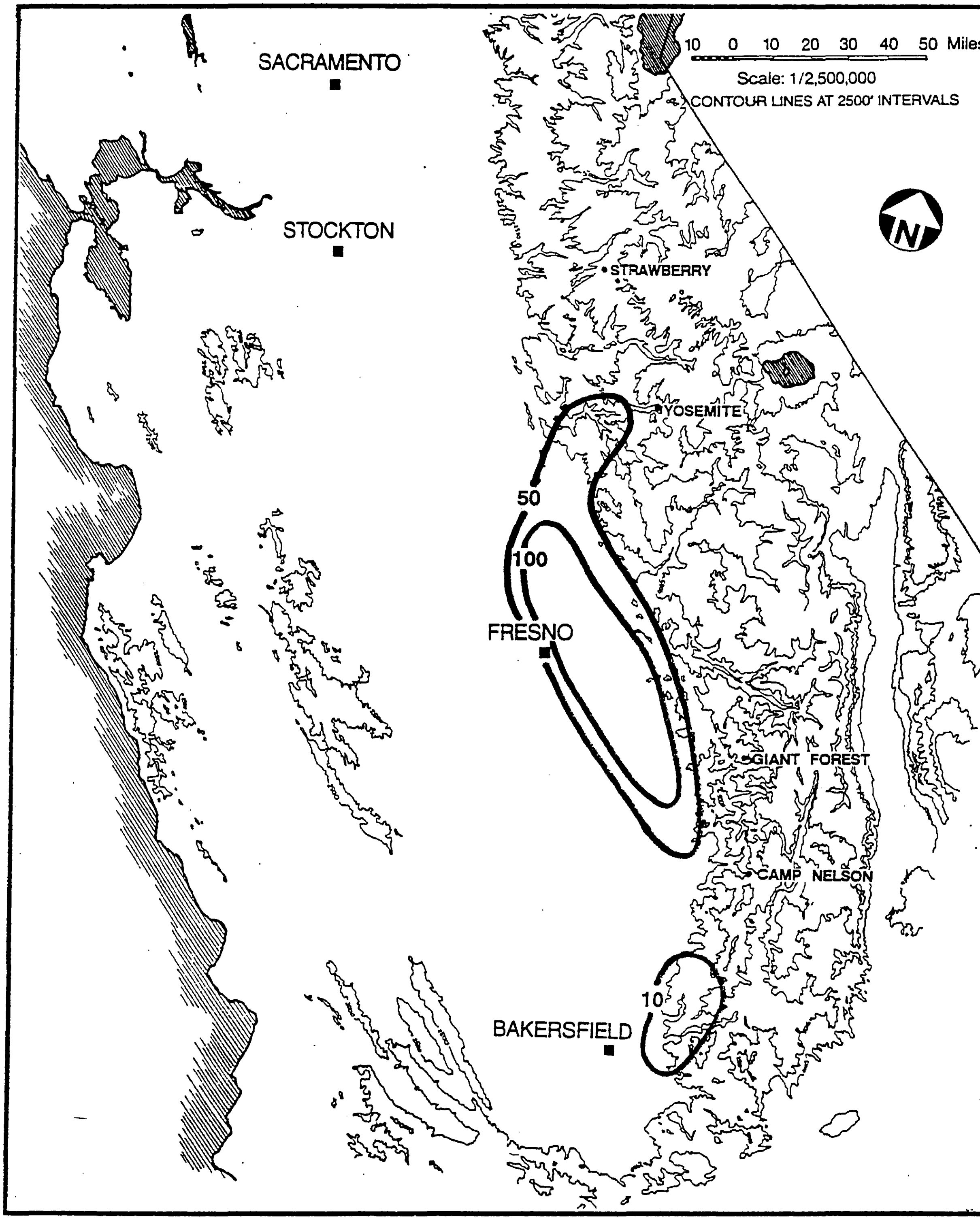


FIGURE 6-17 - Stockton Tracer Isopleths
August 13, 1990: 0600-0800 PDT
(Concentrations are in fl/l)

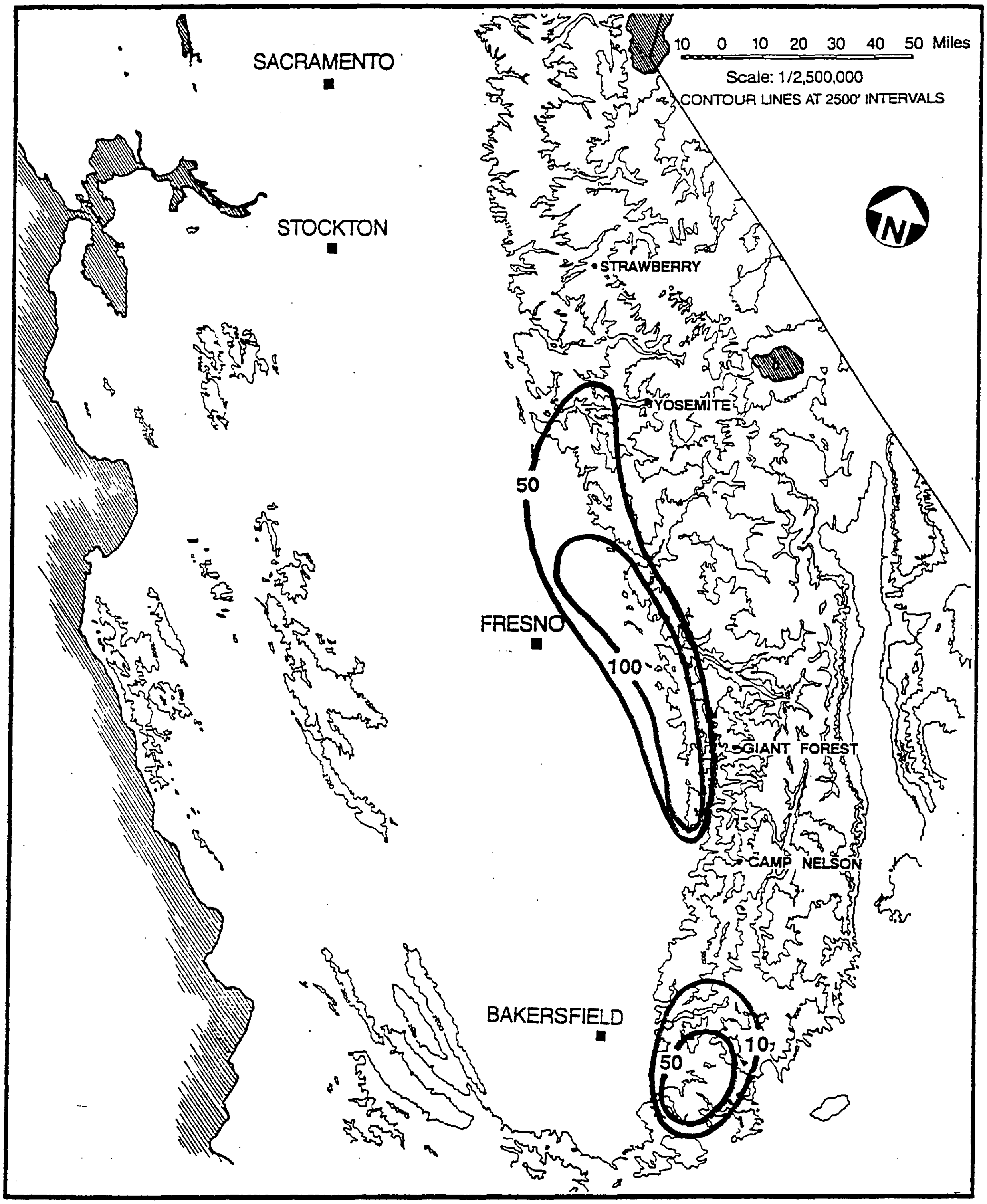


FIGURE 6-18 - Stockton Tracer Isopleths
August 13, 1990: 0800-1000 PDT
(Concentrations are in fl/l)

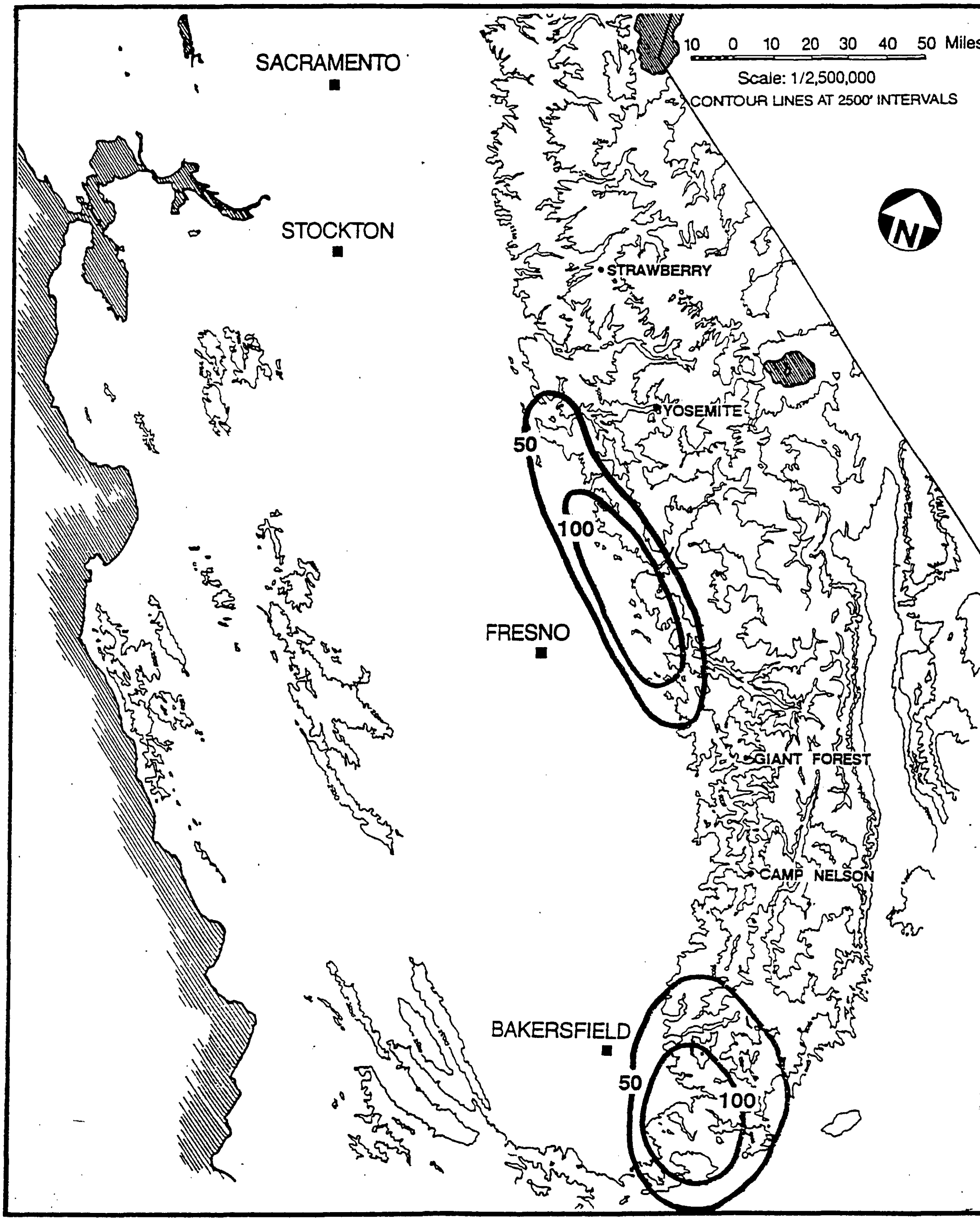


FIGURE 6-19 - Stockton Tracer Isopleths
August 13, 1990: 1000-1200 PDT
(Concentrations are in fl/l)

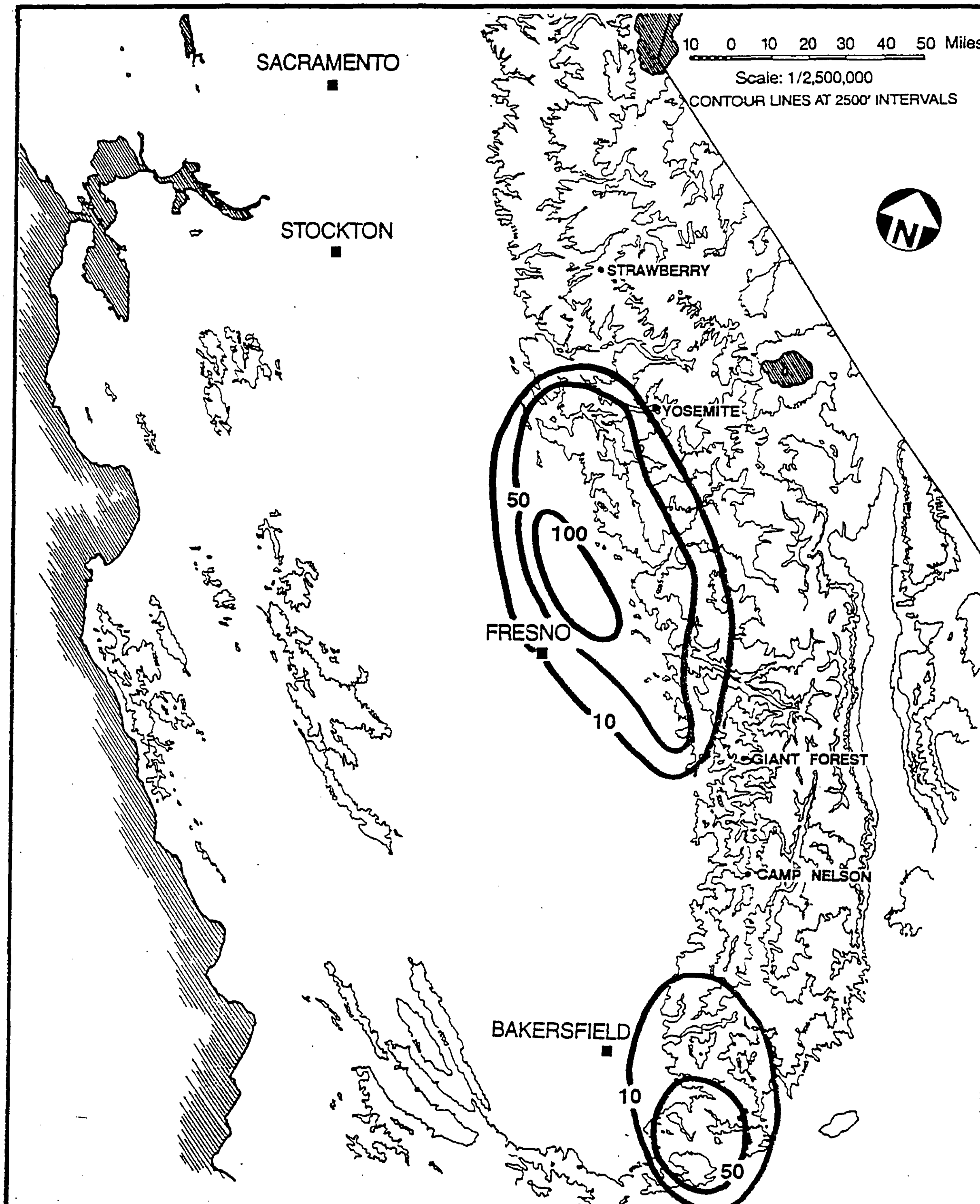


FIGURE 6-20 - Stockton Tracer Isopleths
August 13, 1990: 1200-1400 PDT
(Concentrations are in fl/l)

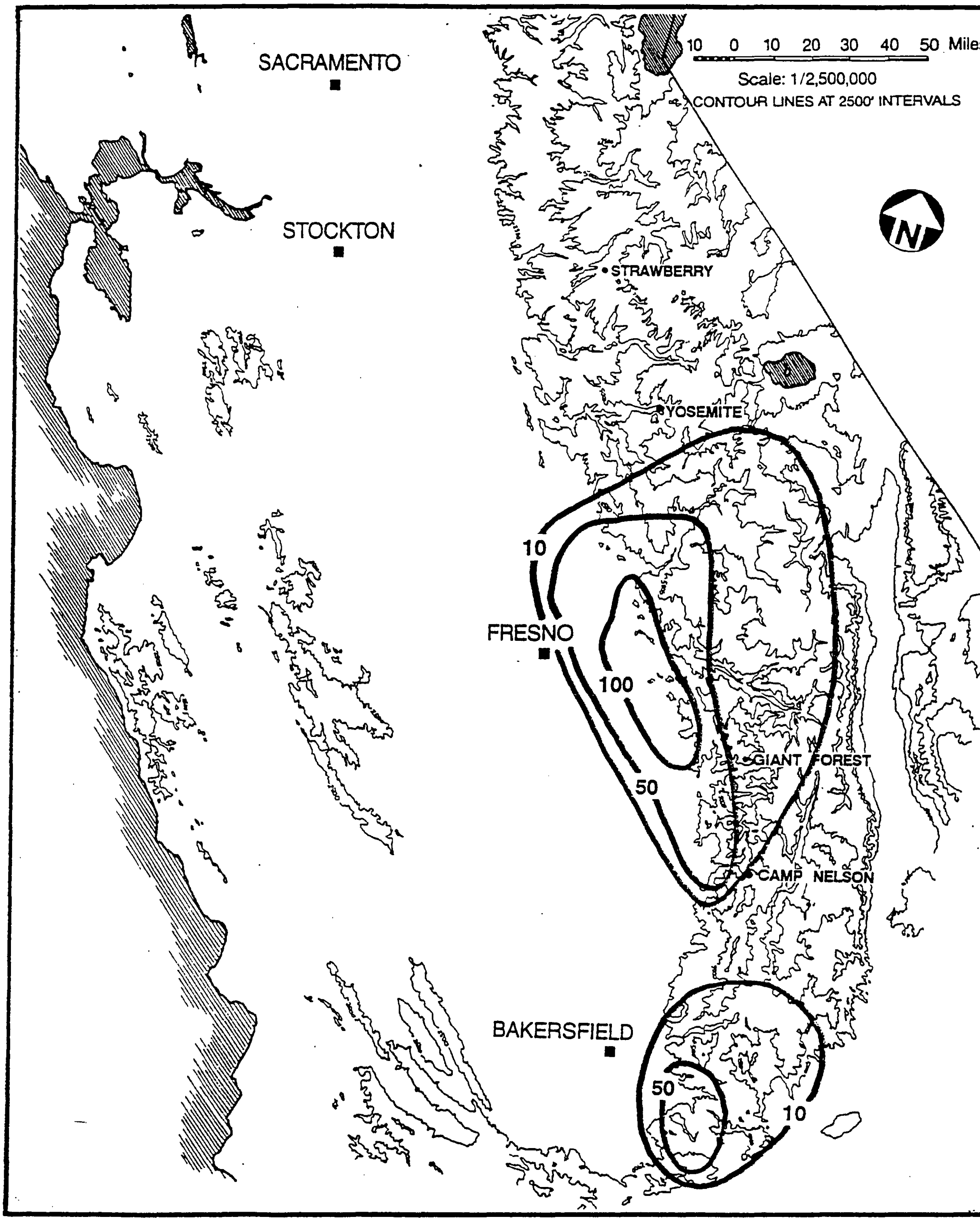


FIGURE 6-21 - Stockton Tracer Isopleths
August 13, 1990: 1400-1600 PDT
(Concentrations are in fl/l)

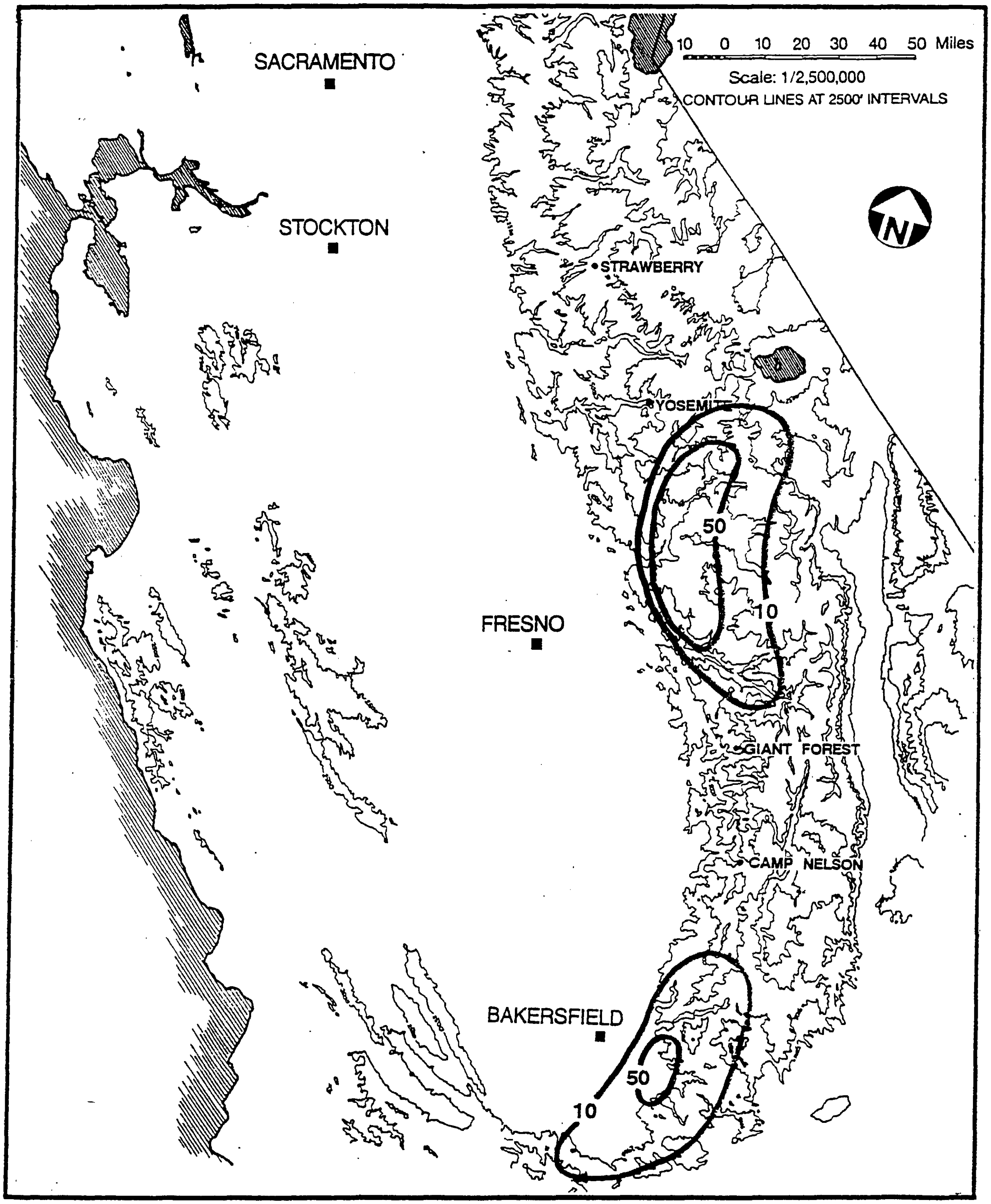


FIGURE 6-22 - Stockton Tracer Isopleths
August 13, 1990: 1600-1800 PDT
(Concentrations are in fl/l)

from migrating along the foothills and forced it aloft. Once at a higher elevation, the tracer plume is carried over and around the surface drainage current and transported to further southern positions in the SJV by way of predominant wind flow aloft. Figure 6-21 shows the surface plumes finally migrated into the mountain regions, east of Fresno and in the Tehachapis. During the sampling period defined by 1400 to 1600 hours on 13 August 1990, impacts of the Stockton plume are seen well into the Sierra Range, with some impacts showing at leeward stations (Mammoth Lakes). During the very next sampling period (see Figure 6-22) no Stockton tracer is detected in the SJV and impacts seen previously in the mountain regions have decreased substantially. Over the next four hours the Stockton plume eventually disperses from the Sierra. No PMCH was detected in the Owens Valley, Bishop, or Edward AFB stations, indicating either substantial dilution in the leeward regions of the Sierra's or the plume is carried from the region by upper level winds.

Airborne observations of the Stockton tracer plume are shown in Figure 6-23. Measurements conducted at 2000 ft. above mean ground surface indicated a well mixed boundary layer in the northern segments of the plume (observations near Yosemite and Visalia). The southern plume segments, which eventually impacted the Tehachapis, showed no discernable concentrations at upper levels. This is possibly due to a very stable and layered atmosphere, thereby confining the tracer plume to very narrow atmospheric strata.

During this test there appears to be four major pathways into the Sierra for the Stockton tracer. These pathways are depicted in Figure 6-24. One pathway is the Merced River Canyon, located east of Modesto, which flows into the Yosemite Valley. The second pathway is the San Joaquin River Canyon which is just east of Mariposa and eventually opens up into Dinkey Creek and Mammoth Pool Reservoir. The third is King's Canyon which is located just east of Fresno and leads into Cedar Grove. The fourth is the Kern River canyon located just east of Bakersfield.

6.2.3 Bakersfield Tracer Release

The Bakersfield area tracer release was conducted several hours after the Stockton and Fresno tracer releases. This was to avoid losing the tracer plume in the southern portion of the sampling grid early in the testing period. 21.4 kilograms of perfluoro 1,3,5 Trimethylcyclohexane (PTCH) was released from 1900 to 2335 PDT at Bakersfield on 12 August 1991. At 0200 to 0400 PDT (13 August 1990) the Bakersfield tracer plume was situated south and east of the city, slightly impacting the Tehachapis. Figures 6-25 and 6-26 illustrate the position of the tracer plume during nocturnal hours of 13 August 1990. By the early daylight hours the plume had penetrated into the Lake Isabella region (see Figure 6-27). By noon the plume had shown some tendency to migrate north, with impacts reaching near Giant Forest. Figure 6-28 depicts the plume position by 1400 PDT. From this point the plume concentration began to decrease with time. By

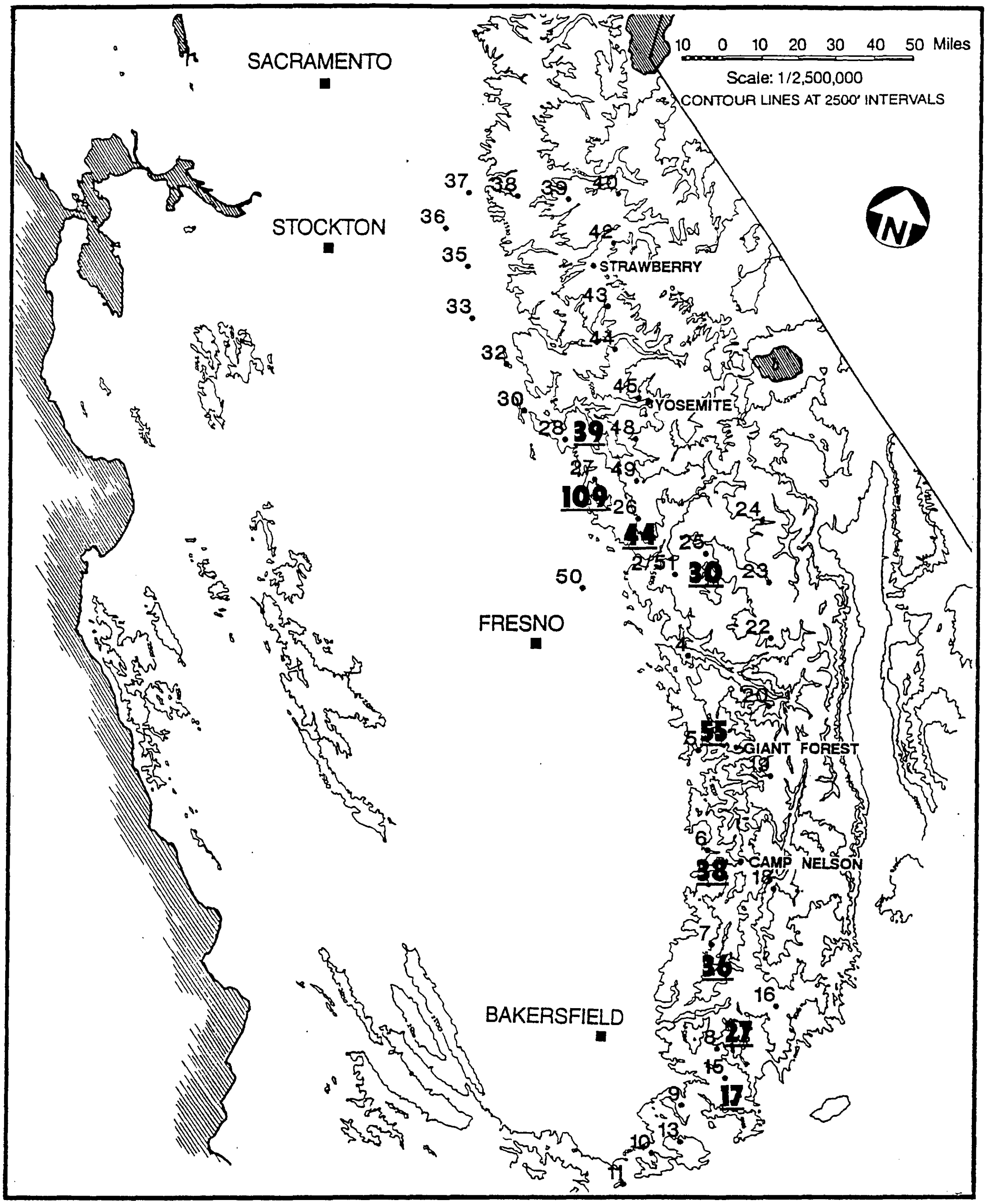


FIGURE 6-23 - Stockton Tracer Concentrations (PMCH)
Airborne - August 13, 1990: 1200-1800 PDT
(Concentrations are in boldface, fl/l)

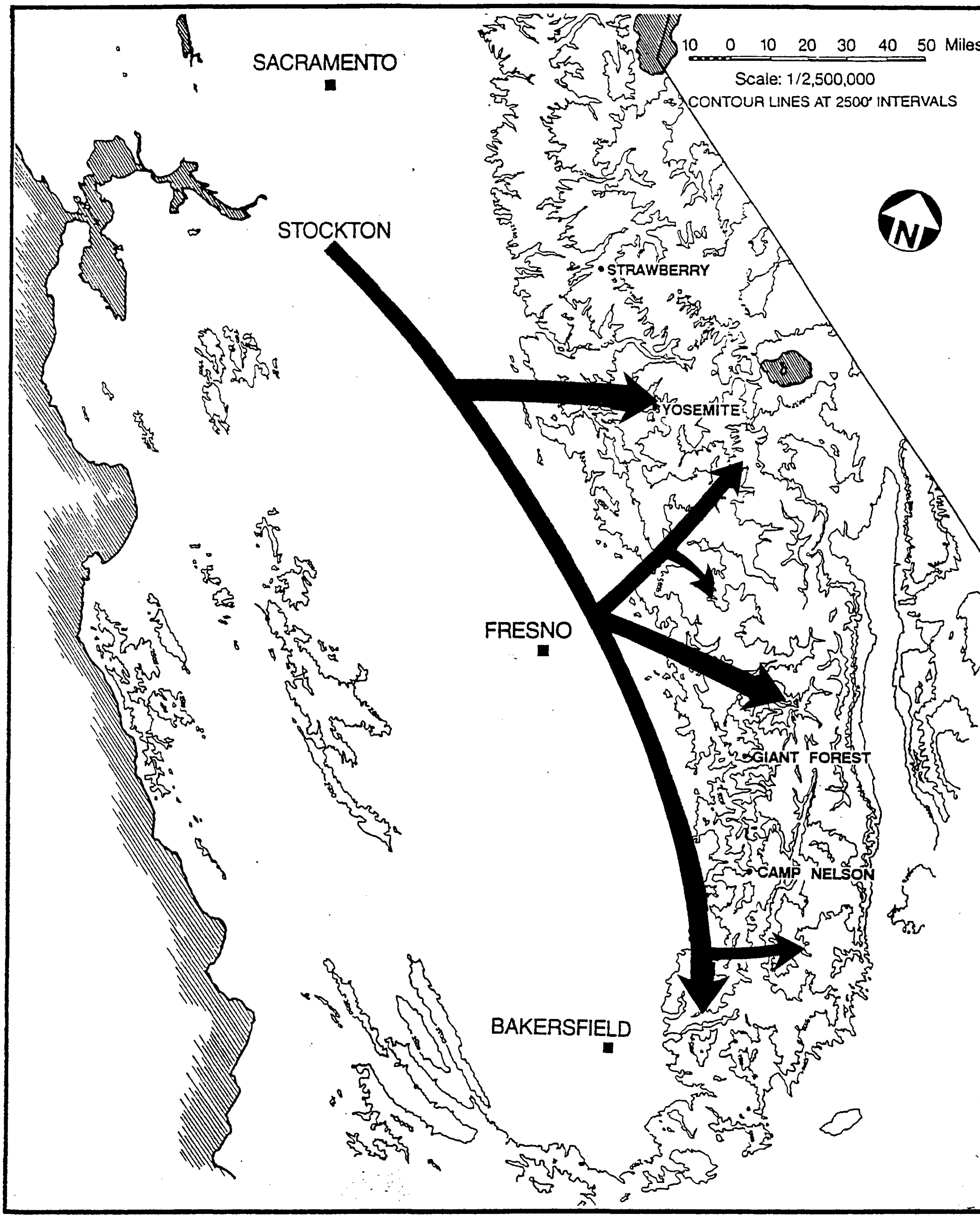


FIGURE 6-24 - Stockton Pathways into the Sierra Nevada: August Test

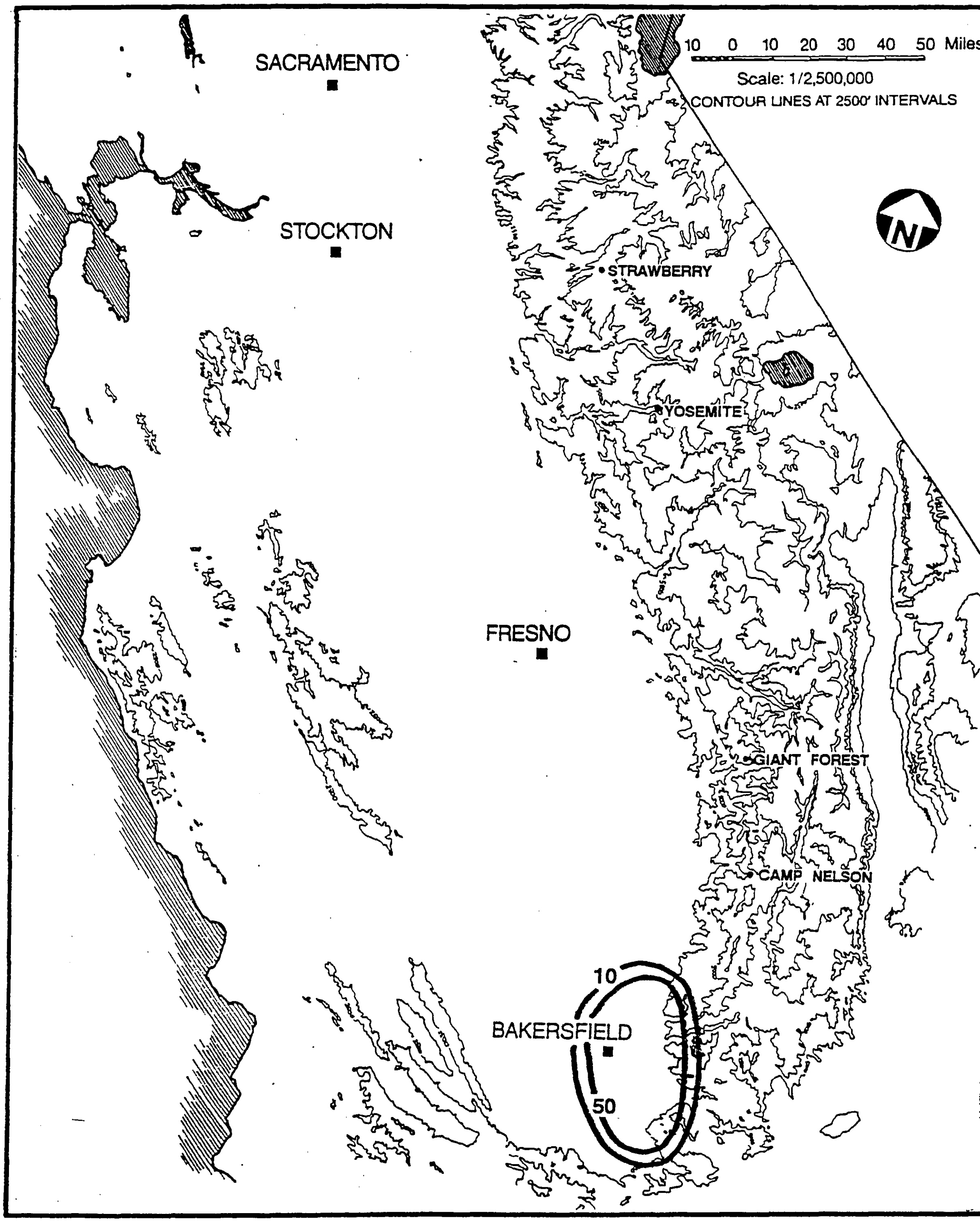


FIGURE 6-25 - Bakersfield Tracer Isopleths
August 13, 1990: 0200-0400 PDT
(Concentrations are in fl/l)

