PART 1. BASIC CONSIDERATIONS

CHAPTER 1. STATIONS; STATION NETWORKS

1.1 Purposes of Station Data

Stations and their networks are established for a primary purpose or type of application, although other applications may also be served. The main purposes of fire-weather (or fire-danger-rating) stations, hydrological monitoring stations, climatological stations, evaporation stations, and air quality monitoring stations are self-evident. The station and network configurations should thus be adapted to user requirements. These requirements will govern what weather elements are measured (for example, fire-weather stations ordinarily do not measure barometric pressure; basic climatological stations measure only temperature and precipitation). These requirements also determine the acceptable instrumental response and accuracy, although there are minimum standards.

1.2 Representativeness

In serving a need, weather stations must, individually or collectively, represent conditions occurring over a designated area. Network data should adequately reveal spatial variations and patterns, besides their possible use for interpolations and calculation of areal mean values (see section 1.3). While they may contribute to a larger area representation, the individual stations are usually intended to also represent a specific location or type of location. In some cases, as in site-specific research or monitoring, the required representative area may be quite small. Usually, however, a station's data are applied to many tens of square miles, if not hundreds of square miles.

Station adequacy may vary depending on what weather conditions or parameters are represented. Among individual parameters, windspeed and wind direction can vary greatly within small distances, as can precipitation. In contrast, afternoon temperature and relative humidity (away from sea-breeze zones or timber canopies) tend to show much areal similarity (at similar elevations) or a usable correlation with elevation.

For fire-danger rating, indexes integrating the weather factors are intended to represent "average worst" conditions, as would be experienced in an open area on a lower south-facing slope—where at least the afternoon fire-danger indexes tend to be relatively high. Because of convenience constraints, this open area at manual fire-weather stations has generally been in a valley bottom near an administrative or field office, where observers are close by.

COMPARABILITY OF STATION DATA

To best fulfill their purpose, it is important that the observed data are comparable among stations in a network. Thus, instrumentation standards and measurement techniques must be similar at all stations; likewise, standard siting and exposure criteria must be adopted. Daily observation times, at which current and 24-hour data are observed, must also be similar. In addition, data from a particular type of network should, as much as possible, be comparable with data from other networks; this will maximize the use of often scarce data for a variety of applications. For example, fire-weather data may fill gaps in the National Weather Service (NWS) climatological station network.

1.3 Network Designs

In establishing or modifying networks of weather stations, there are at least two major questions that arise: (1) What is the minimum number of stations required for adequate data sampling? and (2) where should the stations be located? When budgetary and personnel constraints may force the closure of one or more stations in an existing network, the immediate question becomes which station(s) should be closed; usually, a decision having the least impact on the data sample is sought. The answers will depend upon what is being measured, the type of equipment and the the purpose of the stations, the resolution or accuracy required, and logistical constraints such as accessibility.

Stations within a network may be used to obtain areal averages of weather or fire-weather conditions, but this is usually not sufficient. The stations should also sample the areal variability of conditions, while representing conditions for adjacent and similar subareas. Similarity here refers to topography and ground cover (for example, timber cover and fuel types). It may also be important that the stations enable reliable interpolations of weather or climate at other points.

Several approaches or methods have been used or explored for designing or modifying station networks. To date, in practice, the approaches have been mostly intuitive or subjective, or guided by logistics. These approaches have been the only recourse, given both the lack of information required for objective methods and the practical siting constraints; these constraints have lessened with the advent of remote automatic weather stations (RAWS). Objective methods have been described or reviewed by Fujioka (1985; 1986), Furman (1975), King and Furman (1976), and Munn (1985).

OBJECTIVE METHODS

As outlined by Munn (1985), the three principal objective methods are (1) statistical, (2) modeling, which can be used when the physical systems and spatial weather or climatic patterns are understood, and (3) statistical-modeling (combined statistical and modeling). Statistically derived network designs may be based on the accuracy of interpolated values at points between stations (Munn 1985, citing the method of Gandin 1970). Information required may include numerical values of a "space structure function" (related to the spatial pattern or gradient of a weather parameter) in the region of interest, the variance of errors in station data, and the maximum acceptable interpolation error. Solution of equations will then give a maximum acceptable distance between weather stations, from which the minimum number of stations within a numerically defined area can be calculated.

