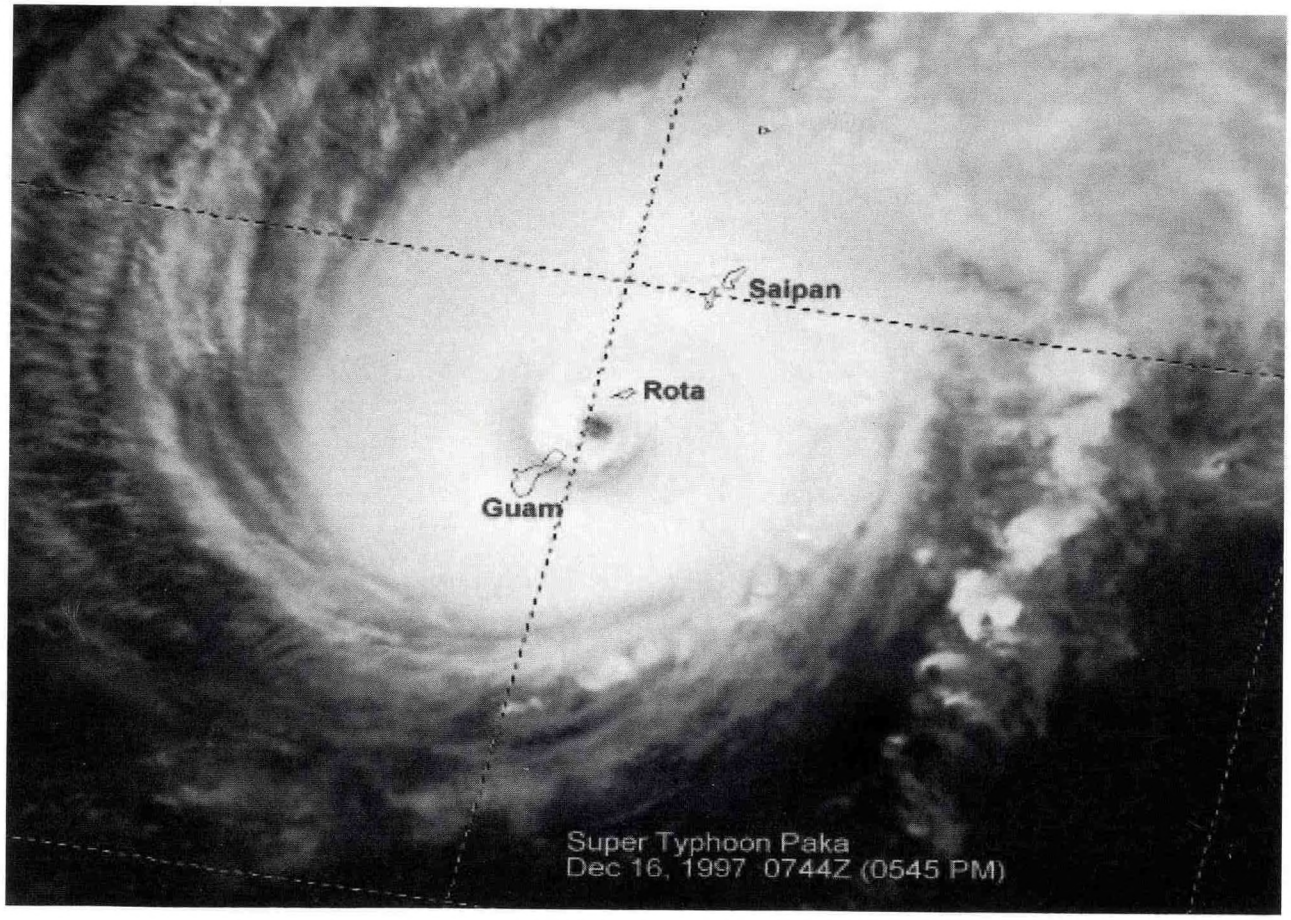
Service Assessment

Super Typhoon Paka
December 2 thru 21, 1997



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Honolulu, Hawaii

Service Assessment

Super Typhoon Paka
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Richard H. Hagemeyer
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NWS Pacific Region Headquarters
Honolulu, Hawaii

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PREFACE

The purpose of this Service assessment is to document the National Weather Service (NWS) performance in fulfilling its mission of providing timely warnings and accurate forecasts during the passage of Super Typhoon PAKA through Micronesia and the Marianas Islands. The NWS's products and services, used by emergency managers, media, and others, are key to public safety with regard to severe weather. The warning process is a partnership between the NWS and all organizations charged with responding to natural hazards. We in the NWS will continue to forge and nurture these relationships to ensure the best possible warning service for our citizens.

Richard H. Hagemeyer
Director, NWS Pacific Region

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I. Service Assessment Team

The NWS assembled this Service Assessment Team to analyze the overall warning process and to evaluate the services provided by the NWS to the territorial government of Guam, the government of the Marshall Islands, the media, the citizens of Micronesia, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI). The team traveled to Guam from December 19-24, 1997, collecting information and interviewing the NEXRAD (Next Generation Weather Radar) Weather Service Office (NWSO) Tiyan, Guam, staff members, Guam territorial emergency management personnel, military meteorological officials, other officials, media, and the public. Additional information was collected on Guam from the Joint Typhoon Warning Center (JTWC), the Andersen Air Force Base (AAFB), Weather Detachment; in Honolulu, the NEXRAD Weather Service Forecast Office (NWSFO) and the Pacific Region Headquarters (PRH); Weather Service Headquarters (WSH); in Kwajalein, Aeromet, Inc.; in the Republic of the Marshall Islands (RMI), Weather Service Office (WSO) Majuro; and in the Federated States of Micronesia (FSM), WSO Pohnpei. All of the information was then compiled and evaluated, culminating in this report.

The team was comprised of the following three people:

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II. Acronyms

AAFB	Andersen Air Force Base
ASOS	Automated Surface Observing System
CNMI	Commonwealth of the Northern Mariana Islands
CPA	Closest point of approach of the eye
CPHC	Central Pacific Hurricane Center
DOD	U.S. Department of Defense
ENSO	El Niño-Southern Oscillation
FSM	Federated States of Micronesia
JTWC	Joint Typhoon Warning Center
HST	Hawaiian Standard Time
LST	Local Standard Time
NEXRAD	Next Generation Weather Radar
nm	nautical miles
NWS	National Weather Service
NWSO	NEXRAD Weather Service Office
NWSFO	NEXRAD Weather Service Forecast Office
PRH	Pacific Region Headquarters
RMI	Republic of the Marshall Islands
SOO	Science and Operations Officer
SST	Sea Surface Temperature
USAF	U.S. Air Force
UTC	Coordinated Universal Time
WFO	Weather Forecast Office
WSH	Weather Service Headquarters
WSO	Weather Service Office
WSR-88D	Weather Surveillance Radar-1988 Doppler

III. Event Summary

Tropical Storm Paka formed in early December 1997, just after the conclusion of the official Central Pacific hurricane season (June 1-November 30). It was named by the Central Pacific Hurricane Center (CPHC), Honolulu, on 1200 Coordinated Universal Time (UTC), December 2, 1997 (2 a.m. Hawaiian Standard Time [HST]), when it was approximately 1200 nautical miles (nm) southwest of Kauai. This unusual post season tropical cyclone genesis was part of a twin development (Tropical Cyclone Pam formed at about the same time in the Southern Hemisphere and eventually moved southward, causing significant damage in the Cook Islands). This was the result of the strong El Niño-Southern Oscillation (ENSO) episode that produced an environment favorable for tropical cyclone genesis. Tropical Cyclone Paka tracked westward between 8-14 kts well south of the Hawaiian Islands, maintaining tropical storm strength (45-55 kts).