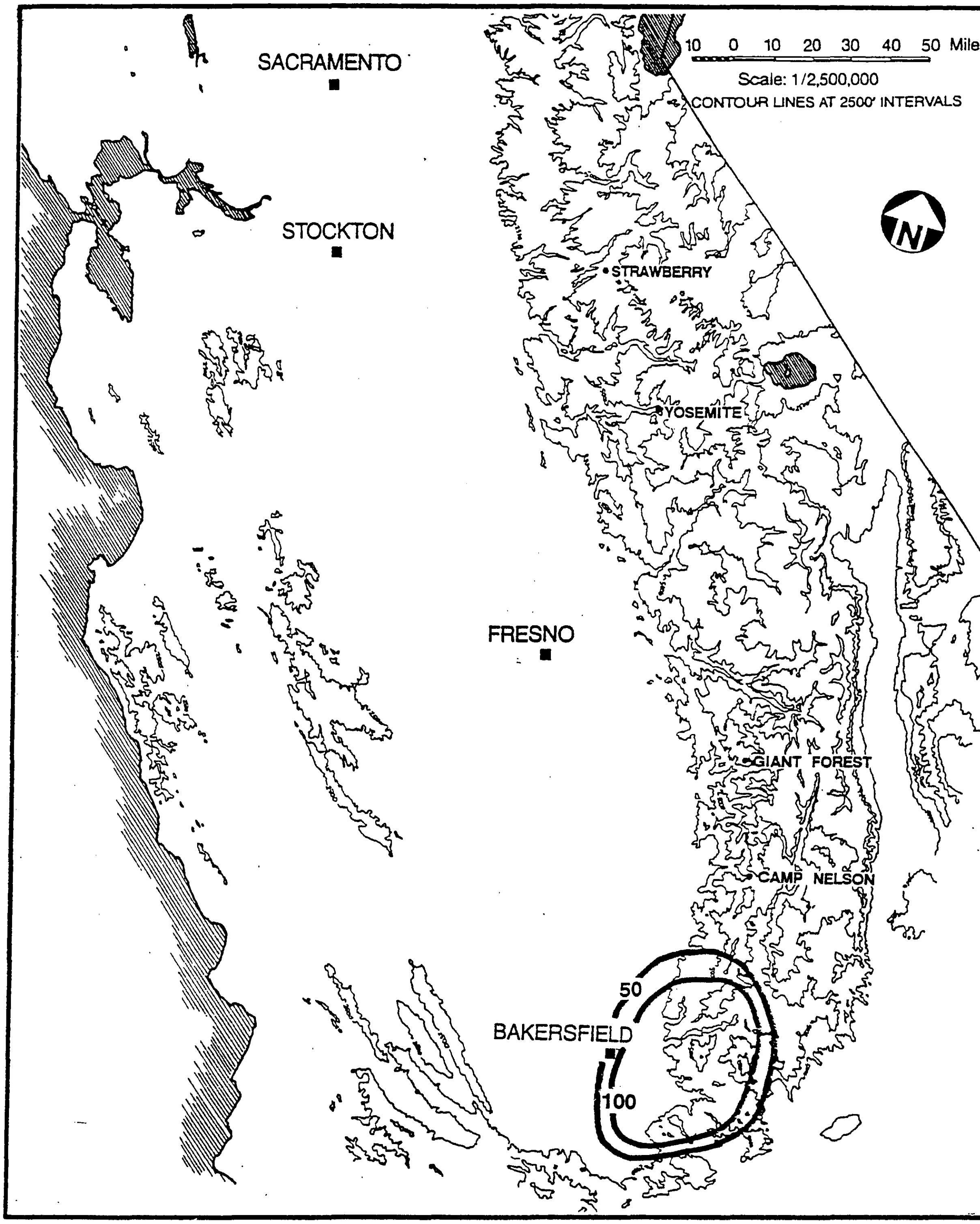


FIGURE 6-26 - Bakersfield Tracer Isopleths
August 13, 1990: 0400-0600 PDT
(Concentrations are in fl/l)

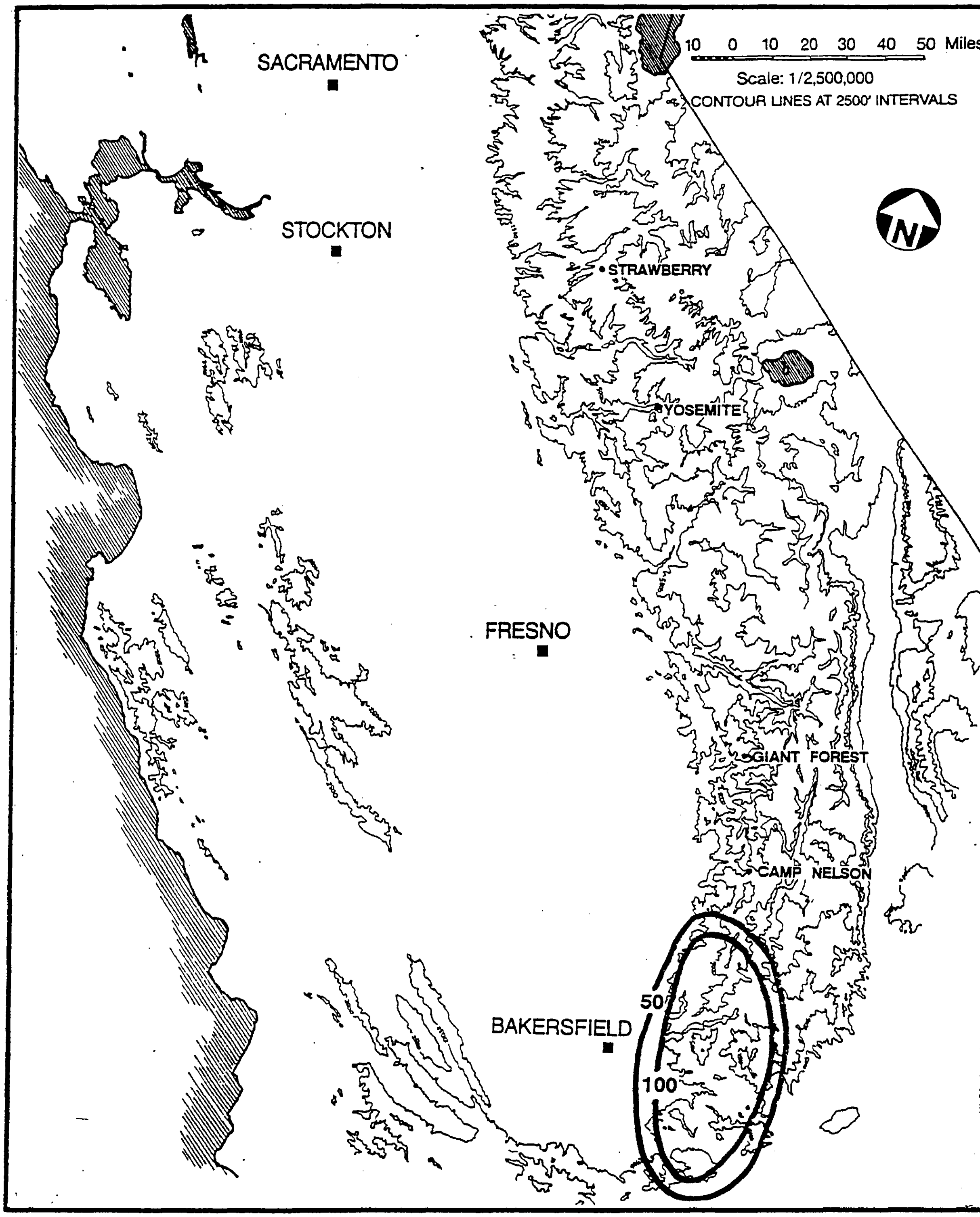


FIGURE 6-27 - Bakersfield Tracer Isopleths
August 13, 1990: 0600-0800 PDT
(Concentrations are in fl/l)

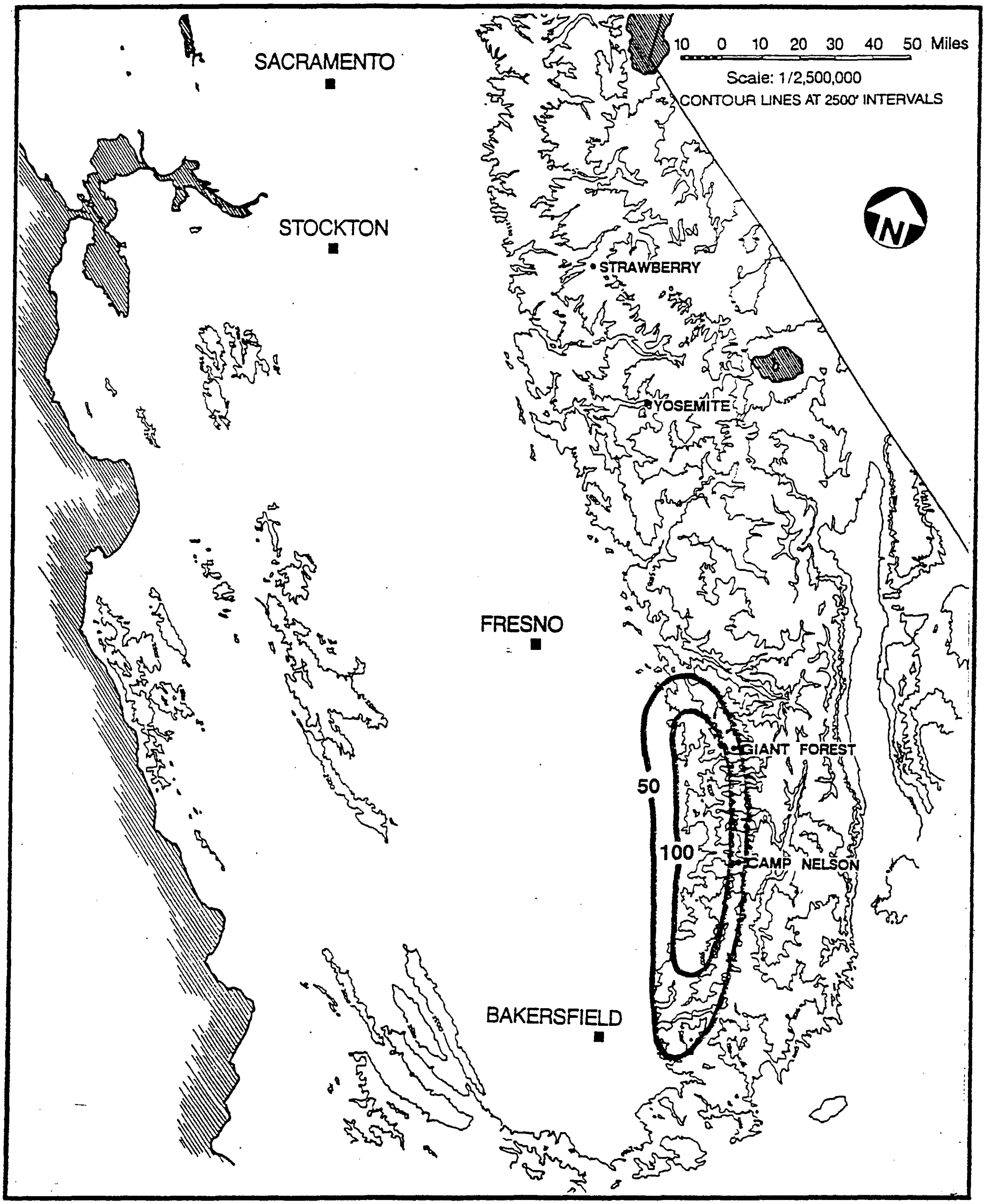


FIGURE 6-28 - Bakersfield Tracer Isopleths
August 13, 1990: 1200-1400 PDT
(Concentrations are in fl/l)

1600 PDT, the Bakersfield plume had dispersed from the sampling grid.

Airborne observations of the Bakersfield plume (Figure 6-29) were consistent with the surface observations. During the 1400 PDT sampling period, PTCH was seen over the Lake Isabella area (131 fl/l) and near the peaks of the Sierra Nevada Range. A concentration of 30 fl/l was observed at an altitude of about 8000 ft MSL. No PTCH was seen in the leeward monitoring sites, indicating either very good dilution of SJV air in the leeward regions, or the plume was carried eastward via upper level wind flow.

There were two pathways observed for Bakersfield tracer to flow into the Sierra Nevada. The pathways are depicted in Figure 6-30. One pathway is the Kern River canyon which starts just east of Bakersfield and heads toward Lake Isabella. Impacts were measured at Democrat Station which is just within the canyon, approximately 30 miles east of Bakersfield. The second pathway is towards the Tehachapi Range.

6.3 Tracer Experiment #2 -- 24 October 1990

The second tracer experiment was started at 1000 hours on October 24, 1990. This test was conducted in anticipation of prefrontal conditions which would promote transport of air pollutants in the San Joaquin Valley into the Sierra. During this particular test, the frontal system showed signs of stalling which ultimately delayed the occurrence of the targeted transport scenario. A sampler malfunction prevented the samplers from starting as scheduled and all samplers had to be reprogrammed to start at a later time. As a result, this test extended approximately 72 hours from the start of the tracer release. Peak ozone levels in the SJV reached 10 pphm (23 October 1990, 1400 hours at Fresno). During the release period, ambient hourly ozone concentrations averaged 8.5 pphm at Fresno, 4.4 pphm at Stockton and 7 pphm at Bakersfield area stations. Peak ozone values during the release day were 7 pphm at Stockton, 10 pphm at Fresno, and 10 pphm at Bakersfield. Due to some unforeseen equipment problems, the tracer sampling network was not completely operational at the time of release, but as time progressed, more stations became operational to eventually capture a major transport event. During the test, samplers collected synchronized two-hour averaged sequential samples. Airborne "grab" samples were collected over the Sierra Nevada Range about 24 hours after the initial release of tracer materials.

6.3.1 Fresno Release

Figures 6-31 through 6-37 depict the progression of the Fresno Plume during this tracer test period. As in the first experiment, PDCH was released in an area configuration from the Fresno area. The original release occurred at 1000 to 1400 PDT on 24 October 1990. During the first 24 hours of the test period, very calm and almost stagnant wind conditions were experienced in the SJV, promoting very little plume

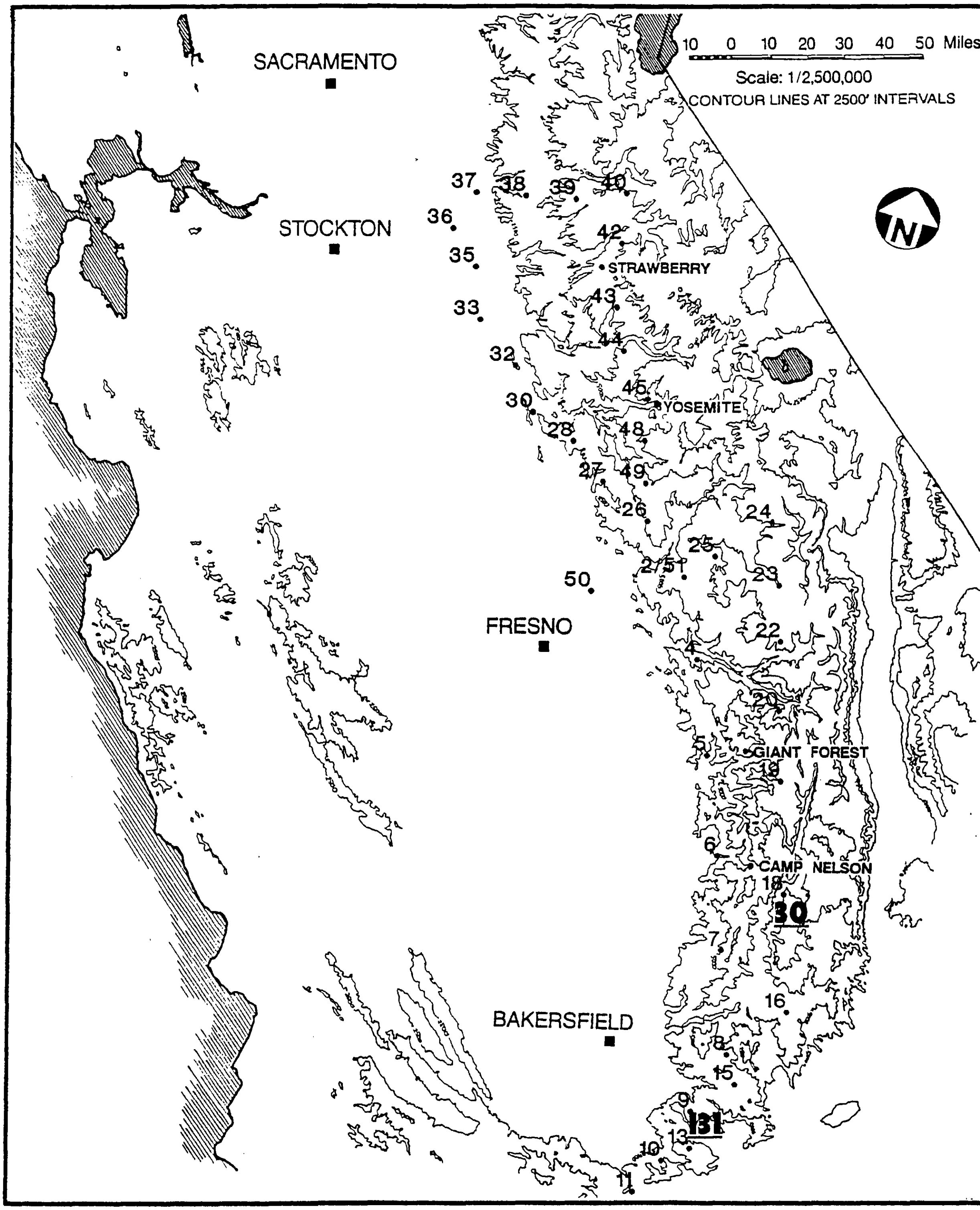


FIGURE 6-29 - Bakersfield Tracer Concentrations (PTCH)
Airborne - August 13, 1990: 1200-1800 PDT
(Concentrations are in boldface, fl/l)

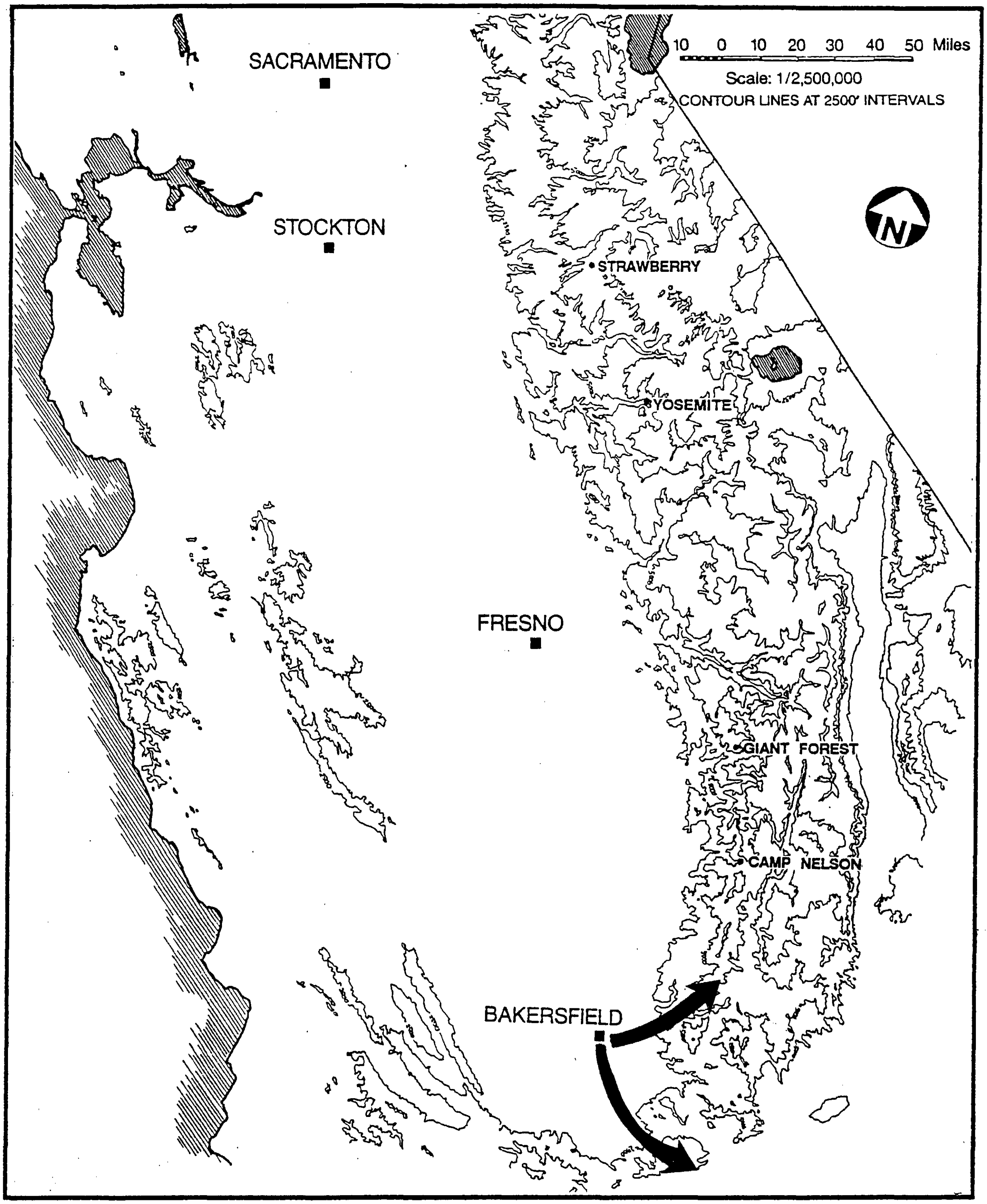


FIGURE 6-30 - Bakersfield Pathways into the Sierra Nevada: August Test

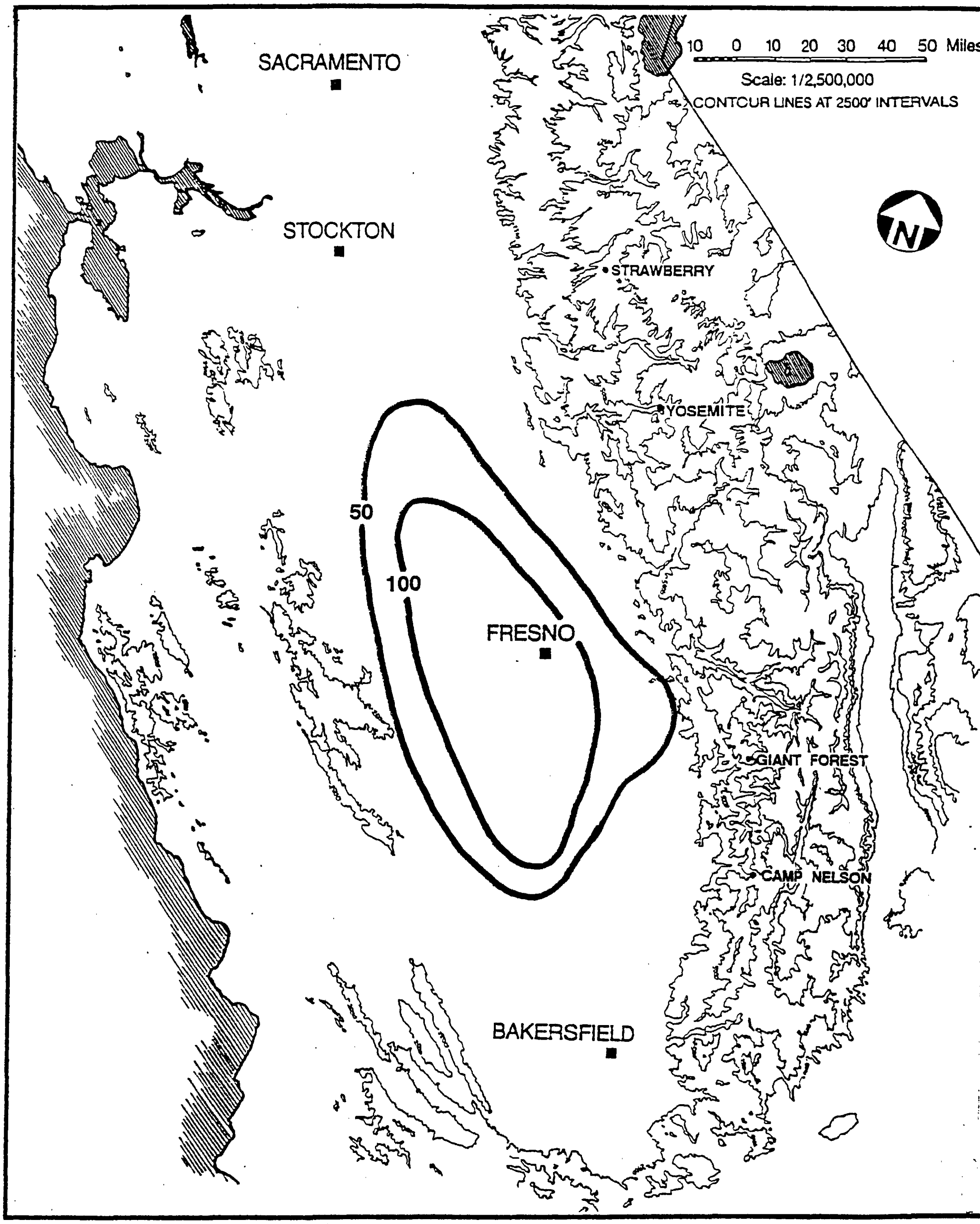


FIGURE 6-31 - Fresno Tracer Isopleths
October 25, 1990: 0800-1000 PDT
(Concentrations are in fl/l)

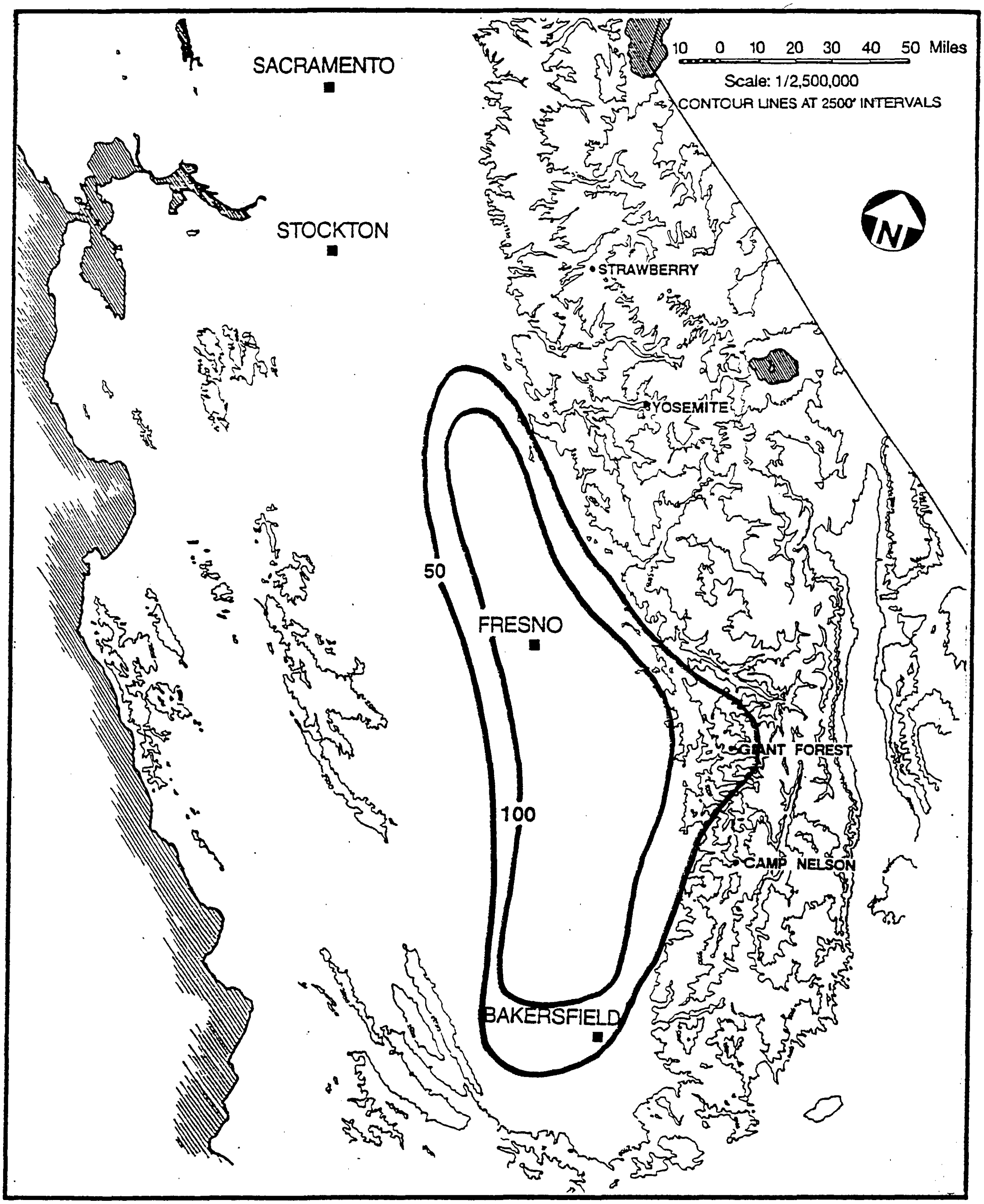


FIGURE 6-32 - Fresno Tracer Isopleths
October 25, 1990: 1600-1800 PDT
(Concentrations are in fl/l)

