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NVO-269
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ATMOSPHERIC OVERVIEW FOR THE NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS, NEVADA TEST SITE, NYE COUNTY, NEVADA

NOVEMBER 1983

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE
LAS VEGAS, NEVADA

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ATMOSPHERIC OVERVIEW FOR THE NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS, NEVADA TEST SITE, NYE COUNTY, NEVADA*

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UNITED STATES DEPARTMENT
OF ENERGY
NEVADA OPERATIONS OFFICE
LAS VEGAS, NEVADA

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I. INTRODUCTION

It has been proposed to use a portion of the Nevada Test Site (NTS) as a repository for the high level nuclear wastes from commercial nuclear reactors. Before environmental impacts can be analyzed, all available information concerning the affected environment must be evaluated, the lacking information identified, and appropriate data collected. The task of this overview is to summarize the available information and identify information requirements concerning atmospheric phenomena.

There are two aspects of atmospheric phenomena: the first is concerned with the effects of weather on the repository itself and the second with the effects of the repository on the air of the surrounding area. It is important to know how the weather will affect the repository during both construction and operation phases and, in particular, the probabililty of extreme weather events such as flash floods and high winds. From an environmental point of view, it is necessary to be able to project the effects of such activities, as construction and increased population, on both the local and regional air quality.

The NTS is an area in south central Nevada that has been reserved for the testing of nuclear devices. Its location is shown in Figure 1. It encompasses an approximately rectangular area of 80 km north to south and 50 km east to west within a region of generally north-south ridges and valleys.

Because of the special use of NTS, there has been a requirement for onsite meteorological data for some time. The United States Weather Bureau (now the National Weather Service (NWS)) started its observation program at NTS in March 1956. Since that time a number of locations have been instrumented to measure wind, temperature, relative humidity, or precipitation or some combination of these for varying periods of time. During the last 25 years

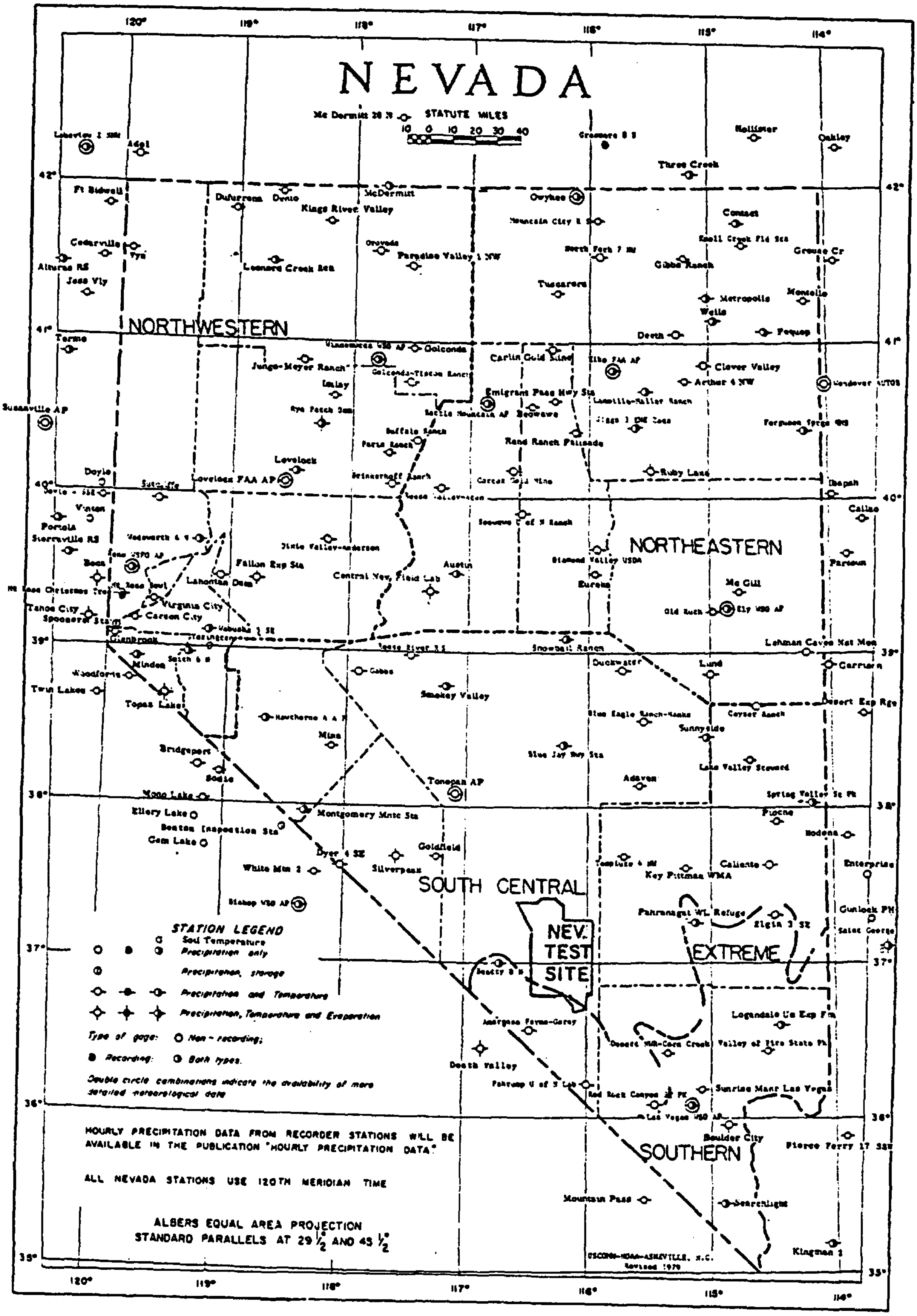

Figure 1: Climatological Stations and Zones for Nevada and the Location of the Nevada Test Site (NOAA, 1980)

there have been changes in both location and emphasis within NTS, and of parameters of interest, so that some areas have longer periods of record than others. In general, the climatological data base is quite large considering the remoteness of the area and the usual sparseness of data in rural Nevada.

This report discusses atmospheric considerations for a nuclear waste repository at NTS. It presents the climatology of Nevada, and NTS in particular, including paleoclimatology for past climatic changes, present climatology for mean meteorological conditions, feature climatological expectations, and occurrences of extreme weather. It discusses air quality aspects including an estimation of present air quality and possible dispersion conditions on NTS. It briefly assesses noise problems. It outlines a plan for an Environmental Impact Statement and covers the federal and state regulations for air quality. It identifies data for climatology and air quality and evaluates their applicability to nuclear waste repository.

II. TOPOGRAPHY

The terrain of NTS is highly irregular, ranging from 2,400 m above mean sea level (MSL) in the north to 950 m MSL in the southeast and 825 m MSL in the southwest. There is a general, but often interrupted, north-to-south slope.

Figure 2 shows NTS place names. Also included are air shed boundaries and numbers, as designated by the State of Nevada Division of Environmental Protection. The air sheds correspond to hydrologic basins of Nevada as determined by Nevada Division of Water Resources (1971). Most boundaries are along ridges and other high terrain surrounding low-lying valleys.

The proposed area of interest for a nuclear waste repository is the southwestern section of NTS, an area that encompasses what was once NRDS. This area consists mainly of Jackass Flats, in the middle sloping downward towards the Amargosa Desert to the southwest, with Yucca Mountain to the west, Shoshone Mountain to the north, and Lookout Peak and Skull Mountain to the east. Descending across Jackass Flats are a number of washes, the most prominant of which are Forty-mile Wash and its tributary, Tonopah Wash.

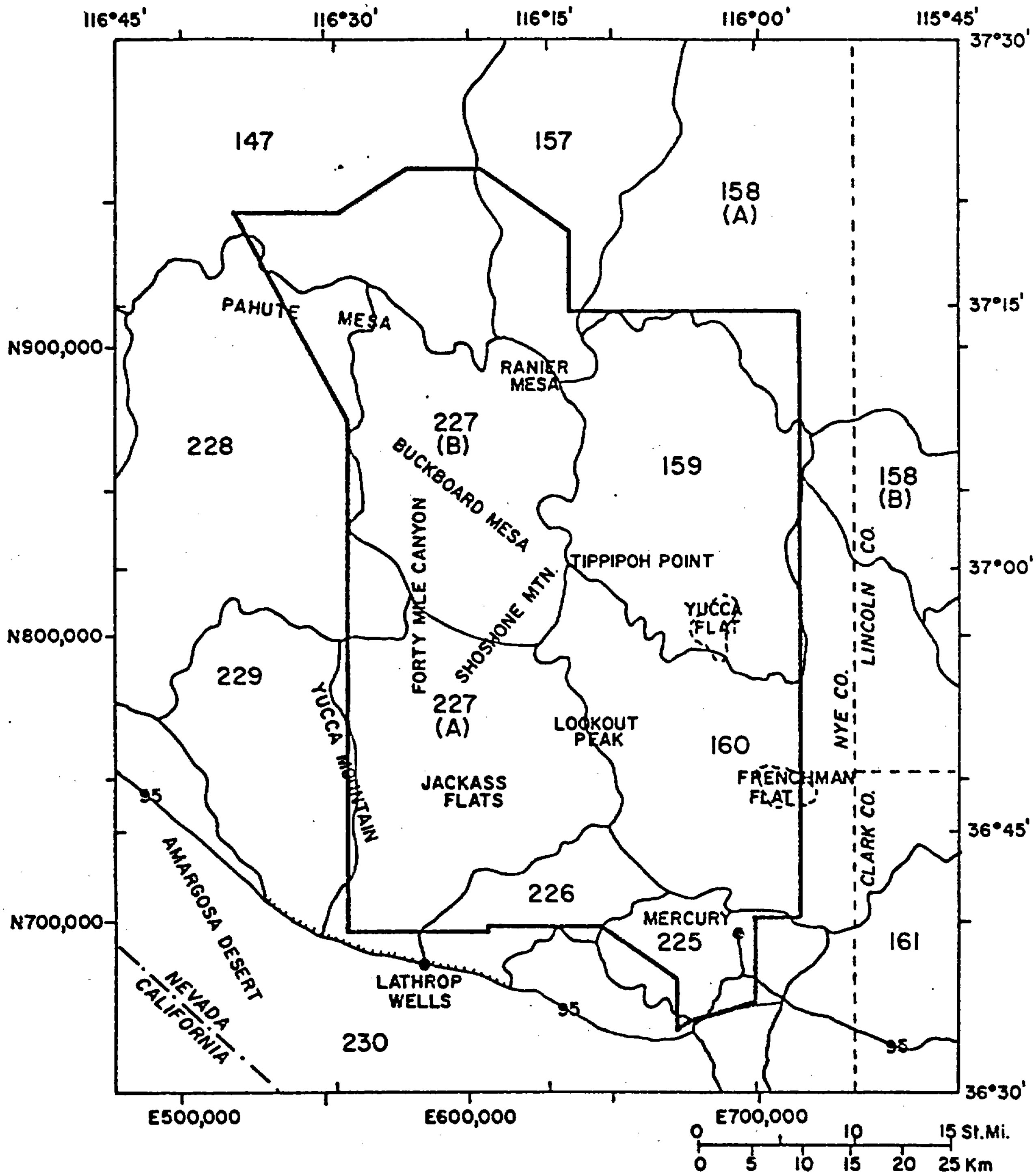

Figure 2: Nevada Test Site with Air Shed Boundaries. (Adapted from Nevada Division of Water Resources, 1971).

III. CLIMATOLOGY AND METEOROLOGY

This section discusses weather as it is related to NTS. Included are paleoclimatology, present or normal climate, future climatological expectations, and severe weather occurrences.

A. PALEOCLIMATOLOGY

Paleoclimatology is the study of past climates throughout geologic time and causes for their variations. It coordinates inferences about climatic elements from fossils and rock characteristics with changes in land and sea distributions, orography, solar radiation and astronomical factors.

The length of time for which the nuclear waste repository will have to remain intact is similar to that of recent climatic changes. Knowledge of the past gives some insight into the future.

The majority of paleoclimatological studies applicable to NTS have been concerned with the Quaternary Period, which consisted of the Pleistocene (glacial) and Holocene (recent) Epochs. The former, following 40 million years of progressive cooling of the earth's temperature, began some one-million years ago. It was marked by a sequence of fairly well-defined ice ages and interglacial periods which affected the climate of the entire earth. Ice ages continued into what has been classified as the Holocene (or recent) Epoch, with the last climax of glaciation in North America being some 18,000 years ago. Several less dramatic variations in climate have occurred since.

Paleoclimatology shows that the area in which NTS is located was not as dry as it is today, as discussed by Morrison (1965). There is geological evidence that the Great Basin contained two large lakes and a number of smaller ones. To support so much water, there must have been a much different ratio of precipitation to evaporation. Mifflen and Wheat (1979) show that the observed pluvial lakes would have required either a mean temperature 5°F lower than today, a 68% increase in precipitation, or a 10% lessened evaporation rate. They conclude that the main cause was an increase in precipitation because of a southward shift in the storm tracks. These pluvial lakes were mainly in the northern part of the Great Basin, although some were in the southern part as well. It does not appear that any of the southwestern part of NTS had a pluvial lake, although the present dry lakes in other parts of NTS, such as Yucca Flat, may have had water in them all the time. Some of the pluvial lakes of southern Nevada shown by Morrions (1965) have been disputed by Mifflin and Wheat (1979). The drainage from the southwest NTS goes into the Amargosa River which, at one time, probably drained into Lake Manley in what is now Death Valley.

There is no evidence that glaciers ever existed on the NTS. The large ice sheet apparently never reached into the Great Basin. The only glaciers that occurred in the Great Basin were at high elevations where permanent snow fields were able to evolve into glaciers. There were glaciers on the eastern slopes of the Sierra Nevada range, the White Mountains of California to the west of NTS, the Ruby Mountains of Northern Nevada, and the Wassatch Range of Utah. It does not appear that the mountainous areas of NTS were high enough to support glaciers, although there is a good chance that the winter precipitation was in the form of snow.

The climate of southern Nevada in the recent geologic past, while less dry than at present, did not have the major disruptive factors such as ice sheets or large bodies of water that other parts of North America had.

B. PRESENT CLIMATE

The climate of an area is comprised of long-term manifestations of weather. It is represented by averages of its weather conditions over a specified interval of time. These averages are referred to as normals.

1. Climatological Classification

The Nevada Test Site is situated between the south central and extreme southern climatological zones of the State of Nevada, as designated by the National Weather Service (Brown, 1960) and shown in Figure 1. Lower elevations have a climate like the extreme south, hot summers and mild winters and arid. Higher elevations have cooler temperatures and somewhat more precipitation but are still rather arid. The southwestern part of NTS is mainly within the extreme southern zone, although mountainous areas tend to modify the local climate.