Tropical Storm Paka crossed the dateline on December 7 (06/1800 UTC) and entered the tropical northwestern Pacific. Responsibility was then transferred from the CPHC to the JTWC, Guam. Paka moved through the Marshall Islands on December 10-13, moving slightly south of west. Paka initially maintained tropical storm strength but was predicted by the JTWC to diminish in strength and to eventually dissipate as it approached the Marshall Islands. Conditions cited by JTWC in predicting Paka to diminish in intensity included moderate vertical wind shear. Table 1 shows the initial predictions issued by JTWC that were used as guidance by WSO Majuro, Republic of the Marshall Islands (RMI) and NWSO Tiyan in their forecasts for Paka's path through the Marshall Islands. The initial track forecasts issued by JTWC called for the storm to move west-northwest into increasing westerly winds aloft and slightly cooler sea surface temperatures (SST).

However, Paka's more west to west-southwest track through the eastern Marshall Islands (before exiting on a more northwest track) encountered less shear and warmer SST (2 degrees C) that was just enough to overcome an earlier sheared upper level environment, and resulted in a more favorable outflow pattern that led to rapid intensification on December 11 (see Figure 1).

Table 1: Predictions of the intensity of Typhoon Paka (kts/mph) as it approached and moved through the Marshall Islands

DATE/TIME (UTC)	POSITION	INTENSITY		24HR FCST	48HR FCST	72HR FCST
06/1800 *verification*	8.9N/179.5W	035G045 kts	040G052 mph	035G045kt ***055G065kt***	035G045kt ***045G055kt***	030G040kt ***045G055kt***
07/1800 *verification*	8.9N/177.8E	055G065 $ kts	063G075 mph	060G075kt ***045G055kt***	035G045kt ***045G055kt***	030G040kt ***065G080kt***
08/1800 *verification*	7.4N/175.4E	045G055 + kts	052G064 mph	040G050kt ***045G055kt***	035G045kt ***065G080kt***	030G040kt ***105G130kt***
09/1800 *verification*	6.8N/172.7E	045G055 kts	052G064 mph	045G055kt ***065G080kt***	040G050kt ***105G130kt***	035G045kt ***115G140kt***
10/1800 *verification*	6.9N/169.9E	065G080 * kts	075G092 mph	070G085kt ***105G130kt***	060G075kt ***115G140kt***	060G075kt ***115G140kt***
11/1800 *verification*	7.4N/166.9E	105G130 kts	121G150 mph	125G150kt ***115G140kt***	125G150kt ***115G140kt***	120G145kt ***140G170kt***
12/1800 *verification*	8.4N/164.1E	115G140 kts	132G161 mph	125G150kt ***115G140kt***	135G165kt ***140G170kt***	135G165kt ***135G165kt***

$ Tropical Storm Watch issued at 9:30 a.m. LST, December 8.

\+ Tropical Storm Warning issued at 9:00 a.m. LST, December 9, for Majuro Atoll, eventually extended to include Mili, Jaluit, and Ailinglaplap Atolls, as Paka traced westward.

* Typhoon Warning issued at 9:30 a.m. LST, December 11 (10/2130 UTC) at 11/00 UTC, an eye formed as Typhoon Paka intensified.

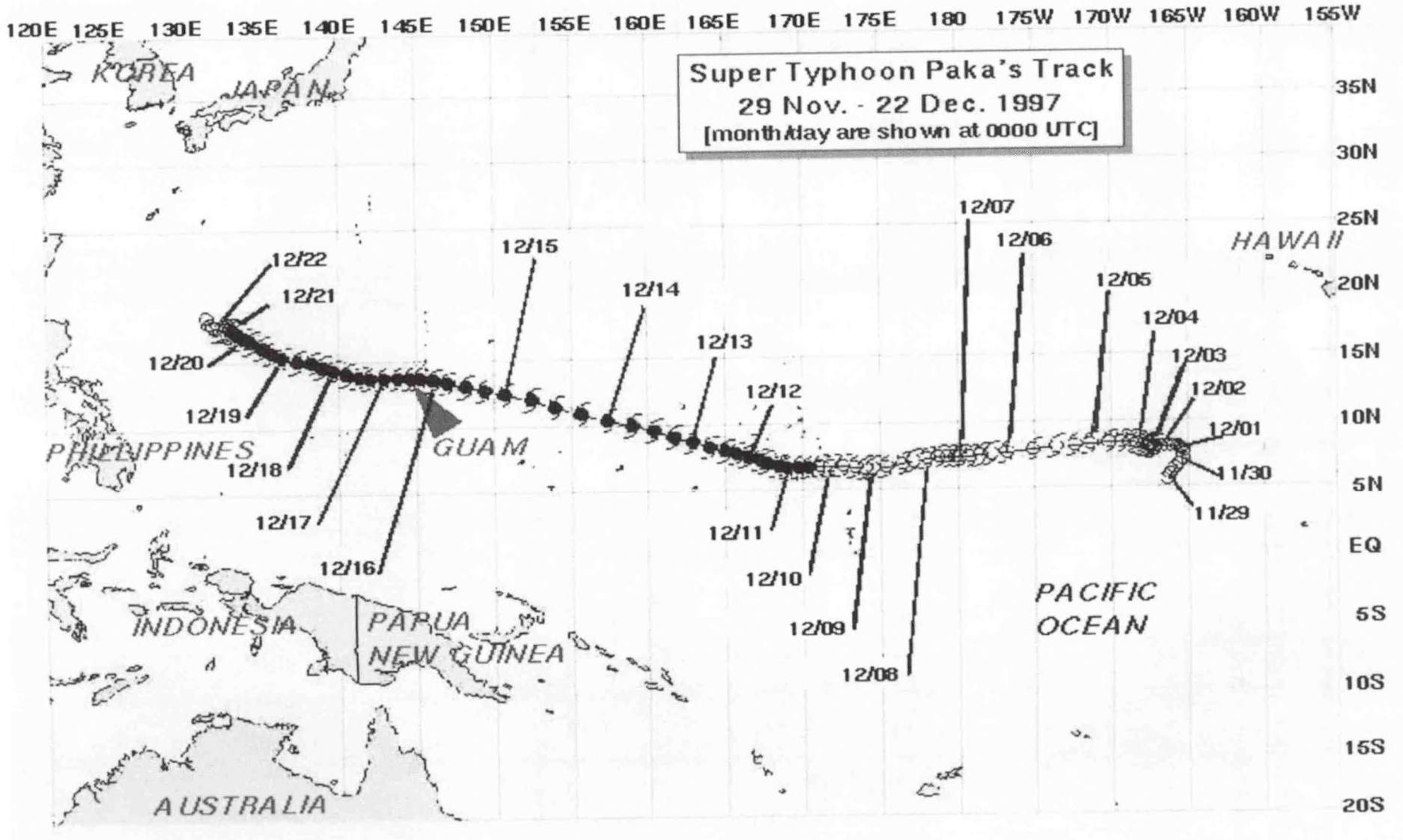


Figure 1: Track of Super Typhoon Paka Courtesy of Joint Typhoon Warning Center

Tropical Storm Paka reached typhoon strength in the Marshall Islands on December 11 at 0600 Local Standard Time (LST) (1800 UTC). Typhoon Paka continued to intensify as it tracked northwest into the FSM on December 12, with Typhoon Watches issued for Kosrae, Pingelap, Mokil, and Ujelang. Paka came within about 40 nm of Ujelang Atoll, the extreme western atoll of the Marshall Islands. Because Ujelang is believed to be uninhabited, the extent of damage is unknown (see Figures 2 and 3).

