REPORT ON THE SAN FRANCISCO BAY AREA STORM

JANUARY 3-5, 1982

PREPARED BY:

WESTERN REGION HEADQUARTERS
NATIONAL WEATHER SERVICE
SALT LAKE CITY, UTAH

SUMMER 1982

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PREFACE

In accordance with instructions contained in NOAA Directives Manual 28-17 and Weather Service Operations Manual, Chapter I-02, a National Weather Service Western Region Survey Team was dispatched to appraise National Weather Service operations, public response to NWS forecasts and statements, and damage in connection with the January 3-5, 1982, San Francisco Bay Area storm.

The Survey Team consisted of the following personnel:

Ronald S. Olson, Chief, Public Services, MSD, WRH, Survey Team Leader
Richard A. Wagoner, MIC/AM, WSFO, San Francisco
Dale A. Goudeau, Deputy MIC, WSFO, San Francisco
Norman Hoffman, Forecaster/Disaster Preparedness Program Leader, WSFO, San Francisco

Members of the team began their fact finding on January 6 and completed the field survey January 8, 1982. The main objective of the survey was to determine effectiveness of NWS services provided to the flood and mudslide stricken areas in the San Francisco Bay Area of California. To accomplish this the Survey Team examined the operations of the San Francisco WSFO and interviewed numerous state, county, and local officials, representatives of the news media, and local citizens.

A rain gage survey was conducted by the California-Nevada River Forecast Center (CNRFC) in conjunction with the California Department of Water Resources. A request for rain gage measurements of the storm in the Bay Area was made via the media and over NOAA Weather Radio. The excellent response included over 600 reports. Those reporting were asked to include information such as type of gage and exposure of the site to help assess the reliability of the report.

The rain gage survey idea was developed by Robert Burnash, Hydrologist in Charge, CNRFC and Don Neudeck, Chief, Flood Operation Branch, California Department of Water Resourses. The survey was coordinated by Ira Bartfeld, Flash Flood Hydrologist, CNRFC.

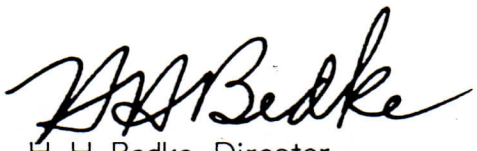
The Survey Team thanks all who kindly cooperated by consenting to interviews and freely giving information. Improvements in the National Weather Service's watch/warning program are dependent upon cooperation and feedback from the news media, public officials, and the general public.

FOREWORD

On January 3-5, 1982, a major storm moved through central California producing widespread damage and death in seven San Francisco Bay Area counties as well as eleven other counties in northern and central California. A Presidental Declaration was issued to bring federal assistance to individuals in the affected counties.

It is customary, following significant storm events, for the National Weather Service to evaluate the effectiveness of its forecast warning service. On January 6, 1982, a Regional Survey Team was dispatched to San Francisco, California. The team visited sites of heavy damage, interviewed federal, state, county officials, and citizens regarding actions taken in response to National Weather Service forecasts and Special Weather Statements.

The findings of the Survey Team reinforce the need for an effective forecast and warning system that disseminates information in a timely manner and elicits appropriate response by the public.



H. H. Bedke, Director
Western Region Headquarters
National Weather Service

EXECUTIVE SUMMARY

Prolonged heavy rain during the period from late afternoon January 3 through January 4, 1982, combined with the effects of recent heavy rains and high tides to produce widespread flooding and mudslides in the area around San Francisco Bay.

On January 7, 1982, the President determined that damages in the State of California were of sufficient magnitude and severity to warrant a major Disaster Declaration under PL 93-288. The counties included in this Declaration were Solano, Sonoma, San Mateo, Santa Cruz, Contra Costa, Alameda, and Marin.

The storm also produced heavy rains and very heavy mountain snows elsewhere in California. Eleven other counties in northern and central California were declared eligible for public assistance or for Small Business Administration assistance programs.

The most severe damages occurred in the hills and coastal ranges around the San Francisco Bay Area where flooding, mudslides, and debris flows destroyed many homes and businesses. Joint federal and state damage estimates indicated that 6,300 residences were damaged, of which 231 were destroyed. There were 1,500 businesses damaged with 65 of these destroyed. Dollar estimates of damage were 109 million to public facilities and 172.4 million to private property. There were 33 deaths, most of which were attributed to mudslides.

This report describes the meteorological conditions that resulted in the unusually heavy precipitation, the hydrologic conditions associated with the flooding and mudslides, operations of the NWS prior to and during this disaster, and the dissemination of forecasts and statements. The report also describes public response to forecasts and weather statements.

The major findings and recommendations of the Survey Team follow:

Finding

The potential for heavy rain and snow over northern and central California was recognized early by the WSFO San Francisco. A Winter Storm Watch was issued for the area 12-18 hours before the onset of precipitation. This was followed by a Winter Storm Warning and Travelers Advisories for many of the mountain areas 12 hours later. Statements issued on January 3 graphically described the changing weather pattern and the copious amounts of moisture moving toward central California.

Finding

On Monday, January 4, NWS forecasters' concerns were with the total heavy storm system. Nothing called the forecasters' attention to the severity of the local situations in the area surrounding San Francisco Bay. There were no obvious reasons to expect, or reports of, extraordinary precipitation occurring in the area. The Bay Area spotter network did not provide reports of heavy rainfall or mudsliding until the network was activated by a call from the WSFO during the afternoon of January 4.

Recommendations:

a. The San Francisco Area Manager and CNRFC HIC should continue to use every opportunity to work with county officials in the area to implement local flood warning systems, utilizing Automated Local Evaluation in Real Time (ALERT)[1]. ALERT systems would provide real-time telemetered event precipitation and stream data in critical areas to both the NWS and responsible government officials. The usefulness, to the NWS, of other governmental agencies' precipitation networks operating in the area should also be investigated.

b. Coordination with SKYWARN, a spotter network involving HAM radio operators, and other spotter networks should be improved. Specific criteria should be developed to ensure that cooperative participants and other observers initiate calls to the NWS when specific criteria is observed, rather than waiting for the NWS to initiate calls.

Finding

Communication channels with emergency services offices were not effectively utilized. NAWAS was not used by either NWS or OES officials. Many telephone lines were out during the storm. County emergency officials either did not have or were not aware of backup communications. The California OES has had a more restrictive policy on the use of NAWAS than other western states. This apparently has led to the system not being used for dissemination of weather-related warnings by the San Francisco WSFO.

Recommendations:

a. Expand the use of NAWAS for weather-related warning dissemination. An agreement should be reached between the NWS and the state OES, establishing guidelines for the use of NAWAS. All NWS watches and warnings should be broadcast over NAWAS with affected counties delineated. A procedure should be established for either the state OES designated control unit, or the issuing NWS office, to request an acknowledgment of warning receipt. A free exchange of critical information between the NWS and other emergency services and law enforcement agencies over NAWAS should be encouraged whenever a life-threatening, weather-related situation is developing or expected to develop.

b. Backup communications and telephone number check-out and update should be stressed during annual drills which are held prior to the rainy season.

c. An emergency backup communications system, such as a two-way radio, should be set up between the WSFO and critical emergency services offices.

Finding

WSFO forecasters did not assess the full impact of high soil moisture, high tides, and record rainfall. Potential damage from mudslides and local flooding is becoming increasingly acute as metropolitan and residential areas spread into the hills and flood-prone areas.

Recommendations:

[1] See Appendix (C) for detailed information.

a. WSFO San Francisco and the California-Nevada River Forecast Center should establish procedures for assessing the impacts of antecedent ground conditions on potential local flooding. The real-time advice and support of an operational hydrologist is an important ingredient in situation assessment and in the formulation of hydrologic advisories. This support becomes increasingly important in situations when data are scarce and flooding is occurring in areas where specific river forecast procedures do not exist. In these circumstances, hydrologists can and should provide significant assistance to meteorologists in the form of situation appraisals, judgments of storm impacts, and other advice. This draws upon the hydrologist's experience, technical knowledge, and general knowledge of the affected area. This level of support is especially important where WSFOs are not staffed with a Service Hydrologist.

b. Antecedent ground conditions should be available to WSFO San Francisco on a routine basis.

c. A program should be initiated, by state and county agencies with responsibility for public safety, to educate the public about flood-prone areas and areas susceptible to land slides. The NWS should assist in this effort.

d. WSFO San Francisco station drills should emphasize the importance of antecedent ground conditions and high tides as they affect local flooding.

e. County officials, many of whom in the past had doubted the need for preparedness for weather-related disasters in their area, should be revisited.

Finding

No hydrologic watches or warnings were issued during the storm. The public was well aware of the expected heavy rain in the area, and some were alerted to specific problems by NWS statements and by flood forecasts for the Russian and Napa Rivers. However, the public did not perceive the scope of the pending disaster, based on any of the NWS products.

The opinions expressed by the vast majority of the public and the media seemed to enforce the idea that this was such a rare event that no one could have foreseen the magnitude of it.

Recommendations:

a. The memory of the storm and the completion of recommendations under findings above should greatly aid the WSFO in recognizing the need for and public utilization of urban flood statements and flood or flash flood watches and warnings. These products should be written as site-specific as possible, detailing specific action to be taken by persons in threatened areas.

Finding

State-of-the-art equipment for relaying real-time precipitation data to the San Francisco Forecast Office should be obtained. Communication procedures with county emergency services offices should be more thoroughly developed, routinely tested, and used. The general feeling of the Survey Team is that the National Weather Service, overall, handled this storm very well. Its total storm forecasts and warnings for northern and central California were both timely and accurate. The NWS is judged to have performed effectively, when the rarity of this type of event in the San Francisco Bay Area is considered.

CHAPTER I

CAUSES OF DAMAGING EVENT

Continuous rain from late January 3 through January 4, 1982, produced up to 16 inches of rain in portions of Marin County and nearly 25 inches of rain in the higher elevations of Santa Cruz County. Rainfall rates were 1/2 inch to 1 inch per hour along the southwest slopes of Marin and Santa Cruz Counties and generally 1/10 to 1/2 inch per hour elsewhere in the Bay Area. It is notable that this intensity lasted nearly 30 hours, as compared to the more common 6 to 12 hours, at any one location, associated with most large storms moving through that area. Depictions of storm totals are shown on pages 3 and 4 with geographical references shown on page 5.

The heavy rains added moisture to the upper soils much faster than percolation could take place. Where steep, unstable slopes existed, the water-logged soils collapsed due to the fluidity of the saturated soils and the great weight of the rain water in the soil. Each acre of the wettest slopes, where over 24 inches of rain fell, received a rainfall mass which totaled in excess of five million pounds. The consequent stress on the slopes was too great and numerous landslides took place.

Although extremely high water was reported on numerous local streams, flooding directly from runoff was not the worst problem. The combination of slope failure and partial damming of streams by debris caused most of the damage. Damming of stream flow by a high tide also caused considerable flood damage. Above normal high tides coincided with maximum rainfall runoff, especially in the northern portion of the Bay Area, Monday afternoon, January 4. The high tide barrier caused streams to back up, flooding many populated areas that would have had only minor urban flooding if the streams had been able to flow freely into the bay or ocean.

CHAPTER 2

DESCRIPTION OF DAMAGES

The most severe damage occurred in the hills of the coastal range, where landslides and mud and debris flows destroyed many homes. Most damaged structures were in known floodplains or near the mouths of canyons. According to newspaper accounts, many residents, indeed many communities, became isolated when their access roads were either washed out or covered by mud. Hundreds of Marin County residents were stranded in San Francisco when Highway 101 was closed by slides. This road was only partially reopened for more than one week, hampering commuters. The community of Inverness (Marin County), population 1,200, was isolated for several days when numerous slides covered the road into town. Five hundred homes were inaccessible in the San Lorenzo River Valley area (Santa Cruz County), because their access road was damaged, and an estimated 1,000 residents in Brookdale, Boulder Creek, Felton and Scotts Valley (Santa Cruz County) were also isolated.

Thousands of people were evacuated from their homes because of slides or flooding. Six hundred people were evacuated in Sausalito (Marin County) after a slide killed one person and destroyed two homes. It was feared that new slides might occur that could destroy dozens more homes. Fifteen hundred residents in Vallejo (Solano County) were evacuated when the water level of Lake Chabot rose so quickly that officials became concerned about the safety of homes below the lake. One hundred families were evacuated in Boulder Creek (Santa Cruz County) due to the danger of more slides and flooding, and two hundred residents in Pescadero (San Mateo County) were evacuated due to dangerous flood waters.

