

Tropical Systems in the Mojave Desert and southern Great Basin

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Hurricanes, tropical storms and tropical depressions as well as the remnant lows from these systems have at times impacted the southwestern United States. Documented examples of tropical depressions or tropical storms which moved over or near the Mojave Desert and southern Great Basin occurred in September 1939, September 1976 and more recently in September 1997. While rare in this area, tropical systems have the potential to create high impact hazardous weather.

There are three primary reasons that tropical storms and hurricanes do not frequently impact the Mojave Desert and southern Great Basin. Tropical systems that originate in the eastern Pacific typically move northwest and away from the coast of Mexico. However, if the weather pattern in the atmosphere features favorable steering currents, a tropical system can be steered into the northern coast of Mexico. This typically involves a trough in the mid and upper levels of the atmosphere just off the coast of California and Baja California. The position and speed of this trough is key, as the trough needs to be able to steer a tropical system towards the Mojave Desert and southern Great Basin without pushing it too far to the east. In addition, the trough must not be strong enough to shear the system apart and remove most of the bands of rain away from the center of circulation. The second key factor involves water temperatures. Water temperatures in the Pacific get cooler as one gets closer to the coast and moves northward. Tropical systems thrive on warm water, typically that which is greater than 80 degrees Fahrenheit. Lastly, the rugged terrain of the region can also help to shear apart a tropical system, leaving it very difficult for the system to arrive in tact by the time it reaches the Mojave Desert.

Historically, the track that favors a tropical system arriving in the Mojave Desert and southern Great Basin is for either a hurricane or tropical storm to make landfall on the west coast of northern Baja California or on the coast of southern California and then move north or northeast. While September has been the only month where documented examples have occurred, the opportunity for a tropical system to threaten the area can just as easily exist in the later portion of August as well as early October. Although the primary impacts of a tropical system in the Mojave Desert and southern Great Basin has been flooding and associated landslides, other threats can include high winds and even tornadoes.



Typical weather pattern for a tropical cyclone or the remnants of one to impact the southwestern United States.

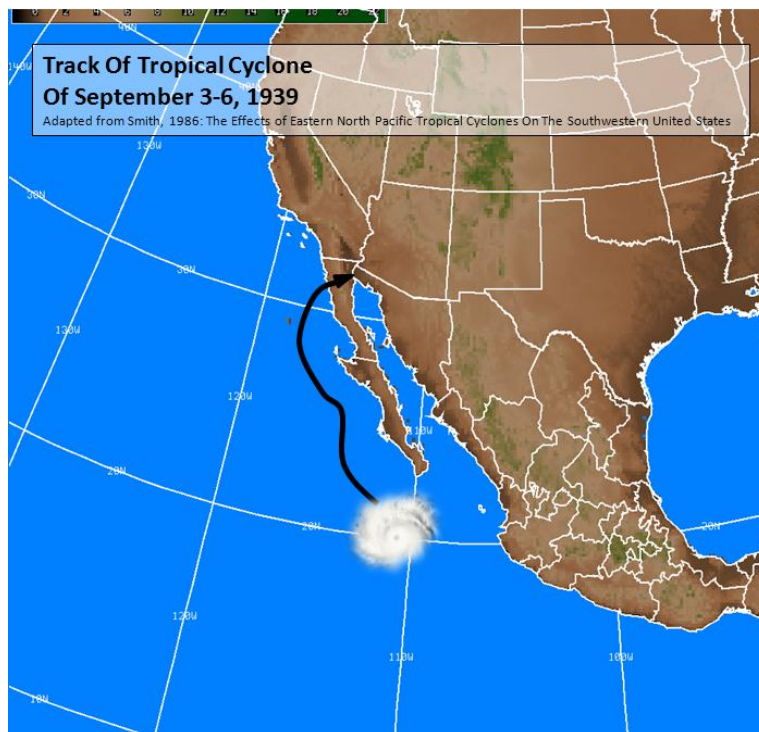
September 1939

September 1939 ranks as the wettest September ever and the second wettest month ever in official Las Vegas weather records since 1937. The total precipitation that month at the official Las Vegas climate station which was located at the old McCarran Airport, now Nellis Air Force Base, was 3.39 inches. In nearby Searchlight, Nevada the total of 8.45 inches fell which ranks as the wettest month ever. These impressive totals were due to three separate tropical systems affecting the area during the course of a month.

The first of these systems affected the area from September 3rd through the 6th with heavy rainfall. Considered a hurricane at one point, this system moved northwest just offshore of the west coast of Baja California before turning northeast moving inland over the northern Baja. Despite the heavy rainfall in Las Vegas and nearby areas, newspaper reports place the main impact being sediment washing onto area roads in low spots.

Rainfall Totals from the Tropical System of September 3-6, 1939

Overton, NV	1.66"	Wikieup, AZ	7.03"
Las Vegas, NV (Downtown)	1.58"	Truxton Canyon, AZ	6.55"
Boulder City, NV	1.44"	Kingman, AZ	5.45"
Las Vegas, NV (Nellis)	1.10"	Mt. Trumbull, AZ	3.70"
Caliente, NV	0.70"	Iron Mountain, CA	5.59"
Mt. Charleston, NV	0.66"	Needles, CA	5.12"
Alamo, NV	0.59"	Parker Reservoir, CA	4.74"
Pioche, NV	0.46"	Twentynine Palms, CA	1.25"