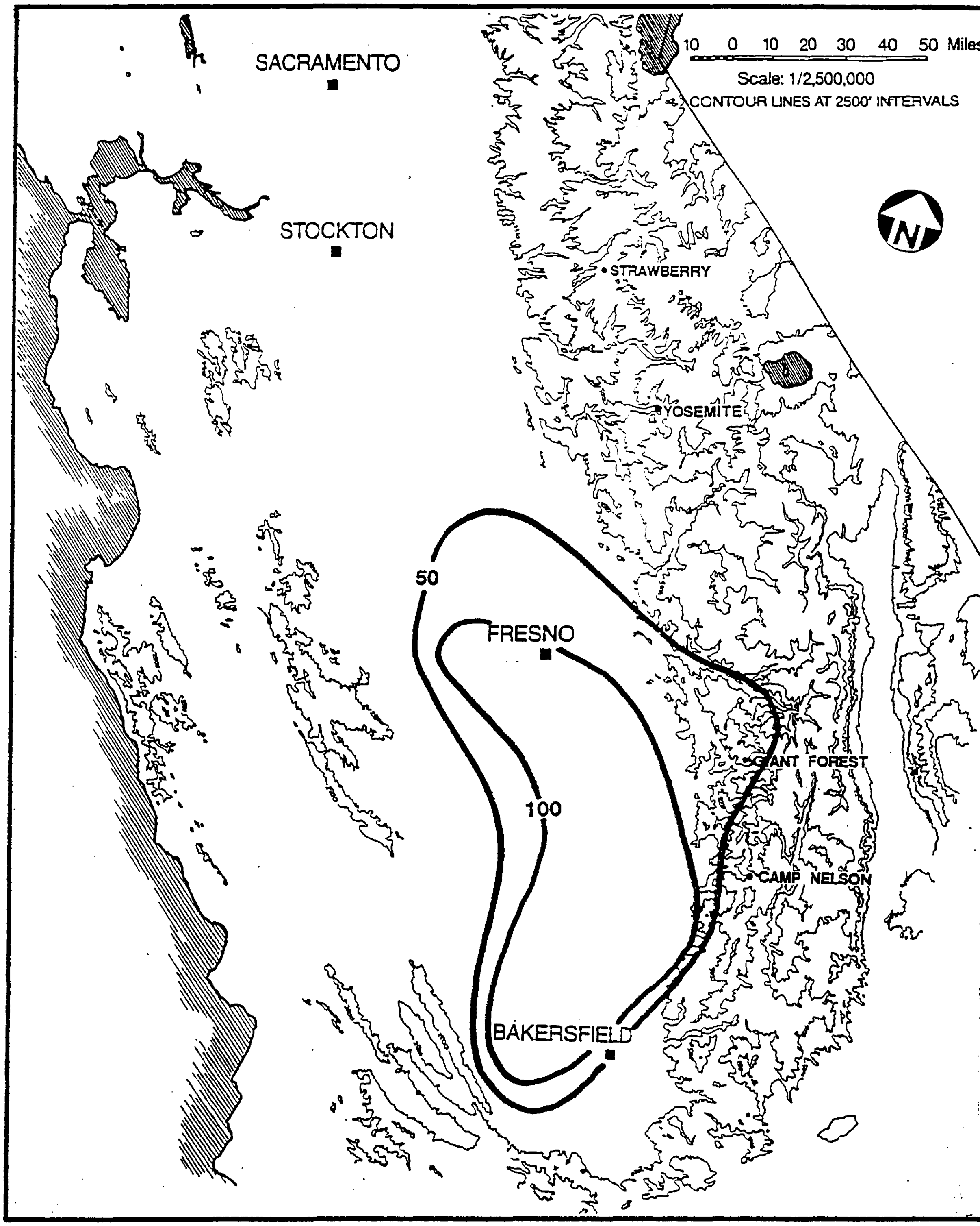


FIGURE 6-33 - Fresno Tracer Isopleths
October 25, 1990: 2200-2400 PDT
(Concentrations are in fl/l)

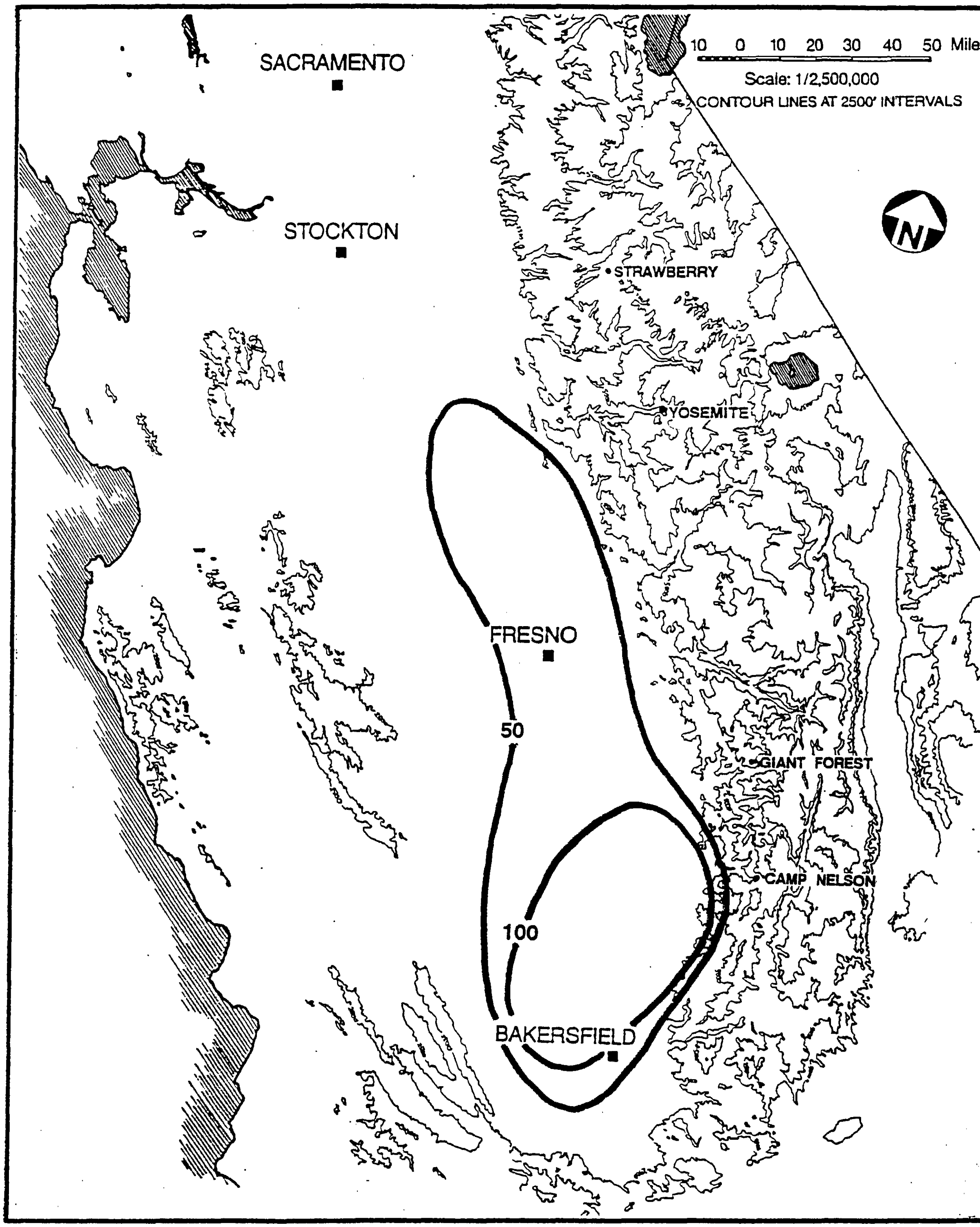


FIGURE 6-34 - Fresno Tracer Isopleths
October 26, 1990: 0600-0800 PDT
(Concentrations are in fl/l)

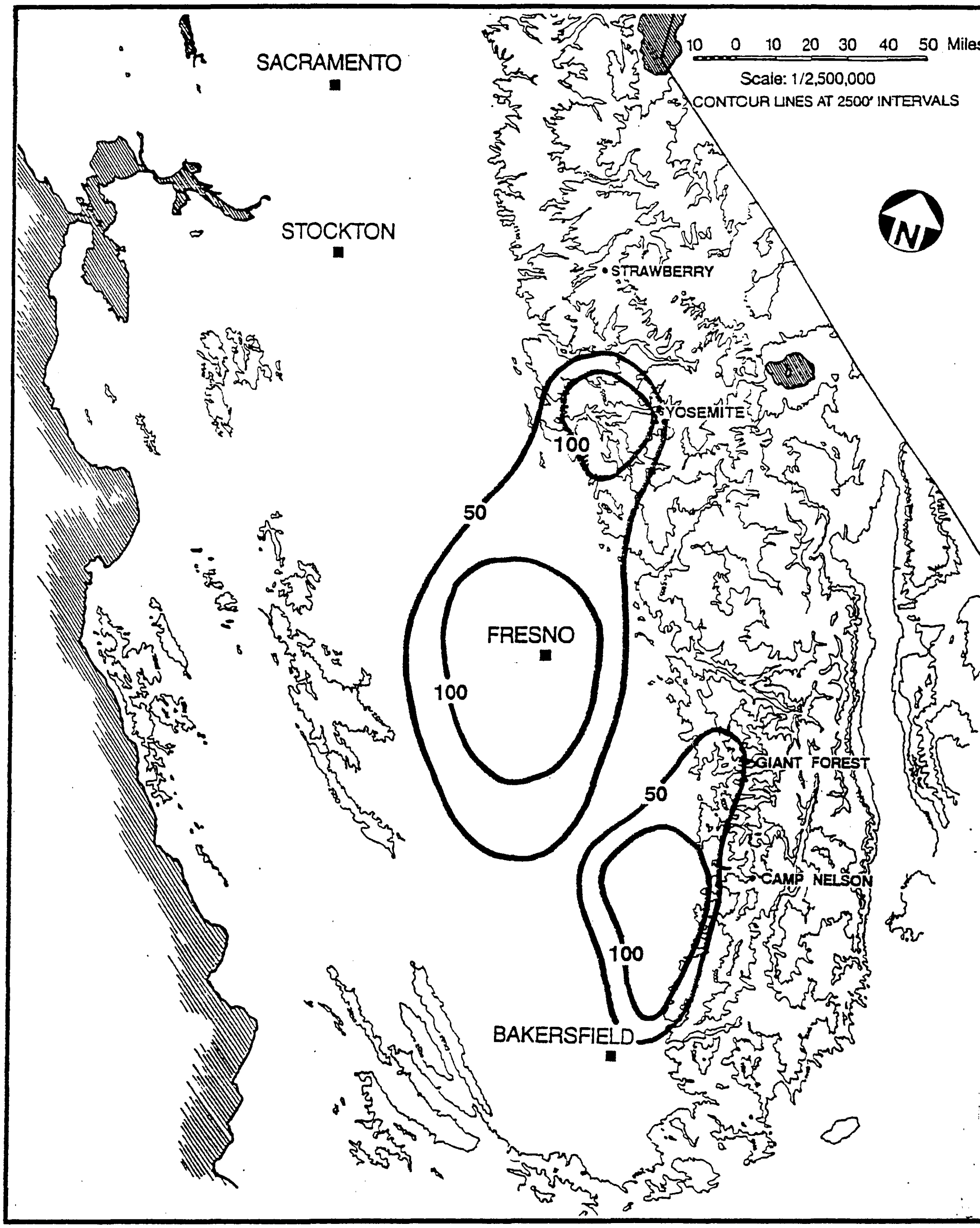


FIGURE 6-35 - Fresno Tracer Isopleths
October 26, 1990: 1000-1200 PDT
(Concentrations are in fl/l)

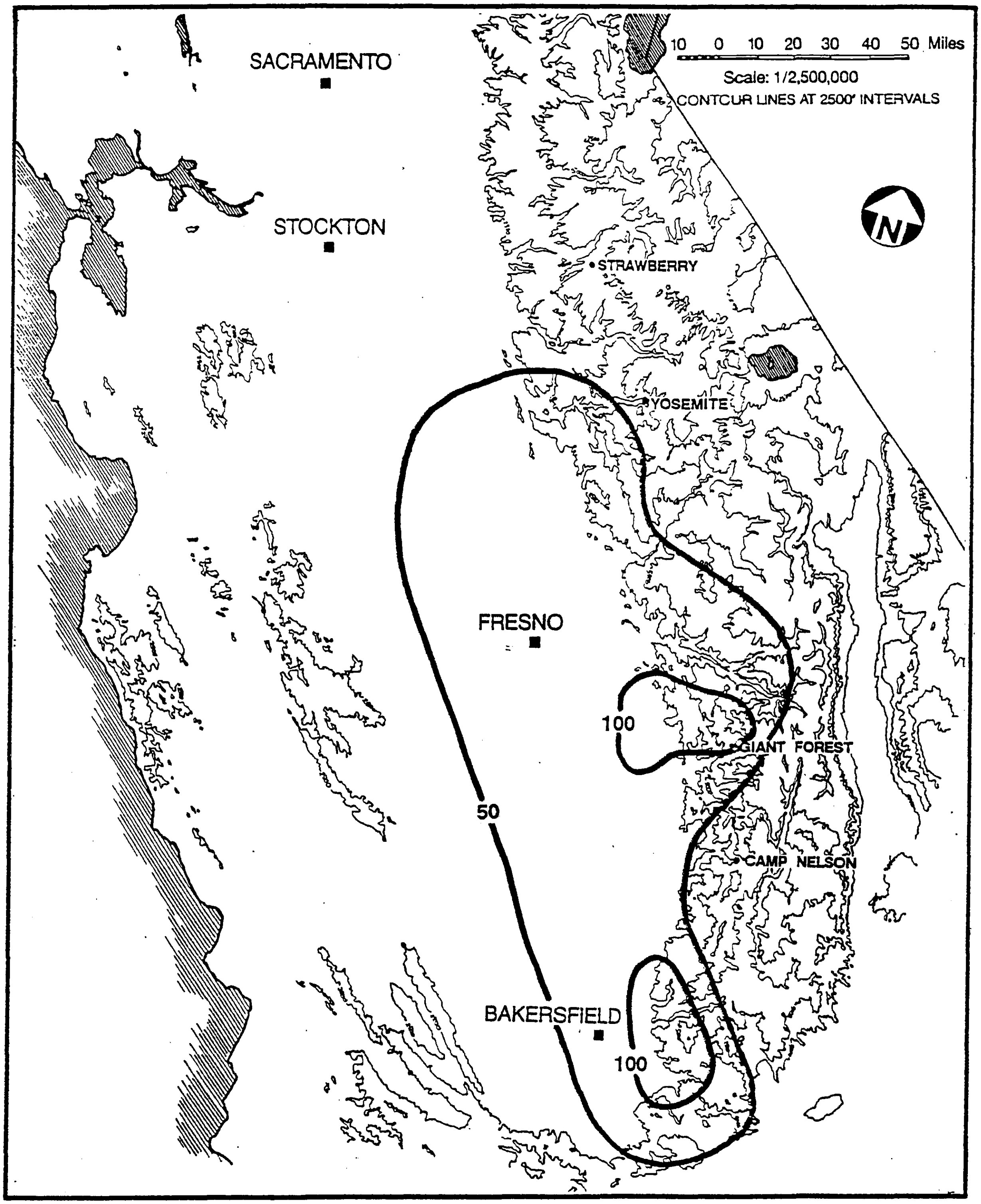


FIGURE 6-36 - Fresno Tracer Isopleths
October 26, 1990: 1600-1800 PDT
(Concentrations are in fl/l)

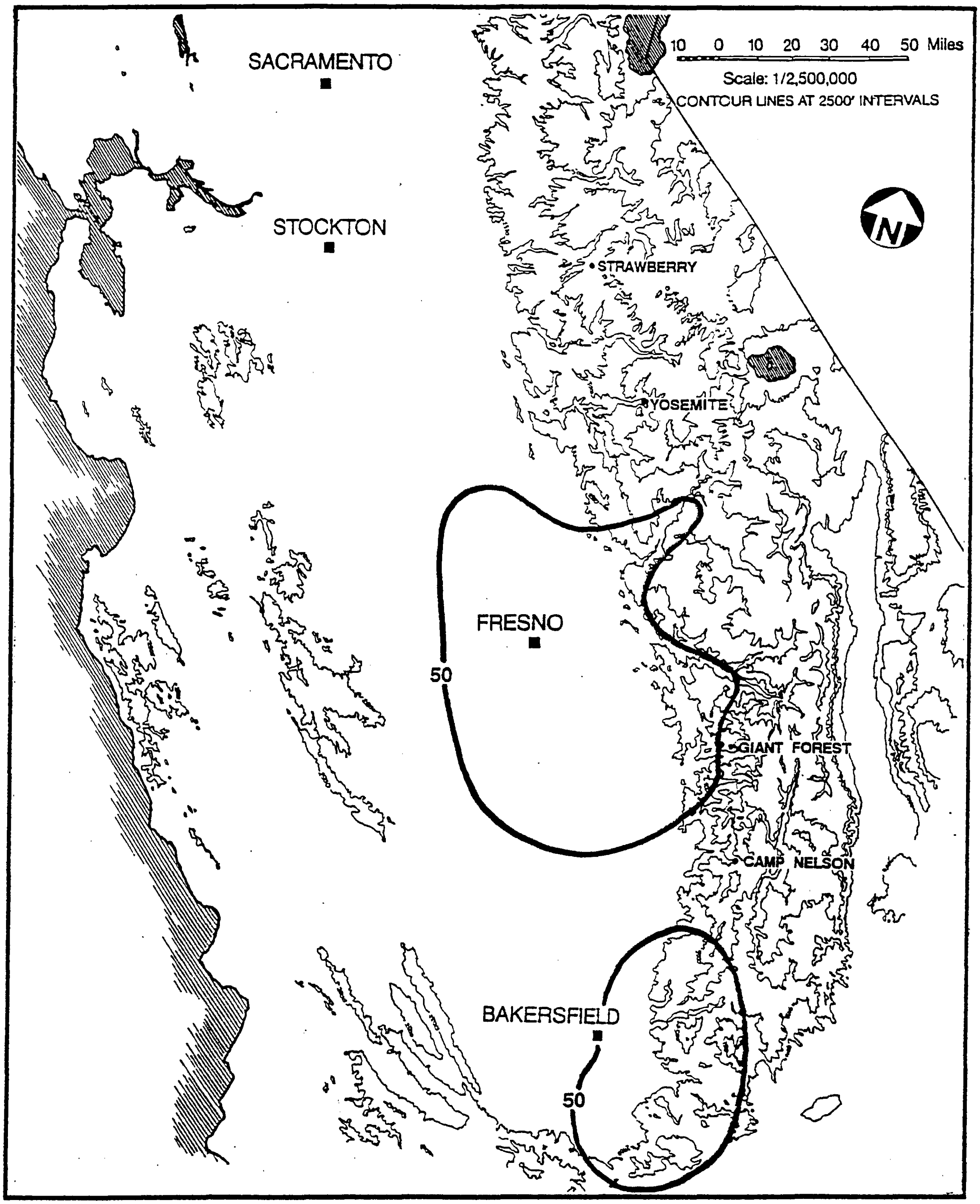


FIGURE 6-37 - Fresno Tracer Isopleths
October 26, 1990: 2000-2200 PDT
(Concentrations are in fl/l)

movement. Figure 6-31 illustrates a surface plume, about 24 hours after the initial release, extending over a larger area of the SJV, with very little evidence of impact into the Sierra Nevada Range. This depiction may be misleading in that airborne data collected during this period indicates a substantial plume aloft in the Tahoe and Strawberry regions of the Sierra. We speculate that a portion of the Fresno plume may have been initially entrained in more complex winds aloft. Figure 6-32 depicts the Fresno plume 32 hours after the initial release, indicating surface distribution throughout the SJV with only limited impacts in the mountain areas (slight incursion into the Giant Forest area). During the next 6 hours the plume seemed to infiltrate a little further into Giant Forest area through the Kaweah River Valley. During this same period, impacts along the SJV locations were fairly constant with a slight tendency for the plume to drift to a more southern position. Figure 6-33 illustrates the extent of the tracer plume at midnight on 26 October 1990, 36 hours after the initial release. As weak nocturnal drainage winds build, the tracer plume slightly retreats from higher elevations. Figure 6-34 depicts the plume position at 0600 to 0800 PDT on 26 October (approximately 42 hours after release) which illustrates a less severe impact in the mountain areas. During the next 6 hours the plume migrates north with considerable penetration into the Sierra. Figure 6-35 shows substantial impacts at the Yosemite Valley and Giant Forest stations but no impacts at higher elevations or leeward facing stations. Nearly 50 hours from the time of release, the Fresno tracer plume still resided, in most part, in the SJV. Approximately 6 hours later, the plume has moved substantially into the Sierra as illustrated by Figure 6-36. A nocturnal drainage wind pattern was once again established and the tracer plume subsequently retreated as seen during 2000 to 2200 PDT (Figure 6-37). During this second retreat, the plume showed signs of losing considerable mass by the marked decline in peak concentration. By noon the next day, there was limited evidence of the tracer plume.

Airborne observations of the Fresno tracer plume are illustrated in Figure 6-38. A substantial plume is detected aloft along the northern portions of the sampling network. (Sierra foothills regions east of Stockton and Sacramento). Impacts in these regions suggest that a portion of the Fresno tracer plume was transported further north than what surface monitoring stations revealed (perhaps early in the test when stations were not fully operational). Once the plume had reached a northern portion, complex air flow near the advancing frontal system may have entrained the plume quickly into the high elevations. Thus impacts were seen in the Tahoe and Strawberry regions of the Sierra. Observations of the Stockton plume, though sparse, suggest that this type of transport occurred in the upper SJV region.

Since the Fresno tracer was initially spread across the valley, many pathways were observed from the SJV into the Sierra. These pathways are depicted in Figure 6-39. Starting from north to south, the first pathway observed was the Merced River Valley which joins the San Joaquin Valley with Yosemite. The second pathway is the San Joaquin River Valley. Tracer appears to flow through Auberry into the river valley and then once penetrated into the Sierra, the tracer spreads north to Westfall Station and

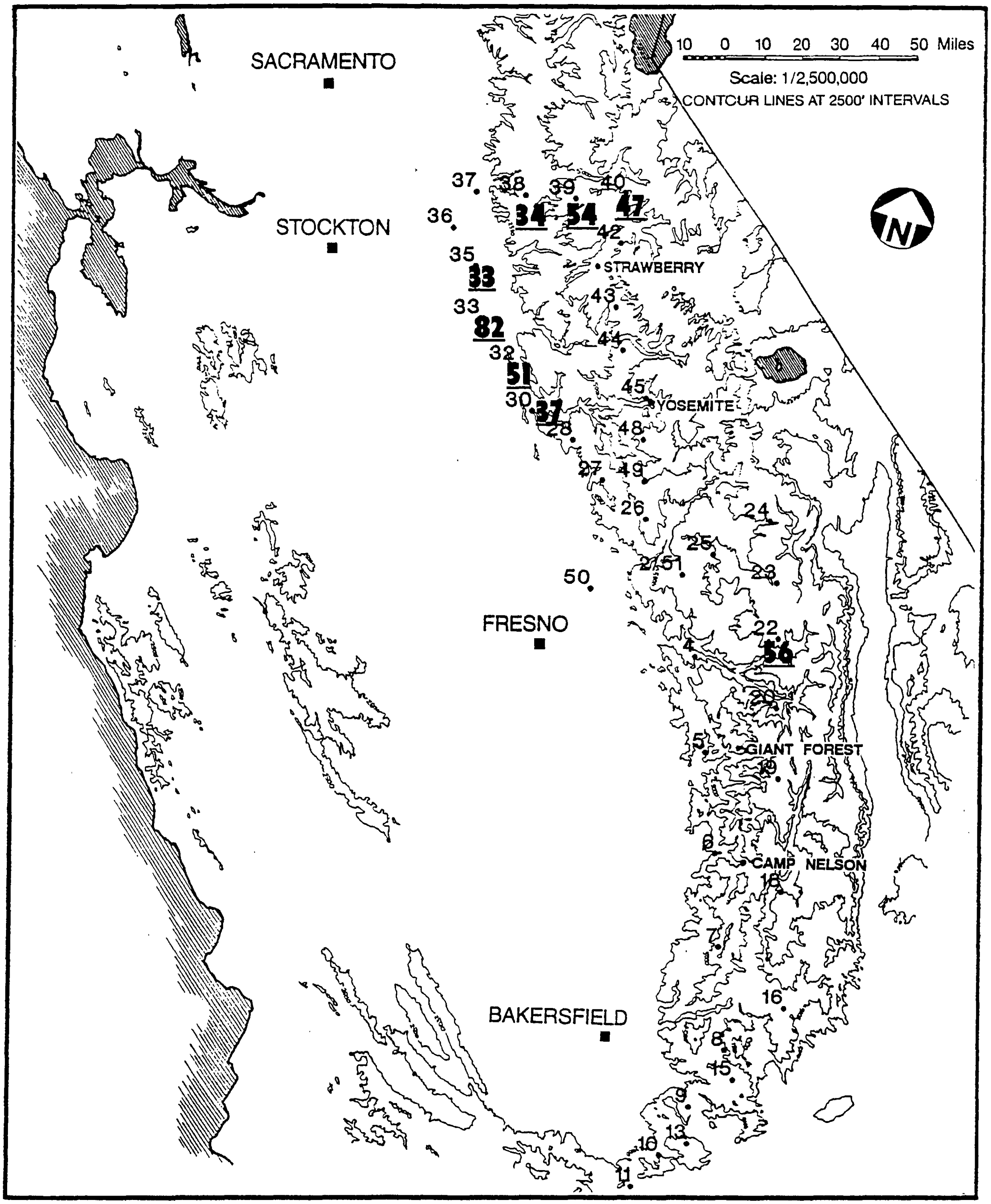


FIGURE 6-38 - Fresno Tracer Concentrations
Airborne - October 25, 1990: 1400-1800 PDT
(Concentrations are in boldface, fl/l)

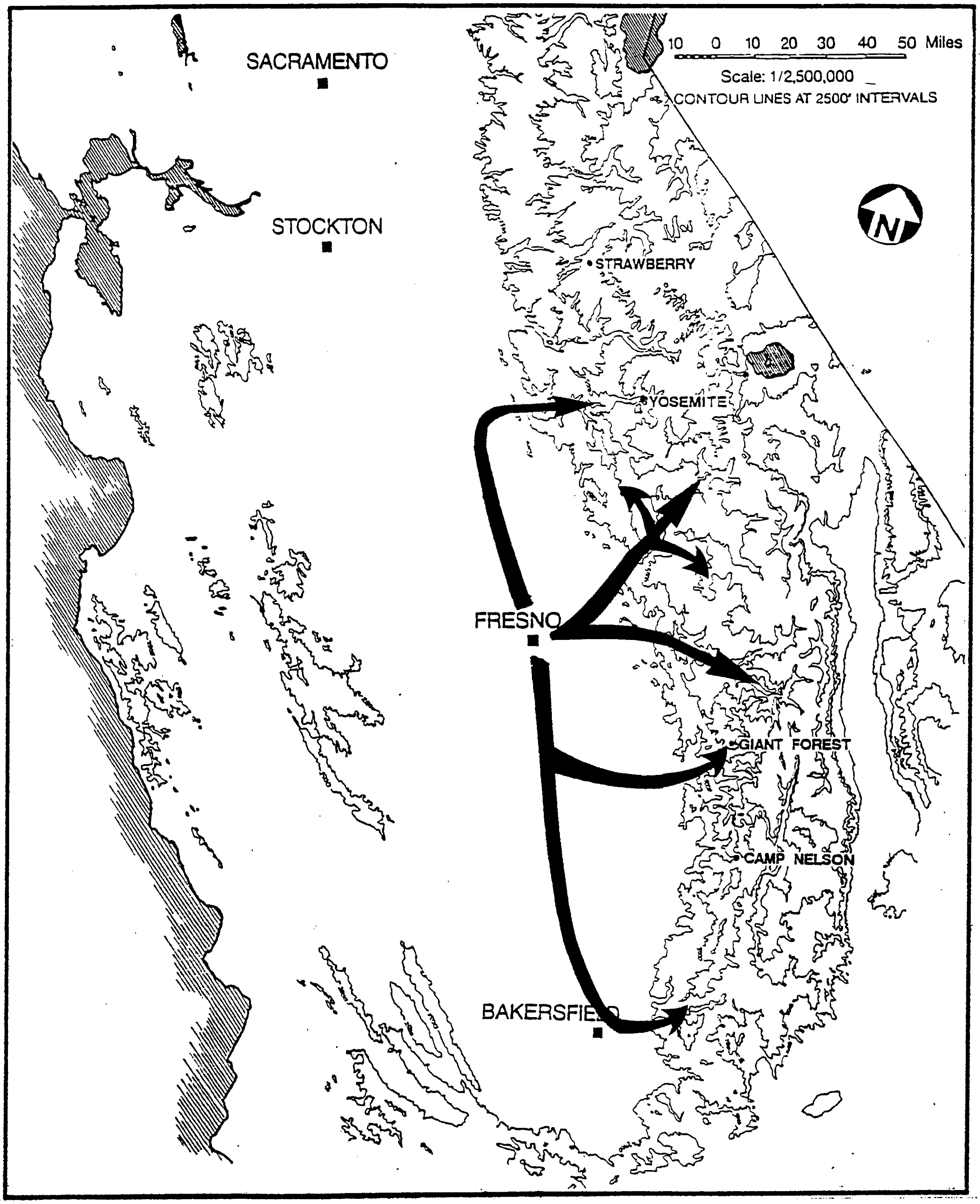


FIGURE 6-39 - Fresno Pathways into the Sierra Nevada: October Test

Mammoth Pool Reservoir, and also east to Dinkey Creek. The third pathway is King's Canyon which begins just east of Fresno and continues eastward towards Cedar Grove. The fourth pathway is the Kaweah River Valley which is located east of Visalia and heads towards Giant Forest in the Sierra. The fifth pathway is the Kern River Canyon which is located east of Bakersfield and goes towards Democrat Station.

6.3.2 Bakersfield Tracer

Figures 6-40 through 6-43 depict the progression of the Bakersfield tracer for this test. Nearly 18 hours after the Bakersfield area tracer release (PTCH) impacts were measured at SJV stations situated between Fresno and Bakersfield. Figure 6-40 illustrates the interpreted position of the Bakersfield plume at this time. Just as with the Fresno tracer plume, the Bakersfield area plume showed some penetration into the Sierra monitoring sites during 1600 to 1800 PDT on 25 October 1990, nearly 17 hours after the Bakersfield release was completed. Figure 6-41 depicts the position of the Bakersfield plume at this time. During the next 4 to 6 hours, the tracer plume migrated to the south, impacting the Tehachapis (see Figure 6-42). Nocturnal drainage flow carried any mountain impacts back into the SJV during the next 6 to 8 hour period. This is evident from the plume position depicted in Figure 6-43. The above pattern repeats, with impacts even further into the Tehachapis and southern portions of the Sierra Nevada. As time progressed the plume concentrations gradually decreased. The Bakersfield tracer plume never quite reached Fresno and never impacted any Sierra Nevada sites north of Giant Forest.

Airborne observations of the Bakersfield plume indicated no measured concentrations in the upper air regions of the Tehachapis or Sierra Nevada Range. These impacts may have occurred during hours after the airborne sampling was conducted.

There were two pathways into the Sierra Nevada for the Bakersfield tracer. These pathways are depicted in Figure 6-44. To the north, the tracer appeared to flow up the Kaweah River valley into Ash Mountain. Surprisingly, none of the tracer was ever measured at Giant Forest, approximately 15 miles east of Ash Mountain. The second pathway was the Kern River canyon just east of Bakersfield. The Bakersfield tracer was also measured at Lebec in the Tejon Pass.