At 1700 LST Guam local time (2300 UTC), Sunday, December 14, a typhoon watch was issued by the NWSO Tiyan, Guam, for all of the Mariana Islands when Paka was about 750 nm east-southeast of Guam. Typhoon warnings were declared for Guam, Rota, Tinian, and Saipan at 0930 LST (1530 UTC), Monday, December 15. At this time, Typhoon Paka was upgraded by JTWC to a super typhoon with sustained winds of approximately 140 kts (161 mph). The predicted track of Paka continued to be near or directly over Guam with the eye making its closest point of approach (CPA) in the early evening of Tuesday, December 16. This turned out to be an accurate forecast as the CPA was about 2100 LST (0300 UTC) on Tuesday, December 16. As Paka bore down on Guam, it slowed to about 7 kts (8 mph). This resulted in maintaining typhoon force-winds across the central portion of the island for over 8-10 hours (Forbes, et al., 1998). Based on NEXRAD Radar (see Figure 4), anemometers, and damage patterns, sustained west to southwest winds of 100-125 kts (115-144 mph) in the southern most part of the outer eyewall affected the northern two-thirds of the island. Paka, like many of the more intense typhoons, contained a concentric eyewall structure (20 and 5 nm based on the U.S. Department of Defense [DOD] NEXRAD). Best estimates for central surface pressure and maximum sustained winds for Paka are 935 mb and 130 kts, making it a super typhoon (Guard, 1998) (JTWC, 1998).

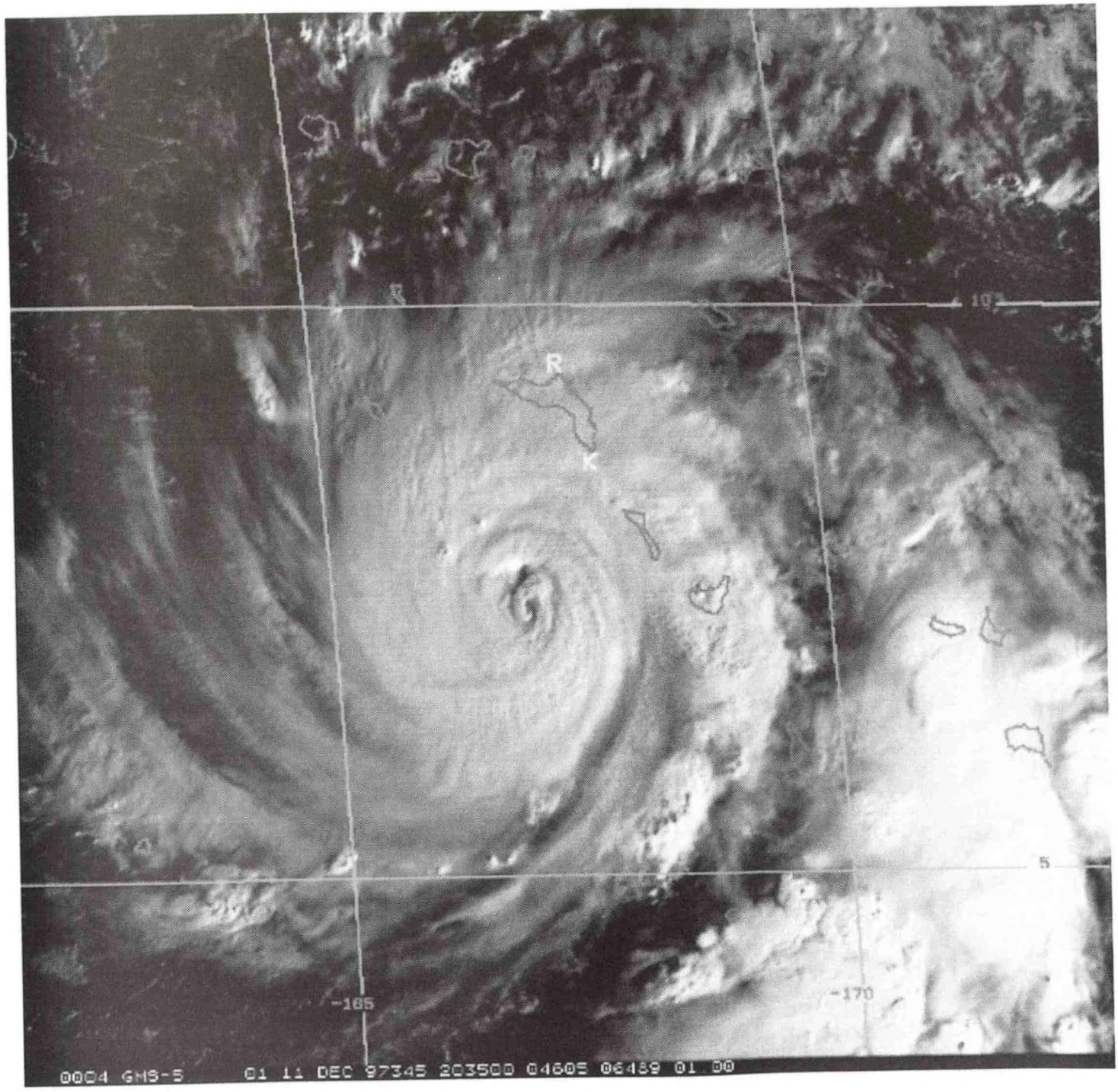


Figure 2: GMS visual picture (1.25 km resolution) at 2035 UTC on December 11,1997 (8:35 am LST December 12th) Courtesy of Aeromet, Inc. Kwajalein Atoll