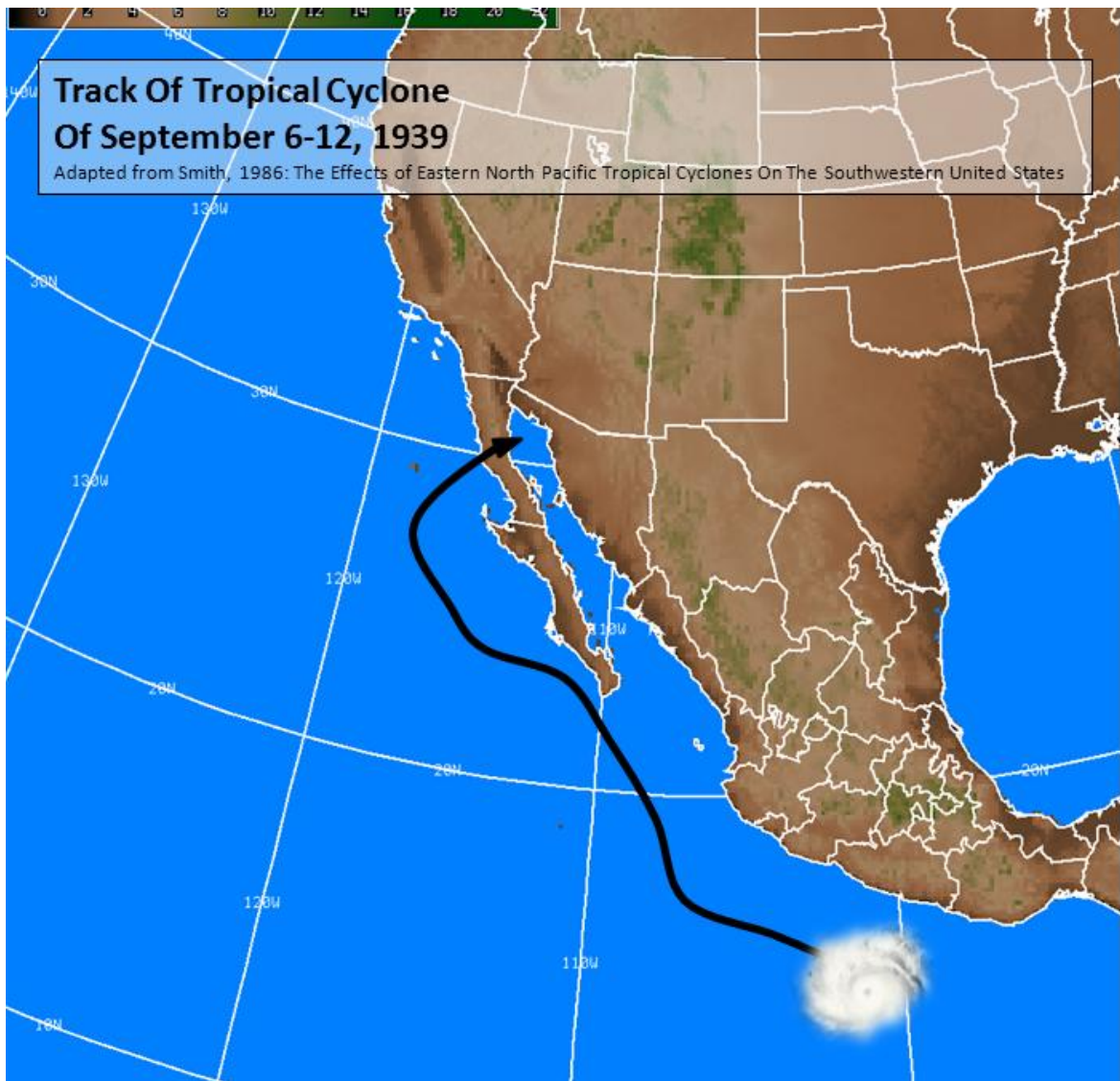
Following a short break, the second tropical system to affect the Mojave Desert and southern Great Basin during September 1939 began to bring rain to the area as early as September 9th and lasted through the 12th. Based on research from Smith (1986), this system originated somewhere off the southwest coast of Mexico and moved northwest remaining offshore through the 11th when a mid-latitude disturbance and associated cold front turned the weakening tropical cyclone inland towards the coast of northern Baja California. The system moved ashore on the 12th and dissipated afterwards.

While rainfall totals overall were not as heavy from this system as they were from the earlier event of the month, it seems likely the wet antecedent condition of the ground enhanced flooding across the area. According to an article in *The Las Vegas Evening Review-Journal*, a wall of water raced down the California Wash near Glendale, Nevada on the night of September 11th and damaged the pavement on a highway. This second period of heavy rain also flooded homes in Eldorado Canyon, Nevada with homes inundated with at least four inches of water. Rain was heavy enough to damage roads in the Eldorado Canyon area “badly” and also halt mining operations at the Diamond Gold Mine. In Las Vegas, heavy rain that fell on the 11th flooded Charleston Boulevard near the intersection of the Tonopah Highway. Flooding also severely damaged what is now Highway 95 between Searchlight, Nevada and Needles, California. One man from Boulder City, Nevada was reported missing after he left for Needles to work on damage to the railroad tracks caused by heavy rain. Northwest Arizona also saw significant flooding as the main road between Needles, California and Oatman, Arizona was heavily damaged and a bridge on the Boulder City-Kingman Highway about 42 miles east of Hoover Dam was taken out by floodwaters. In Death Valley, the wind was strong enough at both the Greenland Ranch and the park service station at Cow Creek that blowing dust was reported from the 10th through the 12th.

The heavy rain also flooded an underpass beneath the Union Pacific railroad 30 miles northeast of Las Vegas resulting in an accident that injured three people around 8 PM on September 11th. Three people, a man and two children from Utah, were hurt in a vehicle that had stopped after becoming stuck in floodwaters and was struck by a bus and moved 45 feet.

Rainfall Totals from the Tropical System of September 6-12, 1939

Searchlight, NV	4.06"	Mt. Trumbull, AZ	3.87"
Caliente, NV	1.34"	Truxton Canyon, AZ	2.83"
Pioche, NV	1.17"	Wikieup, AZ	1.98"
Overton, NV	0.88"	Kingman, AZ	1.18"
Boulder City, NV	0.83"	Parker Reservoir, CA	1.25"
Mt. Charleston, NV	0.79"	Iron Mountain, CA	0.51"
Las Vegas, NV (Nellis)	0.43"	Needles, CA	0.14"
Alamo, NV	0.32"	Twentynine Palms, CA	0.12"
Las Vegas, NV (Downtown)	0.26"	Lake Sabrina, CA	0.10"
Indian Springs, NV	0.18"	South Lake, CA	0.01"
Goldfield, NV	Trace	Barstow, CA	Trace
		Death Valley, CA	Trace