6.3.3 Stockton Tracer Release

Due to the specific meteorological conditions experienced during this test, the Stockton tracer plume was difficult to track since winds initially carried the plume to the north. Unfortunately the test designed called for no monitoring stations in this region. However nearly 36 hours after the initial release, the Stockton tracer was detected in some SJV stations as well as at Mammoth Lakes. We speculate that after the initial northerly

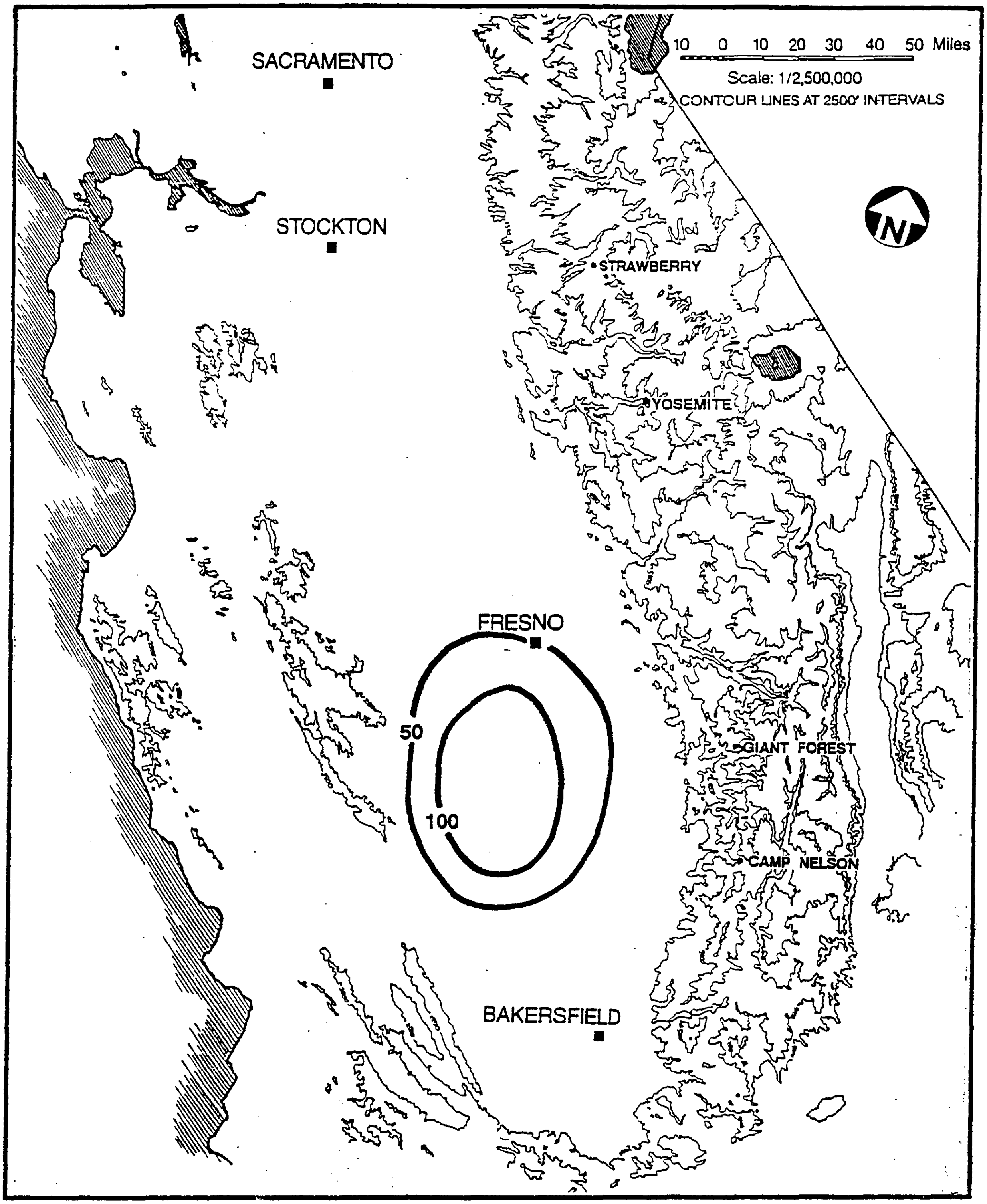


FIGURE 6-40 - Bakersfield Tracer Isopleths
October 25, 1990: 0800-1000 PDT
(Concentrations are in fl/l)

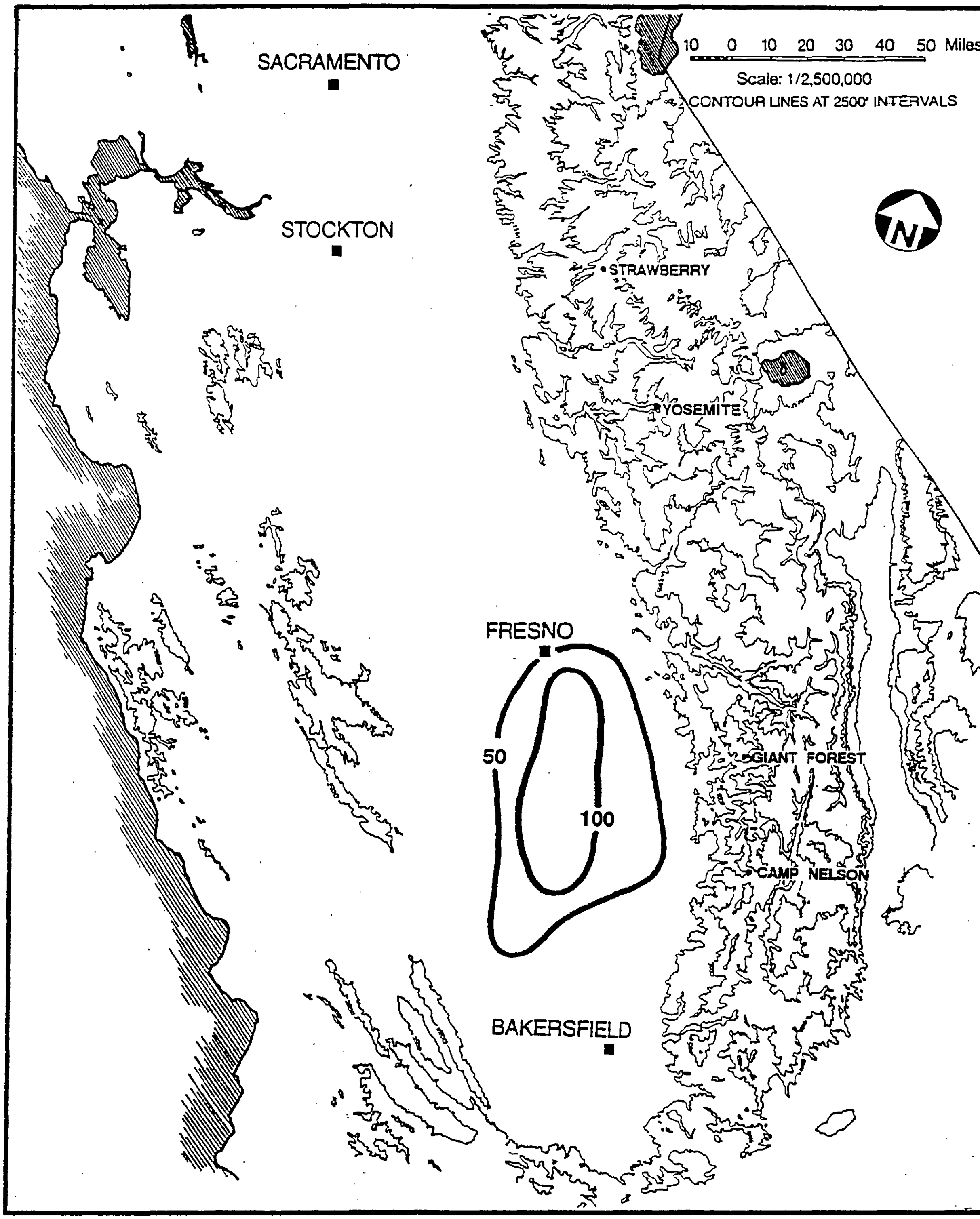


FIGURE 6-41 - Bakersfield Tracer Isopleths
October 25, 1990: 1600-1800 PDT
(Concentrations are in fl/l)

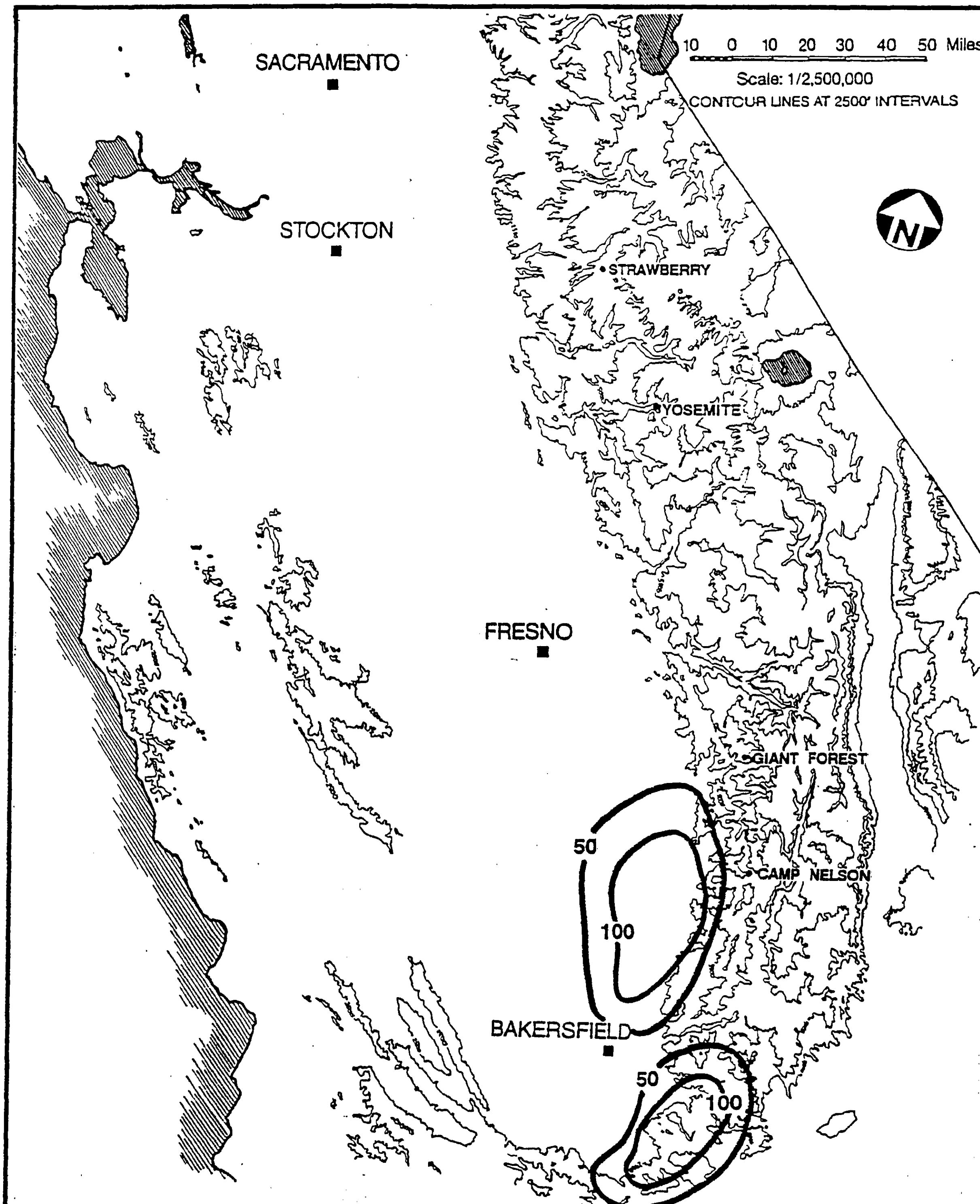


FIGURE 6-42 - Bakersfield Tracer Isopleths
October 25, 1990: 2200-2400 PDT
(Concentrations are in fl/l)

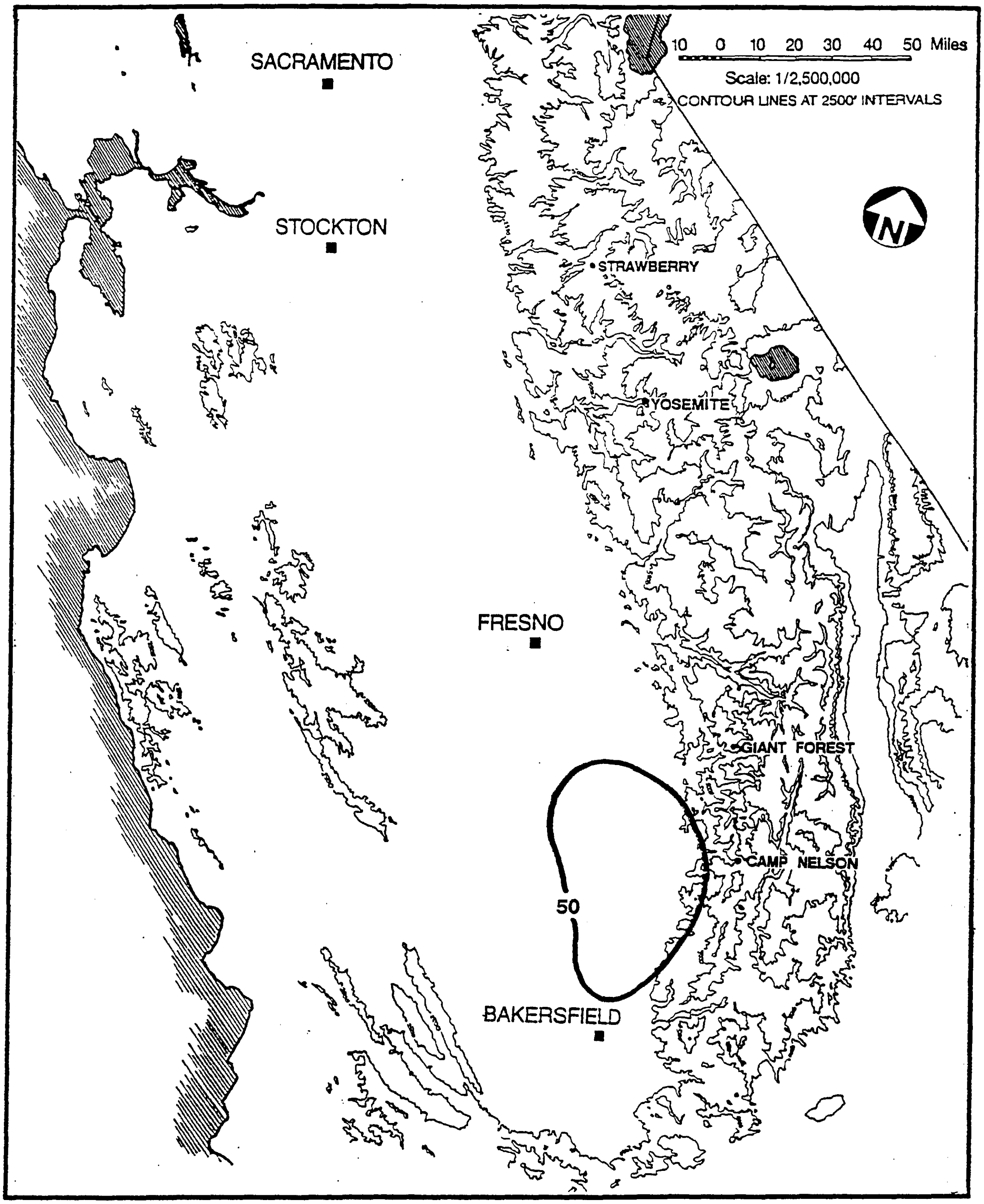


FIGURE 6-43 - Bakersfield Tracer Isopleths
October 26, 1990: 0600-0800 PDT
(Concentrations are in fl/l)

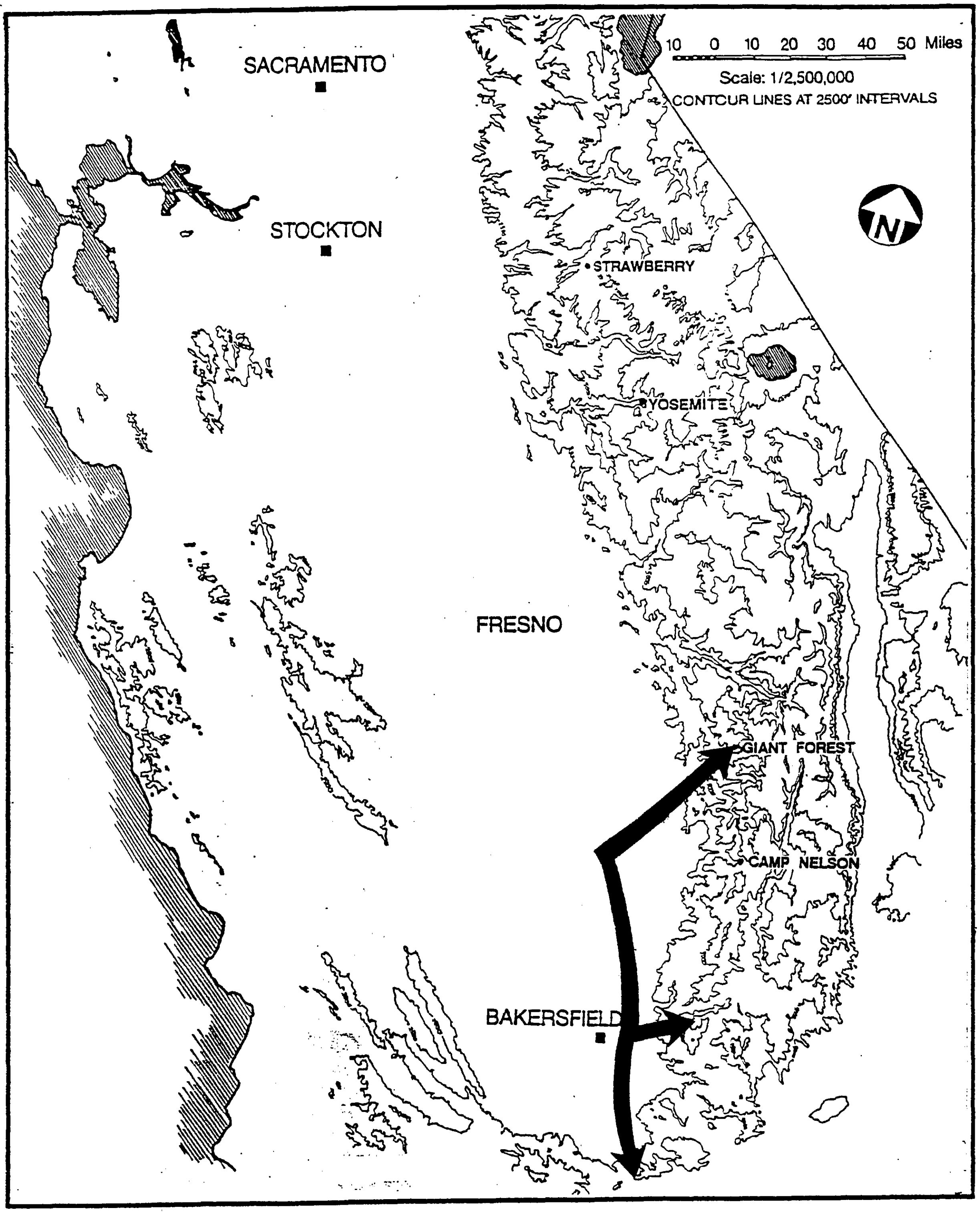


FIGURE 6-44 - Bakersfield Pathways into the Sierra Nevada: October Test

transport, portions of the Stockton plume were entrained in complex wind patterns closer to the emerging frontal system, as seen by observations of the Fresno tracer plume during this test. This may have brought the Stockton tracer into more elevated wind fields which eventually impacted the northern and upper elevation stations like Mammoth Lakes. During this test the Stockton tracer was never detected in Fresno. However, slight concentrations were seen at the Dinkey Creek stations, situated just east of Fresno.

Airborne sampling of the Stockton tracer plume revealed no direct impact in the Sierra Nevada range (24 hours after release). This may be a result of the sampling being conducted relatively early in the test. If the Stockton plume had initially migrated north and was later brought back into the Sierra by upper level air flow, the airborne sampling, conducted only one day after the initial release, would not have captured the Stockton plume.

6.4 Infiltration Process from Valley to Upper Sierra

Infiltration into the Sierra is not a simple process, as depicted by not only this test, but in all tracer releases. It appears that the main body portion of the plume resides in the valley, and a slow seeping process allows the plume to penetrate the mountain regions. This process continues until the entire valley plume is "siphoned" away. Characteristically, impacts in the Sierra can be delayed and de-intensified, but lengthen in duration. Figure 6-45 provides a generic depiction of this theory. In all cases, the tracer plume retreats well from the upper Sierra regions during nocturnal periods, but the overall plume rarely is observed to drain from the foothill regions. This suggests that drainage wind conditions do not dominate the transport process in the lower Sierra regions.

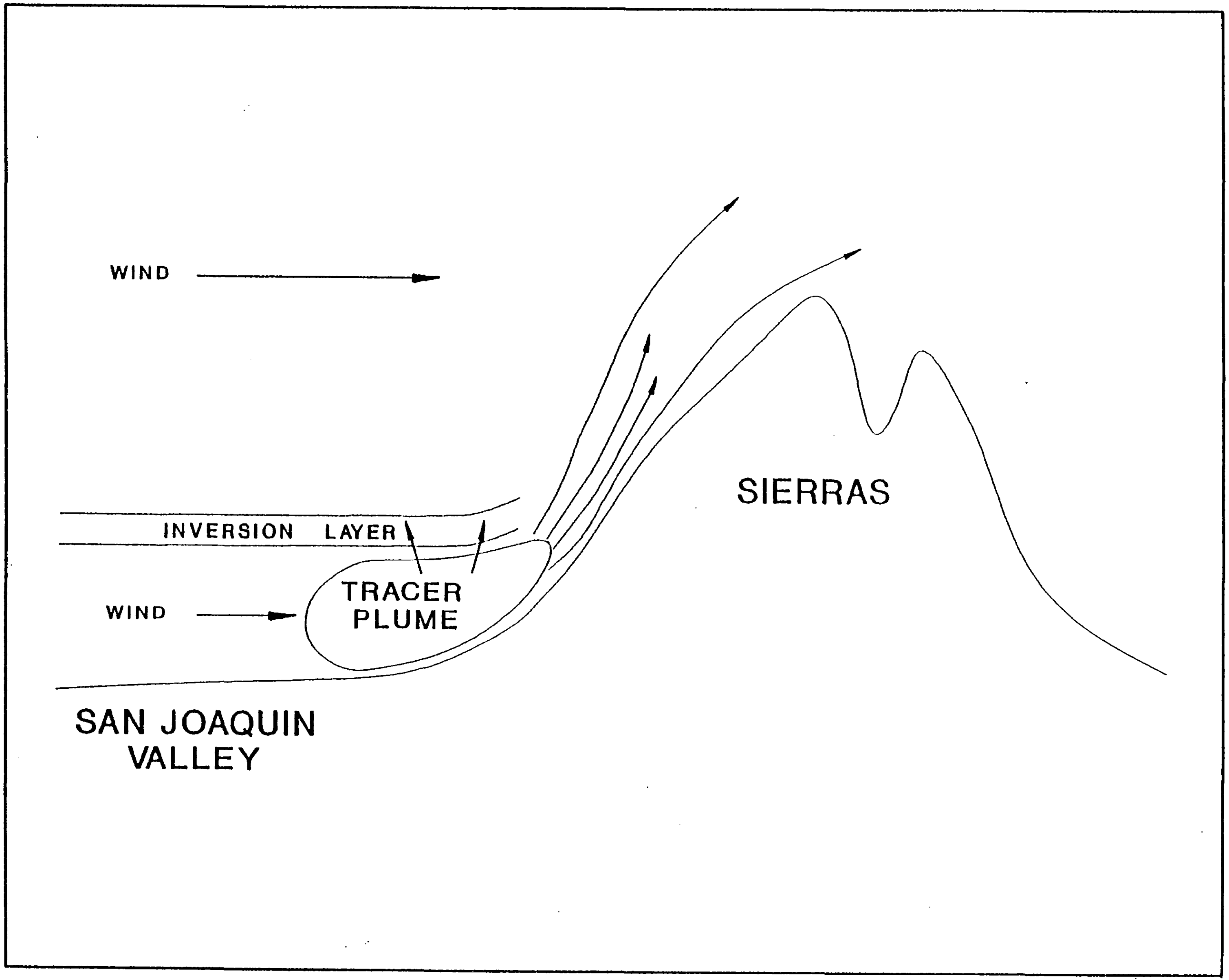


FIGURE 6-45 - Infiltration Mechanism for Air Transport Into the Upper Sierras

7.0 TRAJECTORY ANALYSIS

A trajectory analysis was performed to compare the actual path of the tracer plumes to the predicted path of related air parcels using available meteorological data. The intent of the trajectory calculations is to emulate a release particle and follow the path of that particle through the rest of the test period. For each tracer release, two separate trajectories were calculated for the end of each release hour: one trajectory was calculated using surface level winds (10 m), and the other was calculated using 10 meter wind speeds adjusted for 1000 meters using an exponential formulation. This is not to suggest that the centroid of the tracer plume is at 1000 meters, but implies that surface winds require adjustment for movement aloft to enable reasonable comparison to the true trajectory results. The following trajectory analysis is useful for two reasons: (1) The trajectory analysis assists in explaining anomalies in the tracer data, and (2) it demonstrates how difficult it is to predict atmospheric transport in complex terrain from surface level winds alone.

7.1 Methodology

Trajectories were calculated using available wind speed and wind data concurrent to the two test periods. For the August test period, data were obtained from the SJVAQS network which provided hourly data from over 90 stations in the San Joaquin Valley and the Sierra Nevada. For the October test period, meteorological data was amassed from the CIMIs network, and the National Park Service network.

To calculate the trajectories, a particle from the release location was moved in 30 minute time steps using a $1/r^2$ weighting scheme to calculate the resultant velocity vector at each particle location. For example, at the end of a release hour, a $1/r^2$ weighting scheme was used to find the resultant vector for that particular location for the next hour. The particle was then moved to a new location using the calculated velocity vector for a thirty minute time step, and a new velocity vector was calculated for the new location for that same hour. The particle was then moved to a new location using the newly calculated velocity vector for a thirty minute time step. This iteration was repeated for the duration of the test.

Two types of trajectories were calculated for each test. Initially, all trajectories were calculated using surface wind data (10 m). After further analysis, we decided that the surface wind trajectories grossly underestimated the tracer trajectories, indicating that upper winds had more effect on tracer movement than surface level winds. Unfortunately, upper level wind data were not available, so trajectories were calculated using the surface wind data adjusted for 1000 meter heights using Hellman's equation (

Humphreys (1940), "Physics of the Air"). The Hellman equation is described below.

$$u/u_o = (h/h_o)^{1/5} \qquad (1)$$

where
u = wind velocity at height h
u_o = wind velocity at height h_o
h_o = height of measured surface wind velocities
h = height of desired wind velocity

The results from Hellman's equation compared favorably to upper level winds measured during early morning Fresno soundings for the two test periods. In the following section, the calculated elevated and surface trajectories are compared to the tracer data to determine whether the calculated trajectories could predict tracer movement. It is important to point out that due to test design there are limitations in calculating and comparing trajectories to cloud position at selected intervals. Trajectories follow air parcels from one instant to the next. The tracer plume represents an ensemble average of many trajectories. Some important fundamental differences occur between air parcel trajectories and tracer cloud progression which make it impossible to compare, particularly in the later stages of each test. Furthermore, the tracer releases depict the impact plumes from area release configurations, while trajectories were calculated from a point source from within each respective city. Hence the tracer should disperse through a larger area than would be expected to be shown by trajectory calculations. The results showed that the calculated trajectories were unable to predict tracer movement during low windspeed conditions (< 3 m/s). For wind speeds greater than 3 m/s, the elevated trajectory calculations sometimes provided a good estimate for tracer movement in the valley, however, the calculated trajectories were a poor indication of tracer cloud movement in the complex terrain areas.

7.2 Test 1, August 12-14

7.2.1 Stockton Release, August 12, 1991

The Stockton tracer, PMCH, was released from 1000 until 1400 on August 12, 1991. Figures 7-1 through 7-3 displays the different trajectories for the August test. Figure 7-1 presents the trajectory calculated from surface level winds. Figure 7-2 presents the trajectory calculated from surface winds adjusted to a 1000 meters using Hellman's equation, and Figure 7-3 presents the actual path of the tracer plume and bifurcated portions (This represents several possible actual trajectories the tracer plume followed). The numbers displayed are time steps for the trajectory. The time is presented in hours using the day of the release as the reference. For example hour 14 represents 1400 the day of the release and hour 26 represents 0200 the day following the release.

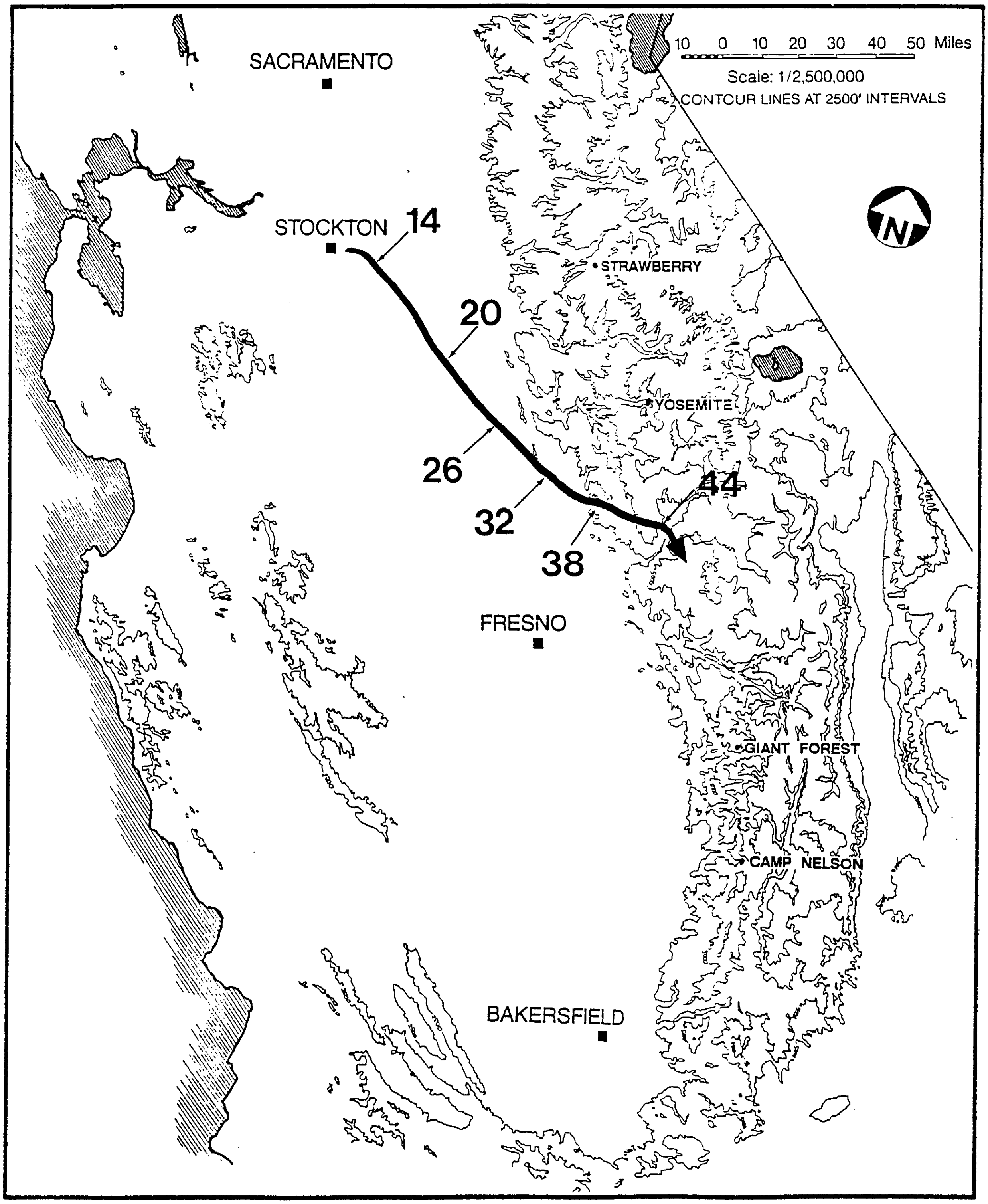


FIGURE 7-1 - CALCULATED GROUND LEVEL TRAJECTORY OF STOCKTON TRACER - AUGUST TEST
(Hours listed are based on clock hour of first test day)

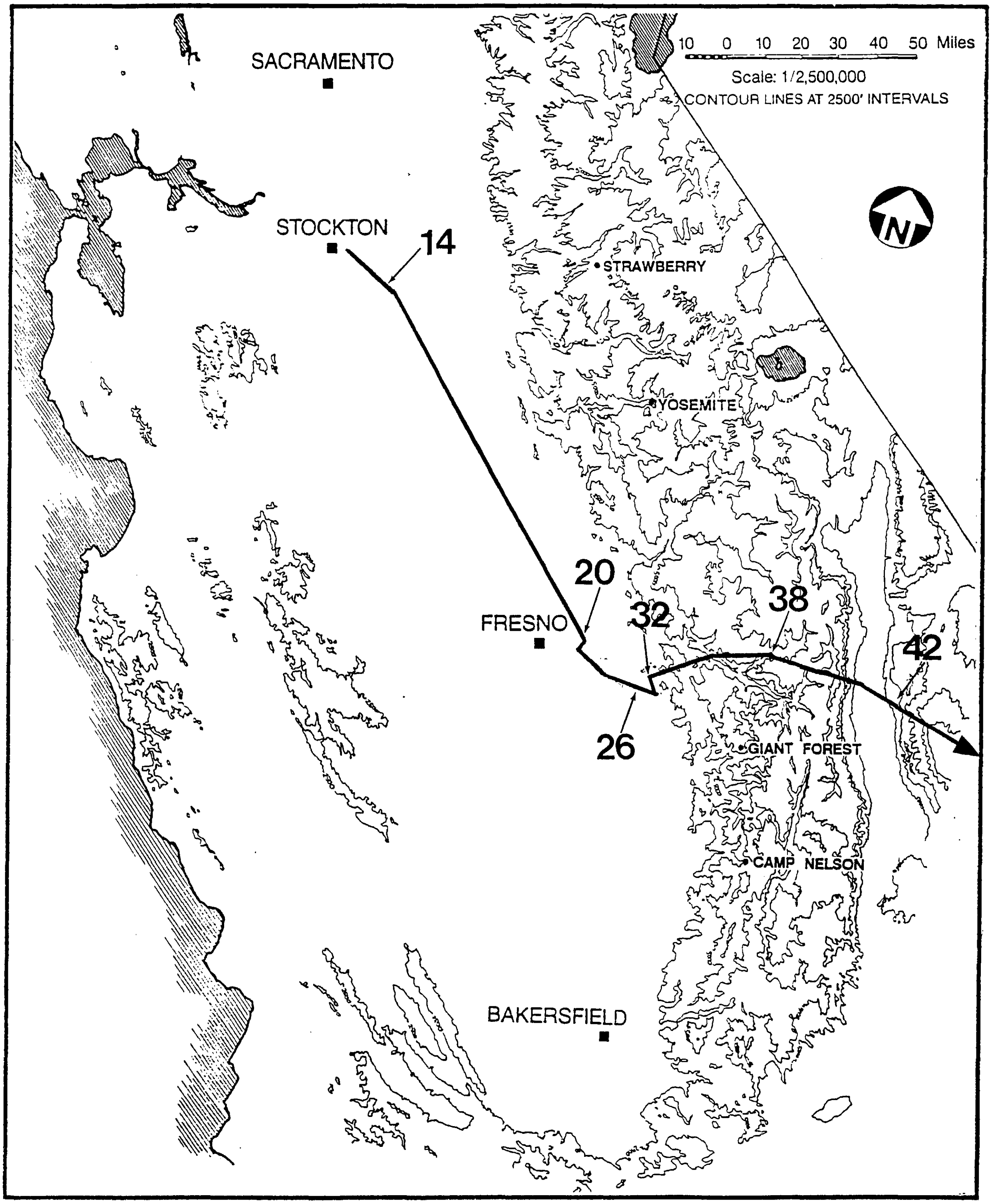


FIGURE 7-2 - CALCULATED ELEVATED TRAJECTORY OF STOCKTON TRACER - AUGUST TEST
(Hours listed are based on clock hour of first test day)