Acceptable errors in daily spatial mean values of the NFDRS Burning Index (BI) formed the basis for maximum station spacings calculated by King and Furman (1976). The greater the BI diversity found among the actual stations sampled, the larger was the number of required stations. Equations utilized the estimated and "actual" BI values for each test day, together with the estimated spatial variance.

These statistical approaches give uniform station spacings, which, of course, can only be used as an approximation in mountainous terrain. Aside from the terrain logistics involved, even for remote automatic stations, certain assumptions or simplifications present problems. For example, interpolation-based methods as just described assume that spatial weather correlations are related only to horizontal distances between stations or points. Fujioka (1985) emphasizes that aspect, elevation, and other characteristics should also be considered.

A design method presented by Fujioka (1985), of the combined statistical-modeling type, considers the climatology and other available information to construct a "target field"—a model of the spatial variability of a weather parameter during a critical period. The data user has an essential role in defining the critical periods, the weather parameters (or variables) used in the decision process, and the area in which the network will lie. A computer evaluates different network designs by estimating the target field, given a particular network arrangement, and comparing the result with the "actual" target field. The error information is used to find better station locations, and the evaluation is repeated until the locations chosen minimize the analysis error.

Fujioka (1986) presents an application of his design method, generating a statistically optimum fire-weather station network for a southern California area. This network is based on a target field representing a Fire Weather Index (calculated from the dry-bulb temperature, relative humidity, and windspeed) during Santa Ana (warm, dry, downslope wind) conditions. These conditions create the greatest fire potential in that area. Fujioka (1986) concluded that further study is required on both the practical and theoretical implications of the network designs that are generated. One important aspect requiring further work is that of defining the target fields.

PRESENT STATUS; SUGGESTIONS

As indicated above, no definitive objective approach is as yet available for network design. Even if a truly optimum station placement were to be generated, suggested relocations of existing stations would be questionable from the standpoint of data continuity. Where new stations are to be added, in the case of RAWS, experience of local personnel and primary representation purposes will be key considerations. Additional stations should ideally contribute maximum information not available from already existing stations. Differences in vegetation types may indicate locations with distinctive differences in some of the weather variables. In mountainous areas, station networks should ideally include stations in a variety of terrain situations, such as valley bottom, slope, and ridgetop. The resulting data, besides revealing variations important for management decisions, will contribute to models that attempt to describe a three-dimensional pattern such as a target field.

CHAPTER 2. STATION TYPES; SITING

2.1 Manual-Type Weather Stations

Traditional, manual-type weather stations (hereafter termed manual weather stations) provide data through the presence of an observer who reads the instruments at scheduled times, enters the data on appropriate forms, and, as required, communicates the data to a central office on a delayed or current basis. The data are obtained on-site—from direct-reading instruments (such as liquid-in-glass thermometers and a "stick" rain gauge) and from mechanically recording instruments (such as a hygrothermograph and a weighing rain gauge)—or in a nearby office through electrically connected readout devices. These devices include dials and strip charts.

Manual weather stations vary in their instrumentation, depending on their purpose. These stations (apart from those staffed by the NWS or the Federal Aviation Administration for primary forecasting and information services to the public) fall into three main types (and networks). These are: (1) climatological stations, as in the NWS extensive network of substations (cooperative stations) reporting only daily temperatures and precipitation, (2) evaporation stations, and (3) fire-weather stations. Additional manual stations are operated to provide weather and climatic data for a variety of research and monitoring needs. Some details, focusing on fire-weather stations, will follow.

2.2 Manual Fire-Weather Stations

INSTRUMENTAL EQUIPMENT

To provide the data necessary for computing fire-danger rating (NFDRS) indexes, a fire-weather station should contain the following basic equipment. More specific forms of equipment for a "standard" fire-weather station are listed in section 6.1.