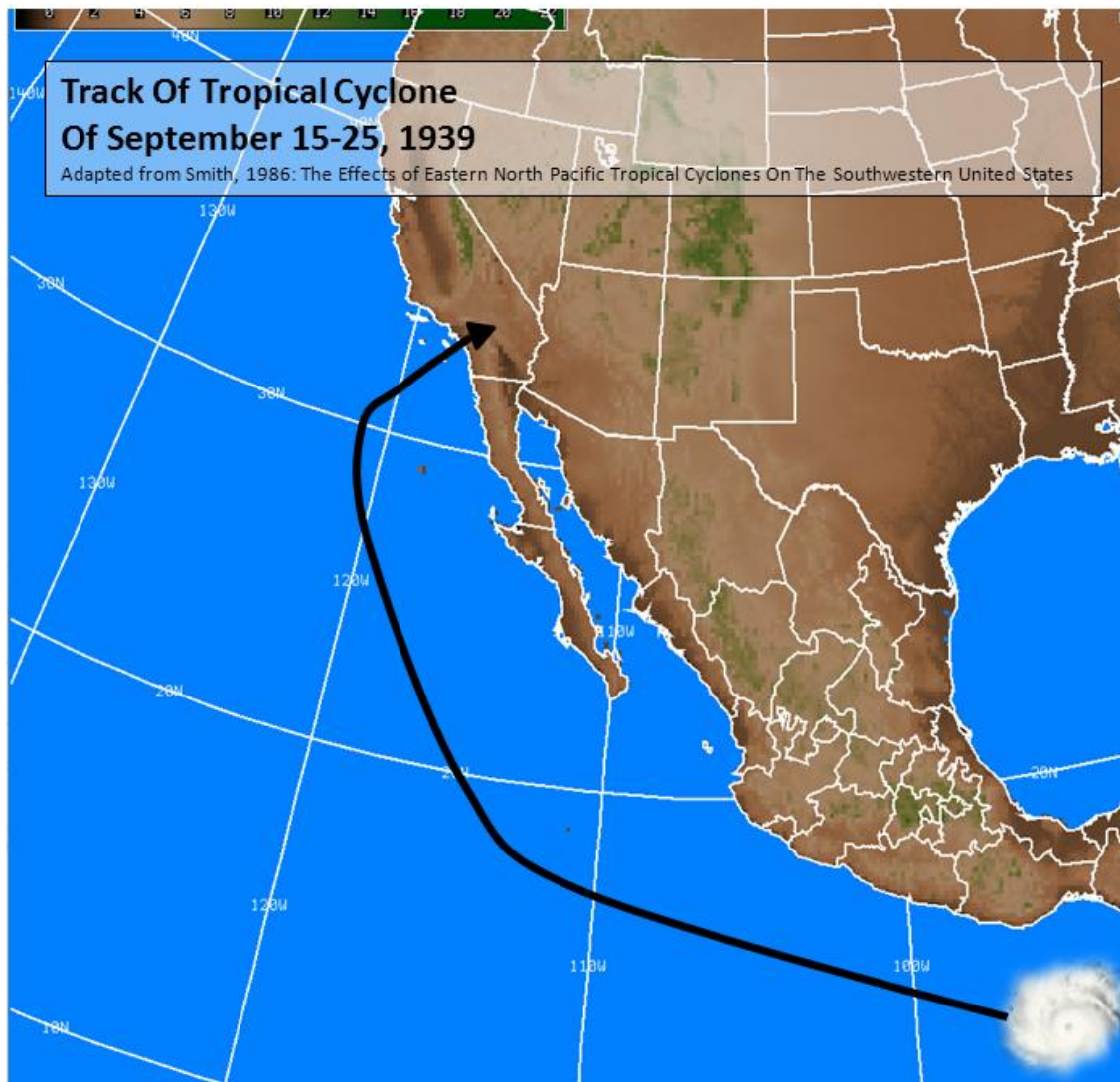


The grand finale of September 1939 came with the rare landfall of a tropical storm on the southern California coast. Research conducted by Smith (1986) places the origin of this system in the Pacific near 10° N, 91° W on September 15th. This system then moved northwest offshore of Mexico's west coast before re-curving inland on the 24th. Landfall on the southern California coast near Long Beach occurred early on the morning of September 25th. Although the system made landfall as a tropical storm with sustained winds of 45 to 50 mph and spread abundant moisture into the Mojave Desert, there is evidence with this system that it was transitioning to an extratropical environment as the high temperature in Las Vegas on September 25th was only 68 degrees – the second lowest on record for the month of September. Rain fell across the Mojave Desert and southern Great Basin primarily on the 23rd through the 26th.

Despite just under two inches of rain falling in Las Vegas, the only damage reported in the area was a rockslide near Boulder City, Nevada. Near Needles, California portions of the Santa Fe rail line were washed out.

Rainfall Totals from the Tropical System of September 15-25, 1939

Mt. Charleston, NV	3.30"	Kingman, AZ	1.97"
Searchlight, NV	3.11"	Wikieup, AZ	1.30"
Pioche, NV	2.23"	Truxton Canyon, AZ	0.77"
Las Vegas, NV (Nellis)	1.86"	Mt. Trumbull, AZ	0.51"
Beatty, NV	1.74"	Needles, CA	2.35"
Boulder City, NV	1.20"	Trona, CA	2.23"
Caliente, NV	1.10"	Parker Reservoir, CA	1.86"
Overton, NV	0.96"	Cow Creek/Death Valley, CA	1.10"
Indian Springs, NV	0.88"	Haiwee, CA	1.09"
Las Vegas, NV (Downtown)	0.75"	Twentynine Palms, CA	1.01"
Alamo, NV	0.65"	Death Valley, CA	0.97"
Goldfield, NV	0.42"	Iron Mountain, CA	0.87"
		Barstow, CA	0.66"
		Lake Sabrina, CA	0.38"
		Independence, CA	0.24"
		South Lake, CA	0.19"



September 1976 – Kathleen

Kathleen is one of only two known tropical systems to have reached the southern portions of the current National Weather Service Las Vegas County Forecast and Warning Area as a tropical storm. Kathleen formed on September 7th off the coast of southwestern Mexico and then moved northwest briefly before taking a more northerly track. Although Kathleen was only a hurricane briefly, the rapid pace at which this system moved northward helped it reach the southwestern United States as a tropical storm. Kathleen weakened to a depression by the time the system moved over San Bernardino and Inyo Counties and eventually Nye County on September 11th.

A tropical storm force wind gust was reported at Needles, California where a gust to 41 mph was measured at the Needles Airport at 2228Z on September 10th. However, earlier that day in Blythe, California winds were much stronger with sustained winds of 40 mph and a peak gust to 58 mph measured at the airport. Thus it is possible sustained tropical storm force winds may have impacted southeastern San Bernardino and southwestern Mohave Counties. The cooperative weather observer at the Parker Reservoir in California remarked “damaging winds” on their monthly observation form, but no numerical estimate of any wind speed is provided. Strong winds were also reported as far north by cooperative weather observers at Mitchell Caverns and Mountain Pass in California and Pahrump, Nevada. Additionally, a 60 mph wind gust from the southeast was measured at Yucca Flat on the Nevada Test Site on September 10th.

According to observations from the Needles Airport, the public reported a funnel cloud in Needles at 00Z on September 11th.

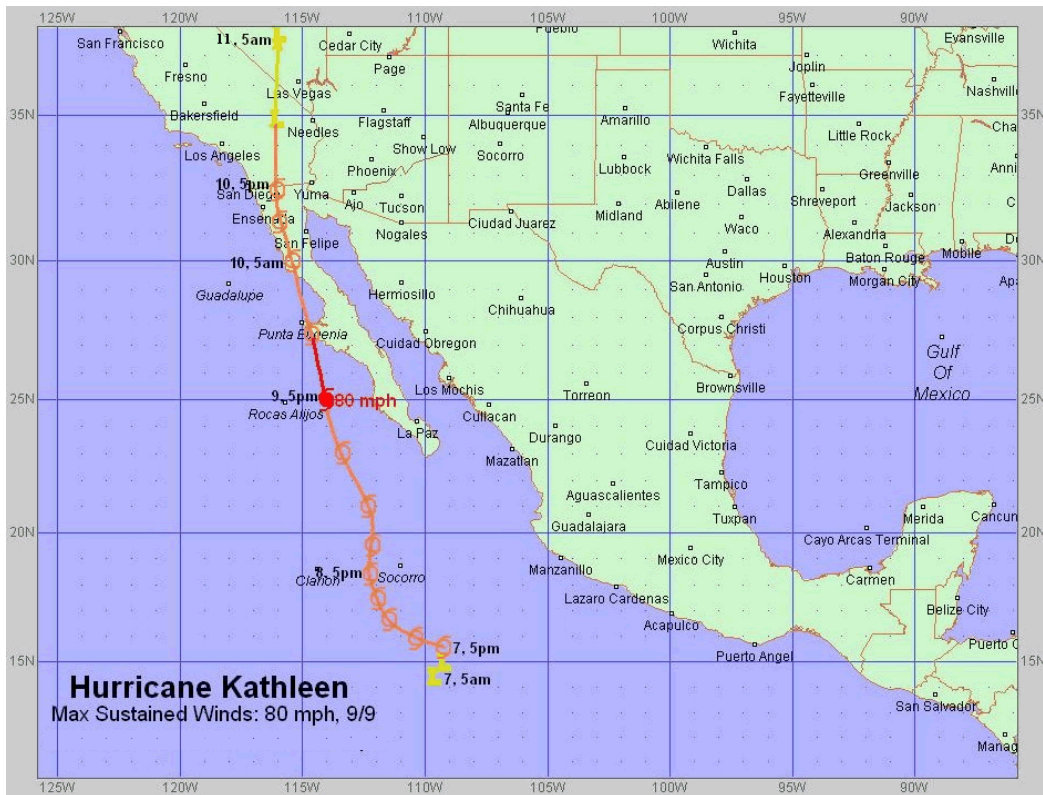
In southern Nevada, heavy rain began to fall by the mid-morning hours of September 10th and lasted until midnight on September 11th. Numerous low lying streets flooded in Las Vegas including the Charleston and Bonanza underpasses which had as much as six feet of water on them. Rain was particularly heavy during the evening commute which resulted in cars stalling in flooded roadways and this triggered traffic back-ups. Many areas were covered with boulders, rocks and gravel, some which were washed into the Las Vegas Valley from the heavy rain that fell in the Spring Mountains. Roads leading to Blue Diamond and Mount Charleston were washed out by torrential rains and there was also road damage in Valley of Fire State Park. Nevada Power Company reported that various parts of Las Vegas lost power.