General climatic categorizations, such as Koppen scheme (Lamb, 1972), can be applied to NTS. The main governing factor is terrain, while exposure to sun and wind is also important. The range is from warm desert (BW in Koppen classification) through dry steppe (BS) approaching boreal forest (Dfa) as elevation increases. The highest elevations of NTS are not quite cold enough, nor do they have quite enough precipitation to qualify for Dfa. They might better be classed as moist steppe (Houghton et al., 1975) which is not a Koppen class.

2. Yucca Flat and Nevada Climatological Stations

A number of meteorological stations have been operated within and near the area of interest by the National Weather Service, Nuclear Support Office in Las Vegas. During this time, a Class 1 weather station has been operated at NTS, first at Yucca Flat and then at Desert Rock Airport. A ten-year climatological summary from the Yucca Flat Weather Station is given in Table 1. This station is near the bottom of a closed basin some 30 km northeast of Jackass Flats. Its location in a closed basin may not be representative of nocturnal conditions at other areas of NTS. At night, there is a tendency for air to flow downhill. A closed basin, however, limits this flow which results in light winds and strong radiational cooling. The effect is to lower the daily minimum temperatures and to increase the incidence of calm winds. A comparison of data from the Yucca rawinsonde and some temperature sensors on the BREN tower (a 465 m tower on Jackass Flats) by Quiring (1969) shows greater pre-sunrise cooling at Yucca than on the slope of Jackass Flats with a temperature difference at a level near the top of the tower of 0.5C for the two-month period studied. This temperature difference is likely to be amplified at lower levels.

In order to show where Yucca data fits into the climatology of Nevada, the normals, means and extremes for the other Class 1 weather stations in Nevada at Elko, Ely, Las Vegas, Reno and Winnemucca are given in Tables 2 -4. As might be expected from its map location, Yucca is also between Las Vegas and Reno in terms of temperatures and precipitation, with more similarity to Reno in many cases. One reason is the closeness of elevations of Reno and Yucca. Another reason, as given by Houghton et al. (1975), is that a relatively warm, dry area exists to the east of the Sierra Nevada mountains because prevailing westerly winds force air upwards on the windward side of the mountains causing condensation of water vapor and, ultimately, precipitation. The drier air then descends and warms in the lee of the mountains. This so-called "banana belt" extends from Las Vegas to Reno and includes Yucca.

TABLE 1

CLIMATOLOGICAL SUMMARY FOR YUCCA FLAT

10-YEAR CLIMATOLOGICAL SUMMARY (1962-1971)

YUCCA FLAT, NEVADA – NEVADA TEST SITE

LATITUDE 36° 57' N
LONGITUDE 116° 03' W
ELEVATION 3,924 Feet

NEVADA COORDINATE SYSTEM (Central)
E680,875
N803,600

MONTH	TEMPERATURE (°F) Averages: Daily Maximum	Daily Minimum	Monthly	Extremes: Highest	Year	Lowest	Year	DEGREE DAYS (Base 65°): Heating	Cooling	PRECIPITATION (Inches): Average	Greatest Monthly	Year	Least Monthly	Year	Greatest Daily	Year	Snow: Average	Greatest Monthly	Year	Greatest Daily	Year
JAN	52.1	20.8	36.5	73	1971	-2	1970	877	0	.53	4.02	1969	T	1971#	1.25	1969	0.9	4.3	1962	4.3	1962
FEB	56.7	25.8	41.3	77	1963	5	1971#	662	0	.84	3.55	1969	T	1967#	1.16	1969	1.9	17.4	1969	6.2	1969
MAR	60.9	27.7	44.3	87	1966	9	1969	634	0	.29	.60	1969	.02	1966	.38	1969	2.0	7.5	1969	4.5	1969
APR	67.8	34.4	51.1	89	1962	13	1966	411	1	.45	2.57	1965	T	1962	1.08	1965	0.7	3.0	1964	3.0	1964
MAY	78.9	43.5	61.2	97	1967	25	1967	147	38	.24	1.62	1971	T	1970#	.86	1971	0	T	1964	T	1964
JUN	87.6	49.9	68.8	107	1970	29	1971#	35	154	.21	1.13	1969	T	1971	.45	1969	0	0		0	
JUL	96.1	57.0	76.6	107	1967	40	1964#	0	366	.52	1.34	1966	0	1963	.77	1969	0	0		0	
AUG	95.0	58.1	76.6	107	1970	39	1968	1	368	.34	1.04	1965	0	1962	.35	1971#	0	0		0	
SEP	86.4	46.7	66.5	105	1971	25	1971	51	103	.68	2.38	1969	0	1966#	2.13	1969	0	0		0	
OCT	76.1	36.9	56.5	94	1964#	12	1971	266	9	.13	.45	1969	0	1967#	.42	1969	0	T	1971	T	1971
NOV	61.8	27.6	44.7	82	1962	13	1966	602	0	.71	3.02	1965	0	1962	1.10	1970	0.5	4.8	1964	2.3	1964
DEC	50.7	19.9	35.3	70	1964	-14	1967	914	0	.79	2.66	1965	T	1969#	1.31	1965	2.3	9.9	1971	7.4	1971
ANN	72.5	37.4	54.9	107	AUG 1970#	-14	DEC 1967	4600	1039	5.73	4.02	JAN. 1969	0	SEP 1968#	2.13	SEP 1969	8.3	17.4	FEB 1969	7.4	DEC 1971

MONTH	RELATIVE HUMIDITY (%) Hour (Pacific Standard Time): 04	10	16	22	WIND (a) (Speeds in mph): Average Speed	Peak Speed	Year	Resultant (Dir/Spd): 23-02 PST	11-14 PST	STATION PRESSURE (Inches): Averages	Highest	Lowest	(b) Average Sky Cover Sunrise to Sunset	AVERAGE NUMBER OF DAYS — Sunrise to Sunset: Clear	Partly Cloudy	Cloudy	Precipitation: .01 inch or more	.10 inch or more	.50 inch or more	1.00 inch or more	1.0 inch or more of snow	Thunderstorms	Temperature Maximum: 90° F or more	32° F or less	Minimum: 32° F or less	0° F or less
JAN	67	49	35	60	6.6	58	1965	233/07	135/26	26.10	26.54	25.42	4.9	13	8	10	2	1	*	*	*	*	0	1	29	*
FEB	67	45	32	56	6.9	52	1967	275/1.1	118/27	26.05	26.42	25.56	5.0	11	8	9	3	2	*	*	1	0	0	*	23	0
MAR	58	31	23	44	8.4	55	1971	240/18	186/45	25.99	26.43	25.48	4.8	12	9	10	3	1	0	0	1	1	0	0	24	0
APR	52	27	21	38	9.1	60+	1970#	250/22	198/51	25.96	26.39	25.50	4.5	13	9	8	3	1	*	*	*	1	0	0	12	0
MAY	46	22	17	31	8.3	60+	1967	260/15	179/72	25.94	26.39	25.47	4.3	14	11	6	2	1	*	0	0	1	4	0	2	0
JUN	39	19	14	26	7.9	60+	1967	272/19	165/82	25.92	26.20	25.56	3.0	19	7	4	2	1	0	0	0	2	14	0	*	0
JUL	40	20	15	28	7.5	55	1971	278/09	185/120	26.00	26.19	25.68	3.0	19	9	3	3	2	*	0	0	4	29	0	0	0
AUG	44	23	16	30	6.7	60+	1968	222/15	182/120	26.00	26.22	25.71	3.0	20	8	3	3	1	0	0	0	4	27	0	0	0
SEP	43	21	17	32	7.0	52	1970	281/13	163/64	26.00	26.36	25.56	2.1	22	6	2	2	1	1	*	0	2	11	0	1	0
OCT	46	24	19	36	6.8	60	1971	286/13	138/37	26.06	26.40	25.52	2.9	20	7	4	1	1	0	0	0	*	2	0	9	0
NOV	61	39	31	52	6.1	51	1970	234/12	152/41	26.08	26.58	25.64	4.8	13	7	10	3	2	*	*	*	*	0	0	23	0
DEC	68	50	41	64	6.6	53	1970	288/19	109/10	26.07	26.59	25.49	4.6	14	8	9	3	1	1	*	1	*	0	1	29	1
ANN	53	31	23	41	7.4	60+	APR 1970#	—	—	26.01	26.59	25.42	3.9	190	97	78	30	14	3	1	3	14	87	2	152	1

* One or more occurrences during the period of record but average less than 0.5 day.

\# most recent of multiple occurrences

\+ trace, an amount to small to measure

(a) Average and peak speed are for the period starting with December 1964. The direction of the resultant wind are from a summary covering the period December 1964 through May 1969.

(b) Sky cover is expressed in the range from 0 for no clouds to 10 when the sky is completely covered with clouds. Clear, partly coudy and cloudy are defined as average daytime cloudiness of 0-3, 4-7 and 8-10 tenths, respectively.

Source: Air Resources Laboratory, Las Vegas, NV.

TABLE 2: CLIMATOLOGICAL SUMMARIES FOR ELKO AND ELY

LATITUDE 40° 50' N
LONGITUDE 115° 47' W
ELEVATION (ground) 5075 Feet

NORMALS, MEANS, AND EXTREMES

ELKO, NEVADA
MUNICIPAL AIRPORT

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days
(a)	(b)	(b)	(b)	27		27		(b)
J	34.5	9.2	21.9	58	1953	-43	1937	1336
F	40.2	16.6	28.4	67	1951	-37	1933	1025
M	49.3	22.8	36.1	73	1943	- 9	1952	896
A	60.4	28.7	44.6	82	1946+	- 2	1936	612
M	70.5	35.4	53.0	92	1954+	15	1953	370
J	79.0	41.5	60.3	101	1954	23	1954+	183
J	91.3	49.1	70.2	104	1934+	30	1932	6
A	89.1	46.0	67.6	103	1940	24	1932	28
S	79.3	36.3	57.8	99	1950	9	1934	229
O	65.8	28.9	47.4	88	1943	9	1954+	546
N	48.1	19.8	34.5	72	1949+	-12	1931	915
D	38.9	14.9	26.9	64	1940	-36	1932	1181
Yr.	62.3	29.1	45.7	104	JUL. 1934+	-43	JAN. 1937	7336

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	27		27		27		27	27		9	
J	1.07	3.35	1956	0.15	1931	1.27	1951	10.7	27.4	1950	16.7	1951
F	0.85	2.93	1932	0.08	1931	0.89	1936	7.0	26.1	1932	9.1	1949
M	0.69	1.82	1957	0.10	1956	0.82	1954	4.7	17.0	1954	11.0	1954
A	0.83	2.03	1935	0.10	1949	1.10	1943	1.3	7.1	1950	8.1	1950
M	0.85	2.41	1957	T	1954	0.91	1935	0.3	2.8	1955	2.8	1955
J	0.70	2.82	1944	0.01	1951	0.86	1932	T	T	1957+	T	1957+
J	0.37	2.35	1950	T	1940	1.04	1950	0.0	0.0		0.0	
A	0.29	2.73	1941	T	1956+	1.03	1941	0.0	0.0		0.0	
S	0.39	1.11	1948	T	1951+	0.52	1949	0.1	1.9	1948	T	1952+
O	0.81	2.76	1938	T	1952	1.31	1938	0.5	4.7	1946	1.0	1956
N	0.93	2.77	1942	0.04	1933	1.31	1950	4.2	16.6	1944	5.1	1957
D	1.05	2.80	1955	0.13	1930	1.62	1950	7.5	31.2	1955	9.2	1955
Yr.	9.13	3.35	JAN. 1956	T	AUG. 1954+	1.62	DEC. 1950	36.3	31.2	DEC. 1955	16.7	JAN. 1951

Month	Relative humidity: 4:00 A. PST	10:00 A. PST	4:00 P. PST	10:00 P. PST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover, sunrise to sunset
(a)	10	10	10	10	9	17					9
J	80	72	70	80	5.7	SW					7.1
F	82	65	58	79	5.9	SW					6.1
M	82	55	50	73	7.1	W					6.6
A	78	41	35	63	7.3	W					6.2
M	80	41	36	65	7.0	SW					5.9
J	72	32	24	51	7.1	SW					3.8
J	59	25	20	30	6.3	SW					3.0
A	54	24	18	36	5.9	SW					2.7
S	58	29	21	43	5.2	E					2.6
O	70	40	31	58	5.1	SW					4.3
N	78	58	51	73	4.4	SW					5.4
D	81	73	70	81	4.8	SW					6.8
Yr.	73	46	40	63	6.0	SW					5.0

Month	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below
(a)	27	27	27	27	9	9	9	27	27	27	27
J	7	8	16	9	4	*	1	0	11	30	9
F	7	7	14	9	2	0	1	0	6	27	5
M	6	9	16	8	2	*	*	0	1	29	*
A	7	9	14	7	*	1	0	0	*	22	*
M	8	11	12	8	*	4	*	*	0	11	0
J	13	10	7	5	0	3	*	4	0	3	0
J	18	10	3	3	0	6	*	20	0	*	0
A	20	8	3	3	0	4	0	16	0	1	0
S	20	6	4	3	0	3	*	3	0	10	0
O	13	9	9	6	*	1	*	0	*	23	0
N	9	8	13	8	1	*	*	0	3	28	1
D	7	7	17	9	3	*	1	0	8	30	5
Yr.	135	102	128	78	12	22	5	43	29	214	20

Means and extremes in the above table are from the existing or comparable location(s). Annual extremes have been exceeded at prior locations as follows: Highest temperature 107 in July 1890; maximum monthly precipitation 6.30 in January 1903; minimum monthly precipitation 0.00 in November 1929 and earlier date(s); maximum precipitation in 24 hours 3.30 in April 1925; maximum monthly snowfall 48.5 in January 1916.