1. Dry- and wet-bulb thermometers (psychrometer).
2. Maximum and minimum thermometers.
3. Instrument shelter for housing the thermometers.
4. Anemometer and windspeed readout device (mechanical counter, buzzer, or flashing lamp).
5. Wind vane and possible direction readout device.
6. Fuel moisture sticks and scale.
7. Nonrecording ("stick") rain gauge.

A hygrothermograph and recording rain gauge will help further, providing daily maximum and minimum relative humidity values and duration of precipitation, respectively. They also provide a check of the basic thermometer and rain gauge readings.

OBSERVATIONS AND TRANSMISSION OF DATA; AFFIRMS

Instruments at standard fire-weather stations throughout the United States are read once daily at either 12 noon or 1 p.m. (1200 or 1300), local standard time (l.s.t.). Some of the data are values for the preceding 24-hour period; these include the maximum and minimum temperatures, maximum and minimum relative humidity, and the precipitation amount and duration (Deeming and others 1977). The data are manually encoded and transmitted by telephone or radio to a central office (such as a National Forest Supervisor's Office) or a subcentral office. There, the data are entered by computer terminal into the Administrative Forest Fire Information Retrieval and Management System (AFFIRMS). AFFIRMS (Helfman and others 1987) is a user-oriented, interactive computer program that enables the display of data and computed fire danger indexes at any terminal in the network. A major function of AFFIRMS is the automatic archiving of the daily observations, which become part of the National Fire Weather Data Library, Fort Collins, CO (Furman and Brink 1975).

LIMITATIONS

The traditional, manual fire-weather stations have been a valuable source of data since their inception in the 1920's. Certain inherent limitations are, nevertheless, recognized, pertaining to station location and number of daily observations. Manual stations have usually been located on the grounds of ranger stations or similar field offices, where observers are conveniently available; also, mostly in the past, at fire lookouts. Particularly in the mountainous Western United States, and with the phase-out of lookout weather stations, the available data often will not indicate the conditions on higher terrain and other pertinent areas. Further, the data from the now once-daily standard observation may not adequately describe a day's important weather features, particularly wind conditions. During fires or other critical situations, personnel may not always be available to read the weather instruments and transmit the data.

Such limitations have led to the development and deployment of remote automatic weather stations (RAWS) (Warren and Vance 1981). These stations are adapted to serve fire-weather and other resource management applications.

2.3 "RAWS" and Other Automatic-Type Stations

The term RAWS refers specifically to the remote automatic weather stations adopted for operational use by the BLM, FS, and NPS. The present units are procured from Handar, which meets agency specifications originally developed by the BLM and FS in 1978. Commercially produced RAWS were first installed in that year and operated for field evaluation. The early RAWS units were procured from LaBarge, and a few of these remain in use.

RAWS units enable much flexibility in the location of weather stations, whether for permanent or semipermanent installations or for temporary use, such as near fires or project work sites. These electronically operated stations are powered by batteries charged by solar panels. The processed data are automatically transmitted via satellite to a downlink such as the BLM's direct readout ground station (DRGS) at Boise, ID. Here, a computer transfers the data to AFFIRMS. Users can access the latest AFFIRMS store of data via commercial telephone connection to a computer terminal or printer (section 38.4). Data can also be retrieved directly from a RAWS platform, appropriately equipped, via telephone or radio links. RAWS data are normally available for each hour of the day and night, adding greatly to knowledge of weather affecting specific problem areas and to the general knowledge of mountain meteorology and climatology.

Other automatic weather stations are available from more than a dozen companies. These stations, referred to as AWS, are similar in many ways to RAWS but generally do not transmit their data via satellite. The various AWS units may be used in either remote or nearby locations. Their data may be retrieved via local cable connection to office devices and displays; by telephone, radio, or infrared links; or on a delayed basis from cassette tape, solid-state storage modules, or strip charts.