Phone service was erratic throughout the entire disaster area for several days and longer in some areas. Water systems were badly damaged in Santa Cruz and the Inverness area of Marin County. Water rationing was in effect in these areas, which meant that many nonessential businesses and industries were shut down. Seventy-two thousand customers were without electricity in Santa Cruz. Six hundred fifty Pacific Gas and Electric customers were without electricity along the Marin and Sonoma Coast. There were scattered pockets throughout the entire disaster area that remained without power for days.

Unemployment was a problem because businesses were either closed or damaged, or employees could not get to their jobs because of flooding and other access problems.

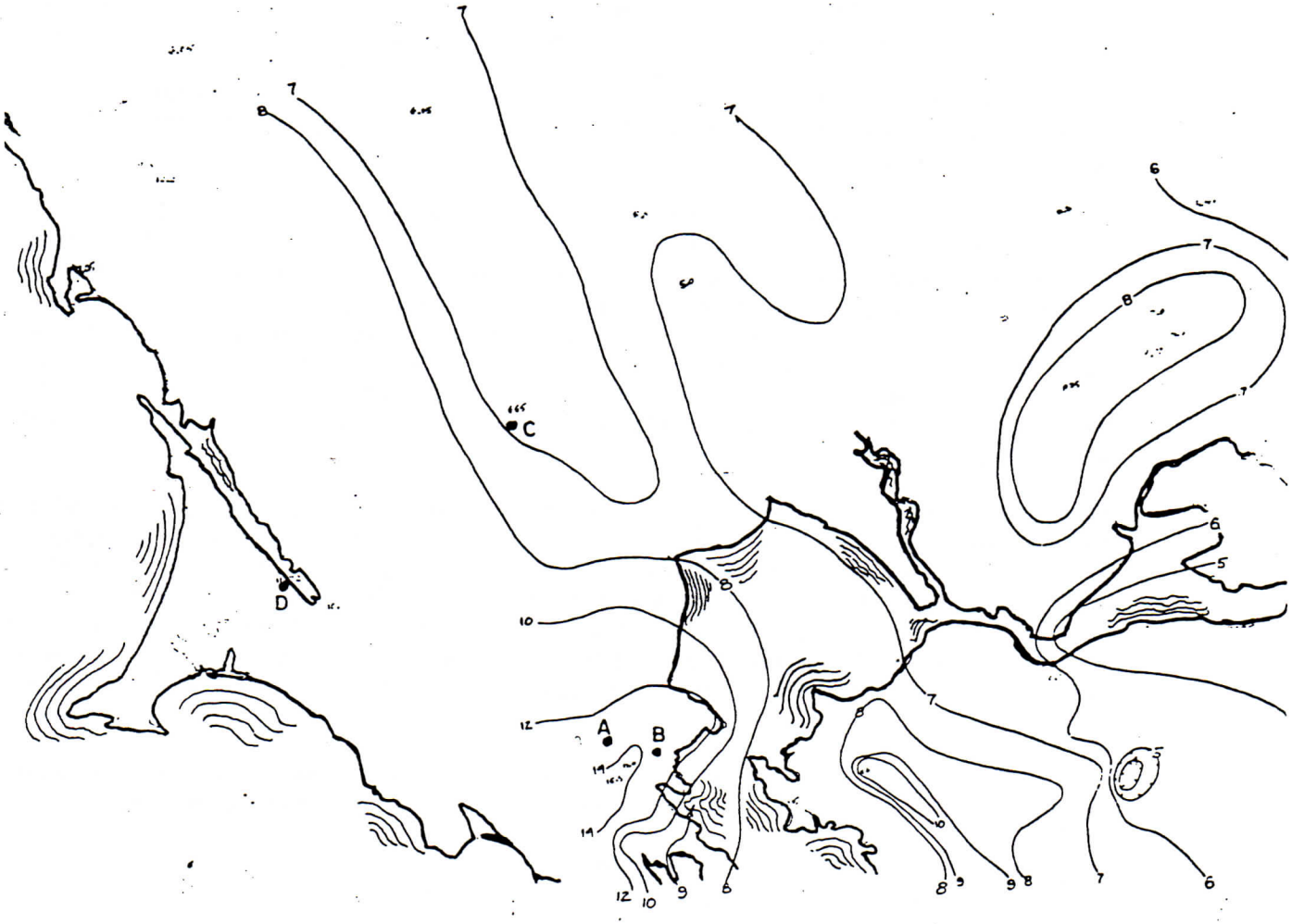
The FEMA/State Assessment Team approximated the damage at near $280 million. The private sector incurred $172 million and the public sector $109 million in damages.

Thirty-three people were killed during the disaster, 24 of whom were killed by landslides and mudslides.

Red Cross preliminary damage assessments indicated that 6,300 residences were damaged and 231 were destroyed. One thousand five hundred businesses were damaged and 65 destroyed, according to the State Office of Emergency Services.

Detailed reports on five of the more severely impacted local areas--San Lorenzo Valley, Corte Madera Creek, Inverness, City of Pacifica, and Petaluma, are included in Appendix A.

Figure 1
Storm Total Rainfall, January 3-4, 1982 (Inches)



KEY

A CORTE MADERA CREEK
B MARIN COUNTY CIVIC CENTER
C PETALUMA
D INVERNESS

Figure 2
Storm Total Rainfall, January 3-4, 1982

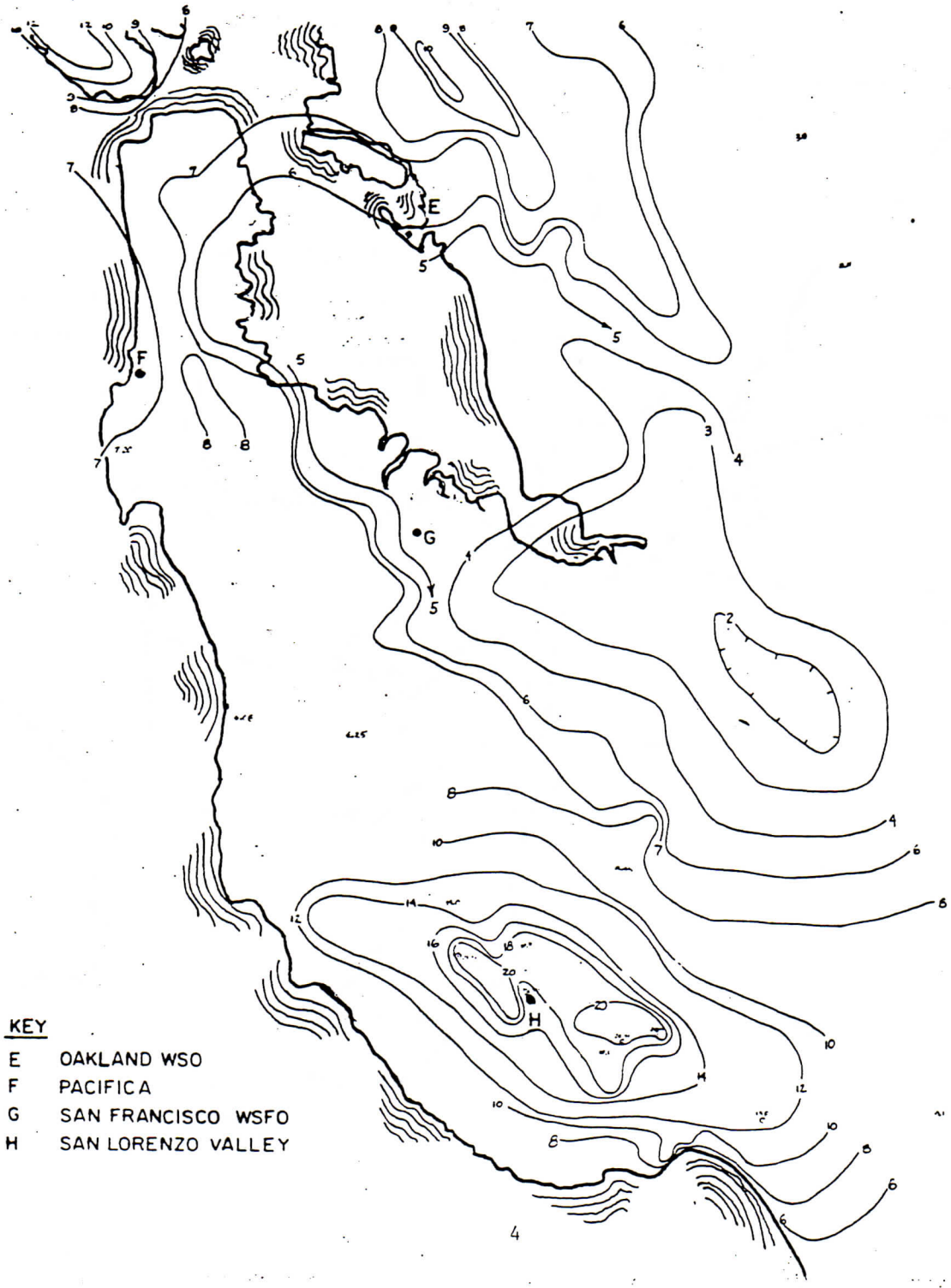
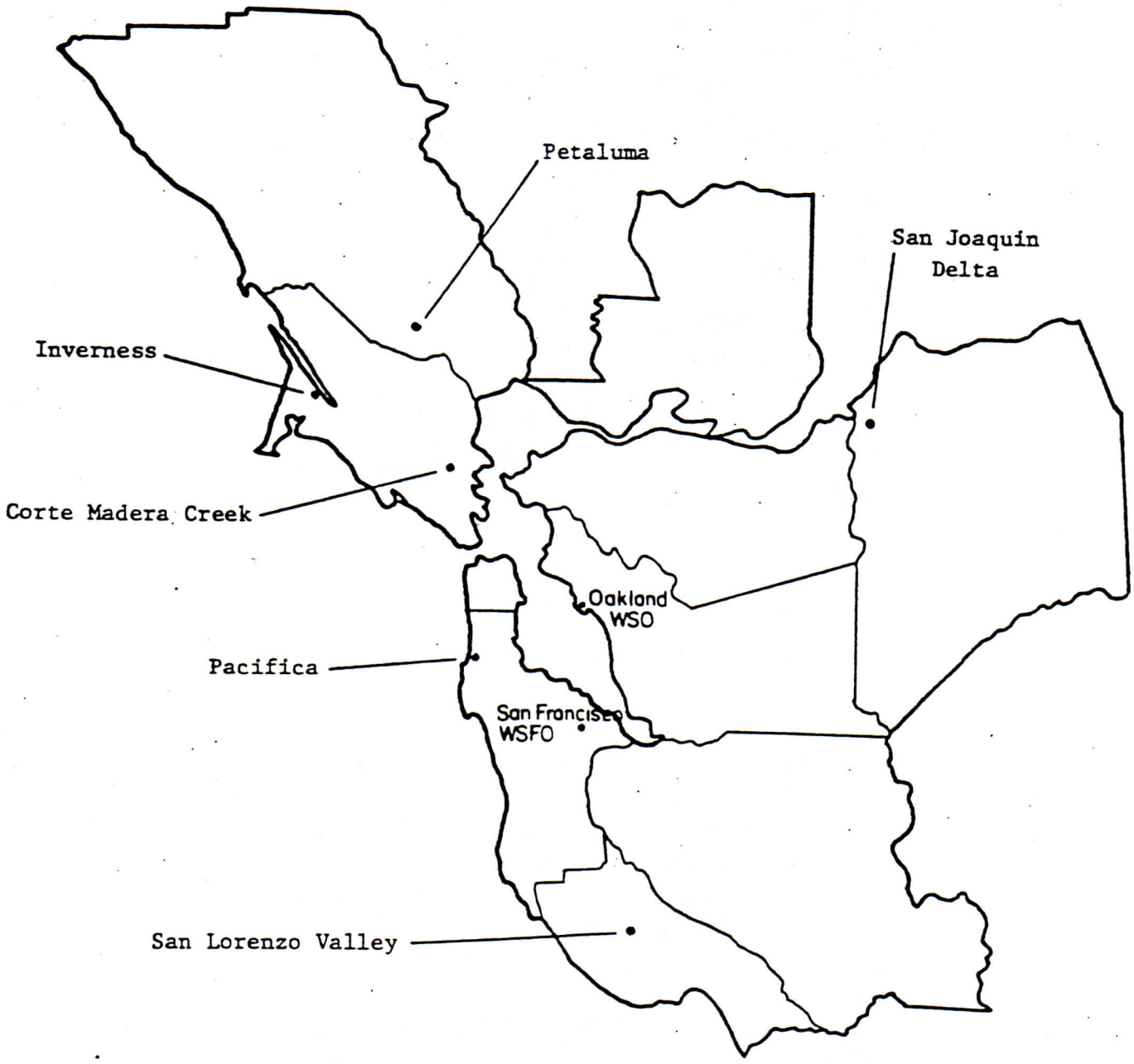


Figure 3
San Francisco Bay Area Locations



CHAPTER 3

BACKGROUND INFORMATION ON THE DISASTER AREA

On January 6, 1982, the Governor of California requested a Declaration of Disaster. On January 7, 1982, the President of the United States determined that damages in the State of California resulting from severe storms, mudslides, high tides, and flooding, were of sufficient severity and magnitude to warrant a major Disaster Declaration under Public Law 93-288. The counties subsequently declared were Solano, Sonoma, San Mateo, Santa Cruz, Contra Costa, Alameda and Marin for individual and public assistance.