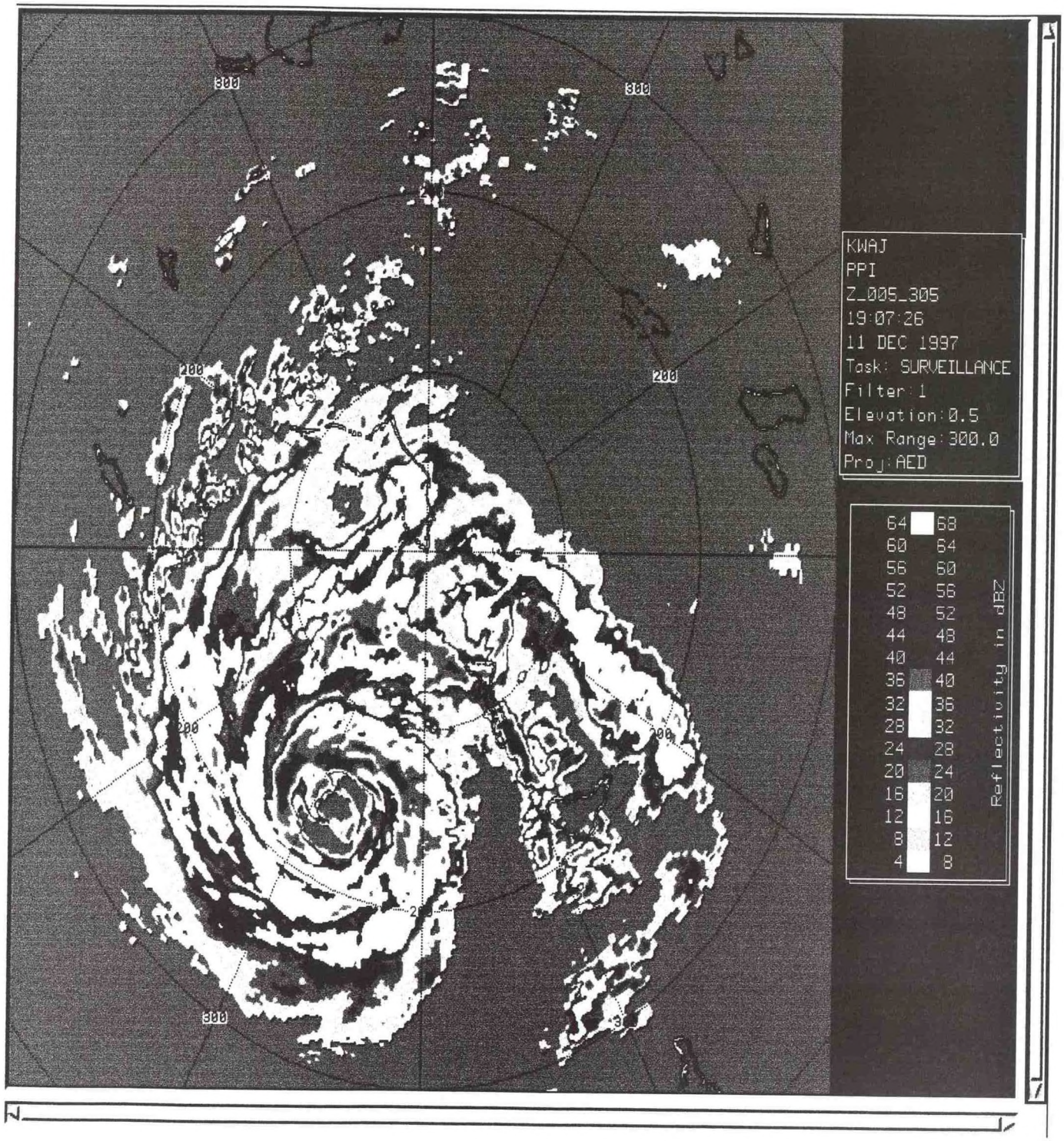
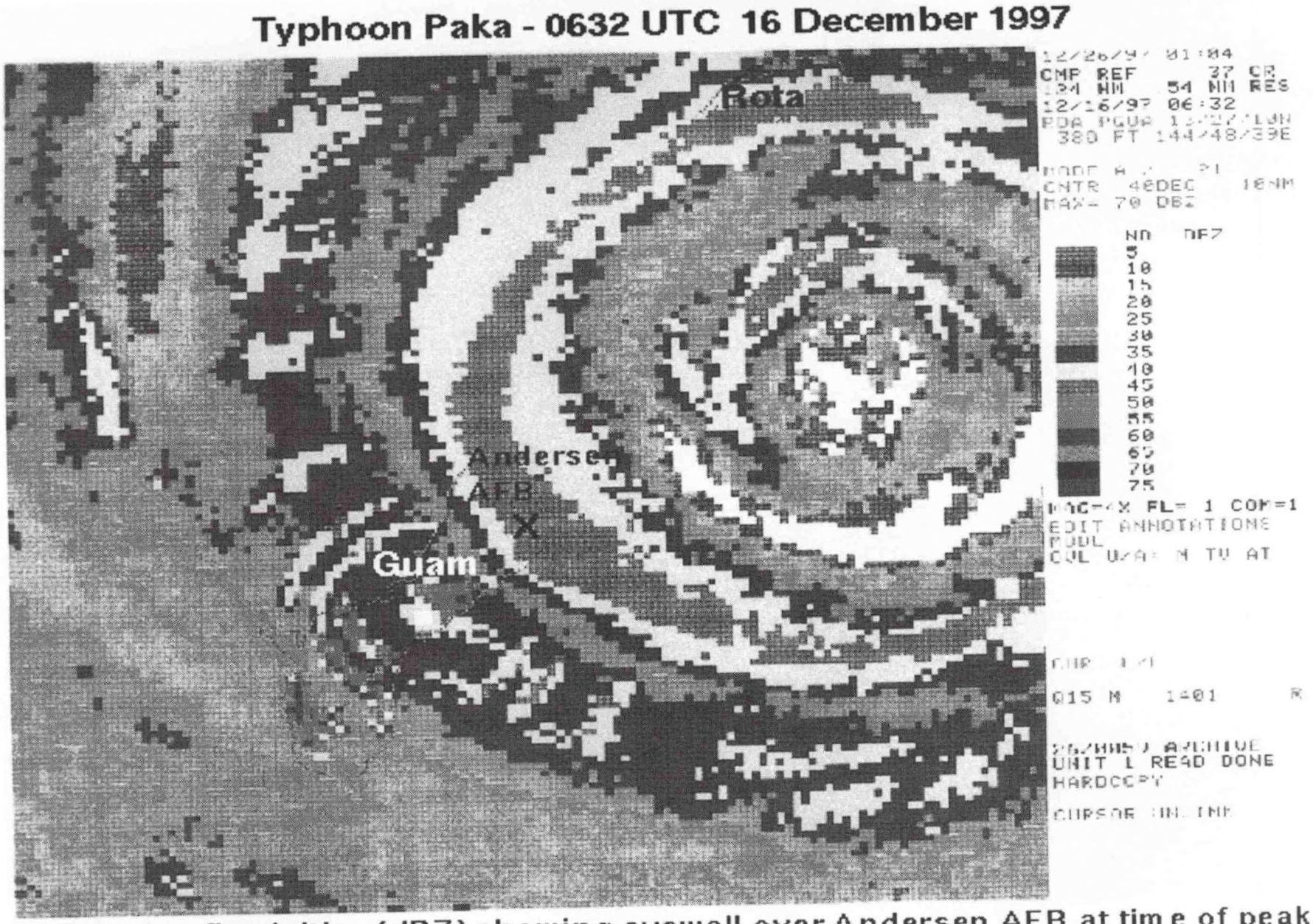


Figure 3: **A 0.5 degree elevation Kwajalein DWSR-93S PPI of reflectivity taken at 1907 UTC on 11 December 1997.**



WSR-88D reflectivities (dBZ) showing eyewall over Andersen AFB at time of peak gust (X indicates the location of the wind instrument)

Figure 4

At the AAFB, located on the northeast end of the island, winds were at first northerly then turned to southerly as the outer eyewall moved across the island. A hot wire anemometer, an FMQ-13, located at the southwest end of the runways recorded a gust of 205 kts, but this is not supported by post-analysis (Forbes, et al., 1998). The incomplete inner eyewall stayed offshore. The island of Rota was north of the eye and thus received strong easterly winds from the outer eyewall. Rainfall reached 20 inches for Guam over 48 hours (see Figure 5).

Deaths and Damages

There was no loss of life in the Marshall Islands caused by Typhoon Paka. However, the devastation caused by tropical storm strength winds in the Ailinglaplap, Arno, Majuro, Mili, Jaluit atolls of the Marshall Islands resulted in considerable damage. This included losses to hundreds of homes, businesses in the hundreds of thousands of dollars, along with heavy losses to island staples such as breadfruit, bananas, and pandanus. The double impact of experiencing a damaging typhoon in the midst of a devastating drought period caused by ENSO will likely result in a longer recovery period for the Marshall Islands.

There were no deaths on Guam and Rota, a tribute to the experienced population, a superior building code, and adequate warning times. Concrete roofed housing and the concrete telephone poles withstood the onslaught of Paka well. In fact, only about 75 of the concrete poles were downed (Guard, 1998). Older structures with tin roofs and wood telephone poles were either damaged or destroyed (see Figures 6-11). Many of these had been compromised by prior typhoons, termites, and salt corrosion. Several thousand people were made homeless; generally these were people living in older structures that did not meet the new building codes. Fortunately, the southern third of the island, which was beyond the outer eyewall, suffered little damage.