The biggest impact from Kathleen in the Mojave Desert was flooding. Hardest hit was Bullhead City, Arizona where rain totals were estimated at two to five inches and damages totaled \$3 million (in 1976 dollars). On the afternoon of September 10th, eight washes in the area swelled with water that ran off from the mountains east of Bullhead City damaging roads, homes, businesses, water and gas lines and culverts. Numerous cars were swept away by the raging waters. The Silver Creek Wash cut a 20 to 40 foot deep section out of Highway 95. The floodwaters cut off Bullhead City from any surrounding areas. One road was washed out near Davis Dam.

Flash floods were also reported in Death Valley, California on September 10th. This resulted in almost every road being closed in the area.

Rainfall Totals from Kathleen

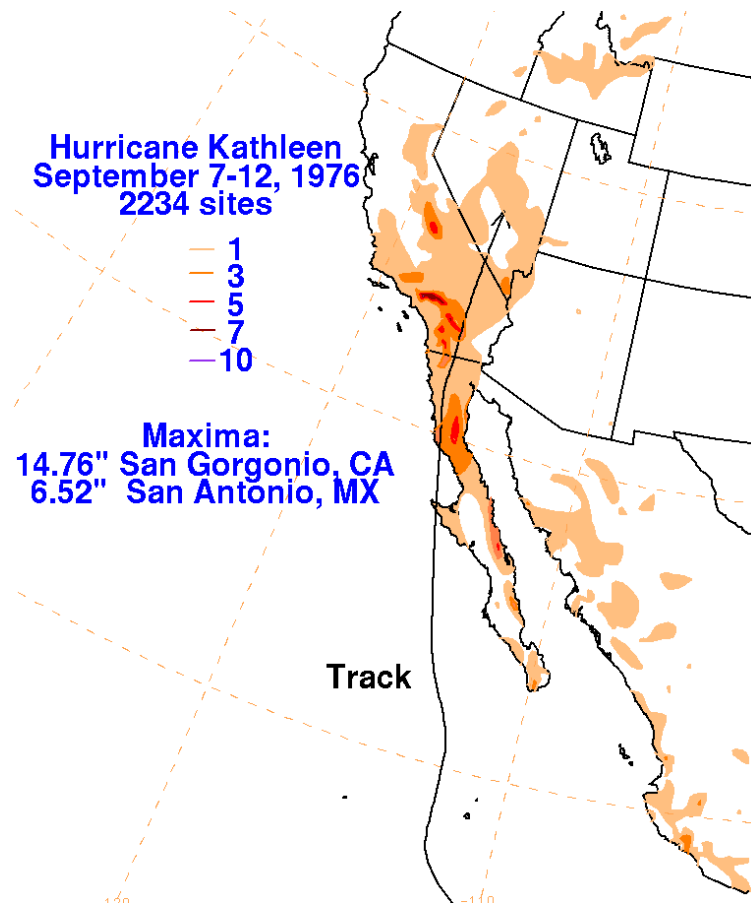
Searchlight, NV	3.40"	Joshua Tree, CA	3.35"
Boulder City, NV	2.86"	Twentynine Palms, CA	2.64"
Silver Peak, NV	1.92"	Barstow-Daggett Airport, CA	2.37"
Pioche, NV	1.57"	Goldstone Echo #2, CA	2.17"
Valley of Fire State Park, NV	1.55"	Needles Airport, CA	2.06"
Beatty, NV	1.52"	Shoshone, CA	1.83"
Key Pittman, NV	1.50"	Trona, CA	1.80"
Lake Valley Steward, NV	1.31"	Mitchell Caverns, CA	1.79"
Geyser Ranch, NV	1.29"	Haiwee, CA	1.75"
Goldfield, NV	1.19"	Mountain Pass, CA	1.56"
Yucca Flat, NV	1.19"	Barstow, CA	1.55"
Pahrump, NV	1.11"	Independence, CA	1.45"
Spring Valley State Park, NV	1.06"	South Lake, CA	1.30"
Desert NWR, NV	0.96"	Iron Mountain, CA	1.12"
NLV-Sunrise Manor, NV	0.96"	Deep Springs, CA	1.11"
Caliente, NV	0.90"	Baker, CA	1.00"
Dyer, NV	0.85"	Bishop Creek Intake 2, CA	0.88"
Las Vegas, NV (Nellis)	0.81"	Lake Sabrina, CA	0.88"
Tempiute, NV	0.81"	Death Valley, CA	0.71"
Lathrop Wells, NV	0.75"	Bishop, CA	0.44"
Las Vegas, NV (McCarran)	0.60"	Parker Reservoir, CA	0.41"
Pahrnagat NWR, NV	0.02"	Davis Dam #2, AZ	2.87"
		Willow Beach, AZ	2.75"
		17 miles SW Pierce Ferry, AZ	2.11"
		Truxton Canyon, AZ	0.73"
		Beaver Dam, AZ	0.40"
		Mt. Trumbull, AZ	0.40"
		Yucca, AZ	0.29"
		Colorado City, AZ	0.23"
		Lake Havasu City, AZ	0.20"
		Kingman, AZ	0.14"
		Peach Springs, AZ	0.12"
		Wikieup, AZ	0.06"
		Tuweep, AZ	0.02"



Maps showing the track and intensity of Kathleen (courtesy NWS Tucson).



The front page of the *Las Vegas Sun* on September 11, 1976 after Kathleen brought heavy rain to the Las Vegas Valley.



Map showing rainfall totals from Kathleen (courtesy HPC).

September 1997 – Nora

Nora, the only documented tropical storm on record to pass near the tip of southern Nevada, initially formed as a tropical depression off the coast of Mexico southwest of Acapulco. Nora then moved northwest and strengthened into a hurricane. Garza (1999) noted that Nora was the third tropical cyclone in 1997 to thrive in the warm Pacific waters off of Mexico that had spread north as a result of the strong El Niño that had formed. Nora finally turned northward on the 23rd, in part due to a weakness in the height pattern to the north of Nora that had developed over the western United States in part due to an omega-like blocking pattern that was in place (Rappaport 1997). It was this weakness and a trough in the mid and upper levels of the atmosphere that eventually developed northwest of Nora that resulted in Nora tracking northward towards Baja California where a landfall was made near Punta Eugenia as a hurricane on the morning of September 25th. After crossing Baja California, Nora emerged in the Gulf of California and made a second landfall about 50 miles south southeast of San Fernando as a hurricane. Although Nora weakened to a tropical storm by the time it crossed the border into the United States on the 25th, Nora was not downgraded to a tropical depression until the time it reached near Lake Mead by the evening of the 25th. The center of Tropical Depression Nora then moved northeast into southwest Utah.