2.4 Other Station Configurations

As previously indicated, automatic stations find use in applications besides fire weather. With the same basic complement of sensors and appropriate additions, RAWS and AWS can be used for various resource management needs, environmental and hydrological monitoring, and research purposes. (Further details are given in section 37.1.) Manual stations for these applications generally use the fire-weather configuration with appropriate additions or omissions. A basic (NWS) climatological station consists only of the maximum and minimum thermometers, mounted in an instrument shelter, and a precipitation gauge. To these, an evaporation pan and its accessories are added at a standard evaporation station; a recording precipitation gauge, psychrometer, and soil thermometers may also be added.

2.5 Site Selection Standards

The following rules should govern the location of a standard fire-weather station, whether a manually operated station or RAWS. The rules apply also to other weather stations.

1. *Locate the station in a place that is representative of the conditions existing in the general area of concern.* Consider vegetative cover, topographic features, elevation, local airflow patterns, etc.

2. *Select a site that will provide for long-term operation and a relatively unchanged exposure.* Consider site development plans—for example, roads, buildings, and parking areas; growth of nearby vegetation; observer availability;

and site accessibility during the intended operational period.

3. *Arrange the station so as to obtain data that are representative of the specific area in which the station is located.* Consider exposure requirements for each instrument in relation to factors such as (1) prevailing wind, (2) obstructions to wind, precipitation, and sunshine, (3) vegetative cover, (4) nearby reflective or radiative surfaces, and (5) topography.

In accordance with the above rules, the following situations should be avoided when selecting a station site:

1. *Sources of dust* such as roads and parking areas. If these are unavoidable, locate the station at least 100 ft away on the prevailing windward (upwind) side of the source.

2. *Sources of surface moisture* such as irrigated lawns, pastures, gardens, lakes, swamps, and rivers. If these are unavoidable, locate the station several hundred feet windward from the source.

3. *Large reflective surfaces* such as white painted buildings; also, natural reflective surfaces such as large rock surfaces. If these are unavoidable, locate the station on the north side of the surface, far enough away to avoid artificial shading (a distance equal at least to the height of the reflective surface or 50 ft, whichever is greater).

4. *Extensive paved or blacktopped areas.* If these are unavoidable, locate the station at least 50 ft to the windward.

5. *Large buildings, trees, and dense vegetation.* Locate the station at a distance at least equal to the height of the obstruction.

6. *Distinct changes in topography* such as hummocks, gullies, peaks, ridges, steep slopes, and narrow valleys.

Additional exposure precautions may be necessary for precipitation gauges (section 18.1), to avoid gauge-catch losses due to wind.

CHAPTER 3. GENERAL REQUIREMENTS OF EQUIPMENT

3.1 Characteristics of Instruments

DESIRABLE CHARACTERISTICS

As stated by the World Meteorological Organization (1983), the most important requirements of meteorological instruments are:

1. Reliability.
2. Accuracy.
3. Simplicity of design.
4. Convenience of operation and maintenance.
5. Strength of construction.

These attributes apply to both manually (or mechanically) and electronically operated instruments. In certain ways, some of the characteristics may be related, while others may require compromises. In addition, cost is certainly an important factor in the actual selection of equipment.

Reliability refers to the maintenance of accuracy over a long period of time and also to continuous performance without loss of data—in the case of instruments with mechanical parts, clocks, and electrical or electronic components. Simplicity of design generally promotes convenience of operation and maintenance and may favor long-time, problem-free operation. This is particularly important where stations are remote from repair facilities. On the other hand, simplicity of design may compromise accuracy or resolution. Resolution refers to the readability of data in fine numerical increments.

Sturdy construction is particularly important where stations are operated in severe or extreme weather conditions, such as powerful winds and riming. Under these conditions, compromise may again be necessary, as a rugged anemometer typically has a higher starting (threshold) speed than a sensitive instrument required for certain applications.

RECORDING INSTRUMENTS

Continuous-recording instruments at manual weather stations have commonly employed charts on clock-driven cylinders (drums); the chart record consists of an ink trace from pens linked to the sensing elements. Instruments of this type include those used to record temperature, relative humidity, precipitation, solar radiation, and barometric pressure. Other recorders, mostly for wind direction and speed, employ a strip chart moving between reels; traces on some of these are produced by inkless pen contact with pressure-sensitive paper.