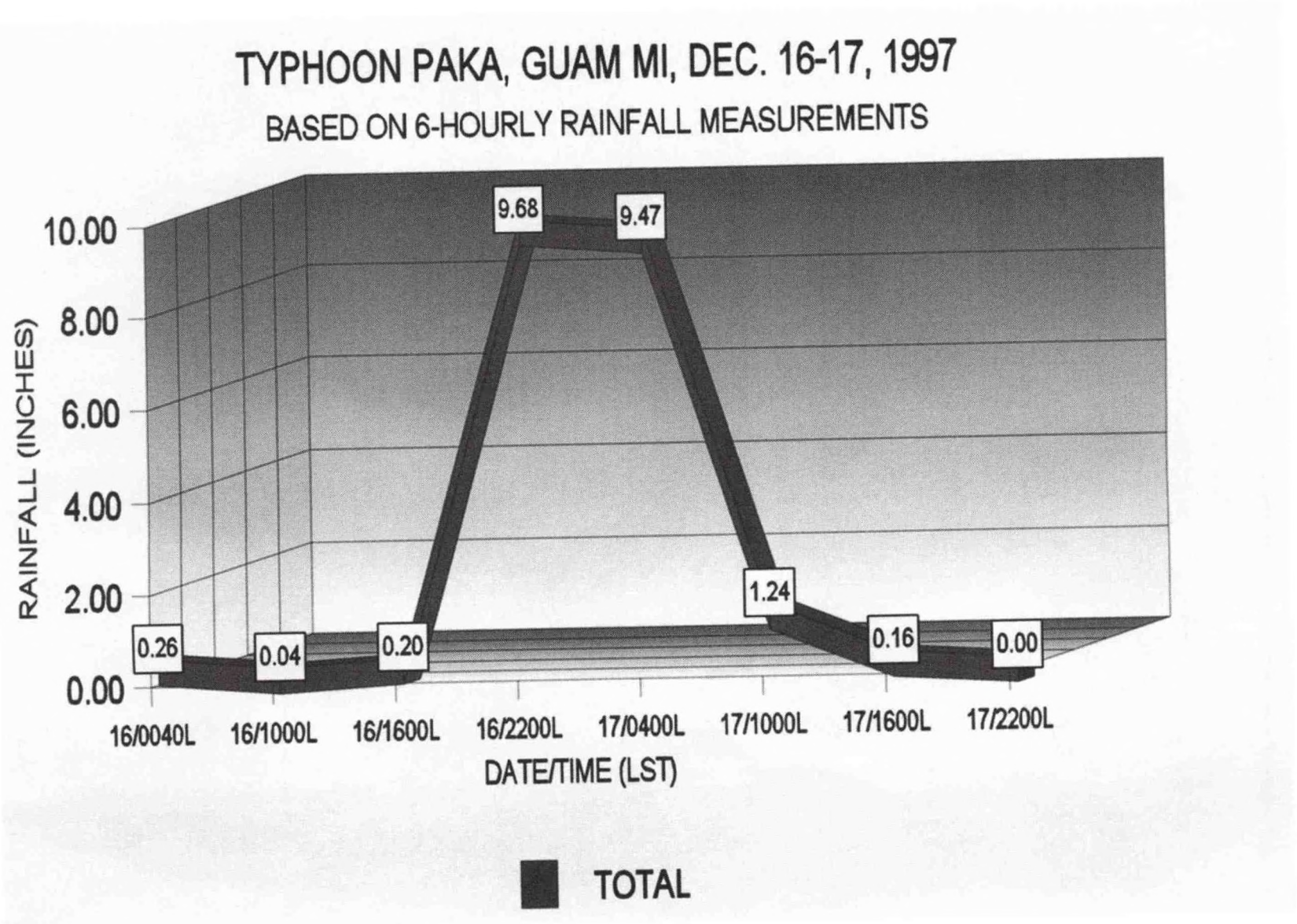

TYPHOON PAKA, GUAM MI, DEC. 16-17, 1997
BASED ON 6-HOURLY RAINFALL MEASUREMENTS
RAINFALL (INCHES)
10.00
8.00
6.00
4.00
2.00
0.00
0.26
0.04
0.20
9.68
9.47
1.24
0.16
0.00
16/0040L
16/1000L
16/1600L
16/2200L
17/0400L
17/1000L
17/1600L
17/2200L
DATE/TIME (LST)
TOTAL

Figure 5

Figure 6: This destroyed school room was not an engineered structure and was attached to the concrete slab only by some small nails. *

Figure 7: Just southwest of Andersen Air Force Base the concrete poles and the majority of palm trees, especially those trees away from the coast, handled Paka well. Leafy vegetation was most often denuded. *

Fig. 8: A devastated warehouse that was first compromised by flying debris. Once the wind entered the building the sheet metal was easily blown out, and away from the support beams.*

Fig. 9: This aerial view demonstrates that newer, engineered structures escaped with minor cosmetic damage but older wood buildings suffered greatly. This area is between Apra Harbor and Tumon. *