LATITUDE 39° 17' N
LONGITUDE 114° 51' W
ELEVATION (ground) 6257 Feet

ELY, NEVADA
YELLAND FIELD

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days
(a)	(b)	(b)	(b)	19		19		(b)
J	37.4	8.6	23.0	66	1951	-27	1949	1302
F	41.4	14.8	28.1	65	1951	-25	1949	1033
M	49.3	21.2	35.3	69	1956+	-13	1952	921
A	58.1	28.2	43.7	77	1950	6	1953+	639
M	69.2	34.2	51.7	87	1954+	7	1950	418
J	78.9	40.3	59.6	99	1954	19	1950	200
J	88.6	48.1	68.4	96	1954+	30	1948	23
A	86.2	46.3	66.3	93	1954+	27	1947	44
S	77.4	38.1	57.8	93	1950	16	1948	228
O	64.4	29.3	46.9	81	1952+	8	1942	561
N	51.1	19.3	35.2	71	1956+	- 9	1955	894
D	41.0	12.8	26.9	65	1939	-23	1951	1181
Yr.	62.0	28.4	45.2	99	JUN. 1954	-27	JAN. 1949	7443

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	19		19		19		19	19		19	
J	0.94	1.92	1953	T	1948	0.95	1952	9.1	10.5	1957	13.1	1943
F	0.90	1.12	1940	0.08	1951+	0.80	1956	6.4	15.8	1956	10.4	1956
M	1.29	2.40	1952	0.07	1955	0.86	1954	8.8	23.5	1952	10.6	1954
A	1.20	2.63	1951	0.16	1950	1.04	1947	3.8	12.2	1941	7.3	1956
M	1.15	2.86	1957	T	1949	1.42	1958	1.3	7.5	1950	4.7	1956
J	0.50	2.39	1945	T	1944+	1.09	1945	0.4	5.0	1939	5.6	1939
J	0.55	1.53	1941	T	1948+	1.22	1952	0.0	0.0		0.0	
A	0.89	1.58	1945	T	1954+	0.69	1957	0.0	0.0		0.0	
S	0.66	2.07	1940	T	1953+	0.95	1947	T	T	1953+	T	1955+
O	0.82	1.76	1941	0.00	1952	0.94	1930	1.0	7.8	1954	7.3	1954
N	0.69	1.60	1946+	0.04	1956	0.78	1954	4.5	15.3	1946	8.2	1951
D	0.88	1.68	1938	0.06	1954+	0.76	1951	6.7	10.9	1949	7.9	1958
Yr.	10.82	2.86	MAY 1957	0.00	OCT 1952	1.42	MAY 1958	42.8	23.5	MAR. 1952	13.1	JAN. 1943

Month	Relative humidity: 4:00 A. PST	10:00 A. PST	4:00 P. PST	10:00 P. PST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover, sunrise to sunset
(a)	5	5	5	5	19	5	14	14		19	14
J	74	61	61	72	11.3	S	66	SE	1952	61	6.1
F	73	54	50	71	11.6	S	54	S	1954	65	5.9
M	69	43	38	64	11.8	S	59	SE	1951	66	6.2
A	68	38	31	54	11.8	S	60	S	1952	64	5.0
M	67	34	32	57	11.6	S	74	S	1946	65	5.0
J	56	25	20	40	11.7	S	63	SW	1953	77	4.1
J	62	23	24	41	11.0	S	50	S	1957	79	3.8
A	60	23	21	37	11.4	S	57	S	1954	80	3.3
S	48	23	18	37	11.1	S	57	S	1953	81	2.9
O	64	30	32	50	11.0	S	65	S	1950	72	4.2
N	72	49	45	69	10.9	S	61	S	1954	66	5.6
D	74	65	64	71	10.9	S	61	SE	1952	60	6.0
Yr.	64	38	36	56	11.3	S	74	S	MAY 1946	70	5.0

Month	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below
(a)	19	19	19	19	19	19	19	19	19	19	19
J	9	8	14	7	2	*	*	0	10	31	8
F	8	8	14	7	2	*	*	0	7	28	6
M	8	9	14	8	3	*	*	0	3	30	1
A	8	9	13	7	1	2	*	0	*	23	0
M	8	11	12	7	*	4	*	0	*	13	0
J	15	9	6	4	*	4	0	1	0	4	0
J	18	11	5	5	0	8	0	8	0	*	0
A	16	11	4	4	0	7	0	4	0	*	0
S	18	8	4	3	0	3	0	1	0	6	0
O	14	9	8	5	*	2	*	0	*	22	0
N	11	7	12	6	1	*	*	0	3	28	2
D	9	8	14	6	3	*	*	0	6	30	4
Yr.	130	108	120	68	12	30	*	14	29	217	21

Source: Brown (1960)

TABLE 3: CLIMATOLOGICAL SUMMARIES FOR LAS VEGAS AND RENO

LATITUDE 36° 05' N
LONGITUDE 115° 10' W
ELEVATION (ground) 2162 Feet

NORMALS, MEANS, AND EXTREMES

LAS VEGAS, NEVADA
MC CARRAN FIELD

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	21		21		(b)	(b)	21		21		21	
J	56.4	33.0	44.2	76	1948	8	1937	663	0.44	2.41	1949	0.00	1942	1.01	1952
F	62.1	38.4	50.4	82	1954	17	1939+	423	0.56	1.90	1941	0.00	1954+	1.01	1940
M	68.8	44.0	56.5	88	1940	19	1939	266	0.38	1.63	1941	0.00	1956	1.14	1952
A	78.6	52.6	65.6	99	1946+	31	1955+	92	0.24	1.66	1941	T	1954+	0.66	1941
M	87.9	60.3	74.1	100	1951	38	1942	0	0.16	0.29	1949	0.00	1954+	0.23	1949
J	98.9	68.2	83.6	116	1940	48	1939	0	0.13	0.36	1955	0.00	1936+	0.30	1955
J	105.4	75.6	90.5	117	1942	56	1940+	0	0.46	1.60	1948	0.00	1949	1.22	1956
A	103.3	73.5	88.4	116	1940+	54	1937	0	0.53	2.59	1957	0.00	1956+	2.50	1957
S	96.2	65.1	80.7	113	1950	43	1948	0	0.34	2.30	1939	0.00	1956+	1.12	1939
O	81.7	53.0	67.4	100	1947	32	1949+	81	0.32	1.13	1947+	0.00	1952+	1.08	1947
N	67.1	40.6	53.9	84	1941+	18	1938	344	0.22	1.04	1946	0.00	1956+	0.56	1946
D	58.1	36.6	46.6	78	1940	14	1945+	564	0.50	1.78	1940	0.00	1956	0.87	1947
Yr.	80.3	53.3	66.8	117	JUL. 1942	8	JAN. 1937	2428	4.38	..30	SEP. 1939	0.00	DEC. 1956+	2.50	AUG. 1957

Month	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: 4:00 A. PST	10:00 A. PST	4:00 P. PST	10:00 P. PST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year
(a)	21	21		21		17	17	17	17	9	9			
J	1.0	16.7	1949	8.0	1949	61	41	34	54	6.5	W			
F	0.2	4.1	1939	4.1	1939	54	33	24	44	7.6	W			
M	T	T	1952+	T	1952+	48	25	19	35	9.7	SW			
A	0.0	0.0		0.0		40	21	16	29	10.1	SW			
M	0.0	0.0		0.0		31	17	12	22	10.6	SW			
J	0.0	0.0		0.0		28	13	10	16	10.6	SW			
J	0.0	0.0		0.0		31	19	14	24	9.5	SW			
A	0.0	0.0		0.0		34	20	16	26	9.4	SW			
S	0.0	0.0		0.0		29	17	12	22	8.2	SW			
O	T	T	1956	T	1956	41	24	19	32	7.4	SW			
N	T	T	1953+	T	1953+	44	28	28	41	6.2	W			
D	T	T	1941+	T	1941+	57	37	31	48	6.0	W			
Yr.	1.2	16.7	JAN. 1949	8.0	JAN. 1949	41	26	19	32	8.8	SW			

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below
(a)	17	9	21	21	21	21	21	21	21	21	21	21	21
J	74	5.4	13	6	12	3	*	*	*	0	*	19	0
F	77	4.0	12	7	9	3	*	*	0	0	0	11	0
M	79	4.1	14	9	8	3	0	*	0	0	0	3	0
A	80	3.8	14	9	7	2	0	1	0	4	0	*	0
M	86	3.3	18	9	4	1	0	1	0	17	0	0	0
J	92	1.6	23	5	2	*	0	1	0	26	0	0	0
J	85	2.8	21	7	3	3	0	5	0	31	0	0	0
A	86	2.1	21	7	3	2	0	3	0	30	0	0	0
S	92	1.3	23	5	2	1	0	1	0	25	0	0	0
O	84	2.3	21	6	4	2	0	1	0	7	0	*	0
N	82	3.3	17	8	5	2	0	*	*	0	0	8	0
D	73	4.6	13	7	11	3	0	*	*	0	0	17	0
Yr.	83	3.2	210	88	70	25	*	13	*	140	*	60	0

LATITUDE 39° 30' N
LONGITUDE 119° 47' W
ELEVATION (ground) 4397 FEET

RENO, NEVADA
MUNICIPAL AIRPORT

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	16		16		(b)	(b)	16		16		16	
J	45.7	16.6	31.2	68	1948+	-16	1949+	1048	1.04	4.09	1943	0.01	1948	2.37	1943
F	50.9	21.6	36.3	70	1950	- 9	1956	804	1.05	1.88	1945	0.22	1953	1.10	1945
M	56.5	24.6	40.6	77	1947	- 2	1949	756	0.70	2.02	1952	0.05	1956	1.21	1943
A	65.8	30.3	47.7	87	1946	13	1956	519	0.46	1.63	1952	0.03	1947	1.60	1952
M	73.2	37.3	55.3	94	1954	20	1950+	310	0.48	1.64	1949	T	1943	0.80	1949
J	80.8	42.1	61.5	100	1954+	25	1954	165	0.42	0.97	1945	0.00	1946	0.66	1945
J	91.8	47.3	69.6	104	1945	35	1955	27	0.23	0.84	1946	0.00	1951+	0.80	1949
A	90.1	44.7	67.4	102	1946	32	1943	61	0.23	0.23	1945	0.00	1957+	0.17	1945
S	82.3	38.7	60.5	101	1950	21	1950	165	0.22	1.02	1950	0.00	1954+	0.80	1950
O	70.2	31.2	50.7	88	1947	13	1946	443	0.55	2.14	1945	T	1954	1.27	1945
N	57.1	23.3	40.2	77	1949	7	1948	744	0.64	2.04	1946	T	1956+	1.23	1949
D	47.2	19.1	33.2	69	1940	- 5	1949	986	0.94	5.25	1955	0.01	1947	2.16	1955
YR.	67.6	31.4	49.5	104	JUL. 1945	-16	JAN. 1949+	6036	6.96	5.25	DEC. 1955	0.00	AUG. 1957+	2.37	JAN. 1943

Month	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: 4:00 A. PST	10:00 A. PST	4:00 P. PST	10:00 P. PST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year
(a)	16	16		16		10	10	10	10	13	13	16	16	
J	7.0	20.0	1956	12.0	1956	81	67	54	77	6.6	S	66	SW	1956
F	4.2	13.8	1946	6.2	1943	81	60	51	75	6.4	S	66	SW	1954+
M	5.0	29.0	1952	16.9	1952	77	45	35	64	7.9	WNW	68	S	1951
A	0.6	3.0	1953	2.0	1953	73	37	30	58	8.2	WNW	66	SW	1945
M	0.2	2.5	1955	2.5	1955	76	34	29	56	7.8	WNW	63	SW	1945
J	T	T	1954+	T	1954+	76	31	24	50	7.6	WNW	66	S	1949
J	0.0	0.0		0.0		72	25	19	43	6.8	WNW	34	S	1956
A	0.0	0.0		0.0		74	26	18	44	6.5	WNW	57	S	1951
S	T	T	1952+	T	1952+	76	31	21	55	5.5	WNW	48	S	1955
O	0.3	2.0	1957	2.0	1957	79	43	31	66	5.7	WNW	66	S	1947
N	1.5	5.4	1946	3.0	1947+	81	54	43	75	5.1	S	59	SW	1945
D	4.0	1.2	1955	5.2	1943	83	67	58	78	5.2	S	72	S	1949
YR.	22.8	29.0	MAR. 1952	16.9	MAR. 1952	77	43	34	62	6.6	WNW	72	S	DEC. 1949

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below
(a)	13	16	16	16	16	16	16	16	16	16	16	16	16
J	65	6.0	10	8	13	6	2	0	2	0	4	28	3
F	68	5.7	9	8	11	6	2	*	1	0	1	26	1
M	68	5.6	10	9	12	6	1	0	*	0	*	28	*
A	74	5.4	10	10	10	4	*	1	*	0	0	19	0
M	75	4.9	12	10	9	4	*	2	*	1	0	7	0
J	81	3.2	18	8	4	3	0	2	0	4	0	2	0
J	91	1.9	25	5	1	2	0	4	*	20	0	0	0
A	92	1.7	25	4	2	1	0	2	*	15	0	*	0
S	90	2.2	22	6	2	2	0	1	*	7	0	3	0
O	77	4.0	16	7	8	3	*	1	*	0	0	19	0
N	69	5.3	11	8	11	4	1	0	1	0	0	27	0
D	58	6.5	7	8	16	6	1	0	4	0	2	29	*
YR.	77	4.4	175	91	99	47	7	13	8	47	7	188	4

Means and extremes in the above table are from the existing or comparable location(s). Annual extremes have been exceeded at prior locations as follows: Highest temperature 106 in July 1931; lowest temperature -19 in January 1890; maximum monthly precipitation 6.76 in January 1916; maximum precipitation in 24 hours 2.71 in January 1903; maximum monthly snowfall 65.7 in January 1916; maximum snowfall in 24 hours 22.5 in January 1916.

Source: Brown (1960)

TABLE 4: CLIMATOLOGICAL SUMMARY FOR WINNEMUCCA

LATITUDE 40° 54' N
LONGITUDE 117° 48' W
ELEVATION (ground) 4299 Feet

NORMALS, MEANS, AND EXTREMES

WINNEMUCCA, NEVADA
AIRPORT

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days
(a)	(b)	(b)	(b)	77		77		(b)
J	37.4	18.2	27.8	64	1953	-36	1937	1153
F	44.0	24.9	34.5	69	1951+	-26	1933	854
M	50.6	28.2	39.4	82	1879	- 3	1954+	794
A	61.4	32.2	46.8	88	1946	9	1953	546
M	71.3	40.4	55.9	98	1910	12	1953	299
J	80.1	47.9	64.0	104	1954+	23	1954	111
J	92.0	56.4	74.2	108	1931	29	1955	0
A	88.4	51.0	69.7	106	1940	26	1887	17
S	77.4	42.4	59.9	103	1950	16	1895	180
O	64.5	32.7	48.6	90	1943	9	1936	508
N	50.3	24.8	37.6	75	1942	- 9	1890	822
D	39.5	20.5	30.0	70	1939	-27	1924	1085
Yr	63.1	35.0	49.1	108	JUL. 1931	-36	JAN. 1937	6369

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	87		87		79		79	79		79	
J	0.96	3.06	1881	0.00	1872	1.45	1881	8.0	33.0	1890	18.2	1890
F	1.01	2.75	1945	T	1889	1.44	1945	4.9	21.7	1922	9.2	1937
M	0.86	5.23	1884	0.00	1873	0.97	1920	4.2	23.4	1952	8.7	1952
A	0.83	3.34	1935	0.06	1921	0.92	1913	1.5	9.8	1896	7.0	1915
M	0.84	2.82	1957	0.02	1871	1.44	1917	0.5	8.4	1896	4.0	1927
J	0.79	2.70	1946	0.00	1919+	1.56	1914	0.1	3.1	1908	3.1	1908
J	0.31	1.53	1913	0.00	1947+	0.80	1938	T	T	1902	T	1902
A	0.18	1.16	1901	0.00	1937+	0.89	1901	0.0	0.0		0.0	
S	0.34	1.53	1940+	0.00	1926+	1.00	1906	T	T	1952+	T	1952+
O	0.79	2.93	1946	0.00	1880	1.64	1951	0.5	10.0	1899	6.0	1899
N	0.84	3.78	1885	0.00	1929+	1.58	1950	2.1	11.3	1947	7.8	1930
D	1.00	3.40	1889	T	1887	1.22	1942	6.0	26.0	1889	10.8	1937
Yr	8.75	5.23	MAR. 1884	0.00	JUL. 1947+	1.64	OCT. 1951	27.8	33.0	JAN. 1890	18.2	JAN. 1890