Although Nora reached the Mojave Desert as a minimal tropical storm, no sustained tropical storm force winds were recorded. However, spotty tropical storm force wind gusts were measured across the area. A RAWS station in Rice Valley, California in far northeast Riverside County recorded a 39 mph wind gust at 1 PM on September 25th. In Mohave County, Arizona a 42 mph wind gust was logged at the Moss Basin RAWS site at an elevation of 5,920 feet at 4 PM. Further north, a 43 mph gust was clocked at the Tweeds Point RAWS at an elevation of 5,200 feet at 9 PM.

Base velocity data reviewed from KESX at the 0.5 degree elevation showed a large area of 40 knot to just under 60 knot winds across Mohave and far southeast San Bernardino County as Nora moved north across the region and a small area of 40-45 knot winds over the Spring Mountains of southern Nevada. While surface observations support that winds of these strengths were not reported in the majority of the area, it is likely that higher elevations (especially above 5,000 feet) of Mohave, Clark and eastern San Bernardino Counties did experience winds of 40 mph or greater as Nora passed through, especially in gusts. This is what the few available RAWS sites recorded. Over the valleys, these winds did not make it to the surface. It is possible some of this was due to the orientation of the valleys in many of these areas being more north to south while the strongest winds were blowing out of a southeast direction. This would have left the valleys “sheltered” from the strongest winds.

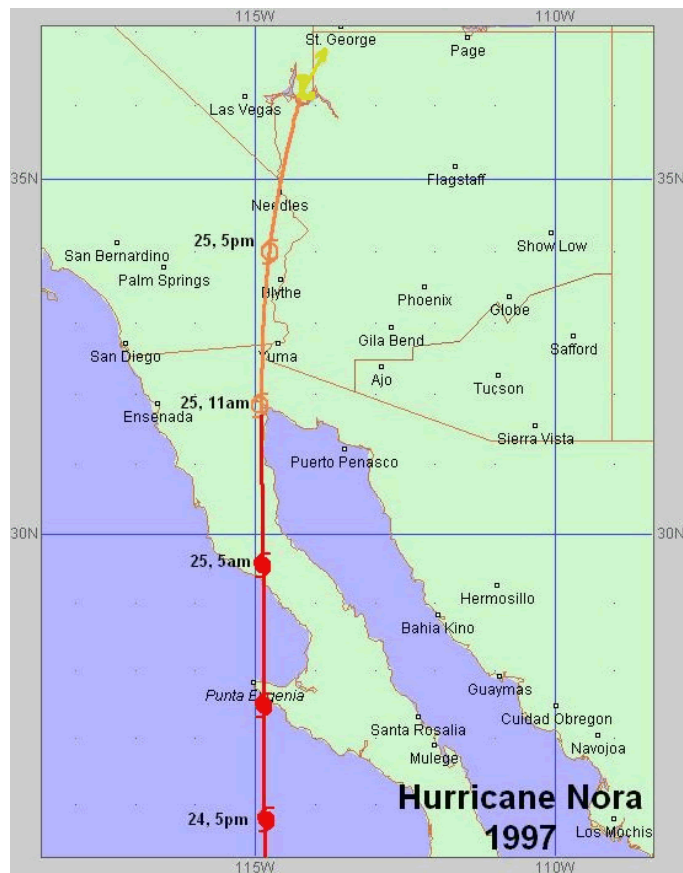
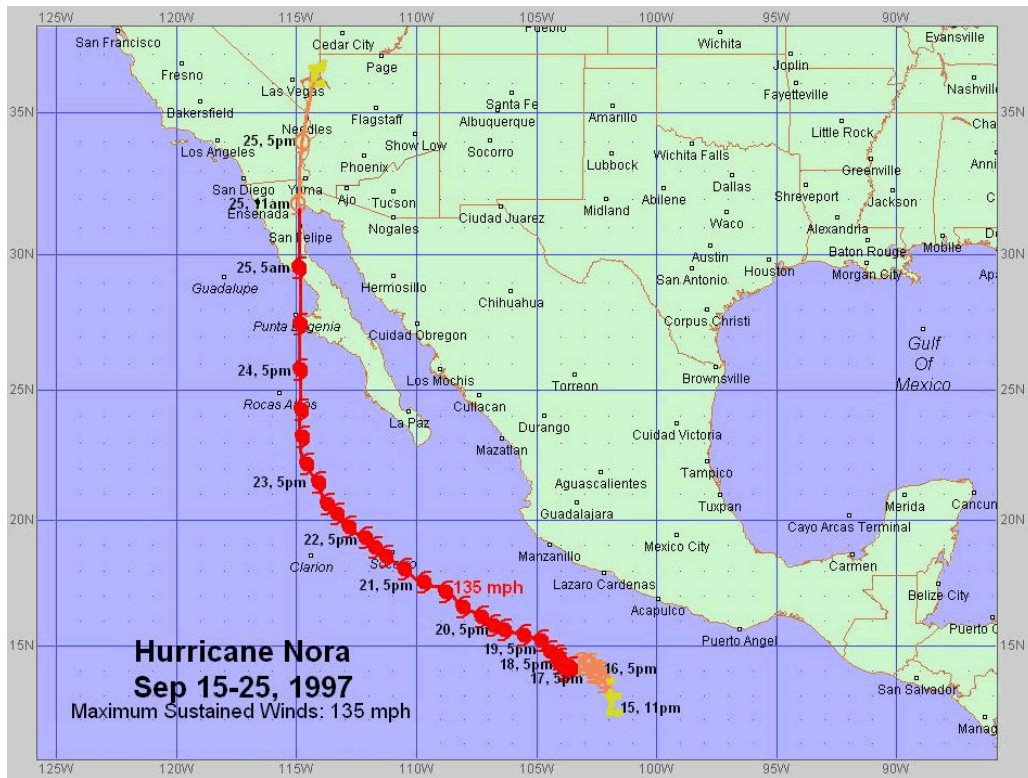
Rain from Nora fell across the area starting late on the 24th and ended early on the 26th. Only one cooperative weather station, Pahrump, did not report any rain. Radar reflectivity shows that Nora had more of the look of a mid-latitude system when it crossed over the Mojave Desert despite being classified as a tropical system. There was a noticeable cut-off on the back edge of the precipitation.

The primary impact from Nora across the Mojave Desert was flooding. In Death Valley National Park, Highway 190 was washed out between Panamint Springs and Stovepipe Wells. Numerous smaller roads throughout the park were also closed due to flooding. Minor flooding took place in Twentynine Palms, California on Highways 62 and 247. In southern Nevada, the Clark County Flood Control District prepared to move 3 million sandbags to the Las Vegas Valley from Fallon Air Force Base. However, while sandbags were needed, flooding was not as severe as expected. Only minor street flooding took place in Las Vegas and in the Pahrump Valley. Access to some outlying homes in Pahrump was cut-off as dirt roads became flooded and impassable. Several people were forced to stay at a shelter set up by the American Red Cross.