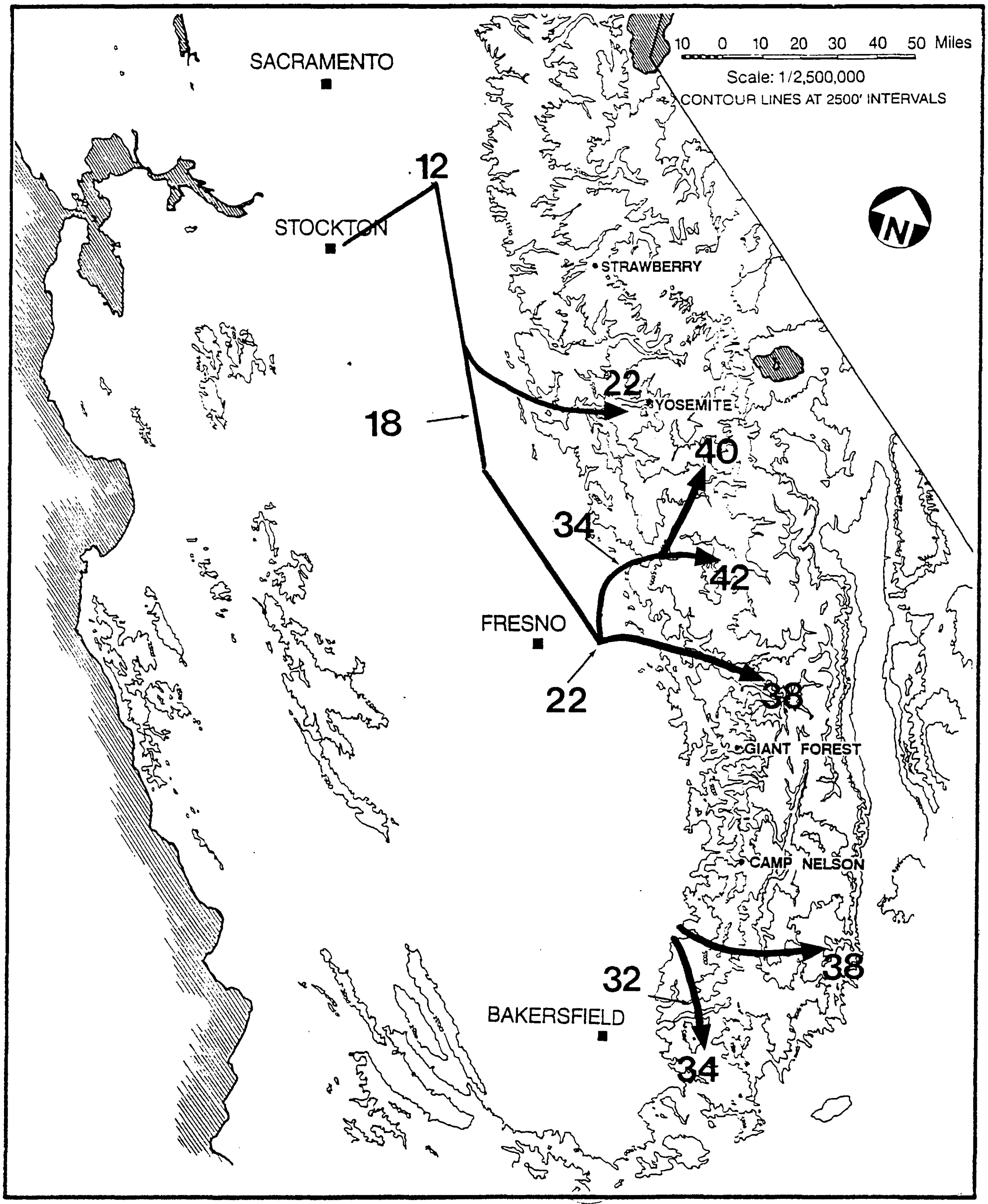


FIGURE 7-3 - ACTUAL TRAJECTORY OF STOCKTON TRACER AUGUST TEST
(Hours listed are based on clock hour of first test day)

As shown in Figure 7-3, the tracer initially flows south along the Sierra foothills until the tracer is just east of Fresno. The trajectory calculated from the surface wind data adjusted for 1000 meters is very close to the actual trajectory during this segment. The trajectory calculated from surface winds, however, underestimates the tracer's movement; while the tracer is just east of Fresno by 2200 PDT (6 hours after completion of release), the surface trajectory is only at Mariposa. Surface winds on this particular afternoon were between 3 and 6 m/s in the San Joaquin Valley.

The next morning, as the westerly winds begin to establish, the tracer is forced eastward into the Sierra. The tracer data suggests that three different entry ways accommodate transport into the Sierra regions. This includes the King's Canyon just east of Fresno where the tracer cloud eventually impacts sites at Giant Forest and Cedar Grove. Part of the tracer plume enters the San Joaquin River Valley, just northeast of Fresno where it is eventually found at Dinkey Creek and Mammoth Pool Reservoir. Transport occurs in the Merced River Valley where tracer is found at the Yosemite site. The calculated trajectories do not account for the flow into the different canyons. The calculated surface trajectory heads east from a point directly north of the San Joaquin River Canyon while the calculated elevated tracer heads directly east through King's Canyon.

The interesting event to note from this test is that tracer found just east of Bakersfield from 0600 PDT onwards on August 13. It is clear from the preceding charts that the tracer was not present at sites along the foothills prior to 0600 PDT, thus proving that the tracer was not present at surface levels when transported from east of Fresno to sites east of Bakersfield. The tracer plume most likely migrated to these southern portions by way of wind currents aloft. The tracer was found at Road's End, Tehachapi, and at China Lake, east of the Sierra which further implies that the tracer was transported aloft. The calculated trajectories, based upon surface wind observations do not account for this transport scenario.

7.2.2 Fresno Release, August 12.

The Fresno tracer, PDCH, was released from 1000 until 1400 PDT on August 12, 1991. Figures 7-4 through 7-6 display the different trajectories for the August test. Figure 7-4 illustrates the trajectory calculated from surface level winds. Figure 7-5 depicts the trajectory calculated from surface winds adjusted to a 1000 meters using Hellman's equation. The integral path of the tracer cloud is depicted in Figure 7-6.

The tracer plume initially travels north before it moves south towards Bakersfield along the foothills. By 2000 PDT (6 hours after the release), the tracer cloud is spread from Fresno to Delano in the South, with the plume centered at Terra Bella. As the plume travelled southward, a portion of the plume appeared to peel off and enter King's canyon as evidenced by concentrations measured at Cedar Grove and Giant Forest at 2000 to 0200 PDT. As the evening progresses, a portion of the plume travels southward until 2400 PDT when concentrations are measured at Ash Mountain, east of Bakersfield

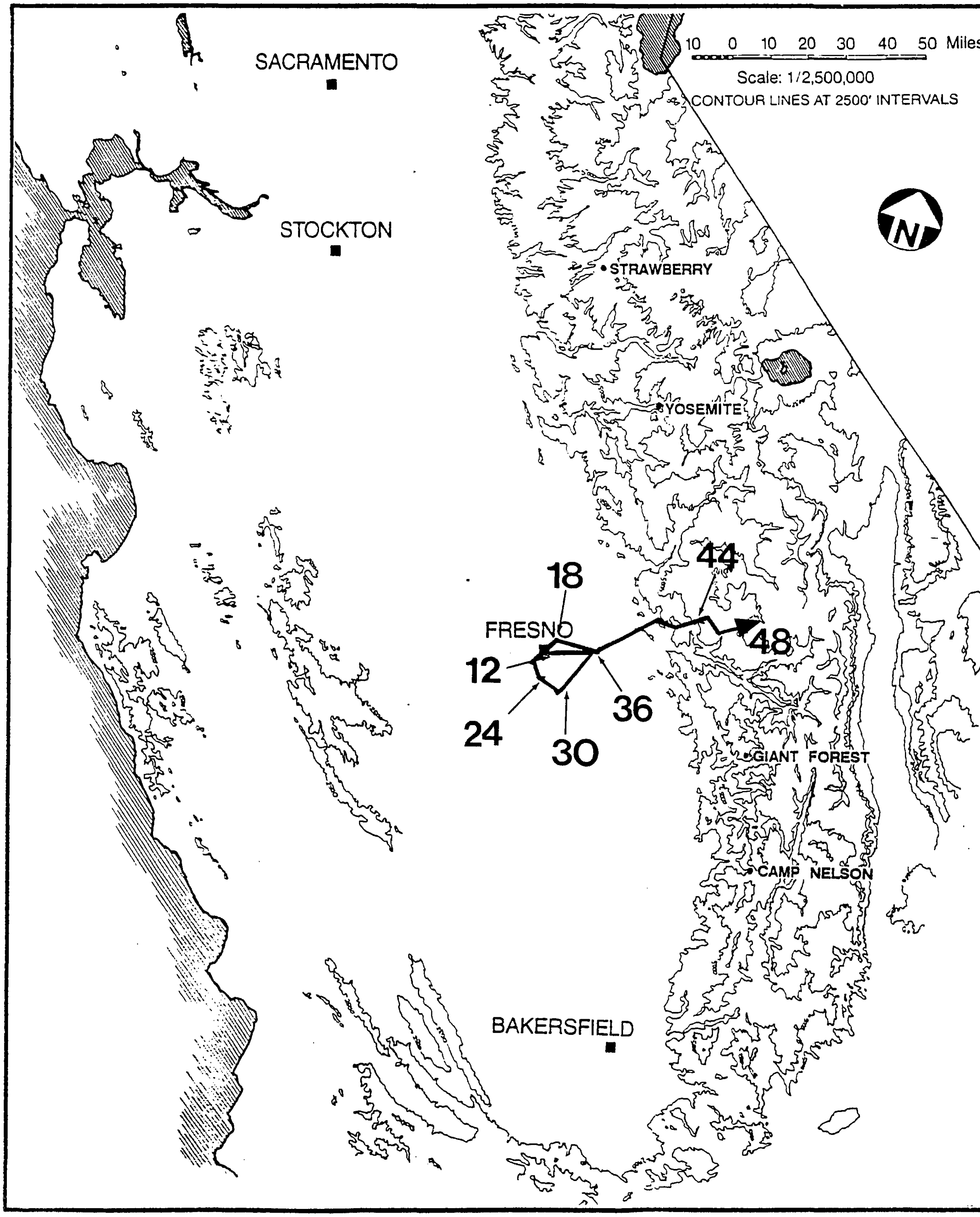


FIGURE 7-4 - CALCULATED GROUND LEVEL TRAJECTORY OF FRESNO TRACER - AUGUST TEST
(Hours listed are based on clock hour of first test day)

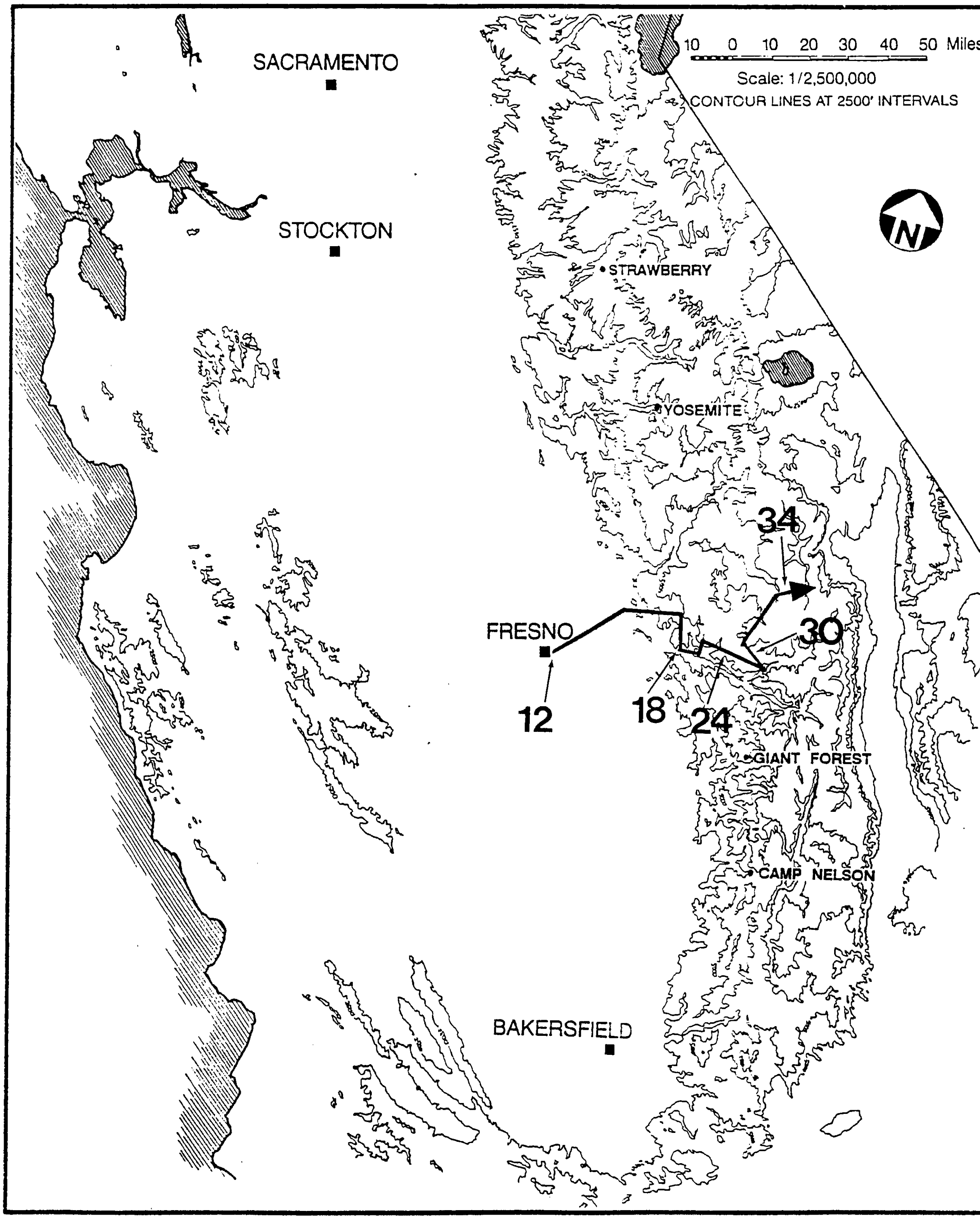


FIGURE 7-5 - CALCULATED ELEVATED TRAJECTORY OF FRESNO TRACER - AUGUST TEST
(Hours listed are based on clock hour of first test day)

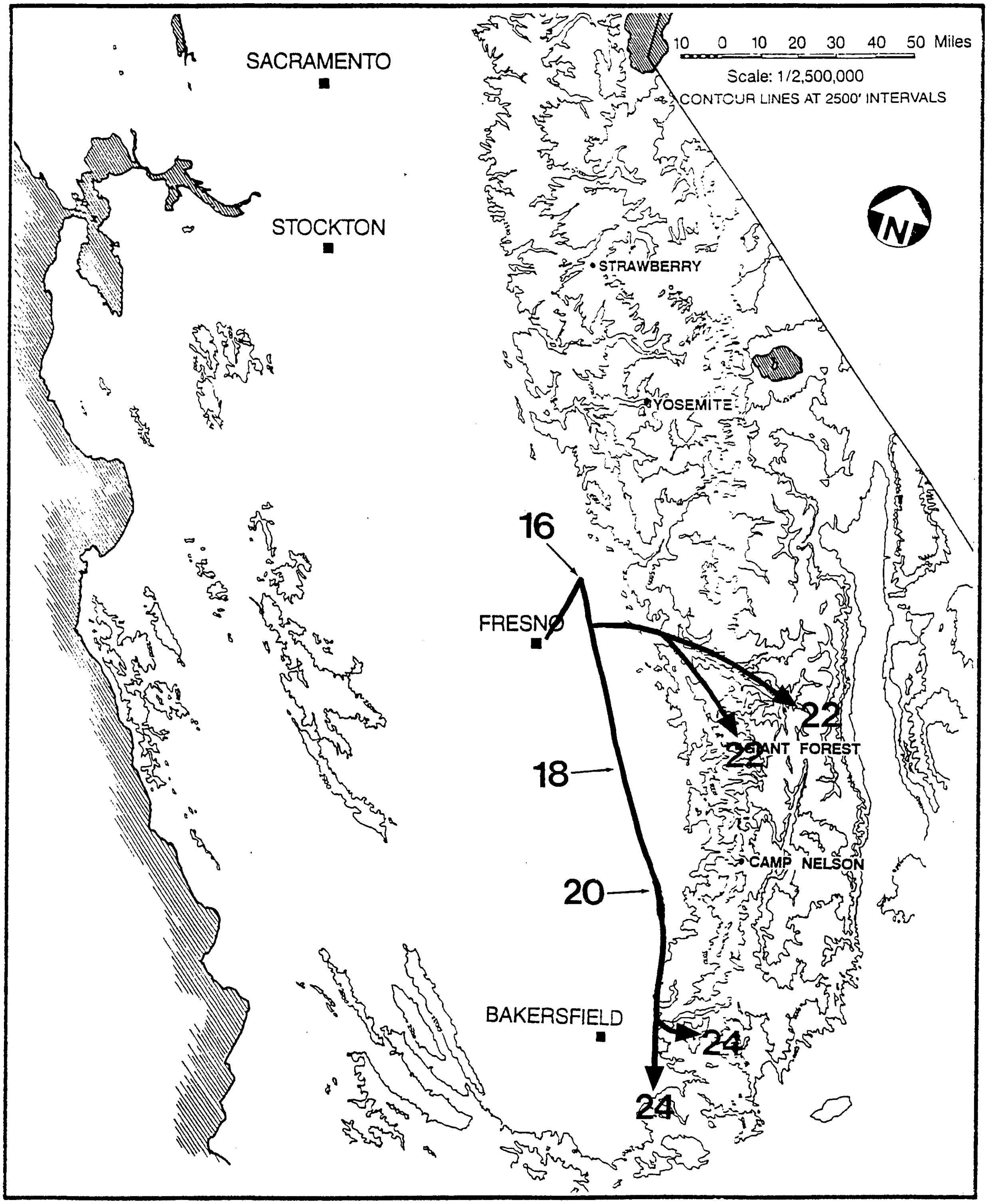


FIGURE 7-6 - ACTUAL TRAJECTORY OF FRESNO TRACER AUGUST TEST
(Hours listed are based on clock hour of first test day)

and Lebec in the Tejon Pass. During the next eight hour segment, the plume settled east of Bakersfield with limited impact in the Sierra. During this period, the concentrations decreased at each site suggesting decrease in the mass of the plume. It is believed that the plume mass is lost through vertical venting into the upper atmosphere. This is supported by the observance of a small convergence zone in the vicinity of the plume position at this time.

The calculated trajectories from wind data do not resemble the actual tracer cloud movement. Initially, the elevated trajectory starts slightly south of Fresno before it heads east into the foothills. Stagnation occurs during the night. During the next day, the calculated trajectory is directly east into the Sierra whereby the actual plume movement is more southerly.

7.2.3 Bakersfield Release, August 12

The Bakersfield tracer, PTCH, was released from 1900 until 2330 PDT on August 12, 1991. Figures 7-7 through 7-9 display the different Bakersfield trajectories for the August test. Figure 7-9 presents the trajectory calculated from surface level winds and Figure 7-8 depicts the trajectory calculated from surface winds adjusted to 1000 meters using Hellman's equation. The actual path of the tracer plume is illustrated in Figure 7-9.

The Bakersfield tracer plume initially traveled east and southeast as is demonstrated by concentrations at Democrat Station and Tehachapi. The plume stays at these two sites for the rest of the evening while positioned in stagnant wind conditions. By the early daylight hours the plume had penetrated into the Lake Isabella region. From this point the plume migrated north with impacts reaching Ash Mountain by noon. During the afternoon hours, the plume dissipated and by 1600 the plume had completely dispersed from the sampling grid.

The calculated elevated trajectory depicts the tracer initially going east into the Sierra foothills until 0400 PDT before eventually heading north until 1000 PDT. The trajectory then heads east until 1400 PDT. The final leg moves southeast.

The calculated ground trajectory shows the tracer stagnating to the southwest of Bakersfield until the morning of August 13 when the parcel starts moving east towards Democrat Station. At approximately hour 1400, the trajectory heads southeast for the remainder of the test.

7.3 October Test, October 24-27

The objective of the October test was to document the breakdown of an ozone episode in the San Joaquin Valley following a severe stagnation period. There was no

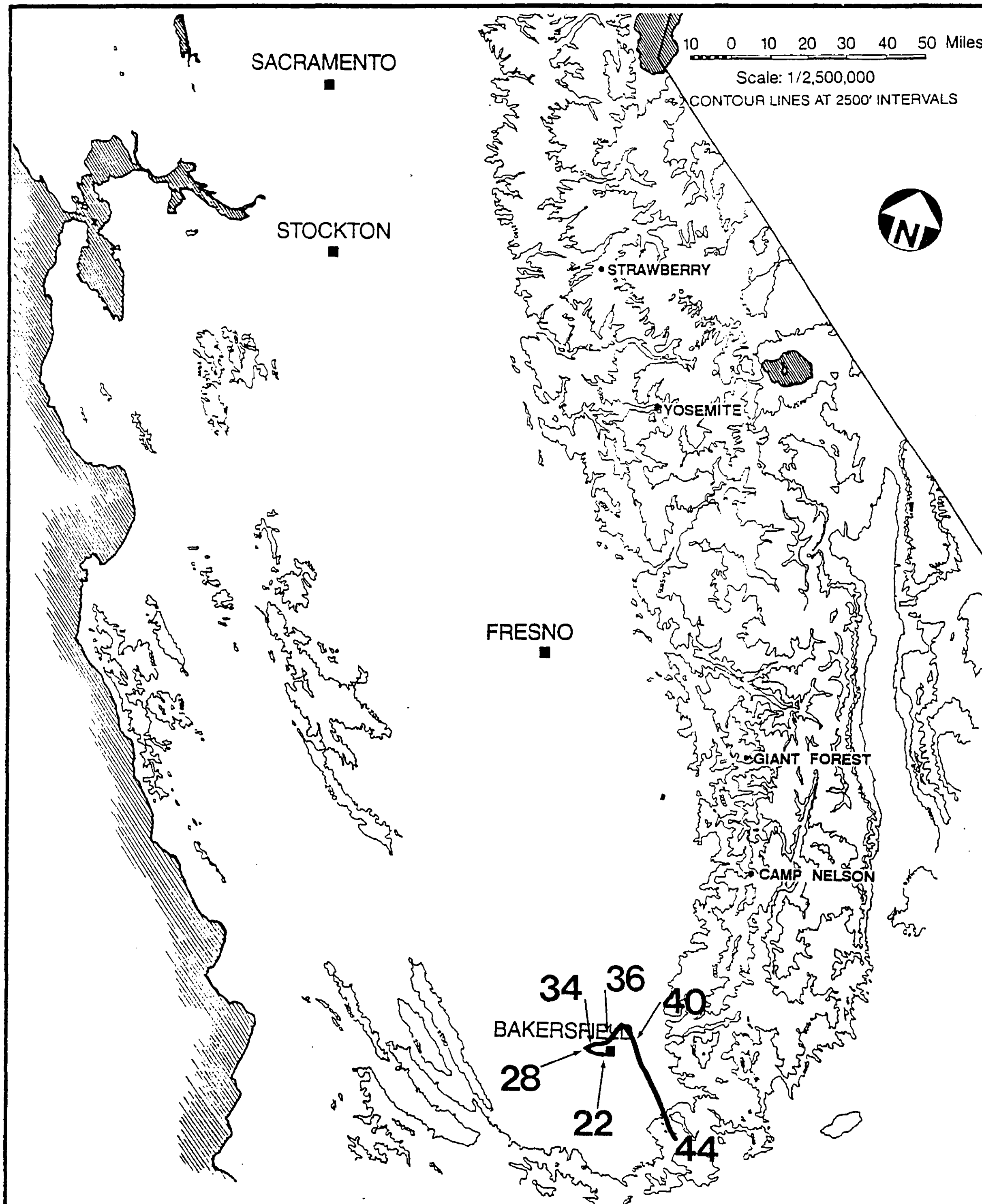


FIGURE 7-7 - CALCULATED GROUND LEVEL TRAJECTORY OF BAKERSFIELD TRACER - AUGUST TEST
(Hours listed are based on clock hour of first test day)

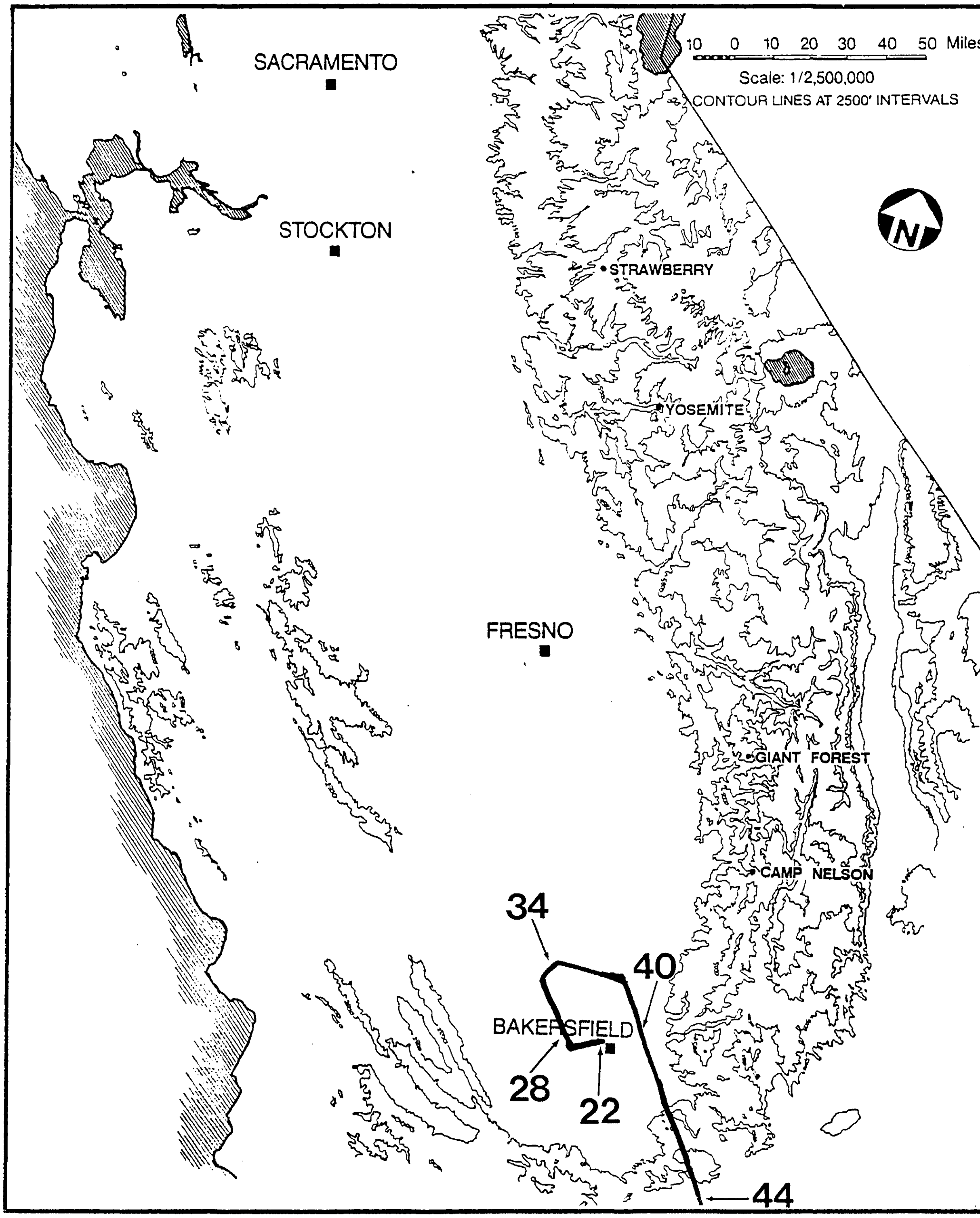


FIGURE 7-8 - CALCULATED ELEVATED TRAJECTORY OF BAKERSFIELD TRACER - AUGUST TEST
(Hours listed are based on clock hour of first test day)

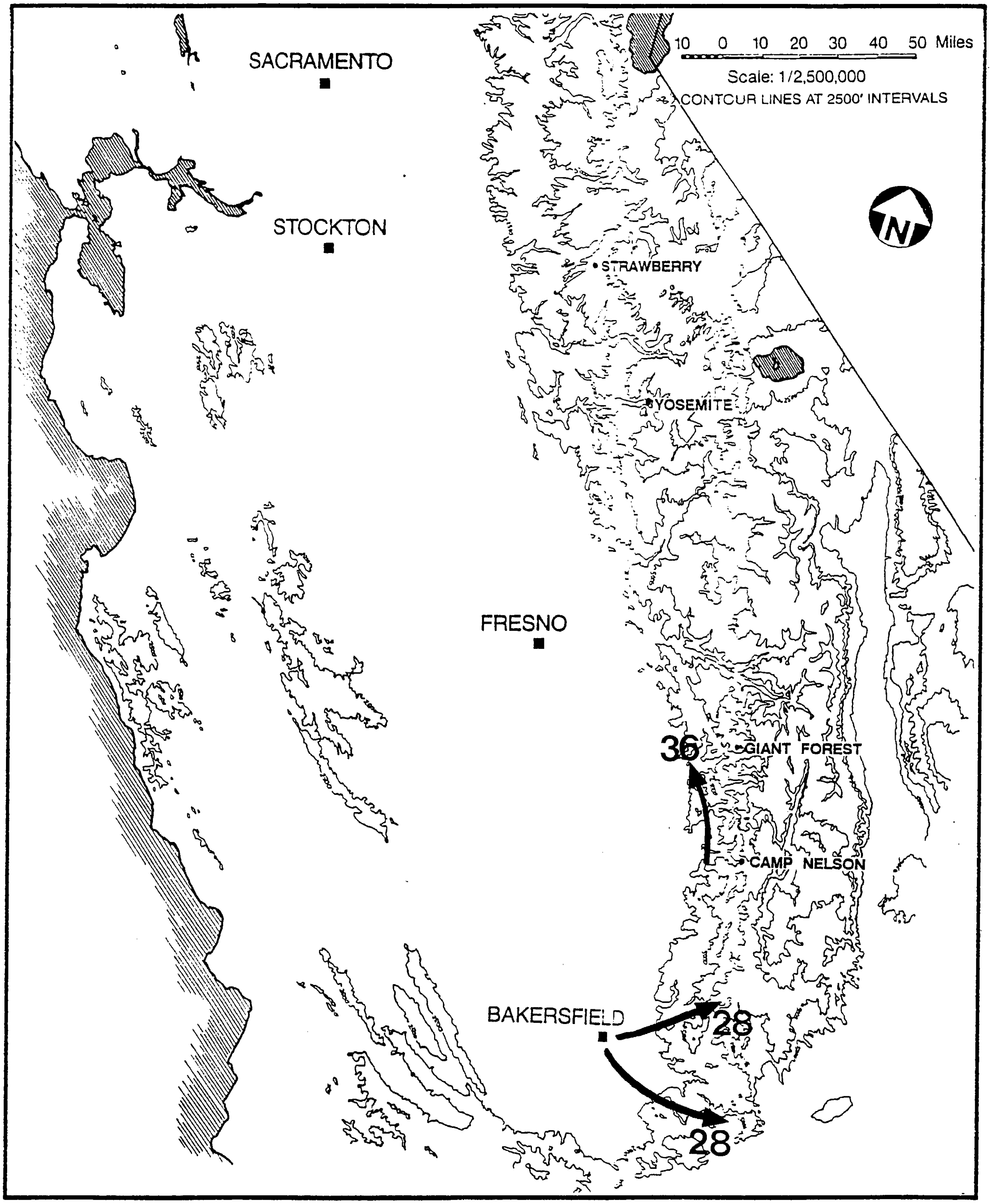


FIGURE 7-9 - ACTUAL TRAJECTORY OF BAKERSFIELD TRACER AUGUST TEST
(Hours listed are based on clock hour of first test day)

breakdown and the stagnation remained for the duration of the test. By a strange twist of fate, there was a bug in the sampler software which prevented the samplers from starting at their appointed time on October 24. This forced the samplers to be started at a later time and enabled the sampling to capture a "worst case" stagnation episode. By the end of the week there was some transport into the Sierras, and fortunately, the sampler malfunction allowed us to document this transport. A listing of the sampler start times for the October test is presented in Table 3-3.

7.3.1 Fresno Release, October 24

The Fresno tracer, PDCH, was released from 1000 until 1400 PDT on October 24, 1991. Figure 7-10 through 7-12 display the different Fresno based trajectories for the October test. Figure 7-10 presents the trajectory calculated from surface level winds and Figure 7-11 presents the trajectory calculated from surface winds adjusted to 1000 meters using Hellman's equation. The actual path of the tracer cloud is illustrated in Figure 7-12 (By definition this is not a true trajectory).