Linkages in recording instruments should be as free as possible from friction, which would dampen the sensor responses; likewise, pressure between the pen and paper should be adjustable to a minimum consistent with a continuous legible trace. Calibration adjustments, determined from comparisons with accurate direct-reading instruments, should be easily and smoothly accomplished with a thumbscrew or other device.

Chart Drives—The chart drive mechanism, which turns the chart drum, most commonly employs a spring-wound or battery-operated clock movement. Newer mechanisms available on some Belfort instruments employ a stepper motor governed by a battery-operated quartz-crystal oscillator.

The clock is either located inside the drum (turning with it) or fixed to the base of the instrument. In the latter design, the drum revolves around the clock. This arrangement makes it easier to eliminate backlash, which can cause timing errors. It also lessens the risk of jarring the clock when charts are changed, since only the drum is removed. Further, when the drum is brought indoors to change the chart during cold weather, the clock can remain in place outdoors; this avoids possible condensation on the clock surfaces and resulting problems.

3.2 Accuracy Standards

The term "accuracy" refers to the closeness to which an instrument reading approaches the true value. Errors can result from the instrument calibration (or shifts in calibration) and from instrument lag during changing conditions. Apart from instrument error, individual readings may suffer from parallax error by the observer when the line of vision is not at right angles to the scale (particularly the scale of a thermometer). Further details concerning accuracy are given by the World Meteorological Organization (1983).

For the purposes of this handbook, instrument accuracy standards are concerned mainly with calibration. The accuracy, specified in various instrument catalogues, typically varies along the instrument's range or scale.

MANUAL-TYPE EQUIPMENT

The following accuracy standards are suggested for manual-type instruments used for fire-weather, climatological, and hydrological purposes. The standards are based largely on values from the World Meteorological Organization (1983). Errors should not be larger than the following (plus or minus) values:

1. Dry bulb and wet bulb thermometers	± 0.3 °F
2. Maximum and minimum thermometers	0.5 °F
except minimum thermometer, below 0 °F	1.0 °F
3. Hygrothermograph temperature	1.0 °F
4. Hygrothermograph relative humidity,	
at 20-80 percent	3 percent
at extremes	5 percent
5. Relative humidity, calculated from dry and wet bulb	3 percent
6. Wind direction	10 degrees
7. Windspeed	1 mi/h
8. Daily precipitation	0.01 inch
9. Daily evaporation	0.01 inch
10. Fuel temperature	1.0 °F

RAWS EQUIPMENT

Some accuracy specifications for sensors at automatic weather stations may be stricter than those listed above (see section 44.2). Sensors for RAWS units, supplied by Handar, have the following specified accuracy:

1. Temperature	± 0.2 °F
2. Relative humidity,	
0 to 80 percent	2 percent
80 to 100 percent	5 percent
3. Windspeed	0.25 mi/h or 2 percent of value
4. Wind direction	2 degrees
5. Tipping bucket precipitation	0.01 inch at rate of 2 in/h
6. Solar radiation	5 percent
7. Barometric pressure	0.02 inch

CHAPTER 4. RESPONSIBILITIES

Typically, different personnel are involved in the installation, observations, and technical maintenance at a weather station. As explained in the Introduction, this handbook treats these tasks pertaining to manual weather stations in three separate parts.

4.1 Installation and Maintenance

Installation of Bureau of Land Management RAWS equipment is performed by personnel from the BLM RAWS Support Facility, located at the Boise Interagency Fire Center (BIFC). Most of the Forest Service RAWS installation is done by agency personnel, with technical support and advice from the BLM RAWS Facility.

