounting unit
11. cataloging unit

Attributes 8 - 11 taken together comprise the 8 digit USGS hydrologic unit code for the area in which a site is located. These 11 attributes combined with the logical operators "and" and "or" are used to find and retrieve desired data quickly and easily. The following command:

```
find state colorado and datatype snow and elevation 11000
and latitude 39 and longitude 106
```

would find the data for 5 snow courses in Colorado between 11,000 and 12,000 feet in the quadrant bounded by 39°-40° north latitude and 106°-107° west longitude. The station location information would be made available to list; actual data could be retrieved in a user selectable report format.

For each datatype two possible output formats are automatically made available. One report displays the data in a format easily interpreted by data users. The other creates a compact format optimized for machine readability. The data can be displayed on a terminal or routed to a file for later use once a report format is chosen. This latter option is particularly advantageous because it provides a readily accessible input file for other applications programs. The data base query system will also be used to generate annual summaries of snow course and SNOTEL data collected in the snow survey program at the conclusion of each water year.

FORECAST/DATA PRODUCTS

A directory is reserved within CFS to store certain data and interpretive information that users might frequently request. This portion of CFS is accessible via the PRODUCTS command. At this level several menu options are available that provide access to water supply outlook information (WSOR, figure 2), current day SNOTEL data (UPDATE), and SNOTEL

data for the current water year (WYSNO). Each of these options are discussed in more detail below.

WSOR

Selecting the WSOR option gives users access to nearly all of the data printed in monthly water supply outlook reports with the exception of graphs and maps. New information is available for viewing by the 6th or 7th of each month, January through June. This timetable is about two weeks before actual delivery of published state reports. The later arrival of printed reports is due to delays imposed by printing and mailing schedules. Information for an entire state or individual basins within states can be retrieved at the user's discretion by selecting a secondary menu option of BULL or REP respectively.

If the user selects BULL the entire water supply outlook bulletin for any western state is made available for printing or downloading. This bulletin contains a statewide narrative that includes a synopsis of current conditions and specifically describes snowpack, precipitation, reservoir storage, and streamflow forecasts. This narrative is immediately followed by more detailed information about each major river basin within the state. Basin output includes a short narrative on local hydrologic conditions and tables of streamflow forecasts, reservoir contents, and individual watershed snowpack summaries. Text information is output in 80 column format while table information is output in 132 column format. For this reason, users must currently have terminals that enable viewing 132 columns or, alternatively, they must download the entire file for subsequent printing on a 132 column printer. Work is in progress to permit viewing the entire water supply outlook report in 80 column format.

Chosing the REP option gives the user a greater degree of selectivity in retrieving water supply information. Under this option, the user is queried for the basin of interest and whether the output is to be sent to a terminal or to a print file. Output is in the same format as under the WSOR option, thus requiring an ability to display or print tables in 132 column format.

UPDATE

A quick look at snowpack and year-to-date precipitation as reported by SNOTEL can be obtained by executing the UPDATE option. This selection prompts the user for a state of interest and then displays a table showing current day's snow water equivalent in inches as well as percent of average. Year-to-date precipitation totals are given as well, but no relation to average is presented because normals have not been calculated in most cases. All sites within each state are grouped by major river basin. The elevation of each site is shown along with each record. A statewide basin snowpack figure as a percent of average is also printed. If a user is interested in getting a quick overview of westwide snowpack conditions, choosing a secondary menu option of WEST instead of a state will output a few selected SNOTEL sites in each state in the format just described.

WYSNO

CFS provides users access to SNOTEL data via two mechanisms. The first avenue is through retrieval of SNOTEL data stored in CFS via a program and associated data base dubbed WYSNO (for Water Year SNOTEL). The second avenue is rerouting report requests through a hardwire connection directly to the SNOTEL Central computer. Both of these methods make it convenient for SCS field offices to access SNOTEL data without having to dial outside of DEPNET as would be the case if the Central computer facility were accessed directly.

WYSNO data files consist of SNOTEL data for the current water year. Each morning at the conclusion of the nominal poll, data are retrieved from the SNOTEL computer by a hardwire link and appended to WYSNO files for each site. Data obtained in this manner have not been edited. Every 15 days, a block consisting of data for the last 30 days is retrieved from the Central computer and overwritten in the WYSNO files. This step enables users to take advantage of any editing that has been performed by SCS Data Collection Offices on the SNOTEL Central computer.

Data resident in WYSNO files can be retrieved by invoking commands whose action and syntax are similar to parallel commands on the SNOTEL Central computer. Frequently used report formats can be named and stored in a directory for later recall. Users with Tektronix 4100 or 4050 series terminals can also execute an interactive program called GROSS

(for Graphical Representation Of Snotel Sensors) to view several parameters for multiple sites over a selectable time range. This facility is valuable to detect erroneous data and observe the effects of storms or melt sequences in a geographic area of interest.