Month	Relative humidity: 4:00 A. PST	10:00 A. PST	4:00 P. PST	10:00 P. PST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset
(a)	68	40	68	21	77	40	42	42		31	27
J	84	66	65	80	8.1	NE	56	W	1956	53	6.4
F	81	59	56	75	8.6	SW	46	SW	1946+	57	6.3
M	77	46	42	67	8.8	SW	63	W	1955	63	6.0
A	70	37	32	57	8.6	SW	45	W	1955+	70	5.9
M	69	32	29	53	8.1	SW	61	N	1951	74	5.3
J	61	28	24	46	7.9	SW	53	W	1950	83	4.0
J	48	20	17	32	7.5	SW	56	W	1957	89	2.4
A	47	20	18	30	6.9	SW	60	S	1951	90	2.2
S	55	26	23	40	7.0	NE	57	W	1952	86	2.4
O	66	37	42	59	7.1	NE	50	W	1950	74	4.1
N	75	50	48	72	7.5	NE	59	SW	1942	62	5.3
D	81	69	64	80	7.5	NE	69	E	1941	53	6.5
Yr	68	41	38	38	7.8	SW	69	E	DEC. 1941	73	4.7

Month	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 90° and above	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below
(a)	77	77	77	77	79	79	79	79	79	79	79
J	9	9	13	9	2	0	*	0	7	28	4
F	8	8	12	9	2	*	0	0	3	24	1
M	10	9	12	8	1	*	*	0	1	25	*
A	10	9	11	7	*	1	*	0	*	15	0
M	12	10	9	7	*	2	*	*	0	5	0
J	16	9	5	5	*	2	*	4	0	1	0
J	23	6	2	2	0	3	0	18	0	*	0
A	23	6	2	2	0	2	0	16	0	*	0
S	20	6	4	3	0	1	*	3	0	4	0
O	17	7	7	5	*	*	*	*	0	17	0
N	12	8	10	6	1	*	*	0	1	25	*
D	9	8	14	8	2	*	*	0	4	28	2
Yr	169	95	101	71	8	12	1	41	16	172	7

REFERENCE NOTES APPLYING TO ALL "NORMALS, MEANS, AND EXTREMES" TABLES.

(a) Length of record, years.
(b) Normal values are based on the period 1921-1950, and are means adjusted to represent observations taken at the present standard location.
* Less than one-half.

\- No record.
† Airport data.
‡ City Office data.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3 tenths; partly cloudy days on 4-7 tenths; and cloudy days on 8-10 tenths. Monthly degree day totals are the sum of the negative departures of average daily temperatures from 65°F. Sleet was included in snowfall totals beginning with July 1948. Heavy fog also includes data referred to at various times in the past as "Dense" or "Thick". The upper visibility limit for heavy fog is 1/4 mile. Data in these tables are based on records through 1957.

Source: Brown (1960)

Unlike Reno, which has a definite winter precipitation maximum associated with storms coming from the northern Pacific Ocean, Yucca shows a tendency for two maxima: one in the winter and one in the late summer. The summer maximum is caused by thunderstorms in warm moist air from the south. The data summary from Yucca, however, is rather short, and the monthly averages are influenced by large amounts of precipitation from a few individual storms. Yucca is close to the edge of an ill-defined boundary between areas of maximum summer and maximum winter precipitation. Houghton (1969) includes all of southern Nevada in the winter maximum area, but later analysis by Houghton et al. (1975) puts the boundary between Las Vegas and Yucca. The closest station outside NTS with climatological precipitation data is at Beatty, about 65 km to the west at about an elevation near 1,000 m MSL. Quiring (1967) has compared data from Jackass Flats to that at Beatty for the years 1958 to 1966 and to the normal amount for Beatty. These are given in Table 5. The short records have similarities between themselves but are different from the longer record, as is shown by the correlation coefficients between the samples. In these years there was a tendency for a summer maximum that was not in the normal data. This shows that short term precipitation data must be viewed with some caution from a climatological point-of-view.

3. NTS Meteorogolocal Stations

NTS meteorological stations have been distributed throughout the area with a number in support of NRDS at Jackass Flats. These last stations are of particular importance for this study, although the lengths of records are not as long as would be desirable for a good climatological data base. Wind and temperature data are available for approximately ten years at NRDS while some

TABLE 5

COMPARISON OF JACKASS FLATS AND BEATTY PRECIPITATION

Station	Precipitation in Inches												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Jackass Flat 1958-65	0.26	0.42	0.18	0.39	0.13	0.08	0.16	0.26	0.51	0.24	0.60	0.64	3.87
Beatty 1958-65	0.38	0.64	0.27	0.56	0.12	0.22	0.12	0.28	0.41	0.12	0.73	0.42	4.27
Beatty - Normal	0.60	0.70	0.48	0.47	0.23	0.09	0.20	0.20	0.19	0.30	0.43	0.58	4.47

Correlation Coefficients

Jackass Flat (1958-65) - Beatty (1958-65)	0.71
Jackass Flat (1958-65) - Beatty (Normal)	0.45
Beatty (1958-65) - Beatty (Normal)	0.57

precipitation data cover twenty years. Several summaries (U.S. Weather Bureau, 1959; Richter, 1960; Quiring, 1967, 1968, 1973, 1979) have been made with most emphasis on the early data. Data collected throughout NTS are stored on magnetic tape and punched cards at the DOE Las Vegas Offices on the Meteorological Data Storage and Retrieval (MDSAR) system. Within the last three years there have been some meteorological data collected in southwest NTS from a mechanical weather station in Jackass Flats, a weather station near the MX missile test area between Lathrop Wells and Jackass Flats, and a MEDA weather station near the southern boundary of NTS along the road to Lathrup Wells. The data from Jackass Flats have not been reduced from strip charts, and the MEDA data are in printed form only. There have also been some precipitation data collected throughout NTS and in the old NRDS by Dr. Richard French of the Desert Research Institute.

The locations of a selected set of stations are shown in Figure 3. Quiring (1971) has compiled a list of all NTS stations operating between 1956 and 1971. This list has not been revised to reflect changes since 1971. For purposes of determining the climatology of the region, it is not necessary to look at all the sites, but rather at a representative few.

Quiring (1968) provides the best climatological summary with detailed studies at four stations for winds and temperature and 24 stations for precipitation. Surface and upper air observations from the Yucca Weather Station were also included. A weakness of Quiring's report is that it covered a period of less than ten years, and planned updates were never completed. The four stations chosen as representative of four different environments were Area 12 on an exposed high plateau, BJY near the center of the closed Yucca Flat basin,

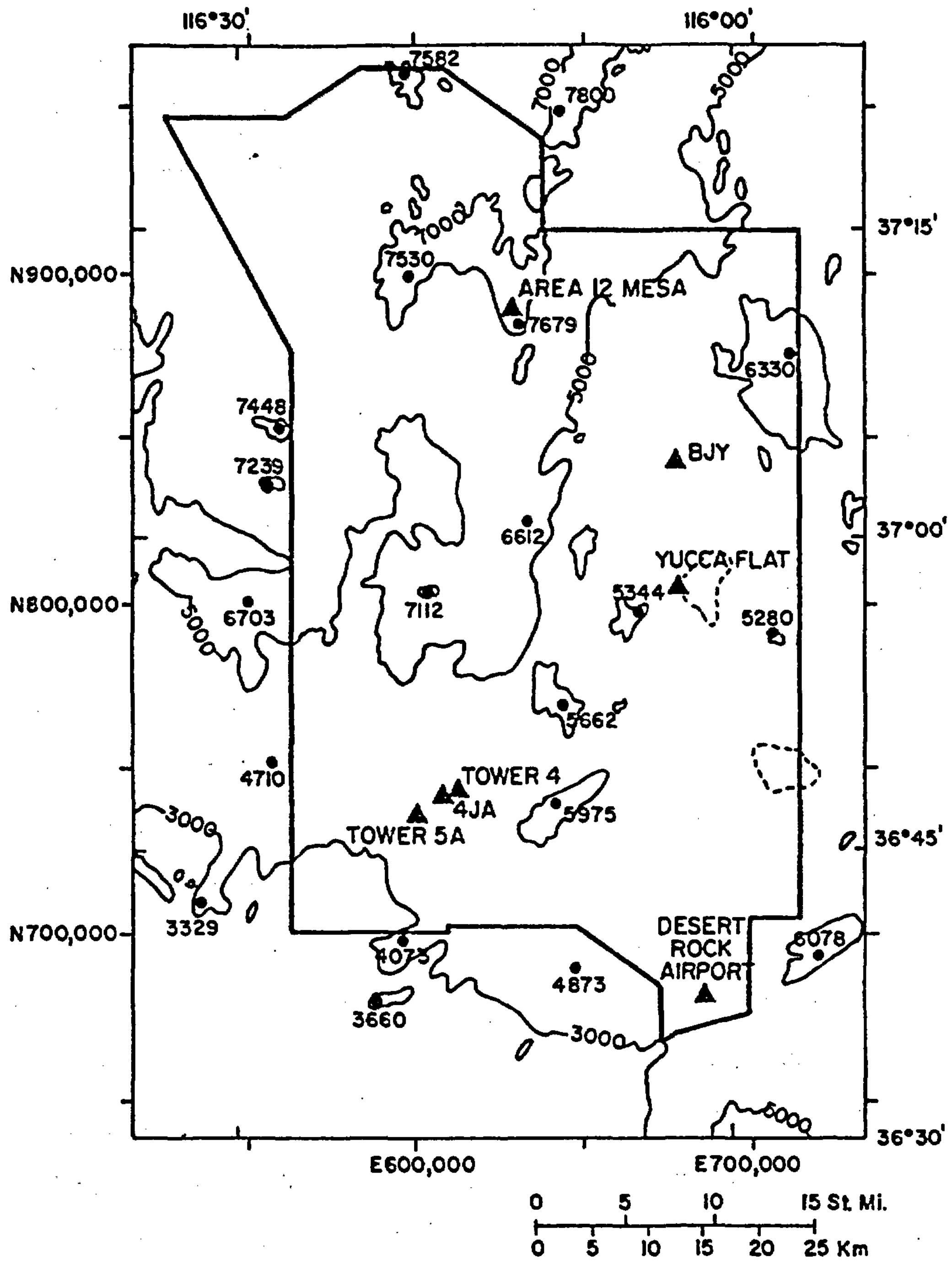

Figure 3: Selected Meteorological Stations in the Nevada Test Site

Tower 4 on the slope of Jackass Flats, and Tower 5A atop an isolated hill in Jackass Flats. Although the Area 12 station might be representative of the higher terrain around Jackass Flats; but at an elevation of 2,280 m MSL, it is 300 to 1,200 m higher than the mountains of southwest NTS.

Quiring's presentation is interesting and useful for making qualitative conclusions about the climatology. The actual numbers that were used to construct the figures are available in Las Vegas and would be necessary to apply these data to dispersion problems. Curves of the hourly wind direction frequencies, the hourly wind speeds, and hourly temperature distributions by percentiles are presented for each month. The wind direction distributions are of particular interest. All stations show a tendency for the wind to be either northerly or southerly. Stations at lower elevations (BJY, Tower 4, Tower 5A) have a predominantly diurnal wind oscillation with northerly winds at night and southerly winds in the day during the entire year, although northerly winds frequently persist all day during winter. These stations have nocturnal winds directed along the local terrain slope while daytime wind directions are more nearly the same at all stations, following the general circulation. The Area 12 Mesa station has a small discernable diurnal fluctuation, its winds are mostly either northerly or southwesterly throughout the day. Winter has slightly more northerly winds while summer has much more southwesterly winds.

Averaged speeds from the four sites show daily maxima in mid-afternoon and annual maxima in the months of April and May. These maximum values are similar for all sites with Tower 5A being the highest at 20 mph. All sites have minimum speeds around the time of sunrise, although the minima are more pronounced at lower sites than at Area 12 Mesa, where differences between daytime and nighttime speeds are small.

Temperature distributions show some differences that can be attributed to location. Area 12 Mesa has lower temperatures than the other sites because of its higher elevation. It also has a smaller diurnal temperature range than the other sites. At BJY there is a large diurnal fluctuations and strong radiational cooling at night with minimum temperatures that sometimes fall below those of Area 12 Mesa. While Tower 4 does not show temperatures as low as BJY, it does show similar high temperatures, indicating a more persistent air drainage there. Tower 5A shows high temperatures similar to Tower 4 but has a smaller diurnal range of temperature. Being situated on a hill in the middle of the sloping terrain places it in warmer air than at Tower 4.

4. NTS Precipitation

Precipitation over NTS and the rest of southern Nevada is governed by two major features of the atmospheric circulation. During winter and spring months, storms bring moisture from the north Pacific into the western United States. While much precipitation falls over the Sierra Nevada range in the form of snow, some falls in the Great Basin also. The amount of winter precipitation in southern Nevada is dependent on the location of the storm tracks. If they happen to be further north, there will be less precipitation that particular year. Since the amounts of precipitation are generally small, there can be large proportionate variations in amount from year to year.

The other major period of time when precipitation is likely to fall over southern Nevada is during the summer, when a large high pressure area prevails over the southern United States causing southeasterly or southwesterly winds to blow into southern Nevada. NTS is near the northwestern edge of the areal extent of the monsoon type thunderstorms associated with the southerly winds that affect the Southwest in the summer. Southeasterly winds bring moisture from the Gulf of Mexico resulting in localized thunderstorms. Southwesterly winds bring in more stable air with less likelihood of thunderstorms. Again there can be a great vagary in the amounts and locations of the precipitation from thunderstorms.

A less common occurrence, but one which can cause copious amounts of precipitation over a wide area is the tropical storm which moves off the west coast of Mexico. These usually occur during September and early October.

Studies of NTS precipitation by Quiring (1968, 1979) show that the total NTS area is small enough that those synoptic features that cause precipitation will generally affect the entire NTS. This appears to be true in both the summer and winter. Then the only factor that will affect the amount of precipitation will be the amount of orographic lifting. Higher terrain will cause more uplift, more condensation, and thus more precipitation. As an example, Station 4JA (near Tower 4) with an elevation of 1,055 m MSL has had an average yearly rainfall over the last 20 years of 4.5 in. while Area 12 Mesa with an elevation of 2,280 m MSL has averaged 12.2 in. per year over the same period of time. In fact, Quiring (1979) found that elevation accounted for 95% of the variance in precipitation probability.