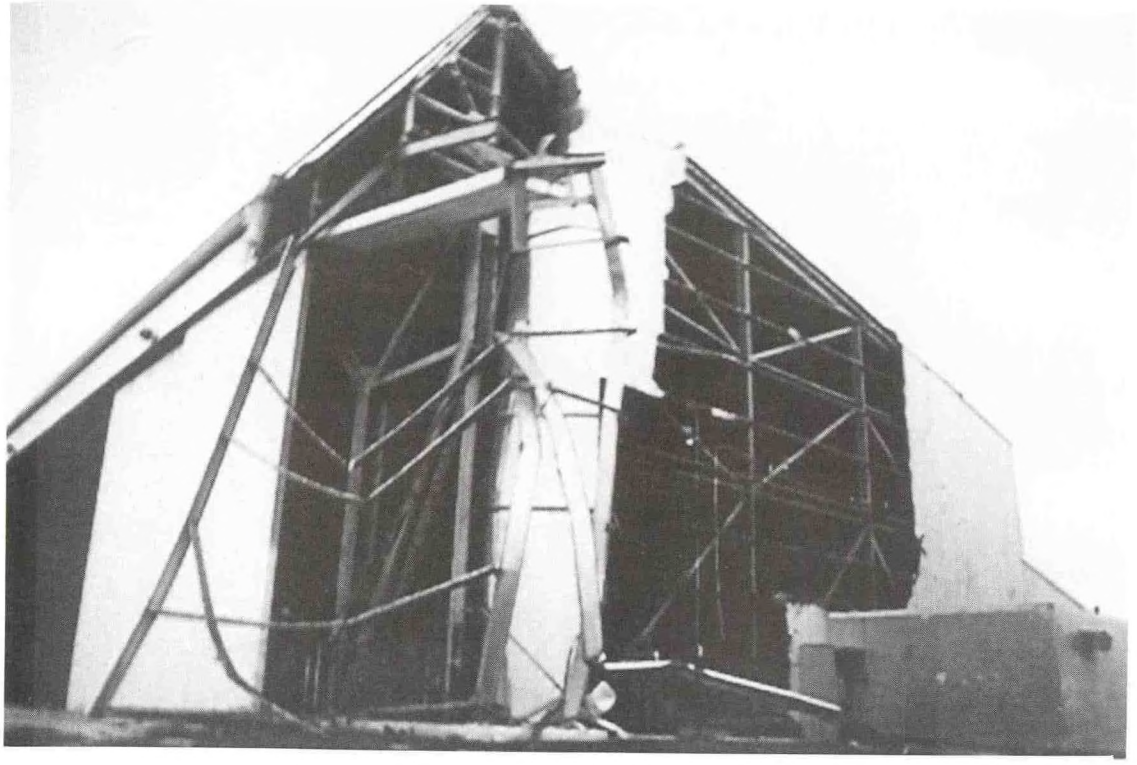


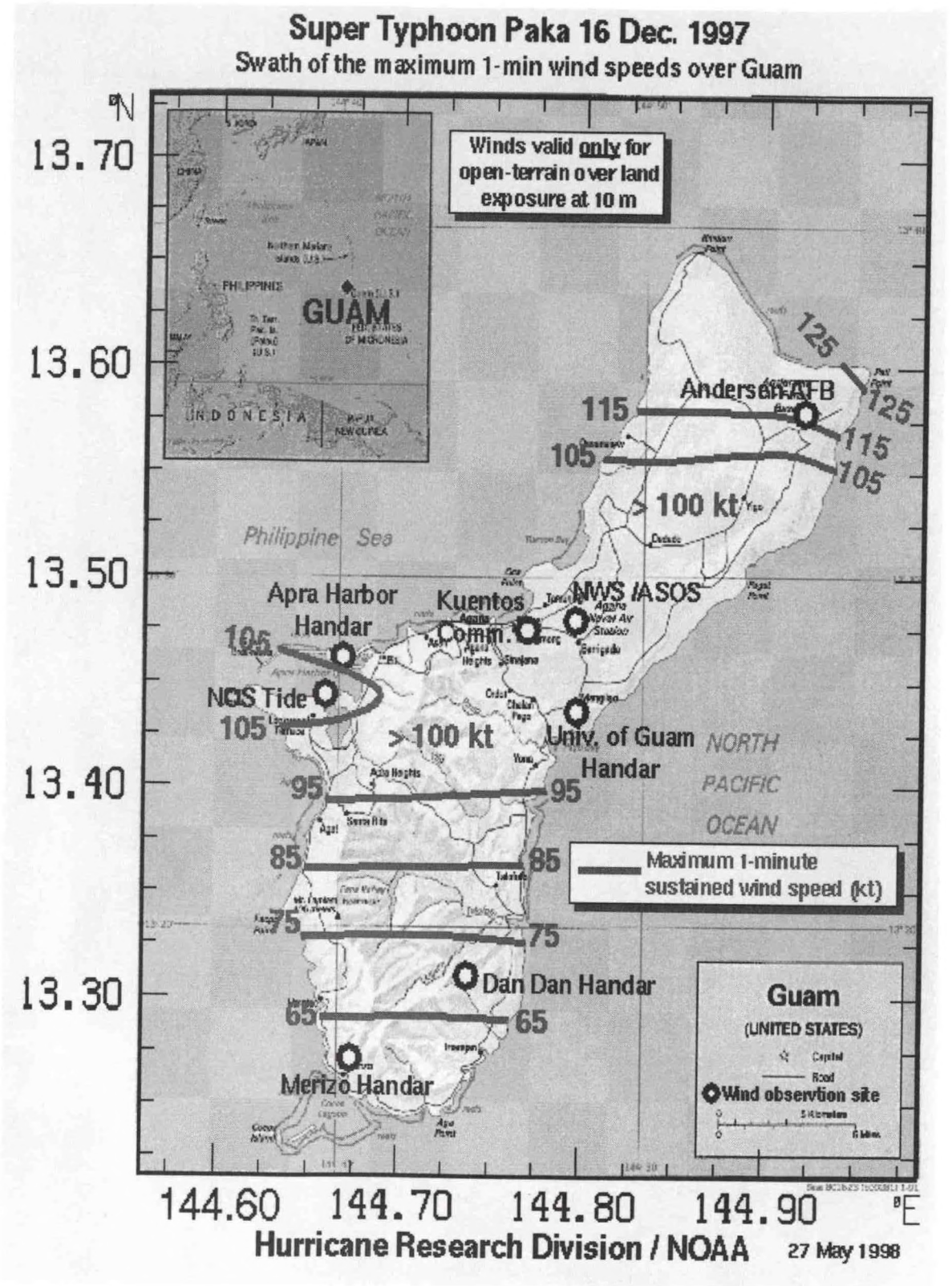
Figure 10: This damaged hangar at Andersen Air Force base is well exposed to the wind and appears to have been damaged when the winds came from the southwest. **

Figure 11: Houses only 100 meters from Tumon Bay, built according to the new building codes, survived the winds with only minor cosmetic damage. **

Interviews with the public demonstrate that the duration (8-10 hours of greater than 64 kts sustained) of the destructive winds, in conjunction with an evening and night passage, gave them the perception that Paka was the worst of the typhoons in the last 25 years (see Figure 12). This includes Omar (1992) and Pamela (1976). Vegetation damage was impressive due to the duration of the winds and the heavy rains. Damage estimates ranged upward of 600 million U.S. dollars (GOV Guam, Super Typhoon Paka, 1998) (see Figure 13).

The NWSO Tiyan, Guam, in conjunction with JTWC, did an excellent job predicting the intensity and arrival time of the typhoon. NWSO Tiyan, Guam, provided timely updates about the storm until its emergency backup generator failed at 1825 LST, the result of copious amounts of water that had blown into the space where the generator was kept. The JTWC assumed the burden of providing weather updates to the few radio stations still left with power and able to broadcast. The NWSFO in Honolulu, Hawaii, became the backup forecast office for several days and produced the official NWS statements, warnings, and advisories until power was restored after storm passage, operations stabilized, and responsibility was transferred back to NWSO Tiyan, Guam. Fortunately, Paka continued its track to the west away from Guam during this period when most radio and TV stations were out and roads were blocked.

The primary issue for the NWSO Tiyan, Guam, and the island in general was sustaining reliable power supplies. Power supply failures and fluctuations caused the DOD NEXRAD radar, the NWSO Tiyan, Guam, and the Automated Surface Observing System (ASOS) to cease operations during the initial passage of the outer eyewall over the island. Failure of island communication links or radio stations could have led to a greater disaster if people had left their shelters during a lull in the winds, or if the typhoon had looped back toward the island.



Swath map of maximum 1 minute sustained wind speeds over Guam during Super Typhoon Paka on 16 December 1997. These peak wind speeds (units = knots) are based on advecting surface wind fields along Paka's track. These wind speeds are valid only for open terrain over land exposure at 10 meter height. The wind observation stations used to produce the swath are also shown (NOAA 1998).