In some instances, users may wish to obtain edited data that have not yet been posted to WYSNO data files. They are afforded the means to do this by a utility option in the WYSNO program named CALLHP. When a user selects this option, he is routed through the hardwire connection to the Hewlett Packard computer system where SNOTEL resides. This rerouting is transparent to the user. WYSNO adds a degree of flexibility not found in SNOTEL report generating software. Once a report has been generated the data list can be output for each site in alphabetic order or short ID order to a user designated file.

APPLICATIONS PROGRAMS

Several modular programs are made available to interactive users under the PROGRAMS command in addition to the WYFOR program already discussed. These include a routine to use streamflow forecasts in irrigation water management (IWM), a program to analyze SNOTEL telemetry and ground truth data (STAG), a routine to examine streamflow forecast accuracy (FEAR), and a cross reference program (XREF) to display site geographical information, and a monthly data base management program (MDMS). A short description of each of these programs follows.

IWM

The primary purpose of the IWM program is to provide a useful, field office planning tool for relating seasonal water supply to onfarm seasonal irrigation needs. Much of the coding in the IWM program is based on procedures found in individual state SCS irrigation guides. Users can select their state from a menu when entering the program to insure that practices and guidelines are appropriate for their area.

A crop water budget is developed for a farm on a field by field basis and aggregated for the entire farm based on user inputs, crop types, crop consumptive use data, climatic zone information, and subsurface soil moisture conditions. Total water demand for the growing season is found for the combination of crops and acres to be planted. At this point, an assessment is made of whether projected spring and summer runoff are sufficient to meet the calculated demand. Streamflow predictions from the gauged location nearest the diversion supplying irrigation water to the farm are used in this step.

Streamflow forecasts at three different levels corresponding to 90 percent, 50 percent, and 10 percent exceedance probabilities are input to the IWM program. These values are translated into probable onfarm water deliveries that can be compared with the calculated water demand. If there is an imbalance, the user is allowed to iterate through the program to try alternative cropping patterns that correct the imbalance.

STAG

This program was principally designed to aid snow survey program personnel in their task of quality assurance associated with operation and maintenance of SNOTEL remote sites. STAG is simultaneously an online data base manager and analysis routine for examining the relationship between telemetered SNOTEL data and corresponding ground truth measurements made in the field by observers. Users are allowed to stratify the data in a variety of ways using predefined keys and perform statistical analyses on the homogeneous groups selected. This program provides a readily available tool to study and evaluate not only the performance of the telemetry component but the physical sensors, ground truth measurement techniques, and reliability of the system as a whole. It has been particularly useful to determine estimation relationships between telemetered snow pillow data and co-located snow courses.

Output from the program consists of summary listings, scatter plots, linear regression analyses, and normal probability error residual plots. Output is in either 80 or 132 column format and can be directed either to the user's terminal or a temporary print file.

STAG is not simply a technical tool; it is also a valuable management tool. It permits SCS program managers to review the performance of organizational units within their jurisdiction. It provides a means for verifying the accuracy and viability of the SNOTEL

system's components. It also affords a means of convincing cooperators that SNOTEL data can be used with confidence, and that it is beneficial for them to begin incorporating it into their operations.

FEAR

FEAR is an acronym for Forecast Error Analysis and Review. The FEAR program is similar to STAG in that it is a key element of the SCS's quality assurance and evaluation process for streamflow forecasts. Like STAG, FEAR consists of a data base and analysis routines. The current data base consists of 50,000 historical streamflow forecasts from 11 states together with their post prediction verifications. This is the largest data base of its kind in the U.S. It is updated annually as published streamflow data become available.

FEAR is the primary analytical tool being used to help discern trends in forcast skill. It is being applied to identify and prioritize forecast procedures in need of updating. It is just as important to know which forecast procedures cannot be improved as to know which ones can and should be. FEAR allows hydrologists to look at past performance and make rational judgments as to what accuracy level is attainable in hydrologically similar regions. Examination of FEAR output can also be useful in assessing the adequacy of present and projected data collection networks. A report by Shafer and Huddleston (1984) described results of utilizing FEAR to analyze seasonal volume forecast accuracy in the Western United States over the past 50 years.

Output products from FEAR include simple descriptive statistics, summary tables, error histograms, and probability plots. The program is sufficiently flexible to permit analyses to be conducted for specific forecast points, dates of forecast, seasonal forecast period, and years of interest. The data base is currently structured by states and does not allow aggregation by major river basins. Output can be sent to a user terminal or to a designated print file.

One recent application of FEAR illustrates its value. The job at hand was to calculate the intervals required to produce reasonable maximum and reasonable minimum forecasts from the most probable forecast at over 400 points in the West. This task was accomplished in a very short time by retrieving all available forecast errors, sorting them by month, station, and forecast period and performing a probability analysis on the historical errors. Forecast error values at 10 percent and 90 percent exceedance levels were obtained and compared with standard errors of the estimate of existing forecast procedures where they were available. These data were regionalized to finally arrive at the desired figures now in use.