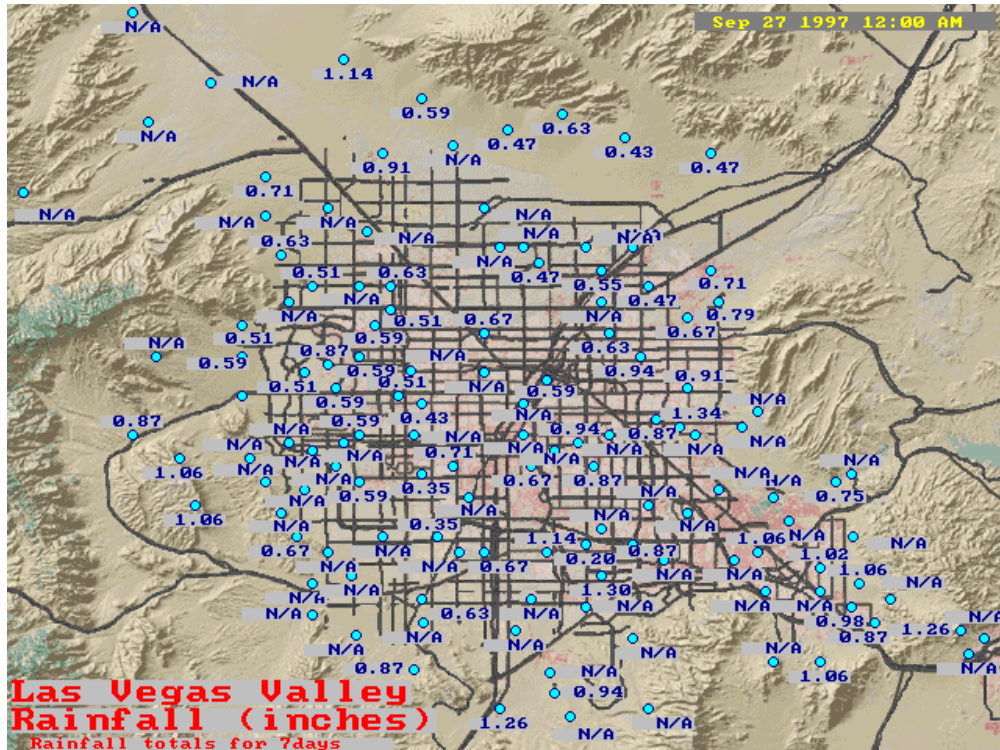
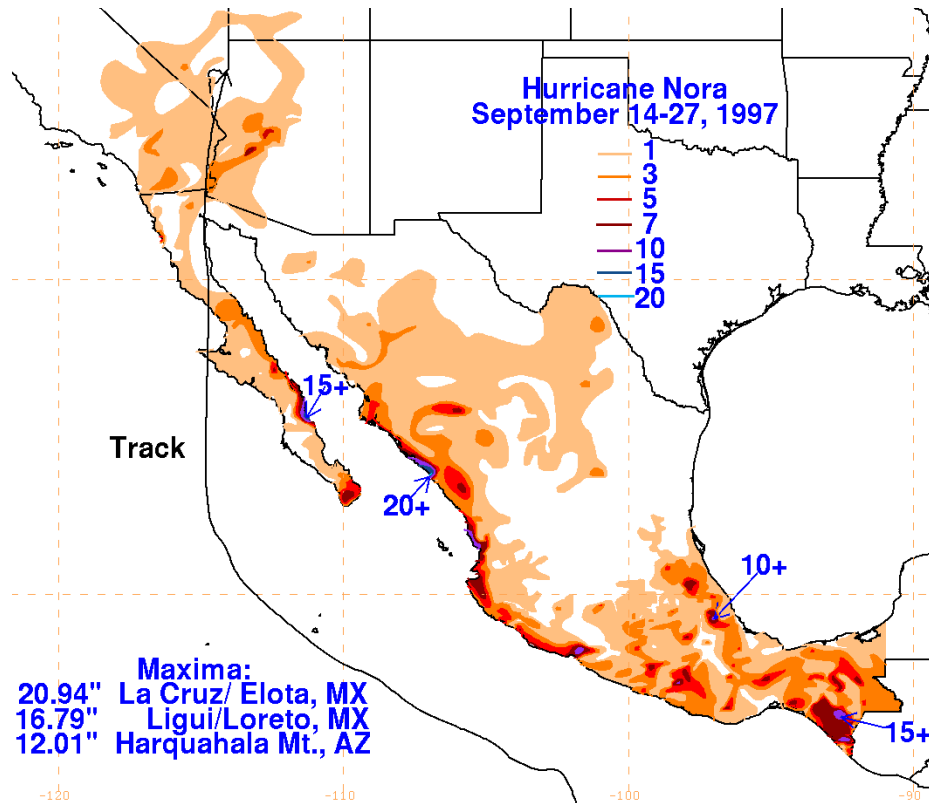
There was one death and one injury associated with Nora in southern Nevada although these were both indirect. A man from Lake Havasu City, Arizona was traveling north near Railroad Pass just before 7 AM on September 25th when he skidded into the side of a tractor trailer. The man was killed and his wife was critically injured.

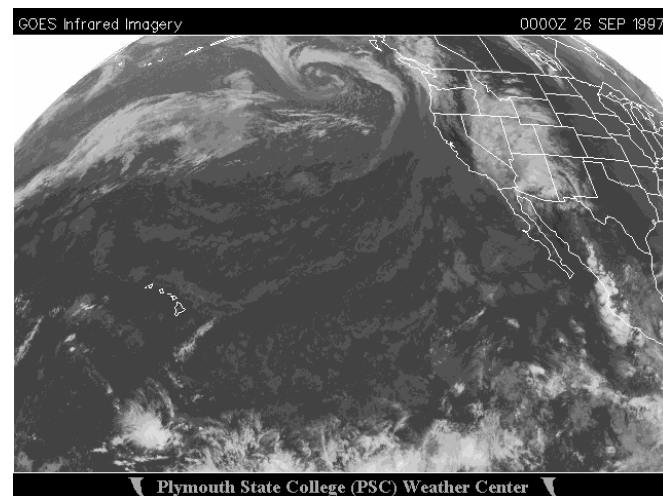
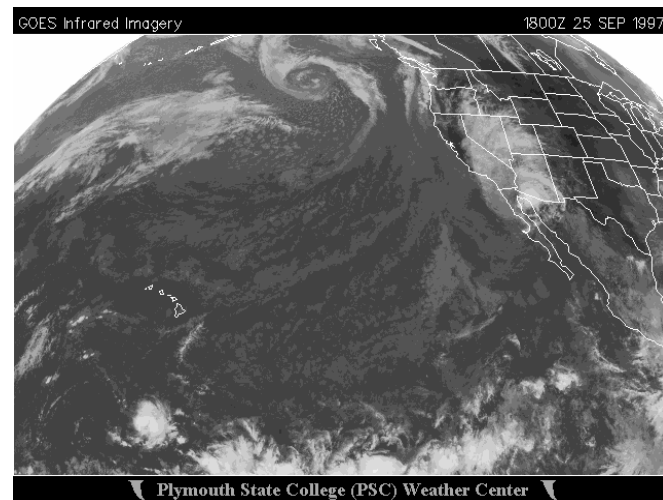
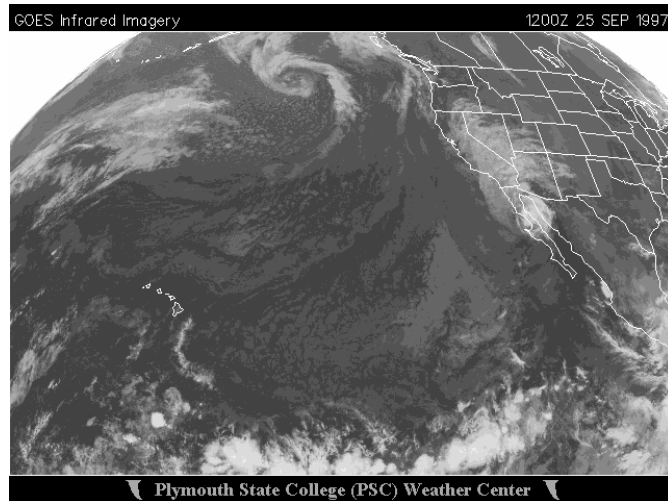
Rainfall Totals from Nora