General Description of the Area:

The San Francisco Bay Area is extremely varied in topography, vegetation, population density, geology, and local climate. It has experienced great population growth in the last 20 years. The population of the San Francisco Bay Area is approximately 5 million, and its area is 7,500 square miles.

Local climates within the region are highly variable. The rainy season begins in October or November and ends in March or April. The average annual rainfall varies from more than 60 inches in the Redwood Forest of Santa Cruz County to 10 inches in the interior low-lying valley areas of Marin and Sonoma Counties.

The region is characterized by large flat areas that surround the San Francisco Bay and extend into adjacent interior valleys. These valleys border on rugged highlands that reach elevations of over 4,000 feet. These highlands form the coast ranges and extend from Santa Barbara on the south to Humboldt County on the north and form a nearly continuous barrier between the Pacific Ocean and the central San Joaquin Valley. The only break in this barrier is where the San Joaquin and Sacramento Rivers flow into San Francisco Bay and the Pacific Ocean.

Owing to the mountainous and hilly character of the San Francisco Bay Area, settlement and development have tended to concentrate in the foothills, river valleys, and flat coastal or bay areas. In recent years, however, development has spread rapidly to the upland areas, where slope-stability problems have become increasingly common.

Hydrology and Flood History:

Periodically, the Bay Area experiences damaging floods. These floods are usually of riverine origin and affect floodplain lands adjacent to the streams. Combinations of high tides, winds, and intense rainfall have caused past coastal flooding and inundation in areas around the San Francisco Bay and Santa Cruz.

Extensive flooding occurred throughout the San Francisco Bay Region in 1955 and 1958, and in parts of the region in 1940, 1952, 1963, and 1964. Losses from the four later floods were about $23 million in 1955, $14 million in 1958, $4 million in 1963, and $17 million in 1964.

Governmental Complexity:

The interlocking governing entities and systems of government in the San Francisco Bay Area are among the most complex of any of the nation. Its five million residents live in 10 counties. An estimated 85% of the region's population live in the Bay Area's incorporated cities. The region's cities and counties do not provide all local governmental services. Like the rest of California, the Bay Area has a large number of special districts, more than 1,200. Roughly one quarter of the Bay Area's special districts have environmental management or development responsibilities.

CHAPTER 4

METEOROLOGICAL ANALYSIS OF THE STORM

During the final two weeks of December 1981, a Rex-type blocking pattern persisted in the mid-Pacific with a strong upper high near 50N 160W and an upper cutoff low near 35N 160W. Short wave troughs were moving over the mid-Pacific high, across the Bering Sea and then southeastward into a trough along the West Coast.

On January 1, 1982, a strong, cold, short wave trough moved across the northern Gulf of Alaska, then turned southeastward over the eastern Pacific, and, in less than 18 hours, spread rain and snow down to near sea level over northern California. By January 2, the storm had spread cold, moist conditions into central California and was turning eastward. Snow levels were down to 500 to 1,000 feet in the San Francisco Bay Area.

To the south, a strong, westerly flow had developed between 30 and 40 degrees north latitude over the central Pacific, and began pushing an upper closed low, northwest of Hawaii, eastward. As the low tracked eastward, it began spreading tropical moisture toward the West Coast. Strong, warm air advection approaching the California coast was evident on satellite photos by January 2.

The cold air continued to grip the state into January 3, 1982. By this time, the southern branch of the westerlies had pushed in over the state and overrunning clouds were spreading over northern and central California. On January 3, another short wave trough was digging southeastward along the British Columbia coast toward Washington and Oregon.

By the morning of January 4, the first of two surface lows had moved onshore into southern Oregon with a front trailing south, then almost east-west through northern California, just north of Marin County. The development and approach of the storm were clearly depicted on satellite imagery as shown on pages 10 and 11.

Surface pressures continued dropping along the north coast off Point Arena as the surface front slipped slowly southward and a new low developed over the eastern Pacific. Cold air continued at the surface over northern and central California most of the day with warm, moist air from the south-southwest riding up over it. The strongest surface winds were along the coast from Monterey to San Francisco. Little or no wind was reported along the coast north of Point Arena.

By mid-day, a 1015 mb high was centered over Redding while the front which became quasi-stationary over Marin County began moving slowly southward. The flow aloft was from the west at 500 mb and from the west-southwest at 700 mb. Radar indicated showers moving east-northeastward along the front with maximum echo tops reaching 18,000 feet.

By evening, the upper air sounding at Oakland showed winds at 3,000 and 4,000 feet had increased to 55-60 knots from the south. This low level jet was moving slowly eastward and had been increasing through the day in response to an increasing confluent flow. As the jet moved eastward, it began funneling up the San Lorenzo Valley, which is oriented near north-south. The rain intensity increased to nearly an inch per hour in the Santa Cruz Mountains by mid-afternoon and continued into the evening. The second surface

low was moving onshore with a comma cloud, associated with an upper level cyclonic circulation, close behind it. This prolonged the heavy rain until nearly midnight over the southern portion of the Bay Area. Moderate to heavy rain fell in many areas for as long as 24 to 30 hours without interruption.

