2. Current Knowledge and Available Data

Setting

MPP is located at Laughlin, NV, about 125 km south-southeast of Las Vegas, 350 km northeast of Los Angeles, and 340 km northwest of Phoenix (see Figure 1). The MPP is a coal-fired, base loaded generating facility with a 153 m high stack. The base of the stack is at 210 m msl. It uses low sulfur (0.6% by wt.) Arizona coal delivered by slurry pipeline. Its SO_2 emission rate averages about 150 tons/day at full operation (Nelson, 1991).

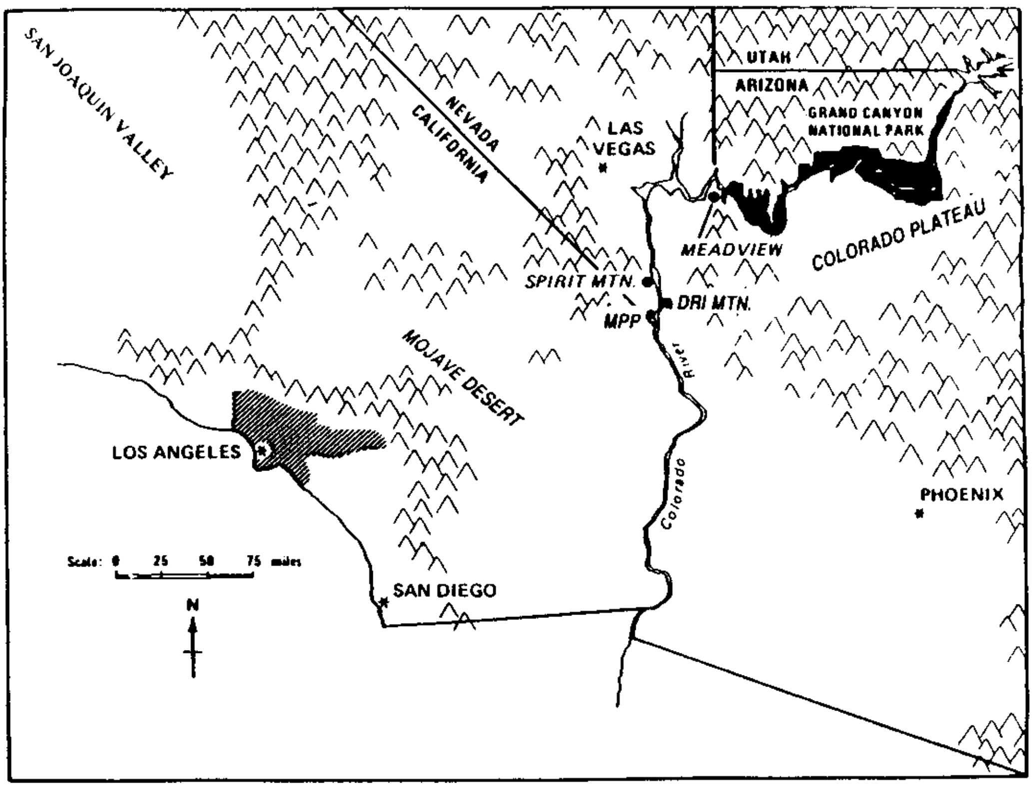

Figure 1. Map of the southwestern U.S. illustrating location of MPP.

The topography in the vicinity of the MPP is complex with sparse vegetation. A portion of the Colorado River Valley, the Mohave Valley, lies to the north of the MPP between Davis and Hoover Dams. The Mohave Valley is bordered on the west by the El Dorado and Newberry Mountains and on the east by the Black Mountains. Long north/south oriented valleys lie to the east (Detrital Valley) and west (El Dorado Valley) of these ranges.

The Mohave Valley walls are not symmetric with respect to the valley axis. Western slopes rise gradually, while eastern slopes rise slowly for the first few kilometers with steep walls further to the east. The border between Nevada and Arizona also extends along the valley axis. The bottom of the valley is about

200-300 m msl and the ridges reach 1200 m msl. Toward the west, the Mohave Valley extends into a high plateau and toward the east into the Detrital Valley plateau (600 m msl). The Mohave Valley narrows significantly as it approaches Hoover Dam. At Lake Mead the terrain flattens. The western entrance to GCNP is at the end of the eastern arm of Lake Mead (180 m msl).

This terrain controls the mesoscale, but not the synoptic scale flow patterns.