C. CLIMATOLOGICAL EXPECTATIONS

A nuclear waste repository requires stable conditions for some period of time following its last use to allow for decay of radionuclides. One aspect of the future that requires investigation is climate and its possible changes.

The future climate in the region surrounding NTS will depend on two general factors. The first is continuation of the natural fluctuations of the

Earth's climate as have been occurring since the Earth's beginning. These changes result from complex interactions among a number of variable processes. These variations include that of the Earth's orbit as first determined by Milankovitch (1930), changes in the sun's output as first measured by Abbot for short term variations and later postulated by Simpson (1934) for longer term variations, changes in volcanic activity, and changes in the ocean-ice-atmosphere system in several different ways. There is ongoing research to determine which variations have enough magnitude to cause the observed climatic variations and how the interactions do occur. If only natural phenomena were acting, the anticipated future climatic change over the next one million years would be similar to changes of the past one million years with a series of glacial and interglacial periods. For NTS this would mean a sequence of wet, possibly cooler years followed by dry, warm years with periods on the order of 25,000 years.

The second aspect of the future climate of the Earth is the contribution of human activity to the changes. The impacts of man on the climate occur in two basic groups: those that are planned and those that are inadvertent. In the former class are wind breaks to reduce evaporation and cloud seeding to increase precipitation. Also included are some proposals for large scale changes of global consequence such as making an inland sea in Africa, removing the Arctic sea ice, and diverting Canadian water to the southwestern United States. Inadvertent changes have for the most part been localized, e.g., changes from forests to crops and the creation of heat sources from urban areas and moisture sources from artificial lakes. In more recent history, however, there is evidence that changes in the atmosphere due to man are occurring over a more widespread area. A major cause appears to be the rapid spread of industrial growth and the attendant reliance on fossil fuels for energy. These changes include higher global background from concentrations of particles and of carbon dioxide and other gases in the air. The actual magnitude of these effects do not seem large enough at the present time to cause large changes in the Earth's climate, although future growth may begin to affect the climate.

One problem in determining the effects of man is that many of his activities are compensatory. Increased particulate loading, as discussed by Robinson (1975), would warm or cool the Earth depending on the types of particles. Increased CO_2 in the atmosphere will probably increase the temperature of the Earth (summarized by Keeling and Bacastow (1975)). At the present time, however, it is difficult to predict what man's ultimate effect will be, although projections of various effects tend towards exponential increase (Lamb, 1977). The net effect may be unstable, but it is likely that the increase in man-made heat alone will cause an increase in the Earth's temperature in the next 100 years. The subsequent climatic changes are complicated because of the interactions among the atmosphere, ice packs, land masses, and oceans. The ice pack would decrease with increased temperature and the extent of the oceans would increase. This could lead to more precipitation in some areas, but the higher temperature would also increase evaporation rates. Some areas might become drier because of the shifts of temperate zones towards the poles. Longer term effects are even more difficult to predict because of the lack of understanding of the interactions between the natural climatic variations and the effects of future human development.

D. SEVERE WEATHER

Instances of severe weather are important during constructional and operational phases of the repository, as these can present hazards to both personnel and machinery. The forms of severe weather that are important for this study are high winds, heavy precipitation, lightning associated with thunderstorms, and extreme summer temperatures.

1. <u>High Winds</u>

High winds in Nevada generally accompany winter Pacific storms in which air, after being forced up the western slope of the Sierra Nevada range, descends with high speed to the east of the range. These winds are similar to Chinook winds in the lee of the Rocky Mountains. Such high winds are most prevalent in northern Nevada, although they do occasionally occur in the south. It is more usual for high winds at Las Vegas to be associated with severe thunderstorms (Houghton et al., 1975). The fastest mile winds for selected return periods at the NWS stations in Nevada have been computed by Thomas et al. (1970). The fastest mile of wind is the highest average wind speed which occurs as one mile of air passes the station. Wind speed distribuitons were fit by lognormal distribution models which were extrapolated to a return period of 100 years. The results are shown in Table 6. Also in that table are the estimated fastest miles and highest gusts for NTS given by Quiring (1968) as taken from Thom (1959). The results from Thom (1959), while similar to those of the Thomas et al. (1970), have a somewhat higher 100-year wind. The maximum gust can be as much as 20 mph higher than the fastest mile wind. It must be pointed out that the wind distribution is dependent on site location. Data in Table 6 from Thomas et al. (1970) are based on measurements in valleys with anemometers 20 feet above the ground. The wind on an exposed ridge or mountain top can be much higher.

Other high winds that can occur are tornadoes. While these are rare in Nevada, they have been sighted. Houghton et al. (1975) have a list of the

TABLE 6

FASTEST MILE OF WIND IN MILES PER HOUR

STATION	RETURN PERIOD (years) 2	5	10	25	50	100
Elko[1]	50	57	60	65	68	70
Ely	47	53	56	60	62	65
Fallon	39	44	46	49	51	53
Las Vegas	52	59	62	66	69	72
Reno	51	60	66	72	76	81
Tonopah	52	56	58	60	62	64
Winnemucca	47	54	58	62	65	68
Nevada Test Site[2]						
Fastest mile	48	55	61	—	75	82
Highest gust	62	72	79	—	97	101

[1]Nevada weather stations from Thomas et al. (1970).

[2] Nevada Test Site from Thom (1959) in Quiring (1968).

sightings of tornadoes, water spouts and funnel clouds in Nevada from 1947 to 1974. Of the 51 sightings, the southern part of the state had four tornadoes, one water spout, and six funnel clouds. It is likely that there have been more occurrences which have not been seen due to the sparseness of population. Even so, the chance of a tornado at NTS is probably small, since meteorological conditions conducive to tornado formation (Fujitu, 1973) do not occur often over southern Nevada. McDonald et al. (1975) have determined the probabilities for tornadoes and straight winds at NTS. For a straight wind, exceedances of 100 mph and 300 mph have probabilities of 1.0×10^{-3} and 4.0×10^{-8} respectively. The same probabilities for tornado winds are 5.9×10^{-7} and 5.5×10^{-9}.

2. <u>Precipitation Extremes</u>

Large amounts of precipitation can occur in the presence of thunderstorms. The ground cannot absorb a large amount of water which leads to flash flooding in some low lying areas. The presence of dry stream beds or washes on NTS attests to the fact that flash floods have occurred in the past. The amount of rain that a particular area can handle is dependent on the terrain and soil type. A steep area will have faster run off than gradual terrain. Some soils are more porous to water than others although, in most cases, heavy precipitation would have little time to sink into the soil. To determine the actual flooding potential of NTS, one would have to look at a specific site with some representative precipitation rate and compute the amount of flooding. This has been done for the Tonopah Wash area by Christensen and Spahr (1980). As with the normal amounts of precipitation, the greatest 24-hour values also have an altitude dependence. Thompson et al. (1970) have determined the greatest 24-hour precipitation for various return periods for precipitation stations in Nevada.

Table 7 shows data from stations around NTS. The Beatty results should be indicative of the lower areas of the southwest NTS with Goldfield being more representative of the higher elevations. In most cases thunderstorm precipitation will fall for much less than 24 hours putting the amount of rain in Table 7 in the ground in closer to an hour. This higher rainfall rate is even more conducive to flash floods.

3. Lightning and Thunderstorms

Lightning is associated with thunderstorms and can occur within clouds or between the clouds and the ground. The latter is obviously more harmful to surface operations of a waste repository. Cloud to ground lightning can occur more readily at an exposed location, such as a ridge or a tower. Quiring (1972) has compiled a set of lightning and thunderstorm statistics for Yucca Flat. July and August had the most lightning with the time of highest frequency of lightning in the early evening. This time is biased because observations of lightning are easier at night. The presence of cumulonimbus clouds on thunderstorm days may be a better indicator of lightning. These reach a maximum frequency in mid-afternoon. Thunderstorm days occur on 16% of the days in July and August and 5% of the days for the entire year. Precautions should be taken to guard against lightning damage.

4. Temperature Extremes

Desert regions of southern Nevada have extremely high temperatures during summer. The climatological summary for Las Vegas, shown in Table 3 above, has daily maximum temperatures greater than 100°F for July and August and extremes as high as 117°F. Exposure to these high temperatures along with the low relative humidities can affect personnel and machinery if precautions are not taken.

TABLE 7

GREATEST 24-HOUR PRECIPITATION IN INCHES

Station	Elevation m	RETURN PERIOD (years) 2	5	10	25	50	100
Las Vegas	659	0.84	1.33	1.65	2.07	2.39	2.69
Boulder City	770	0.90	1.34	1.62	2.01	2.27	2.52
Beatty	1010	0.88	1.29	1.57	1.91	2.17	2.43
Caliente	1342	1.11	1.56	1.84	2.25	2.52	2.81
Goldfield	1734	1.03	1.60	1.99	2.46	2.84	3.19
Pioche	1862	1.46	2.06	2.46	2.96	3.37	3.73
Adaven	1905	1.38	1.86	2.16	2.58	2.85	3.15

After Thomas et al. (1970)

Since elevations of NTS are greater than that of Las Vegas, temperature extremes are lower. Yucca Flat daily maximum and extreme summer temperatures (Table 1) are about 10°F less than Las Vegas, while those at lower NTS elevations approach those of Las Vegas. NTS temperature extremes should still be considered during construction and operation of a waste repository.

Winter temperatures at NTS reach low enough values that personnel and machinary must be protected. Yucca Flat extremes are below 0°F, and daily minimums are below freezing. Higher, exposed ridges have lower temperature extremes and, with strong winds, would have a high wind-chill factor which would effect personnel.

IV. AIR QUALITY OF NTS

This section discusses the air quality of NTS. Included are estimates of the present air quality, influence of terrain on dispersion and conditions under which pollutants would disperse.

A. PRESENT AIR QUALITY

The air quality of an area is ranked by the amount of air pollution present; the better the air quality is, the less the air pollution. Air pollution refers to excess airborne material and can be in gaseous or particulate form. It can occur naturally or anthropogenically. Air pollution is quantified by measurement of pollutant concentrations; air quality, by effects of pollutants on human health and certain aesthetic qualities.

1. Estimated Air Quality of NTS

The present air quality in southwest NTS is mostly an unknown quantity. There does not appear to have been any data collected in the area that would give the concentrations of so-called criteria pollutants, i.e., those pollutants for which national ambient air quality standards exist: sulfur dioxide (SO_2), nitrogen dixoide (NO_2), carbon monoxide (CO), ozone (O_3), total suspended particulate (TSP) matter, and lead (Pb). Previous interest in ambient data has only been for radioactive species.

Present air quality is probably good in most instances. There are no significant sources of SO_2, NO_2 or CO in NTS. The nearest major source would be Las Vegas, some 130 km away. Background measurements to the northeast of Las Vegas show low concentrations of these quantities (DRI, 1979).

The O_3 and TSP probably have high concentrations at times. Measurements of O_3 in remote areas of the Southwest show increases during the spring and summer months, reaching concentrations over 100 ppb. Causes for high O_3 have been attributed to transport of polluted air from southern California urban areas (Macias et al., 1980) and to intrusion of stratospheric O_3 at the backside of high pressure systems (Johnson et al., 1979). Instances of high TSP in remote areas are usually caused by high winds which raise large amounts of soil particles into the air. These high winds can be either short term in whirlwinds and dust devils, or they can be longer term winds associated with frontal passages. Whatever the cause, the particles put into the air by wind are generally large compared to those produced by combustion and thus fall out rather quickly when the wind subsides. A rural area might have an annual average TSP concentration of 25 $\mu g/m^3$, but have extremes of more than 150 $\mu g/m^3$. One factor in the amount of TSP is the degree of disturbance of the land. A natural, high desert area will have less wind-blown dust than areas where dirt roads have been built or where the soil has been disturbed by agriculture or mining.

2. Measured Air Quality in Area Near NTS

There have been some studies of air quality in rural areas of southern Nevada that have similar characteristics to NTS.

The Division of Environmental Protection of the State of Nevada has compiled a list of estimated TSP emissions for each hydrologic sub-basin. This was done by estimating the soil type and vegetation along with wind speeds and published emission factors. Results show that natural sources of TSP in rural areas are larger than other sources.

The Desert Research Institute has collected ambient air quality data 70 km northeast of Las Vegas as a part of the permitting process for a power plant expansion (DRI, 1979). Background concentrations of SO_2 appear to be below 10 ppb. The reported measurements were the highest one- and three-hour averages which would include some impact from the existing power generating units. These measurements were as low as 12 ppb. NO_2 concentrations never exceeded 10 ppb for monthly averages and were probably less than that. Ozone showed a seasonal trend, having one-hour values over 100 ppb in late spring and early summer and near 35 ppb in winter. The 24-hour TSP concentrations had a variation between 8 and 123 $\mu g/m^3$ and an annual geometric mean near 30 $\mu g/m^3$. Causes for specific high values were not given.

A final aspect of air quality is visibility. As with other air quality parameters, visibility in remote regions of the Southwest is good but with variation. Measurements of visibility have been made to the east and south of NTS in such areas as the Grand Canyon and Southern California desert (A. Pitchford et al., 1980). Visibility has been found to range between 50 km and 350 km. Lower values are assocaited with southerly winds while higher ones occur with northerly and westerly winds. Visibility is better during winter than summer. During certian summer periods, most of the Southwest has hazy conditions with relatively low visibility. While the causes of this haze are not clear, there is evidence that small particles are transported from urban areas and copper smelters and that fine soil particles also contribute (M. Pitchford, et al., 1981). There is also an effect on visibility because of local wind blown dust which will last as long as soil particles remain suspended. Visibility and the causes for its degradation are subjects of current research[(1)] which may be useful to future sutdies of the impacts of the nuclear waste repository.

[(1)] Current research is summarized in symposium entitle Plumes and Visibility: Measurements and Model Components, Grand Canyon, AZ, Nov 10-14, 1980. Papers are to be published in Atmospheric Environment in 1981.

B. DISPERSION CONDITIONS

Construction and operation of a nuclear waste repository will have some environmental effects on air quality. Many activities act as sources of air pollution. Trucks emit diesel exhaust and stir up soil particles on dirt roads. Mining operations have similar emissions from heavy equipment and from tailings piles. Concentrations of the various air pollutants depend on, among other factors, atmospheric dispersion characteristics both near to and far from the sources. The dispersion of an air pollutant is dependent on wind speed, stability, mixing height and terrain.

1. Wind Speed

Dispersion increases with increasing wind speed. Pollutants with a fixed emission rate are mixed in a larger parcel of air as wind speed increases and thus have lower concentrations. The wind's effect is not always so simple; some sources, such as disturbed ground, have higher emission rates at higher wind speeds.

2. Stability

The stability of the air determines the mixing characteristics. Unstable air has a great deal of vertical motion caused by the heating of lower layers which become less dense than the air above and begin a convective overturning that continues until the source of heat diminishes. Stable air has little or no vertical motion with the lower layers being oftentimes colder than the upper layers. Pollutants in unstable air will usually, but not always, have lower concentrations than in stable air.