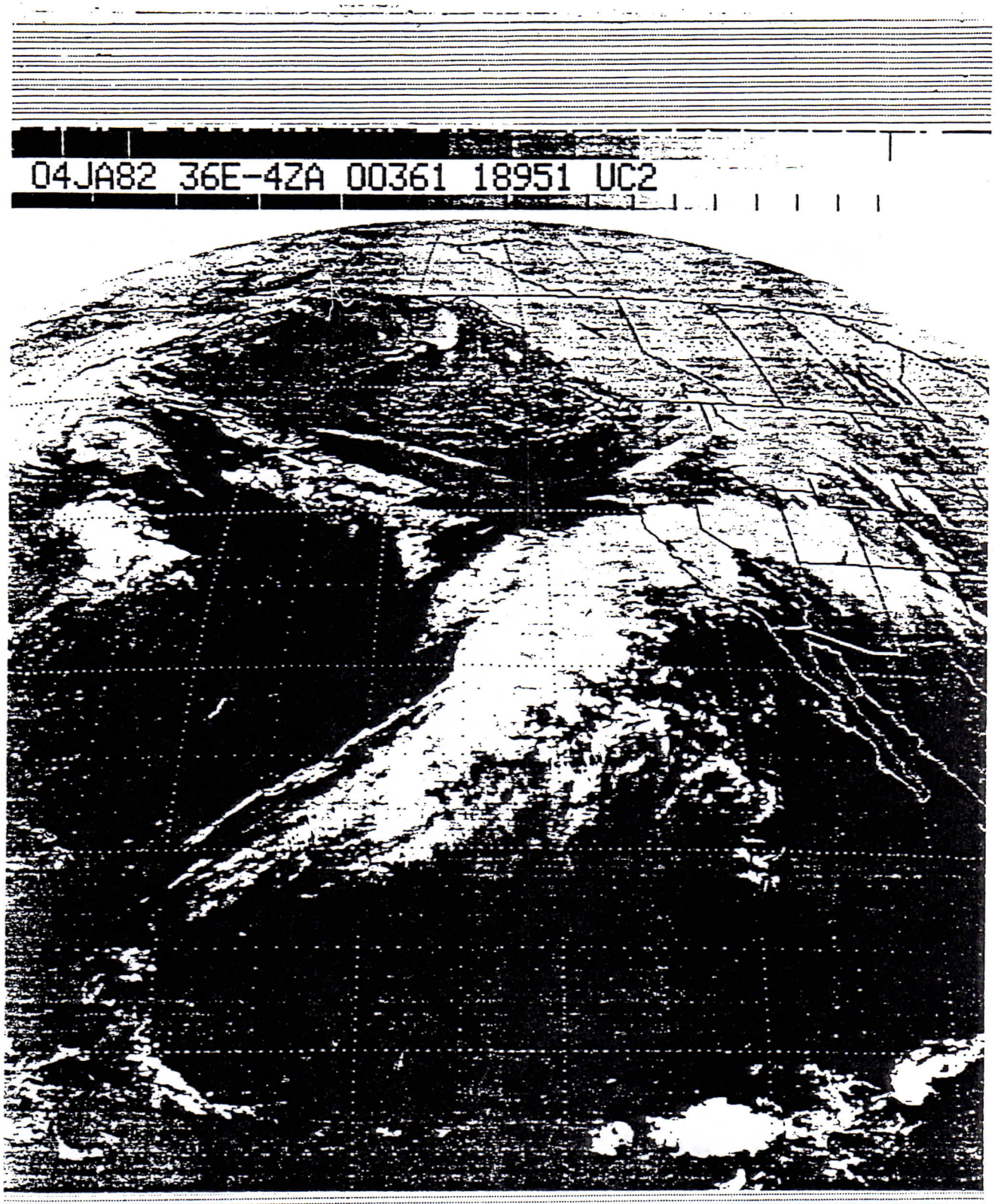


Figure 4
Satellite Photo, 1/4/82 1245 GMT

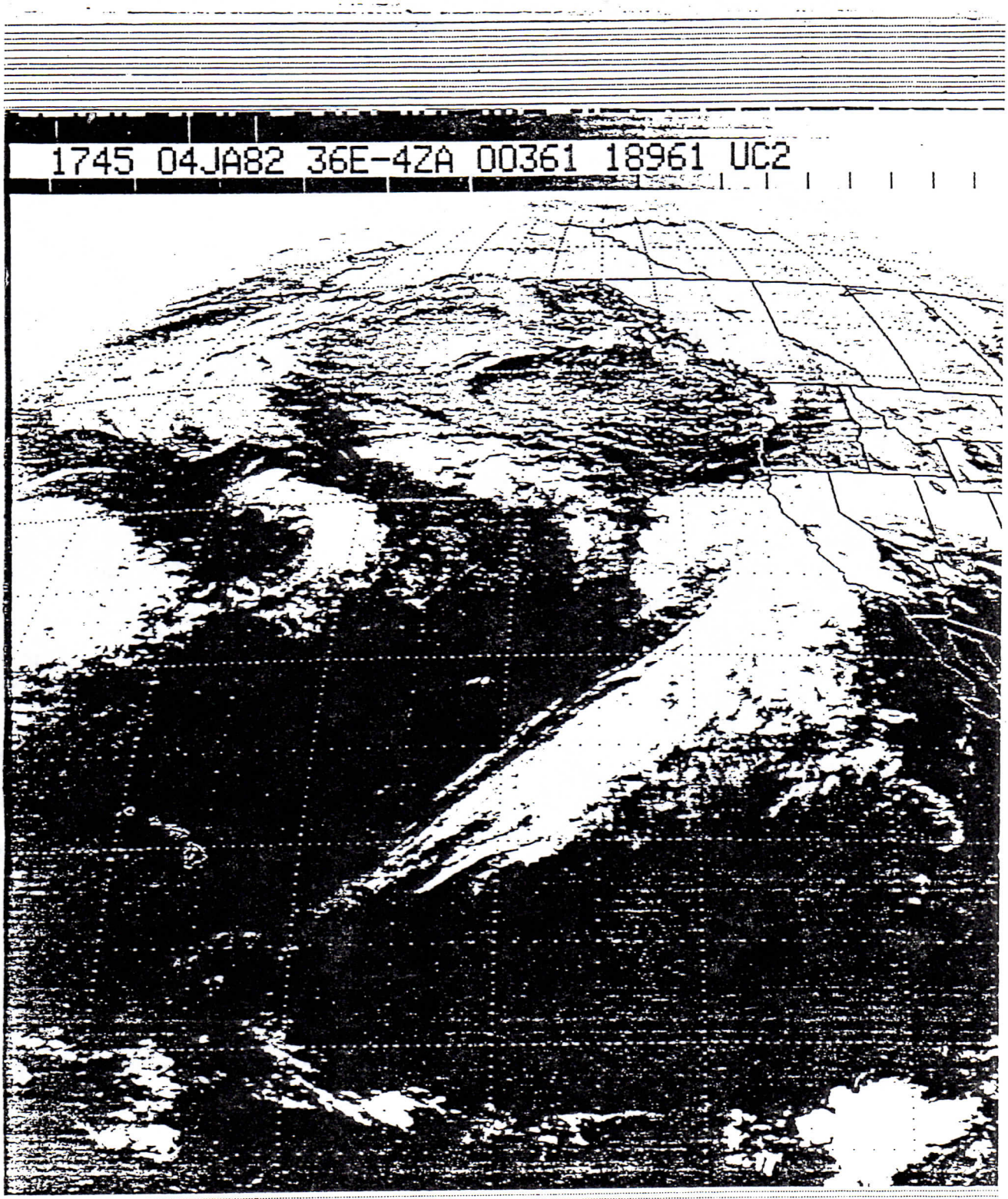


Figure 5
Satellite Photo, 1/4/82 1745 GMT

CHAPTER 5

HYDROLOGICAL SITUATION

The long, dry season from April through October, which is characteristic of the San Francisco Bay Area, generally leaves the soil parched and ready to absorb any rains which fall in early winter. The general precipitation pattern for October through December of 1981 had produced approximately twice the normal monthly precipitation amounts in the vicinity of San Francisco.

Soil moisture accounting is regularly performed for one river basin which drains directly into San Francisco Bay. That basin, the Napa River, is indicative of the general soil moisture conditions which existed as of January 1. The total capacity of the soil to hold moisture has been analyzed as 19.14 inches, 16.36 inches of moisture had already been absorbed, i.e., 85% of saturation had been reached. Surface soils were at 99% of saturation, while deeper soils had the capacity to absorb only 2.7 inches of additional moisture, if it were slowly applied.

Late on January 3, heavy rains added moisture to the upper soils faster than percolation could take place and some flooding resulted. Where steep, unstable slopes existed, some saturated soils collapsed.

CHAPTER 6

DATA ACQUISITION AND COMMUNICATIONS

Meteorological data and information from surface, upper air, radar and satellite observations are available at WSFO San Francisco. These data arrive via several communication channels. In addition, other non-routine communication systems and data networks are available at the WSFO. This chapter will discuss those sources and channels of communications.

Communications Networks:

The following is a list of communication networks available at WSFO San Francisco as of January 4, 1982.

AFOS

Teletypes

- Service A
- Service C
- RAWARC
- Request/Reply
- NWWS (northern California)
- WCMC (West Coast Marine Circuit)

Radio

- NWR (NOAA Weather Radio)
- HAM Radio transmitter/receiver (requiring volunteer operators)

Facsimile

- NAFAX
- FOFAX
- RAFAX
- MAFAX

Telephone

- Commercial
- FTS
- California Wats (out only)

Auxiliary Equipment

- Telex
- Silent "700" Computer Terminal

Surface Observations:

Several types of surface observations are available to the San Francisco WSFO, including:

1) Aviation reports from first- and second-order stations and second-order Aviation Weather Reporting Stations (SAWRS);
2) Reports from cooperative observers in the hydrologic and public service networks;
3) Reports from automated reporting equipment and,
4) Reports from the public - Spotter networks including SKYWARN, HAM radio network, law enforcement agencies, other agencies.

The weather reports which provide real-time information in the vicinity of the Bay Area are available from the following locations:

1) Service "A" data - WSO, FAA, SAWRS, Military:
San Francisco, Oakland*, Hayward*, Salinas, Monterey*, San Jose*, Concord*, Napa*, Livermore*, Fairfield, Alameda, Mountain View*.
* - Site does not routinely report precipitation amounts.

2) Coast Guard Observations:
Pigeon Point, Pillar Point, Davis Point (wind only); San Francisco Pilot Boat (wind, pressure, sea state).

3) Other Agencies:
Marin Civic Center, Kentfield, Santa Cruz, Hollister, Salinas, San Francisco City, Oakland City, and Redwood City.
Point Reyes*, Point Bonita*.
* - Site does not routinely report precipitation.

4) General Public: The public reported very heavy rain along Highway 17 between San Jose and Santa Cruz about 6:20 p.m., January 4, 1982, via telephone.

5) SKYWARN Spotters: There are a large number of SKYWARN spotters throughout the Bay Area. As of January 4, 1982, there were 8 spotters in each of the two most heavily damaged counties, Marin and Santa Cruz. The San Francisco WSFO keeps an up-to-date, county-by-county listing of the spotter's name, location, telephone number, and HAM radio status, located near the lead forecaster's desk. The SKYWARN program was activated by the WSFO at 4:30 p.m., January 4, 1982, and was in operation throughout the remainder of the storm.

6) Automated Precipitation Networks: Automatic Precipitation Networks are accessible to the WSFO on an as-needed basis through the CNRFC computer via FTS telephone line and Silent "700" terminal. The closest network is the ALERT network in Monterey County. Other networks are to the north and east of the Bay Area. The CNRFC has also prepared a computerized program which automatically produces rainfall maps for the entire CNRFC automatic data base. These maps are prepared at 1:30 a.m. and 1:30 p.m. The San Francisco WSFO has a computer terminal which the forecaster can use for requesting this information. Several water districts in the Bay Area maintain precipitation networks. Some of this information is currently available to WSFO San Francisco, but only via phone contact initiated by the forecast office.

7) Automated Buoy Reports:
EB 12 and EB 13 (report wind, temperature and pressure, only).

Upper-Air Observations:

An upper-air sounding is taken at the Oakland WSO twice a day. All observations were completed on schedule during the storm period.

Radar Observations:

The Sacramento WSO provided hourly radar observations throughout the storm. Sacramento has a WSR-57 10 cm radar with a 250-mile range. Terrain and relatively low tops of the rain-producing clouds limited coverage in the Bay Area, which is 50 - 80 nmi from the radar antenna. Figure 6 on page 16 depicts the radar coverage and beam blockage of WSO Sacramento.

Satellite:

WSFO San Francisco is colocated with San Francisco Satellite Field Service Station. Thus, there are routinely available a wide selection of satellite pictures and a continually updated satellite loop. The GOES Satellite System and related communications were fully operational throughout the storm.

Hydrologic Gages:

The only real-time river gage information in the Bay Area, available to the WSFO, is on the Napa and Russian Rivers in Napa and Sonoma Counties and in Monterey County. These are collected by the CNRFC computer and can be accessed by the San Francisco WSFO using a Silent "700" computer terminal and dialing into a telephone port on the CNRFC computer.

Dissemination Communication:

Forecasts, Special Weather Statements, Watches and Warnings are disseminated to the media and public via AFOS, Dedicated Request/Reply Teletype, NOAA Weather Wire Service (NWWS), NOAA Weather Radio (NWR), and telephone recordings. In addition, Watches and Warnings are disseminated to appropriate emergency services offices via telephone. During the January 3-4, 1982 storm, communications systems were operational with two exceptions. The NWR transmitter on Mt. Pise, which services most of the Bay Area, was out of service from 1:30 p.m. to 4:30 p.m., January 4, 1982. Telephone service to many of the storm-affected areas was out for varying lengths of time beginning on the morning of January 4. Telephone service at the WSFO was uninterrupted during the storm.

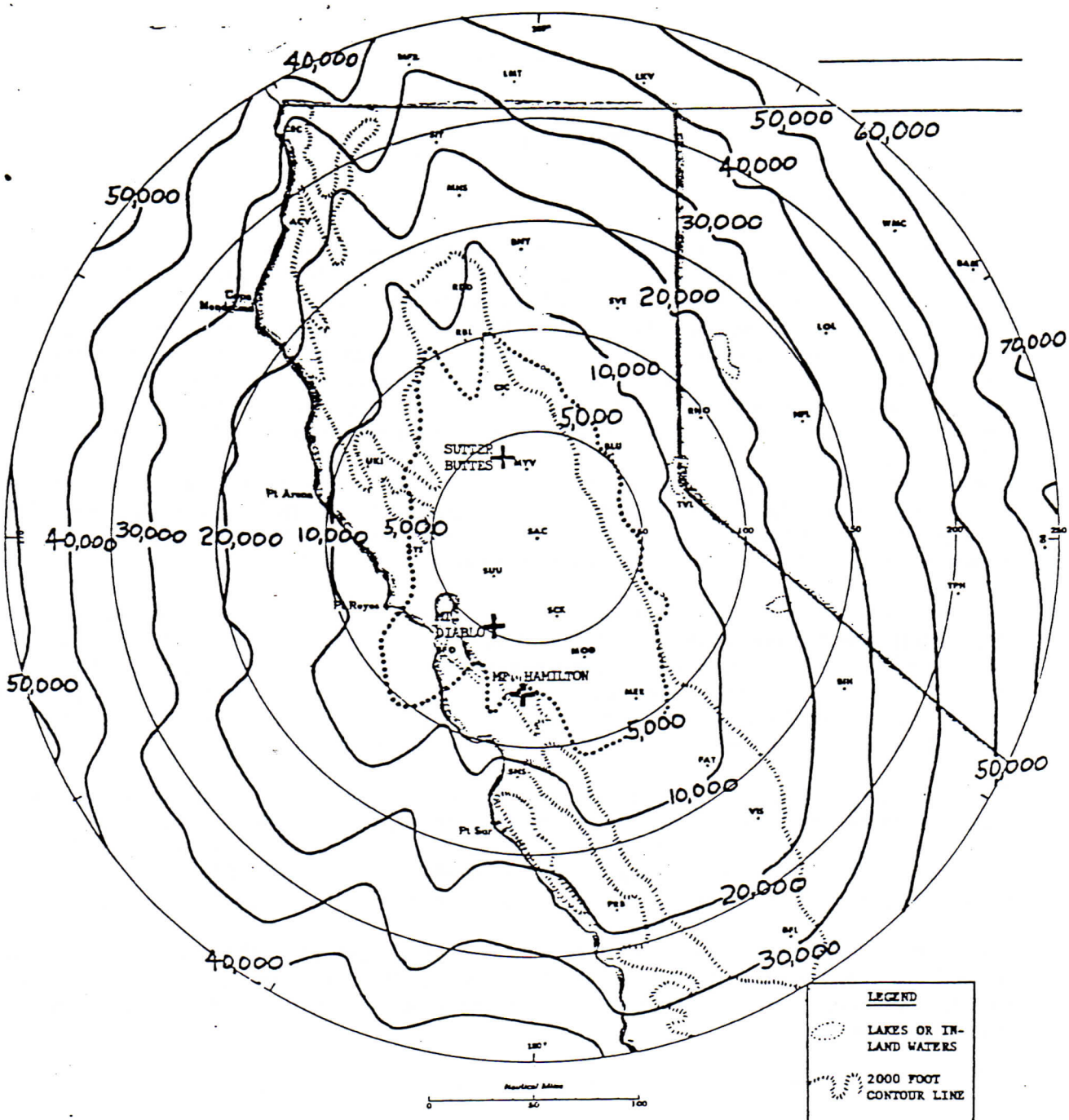


Figure 6
Sacramento, California Radar Beam

CHAPTER 7

FORECASTS AND STATEMENTS

Guidance from NMC:

The forecast models and guidance products were good. Synoptic scale features were handled well and QPF guidance was, over most of the district, good in terms of areal predictions and, to a lesser extent, predicted amounts. The first indication of developing warm advection, was on the 48-hour LFM from 0000Z January 2 valid 0000Z January 4. The 48-hour panel forecast warm, moist overrunning of cold air across northern and central California, a 1005 mb low west of San Francisco, high relative humidity, and up to plus 4 vertical velocity over San Francisco. The 48-hour issued from 0000Z January 3, had a total of 2.56 inches of rain falling in the 12-hour period ending 0000Z January 5.