Figure 12

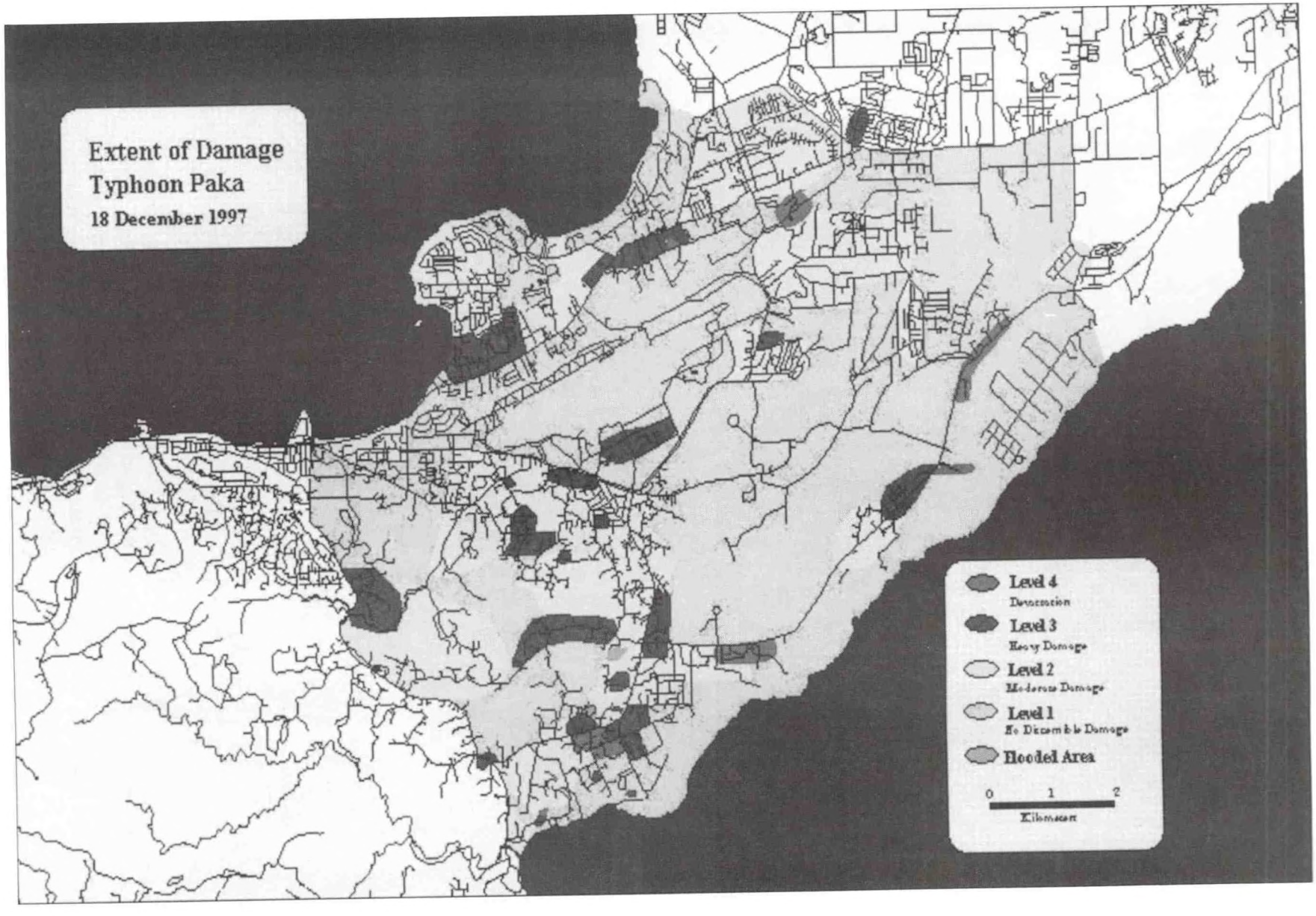


Figure 13: Preliminary Damage Index

Post analysis of Paka's wind structure was compromised by the loss of all level two radar data, the ASOS located at Guam International Airport, and the failure or loss of other anemometers on the island. The loss of ASOS data during the peak wind period of tropical cyclone passage is a recurring problem (Powell, M., Houston, S., Monthly Weather Review, May 1998). Another issue was communications. A popular TV and radio personality did forecast a much earlier CPA that was at variance with the official forecast. Additionally, the last forecast made by NWSO Tiyan before power failure also changed the CPA to a number of hours later than previous forecasts; this was a result of confused communications between JTWC and the NWSO. By this time, the high winds were affecting the island and preparations were as complete as they were going to be.

Table 2: Summary of Paka

Date and time (UTC)	Event
11/28 1800	Disturbance that becomes Paka first noted
12/02 1800	Tropical storm is named Paka
12/06 1800	JTWC assumes responsibility for Paka
12/10 1800	Paka reaches typhoon intensity, passes Marshalls
12/14 0700	Watch issued for Marianas
12/14 2330	Super typhoon status achieved (130 kts), Warning issued for Marianas (see Figure 2)
12/16 0700	Outer eyewall reaches northern Guam
12/20 0000	Rapid collapse of Paka begins in west Pacific

IV. Summary of Findings and Recommendations

The findings and recommendations are organized in a fashion following recent severe weather service assessments (e.g., Arkansas, March 1997 Tornado Outbreak). Subtopics include observations, guidance, warnings, service coordination, dissemination, response, preparedness, and system infrastructure.

A. Observations

FACT: The primary observation tool for the western Pacific is the Japanese geostationary satellite. Interpretation of the data from this platform for typhoon track and intensity is the responsibility of JTWC. Paka exhibited a near straight track through the Marshall Islands and moved directly toward Guam.

FACT: As Paka approached Guam, the Weather Surveillance Radar-1988 Doppler (WSR-88D), operated by AAFB, supplied unsurpassed views of the storm reflectivity structure, wind fields derived from Doppler radar, and storm motion.

Finding 1: Typhoon Paka's intensity and subsequent intensification in the Marshall Islands was under forecasted, as it traveled through a populated island chain and took a more westerly track. This made it difficult to establish a proper level of preparedness for a close point of approach of a possible typhoon when the official forecast called for dissipating the storm in the later stages of the forecast period.

Recommendation 1: NWS PRH, CPHC and JTWC should work together to reanalyze Paka's evolution in the vicinity of the Marshall Islands. This analysis should be directed at determining the rationale behind the issued forecast. Further study should then be conducted to determine what additional information might be used to improve the forecast intensity and track in the future.

Finding 2: Once the typhoon reached the island, there were several anemometers capable of measuring the typhoon wind field, but most official instruments were damaged, destroyed, or lost power in the high winds or were not calibrated to measure super typhoon-force conditions. In some cases, the instruments were not well exposed.

Recommendation 2: NWS PRH should re-site replacement wind measuring instruments to obtain better exposure and place these sensors at the standard 10 meter height. In addition, the NWS PRH will better ensure that ASOS data are preserved after power is restored by establishing maintenance procedures that put equal priority on downloading archived data before restoring ASOSs to full operation.

Finding 3: Several of the sensors provided suspicious data (e.g., AAFB hot wire anemometer measured a 205 kt [236 mph] gust). These sensors were designed to provide high frequency information to support aircraft landing and take-off conditions, not to accurately measure super typhoon winds.

Recommendation 3: Since Guam is frequently affected by typhoons, more robust wind sensors capable of measuring high winds found in tropical cyclones should be developed and deployed, which would be beneficial for understanding future damage patterns.

B. Guidance

FACT: The numerical models and their interpretation by JTWC resulted in an excellent forecast for Paka's track. This forecast was used by NWSO Tiyan, Guam, as guidance in their public typhoon advisories, as is stated in the Memorandum of Understanding between NWS and the Naval Meteorology and Oceanography Command.

C. Predictions, Watches, and Warnings

FACT: Watches and warnings were given in a timely fashion by NWSO Tiyan, Guam, with the first watch for Guam being issued 48 hours in advance. The first typhoon warning for Guam was issued 33 hours preceding the arrival of the outer eyewall in northern Guam. From the first watch issued for Guam and the CNMI to outer eyewall arrival on Guam, 18 advisories were released; all save the last advisory forecasted the arrival of typhoon-force winds in the early evening of Tuesday, December 16 (Guam local time). The typhoon intensity was clearly stressed in these advisories.