Transport Regimes

Several modeling and measurement studies have been conducted in the vicinity of the MPP over the past 20 years (Freeman and Egami, 1988; Yamada, 1988; Koracin *et al.*, 1989; White *et al.*, 1989). Results from these studies provide a conceptual model of pathways by which MPP emissions can reach GCNP. Figure 2 illustrates the three synoptic flow patterns of greatest importance; (1) summertime dry southwesterly flow (flow from the southwest toward the northeast), (2) summertime monsoons, and (3) winter storms.

Both mesoscale and synoptic scale meteorological conditions influence the movement of the MPP plume. The relative influence from each of these transport and transformation scales differs from summer (June, July, August) to winter (December, January, February). Southerly to southwesterly flows are needed to transport MPP emissions to the GCNP. Spring and fall are transitional periods that contain mixtures of the summer and winter regimes and are not as well-differentiated from each other. Figure 3 illustrates the dominant air flow for each quarter of 1990 as derived from the Dri Mountain wind data.

During the summer, southwesterly, westerly and southerly winds are common in the vicinity of the MPP. There are two distinct cases; one with dry airmasses and a second with moist monsoon airmasses, respectively. During the winter, the most common situation is northerly winds associated with a high pressure ridge over the Pacific Coast. However, infrequent frontal passages result in westerly and southwesterly flows on the order of 10% of winter days. The latter conditions can transport MPP emissions toward GCNP.

Dry, Southwesterly Flow from Southern California and the Pacific Ocean

The most common occurrence is dry, southwesterly synoptic flow caused by heating of the Mojave Desert which creates a lower pressure with respect to incoming air masses. These air masses traverse the Mojave Desert after entraining pollutants emitted from urban southern California. These include pollutants flowing through Tehachapi, Cajon and Banning passes.

This scenario has a high frequency of occurrence during the summer months. The regimes change daily from decoupled flow during the night with localized circulation patterns within the Mohave Valley and along the slopes of