Upper level NMC guidance charts, as early as January 1, were indicating a confluent flow downstream from the Rex-type block over northern and central California. By 0000Z January 2, the 48-hour panel of the LFM indicated two short waves would be phasing together just off the California coast early Monday morning, January 4.

Maximum rainfall areas were pinpointed well. However, actual rainfall amounts in the area from Marin County southward to Santa Cruz County were generally 150 to 250 percent of forecast. Even though both models were forecasting large rainfall totals, they did not come near the maximum totals of 15 to 25 inches of rain that fell during the 25 to 30 hour period in this area. No "Excessive Rainfall Forecasts" were issued by the Heavy Precipitation Branch of NMC for California during this storm.

The increase in surface gradient along the California coast was forecast, but the strength and the length of the southwesterly fetch that developed were depicted as a more west or a west-southwest fetch by both the LFM and Spectral models. This was due, in part, to the models not forecasting the deepening of the low off the California coast nor the rapid eastward movement of a surface high over southeast California into Arizona.

The progs did indicate a weak, stationary front across northern California, but there was no real indication of the strength of the low-level jet that developed along the coast. All in all, NMC guidance did forecast the general synoptic pattern but was weak on the small-scale features.

Satellite Information from the San Francisco Satellite Field Service Station:

Development of the moist southern branch of the jetstream was well advertised by satellite imagery and San Francisco Satellite Field Service Station discussions. San Francisco Satellite Field Service Station discussions indicated a band of precipitation through the Bay Area late Sunday evening, January 3, 1982. Discussions at 12Z and 18Z Monday, and 00Z, Tuesday, indicated moderate to locally heavy rain continuing across the same area. The 06Z discussion and other available satellite information gave very good guidance on the ending of the precipitation episode.

Although the satellite information and discussions prior to and during the storm were excellent in the larger scale, they failed to provide the trigger needed to indicate the magnitude of the total rainfall during the storm. No specific rainfall rate estimates were generated by San Francisco Satellite Field Service Station during the storm.

Radar Information from Sacramento WSO:

The Sacramento WSO radar, WSR-57, indicated a nearly continuous area of light to occasionally moderate level echoes over the Bay Area from late Sunday afternoon, January 3, 1982, through 11:30 p.m. PST, January 4. No coordination calls were made between the Sacramento WSO and the San Francisco WSFO during this period.

The Sacramento radar is 50 to 80 nmi from the Bay Area. Coverage of the areas of heaviest rain in Santa Cruz County was blocked, to a considerable degree, by intervening terrain.

The Sacramento radar indicated a melt level of only 2,000 feet during the early portion of the storm. The steady lifting of the melting level to around 7,000 feet supports the significant role warm advection played in the precipitation mechanism. Radar tops were generally uniform varying from 12,000 feet to around 18,000 feet.

Forecasts and Statements from the San Francisco WSFO:

The San Francisco WSFO recognized the potential for heavy precipitation developing over portions of northern and central California by Saturday night. At 2:00 a.m., Sunday, January 3, 1982, the WSFO issued a Winter Storm Watch for the Sierra-Nevada Range for Sunday night and Monday. An 80% chance of rain was forecast for the San Francisco Bay Area for Sunday night and Monday. A Special Weather Statement issued at 3:00 a.m., Sunday, January 3, gave an excellent description of the changing weather pattern and the potential for 1 to 2 feet of snow in the Sierra Nevadas and 1 to 2 inches of rain over most of the lower elevations of northern and central California by Monday afternoon.

The 9:00 a.m. forecasts continued the Winter Storm Watch for the Sierra Nevadas and indicated locally heavy rain expected in the Bay Area.

At 2:00 p.m., a Winter Storm Warning was issued for the Sierra Nevadas and a Travelers Advisory was issued for the northern California mountains for snow and wind. Rain, heavy at times, through Monday was forecast for the Bay Area. A Special Weather Statement issued at 3:00 p.m., Sunday, gave a vivid description of the storm moving toward California, describing its subtropic origin and copious amounts of moisture. Copies of all Special Weather Statements comprise Appendix B.

At 9:00 p.m., the northwest California forecast was updated, changing the Travelers Advisory to a Winter Storm Warning. Heavy snow with strong winds was forecast with snow level 1,000 to 1,500 feet. A Storm Warning was issued for the north coast for strong winds and heavy rains into Monday. Other warnings and forecasts were unchanged. A Special Weather Statement also issued at 9:00 p.m. indicated wind gusts up to 54 mph and that up to 3/4 of an inch of rain had already occurred along the northwest California coast during the evening.

At 10:00 p.m., Sunday evening, the Bay Area forecast was updated to include snow on the hills and a Gale Warning. It also continued the locally heavy rain forecast into Monday.

Forecasts and warnings were basically unchanged at 2:00 a.m., Monday. A Special Weather Statement issued at 5:00 a.m., Monday, gave another good picture of the large scale severe winter storm moving across northern and central California.

A 7:00 a.m. update added a Travelers Advisory for snow and wind in the north end of the

Sacramento Valley. A chance of thunderstorms was added to the Bay Area forecast. This forecast also continued the locally heavy rains and the Gale Warning into Monday night.

At 9:00 a.m., Monday, a Winter Storm Warning was issued for the Mount Shasta-Siskiyou area. A Travelers Advisory was issued for the Napa, Sonoma, and Santa Rosa area for snow and wind in the mountains and locally heavy rains in the lower elevations.

A Special Weather Statement issued at 11:30 a.m., headlined flooding problems near the central California coast and continued to advertise other warnings and travelers advisories that were in effect across northern California. The statement specified flooding currently under way in Marin County and street and highway flooding in other sections of the San Francisco Bay Area. Predictions of another 1 to 3 inches of rain and additional flooding in the Bay Area were covered in the statement.

The 2:00 p.m., Monday, forecast continued all the previously issued warnings and advisories through Monday night.

A Special Weather Statement issued at 4:00 p.m. provided more detail on the Bay Area situation as well as the heavy snow situation in the northern mountains and the Sierra-Nevada Range. The statement referred to travel in the Bay Area as "extremely hazardous" with considerable flooding in Marin County and other San Francisco Bay Area locations. Near record 24-hour rainfall amounts were mentioned, including 8 inches already measured at the Marin Civic Center. This statement indicated a tapering off of the rain under way in the north and spreading slowly to the south. Several feet of snow were indicated to have already fallen in the Sierras, with several additional feet expected Monday night.

At 6:55 p.m., Monday, a Special Weather Statement was issued covering the heavy rains and flooding in Santa Cruz County and western San Mateo County. The statement specified the San Lorenzo River and other streams draining into the ocean. Two to four inches of additional rain were forecast between 7:00 p.m. and midnight with rain tapering off rapidly after midnight. Motorists were advised to avoid the area and others in the area were advised to be alert for flooding of streams in low-lying areas. No other specific actions were suggested.

At 2:00 a.m., Tuesday, January 5, 1982, the Winter Storm Warnings were continued for northwest California and the Sierra Nevadas. Other warnings and advisories were dropped.

A final Special Weather Statement on the storm was issued at 8:00 p.m., Tuesday, January 5, 1982. The statement summarized the record rains which fell over the Bay Area since late Sunday and the meteorological conditions which produced the rain.

There were no specific flash flood products issued during the storm.

River Forecasts and Guidance from the California-Nevada River Forecast Center

The CNRFC issued flood forecasts for the Napa and Russian Rivers which flow through Sonoma and Napa Counties, respectively. Flood "Bulletins", forecasting crests near or above flood stage for specific locations on both rivers, were issued by the CNRFC at 7:00 a.m., 11:30 a.m., and 3:30 p.m., January 4, 1982. These forecasts were both timely and accurate, with one exception. A forecast for the Napa River was for water levels a few feet higher than what occurred.

To the south of the Bay Area, the nation's oldest ALERT program installed in Monterey County in 1977[2] provided valuable information for that area. The combination of continuous rainfall information and discharge forecasts clearly defined the seriousness of the situation in Monterey County and allowed county officials there to act with greater effectiveness.

There was only one coordination call between the California-Nevada River Forecast Center and San Francisco Forecast Office on January 4, 1982. The San Francisco lead forecaster contacted the CNRFC at 6:00 p.m., January 4, 1982, regarding flooding in Santa Cruz County. The CNRFC was unable to provide any guidance in that area. Although news reports had made CNRFC personnel aware of some of the problems in the Marin-Santa Cruz strip, they stated that they were without any reliable local data which would allow them to provide assistance.

[2]Appendix C and D

CHAPTER 8

DISSEMINATION OF FORECASTS, WARNINGS AND STATEMENTS; DISASTER PREPAREDNESS AND USER RESPONSE

Dissemination:

Forecasts, warnings, and statements issued by the San Francisco Weather Service Forecast Office and the California-Nevada River Forecast Center during the period January 3-5, 1982, are discussed in Chapter 7 of this report. This chapter will discuss the dissemination of these products and the user response to them.

All forecasts, warnings, and statements covered in Chapter 7 were disseminated in a timely manner through normal channels, i.e., AFOS, Dedicated Request/Reply Teletype, NWWS, and NWR, with one exception. The forecasts issued at 2:00 p.m., Monday, January 4, 1982, and the Special Weather Statement issued at 4:00 p.m., January 4, 1982, were not transmitted over the Mount Pise NWR transmitter until after 4:30 p.m., January 4, 1982, due to the transmitter being out of service. The Mt. Pise NWR transmitter serves the majority of the Bay Area.

There was only one direct personal contact with the northern California Office of Emergency Services (OES) during the storm. At 7:10 p.m., January 4, 1982, the WSFO lead forecaster called the OES to inform them of flooding problems in Santa Cruz and western San Mateo Counties and specifically of the problems related to the San Lorenzo River. This information was also contained in a Special Weather Statement disseminated to the media and to the public at 7:17 p.m., Monday, January 4, 1982. The forecaster issued a Special Weather Statement rather than a watch or warning since he was not aware of the extreme problems produced by landslides in the area, and satellite information indicated the storm was beginning to move out of the area. No feedback regarding the severity of the problem was received by the NWS from OES or other government agencies.

The CNRFC "Bulletins", which forecast flood crests on the Napa and Russian Rivers, were transmitted over the northern California NWWS at approximately 7:00 a.m., 11:30 a.m. and 3:30 p.m., January 4, 1982. The California Department of Water Resources and the northern California OES have drops on the NWWS. The OES retransmitted the "Bulletin" on their emergency teletype loop. This teletype loop has drops in county flood agent offices throughout northern California. Damage along the Napa and Russian Rivers was relatively minor compared to that caused by landslides, flooding of small streams and other drainage areas, etc., in the Bay Area. Thus, the Survey Team did not follow up on user response in the Napa and Russian River floodplains.

Disaster Preparedness:

The following is a summary of recent contacts in the Bay Area made by WSFO San Francisco personnel with the principal purpose of disaster preparedness:

a) There was an intensive effort to coordinate with Bay Area county officials during the period June through November 1978. The Area Manager and Deputy MIC met with officials from Napa, Sonoma, Marin, Santa Clara, Alameda, Contra Costa and Monterey Counties. All expressed a high degree of interest in our products,

especially during heavy rainfall periods. They also stressed the desirability of the NWS coordinating with county flood control personnel before issuing Flash Flood Watches and Warnings. Coordination telephone numbers were updated. In addition, Santa Clara and Contra Costa provided the NWS with telephone numbers where real-time precipitation data could be obtained from county networks in their counties.

b) In December 1980, the Area Manager met with the Santa Clara County officials. They discussed dissemination and exchange of weather information. Santa Clara County volunteered to supply weather information over Highway 17 connecting San Jose and Santa Cruz.

c) During 1981, there were 12 meetings with HAM radio operators and organizations for the purpose of establishing and organizing the SKYWARN spotter and communication network. The last meeting in early December included a test of the SKYWARN program. A few problems were identified during the test. These problems were being investigated, but had not been solved as of the January 3-4, 1982, storm. The most important shortcoming of the program was that it was not self-activating.

d) In January 1981, the Area Manager met with Jack Eldridge, local FEMA representative, to discuss disaster preparedness, in general, and oil spill procedures.

e) In November 1981, the Area Manager met with northern California emergency services staff to discuss emergency procedures.