The BLM's maintenance organization (chapters 42 and 43) provides much of the maintenance, on contract, for the Forest Service RAWS equipment. At present, most of the contracted FS maintenance is of the "depot" or bench type, which covers repair and calibration of equipment. Forest Service personnel are responsible for field (or preventive-type) maintenance and for transporting equipment to the depot facility at BIFC. Beginning in 1988, under a new agreement, all FS RAWS will receive BLM depot maintenance; the BLM will also perform a "watchdog" (quality-control data monitoring) service on all data downlinked at Boise. A smaller number of Forest Service stations have contracts for "full-ride" maintenance, which includes field maintenance (USDA FS, Pacific Northwest Region, RAWS Work Group 1987).

Equipment at manual stations likewise should be installed by qualified personnel, who may be on staff at district or central headquarters of an agency. In the past, installation of fire-weather equipment was often done under supervision of the National Weather Service. Simple, daily maintenance can be done by trained observers, but technical maintenance in the field or at a workbench facility should be performed by agency specialists or contracted to local shops (chapter 29).

4.2 Observer Requirements

Observers at manual stations of the BLM, FS, and NPS are typically persons with specialties outside the field of weather (meteorology). As a prerequisite, therefore, training should be provided to foster proper skills and awareness in observing practices; familiarity with instruments and simple maintenance measures should be included. For best results, the training should be through formal courses, conducted either through correspondence or at a central location. Periodic refresher training and contact with other observers is also advisable (World Meteorological Organization 1983).

Observer responsibilities include the following tasks (further details are contained in various chapters of Parts 2C and 2D):

1. Making the required observations at the required times with the required accuracy.
2. Encoding and logging or dispatching the data as necessary; actual transmission of data, by radio or telephone, may be the task of another person.
3. Changing the charts of recording instruments on scheduled days; maintaining proper inking of pens.
4. Performing calibration checks of recording instruments and making simple adjustments as necessary.
5. Maintaining the instruments in good order. This includes daily or periodic external dusting and cleaning of instruments (with water or cleaning solvent as necessary) to maintain easy readability of marked graduations, maintain free movement of linkages on recording instruments, and deter corrosion.
6. Noting instrumental defects, such as column separations in thermometers; applying simple corrective measures or reporting to supervisor for further action.

4.3 Management

This section describes the responsibilities for managing a network of weather stations. Specific details are given for the Forest Service, but an analogous order of management exists for Bureau of Land Management and National Park Service stations.

Within the Forest Service, Fire Management has retained the overall management of manual stations and the RAWS network at both the Regional and Forest levels. At the Forest level, the station programs are managed, in most cases, by the Supervisor's Office fire organization; here, the Forest Dispatchers and Assistant Fire Staffs have chief responsibility. At the District level, either the Fire Management Officer or other key personnel are responsible for management or assisting in management (USDA FS, Pacific Northwest Region, RAWS Work Group 1987). As recommended by the RAWS Work Group, this general arrangement should continue with appropriate staffing as the role requires. Establishment of a RAWS regional information sharing exchange, with assigned responsibilities, is also recommended. Interagency sharing of information is an additional goal.

CHAPTER 5. DATA MANAGEMENT

As discussed here, data management refers to steps or treatment measures taken with the weather data after their collection (observation) and transmission/retrieval. The data collection and means of retrieval have been described earlier (sections 2.2 and 2.3) and will be covered in greater detail in succeeding chapters and in appendix 6. Beyond these fundamental requirements, management pertains to storage (of retrieved RAWS data), quality control, archiving, and display and use of the data. The use of data refers to its analysis, particularly by computer processing, to obtain various statistical and graphical outputs (section 5.4).

5.1 Storage of Retrieved RAWS Data

Beginning in 1988, all RAWS data downlinked by the BLM at Boise will be automatically stored on computer tape; previously, only the BLM RAWS data were stored in this manner. Within 2 weeks following each quarter of the year, the BLM will send the RAWS data tape to the Western Regional Climate Center (WRCC), located at the Desert Research Institute, Reno, NV. Here, the data will be permanently stored and archived (section 5.2).

In the absence of automatic data storage, one of the most common methods of storing user-retrieved RAWS data has been to retain hard-copy, 24-hour printouts from AFFIRMS. The resulting data file, however, is not in an efficient form, particularly for data analyses. An alternate storage method has been to transfer ("dump") each day's data from AFFIRMS into a Data General (DG) computer file, or onto a hard disk of a personal computer that is interfaced with the DG system. This approach enables the user to build a data base and perform data analyses using a variety of currently available software.