The stability of air near the earth's surface is determined, in large measure, by the change in temperature with altitude (temperature lapse rate) and, to a lesser extent, by the change in wind speed with altitude (wind shear). A parcel of air moving in the vertical without heat exchange with its surroundings cools as it ascends and warms as it descends at a rate of 10 C/km, the adiabatic lapse rate. If the atmospheric lapse rate is also also adiabatic, this is the neutral condition because there is no density difference between the parcel and its environs to accelerate the parcel. At other times the atmospheric lapse rate can be either greater or less than the adiabatic lapse rate. The former condition is called superadiabatic and is unstable. An ascending parcel will not cool as fast as its surroundings and will accelerate because it is less dense than its surroundings. When the lapse rate is less than adiabatic, it is a subadiabatic lapse rate and the atmosphere is stable. A vertical motion will be damped because the buoyant forces are acting opposite to the motion. Wind shear acts to mix air by mechanical means. This forces air towards the neutral condition regardless of whether it is stable or unstable. Mixing air tends to assume an adiabatic lapse rate.

The causes of a particular stability of the atmosphere near the surface are a combination of incoming solar radiation, outgoing long wavelength radiation from the Earth's surface, and wind shear. If the solar radiation is greater than long wavelength radiation, temperature near the surface increases causing a superadiabatic lapse rate and unstable motions. Stable conditions occur when there is more outgoing than incoming radiation, so that the surface cools. In fact, the surface may cool so much that temperature increases with height. This is called an inversion condition and is very stable. Neutral conditions occur when the net radiation flux at the surface is low and when the wind is strong enough to mix the air.

Changes in the lapse rate also occur above the surface. One cause of an inversion aloft is air subsidence associated with a high pressure system. As the air sinks, it warms with its temperature becoming greater than that of the air below. A subsidence inversion often forms between 1500 and 5000 m above the surface, depending on the strength of the high pressure system and convection in the lower layers.

Because radiation is so important in determining stability, there is a diurnal variation of stability that follows the solar cycle. Before the sun rises, there is a surface-based inversion caused by radiational cooling near the ground. During early morning hours, this inversion is gradually eroded by convection from the heated surface until it is destroyed. The lower part of the atmosphere is unstable at this point. As the day continues past noon, insolation decreases and horizontal winds increase bringing the air towards neutral conditions. As insolation disappears, the ground begins to cool again and the inversion reforms. Examples of morning and afternoon lapse rates are shown in Figure 4 as measured by aircraft north of Las Vegas.

3. Stability Classification

A number of stability classification schemes have been devised to simplify the computation of dispersion. The most used scheme is that originally due to Pasquill (1961) as modified by Gifford (1961) and presented by Turner (1970). This is referred to as the Pasquill-Gifford stability classification. Figures 5 and 6 present descriptions of these classes along with the conditions that cause them. Each dispersion category has a specific amount of dispersion associated with it that has been determined by experimental methods. Turner (1970) has provided curves of dispersion coefficients versus distance from the source. Most dispersion experiments have been done over relatively flat terrain or in urban areas. There is evidence (Start et al., 1975) that diffusion in neutral and stable

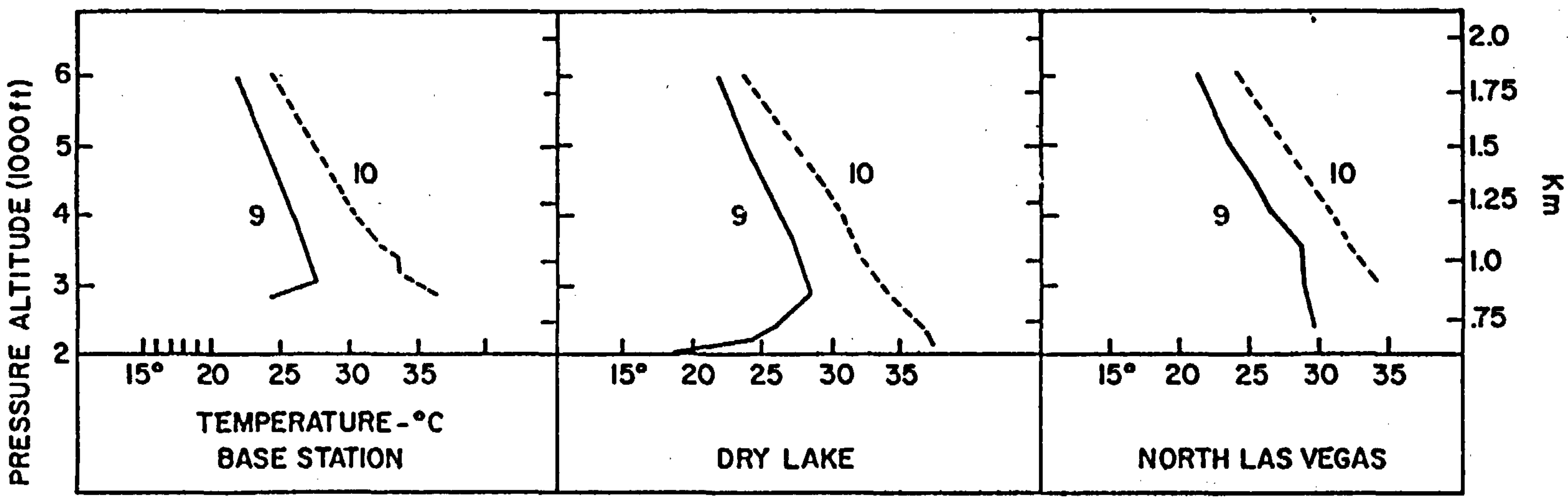

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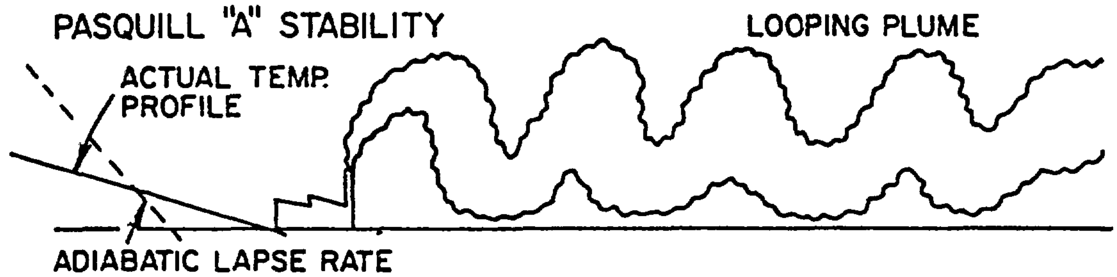
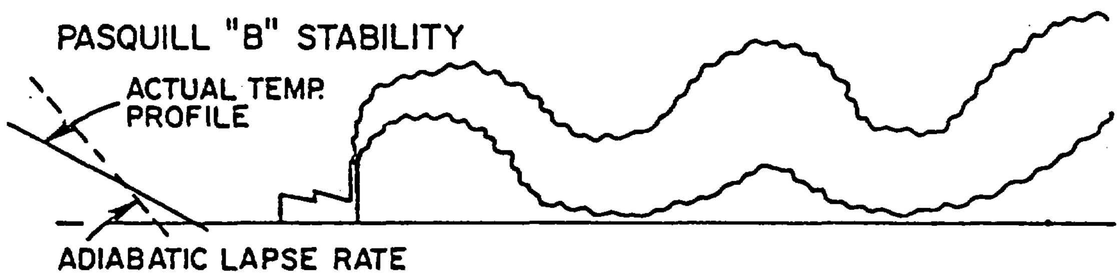
Figure 4: Morning and Afternoon Temperature Profiles North of Las Vegas August 26, 1974. Measured by Desert Research Institute from Airplane (DRI, 1979).



STABILITY: EXTREMELY UNSTABLE

WIND SPEED: 3 m/sec OR LESS. MOSTLY CONVECTIVE TURBULENCE

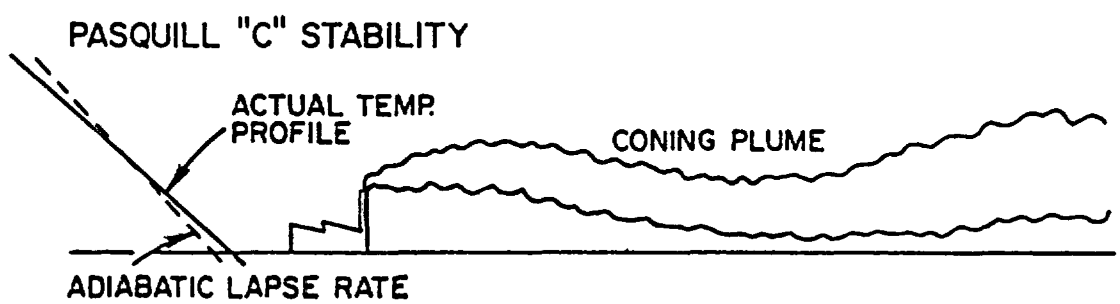
CONDITIONS: DAYTIME INSOLATION; MODERATE TO STRONG



STABILITY: MODERATELY UNSTABLE

WIND SPEED: LESS THAN 4 m/sec MOST CONVECTIVE TURBULENCE

CONDITIONS: DAYTIME INSOLATION; MODERATE TO STRONG



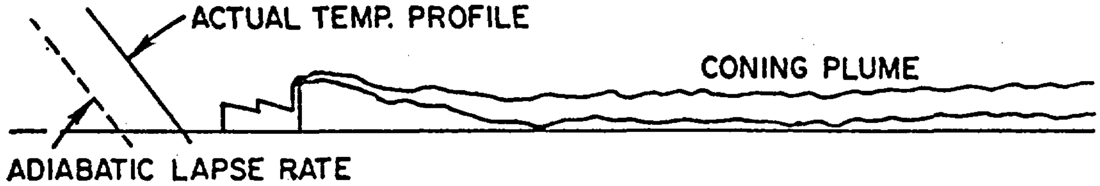
STABILITY: SLIGHTLY UNSTABLE

WIND SPEED: LESS THAN 6 m/sec MECHANICAL & CONVECTIVE TURBULENCE

CONDITIONS: DAYTIME INSOLATION; MODERATE TO STRONG

Figure 5: Conditions and Plume Behavior for Pasquill-Gifford Stability Classes A, B and C.

PASQUILL "D" STABILITY

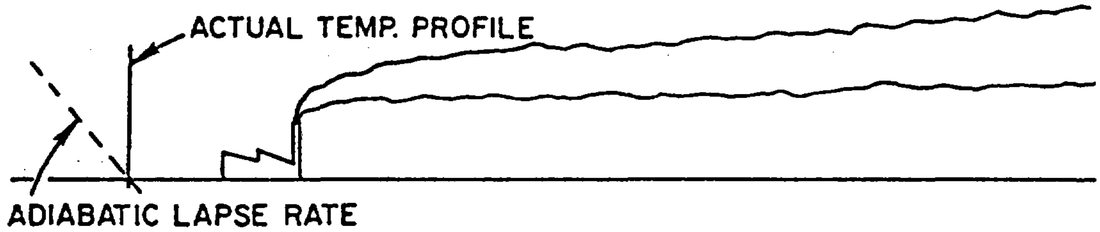


STABILITY: NEUTRAL

WIND SPEED: ALL, NO CONVECTIVE TURBULENCE

CONDITIONS: DAYTIME INSOLATION; SLIGHT: NIGHTTIME; CLOUDY

PASQUILL "E" STABILITY

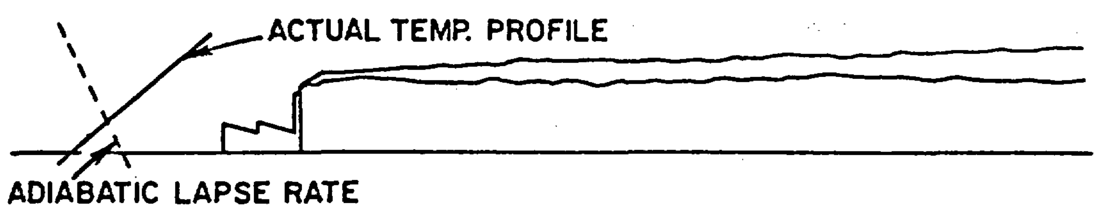


STABILITY: SLIGHTLY STABLE

WIND SPEED: USUALLY LESS THAN 4.5 m/sec

CONDITIONS: NIGHTTIME; MODERATE OUTGOING RADIATION

PASQUILL "F". STABILITY



STABILITY: MODERATELY STABLE

WIND SPEED: USUALLY LESS THAN 3 m/sec

CONDITIONS: NIGHTTIME; STRONG OUTGOING RADIATION

Figure 6: Conditions and Plume Behavior for Pasquill-Gifford Stability Classes D, E and F.

conditions is faster in regions of complex terrain than in regions of flat terrain. The relationship between terrain and diffusion is complex and the subject of a number of past and present research projects. Plans for two projects are given by Hilst (1978) and Hovind et al. (1979). Methods to adjust diffusion coefficients in complex terrain may come from these projects.

In order to determine the dispersion conditions on NTS, it is necessary to know the joint frequency distribution of wind speed and direction for the various Pasquill-Gifford classes on a site-specific basis. The classes at a particular location where there are wind data can be determined in several ways. At a weather station where cloud cover and cloud ceiling are observed, stabilities can be determined, following Turner (1970), with a computer program of the National Climatic Center known as the "Stability Array", or STAR, program. STAR distributions can be obtained for any Class I NWS station as well as many stations in the Department of Defense network. While the STAR program could probably be run with Yucca weather station data, care must be taken in applying these distributions to other areas. A comparison of the wind directions at Tower 4 and BJY shows similarity in winds but with actual directions having a definite terrain dependence. This is particularly true for nocturnal winds. If Yucca data are not available from the STAR program, there are other stations in southern Nevada that would be available such as Nellis Air Force Base and Las Vegas. Wind directions from these sites will again have the problem of not necessarily being applicable to a particular site on NTS. As an example of STAR program output, the annual distributions for stability Class D from Nellis are given in Tables 8 and 9. The STAR program cannot be run for other NTS stations because cloud cover and cloud ceilings are not reported. Stabilities at those sites are probably similar to those at Yucca, but again it must be emphasized that the wind frequency distributions will be site specific.