California-Nevada River Forecast Center (CNRFC) - ALERT Contacts in San Francisco Bay Area

Prior to the January 3-5 storm, the ALERT program had been discussed with officials of Napa, Santa Clara, and Santa Cruz Counties.

Napa County, due to the existence of a system of radio-interrogated rain gages installed with federal funds in 1965 and maintained by the State of California, expressed little interest in the ALERT program.

Santa Clara County has expressed substantial interest in the program, but thus far has not been able to install such a system.

Proposition 13 was believed to have been a significant factor in the counties' attitude. A single recording (but not telemetered) event gage was, however, established at Saratoga Gap to gather historical data for a possible future system. On a monthly basis, a printout of data from that site is provided by the county to the CNRFC for use in future studies.

Santa Cruz County was presented with a complete design for an ALERT system at a meeting held on May 20, 1981. This proposal encompassed the area where the most serious damage occurred in the January storm. Santa Cruz representatives were Wilson Fieberling, Director of Public Works, City of Santa Cruz and D. A. Porath, Santa Cruz County Flood Control District Engineer. The plan, which was drawn up by Ira Bartfeld, California-Nevada River Forecast Center ALERT Hydrologist, was presented by Don Neudeck of the State of California, Department of Water Resources. Mr. Neudeck had provided valuable suggestions and major assistance in CNRFC ALERT programs in Monterey and Ventura Counties.

Santa Cruz representatives indicated they would review the plan and inform the NWS of their decision. The first contact by county officials was, however, after the January storm.

User Response

Nearly all media, government officials, and general public comments indicated awareness of heavy precipitation forecast for northern and central California, including the Bay Area. However, they did not perceive this as any danger to them or their areas of responsibility, nor did they take any specific action based on the forecasts or statements. In most cases, the affected public and the media were aware of specific problems of mudslides and flooding in the Bay Area before the NWS had any information on the severity of these problems.

Officials in the severely affected areas either did not have time, due to more urgent emergency actions, or they did not know how to communicate with the National Weather Service. At least two county emergency officials, who were trying to get updated information from the NWS, did not know they could get it over NAWAS. Both of these counties have NAWAS available in their communication centers. It is believed, but not certain, that the NAWAS system was operational in their areas at the time.

The NWS, the emergency service agencies, other government officials, and the general public were all hampered by the lack of awareness of the threat of widespread mudslides in the area. Previous episodes of mudslides in the Bay Area were much smaller in magnitude.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

Finding 1.

The potential for heavy rain and snow over northern and central California was recognized early by the WSFO San Francisco. A Winter Storm Watch was issued for the area 12-18 hours before the onset of precipitation. This was followed by a Winter Storm Warning and Travelers Advisories for many of the mountain areas 12 hours later. Statements issued on January 3 graphically described the changing weather pattern and the copious amounts of moisture moving toward central California.

Finding 2.

On Monday, January 4, NWS forecasters' concerns were with the total heavy storm system. Nothing called the forecasters' attention to the severity of the local situation in the area surrounding San Francisco Bay. There were no obvious reasons to expect, nor reports of, extraordinary precipitation occurring in the area. The Bay Area spotter network did not provide reports of heavy rainfall or mudsliding until the network was activated by a call from the WSFO San Francisco on January 4.

Recommendations:

a. The San Francisco Area Manager and CNRFC HIC should continue to use every opportunity to work with county officials in the area to implement local flood warning systems, utilizing Automated Local Evaluation in Real Time (ALERT)[3]. ALERT systems would provide real-time telemetered event precipitation and stream data in critical areas to both the NWS and responsibile government officials. The usefulness, to the NWS, of other governmental agencies' precipitation networks operating in the area should also be investigated.

b. Coordination with SKYWARN, a spotter network involving HAM radio operators, and other spotter networks should be improved. Specific criteria should be developed to ensure that cooperative participants and other observers initiate calls to the NWS when specific criteria are observed, rather than waiting for the NWS to initiate calls.

Finding 3.

Communication channels with emergency services offices were ineffective. NAWAS was not used by either NWS or OES officials. Many telephone lines were out during the storm. County emergency officials either did not have or were not aware of backup communications. The California OES has had a more restrictive policy on the use of NAWAS than other western states. This apparently has led to the system not being used at all for weather-related warnings by the San Francisco WSFO.

[3]See Appendix (C) for detailed information.

Recommendations:

a. Expand the use of NAWAS for weather-related warning dissemination. An agreement should be reached between the NWS and the state OES, establishing guidelines for the use of NAWAS. All NWS watches and warnings should be broadcast over NAWAS with affected counties delineated. A procedure should be established for either the state OES designated state control unit, or the issuing NWS office to request an acknowledgment of warning receipt. A free exchange of critical information between the NWS and other emergency services and law enforcement agencies over NAWAS should be encouraged whenever a life-threatening, weather-related situation is developing or expected to develop.

b. Appropriate state and county officials should be contacted by Forecast Office personnel at least once a year to check telephone numbers, other communication systems, emergency procedures, etc. Realistic drills should be held prior to each rainy season involving as many state and county officials and storm reporting networks as possible.

c. An emergency backup communications system, such as a two-way radio, should be set up between the WSFO and critical emergency services offices.

Finding 4.

WSFO forecasters did not assess the full impact of high soil moisture, high tides, and record rainfall. Potential damage from mudslides and local flooding is becoming increasingly acute as metropolitan and residential areas spread into the hills and flood-prone areas.

Recommendations:

a. WSFO San Francisco and the California-Nevada River Forecast Center should establish procedures for assessing the impacts of antecedent ground conditions on potential local flooding. The real-time advice and support of an operational hydrologist are important ingredients in situation assessment and in the formulation of hydrologic advisories. This support becomes increasingly important in situations when data are scarce and flooding is occurring in areas where specific river forecast procedures do not exist. In these circumstances, hydrologists can and should provide significant assistance to meteorologists in the form of situation appraisals, judgments of storm impacts, and other advice. This draws upon the hydrologist's experience, technical knowledge, and general knowledge of the affected area. This level of support is especially important where WSFOs are not staffed with a Service Hydrologist.

b. Antecedent ground conditions should be available to WSFO San Francisco on a routine basis.

c. A program should be initiated, by state and county agencies with responsibility for public safety, to educate the public on flood-prone areas and areas susceptible to landslides. The NWS should assist in this effort.

d. WSFO San Francisco station drills should emphasize the importance of antecedent soil moisture conditions and high tides on local flooding.

e. County officials, many of whom in the past had doubted the need for preparedness for weather-related disasters in their area, should be revisited.

Finding 5.

No hydrologic watches or warnings were issued during the storm. The public was well aware of the expected heavy rain in the area, and some were alerted to specific problems by NWS statements and by flood forecasts for the Russian and Napa Rivers. However, the public did not perceive the scope of the pending disaster based on any of the NWS products.

The opinions expressed by the vast majority of the public and the media seemed to enforce the idea that this was such a rare event that no one could have foreseen the magnitude of it.

Recommendation:

a. The memory of the storm and the completion of recommendations under findings above should greatly aid the WSFO in recognizing the need for and public utilization of urban flood statements and flood or flash flood watches and warnings. These products should be written as site-specific as possible, detailing specific action to be taken by persons in the threatened areas.

Finding 6.

The San Francisco WSFO does not have a Service Hydrologist or a dedicated Disaster Preparedness position. This puts an added burden on the Area Manager, the Deputy MIC, and the Disaster Preparedness Program Leader. The Disaster Preparedness Program Leader has limited time to devote to this program and little to devote to strictly hydrologic problems.

Recommendation:

a. The RFC Flash Flood Hydrologists should spend a number of days at WSFOs without Service Hydrologists. This time should be spent training forecast personnel in hydrologic techniques and reviewing with them rivers, streams, and other flood-prone areas in their area of responsibility. They should review the need for real-time data and emphasize the need for involvement by WSFO staff in implementing ALERT programs in their service area to obtain vital data at minimum cost to the NWS.

b. Other WSFO and WSO personnel, such as the SNS, should be alert to spotting potential flash flood problem areas. These should be documented, and the information added to appropriate SDMs and RDO Manuals.

Finding 7.

The CNRFC had prepared a recommendation for an ALERT system for the San Lorenzo River Basin based on a recently published report by the Corps of Engineers for that basin. Unfortunately, a tight travel budget precluded presentation of the recommendation by a CNRFC staff member. The CNRFC proposal was made to Santa Cruz officials by a member of the California Department of Water Resources. No action was taken regarding the ALERT system by Santa Cruz officials prior to the January 3-4, 1982 storm.

The Corps of Engineers published report on the San Lorenzo River Basin and the recommendation of an ALERT system for the basin by the CNRFC were not common knowledge to WSFO personnel.

Recommendation:

a. The RFC HIC should do as much as possible to keep the Area Manager up-to-date as to RFC, and other federal and state agencies involved in hydrologic activities, findings in the Area Manager's area of responsibility. The Area Manager should review the information and ensure that all of his forecasters are aware of appropriate flood-related information in the WSFO's forecast area, and that WSO MIC/OICs are also up-to-date on findings in their areas of responsibility.

Finding 8.

The EBS system has not been finalized in the Bay Area. Since no short-fuse warnings were issued during this storm, the EBS system would not have been used any way.

Recommendation:

a. The status of the EBS system in northern California should be reviewed by state and county emergency services officials and the San Francisco WSFO MIC/Area Manager and an attempt made to finalize the area EBS programs.

Finding 9.

No specific rainfall rate information was provided by either the San Francisco Satellite Field Service Station or the Sacramento radar unit.

Recommendation:

a. Both NESS and NWS radar offices should review this storm and investigate methods of estimating QPF for weather systems such as the January 3-4, 1982 storm. If research indicates current equipment and the state-of-the-art science can produce useful QPF from storms of this type, routine procedures should be developed.

Finding 10.

The Marin Civic Center normally reports temperatures to the WSFO San Francisco hourly and precipitation every 12 hours. Most WSFO personnel were unaware that the precipitation amount could be reported as often as needed by the Marin observers. During the routine Marin hourly temperature call at 10:00 a.m., January 4, Marin reported over 8 inches of rain in the last 18 hours. This was the first indication to the WSFO forecasters that the rain was locally much heavier than assumed.

Recommendation:

a. Request Marin observers to report precipitation amounts whenever specific criteria are met. Also, maintain forecaster awareness of all available observations through documentation, drills, etc.

Finding M.

The downtown San Francisco rain gage is inaccurate. The gage often catches only about half of what is reported at nearby sites.

Recommendation:

a. Repair or replace that rain gage.

Finding 12.

The general feeling of the Survey Team is that the National Weather Service handled this storm very well, overall. Storm forecasts and warnings for northern and central California were both timely and accurate. However, the local problems in the Bay Area could have been handled more effectively had state-of-the-art equipment been available for relaying real-time precipitation data to the San Francisco Forecast Office. If communication procedures with county emergency services offices had been more thoroughly developed and routinely tested, problems associated with the storm could have been quickly identified and handled more effectively.

APPENDIX A

SAN LORENZO VALLEY, SANTA CRUZ COUNTY

The San Lorenzo Valley is an unincorporated part of Santa Cruz County and includes all of the San Lorenzo River Basin and its tributaries upstream of Henry Cowell Redwoods State Park (southern unit). The major tributaries are Zayante Creek, Love Creek, Bear Creek, Kings Creek, and Boulder Creek. The unincorporated towns of Felton, Ben Lomond, Brookdale, and Boulder Creek are all within the San Lorenzo Valley. The area is characterized by low density residential and commercial development surrounded by forest.

Bearing the brunt of the storm, the hills of the San Lorenzo Valley received rainfall in amounts of 10" - 18" with numerous reports in excess of 24". The great weight of the water in the soil exerted excessive stress on the slopes which triggered numerous landslides and mudslides. The slide situation was so delicate that rescue workers feared the propeller wash from helicopters and small planes would topple trees around them.