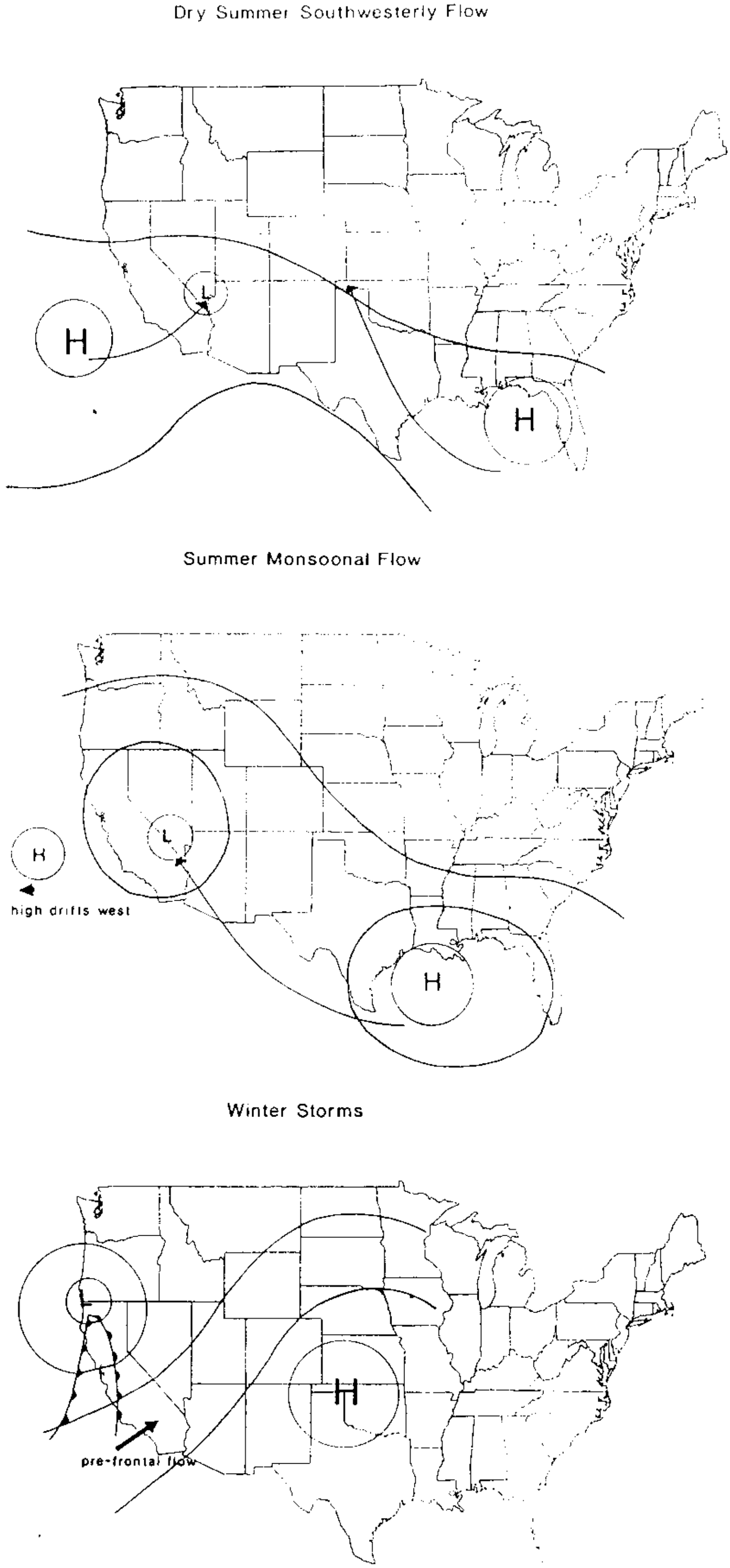

Figure 2. Synoptic flow patterns of concern. a) Dry summer southwesterly flow. b) Summer monsoonal flow. c) Winter storms.