5.2 Archiving of Data

As stated above, all RAWS data downlinked at Boise will be permanently archived at WRCC; previously, the BLM RAWS data were archived in a file maintained at BIFC. At WRCC, the RAWS data (for all 24 hours of the day) will be stored as received from the BLM. The data will also be converted to National Climatic Data Center (NCDC) format and archived for standard climatological use.

In addition, AFFIRMS will continue to archive the 1300 l.s.t. RAWS data in the National Fire-Weather Data Library (NFWDL), where all agencies' manual fire-weather data reside. The library is located at the USDA's National Computer Center at Fort Collins, CO (NCC-FC). For NFWDL archiving, the data must first be transferred or entered into AFFIRMS in NFDRS format. This transfer has been done automatically for BLM RAWS data, but until 1988 it was a manual process for FS RAWS data.

To more fully automate the NFWDL archiving, all RAWS data downlinked at Boise are now automatically transferred to AFFIRMS, which also performs NFDRS calculations. Without this automatic transfer, user-retrieved 1300 RAWS data (appendix 6) must be manually transposed to NFDRS format and then manually entered into AFFIRMS; the appropriate data are obtained from the listing retrieved shortly after the nearest 3-hourly RAWS transmission time (for example, near 1300 P.s.t.; 1400 m.s.t.).

The past dependence on manually entering FS RAWS data, for archiving in the NFWDL, has led to many missing daily records and provides an opportunity for error (USDA FS, Pacific Northwest Region, RAWS Work Group 1987). RAWS data from some locations were never archived. In areas with year-round RAWS operation, such as the FS Pacific Northwest Region, data from many stations have been archived only during the main fire season. The new arrangement, described above, should greatly reduce such problems.

5.3 Quality Control

Before they are archived, whether on paper forms or computer tape, weather data should be checked for possible errors. In the case of RAWS data, current AFFIRMS listings can be checked and corrections entered where necessary. Depending on the type of weather station or data collection system, several major sources of error exist. These include instrument error, observational error, and transmission or transcription error. (Poor exposure of sensors can also lower the data quality; thus siting and installation standards, outlined in section 2.5 and in later chapters, must be followed.)

In most cases, station data can be spot-checked or otherwise verified by the observer or persons involved in data entry or retrieval. Readings at manual stations can be compared with traces from recording instruments. In some cases, particularly with relative humidity, the recording instrument will be found in error. Data from a RAWS, if situated nearby, can be checked with manual observations.

Comparison with neighboring stations and knowledge of basic meteorology and local climatic conditions can help in detecting highly unlikely data values. Reasonable or acceptable values will vary with the particular weather situation and time of year. Quality-control results with this type of data checking will, unfortunately, vary with the individual's meteorological background and experience.

The RAWS data are checked by BLM watchdog procedures, which provide a daily computerized screening of data downlinked at Boise; further details are given in section 43.1. Prior to 1988, the watchdog service was limited mainly to BLM RAWS data.

National Weather Service personnel also monitor RAWS data, primarily for fire-weather forecasting, and may call the appropriate office if there appears to be a problem. In addition, data entered into AFFIRMS for archiving at the NFWDL undergo a screening program (Furman and Brink 1975). The acceptability criteria, however, are rather loose. For example, dry bulb temperatures are accepted between –99 and +136 °F; 24-hour precipitation, as high as 9.99 inches.

Questionable or missing data can be treated in several ways, ranging from taking no action to estimating or synthesizing replacement data. For purposes of fire-danger calculations or future analyses, it is better to relegate highly questionable data into the missing category than to leave the data "as is." When creating substitute data, one may interpolate from adjacent stations if such data are available, applying adjustments for known average differences (Finklin 1983). For RAWS data, information from the preceding hour or two may be used as the basis for corrections. Unless a storm has occurred, diurnal trends may be extrapolated from the typical hourly changes on other days.