The San Lorenzo Valley floodplain is very narrow, due to the deeply incised water courses, and broadens where tributaries feed into the San Lorenzo River. There is development in the floodplain but, due to the steep terrain, most development is above the 100-year flood level. The U.S. Army Corps of Engineers' preliminary flood frequency calculations show the San Lorenzo River at Big Trees at only a 10-year flood event.

The San Lorenzo River Basin was the most heavily affected area in the declared counties. Almost every problem found in this disaster was evident in the San Lorenzo Valley. Landslides, mudslides, and flooding caused loss of life and numerous injuries, loss of access and utilities, and damage and destruction of many buildings and facilities.

An estimated 14 people were killed by landslides and mudslides in the San Lorenzo Valley. Reliable information on damages in San Lorenzo Valley is not available. However, of the 400 families from San Lorenzo Valley who registered at Disaster Assistance Center, 39 reported their homes were destroyed, 152 reported major damage, and 217 reported minor damage.

CORTE MADERA CREEK

Eight to ten inches of rain in 24 hours, coupled with extraordinarily high tides, caused flooding in the Corte Madera Creek area. The cities of Fairfax, San Anselmo, Ross, Larkspur, and the community of Kentfield in Marin County all suffered serious damage. The U.S. Army Corps of Engineers' Corte Madera project has not been completed. U.S. Army Corps of Enginers estimated the project in its unfinished form was only 1/3 effective. Had the project been complete as originally designed, there may have been little or no damage downstream of San Anselmo. Preliminary flood frequency calculations indicate the discharge on the Corte Madera to be between the 50 and 100-year flood event. Damage figures quoted below are also preliminary.

Fairfax, the town highest in the watershed, had numerous reports of slope failure. Several sections of Fairfax were isolated by slides which blocked the access roads. Six houses were destroyed by mudslides, and phone and electricity were out for a period of time. Almost all the businesses on Bolinas Road and Roadway (commercial area) suffered water damage. Loss was estimated at $2.5 million for the private sector and $.5 million for the public sector. Much of the commercial area of Fairfax is within the 100-year floodplain.

San Anselmo suffered serious damage. The main street, San Anselmo Blvd., was a river 3-4 feet deep. All the commercial properties in this area suffered water damage to some extent. It is estimated that $4 million in damages occurred. Two deaths were attributed to the storm, one house was destroyed, and 30 or more houses and 30-40 businesses were damaged. Utilities were erratic for several days. A curfew was enforced in downtown San Anselmo. Only merchants and their employees were allowed downtown during daylight hours. Car traffic was banned. Almost all of the commercial and much of the residential development in San Anselmo is within the 100-year floodplain.

The commercial area of Ross was heavily impacted. Businesses were damaged by water and silt. Slope failure in the hills of Ross destroyed several homes. Numerous residences along Sylvan Lane, Poplar Avenue, and Redwood Drive suffered water damage. The commercial area of Ross and several residential streets lie within the 100-year floodplain.

Four or more homes in Larkspur were destroyed and numerous homes were damaged. The Madrone Canyon area suffered serious damage from mudslides. Combined losses for the Madrone Canyon area and Corte Madera Creek area are estimated at $3 million. Designated floodplain areas are small.

INVERNESS, MARIN COUNTY

The unincorporated town of Inverness, Marin County (population 1,200), is situated such that development occurs primarily in three, steep and rugged canyons. Relatively dense single-family residential development is found along the roads leading into the canyons. Commercial development is mainly found along the main access road to Inverness which runs along the edge of Tomales Bay.

A combination of slope failure and flooding resulted in debris flows which rushed down the steep, developed canyons and destroyed or severely damaged many houses. Twelve houses were either totally destroyed by the flows or are irrepairable, (one was actually pushed into Tomales Bay). Most of the damage occurred in Alder Creek Canyon, also known as "Second Valley" and the Vallejo Avenue area of Inverness Park. Fortunately, there were no deaths or serious injuries, even though many families evacuated just as the debris flows entered the house.

A vast quantity of debris came out of the canyons. Much debris and mud flowed into Tomales Bay while 300,000 cubic yards of mud was removed from public property (roads, mouths of creeks, etc.). The water system was effectively destroyed when the main pipe ruptured and reservoirs were damaged. The repair is estimated to take about eight months. Inverness was isolated by slides across Sir Francis Drake Boulevard for one day. The road was cleared enough to bring in supplies and heavy equipment for the clean up.

CITY OF PACIFICA, SAN MATEO COUNTY

Heavy rainfall on January 3, 4, and 5, 1982, caused considerable flooding and landslide damage in the City of Pacifica, San Mateo County. There was over $3 million worth of damage to personal property and $2 million in public property damage. A total of 300 homes were damaged, five of which were destroyed. The greatest impact was in the Linda Mar District where both flooding and landslides occurred.

The rainfall, which ranged from 6.45 inches to 8.71 inches during two days, added moisture to already saturated surface soils. Where steep, unstable slopes existed, the

soils collapsed. Five houses were destroyed. Four hundred ninety-five houses are considered threatened because of the possibility of future slides. Most of these households are on one of the following types of alert: (1) If there is any rainfall, the house must be evacuated. (2) If there is moderate to heavy rainfall, the house must be evacuated.

Rapid run-off resulted in flooding of a densely developed single-family residential and retail commercial area that surrounds the intersection of Linda Mar Avenue and De Solo Drive. This area, of about 160 acres, is primarily within the 100-year floodplain of the San Pedro Creek Basin. Serious flooding occurred in this area in 1962 and 1972. The damages at that time amounted to $252,000 and $120,000 respectively, when floods inundated approximately 145 acres.

PETALUMA

The City of Petaluma suffered extensive damages as a result of flooding. Residential areas were especially hard hit with approximately 550 homes inundated. The flooding covered a larger area than identified as Zone A in the floodplain maps.

Almost all of the flooding in Petaluma resulted from overflows of the Willow, Lunch, and Washington Creeks and the Petaluma River which run through the City.

Willow Creek, a major tributary of the Petaluma River, caused damage to approximately 100 mobile homes in the northwestern section of town. An area along the Petaluma River near the center of town, where Lunch and Washington Creeks join the river, received heavy damage. A large number of homes were flooded by eighteen (18) inches to six (6) feet of water.

High tide was identified as inhibiting the drainage of the Petaluma River, contributing to the severity of the flooding.

SFOSPSSFO
WOUS00 KSFO 031200

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE SAN FRANCISCO CA
3 AM PST SUNDAY JAN 03 1982

..WINTER STORM WATCH FOR THE SIERRA NEVADA FOR TONIGHT AND MONDAY..

RAIN...WITH SNOW ABOVE 2000 FEET IN THE NORTH AND 5000 FEET IN SOUTH...WILL SPREAD OVER THE SIERRA NEVADA TONIGHT AND MONDAY. STRONG GUSTY WINDS AND LOCALLY HEAVY SNOW WILL MAKE DRIVING CONDITIONS HAZARDOUS IN THE SIERRA NEVADA.

THIS MORNING...THE STORM SYSTEM IS LOCATED ABOUT 600 MILES WEST OF NORTHERN CALIFORNIA AND IS MOVING RAPIDLY EASTWARD. CLOUDINESS AHEAD OF THIS SYSTEM WILL SPREAD OVER NORTHERN AND CENTRAL CALIFORNIA TODAY WITH RAIN BEGINNING ALONG THE COAST THIS EVENING AND SPREADING EASTWARD TONIGHT AND MONDAY.

THIS SYSTEM...WHICH HAD ITS ORIGIN NORTH OF HAWAII...WILL NOT BE AS COLD AS THE STORM OF SATURDAY NIGHT. IT WILL HAVE THE POTENTIAL FOR MORE PRECIPITATION BECAUSE OF ITS WARMER TEMPERATURES AND BECAUSE OF ITS TROPICAL MOISTURE SOURCE. THE COLD AIR CURRENTLY OVER THE STATE WILL BE SLOW TO WARM. SO AS THIS THE STORM SYSTEM MOVES OVER THE COLD AIR TONIGHT...SNOW LEVELS WILL STILL BE LOW AND THERE IS A POTENTIAL FOR HEAVY SNOW IN THE SIERRA RANGE.

WITH THE AIRMAS OVER THE STATE GRADUALLY WARMING THE SNOW LEVEL BY MONDAY AFTERNOON WILL BE 4000 FEET IN THE NORTH AND TO 7000 FEET IN THE SOUTH.

PRECIPITATION AMOUNTS WILL RANGE FROM 1 TO 2 INCHES OVER MOST OF NORTHERN AND PORTIONS CENTRAL CALIFORNIA WITH FROM 1 TO 2 FEET OF SNOW FALLING ON THE SIERRA NEVADA BY MONDAY AFTERNOON.

ANOTHER STATEMENT WILL BE ISSUED AT 3 PM THIS AFTERNOON.

N. HOFFMANN....LEAD FORECASTER

'82 JAN 3 PM 2:32

SFOSPSSFO
WOUS00 KSFO 032300

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE SAN FRANCISCO CA
3 PM PST SUNDAY JAN 03 1982

..WINTER STORM WARNING FOR THE SIERRA NEVADA TONIGHT AND MONDAY..

..AND TRAVELERS ADVISORY FOR THE NORTHERN MOUNTAINS..

LOCALLY HEAVY SNOWS WILL SPREAD INTO THE SIERRA NEVADA TONIGHT AND MONDAY. ALONG WITH GUSTY WINDS THE HEAVY SNOWFALL WILL MAKE DRIV NG CONDITIONS HAZARDOUS. SNOWFALL FROM 1 TO 4 FEET OR MORE IS EXPECTED.

..LOCALLY HEAVY SNOW WILL FALL IN THE NORTHERN MOUNTAINS TONIGHT BUT ACCUMULATIONS UP TO ABOUT A FOOT ARE EXPECTED. HOWEVER GUSTY WINDS WILL MAKE DRIVING CONDITIONS HAZARDOUS THERE ALSO.

A STORM SYSTEM OFF THE CALIFORNIA COAST IS THE CULPRIT THIS TIME. IT IS OF SUBTROPICAL ORIGIN THUS CONTAINS COPIOUS AMOUNTS OF MO STURE. LOCALLY HEAVY RAIN FALL IS FORECAST TO OCCUR IN THE COASTAL MOUNTAIN TONIGHT AND MONDAY WITH ACCUMULATION OF ABOUT 1 TO 3 INCHES EXPECTED. THE RAIN AND SNOW WILL LIKELY CONTINUE INTO MONDAY NIGHT AND TUESDAY.

THE NEXT STATEMENT ON THIS STORM WILL BE ISSUED ABOUT 3 AM MONDAY.. OR SOONER IF CONDITIONS WARRENT.

CHARLES ROBERTS..LEAD FORECASTER
WSFO SAN FRANCISCO CALIFORNIA

NNNNCZC
WWUS PWRE 041300
BULLETIN
SPECIAL WEATHER STATEMENT

NATIONAL WEATHER SERVICE SAN FRANCISCO CA
5 AM PST MONDAY JAN 04 1982

'82 JAN 4 AM 5:23

..WINTER STORM WARNING FOR THE SIERRA NEVADA AND IN THE MOUNTAINS OF NORTHWEST CALIFORNIA TODAY...

..AND TRAVELERS ADVISORY FOR THE NORTHERN MOUNTAINS..

LOCALLY HEAVY SNOWS HAVE SPREAD INTO THE SIERRA NEVADA DURING THE NIGHT. GUSTY WINDS COMBINED WITH HEAVY SNOWFALL ARE MAKING DRIVING CONDITIONS HAZARDOUS. SNOWFALL FROM 1 TO 4 FEET OR MORE IS EXPECTED BEFORE THE STORM MOVES OUT OF THE STATE TUESDAY. PERSONS INTENDING TO DRIVE THROUGH THESE AREAS TODAY SHOULD USE CAUTION AND EXPECT TRAVEL DELAYS.

THE STORM SYSTEM IS MOVING ONSHORE NORTHERN CALIFORNIA THIS MORNING AND IS PRODUCING STORM FORCE WINDS AS HIGH AS 60 MPH ALONG THE COAST. STORM WARNINGS ARE UP ALONG THE COAST FROM THE OREGON BORDER TO POINT PINOS. STRONG WINDS HAVE ALSO BEEN REPORTED IN THE SACRAMENTO VALLEY.