Mt. Charleston/Kyle Canyon, NV	3.53"	Twentynine Palms, CA	2.67"
Mt. Charleston/Lee Canyon, NV	3.21"	Mitchell Caverns, CA	2.15"
Goodsprings, NV	1.61"	Parker Reservoir, CA	2.15"
Cal-Nev-Ari, NV	1.42"	Hunter Mountain, CA	2.06"
Valley of Fire State Park, NV	1.42"	Haiwee, CA	1.84"
Amargosa Valley, NV	1.26"	Iron Mountain, CA	1.83"
Sloan, NV	1.26"	Mountain Pass, CA	1.63"
Wildcat Wash, NV	1.26"	Barstow-Daggett Airport, CA	1.55"
Elgin, NV	1.17"	Trona, CA	1.54"
Spring Mountain Ranch, NV	1.15"	Goldstone Echo #2, CA	1.53"
Desert Rock, NV	1.14"	Shoshone, CA	1.51"
Duck Creek at Paradise, NV	1.14"	Needles, CA	1.50"
Fossil Ridge, NV	1.14"	Mid Hills, CA (RAWS)	1.42"
Searchlight, NV	1.06"	Barstow, CA	1.17"
Desert NWR, NV	1.00"	Death Valley, CA	1.16"
Beatty, NV	0.99"	Mojave River Sink, CA	0.95"
Pioche, NV	0.95"	Baker, CA	0.70"
Red Rock Canyon, NV (RAWS)	0.92"	Independence, CA	0.62"
Floyd Lamb Park, NV	0.91"	Bishop Creek Intake 2, CA	0.16"
East Henderson #2, NV	0.87"	Bishop, CA	0.13"
Las Vegas, NV (Nellis)	0.85"	Hualapai Mountain, AZ	4.50"
Caliente, NV	0.79"	Moss Basin, AZ (RAWS)	4.21"
Las Vegas, NV (NWS Office)	0.77"	Music Mountain, AZ	3.22"
North Las Vegas, NV	0.76"	Wikieup, AZ	2.72"
Boulder City, NV	0.72"	Nixon Flats, AZ (RAWS)	2.46"
Las Vegas, NV (McCarran)	0.71"	Mt. Logan, AZ (RAWS)	1.98"
Laughlin, NV	0.70"	Yellow John Mountain, AZ	1.79"
Overton, NV	0.65"	Havasui, AZ (RAWS)	1.64"
Las Vegas/Lone Mountain, NV	0.63"	Black Rock, AZ (RAWS)	1.58"
Callville Bay, NV	0.62"	Union Pass, AZ (RAWS)	1.41"
Oriental Wash, NV (RAWS)	0.62"	Lake Havasu City, AZ	1.32"
Goldfield, NV	0.60"	Yucca, AZ	1.26"
Las Vegas, NV (Downtown)	0.59"	Kingman, AZ	1.13"
Oak Creek, CA (RAWS)	0.58"	Colorado City, AZ	1.12"
Dyer, NV	0.55"	Willow Beach, AZ	1.05"
Coyote Wash, NV (RAWS)	0.53"	Tweeds Point, AZ (RAWS)	1.03"
Hiko, NV	0.53"	Robinson Tank, AZ (RAWS)	0.97"
Echo Bay, NV	0.52"	Pipe Spring Nat'l Mon, AZ	0.95"
Kane Springs, NV (RAWS)	0.51"	Peach Springs, AZ	0.86"
Summerlin Northwest, NV	0.51"	Meadview, AZ	0.65"
Pahrangat NWR, NV	0.47"	Bullhead City, AZ	0.58"
Toquop Wash, NV (RAWS)	0.46"	Hurricane, AZ (RAWS)	0.55"
Immigration Wash, NV (RAWS)	0.44"	Temple Bar, AZ	0.55"
Silver Peak, NV	0.30"	Olaf Knolls, AZ (RAWS)	0.44"
Overton Beach, NV	0.28"	Beaver Dam, AZ	0.32"
Bunkerville, NV	Trace		

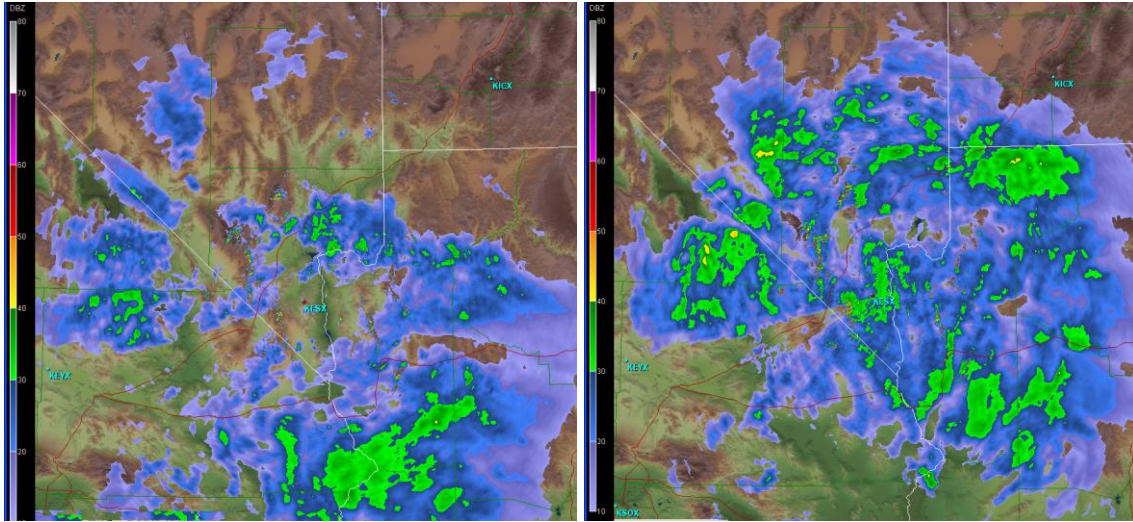


Maps showing the track and intensity of Nora (courtesy NWS Tucson).