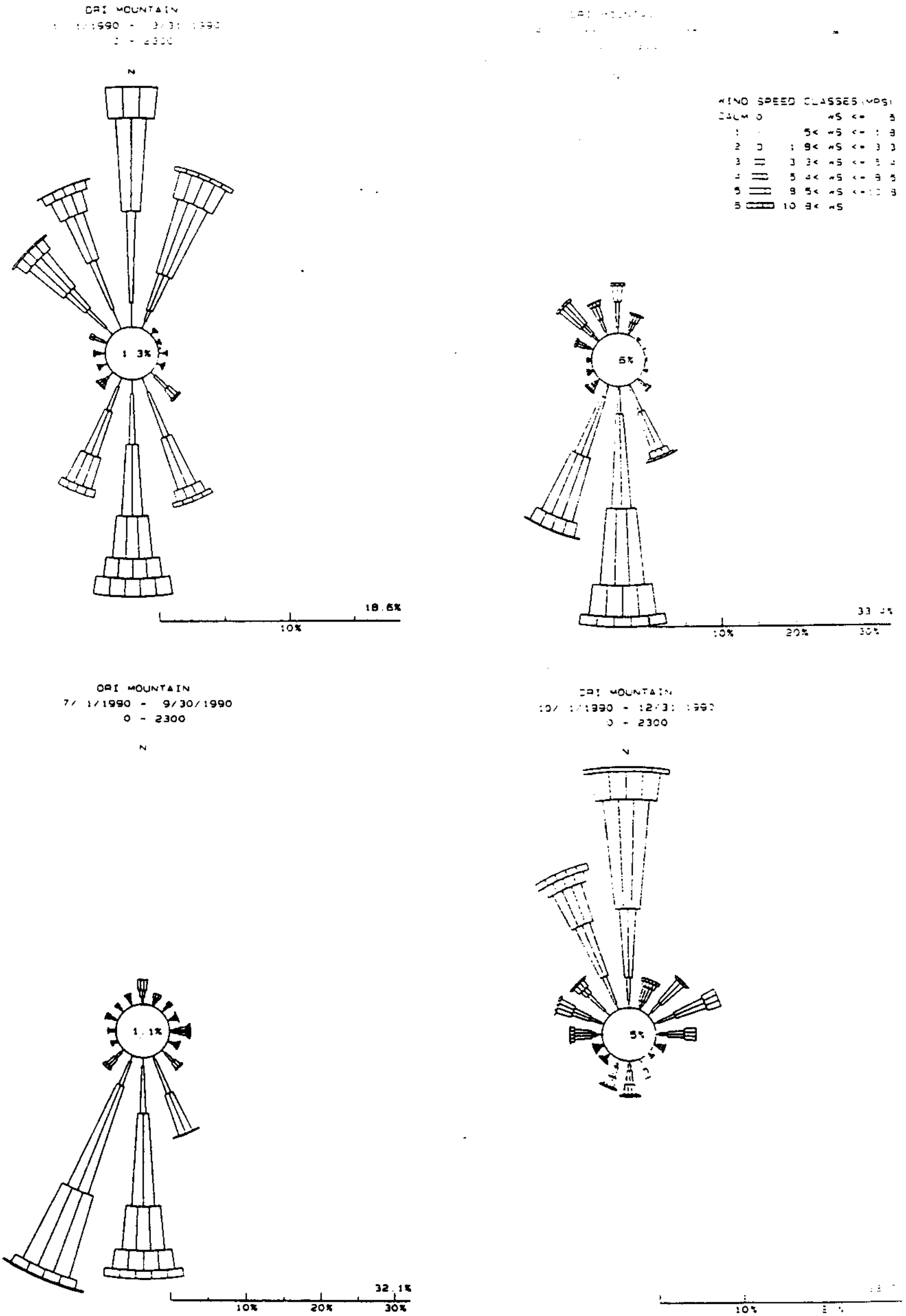

Figure 3: Dri Mountain quarterly wind roses from 1990.

the constraining mountains, to coupled flow that is dominated by the synoptic winds aloft.

Summer Monsoons

During July and August, moist air is frequently transported from the Gulf of California and/or the Gulf of Mexico in southeasterly to southerly flows. Synoptic wind speeds vary from 6 to 20 m/s at 6000 m agl. These air masses traverse northern Mexico, the southern part of Texas, New Mexico, and most of the state of Arizona. Pollutants emitted from the smelters in Arizona and Mexico as well as those from Phoenix and Tucson can be entrained into this airmass. This synoptic flow is driven by a large-scale low over the western part of the U.S. created by strong surface heating.

Differential heating causes updraft motions on the slopes of mountain on both sides of the valley, resulting in chains of clouds developing along the ridgetops. These clouds may offer a mechanism for rapid oxidation of SO_2 to SO_4 if the plume is entrained in them and if oxidants such as H_2O_2 are present in sufficient amounts.

The reacted and unreacted emissions could then be carried through the Mohave Valley by the southerly component of the wind toward Lake Mead, after which they might be transported toward GCNP by locally channeled flow or caught up in the monsoonal flow and transported across the plateau to the GCNP. Summer monsoon episodes are usually of 3 to 5 days in duration.

Winter Storms

In general, the synoptic weather patterns are not as favorable for transport from MPP towards GCNP in winter. The Great Basin and the Colorado Plateau are frequently dominated by high pressure cells creating a flow that is not conducive for transport from MPP to GCNP. Southwesterly to westerly flow occurs mainly during the movement of frontal systems, developing over the Pacific Ocean from west to east. These storms in general exhibit a minimal warm frontal activity. As a consequence the southwesterly to westerly flow needed for transport from MPP to GCNP will occur as the cold front with its associated trough approaches the Mohave Valley. This weather type can last from a day to three days, be wet or dry, and usually there are about ten cases during the winter period.

WHITEX

The Winter Haze Intensive Tracer Experiment (WHITEX), conducted by the National Park Service, was designed to evaluate the feasibility of attributing single point source emissions to visibility impairment in selected geographical regions. WHITEX was conducted during a six week period in January and

February 1987. During this time, an artificial tracer, deuterated methane (CD_4), was released from the NGS. Aerosol, optical, tracer and other properties were measured at Hopi Point, which is in GCNP, and other locations. Synoptic weather maps indicated a high frequency of high pressure over the area, which resulted in transport of the NGS plume from the northeast toward GCNP. Trajectory analysis and deterministic modeling indicated transport from the area of NGS to Hopi Point during the period with highest sulfate concentrations.

The extinction budget at Hopi Point indicated that sulfate aerosol (and associated water) contributed two-thirds of the non-Rayleigh light extinction during WHITEX. Attribution analysis used the Tracer Mass Balance Regression (TMBR) receptor model and the Differential Mass Balance (DMB) hybrid model. According to the NPS analyses, NGS contributed substantially to sulfate and light extinction at Hopi Point.