BECAUSE OF OF THE STORMS SUBTROPICAL ORIGIN IT CONTAINS COPIOUS AMOUNTS OF MOISTURE. LOCALLY HEAVY RAIN FALL IS FORECAST TO OCCUR IN THE COASTAL MOUNTAINS TODAY WITH ACCUMULATION OF ABOUT 1 TO 3 INCHES EXPECTED. BECAUSE OF THE WARM STRUCTURE OF THIS STORM SNOW LEVELS WILL BE RISING DURING THE DAY. TEMPERATURES HAVE BEEN GOING UP DURING THE NIGHT OVER MOST OF THE BAY AREA AND NORTHERN CALIFORNIA AS WINDS INCREASED FROM THE SOUTH.

RAIN WILL CONTINUE THROUGH THIS EVENING AND SKIES SHOULD BEGIN CLEARING FROM THE NORTH LATER TONIGHT AND OVER MOST NORTHERN AND CENTRAL CALIFORNIA TUESDAY AND TUESDAY NIGHT.

FURTHER STATEMENTS WILL BE ISSUED AS NECESSARY.

N. HOFFMANN....LEAD FORECASTER

NNNN

SFOSPSSFO
W

82 JAN 4 PM 12:05

U
S30 KSFO 042000

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE SAN FRANCISCO CA
11.30 AM PST MONDAY JAN 04 1982

..HEAVY RAIN AND FLOODING NEAR THE CENTRAL CALIFORNIA COAST..

..WINTER STORM WARNINGS IN THE NORTHERN MOUNTAINS AND SIERRA NEVADA..

..TRAVELERS ADVISORY FOR PORTIONS OF NORTHERN CALIFORNIA..

HEAVY RAIN DURING THE PAST FEW HOURS ALONG THE CENTRAL CALIFORNIA COAST HAS CAUSED CONSIDERABLE FLOODING IN MARIN COUNTY AND STREET AND HIGHWAY FLOODING IN OTHER SECTIONS OF THE SAN FRANCISCO BAY AREA. MANY STREETS AND HIGHWAYS ARE REPORTED CLOSED IN MARIN COUNTY AS WELL AS OTHER SECTIONS OF THE AREA. ONE TO THREE INCHES OF ADDITIONAL RAINFALL CAN BE EXPECTED ALONG THE CENTRAL CALIFORNIA COAST BEFORE THE STORM THE STORM DIMINISHES ON TUESDAY. THE RAINFALL WILL GRADUALLY END FROM THE NORTH AS THE RAIN PRODUCING FRONT MOVES SOUTHWARD ACROSS THE STATE BUT ADDITIONAL FLOODING CAN BE EXPECTED IN ALREADY DRENCHED SECTIONS OF THE BAY AREA.

WINTER STORM WARNINGS REMAIN IN EFFECT FOR THE NORTHERN MOUNTAINS OF THE STATE AND FOR THE SIERRA NEVADA WHERE SEVERAL FEET OF NEW SNOW HAVE BEEN ADDED TO THE SNOW PACK OVERNIGHT. MANY MOUNTAIN AREAS WILL ACCUMULATE SEVERAL MORE FEET OF SNOW BEFORE THE STORM SUBSIDES TUESDAY. MOST HIGHWAYS IN THE NORTHERN PART OF THE STATE ARE SNOW COVERED AND TRAVLERS ADVISORIES REMAIN IN EFFECT FROM THE NORTHERN SACRAMENTO VALLEY NORTHWARD.

STORMY CONDITIONS CONTINUE OVER THE NORTHERN HALF OF CALIFORNIA WITH GALE OR STORM WARNINGS IN EFFECT ALONG MUCH OF THE COAST AND HIGH WINDS IN MANY INLAND SECTIONS.

THE HEAVIEST PART OF THE STORM IS STRIKING THE CENTRAL CALIFORNIA COAST THIS AFTERNOON AND WILL CONTINUE INTO TONIGHT. THE HEAVY RAIN WILL GIVE WAY TO SCATTERED SHOWERS ON TUESDAY AS THE MAJOR PORTION OF THE STORM MOVES SOUTHEASTWARD INTO NEVADA AND SOUTHERN CALIFORNIA.

THE BRIGHT SPOT IN THE FORECAST IS THAT DRY WEATHER IS EXPECTED TO RETURN TO NORTHERN AND CENTRAL CALIFORNIA BY WEDNESDAY MORNING AND REMAIN FOR THE REST OF THE WEEK.

DALE GOUDEAU...METEOROLOGIST

SFOSPSSFO
WOUS00 KSFO 050000

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE SAN FRANCISCO CA
4 PM PST MONDAY JAN 04 1982

..HEAVY RAIN AND FLOODING NEAR THE CENTRAL CALIFORNIA COAST..

..WINTER STORM WARNINGS IN THE NORTHERN MOUNTAINS AND SIERRA NEVADA..

...TRAVELERS ADVISORY FOR PORTIONS OF NORTHERN CALIFORNIA..

HEAVY RAIN ALONG THE CENTRAL CALIFORNIA COAST TODAY HAS CAUSED CONSIDERABLE FLOODING IN MARIN COUNTY AND OTHER SAN FRANCISCO BAY AREA LOCATIONS. MANY STREETS AND HIGHWAYS IN THE BAY AREA ARE UNDER WATER AND TRAVEL IS EXTREMELY HAZARDOUS. ONE TO THREE INCHES OF ADDITIONAL RAINFALL CAN BE EXPECTED FROM MARIN COUNTY SOUTHWARD TO NEAR SANTA MARIA BEFORE THE RAIN DIMINISHES ON TUESDAY. NEAR RECORD 24 HOUR RAINFALL TOTALS HAVE ALREADY BEEN REPORTED FROM AROUND THE BAY AREA. MARIN CIVIC CENTER MAY EXCEED 8 INCHES FOR THE DAY WITH OTHER BAY AREA READINGS IN THE 3 TO 6 INCH RANGE. THE HEAVIER RAIN IS GRADUALLY TAPERING OFF FROM THE NORTH BUT IS ALSO SPREADING SOUTHWARD AS THE STORM SYSTEM MOVES SOUTHEASTWARD. THESE EXCESSIVE RAINFALL AMOUNTS ARE CAUSED BY SUBTROPICAL AIR WHICH IS CAPABLE OF CARRYING LARGE AMOUNTS OF MOISTURE AS IT FLOWS NORTHWARD FROM THE VICINITY OF THE HAWAIIAN ISLANDS. THE STORM IS EXPECTED TO MOVE ACROSS THE STATE AND INTO NEVADA AND SOUTHERN CALIFORNIA ON TUESDAY LEAVING ONLY SCATTERED SHOWERS IN ITS WAKE.

WINTER STORM WARNINGS REMAIN IN EFFECT FOR THE NORTHERN MOUNTAINS AND THE SIERRA NEVADA WHERE SEVERAL FEET TO NEW SNOW WERE ADDED LAST NIGHT AND SEVERAL MORE FEET ARE EXPECTED AGAIN TONIGHT. MOST HIGHWAYS IN THE NORTHERN PART OF THE STATE ARE SNOW COVERED AND TRAVELERS ADVISORIES ARE IN EFFECT THERE. VERY COLD AIR OVER OREGON IS GRADUALLY SPREADING SOUTHWARD BEHIND THIS STORM SYSTEM CAUSING SNOW LEVELS TO LOWER TO NEAR 500 FEET IN THE NORTH TONIGHT AND TO 3000 FEET IN THE SOUTHERN SIERRA NEVADA BY TUESDAY.

STORMY CONDITIONS CONTINUE OVER MUCH OF NORTHERN AND CENTRAL CALIFORNIA WITH GALE OR STORM WARNINGS IN EFFECT ALONG MUCH OF THE COAST AND HIGH WINDS AND HEAVY RAIN OR SNOW IN MANY INLAND SECTIONS.

THE HEAVIEST PART OF THE STORM IS STRIKING THE CENTRAL CALIFORNIA COAST THIS EVENING BUT THE THINGS ARE LOOKING UP. THE BRIGHT OUTLOOK IN THE FORECAST IS THAT DRY WEATHER IS EXPECTED TO RETURN TO THE STATE ON WEDNESDAY AND CONTINUE FOR THE REST OF THE WEEK.

DALE GOUDEAU...METEOROLOGIST

SFOOPUSFO
WOUS00 KSFO 050400

'82 JAN 4 PM 7:17

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE SAN FRANCISCO CA
6.55 PM PST MONDAY JAN 04 1982

...HEAVY RAIN AND FLOODING IN SANTA CRUZ COUNTY AND WESTERN SAN MATEO COUNTY...

HEAVY SUSTAINED RAIN IN THE SANTA CRUZ AREA NORTHWARD ALONG THE COAST IS CAUSING LOCAL FLOODING OF STREAMS..MAINLY THOSE DRAINING INTO THE OCEAN..INCLUDING THE SAN LARENZO RIVER. ANOTHER TWO TO FOUR INCHES OF RAIN CAN BE EXPECTED IN MANY AREA BETWEEN 7 PM AND MIDNIGHT WHEN RAIN SHOULD BEGIN TAPERING OFF QUITE RAPIDLY. MOTORIST SHOULD AVOID THIS AREA TONIGHT IF AT ALL POSSIBLE. ANYONE WITHIN THIS AREA SHOULD BE ALERT FOR FLOODING OF STREAMS AND LOW-LYING AREAS.

RAIN IS FORECAST TO END IN MOST AREAS TUESDAY MORNING WITH DRY WEATHER EXPECTED FOR THE REST OF THE WEEK.

KEITH EWING...LEAD FORECASTER

APPENDIX C

COOPERATIVE FLOOD WARNING PROGRAM

The National Weather Service has implemented local cooperative flood warning systems, utilizing Automatic Local Evaluation in Real Time (ALERT) in many areas of the Western United States. Such systems are appropriate to the flood problems associated with rapidly cresting basins.

The National Weather Service is in a position to provide local agencies with substantial support in the areas of system design, system software, streamflow simulation modeling, and assessment of meteorological conditions from radar data and satellite imagery. These services, which have cost many millions of dollars to develop, are provided without charge to the local cooperating agency.

The cooperating local agency is responsible for providing and maintaining precipitation and river gages and locally installed automated data collection and processing equipment.

The remote precipitation and river gages are fully automatic, modular, self-contained, self-powered, event-reporting units. The receiving station includes a microcomputer, data logger, and CRT data display.

The cost of the receiving station is approximately seven thousand dollars ($7,000), while a remote field event-reporting gage can be purchased for under three thousand dollars ($3,000).

Local installation and maintenance costs for the system are generally within the overhead ability of local agencies. The major cost variable associated with installation and maintenance is site availability. With access by vehicle, the installation cost per remote gage is approximately four hundred ($400) per gage. Most of this is accounted for by personnel costs. The annual maintenance cost per gage is estimated to be two hundred dollars ($200).

The local data system, in conjunction with continuing hydrometeorological information provided by the National Weather Service, can maximize warning lead-time potential in flood situations, minimizing loss of life and movable property damage.

The design and implementation of a local response plan by the agency completes the warning system. Local warning dissemination becomes the responsibility of the local agency in conjunction with Flash Flood Warning Statements issued by the National Weather Service to the media and through NOAA Weather Radio.

APPENDIX D

ALERT SYSTEM PERFORMANCE IN MONTEREY COUNTY

The first report associated with the extreme storm was automatically received by the monitoring minicomputer on January 3 at 0906 hours. By January 5 at 1654 hours, when the last report from the storm was received, 2381 correct reports had been entered into the minicomputer files. A review of the accumulator value, which is a part of each report, indicated that seven randomly distributed one millimeter increments were not received and that one garbled increment had been posted.

At no time was the information from any site in error by more than one millimeter. Overall, 99.67% of the event-triggered transmissions were correctly received. The resulting discharge forecasts produced by the ALERT software for the affected drainages were excellent. Due to the siltation which took place during the storm, forecast discharges appear to represent the best record of flow which can be obtained.

Rainfall at the wettest reporting site in Monterey County totaled 10.32 inches. The combination of continuous rainfall information and discharge forecast removed virtually all ambiguity as to the seriousness of the situation and allowed Monterey County officials to act with greater effectiveness.