5.4 Data Display and Use

Toward their application, station data may be displayed on a current basis, together with derivative parameters, on a computer screen or in printout form. Or a set of archived data may be summarized or analyzed by computer program.

DISPLAY OF FIRE-WEATHER DATA

Standard display formats are available in AFFIRMS (Helfman and others 1987) to display fire-weather data (RAWS or manual station data). A display including fire-danger rating outputs can be generated immediately after the RAWS or manual-station data have been entered into AFFIRMS. Custom display features can be utilized to track key outputs such as the various fuel-moisture parameters.

COMPUTER PROGRAMS USING ARCHIVED DATA

Programs discussed here are mostly those accessible at the NCC-FC. These programs apply to data archived in the NFWDL. Among programs or software available for applications with other data bases, most comprehensive is the CLICOM system (below), which can be used with a personal computer.

Programs at National Computer Center at Fort Collins—Several computer programs are available at the NCC-FC to summarize weather data from the NFWDL. A set of two programs was developed to aid fire managers in planning prescribed burning (Bradshaw and Fischer 1981a,b). These programs, RXWTHR (Prescribed Fire Weather) and RXBURN (Prescribed Fire Conditions), provide climatic probabilities of obtaining prescription conditions during successive 10-day periods of the fire season. Furman (1979) provides two programs, PRESCRB and MERG3, that also identify the most climatologically favorable 10-day periods for burning, with the additional consideration of smoke management.

The FIREFAMILY program (Main and others 1982) is a set of three major routines designed to aid a wide range of fire management planning. The FIRDAT routine produces frequency distributions, tables, and graphs of NFDRS indexes and components. It can also produce a list of daily weather, fuel moisture, and NFDRS outputs for convenient tracking of changing values.

Programs RXBUILD and RXFIRES (Bevins and Fischer 1983) examine both NFWDL data and archived fire report information to evaluate alternative prescriptions for unscheduled (naturally or accidentally ignited) prescribed fires. Qualifying fires are, in the computations, "allowed to burn" under prevailing weather conditions until extinguished by precipitation or until they burn out of prescription. The output information enables fire managers to assess how well various prescriptions meet prescribed-fire goals.

Another set of programs (Bradshaw and Fischer 1984) was designed to aid in a broad range of wildland management activities and research studies. These programs provide tables showing average values, standard deviations, extreme values, etc., in addition to probabilities (frequency distributions), of the basic weather elements. Programs can also adjust averages that are based on short periods of record or incomplete data.

These and other devised programs require a weather data base covering enough years to give a representative sampling, ideally at least 10 to 20 years, depending on the weather parameter (Finklin 1983). With the archived RAWS data covering only a few years, to date, the programs should at present be run only with manual data bases, or with combined manual and RAWS data at sites where a RAWS has replaced the manual station. The archived manual fire-weather data extend back to the 1950's for Forest Service Northern Region stations and to the 1960's in other Regions.

CLICOM System—CLICOM (Climate Computing) is a climatological data processing system that has become well established since its release in early 1986. CLICOM was developed at the NCDC under sponsorship of the World Meteorological Organization. Designed for use with a microcomputer (personal computer), CLICOM incorporates both commercial and NCDC software. The software includes a database management system and a comprehensive set of programs for summarizing and graphing climatological and related types of data. Processing includes quality-control (data-validation) procedures.

CLICOM was designed originally to serve needs in developing nations, particularly to help archive climatological data from old manuscript forms, and this goal is being implemented. But CLICOM has also become a standard component of official climatological operations in the United States. An improved version, designated CLICOM Version 2.0, was released in early 1988. The WRCC is in the process of installing CLICOM systems (Version 2.0) in each of the 11 State Climatologist offices in the Western Region. Although current users are mainly climatologists, CLICOM has a potential for a wider range of applications. Further details about the system can be obtained from:

National Climatic Data Center
Database Administration
Attention: CLICOM
Federal Building
Asheville, NC 28801-2696
Phone: (704) 259-0387 (FTS 672-0387)