XREF

This program enables users to examine cross reference files ordered by state and scan lists of stations according to the type of data measured. Information is provided, if available, on site name, site ID, elevation, latitude, longitude, section, township, range, and Standard Hydrologic Exchange Format (SHEF) ID. XREF is a temporary expedient to help users locate stations of interest in a general geographic area. It will eventually be replaced by a combination of report retrieval capabilities in the CFS operational data base and a yet to be developed SNOTEL site biographic data base.

MDMS

The Manual Data Management System (MDMS) program is a holdover from a former period when CFS did not exist. It contains data on a monthly time step for snow courses, precipitation stations, reservoirs, and stream gauging stations. Data are organized by state within the MDMS data base. A number of report retrieval routines are available to generate full station summaries, abbreviated summaries giving extremes and averages, and user defined basin lists. Several sorting and simple correlation routines are also supported.

MDMS is also a temporary fixture; all data held there will be eventually transferred to the ODB. Functionally equivalent report retrieval and file manipulation routines found in MDMS will be developed to run against the ODB. Completion of this task is not expected until 1987.

UTILITY PROGRAMS

There are two categories of utility programs in CFS at different menu levels. The

first menu level contains system utility routines. It can be accessed using the command UTIL. The second set of utilities are devoted to performing statistical analyses. They can be accessed by entering the command ANAL from the menu list that appears when the CFS command is invoked from the first menu.

ANAL

Utility routines found here include a Log Pearson III frequency analysis program, various character plotting routines, several probability analysis functions, and a suite of simple and multivariate regression programs.

All of these utility programs are designed to facilitate screening hydrologic data, making interpretations and developing new forecast procedures. In most instances, some form of graphical output is displayed to help the user visualize the analysis results. Except for the character plot routines, most graphical displays are designed to be output to Tektronix graphics terminals.

UTIL

Under UTIL the user is given the ability to do three tasks: print a file; exchange mail messages; and perform file maintenance. The file printing option is invoked by entering PRT. This option allows a user to list all the files in his directory including print files that may have been created during the current work session. The user is then queried for the file he wishes to display or download to his remote site.

Choosing the MAIL option allows users to view messages sent to them by other users or snow survey personnel, send messages to other users or CFS system monitors, and discard old messages. The MAIL routine also permits mail to be sent to designated groups of users simultaneously. This facility is very efficient for SCS personnel to communicate perishable information rapidly between offices.

The last utility option is invoked by entering the command FILES. This action produces a list of filenames in the user directory one at a time; the user is queried as to whether or not each file should be deleted. Unnecessary files must be removed periodically by this method or the directory space allocation will be exceeded and resident files will be lost. Lack of available directory space will also cause an abnormal termination of a CFS session.

USER ACCESS

Users wishing to access CFS need only submit a letter of request to an SCS office or to snow survey program personnel and enter into a simple agreement. Logon ID's and passwords are issued upon enactment of the agreement. The same agreement form is valid for both SNOTEL and CFS. Access is open to all governmental agencies and the general public. No fees are currently charged for normal accessions and none are projected for the near term. A nominal cost recovery fee is levied for major data base dumps that require special handling or involve substantial personnel costs.

CFS is designed primarily to accommodate interactive asynchronous traffic. CFS presently accommodates forty asynchronous communication lines. Twenty-four Paradyne* modems enable users to access CFS at 300, 1200, or 24000 bps from commercial or FTS telephone lines. The Paradyne modems support the Microcom* MNP, hardware enabled, error checking protocol. There are also sixteen asychronous ports available on DEPNET lines. DEPNET supports a range of transmision rates using X.25 packet switching transmission protocol with error checking.

The MNP error checking protocol mentioned above will aid in implementing the Standard Hydrologic Exchange Format (SHEF) software. This capability is planned for introduction in CFS in 1987. Software conversion and the porting of a SHEF decoder are scheduled for 1986.

SUMMARY

A Centralized Forecasting System (CFS) has been developed and implemented on a minicomputer at the Soil Conservation Service's West National Technical Center in Portland, Oregon. This system is SCS's primary focal point for snow survey data collection, data exchange and product dissemination in the Western U.S. CFS is designed to support a number

of functions including streamflow forecasting, interagency coordination, data base management, hydrologic modeling, report generation, conservation applications programs, and data quality assurance. It is an integral part of the agency's overall effort to rely more heavily on automation at all organizational levels to increase productivity. This system is intended to expedite delivery of hydrologic data and interpretive products to local users where they can be incorporated into comprehensive conservation planning programs.

CFS supports snow survey and water supply forecasting activities in 11 western states. It consists of a single large operational data base and several smaller data bases. It also has a variety of application and analyses programs that are readily accessible to the public. The system is designed primarily to serve interactive users but it does support limited syunchronous communication. Up to 64 simultaneous users can be accommodated. CFS is continuing to evolve but it is already a functional and viable system that is filling a need for timely and dependable services.

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*Reference to any manufacturer's product does not imply an endorsement or recommendation by the Soil Conservation Service.

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