TABLE 8

FREQUENCY DISTRIBUTION FOR D STABILITY AT NELLS AFB, NEVADA

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION =23112 NELLIS AFB,NV 240BS 1958-67

	SPEED(KTS)						
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000293	0.000765	0.001668	0.004832	0.001340	0.000388	0.009294
NNE	0.000346	0.000914	0.003255	0.009652	0.003804	0.001416	0.019387
NE	0.000560	0.001999	0.006694	0.012896	0.002684	0.000720	0.025553
ENE	0.000502	0.001816	0.005266	0.004969	0.000377	0.000046	0.012975
E	0.000598	0.002216	0.004683	0.003096	0.000354	0.000046	0.010993
ESE	0.000290	0.001211	0.002399	0.002719	0.000286	0.000114	0.007018
SE	0.000166	0.000651	0.002650	0.005003	0.000685	0.000171	0.009327
SSE	0.000178	0.000411	0.002147	0.007984	0.002330	0.000537	0.013588
S	0.000604	0.001633	0.009618	0.028499	0.008430	0.002364	0.051149
SSW	0.000361	0.001234	0.004192	0.015455	0.007345	0.003324	0.031910
SW	0.000275	0.000891	0.002627	0.009492	0.003872	0.001885	0.019042
WSW	0.000096	0.000400	0.000765	0.002444	0.000720	0.000343	0.004768
W	0.000261	0.000731	0.001199	0.002273	0.000594	0.000148	0.005207
WNW	0.000177	0.000480	0.001314	0.004112	0.001782	0.000765	0.008630
NW	0.000280	0.000765	0.001165	0.004169	0.001885	0.000685	0.008950
NNW	0.000061	0.000274	0.000583	0.001085	0.000263	0.000126	0.002391
TOTAL	0.005049	0.016391	0.050225	0.118680	0.036758	0.013079	

RELATIVE FREQUENCY OF OCCURRENCE OF D STABILITY = 0.240182

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH D STABILITY = 0.003164

Source: National Climatic Center, Asheville, NC

TABLE 9

RELATIVE FREQUENCY DISTRIBUTION FOR D STABILITY AT NELLIS AFB, NEVADA

ANNUAL FREQUENCY DISTRIBUTION STATION =23112 NELLIS AFB,NV 240BS 1958-67

SPEED(KTS)

DIRECTION	1 - 3	4 - 6	7 - 10	11-16	17-21	GREATER THAN 21	AVG SPD	TOTAL
N	12	67	146	423	118	34	12.9	800
NNE	14	80	285	845	333	124	14.1	1681
NE	16	175	586	1129	235	63	12.2	2204
ENE	14	159	461	435	33	4	10.1	1106
E	16	194	410	271	31	4	9.4	926
ESE	6	106	210	238	25	10	10.4	595
SE	4	57	232	438	60	15	11.9	806
SSE	8	36	188	699	204	47	13.7	1182
S	24	143	842	2495	738	207	13.6	4449
SSW	11	108	367	1353	643	291	14.9	2773
SW	9	78	230	831	339	165	14.6	1652
WSW	2	35	67	214	63	30	13.6	411
W	10	64	105	199	52	13	11.8	443
WNW	7	42	115	360	156	67	14.4	747
NW	11	67	102	365	165	60	14.0	770
NNW	1	24	51	95	23	11	12.4	205
AVG	2.5	4.9	8.8	13.4	18.6	24.3	13.0	
TOTAL	165	1435	4397	10390	3218	1145		

NUMBER OF OCCURRENCES OF D STABILITY = 21027

NUMBER OF CALMS WITH D STABILITY = 277

Source: National Climatic Center, Asheville, NC

A second method of determining the stability class is to measure the standard deviation of the horizontal wind direction, σ_θ. The σ_θ can be found either by direct measurement as is presently recommended (Hanna et al., 1977) or by reanalysis of strip chart data by a method in Slade (1968). A relationship between σ_θ and the actual horizontal dispersion coefficient is available from Pasquill (1976). There are also tables in Slade (1968) and EPA (1980c) which give the Pasquill-Gifford classes for ranges of σ_θ. The latter is particularly useful because it includes corrected stability classes for nighttime conditions adapted from Mitchell and Timbre (1979). At night, σ_θ can be large because of light, variable wind speed conditions. Without a correction, this would lead to the erroneous conclusion that the atmosphere is much more unstable at night than it really is. In fact, this conclusion was drawn by Peterson (1975) in a report which gave wind frequency distributions as a function of stability class for NTS. He used Slade's (1968) method to determine the distributions for an area east of Jackass Flats. He found that over an entire year it was unstable 71.5% of the time, neutral 23.7% of the time and stable 4.5% of the time. Since at least half the measurements were made at night, this runs much too low a percentage of stable conditions.

4. Inversion Statistics of NTS

One other measurement has been made that gives some insight into the stability at NTS. This is a measurement of the vertical temperature profile by routinely released rawinsonde balloons. As a part of the NWS upper air network, rawinsondes have been released at Yucca Flat (from 1958 to 1978) and the Desert Rock Airport (from 1978 to present) just before 0000 and 1200 Greenwich Mean Time (GMT) or 0400 and 1600 PST.. Other rawinsonde stations in Nevada are located at Ely and Winnemucca. Formerly there was on at Las Vegas. The only stability analyses that have been done on Yucca Flat data are those involved with the inversions (Quiring, 1973), i.e., stable conditions. While stable conditions have the worst dispersion characteristics, they occur only part of the time, and other conditions are nêcessary to determine the long-term impacts. A look at the inversion statistics, however, will give some insight into possible worst-case dispersion conditions. A comparison is made between Yucca Flat and the other Nevada stations in Table 10 where the Nevada statistics are from Hosler (1961). Yucca and Las Vegas statistics are quite similar. Inversion frequencies in sloping Jackass Flats are also probably similar to those at Las Vegas (and thus Yucca), since the grade of Jackass Flats is comparable to that in the vicinity of McCarran Airport, Las Vegas, where rawinsonde releases occurred. High terrain surrounding the valleys, however, will often be above the inversion. Table 11 shows the median depths of surface inversions and the median heights of the bases of the elevated inversions at Yucca Flats. The surface inversions tend to have depths below 300 m which is below most of the surrounding terrain.

5. Stability Climatology

Holzworth (1974) has compiled a climatology of atmospheric stability in the United States from NWS rawinsonde soundings. Both inversion and lapse conditions are considered as well as elevated inversions. Holzworth gives examples for selected stations along with isopleth figures of inversion or lapse frequencies. More detail could be obtained from either the original data or by reconstruction from rawinsonde data. The closest station to NTS was at Las Vegas. The Yucca Flat data could be used if the statistics were recomputed.

TABLE 10

SURFACE BASED INVERSION FREQUENCIES IN PERCENT

	Las Vegas[1]		Ely[1]		Winnemucca[1]		Yucca Flat[2]	
Season	0000 GMT	1200 GMT	0000 GMT	1200 GMT	0000 GMT	1200 GMT	0000 GMT	1200 GMT
Winter	2	92	22	86	6	82	3	89
Spring	0	86	0	78	0	88	0	84
Summer	1	89	1	96	0	92	1	93
Fall	0	90	9	91	1	91	1	91

[1] from Hosler (1961): Two years of data: 6/57 - 5/59.

[2] from Quiring (1973).

TABLE 11

INVERSION STATISTICS FOR YUCCA FLAT[1]

Elevation of Yucca Flat is 1,196 m MSL

		Surface Based		Elevated Inversions with Surface Based Present		Elevated Inversions with Surface Based not Present	
Sounding GMT	Season	Frequency %	Ht. above Station (m)	Frequency %	Ht. above Station (m)	Frequency %	Ht. above Station (m)
0000	Winter	2.6	145	1.6	1,346	64.9	1,422
0000	Spring	0.2	152	0	-	38.6	2,674
0000	Summer	0.9	168	0.2	4,380	20.8	3,416
0000	Fall	0.7	191	0.2	823	49.7	2,189
1200	Winter	89.0	283	57.7	1,271	6.7	1,423
1200	Spring	84.2	206	35.1	2,036	6.8	1,676
1200	Summer	93.1	247	23.0	3,193	2.9	1,143
1200	Fall	91.2	276	46.7	1,978	5.0	1,920

[1] from Quiring (1973)

6. <u>Mixing Height</u>

The mixing height is that height above the surface to which vertical mixing occurs. The mixing height concept assumes that there is unstable air at the surface, and that a pollutant released within this layer will be well-mixed up to the mixing height. Thus, a greater mixing height will result in a lower concentration. During stable conditions, there is technically no mixing height. The stable atmosphere generally has wave-like motions which move pollutants up and down but do not disperse them very rapidly.

7. <u>Terrain Influences</u>

Terrain features surrounding a source influence the dispersion of pollutants by changing dispersion parameters as above and by modifying wind and temperature.

Most terrain influence on meteorology is caused by differential heating or cooling. Air near the surface of a valley moves upslope as it is heated during the day and downslope at night as it cools. This local influence is more predominant at night when there is no insolation and the near surface motions can be decoupled from the upper air flow. The amount of local influence during the day depends on the insolation, the strngth of the upper flow, and the orientation of the terrain. In many situations the synoptic flow and the local daytime flow reinforce each other so that they become indistinguishable except for a possible slight direction shift. The terrain of a valley forces the winds along the axis of the valley; this casues most of the impacts from a pollution source to be along the axis as well. On higher exposed ridges or mountains where the winds are less influence by local effects, there is less change in speed and direction from day to night. The synoptic situations is the governing influence. There is also an altitude dependence of temperature. The lower elevations are warmer during the day but can be cooler at night than the higher elevations. The formation of an inversion in the valley causes poor dispersion during the night.

If a source is near high terrain, there is a chance that ground-level pollutant concentrations would be greater than if the source were in flat terrain. This situation could occur in extremely stable air with light winds from the source towards high terrain. The ground is effectively brought up to meet the plume. An EPA model has been developed (Burt, 1977) to estimate plume impacts on high terrain. While this model has some verification for elevated sources (Burt and Slater, 1977), the frequency of the necessary conditions needs to be determined for each situation.

The main terrain influence on nuclear waste repository emissions will be air flow in preferred directions and modified diffusion coefficients.

8. Pollution Potential

The potential for limited dispersion has been investegated for the entire United States. Niemeyer (1960) considered the stagnating anticylone to be the meteorological condition that would give the highest potential for an air pollution episode. This situation causes light winds and low mixing heights. Holzworth (1962) later applied slightly different criteria to the western United States. Conditions conducive to air pollution episodes evolved into those given by Holzworth (1972): 1) all mixing heights 1500 m or less, 2) all mixing layer winds 4 m/s or less, 3) no significant precipitation during 12-hour periods covering mixing height calculations, and 4) the above conditions lasting for at least two days (five successive mixing height and wind speed calculations). Mixing heights and wind speeds are determined from the rawinsonde soundings. The afternoon mixing height is important for an episode condition as it determines the maximum amount of dispersion that can occur. Strong subsidence with weak net radiation leads to low daytime mixing heights and worse pollution episodes. The morning mixing layer is generally either non-existent (as in rural areas) or shallow (as in urban areas). While pollutant concentration can increase during these morning hours, it usually decreases during the day as the mixing height and wind speeds increase. The number of episode days for five years of data is much higher in the western than eastern United States, because of the persistent high pressure ridge over the mountain areas of the West during the winter. During the five years studied, Las Vegas had more than 250 episode-days which means that a maximum of 25 two-day episodes occurred each year. One anomoly in the West occurred at Ely which had less than 25 episode days during the five years because morning wind speeds were often greater than 4 m/s. These would not be episode days according to Holzworth (1972) even though the dilution might be low. By comparing the statistics of episode days at Las Vegas and Ely, it is seen that local influences such as nocturnal drainage winds affect both the statistics and the dispersion. Most of the area of interest to NTS is on sloping terrain which will enhance the dispersion of pollutants. The need for site-specific information is again apparent.

9. Dispersion Data on NTS

Some actual dispersion data have been collected in conjunction with the various activities of NTS. Angell and Pack (1961) analyzed the motions of several constant volume ballons (tetroons) released from Yucca Flat over a three day period. They found complicated vertical velocities over NTS. Most of the tetroon flights were high above the terrain. Randerson (1972) studied the time rate of change of horizontal diffusion parameters associated with a nuclear debris cloud that was released from NTS. This study has some applicability to accidental releases from a waste repository.

Of specific interest might be the data collected during the operation of the NRDS in which downwind concentrations of radioactivity were measured at ground level at more than 100 km from the source. There is some evidence that for the slightly unstable conditions during the tests the dispersion was close to that predicted by the Pasquill-Gifford dispersion parameters. The applicability of this diffusion work to the present situation is tenuous, because most of the previous tests had plume rises greater than 1,000 m. The waste repository will have sources at or near ground level with little plume rise.

V. NOISE

The development and operation of the nuclear waste repository can be a source of unwanted sound. Noise emissions from construction activities have become an environmental issue at many industrial development sites. These noise sources are from activities such as heavy equipment, vehicle traffic, drilling and blasting. Therefore, it is important to evaluate the potential for environmental noise problems prior to large-scale nuclear waste repository development in the NTS.

A. NOISE CONCERNS

The areas of interest for the repository are located at a significant distance away from any population and remote from any anthropogenic noise sensitive receptor sites. For these reasons, it appears that noise will not be a serious environmental problem. Nevertheless, the following are identified as potential concerns:

1. What noise levels are likely to be associated with the various stages of nuclear waste repository?
2. Where and how far are the noise-sensitive receptor sites located relative to the development area? What will be the effects on wildlife?

B. NOISE ASSESSMENT

In order to adequately address the above noise concerns, the following information is required: 1) baseline noise conditions, 2) quantitative data on nuclear waste repository (noise sources), 3) receptor sites, 4) noise propagation models appropriate to the terrain and meteorological conditions of the locale, and 5) noise regulations. These items are discussed in the following section.

1. Baseline Noise Conditions

Quantitative data on ambient noise conditions are essentially nonexistant for remote areas of Nevada including NTS. In the absence of any major activity in the proposed repository development area, it can be assumed that the environment is generally quiet. For this reason, any anthropogenic addition of noise (aircraft, vehicles, machinery, etc.) above the natural background can be considered a nuisance.

2. Quantitative Data on Nuclear Waste Repository Noise Sources

Although published information is not available for noise sources due to nuclear waste repository construction and operation activities, studies of noise emissions from geothermal operations have been made (Leitner, 1976, 1980, and Shinn, 1976). (Geothermal operations have many similar activities with the waste repository.)

An EPA document describes typical sound pressure levels (SPL) for construction activities (EPA, 1971).

Anticipated noise sources include

- road and site preparation,
- drilling and blasting,
- support facilites construction
- operation of repository, and
- vehicular traffic.

3. Receptor Sites

Any analysis for noise impacts must consider the types and locations of noise receptors in the vicinity of the proposed project site. Since the proposed area is at a significant distance away from any population, some of the typical noise sensitive receptors such as residences, schools, health care facilities, hospitals, etc. can most likely be ignored. However, other noise receptor sites that are probably more pertinent to the proposed site are outdoor recreation areas, designated wilderness lands and critical wildlife habitats such as migratory trails, nesting areas, etc. These sensitive sites should be considered.

4. Noise Propagation Models

Although the accuracy and validity of noise propagation models are questionable, they are one of the few methods available to assess noise impacts. Noise models have been used with reasonable success for geothermal development of the Geysers - Calistoga areas in northern California (Pacific Gas and Electric, 1977). There are no readily accepted models by the regulatory agencies. In addition, the applicability of these models to the pristine desert environment of complex terrain and meteorology is not tested.