Due to the stagnant conditions in this test, the tracer occupied a large portion of the San Joaquin Valley from Mariposa to Bakersfield from which it eventually flowed into the Sierra through different pathways as some westward flow was established.

During the day of release winds were very light in the San Joaquin Valley and as a result the tracer slowly dispersed into a fairly uniform cloud in the central part of the SJV. By 1400 PDT on October 25, the tracer was spread across the valley from El Nido and Mariposa in the north to Terra Bella and Delano in the south. During 1400 to 1600 PDT on October 25 (24 hours after the release was completed), the tracer plume was observed to migrate up the Kaweah River Canyon where it impacted Ash Mountain and Giant Forest for the following eight hours.

Approximately 44 hours after the release, portions of the tracer plume from the northern part of the valley flowed into the Merced River Canyon. This is evidenced by tracer measured at the Yosemite site. Approximately 48 hours after the release, tracer also moved up the San Joaquin River Canyon and was found at Auberry, Westfall Station, Dinkey Creek, and then Mammoth Pool Reservoir.

During this time, tracer laden air also appeared to flow into King's Canyon such that the plume was found for several hours at Cedar Grove. Tracer was also measured in the southern Sierra at Democrat Station and Tehachapi.

The calculated trajectory, adjusted for winds at 1000 meters, stagnates to the south of Fresno before it eventually heads west and then south towards the west of Bakersfield. The calculated surface wind trajectory stagnates to the south of Fresno for the entire test. Neither trajectory displayed movement into the Sierra.

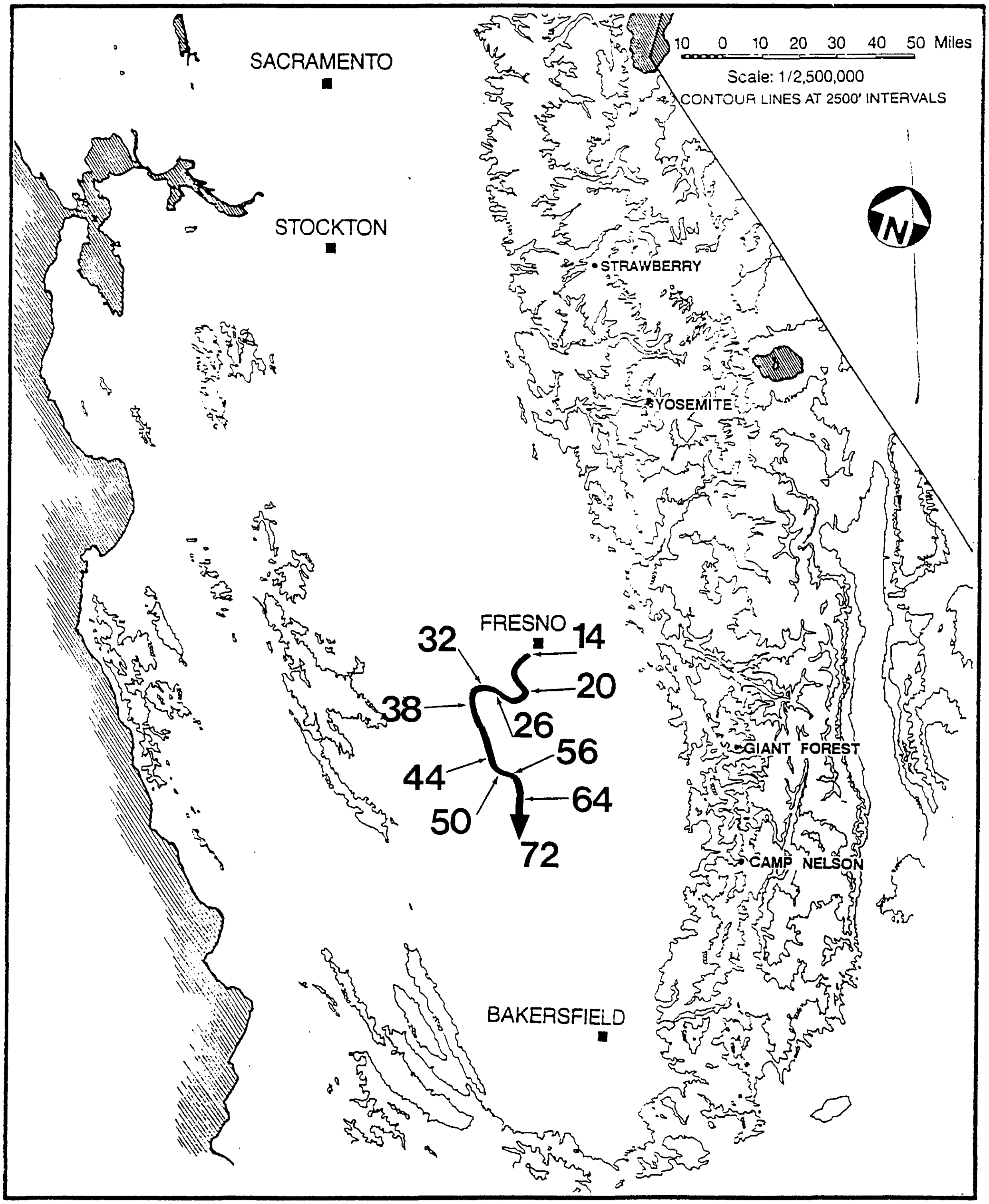


FIGURE 7-10 - CALCULATED GROUND LEVEL TRAJECTORY OF FRESNO TRACER - OCTOBER TEST
(Hours listed are based on clock hour of first test day)

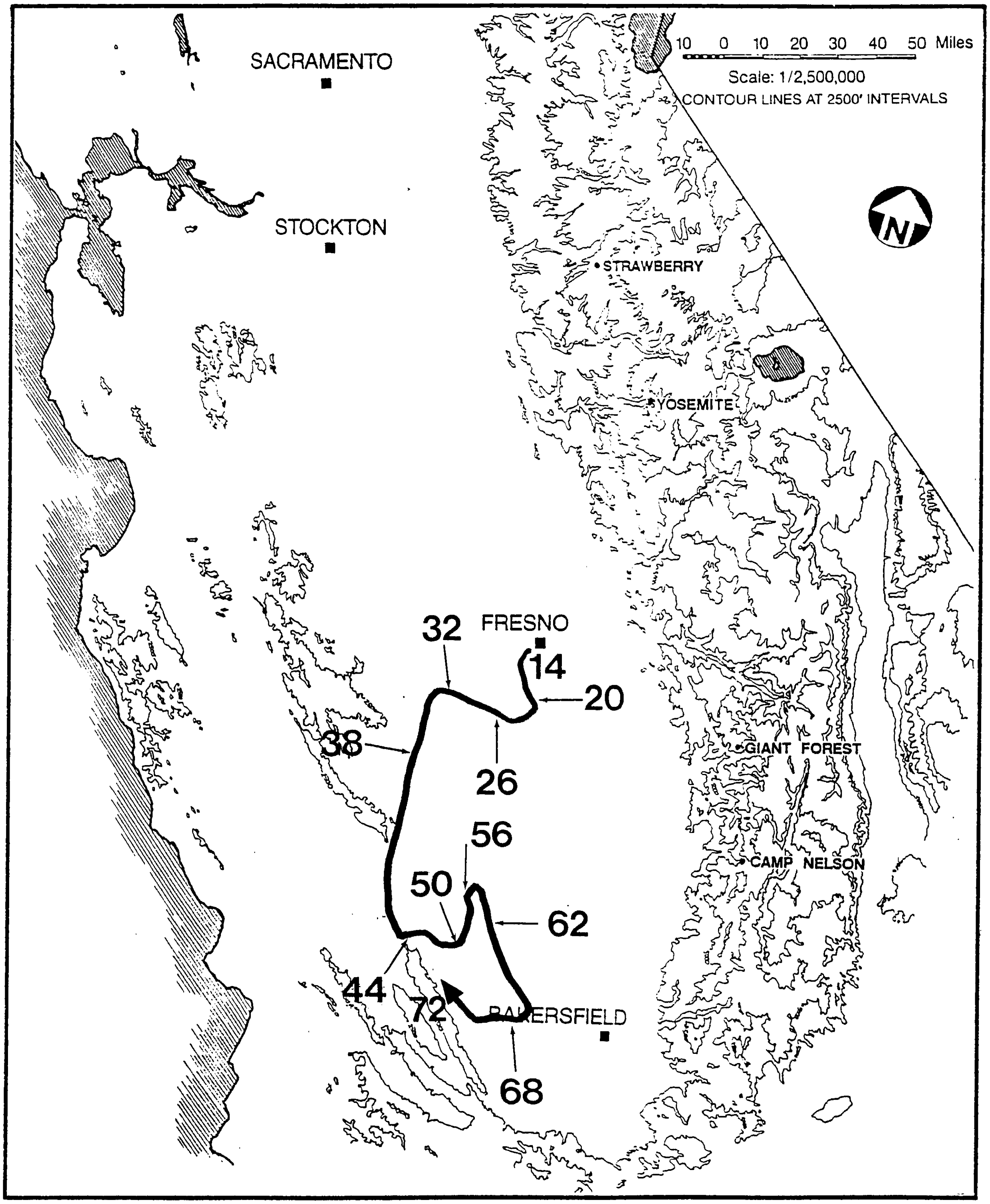


FIGURE 7-11 - CALCULATED ELEVATED TRAJECTORY OF FRESNO TRACER - OCTOBER TEST
(Hours listed are based on clock hour of first test day)

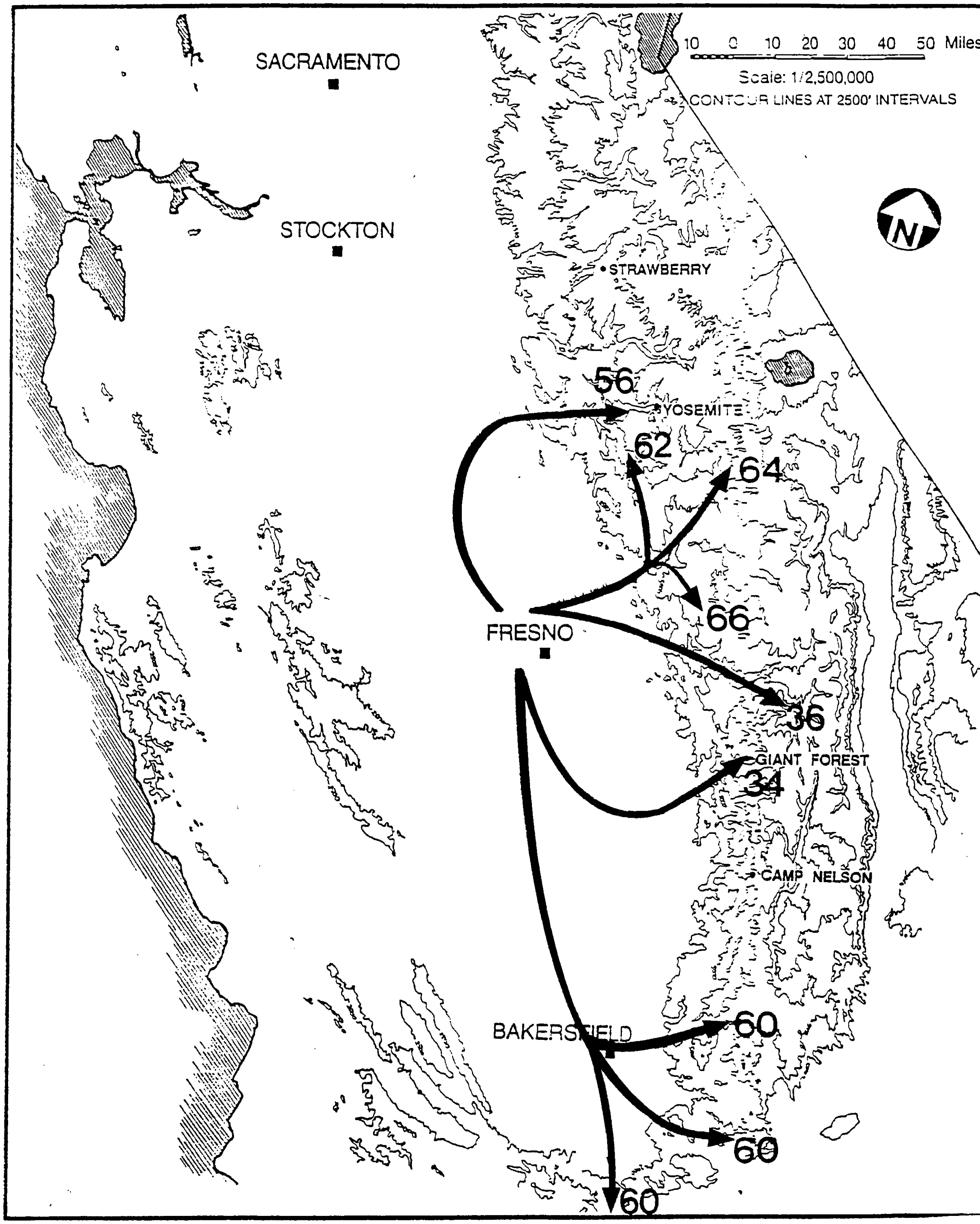


FIGURE 7-12 - ACTUAL TRAJECTORY OF FRESNO TRACER - OCTOBER TEST
(Hours listed are based on clock hour of first test day)

Due to the extreme length of time from when the initial tracer material was released and eventually impacted the Sierra, a particle trajectory analysis is inappropriate for this test. This is particularly the case since the wind conditions were extremely light within the SJV which contributed heavily to trajectory uncertainty.

Tracer impacts from the Stockton and Bakersfield releases showed very little correlation with trajectories constructed from surface wind measurements (adjusted and unadjusted). For this reason, these comparisons are not presented.

8.0 CORRELATIVE STUDIES

An important objective of this study is to correlate the movement of the tracer with actual pollutant impacts in selected Sierra regions. In this section, four different analyses are performed: 1) Determine whether a relationship exists between the tracer data and ozone impacts in Sierra regions, 2) Determine the different source contributions to the various Sierra regions based upon the tracer findings, 3) Determine whether the tracer released was accounted for and thus estimate how much tracer was lost due to several possible sink processes, and 4) determine how representative the test days were of typical summer conditions. In section 8.1, the tracer data is compared to ozone data at five separate Sierra sites. In section 8.2, tracer dilution rates were calculated to indicate the relative contributions of each of the urban centers to pollutant impacts in the different Sierra regions. In section 8.3, a mass balance was performed to show what proportion of the mass released was measured in the sampling analysis network. In section 8.4, an analysis of Fresno ozone concentrations is performed to determine the amount of days during the July-October time period that were similar to the test days.

8.1 Comparison of Ozone and Tracer Impacts at Selected Sites

It is apparent from the tracer data that transport occurred from the three source areas in the San Joaquin Valley into the Sierra region. However, it is not clear what relationship exists between tracer impacts and pollutant impacts in the Sierra. To clarify this relationship, an attempt was made to correlate ozone values with tracer concentrations measured at Sierra sites. We recognize that the occurrence of ozone, as a reactive pollutant, does not necessarily have to coincide with tracer impacts, a non-reactive chemical. However, some correlations do exist, particularly when sampling is performed at a site which resided at the boundary of two air mass regions (i.e. above or below the inversion layer). Looking for the occurrence of tracer impacts associated with advected ozone concentrations, particularly during off-peak hours, can lend insight to understanding transport issues affecting air quality in the Sierra. Ozone data were obtained from the San Joaquin Valley Air Quality Study and National Park Service network database at five stations close to or collocated with tracer sample sites. These sites are Yosemite (El Portal), Wawona (Westfall Station), Ash Mountain, Giant Forest, and Grant Grove (Cedar Grove). Of these sites only Ash Mountain and Giant Forest were collocated ozone/tracer sites; all other ozone sites were located within 15 miles of tracer sample sites.

A limiting factor in this analysis was the necessity to examine sites where the tracer plume impacted the sites for several hours in a row. The October test proved to be an excellent test for this comparison. Due to the stagnant meteorological conditions, the

Fresno released tracer spread throughout the valley and then eventually moved into the Sierra. Five Sierra sites had sequences of Fresno tracer long enough to provide a reasonable comparison. In contrast, only one station was used for this comparison from the August test.

Six time-series concentration plots of ozone and Fresno tracer are provided for different Sierra locations in Figures 8-1 through 8-6. The tracer and ozone are scaled on the y axis in units of femtoliters/liter for the tracer, and part per billion for the ozone. There is no expectation that the curves should be identical. However, if the ozone is being transported from the valley which contains tracer and ozone or precursors, then the shape of the curves should be similar (i.e. time of peak arrivals may agree).

Figure 8-1 is a plot of tracer and ozone concentrations at Ash Mountain for the October test. The ozone concentrations behave as expected in this sequence, increasing during the daylight hours and decreasing during the nocturnal hours. The excellent correlation suggest that the air is well mixed with tracer and pollutant precursors from Fresno. As diurnal heating drives more valley air into the Sierra, more pollutants and tracer are transported in. Air quality impacts are largely transport dependent at this site. Further examination reveals that the data at Giant Forest (Figure 8-2), located just east of Ash Mountain in the Kaweah River Valley, exhibits the same trend except that the Giant Forest data lags approximately 2 hours behind the Ash Mountain data. For example, ozone and tracer peaks occur at 1600 PDT on the 25th and 1400 PDT on the 26th at Ash Mountain while the tracer peaks at Giant Forest occur at 1800 and 1600 PDT.

The most likely transport occurring in this scenario is that during daytime hours, westerly winds force valley air up the Kaweah River Valley into Giant Forest thus accounting for the lag in peak concentrations at Giant Forest. However, in the evening hours a reversal occurs during which drainage winds from the higher elevation Giant Forest site flow back through the Kaweah River valley into the San Joaquin Valley. This is supported by the data which show a quicker decrease in ozone concentrations at Giant Forest than at Ash Mountain.

Figure 8-3 is a time series plot of ozone and Fresno tracer at Cedar Grove for the October test. The correlation is not as evident at this site, but there is clearly a trend that shows the tracer concentrations to increase and decrease with ozone concentrations further suggesting a great transport dependence at this site.

Figures 8-4 and 8-5 are plots of ozone and Fresno tracer at Wawona and Yosemite for the October test. The Wawona ozone site is approximately 10 miles from Westfall station where the tracer was sampled. The Yosemite site is approximately 15 miles away from the Yosemite/El Portal site where the tracer was sampled. The Wawona site (Figure 8-4) shows a reasonable correlation between the tracer and ozone concentrations as the tracer concentrations decline with the decrease in ozone concentrations. The tracer concentrations at Yosemite (Figure 8-5) also appear to closely correlate to the ozone.

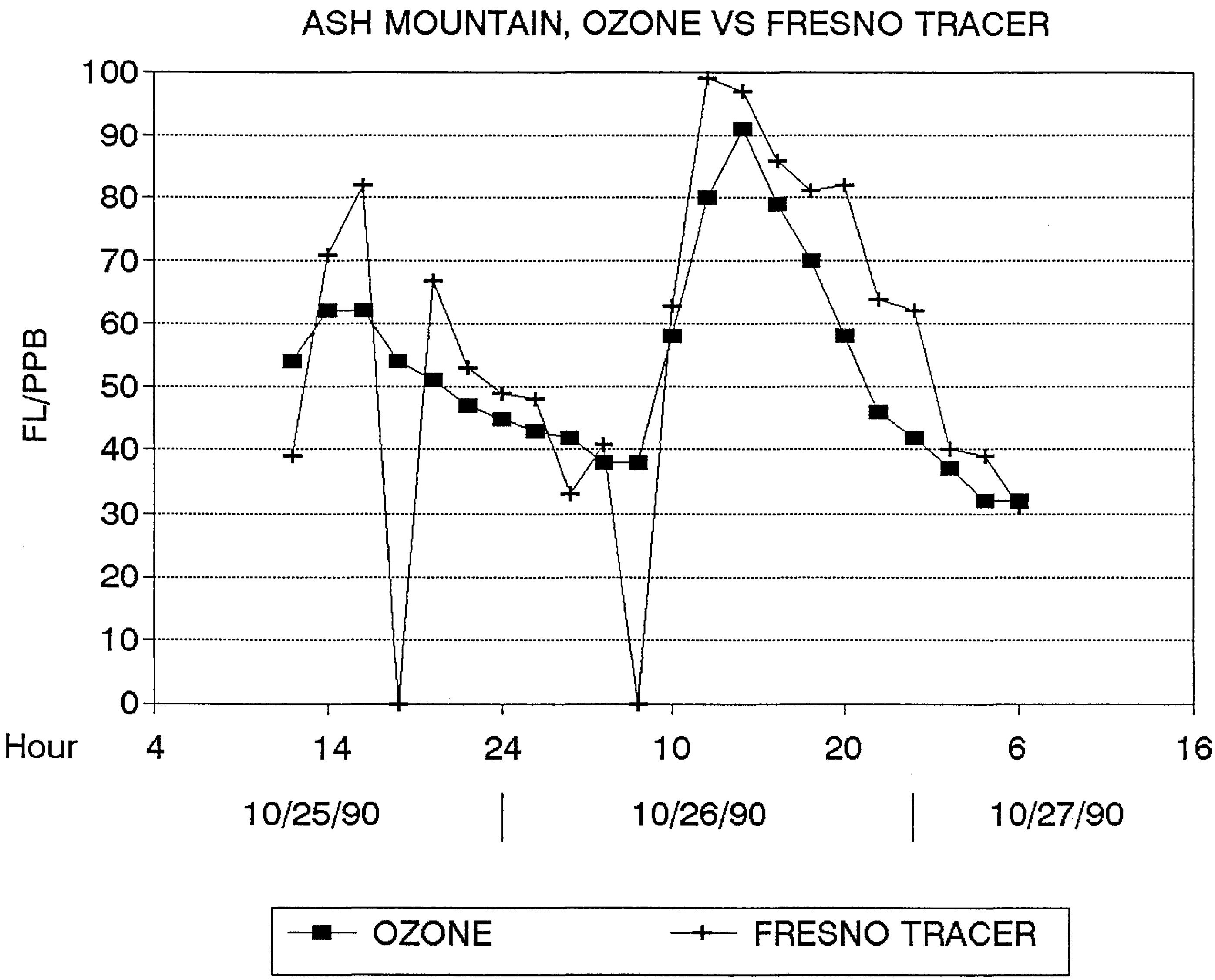


FIGURE 8-1 - Comparison of Ozone Concentrations with Fresno Tracer Concentrations - Ash Mountain: October Test

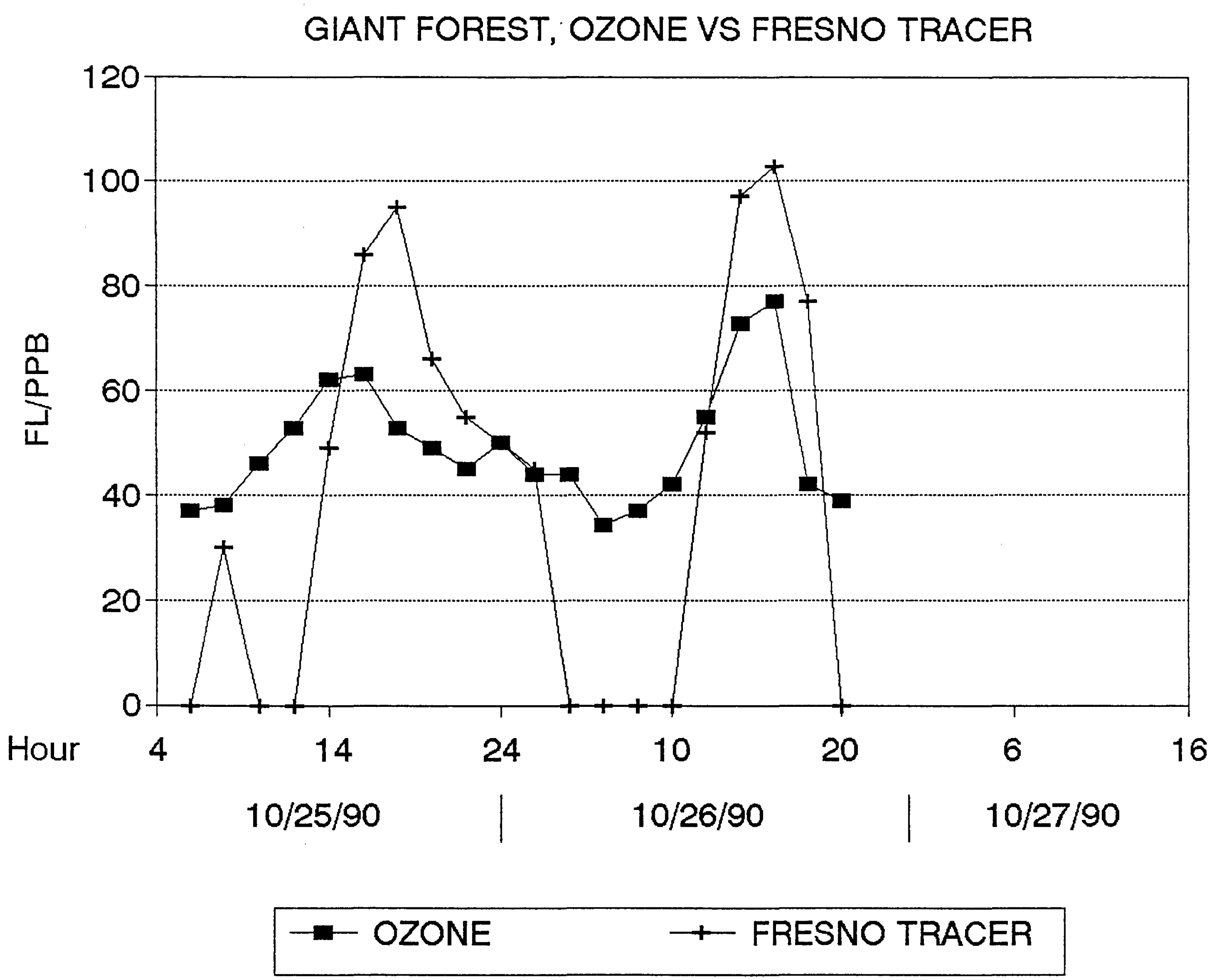


FIGURE 8-2 - Comparison of Ozone Concentrations with Fresno Tracer Concentrations - Giant Forest: October Test

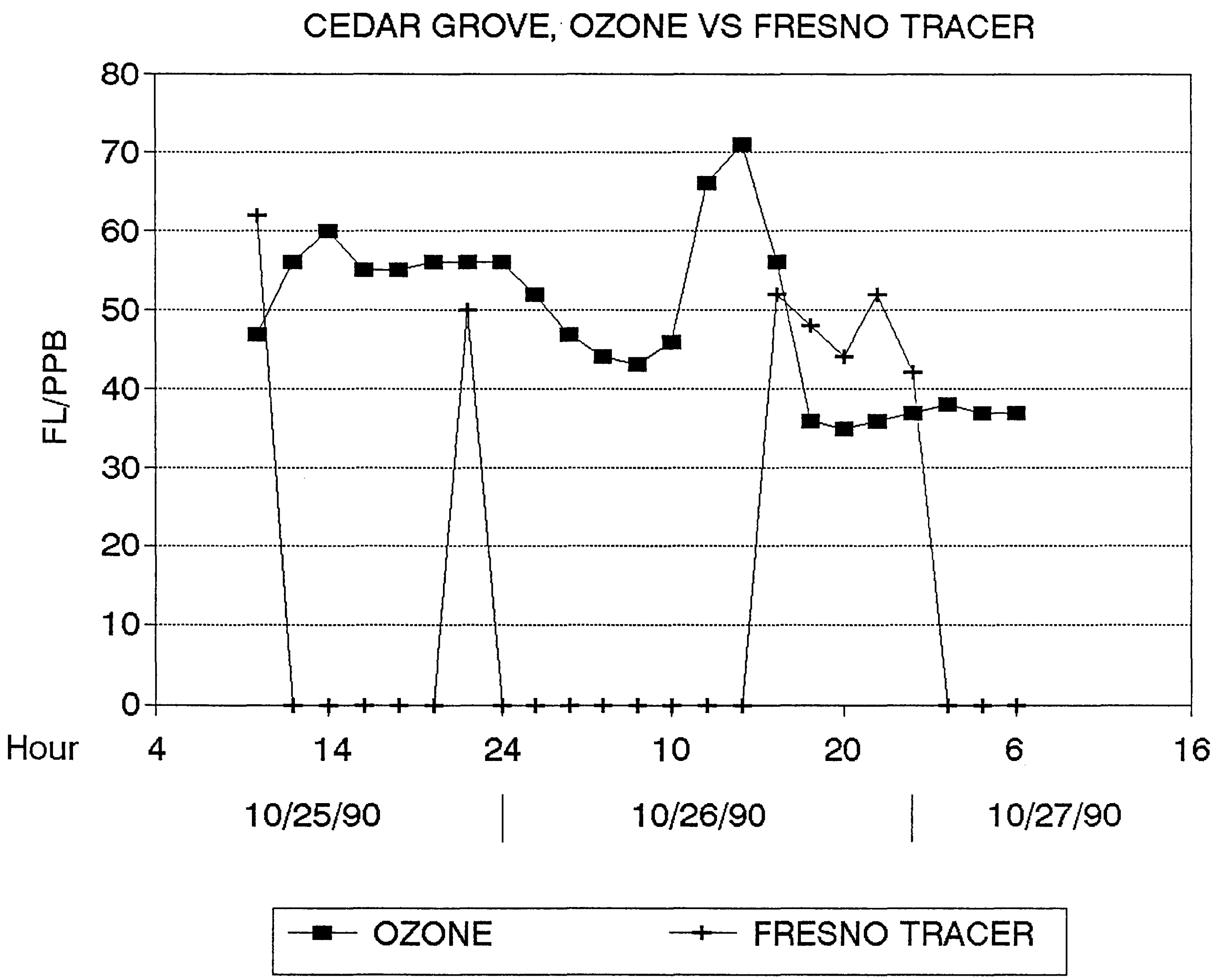


FIGURE 8-3 - Comparison of Ozone Concentrations with Fresno Tracer Concentrations - Cedar Grove: October Test

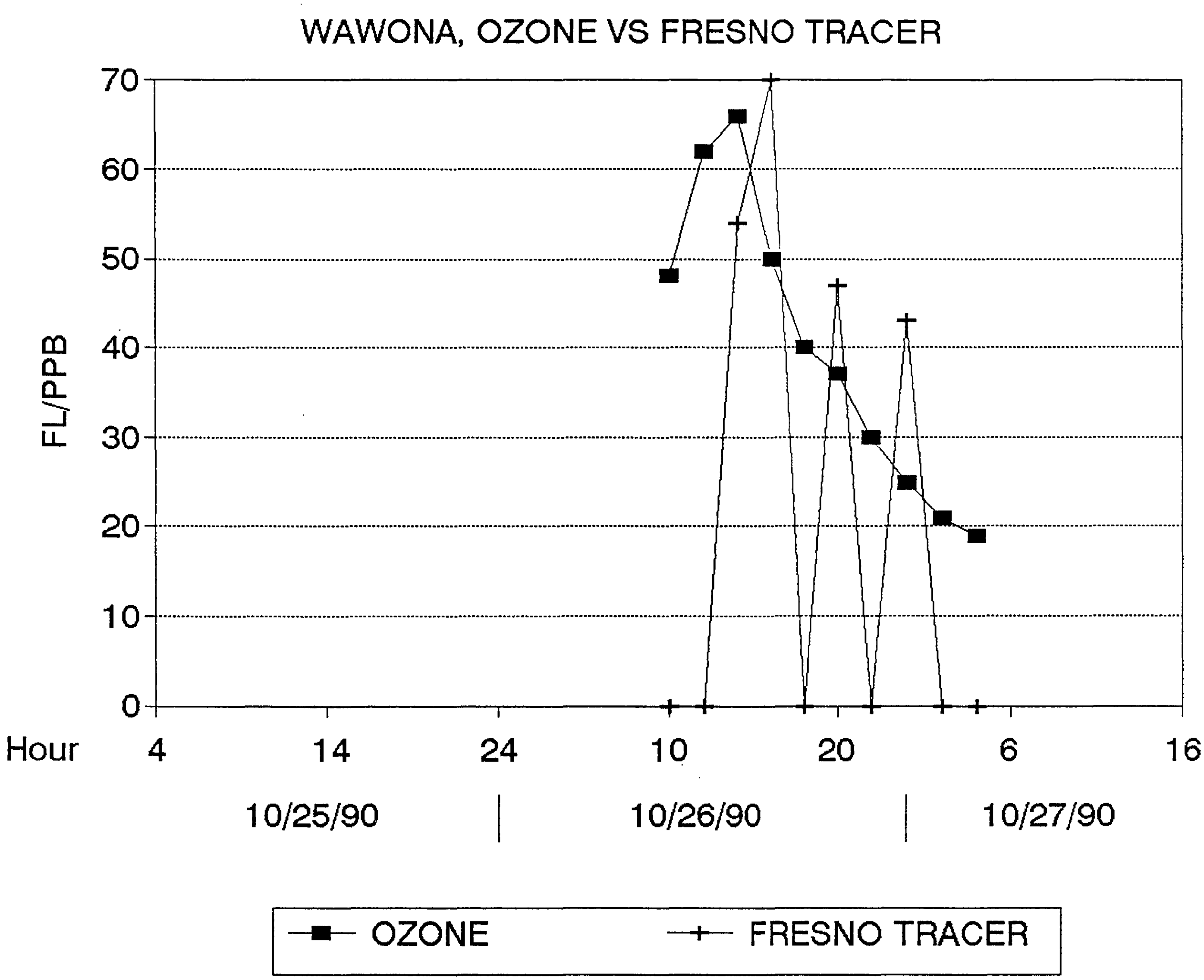


FIGURE 8-4 - Comparison of Ozone Concentrations with Fresno Tracer Concentrations - Wawona: October Test