The WHITEX data analysis methodology, results, and use of the results were cause for considerable controversy. The Committee on Haze in National Parks and Wilderness Areas evaluated WHITEX (National Research Council, 1990). The Committee neither fully supported or fully discredited the WHITEX report. Based on evaluations of meteorological, photographic, chemical and other physical evidence, the Committee concluded "at some times during the study period, NGS contributed significantly to haze in GCNP." However, the committee also concluded that "WHITEX did not quantitatively determine the fraction of $SO_4^{=}$ aerosol and resultant haze in GCNP that is attributable to NGS emissions."

A key uncertainty identified by the Committee is the use of TMBR and DMB to apportion secondary species such as $SO_4^{=}$. Limitations of the regression analyses noted by the committee are: "(1) satisfactory tracers were not available for all major sources; (2) the interpretation did not adequately account for the possible covariance between NGS contributions and those from other coal-fired power plants in the region; and (3) both models employ inadequate treatment of sulfur conversion, which is an important controlling factor in the formation of haze at GCNP." Another limitation noted by the Committee was the lack of measurements within the canyon (beneath the rim). A more complete review of the National Research Council WHITEX evaluation is provided in Appendix 8.

SRP Study

The Navajo Generating Station Visibility Study was conducted for the SRP, the operators of NGS, from January 10 through March 31, 1990. Its purpose was to address visibility impairment in GCNP during the winter months and the level of improvement that might be achieved if SO_2 emissions from NGS were reduced. The study was performed to provide input to the rulemaking process of the EPA regarding NGS SO_2 controls (Richards *et al.*, 1990).

Perfluorocarbon tracers were released from each of the three stacks of NGS. Surface and upper air meteorology, particle and gaseous components, and tracer measurements were made at many sites. Deterministic modeling was done to estimate the contribution of NGS and other sources to sulfate levels for two 6 day periods with poor visibility. Various data analysis techniques were used to examine the relationships among NGS emissions, meteorology, air quality, and visibility during both episode and non-episode conditions.

The SRP study concluded that NGS emittants were absent from the vicinity of Hopi Point most of the time . The study estimated that the average contribution of NGS to fine sulfur at Hopi Point was small, although NGS sulfur dominated during one 4-hour period. However, it was noted that the frequency of wind directions transporting the plume toward GCNP were lower than normal during this time period.

MPP Emission Modulation Studies

The MPP was inoperable for the seven month period June through December 1985. Using data from the period of shutdown and during operation of MPP, a study was done by SCE (Murray *et al.*, 1990) to assess the effect of MPP upon particulate sulfur levels at Spirit Mountain, Meadview, and Hopi Point. Spirit Mtn. is 20 km northwest of MPP, Meadview 110 km north-northeast of MPP and Hopi Point 240 km northeast of MPP. Meadview, 5 km west of the boundary of GCNP, is expected to have the highest particulate sulfur impact from MPP among the three sites. The study found no statistically significant difference in sulfate levels at the three sites between operation and shutdown of MPP. It was suggested that the substantial year to year variability of sulfate was responsible for not detecting a statistically significant difference. The 95% confidence bounds for the MPP impact was from less than 11.6% to less than 21% at Meadview and less than 3.3% to less than 7.8% at Hopi Point during favorable transport conditions. The upper limit on average sulfate at Meadview was estimated to be 15%, which is the level of uncertainty in the statistical analysis.

From data presented by Murray, it can be seen that sulfate levels at Spirit Mountain, generally not affected by MPP, were greater during the outage compared to non-outage periods, indicating higher background levels during the outage. However, at Meadview, average sulfate levels were lower during the outage. Thus, levels at Meadview were lower during the outage even though regional levels were higher. While suggestive, the number of samples was not sufficient to prove an impact from MPP. This comparison, done as part of the scoping process, appears in Appendix 4.

A more sophisticated study of the outage will be conducted under the Desert and Intermountain Air Transport program at DRI, sponsored by SCE. Chemical and physical analysis of filters for the SCENES program, used in Murray's study, were analyzed only every third day. Samples for the intermediate days were archived. The new study will analyze all samples, including those previously analyzed. A more sophisticated meteorological classification scheme will also be done. The sulfate levels for the same meteorological regimes can then be compared for the outage and non-outage conditions. Other emission modulations of shorter duration (i.e. periods where only one of the two units at MPP was operating) will also be analyzed. Deterministic wind field and transport modeling will be done for each of the meteorological regimes. The modeling will account for variations within each regime. A detailed compilation of regional SO_2 emissions for the control and outage periods will be done. A draft version of the outage study plan appears in Appendix 5.