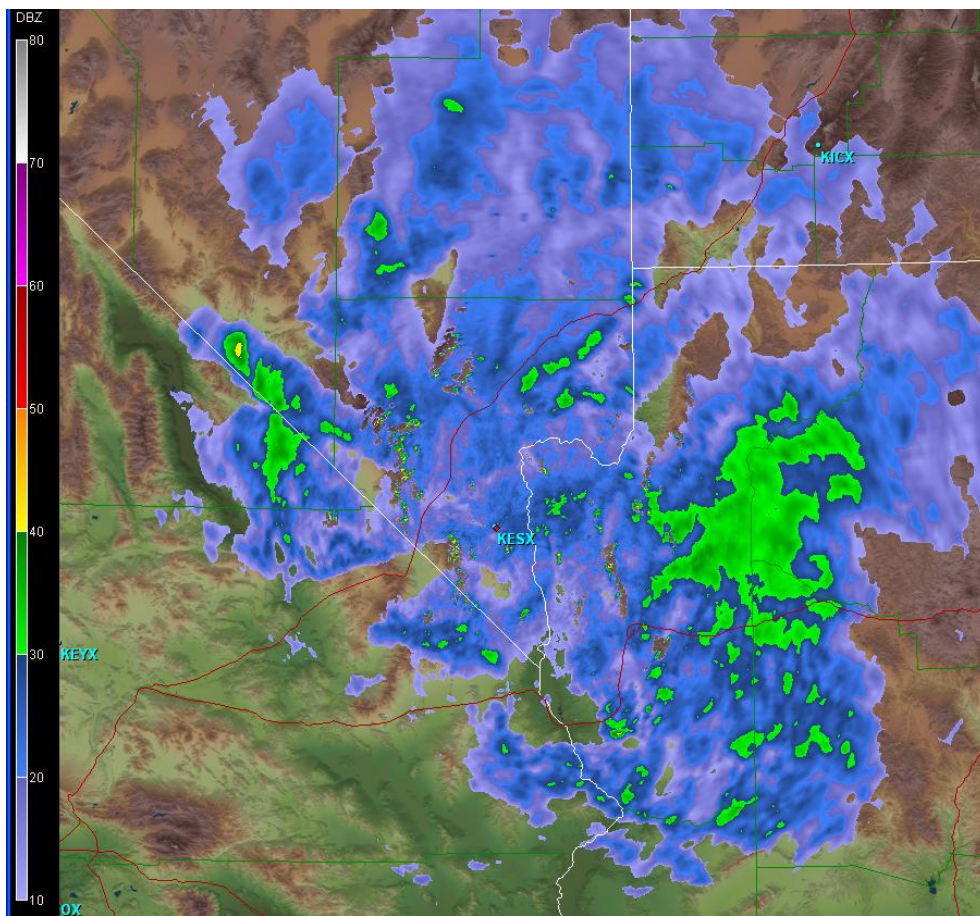




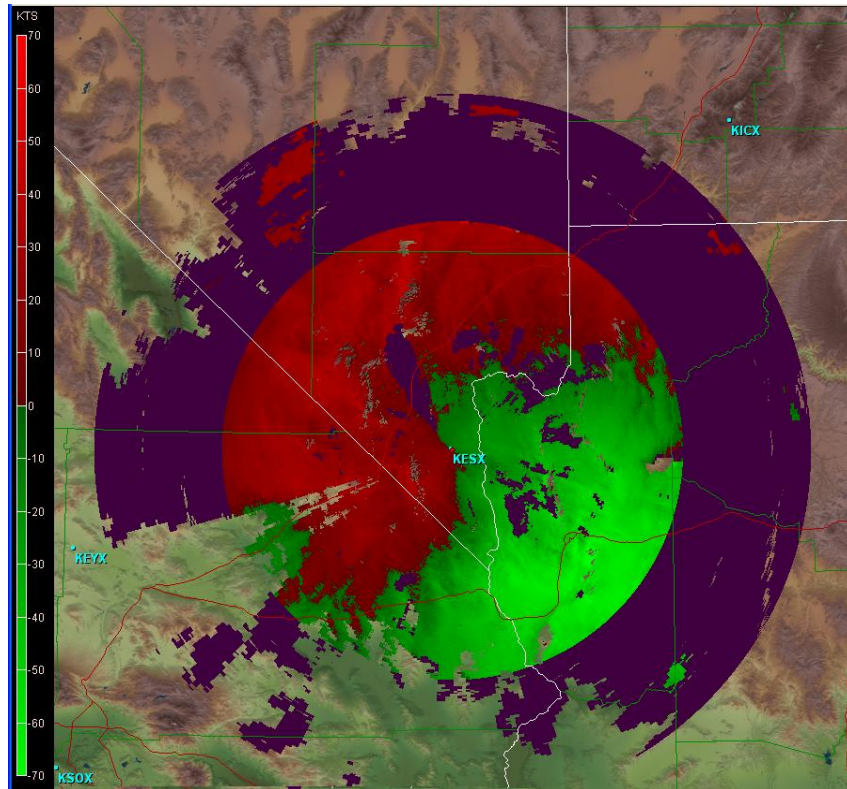
Infrared satellite images of Nora moving north over the lower Colorado River Valley and into the Mojave Desert (Courtesy Plymouth State University).



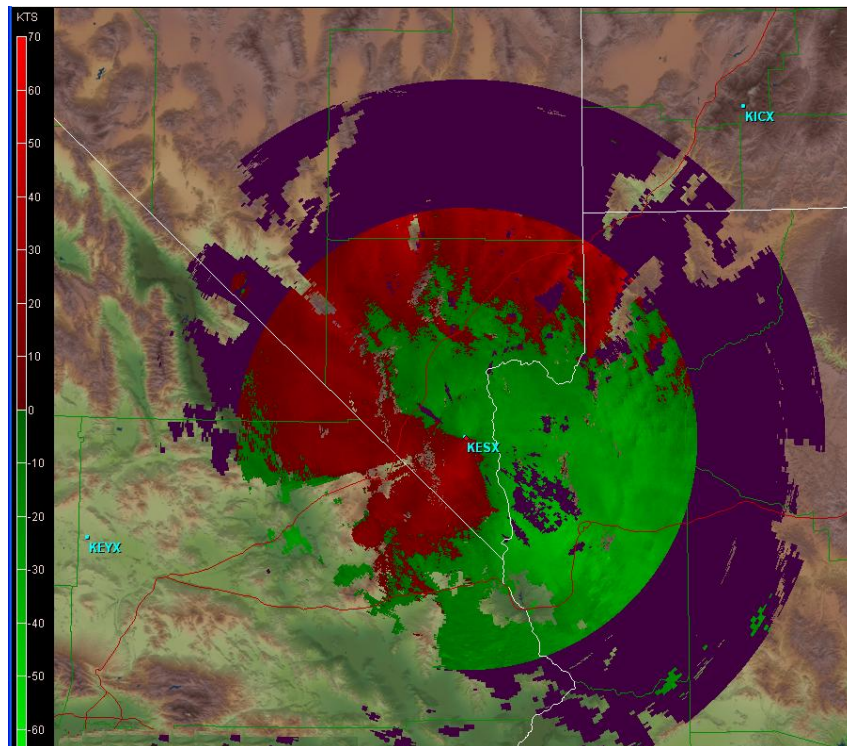
KESX 0.5 degree reflectivity at 20:31Z (left) and 23:51Z (right) on September 25, 1997.



KESX 0.5 degree reflectivity at 0252Z on September 26, 1997 when the center of Nora was passing across Mohave County.



KESX 0.5 degree base velocity at 2351Z on September 25, 1997 showing a large area of 40 to 60 knot winds over Mohave County.



KESX 0.5 degree base velocity at 0252Z on September 26, 1997 as the center of Nora moved across Mohave County.

References

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Rappaport, Edward. "TPC NHC NORA 1997 PRELIMINARY REPORT." *National Hurricane Center*. 30 Oct. 1997. Web. 21 Sept. 2011.
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Additional information was also collected from the National Climatic Data Center (NCDC) as well as various articles in the *Las Vegas Review-Journal* and *Las Vegas Sun*. Some maps and graphics were also obtained online from the websites of the National Weather Service in Tucson, AZ (<http://www.weather.gov/twc>) and the Hydrometeorological Prediction Center (<http://www.hpc.ncep.noaa.gov/tropical/rain/tcraifall.html>).