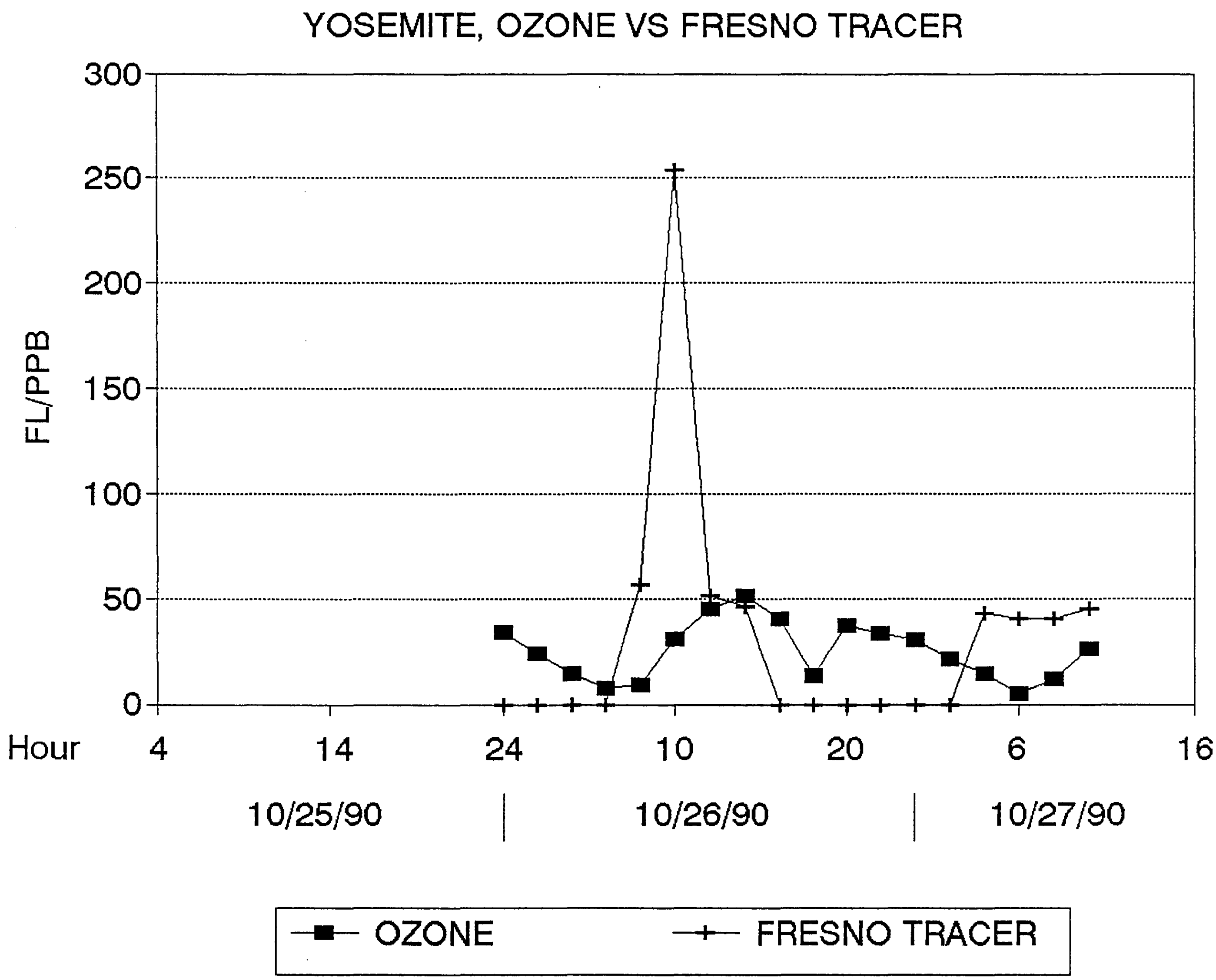


FIGURE 8-5 - Comparison of Ozone Concentrations with Fresno Tracer Concentrations - Yosemite: October Test

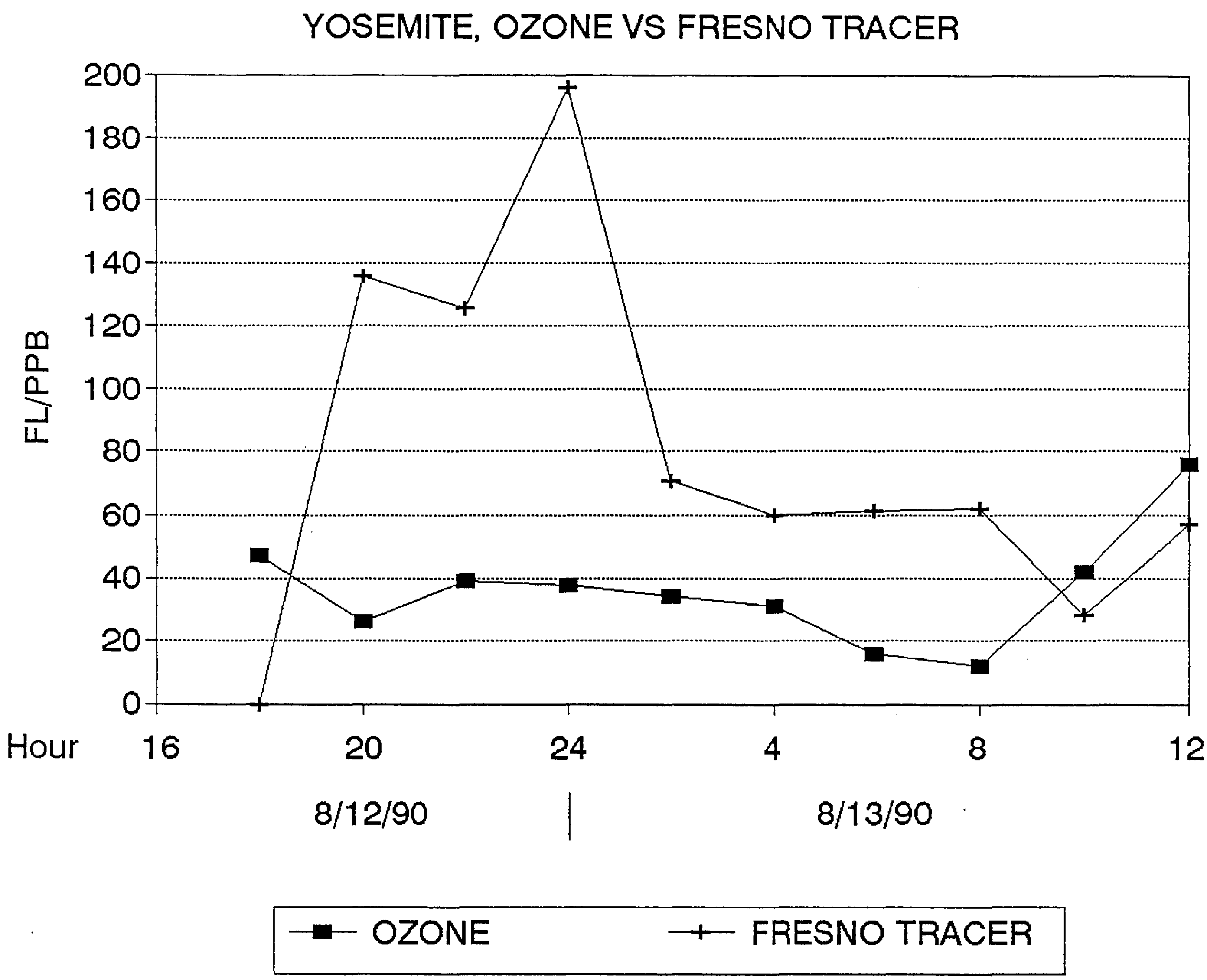


FIGURE 8-6 - Comparison of Ozone Concentrations with Fresno Tracer Concentrations - Yosemite: August Test

Upon closer examination, there is a four hour lag between the peak tracer concentration and peak ozone concentration. Since the tracer was measured at El Portal, approximately 15 miles west of Yosemite Village on the Merced River, it is likely that the four hour lag is due to the distance between the station sites. If one shifts the tracer data four hours forward, the tracer data provides an almost perfect correlation to the ozone observations measured at Yosemite Village.

Figure 8-6 is a plot of ozone and Stockton tracer concentrations at Yosemite for the August test. The correlation between ozone and tracer is negligible for this test since the tracer arrived at the site in the evening during which the maximum tracer impact was measured. The ozone, in contrast, will not reach very high levels in the evening since there is no daylight to convert the nitrogen oxides to ozone and although the ozone concentrations may be low at this time, there may be high concentrations of ozone precursors present. The tracer concentrations do show some correlation with the ozone, decreasing into the later hours of the night and increasing with the ozone during 1000-1400 PDT.

8.2 Source Apportionment

An important issue regarding pollutant transport into the Sierra Nevada is the effects the different source areas have on various regions in the Sierra Nevada. The relative contributions of the different source areas must be known to formulate an effective plan to control pollutant impacts in the Sierra. This section addresses source apportionment findings as a result of the tracer data from this study.

8.2.1 Methodology

To compare the effects of the different release points on impacts in the different Sierra regions, all concentration values measured in the Sierra were normalized to CHI/Q values. CHI/Q, in its simplest terms, is the concentration divided by the release rate to provide an inverse dilution rate from which concentrations of different tracers can be compared. CHI/Q can be calculated from the following relation:

$$\text{CHI/Q} = (\text{Ct} * \text{MW})/(\text{Rt} * 22.4)$$

where Ct = concentration of tracer in femtoliters/liter
MW = molecular weight of tracer in gms/mol
Rt = release rate of tracer in gms/sec

The units of CHI/Q are $m^3/s * 10^{-12}$. The 22.4 value is a conversion factor.

8.2.2 Results

CHI/Q values were calculated for each tracer at each Sierra site. To simplify the analysis, the maximum CHI/Qs measured at each site were plotted for each test and are presented in Figures 8-7 and 8-8. Each plot represents the maximum CHI/Q value measured at each Sierra site for a particular test. The numbers are presented in colors designating the tracer measured; red represents the Stockton tracer, green represents the Fresno tracer, and black represents the Bakersfield tracer.

Figure 8-7 is a plot of the maximum CHI/Q measured at each sierra site for the August test. As can be seen, the impacts of the different release areas are generally local in nature. For instance, the Stockton tracer impacted the northern region of the Sierra, the Fresno tracer impacted the central part of the Sierra, and the Bakersfield tracer impacted the southern region of the Sierra. In the October test (Figure 8-8), the impacts are much different. The Stockton tracer is only responsible for the largest impact at Mammoth Mountain and the Bakersfield tracer is only responsible for the largest impact at Tehachapi. All other Sierra Sites were severely impacted by the Fresno tracer. The Fresno tracer was responsible for the largest impacts at Sierra sites between Yosemite and Democrat station.

Figures 8-9 and 8-10 display the percentage of maximum impacts at each Sierra site resulting from each specific tracer for each test. As in Figures 8-7 and 8-8, the Stockton tracer is represented in red, the Fresno tracer in black, and the Bakersfield in blue. Figure 8-9 shows the percentage breakdowns for the Sierra sites for the August test. The Stockton tracer influences sites from Yosemite to Lebec, with the majority of its influence in the Sierra areas north of Fresno. The Fresno tracer impacted sites between Westfall Station (South gate of Yosemite Park) to Lebec in the south but the majority of the Fresno impacts are measured in the Sierra east of Fresno. The Bakersfield tracer impacted only two Sierra sites during this test: Ash Mountain to the north and Democrat Station to the east of Bakersfield.

Figure 8-10 shows the percentage of maximum impacts for each tracer at Sierra sites during the October test. The Stockton tracer only impacted one Sierra site at Mammoth Mountain. The Fresno tracer had the most influence, impacting Sierra sites from Yosemite to Tehachapi in the south. The Bakersfield tracer impacted Ash Mountain to the north, Democrat station to the east, and Tehachapi to the southeast. It is surprising that even at southern Sierra sites, the Fresno tracer was more predominant than the Bakersfield tracer. This was probably due to the staggered release times of tracer gases at these two locations.

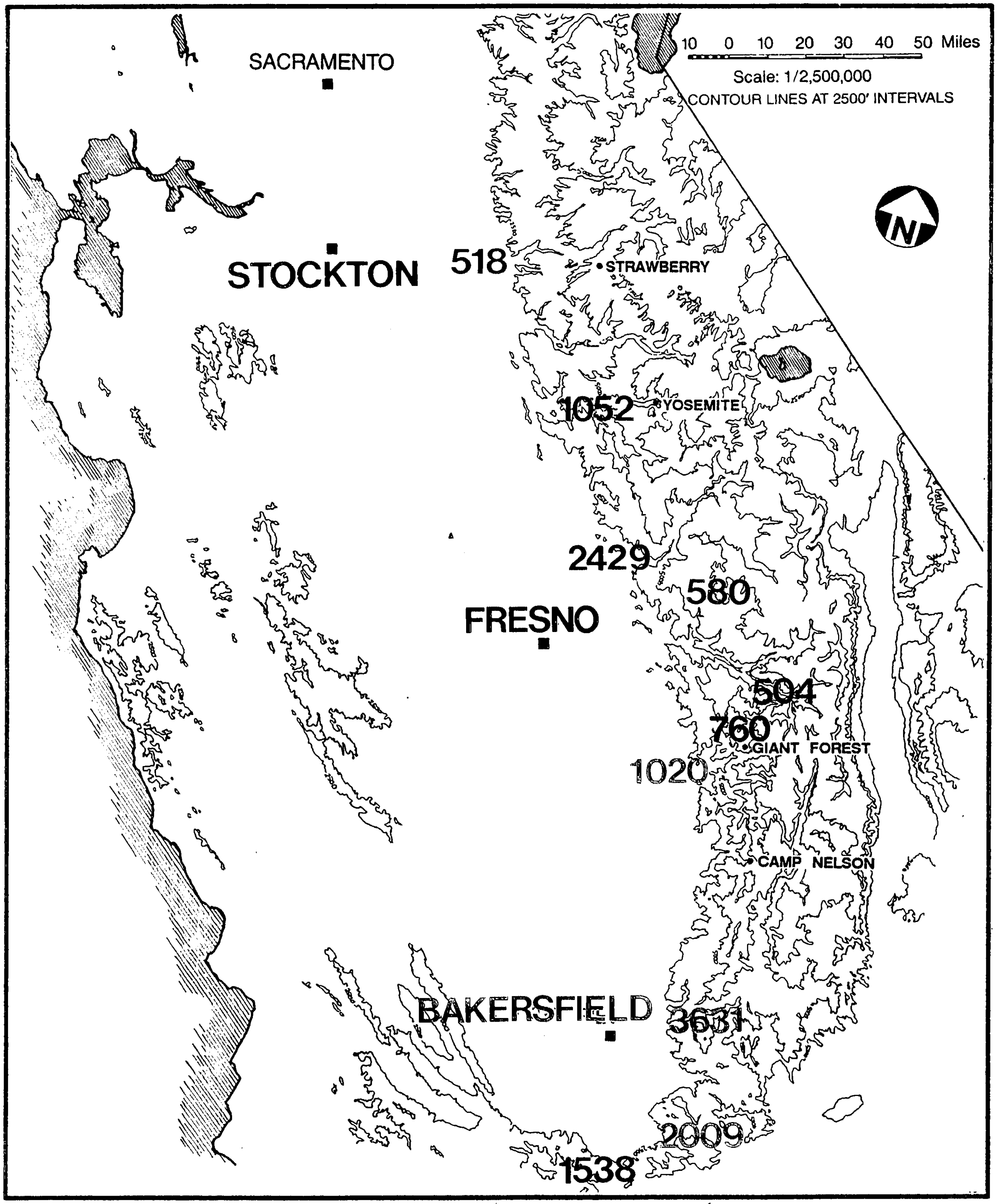


FIGURE 8-7 - MAXIMUM CHI/Q VALUES MEASURED AT EACH SITE: AUGUST TEST (CHI/Q units are s/m^3 * 10^{-12})

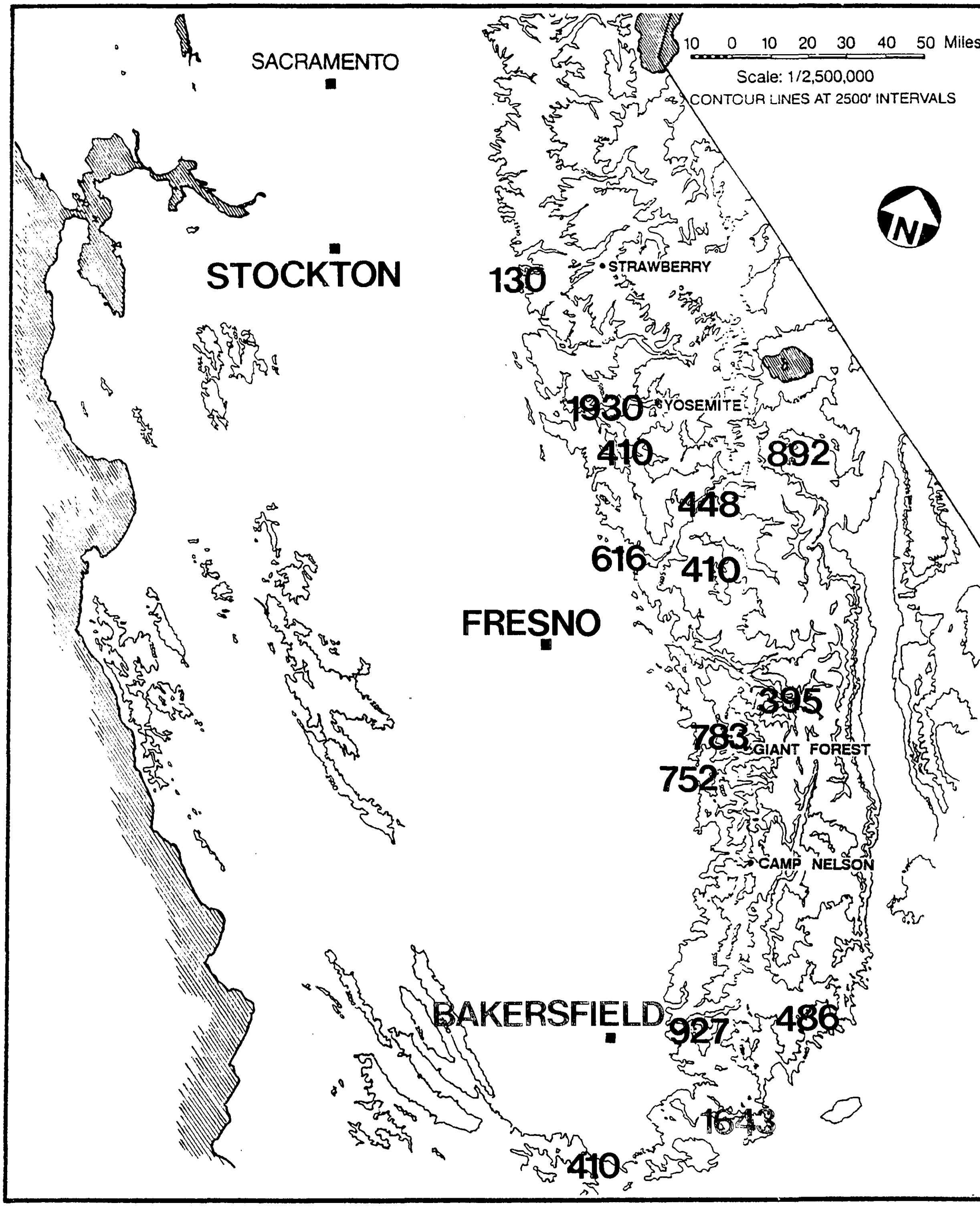


FIGURE 8-8 - MAXIMUM CHI/Q VALUES MEASURED AT EACH SITE: OCTOBER TEST (CHI/Q units are s/m^3 * 10^{-12})

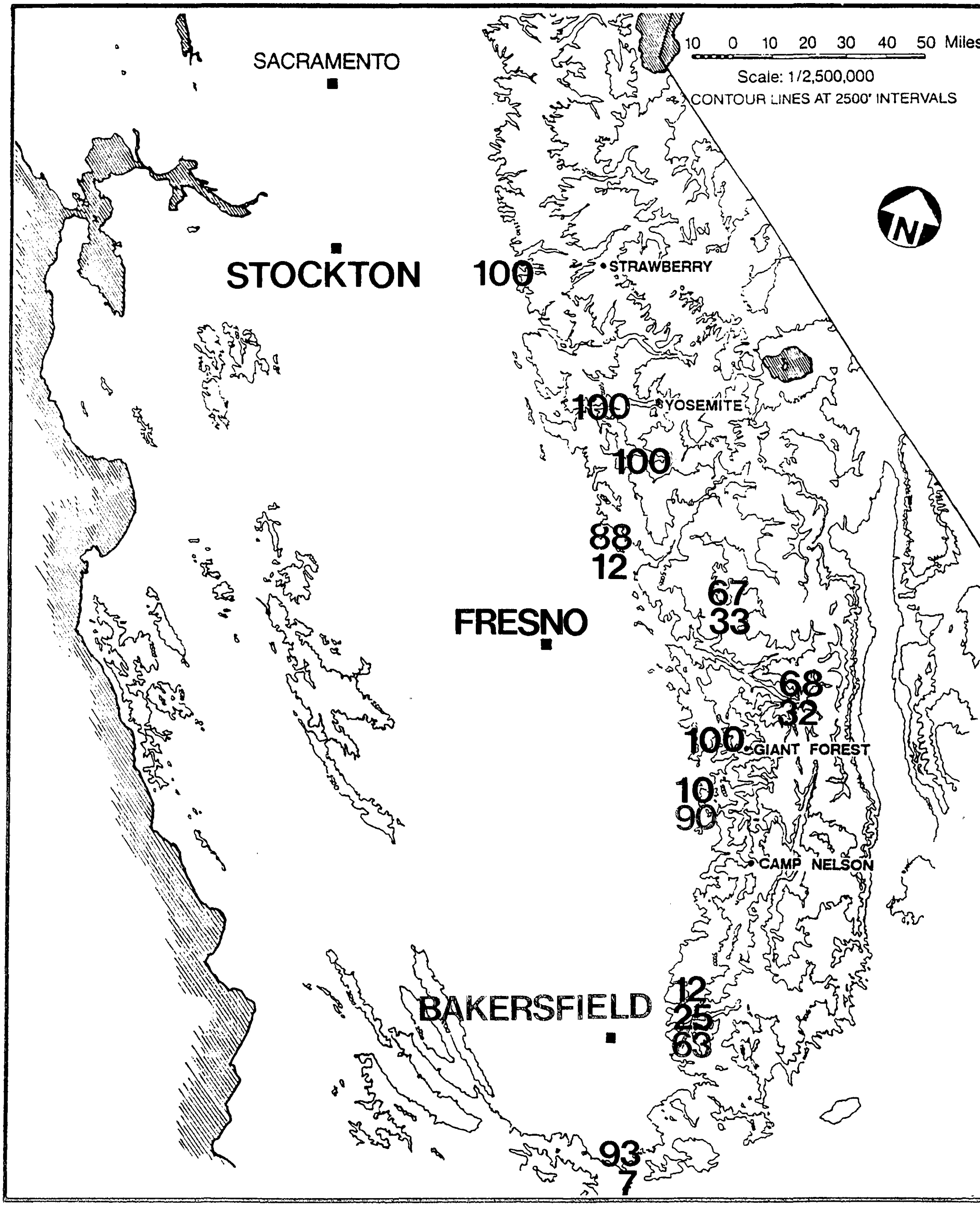


FIGURE 8-9 - PERCENT CONTRIBUTION OF EACH TRACER TO THE TOTAL MAXIMUM CHI/Q VALUES MEASURE AT EACH SITE: AUGUST TEST

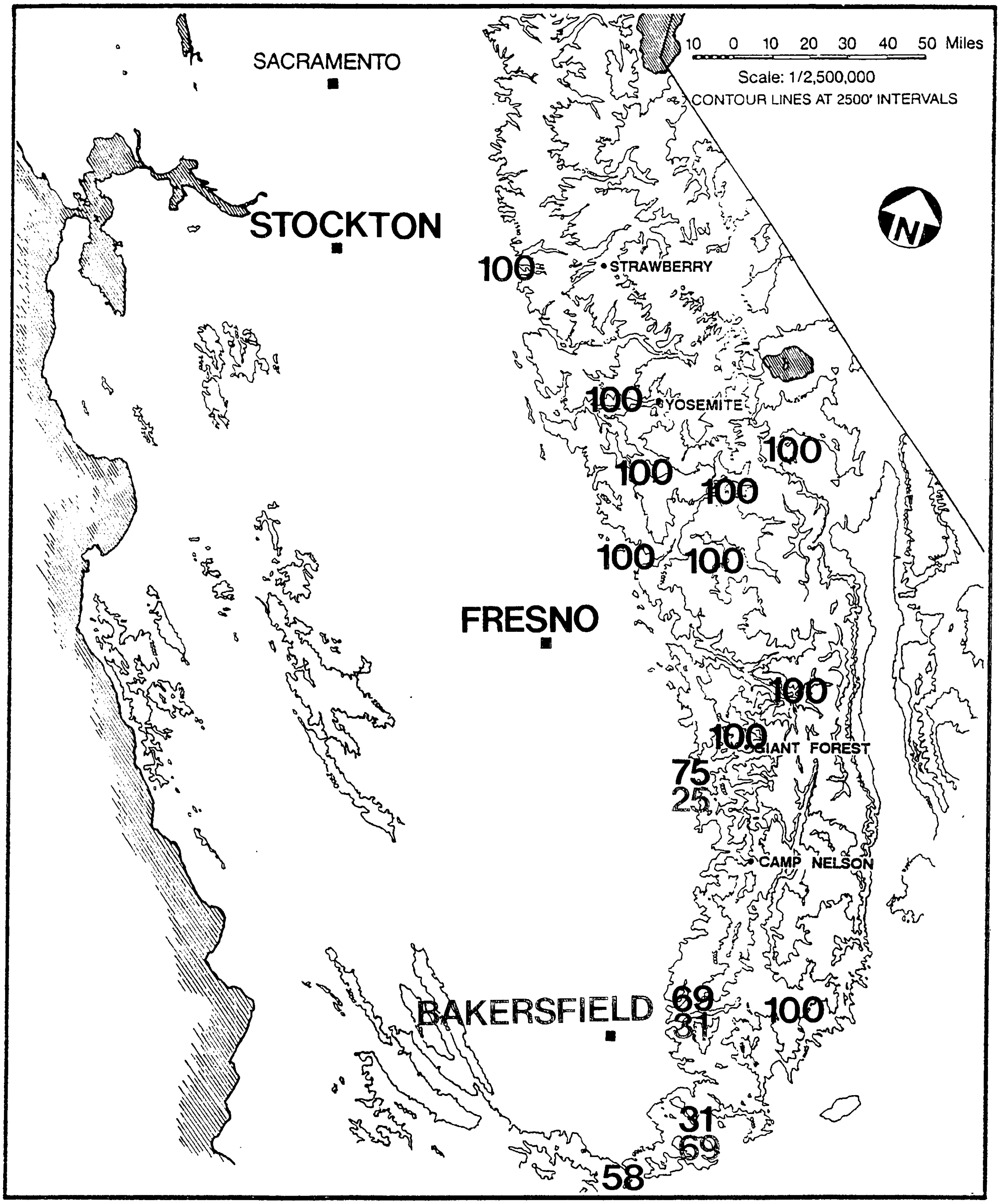


FIGURE 8-10 - PERCENT CONTRIBUTION OF EACH TRACER TO THE TOTAL MAXIMUM CHI/Q VALUES MEASURED AT EACH SITE : OCTOBER TEST

8.2.3 Comparison With SJVAQS Results

CHI/Qs were generated from the SJVAQS tracer data measured at Sierra sites (Tracer Technologies, "San Joaquin Valley Air Quality Study", 1991) to compare with the findings of this study. There are several differences that must be acknowledged when comparing the SJVAQS data to the data from this program:

1) All SJVAQS releases were point releases performed between 0600 and 1000 PDT.

2) The northern SJVAQS release location was Pittsburg, just east of the San Francisco Bay Area.

3) There were fewer Sierra sites for SJVAQS.

4) SJVAQS tracer releases were conducted in anticipation of a poor air quality episode rather than the breakdown of such an episode.

Figure 8-11 displays the maximum CHI/Q values at Sierra sites for the July 13 SJVAQS test. The Fresno tracer impacts are east of Fresno, while the Bakersfield tracer impacts are to the east and south of Bakersfield. Figure 8-12 depicts the maximum CHI/Q values at Sierra sites for the August 3 SJVAQS test. The Fresno tracer impacts are east and south of Fresno, while the Bakersfield impacts were east and southeast of Bakersfield. It is interesting to note that although the Pittsburg tracer was measured at sites throughout the SJV, there were no impacts from the Pittsburg tracer measured in the Sierra for this test.

Figure 8-13 displays the maximum CHI/Q values at Sierra sites for the July 27th SJVAQS test. The purpose of this test was to evaluate the effects of the breakdown of an ozone episode in the Bay Area and thus only Bay Area releases were performed for this test. For consistency, the impacts displayed in Figure 8-13 are from the ground release in Pittsburg. The tracer from this release impacts the Sierra east of Fresno at Cedar Grove to Democrat Station in the south.

In comparing the effects of the different source areas on Sierra impacts for both sets of tests, we make the following observations.

1) Under normal upvalley flow, the northern source areas (Pittsburg, Stockton) can influence Sierra sites from Yosemite southward. Surprisingly, during all tests conducted there were minimal impacts at Sierra locations east of Stockton such as Strawberry and Cherry Lake.

2) The Fresno tracer appears to consistently affect Sierra sites to the east and south. Under certain stagnation conditions, the Fresno tracer can influence Sierra sites

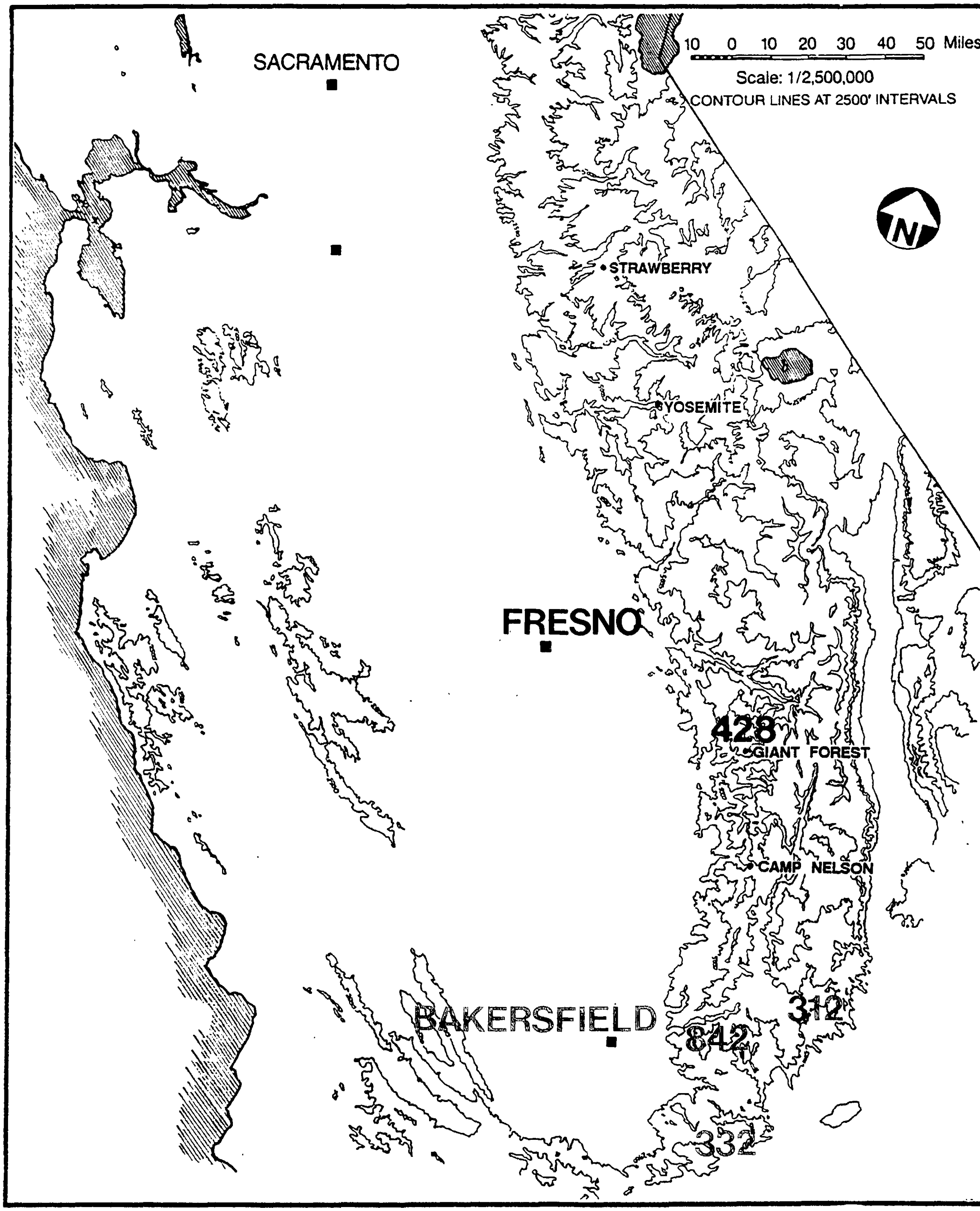


FIGURE 8-11 - MAXIMUM CHI/Q VALUES MEASURED AT EACH SITE: SJVAQS: JULY 13-15, 1990.