Finding 4: The last advisory (1730 LST COR) issued by NWSO Tiyan, Guam, forecast the CPA to be at 2200 LST which was several hours later than all the prior forecasts and was based on the prior telephone communication between JTWC and NWSO Tiyan, reflecting JTWC's thinking at that time. JTWC shortly thereafter readjusted the speed of Paka such that the CPA would occur earlier, but by this time NWSO Tiyan had lost power due to winds and rain. Since conditions had already deteriorated and the public had already taken shelter, this delay in the CPA did not result in the unnecessary risk of life or property.

Recommendation 4: NWSO Tiyan, Guam, should not release their advisory until they have received the JTWC official tropical cyclone forecast.

D. Service Coordination

FACT: When power failed at the NWSO Tiyan, Guam, JTWC assumed the provision of briefings for the local media and the NWSFO/CPHC Honolulu assumed public warning and forecast responsibilities.

Finding 5: When JTWC assumed the burden of updating local media and government organizations, they described wind speeds in kts rather than miles per hour, which caused minor confusion on the part of some of the public. Even before the assumption of responsibility by JTWC, there were instances when JTWC and NWSO Tiyan, Guam, products did not conform to the same convention and sequence of numbers which caused some confusion.

Recommendation 5: NWSO Tiyan, Guam, should develop a checklist to pass to JTWC and NWSFO/CPHC Honolulu so that these offices, if they assume NWSO Tiyan, Guam, responsibilities, can use the terminology that is understood by the citizens in the forecast area. Furthermore, the NWS must establish more standard procedures for typhoon products issued by NWSO Tiyan, Guam.

E. Dissemination

FACT: The media are the primary source of weather information for the public. Interviews with the media demonstrate that prior to the power outage at the NWSO Tiyan, Guam, content and timeliness of the advisories from the NWSO to local government and media were excellent.

Finding 6: One station, which among its resources has a cable channel dedicated to weather, issued forecasts for the CPA that were markedly different from the NWSO Tiyan, Guam, official forecast. This did cause considerable confusion on the part of the public. In particular, this station used "Crawlers" script that moves across the bottom of the screen to present their forecast. These "Crawlers" are perceived by the public as official information, when in fact it was unofficial information.

Recommendation 6: The NWS PRH should work with the local media on Guam, ensure that the media clearly and frequently identify the source of their information and, if necessary, inform the public that their forecasts are at variance with the NWS typhoon warnings.

Finding 7: The Internet Home page maintained by the NWSO Tiyan, Guam, office was accessed frequently as Super Typhoon Paka approached Guam and the CNMI. However, once NWSO Tiyan,

Guam, lost power and transferred warning and forecast operations to NWSFO/CPHC Honolulu, updating of their (Tiyan) home page was not done, resulting in the home page not being updated for several days.

Recommendation 7: The NWS PRH should develop procedures so that NWSO Tiyan, Guam, will establish provisions to have their home page backed up when and if they have to transfer operations to NWSFO/CPHC Honolulu.

F. Response

FACT: The population of Guam is highly experienced with respect to typhoons and had the appropriate response to the watches and warnings issued by NWSO Tiyan, Guam. Evidence for this is that there was no loss of life in a typhoon that produced sustained winds in excess of 64 kts for 8-10 hours.

FACT: The local authorities were well informed about Paka's track and intensity and responded accordingly.

G. Preparedness

Finding 8: Interviews with the media and the local authorities conducted by the assessment team while in Guam demonstrated that the MIC, NWSO Tiyan, Guam, maintained a superior level of communication to these groups. However, the need for more frequent updating of information was noted.

Recommendation 8: NWS PRH needs to establish procedures whereby the primary and back-up office provide more frequent advisory bulletins as a typhoon impacts the local area.

H. System Infrastructure

FACT: The AAFB NEXRAD is often down even during normal weather conditions due to power fluctuations that damage circuits. When parts are ruined by these power problems, the USAF, which operates this radar, must obtain replacement parts through a complicated process. The NEXRAD was down for several days and only became operational about 6 hours prior to landfall due to a remarkable effort on the part of the local AAFB Wing Commander.

FACT: The NEXRAD radome survived the storm despite it being in the outer eyewall for several hours. Winds were estimated to be 100 kts with gusts reaching 130 kts (Forbes, et al., 1998).

Finding 9: Emergency power to the NWSO Tiyan, Guam, to the U.S. Air Force (USAF) NEXRAD, and to other critical sensors such as ASOS failed during the passage of the outer eyewall of Paka, causing a loss of vital information to everyone. Heavy rains, driven by high winds, were responsible for these failures.

Recommendation 9: NWS PRH should establish and maintain reliable emergency power to the NWSO Tiyan, Guam, and to all vital sensors. Place back-up generators for the NWSO Tiyan, Guam, in locations where personnel can safely reach them during high winds and heavy rains.

Finding 10: Communication links between the NWSO Tiyan, Guam, civil defense, and the media were either compromised or failed completely during the height of the storm between the NWSO and civil defense, and between the NWSO and the media. Additionally, the NWSO Tiyan, Guam, uses telephone fax as their primary tool to disseminate warnings to the media and Guam Civil Defense (besides NOAA Weather Radio) due to the non-existence of a weather wire for the Mariana Islands, and an inoperative Emergency Alert System.

Recommendation 10: NWS PRH should work with the Guam Civil Defense and the local media to establish more robust communication links (between the NWSO Tiyan and emergency teams and the NWSO Tiyan and the media) to ensure timely updates.

Finding 11: The NEXRAD level two archive data recording device was unreliable and resulted in loss of this valuable information during the passage of Super Typhoon Paka. The problem appears to be a design flaw with the tape drives.

Recommendation 11: The NWS should request that the three NEXRAD agencies review the requirement for a more reliable and robust level two archive data recording system.

Finding 12: The current building that houses the NWSO Tiyan, Guam, cannot withstand super typhoons without significant water damage that compromises all electrical systems.

Recommendation 12: The current construction plans for a new Weather Forecast Office (WFO) should be modified to ensure that the new WFO Tiyan building can withstand super typhoons. It should include a media access room to provide for timely release of information to the media and the public. The emergency power source to this building must be located such that technicians can reach this power source to make adjustments during the height of the typhoon.

Finding 13: The NWSO Tiyan relies on the JTWC for post storm analysis and assessment. The JTWC also provides professional development training to the forecasters of NWSO Tiyan. A Science and Operations Officer (SOO) is not currently authorized for the office. When the JTWC moves to Honolulu in 1999, the above functions and responsibilities will be transferred to NWSO Tiyan.

Recommendation 13: Authorize and fill a SOO position at NWSO Tiyan.

Finding 14: The NWSO Tiyan, Guam, does not have access to the Kwajalein radar in the Marshall Islands. Views of the storm would have benefited the JTWC and NWSO Tiyan forecasters in their storm advisory and warning issuances for the Marshall Islands and would have provided early views of the storm as it moved into the western states of the Federated States of Micronesia, and as it approached the Mariana Islands.

Recommendation 14: NWS PRH should seek permission to access the Kwajalein radar for NWSO Tiyan, Guam, and NWSFO/CPHC Honolulu.

V. Sources and Credits

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Figure 3 — Courtesy of Aeromet, Inc., Kwajalein.

Figure 4 — Courtesy of Andersen AFB, Guam.

Figure 6 thru 9 — * Photos courtesy of Dr. Art Chiu, University of Hawaii.

Figure 10 and 11 — ** Photos courtesy of Dr. Gary Barnes, University of Hawaii.

Figure 13 — Damage Assessments courtesy of the Federal Emergency Management Agency.