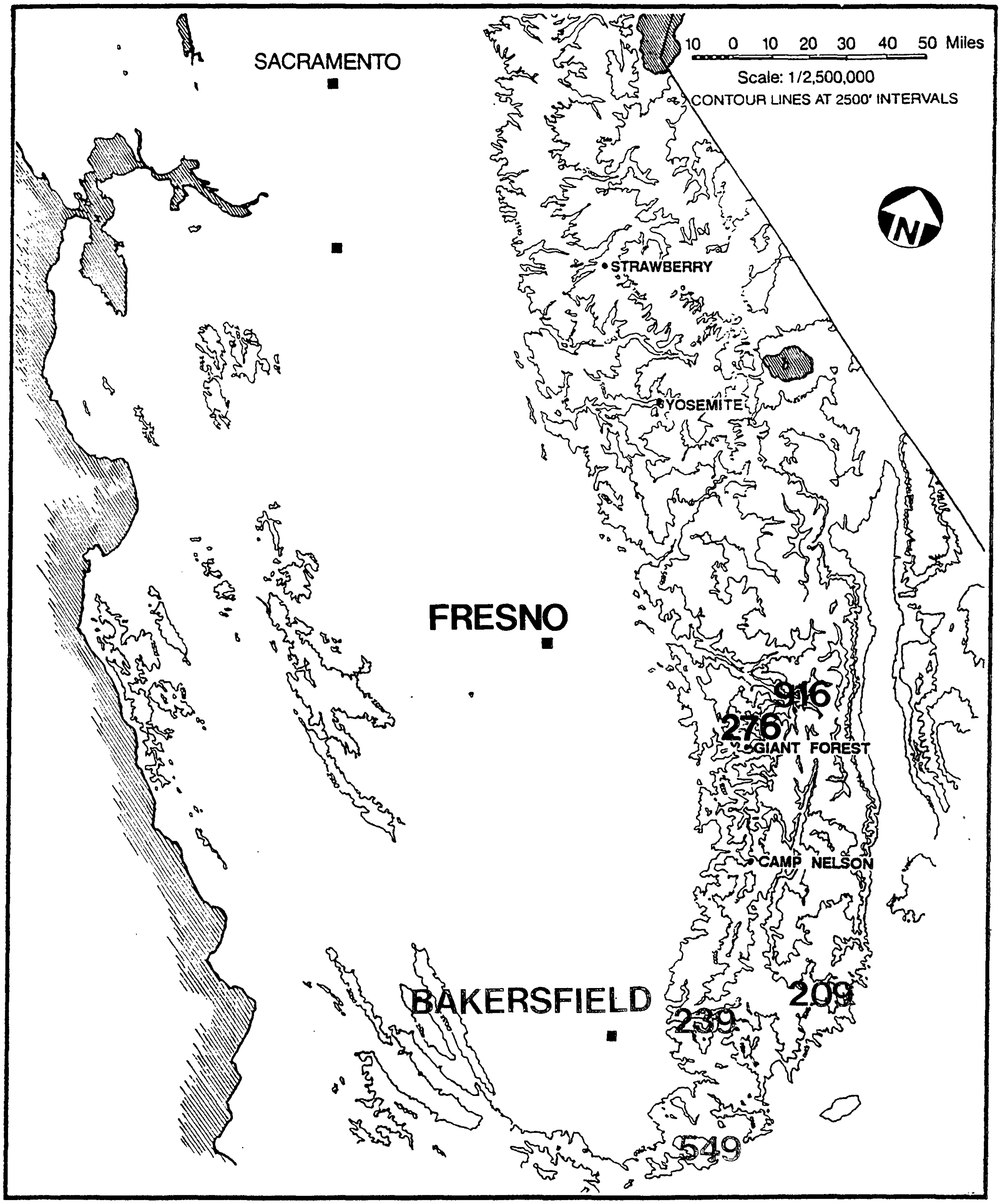


FIGURE 8-12 - MAXIMUM CHI/Q VALUES MEASURED AT EACH SITE: SJVAQS: AUGUST 3-5, 1990

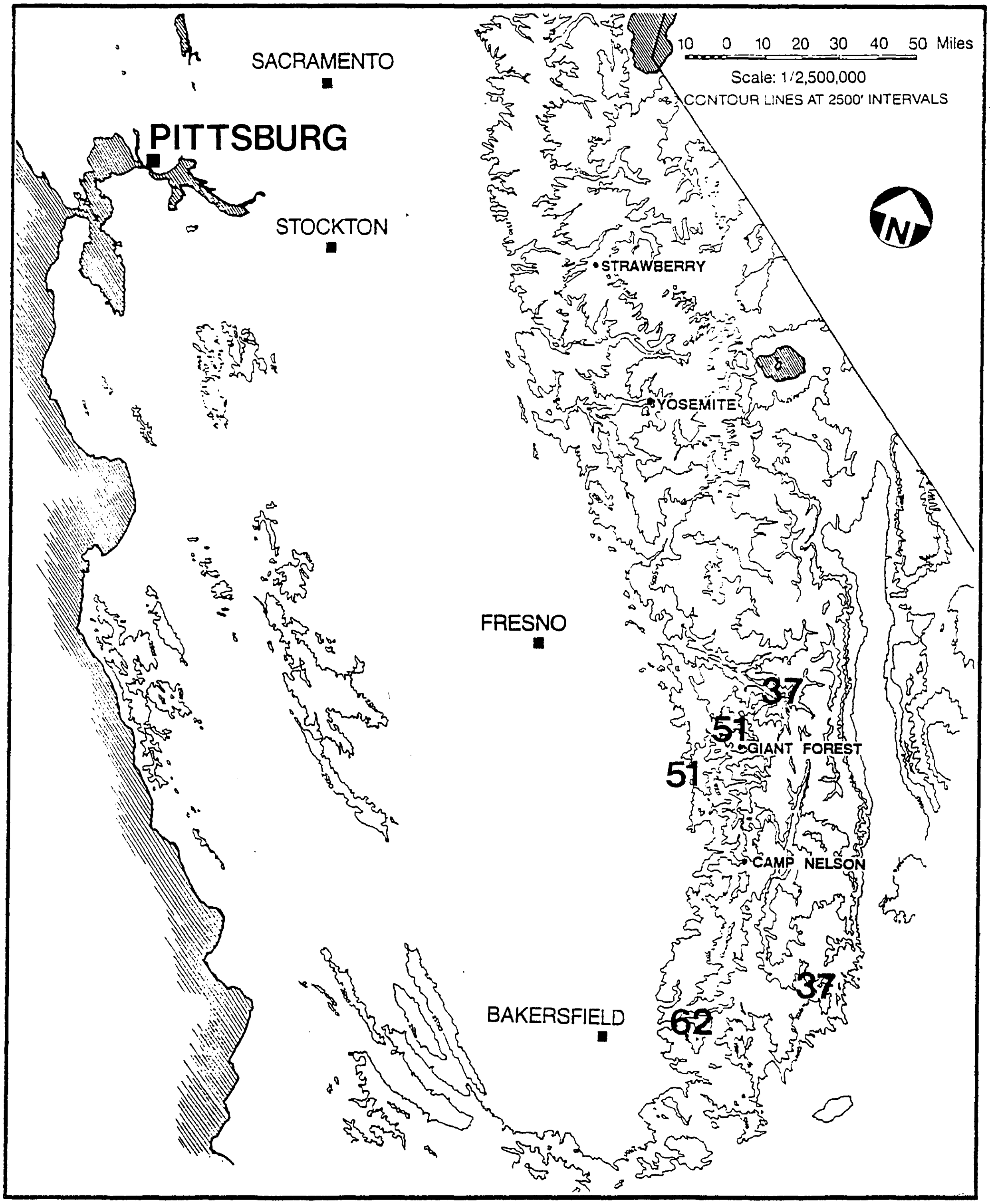


FIGURE 8-13 - MAXIMUM CHI/Q VALUES MEASURED AT EACH SITE SJVAQS: PITTSBURG RELEASE: JULY 27-28, 1990. (CHI/Q units are s/m^3 * 10^{-12})

north of Fresno.

3) The Bakersfield tracer always impacts the Sierra to the east and southeast of Bakersfield. Bakersfield tracer was measured for two different tests at Ash Mountain, but never penetrated Sierra sites east of Ash Mountain.

8.3 Mass Balance

Tracer gases emitted during the field experiments are transported by prevailing winds. As dispersion occurs in the atmosphere, portions of the tracer plume reach the extremities of the sampling gird (i.e. horizontal boundaries). Other portions of the tracer plume are advected from the study area by winds aloft, which is a difficult mass flux to assess. To fully gauge the air quality impacts of SJV emissions, it is useful to perform mass balance calculations of the tracer released to determine how much tracer gas has been advected or remains in the study area.

Mass balance is an attempt to account for all gas emitted from the source location. The estimates are most accurate when the tracer passes over an adequately dense network of air samplers. Mass balance calculations were performed for all releases to identify the differences in impacts resulting from the different releases. The mass of tracer was estimated for each hour of each test thus providing a time-series history of the total amount of tracer in the sample area at any given sampling time.

Typically, with a dense sampler network, mass balance estimates should account for all the mass released within a few hours of the release. It is important that the tracer plume be properly defined within several hours of the release to fully account for the mass released before there is dispersion into upper air areas. Mass estimates performed in this manner, such as during the South Coast Air Quality Study (SCAQS), typically accounted for 90% of the mass within four hours of the tracer release (Tracer Technologies, "Southern California Air Quality Study Perfluorocarbon Tracer Data Analysis", 1991). In contrast, the TAAPs tracer tests were not designed for accurate mass balance estimation. The TAAPS sampler network contained thirty two samplers within a sampling area that spanned approximately 45,000 square miles. The network was clearly not dense enough to provide an accurate representation of the plume structure needed for accurate mass balance measurements.

In spite of the low sampler density, the mass balance analysis did provide an interesting result. During the October test, mass estimates accounted for 85% of the tracer 56 hours after the tracer was released. This provides evidence that tracer deposition plays a relatively small role in the dissipation of tracer through time and implies that transport, not deposition, is the principle mechanism for the depletion of tracer mass within the sample area.

8.3.1 Methodology

Two assumptions were made in performing the mass balance calculations. First, the test area was divided into 20 km grids and it was assumed that the tracer was uniformly mixed within each grid up to the mixing layer height. Secondly, a three day average mixing height was calculated for each 2 hour period for using the August data available for the three days prior to the intensive at each location where mixing height was measured.

The mass balance was calculated using the tracer data collected during the two intensives and mixing height data obtained from the San Joaquin Valley Air Quality Study. To calculate the mass of tracer for each test, the study region was divided into zones measuring 20 kilometers by 20 kilometers each. For each two hour period a representative concentration for each grid zone was calculated using a $1/r^2$ weighting for all the tracer data collected. A representative mixing height was calculated using $1/r^2$ from all mixing heights measured for that two hour period. The mass in the grid was then calculated by determining the volume in each grid (20 km * 20 km * mixing height) and multiplying by the representative concentration for the specific grid. The total mass for the two hour period was then calculated by totalling the mass from all the grids for the respective two hour period.

8.3.2 Results

Accurate mass estimation requires a dense sampler network to precisely define the plume dimensions within a few hours of the release. Mass estimates performed for other PFT studies, such as the South Coast Air Quality Study (SCAQS) accounted for up to 90% of the mass released within a few hours of the release (Tracer Technologies, "Southern California Air Quality Study Perfluorocarbon Tracer Data Analysis",1991). The SCAQS test consisted of 50 sampling locations within the Los Angeles Basin, providing an excellent network for this type of analysis. The sampler density for the TAAPS study was not optimal for accurate mass balance estimates. Normally, the mass will be accounted for within a few hours of the release before the tracer has a chance to disperse into the upper atmosphere. Unfortunately, the sampler density for this study did not enable a precise definition of the plume for a majority of the releases.

During the October intensive, the meteorological conditions were very stagnant in the valley which allowed the Fresno tracer to slowly migrate over a large portion of the SJV. Since the tracer was fairly evenly spread over such a large area, thus intercepted by several sample sites, the TAAPS sampler network was able to adequately define the tracer plume. The Fresno tracer mass estimates for the October test are presented in Figure 8-14. The mass estimates for the Fresno tracer account for approximately 85% of the tracer during test periods 15 and 27. Since the tracer was accounted for more than two days after the release within a 15% error margin, this suggests that very

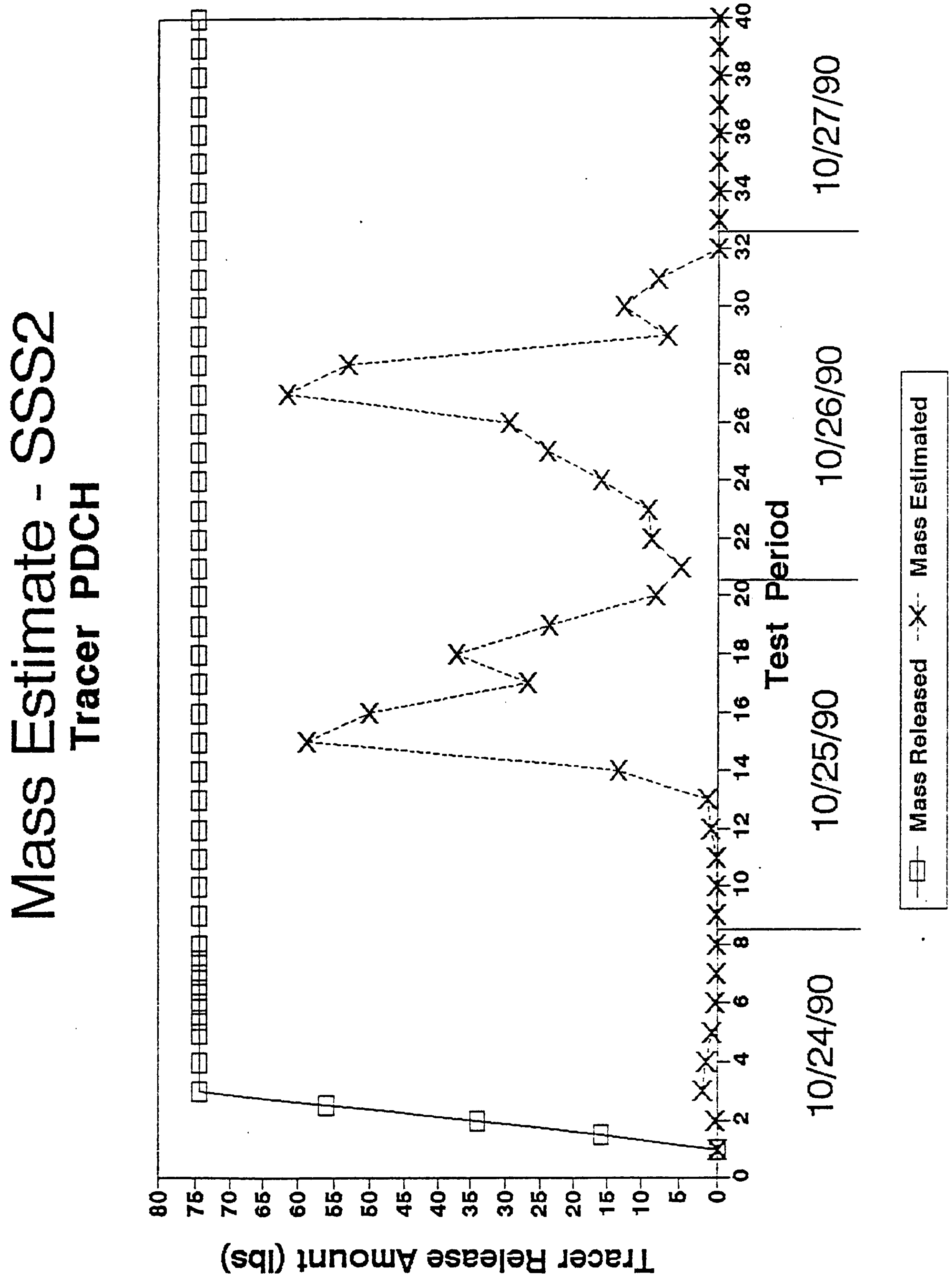


FIGURE 8-14 - MASS ESTIMATE VS AMOUNT OF TRACER RELEASED: FRESNO TRACER, OCTOBER TEST

little deposition losses occurred. From these data it is reasonable to assume that no more than 15% of the tracer was lost due to deposition. It is important to note that this is an upper bound for deposition because the assumption is that deposition was responsible for all the unaccounted tracer. This is highly unlikely since there were probably some losses due to transport out of the grid, particularly in the vertical. Secondly, one would expect even less deposition during more typical days when wind speeds are substantially greater in the SJV. Finally, the 15% deposition estimate is well within the experimental error for a mass balance calculation.

This result demonstrates, as expected, that deposition plays a very minor role in tracer depletion and that transport is the principal mechanism by which tracer is removed from the sample area. The tracer will either be transported by winds outside of the sample area or advected above the mixing layer into the upper atmosphere thus providing a powerful indicator for the transport mechanisms involved.

Figure 8-14 also indicates the difficulty in attempting to do a mass balance with the diffuse sampling network. If one looks at the plot, the amount of tracer "disappears" during the test and then returns. Obviously the tracer is always present but the sampling array does not accurately reflect all of the tracer.

Due to the inadequate sampler density, the mass evaluations resulting from the remaining releases grossly underestimated the amount of tracer released. The best remaining mass estimates were calculated for the Stockton and Fresno releases of the August test. Both estimates accounted for approximately 30% of the mass released.

8.4 Representativeness of Test Days

In this section, an attempt is made to determine the frequency of the test conditions during summer and fall. Comparing meteorology of different time periods is an extremely different task. To simplify the task, we decided to compare the ozone concentrations at Fresno for test and non-test periods. A study of the ozone concentrations will provide an overall view of the meteorology and dispersion characteristics during a given period and provide a simple method for comparing test days to non-test days. The Fresno ozone concentrations for the 1990 July - October time period are shown in Figures 8-15 and 8-16.

TEST 1 - Breakdown of Ozone Episode

The August 12-14 test demonstrated the breakdown of a typical summer ozone episode. Prior to the test period, ozone concentrations at Fresno were measured as high as 13 pphm for two days. Once the test began, ozone concentrations decreased steadily during

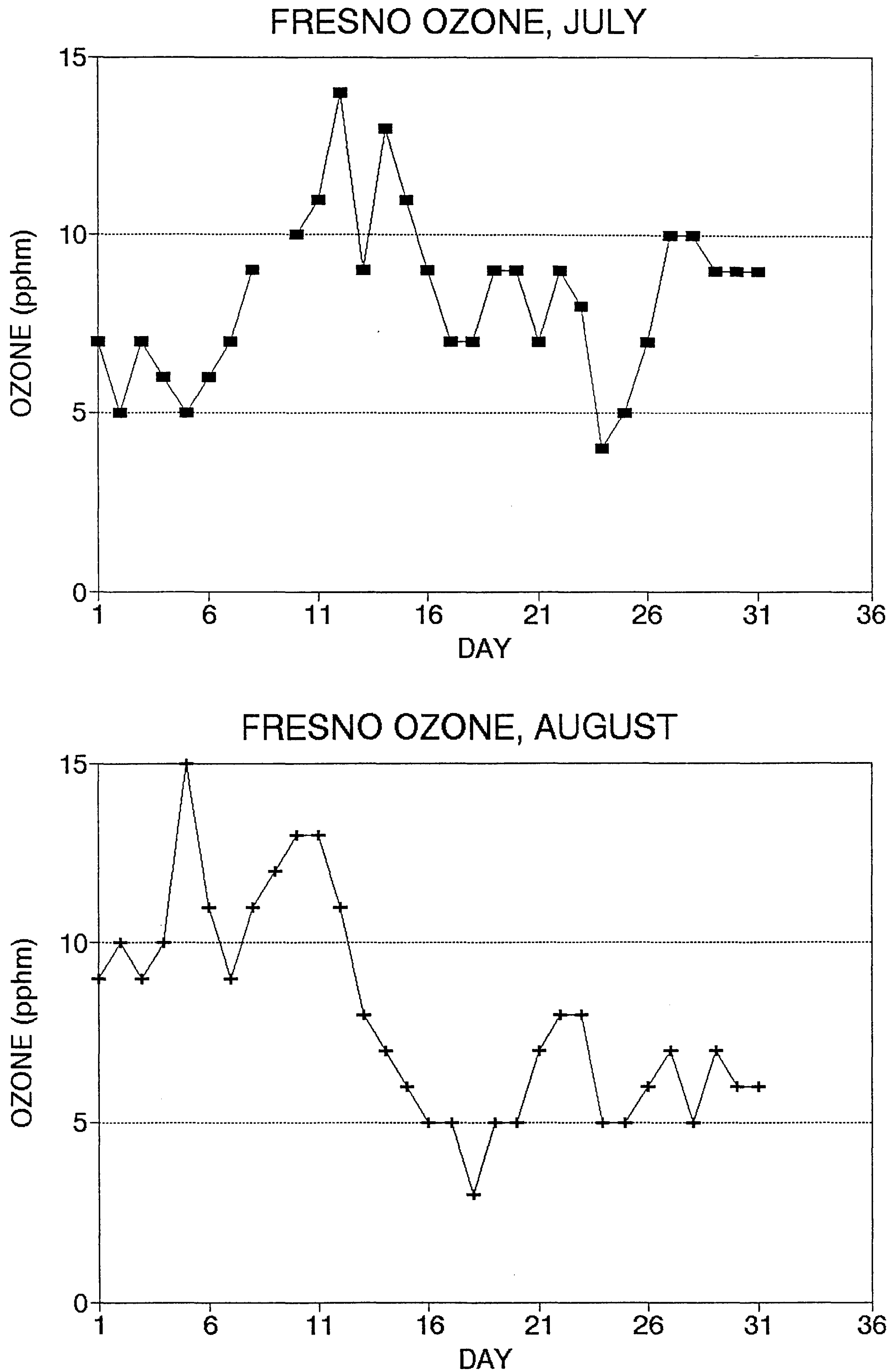
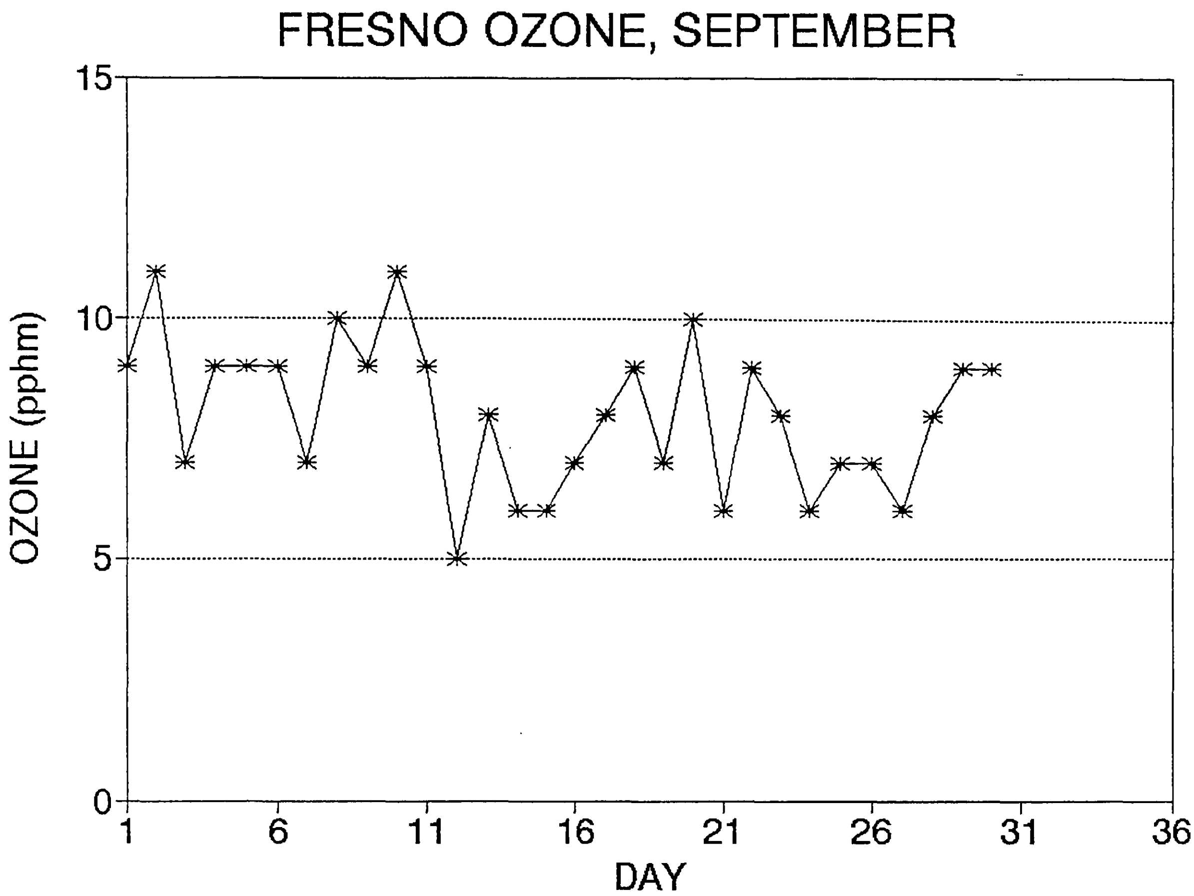


FIGURE 8-15 - Fresno Ozone Concentrations: July/August 1990



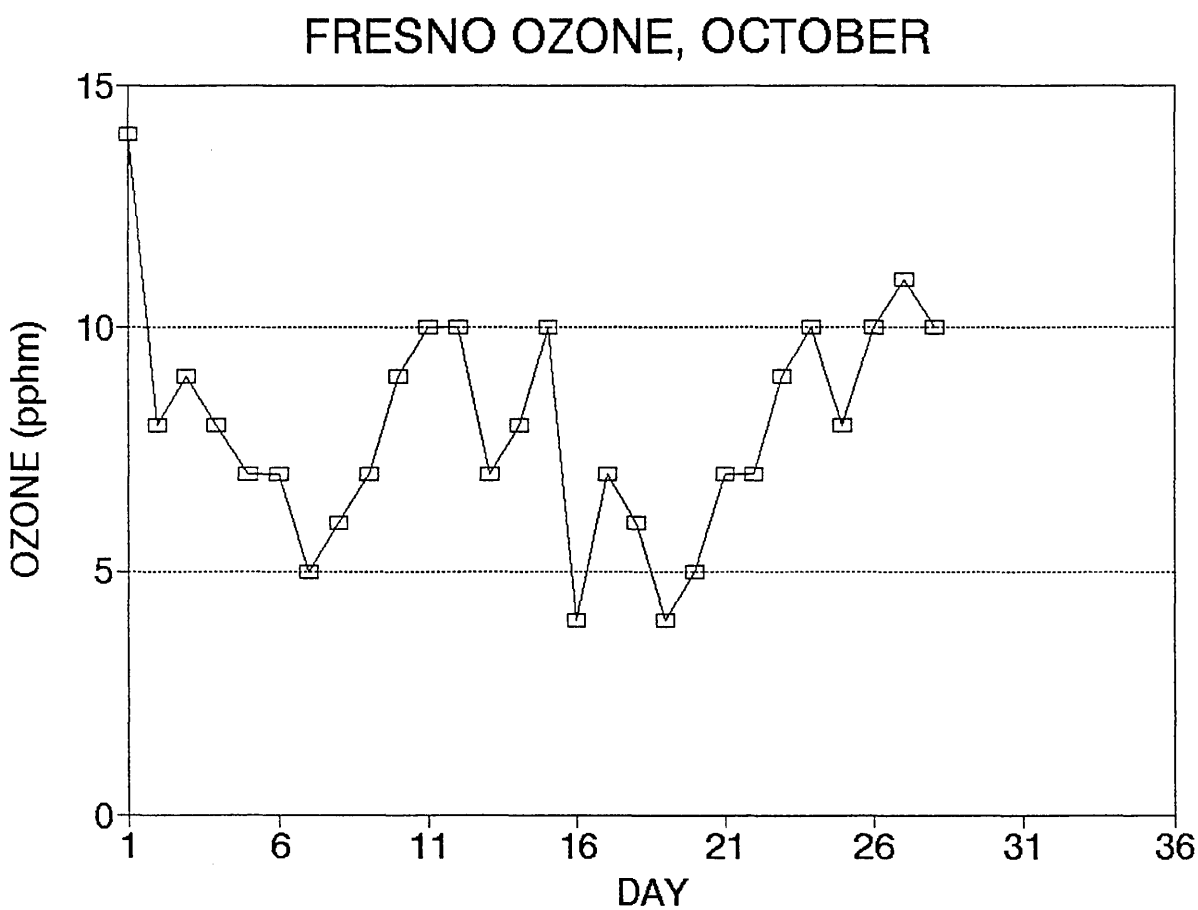


FIGURE 8-16 - Fresno Ozone Concentrations: September/October 1990

the test. On the last day of testing the highest ozone concentration measured at Fresno was 7 pphm.

During the July-October time period there were three other periods similar to the test period: July 15-17, September 11-13, October 15-17. All these periods were characterized by moderately low ozone concentrations following a period of ozone concentrations greater than 10 pphm. Including the test period, there were 9 days during the July-October period that were similar to the August test days.

TEST 2 - Stagnant Condition

The October 24-27 test was a typical stagnation period during which ozone build-up occurs in the San Joaquin Valley. Ozone concentrations at Fresno were relatively high for the duration of the test period ranging from 8 to 11 pphm, relatively high for October.

During the July-October period there were six periods similar to the October test where ozone concentrations were greater than 9 pphm for two or more days. These periods are July 10-15, July 28-31, August 1-13, September 8-11, September 29-October 1, and October 10-12. Including the test period, there were approximately 37 days during the July-October time period that were similar to the October test days.

9.0 CONCLUSIONS

During this study tracer gases were used to determine the transport of pollutants from source areas in the San Joaquin Valley to receptor areas in the Sierra Nevada. Several data analysis techniques were applied to define transport into the Sierra Nevada range. A complete isopleth analysis was performed to provide a time-series definition of the plume. A trajectory analysis was completed to determine whether tracer transport could be predicted by surface level winds. A direct comparison of ozone and tracer measurements was conducted to determine the extent of correlation between pollutant impacts in the Sierra with tracer concentrations from different source areas. A comparison of normalized tracer concentrations was used to resolve the effects of the three source areas on different regions of the Sierra Nevada. Finally, mass balance calculations were performed to verify the amount of tracer released and to gain confidence that the tracers used accurately depict air mass transport.

This study has provided informative insight into the transport of pollutants from the San Joaquin Valley and the use of atmospheric tracers in studying pollutant transport. The major findings of the study are summarized below:

1. **Tracers are an excellent indicator of pollutant transport.** Results from the study indicate that the tracers are excellent surrogates for determining pollutant transport. Comparisons made between ozone and tracer concentrations show that there is an almost perfect correlation between the Fresno tracer and pollutant impacts at two Sierra locations. This implies that the ozone measured at these locations is transported from Fresno, thus implying that the that the ozone measured at these sites can be fully attributed to the Fresno area. Secondly, deposition losses are minimal such that transport is the main mechanism by which tracer is removed from the study area. This precludes any depletion of the tracer within the study domain that could underestimate the effects of source areas on pollutant impacts.

2. **Pollutant flow is predominantly transported into the Sierra through river valleys and canyons.** Occasionally, pollutants will get mixed aloft and transported down into the Sierra, but the majority of the transport occurs through river valleys and canyons. The mechanism by which the pollutants are transported into the Sierra is fairly complex. The tracer tends to be initially pushed up against the Sierra foothills whereupon the tracer slowly seeps into Sierra regions via major canyons and river valleys. During nighttime, there is diurnal drainage that moves the tracer back into the foothills but once into the early daylight hours, a return flow is established which tends to push the tracer back into the upper Sierra. Nocturnal

drainage flow provides minimal effect in removing pollutants from the Sierra foothills into the San Joaquin Valley.

3. **Pollutant transport is dominated by upper level winds within the mixing layer.** Trajectories calculated from surface level winds grossly underestimate the movement of pollutants. Under moderate windspeeds, trajectories calculated from winds adjusted to 1000 meter levels provided reasonable estimates of the plume movement in the San Joaquin Valley, but failed to provide sensible estimates once the plume reached the Sierra foothills. This indicates that pollutant transport in the San Joaquin Valley appears to be dominated by upper level winds.

4. **Stockton and Fresno emissions have the greatest impact on air quality in the Sierra Nevada.** Normalized results from the testing performed indicate that emissions from Stockton and Fresno influenced a large portion of the Sierra Nevada from Yosemite to the Tehachapis. In contrast, Bakersfield emissions were very localized. Bakersfield emissions only impacted the southern regions of the Sierra. These findings were validated with data obtained from the SJVAQS.

5. **Test days were representative of approximately 40% of the July through October time period.** A comparison of ozone concentrations measured at Fresno during test and non test days during the July - October time period showed that there were 9 other days similar to the ozone episode breakdown in the August test, and 33 days similar to the stagnant conditions experienced during the October test.

There are several major pathways for pollutant transport into the Sierra. In the northern Sierra, the Merced River Valley is a pathway from the SJV into Yosemite. In the central Sierra, the San Joaquin River Valley is an entry way through which pollutants are transported to Wawona, Mammoth Pool Reservoir, and Dinkey Creek. To the east of Fresno, the King's canyon is an entryway to Cedar Grove and Giant Forest. East of Visalia, the Kaweah River Valley is a pathway to Ash Mountain and Giant Forest. In the southern Sierra, the Kern River Canyon is a passage to Democrat Station and Lake Isabella.

10.0 REFERENCES

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