5. Regulations

There are no local ordinances and state standards or regulations governing noise levels in Nevada. Industrial noise emissions are subject to Federal Occupational Safety and Health and the Nevada Industrial Commission regulations.

For federal regulations, the EPA has published a "Levels Document" which identifies noise levels to protect against community annoyance (EPA, 1974). Another document which discusses environmental noise is specific to geothermal industry operation (USDI Geological Survey, 1975). This document states that geothermal-related activities on Federal leases shall not exceed a noise level of 65 dB (A)[2] at the lease boundary or at 0.8 km from the source. In absence of any noise regulations for a waste repository, this may be used as a guide.

[2] dB(A) is a weighted sound level in decibels measured with a sound level meter with a weighing network (filter) approximately to the frequency sensitivity of the human ear.

C. RECOMMENDATIONS

Although the effects of noise do not appear to be a significant problem, the following items are recommended for future impact analyses.

- Background Noise Measurements

  Existing environmental noise conditions should be documented prior to development of the nuclear waste repository. Since there are no measurement standards, it is suggested that document "Guidelines for Acquiring Environmental Baseline Data on Federal Geothermal Leases" (USDI, 1977) be used.

- Source Measurements

  Noise emissions data should be collected through field measurements for noise sources pertaining to the development and operation of the nuclear waste repository.

- Noise Receptor Sites

  The typical sensitive receptor sites (residences, hospitals, schools, etc.) are probably not important in the proposed development area. The locations for recreation, wilderness and sensitive wildlife areas should be identified and classified.

- Noise Standards

  If sensitive receptor sites are located near the proposed site, a noise standard similar to these for geothermal development (USDI Geological Survey, 1975) should be considered.

VI. REQUIREMENTS FOR AN ENVIRONMENTAL IMPACT STATEMENT

The National Environmental Policy Act of 1969 (Public Law 91-190) requires that federal agencies prepare an Environmental Impact Statement (EIS) for each proposed action which would significantly affect environmental quality. Among the topics that need to be addressed are adverse environmental effects that cannot be avoided, alternatives to the proposed actions, the relationship between short-term uses of the environment and enhancement of long-term productivity, and the irreversible or irretrievable commitments of resources. The EIS should cover all aspects of the environment including that of air quality.

A. EIS PROCESS

A nuclear waste repository on southwest NTS would almost certainly qualify as having a significant impact on the surrounding environment and thus would need an EIS. The actual contents of EIS and the amount of information presented have for the most part been left to the discretion of the preparing agency. This has led to EIS's of wide-ranging quality and quantity. Some have a great deal of on-site air quality and meteorological data while others have very little or none at all. A part of the problem seems to arise because of the rather nebulous connection between EIS preparation and the pollution control programs of the agencies (both state and federal) in charge of permitting the actions. Many air pollution issues have been left to the agencies and the courts to resolve. Consultation with a person versed in federal and state environmental law would probably be fruitful in preparation of a plan for the EIS.

B. EIS PLANS

A possible plan for the preparation of the EIS would consider the requirements of the various permitting agencies as is discussed in Section VII. The acquisition of permits to construct and operate is an action separate from the

EIS, but it does give some direction as to the requirements for the EIS. In order to obtain a permit, it is usually required that a plan be devised which might include pre- and post-construction monitoring and modeling of the effects of the proposed sources. The extent of these plans depends on the circumstances of the construction. For instance, a major stationary source proposed for an area with air quality which either is better than the national ambient air quality standard or is unclassifiable, is subject to preconstruction review under the Prevention of Significant Deterioration (PSD) requirements of the Clean Air Act Amendments of 1977. Various monitoring and modeling requirements are detailed in an available guideline (EPA, 1980a). Following PSD guidelines would be the most restrictive and complete plan for that part of the EIS dealing with sources at the repository. Other topics not covered by PSD, such as the effects on air quality of a large number of people in a previously sparsely populated area, would also need to be addressed in the EIS.

There is some question as to the applicability of PSD regulations to the nuclear waste repository. The repository is similar to a mine but with little or no processing of the mined material. The major sources are mobile rather than stationary. The size of the operation and the length of time for construction activities might influence the decision to require a PSD permitting process. With this in mind, it is recommended that a PSD type program be planned. It could be modified at a future date.

1. Monitoring

A normal PSD program generally requires that preconstruction monitoring be conducted for the criteria pollutants: sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), total suspended particulate (TSP) matter, ozone

(O_3), and lead. This determines existing baseline concentrations. Within the guidelines (EPA, 1980a) there is a flow diagram to determine if monitoring is necessary. This requires various screening models and estimates to pick the proper path through the diagram. There are circumstances in which preconstruction monitoring would not be required. For the present exercise, it is better to assume that preconstruction monitoring for air quality and meteorological data would be necessary.

The location of the air quality monitors should be near the point(s) of maximum impact as determined from screening models. There should also be monitoring in the vicinity of fugitive emissions, such as near the spoils pile. Gaseous air quality data should be collected with continuously operating analyzers and should be averaged over a period of an hour. The TSP and lead data should come from 24-hour integrated samples. These averaging times are required by EPA and may not be of short enough length to do more detailed correlative analysis with meteorological data. The minimum length of time necessary for air quality data collection is one year.

Visibility measurements could also be made, as proposed in a draft EPA document (EPA, 1980b), by a continuously operating nephelometer and some sort of long path measuring device, such as a telephotometer. The proposed visibility regulations apply only to Class I areas of which none will be affected by the waste repository. The minimum length of time necessary for air quality data collection is one year.

Meteorological data are essential for determining the atmospheric dispersion conditions at the site. Even though many measurements have been made in Jackass Flats, site specific data are necessary if the repository is in another location. Measurements should be made at the location of the proposed source and at the site(s) of maximum impact(s). Data should include wind speed and direction averaged over an hour, atmospheric stability as determined from the standard deviation of wind direction, hourly average surface temperature for comparison with climatological data and for plume rise calculations, and hourly precipitation data. The mixing heights should also be available, either as measured on-site or as extrapolated from the Desert Rock rawinsonde. Commerical acoustic sounders are available to make onsite measurements of mixing height and, in some configurations, are claimed to be able to measure winds up to 1,500 m above the surface. Recommendations have been made that five years of meteorological data, where available, be used to develop a data base. This is more than would be practicable at NTS. At the very least, one year of data should be collected and the representativeness of that particular year determined by comparing other NTS or Las Vegas data for the year to their normal levels.

2. Modeling

An important part of the EIS is an estimation of the effects of construction and operation of the repository on air quality. To do this, the dispersion of effluents from various sources must be modeled. The choice of model for this source is not clear cut. There are model guidelines available (EPA, 1978, and draft revision 1980) which prescribe certain EPA-approved models and certain methods of applying the models. Figure 7 shows a flow diagram of the steps involved in this modeling. The first level is a rough screening to see if the effects are going to be significant. Models at other levels become more complicated. Depending on the source, the more complicated ones might not be necessary. Several problems will arise when such models are applied to the waste repository on NTS. One is that the terrain on NTS is rather complex

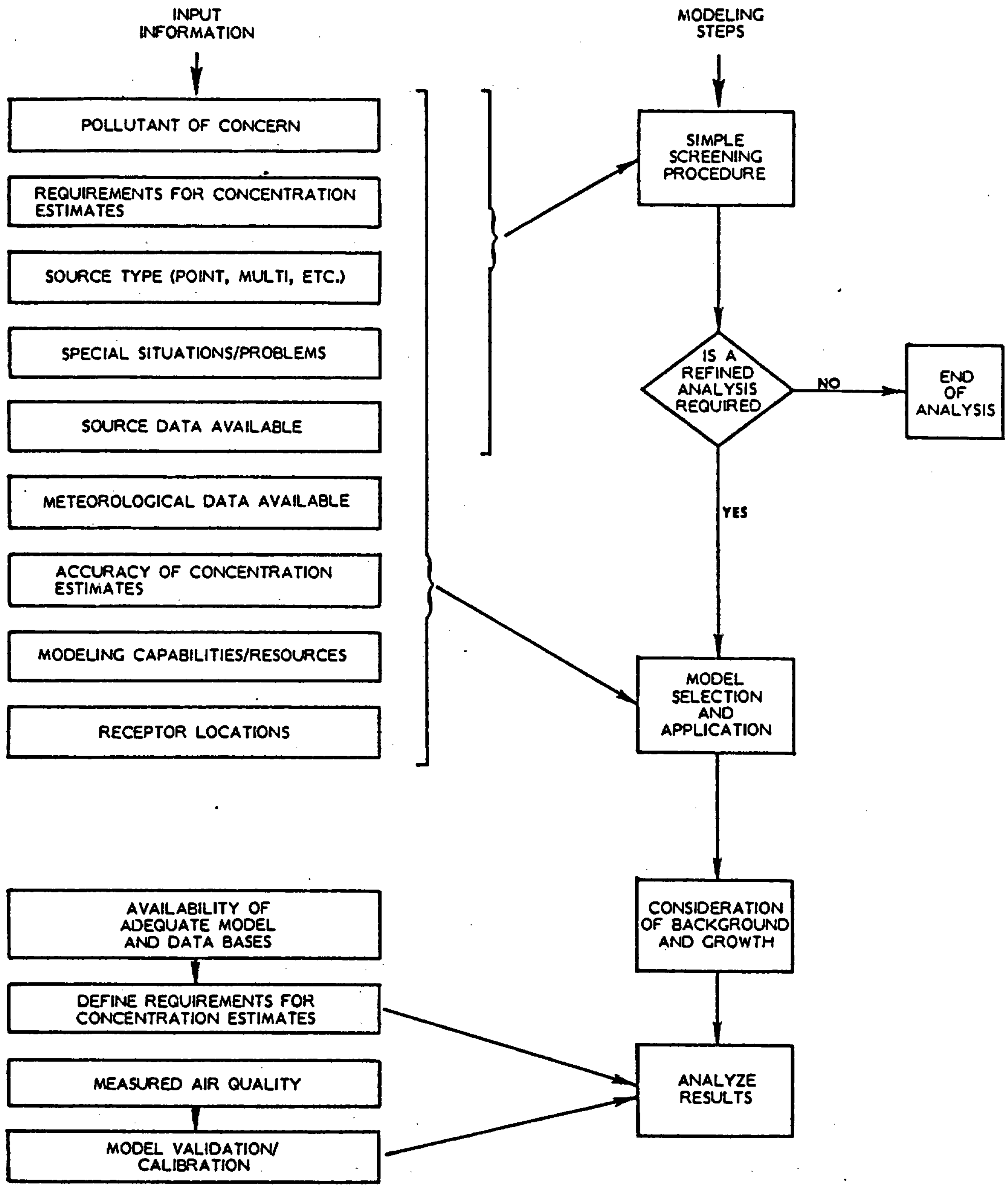


Figure 7: Selection and Application of Air Quality Model Data Bases (EPA, 1980a).

while most of the recommended models are applicable on flat terrain. The only presently approved complex terrain model, the Valley model, is only for screening to give rough upper bounds. Provisions can be made on a case-by-case basis to apply a different model. A second problem is that many are not applicable to construction and fugitive emissions.

The application of a model requires two sets of input data: meteorological and emissions data. In order to define emissions, the source configuration must be known with some degree of accuracy and emission factors for the various contributions must be estimated. Some contributions will be fugitive dust and gaseous emissions from the movement of trucks and heavy equipment on dirt roads, exhaust from mining operations, and fugitive dust from the spoils pile. If waste rock is processed, this will also contribute emissions. Emission factors for dust have been developed by Cowherd et al. (1974) which might be applicable, although it is necessary to know the soil silt content, soil moisture, and wind speed. Emission estimates for most other sources can be found in EPA (1976). Any mitigating factors, such as dust suppression by watering the spoils pile, must also be included.

3. Other Requirements

Besides the effects of the waste repository itself, the EIS should address the effects caused by the projected population increase in southern Nevada, whether it occurs in an unpopulated area or in an already existing urban area. These are two separate problems. The first would affect a presently clean area and might have to be treated somewhat like the PSD problem. The second increase would likely add to the population of Las Vegas, which already has problems with the nonattainment of national ambient air quality standards for TSP and CO. This would also increase traffic on the highway to NTS, the effects of which would have to be estimated. Other aspects would be the increased traffic passing through Las Vegas with supplies and equipment for NTS and the possible need for more electric power generation.

VII. AIR QUALITY REGULATORY REQUIREMENTS

Legislation to protect and enhance the quality of the nation's air resources was enacted in the Clean Air Act of 1967 and its Amendments of 1970, 1973, 1974 and 1977. These federal regulations are enforced by the Environmental Protection Agency (EPA). Apart from these federal regulations, each state as well as local governments are free to set and enforce their own regulations. The source must then comply with the most stringent of the Federal, State or local air quality standards.

In the State of Nevada there are two local agencies, Clark and Washoe Counties, with the legislative authority to regulate air quality within their respective county boundaries. Since the area of interest, Nevada Test Site (NTS), is not within the above mentioned county boundaries, the air quality jurisdiction lies under the Nevada Department of Conservation and Natural Resources, Division of Environmental Protection. Therefore, air quality permits are required for any new emission sources due to the Nuclear Waste Repository on NTS except as exempted under the Nevada Air Quality Regulations and the Federal Regulations.

A summary of the required permits is presented below.

A. FEDERAL REGULATIONS

1. National Ambient Air Quality Standards

The EPA has promolgated ambient standards, National Ambient Air Quality Standards (NAAQS). The Ambient Air Quality Standards for Nevada and the NAAQS are presented in Table 12. Two sets of standards are prescribed; the primary standard is designed to protect the public health and the secondary standard is to protect the public welfare.

NATIONAL AND NEVADA AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Time	Standard, $\mu g/m^3$ (ppb) National Primary	National Secondary
Sulfur Dioxide	3 Hours	—	1300 (500)
	24 Hours	365 (140)	—
	Annual	80 (30)	—(1)
Particulates	24 Hours	260	150
	Annual Geometric	75	60(2)
Nitrogen Dioxide	Annual	100 (50)	100 (50)
Oxidant (ozone)	1 Hour	235 (120)	235 (120)
Carbon monoxide (Nevada) above 5,000 feet	1 Hour	40 (mg/m^3)	40 (mg/m^3)
	8 Hours	6.67 (mg/m^3)	6.67 (mg/m^3)
Lead	Quarterly Arithmetic Mean	1.5	1.5
Hydrocarbons (less methane)	3 Hours	160 (240)	160 (240)

(1) Nevada has Annual Secondary Standard for sulfur dioxide of 80 $\mu g/m^3$.

(2) Nevada has Annual Secondary Standards for particulates of 75 $\mu g/m^3$.

2. Prevention of Significant Air Quality Deterioration

In addition to the ambient concentration limitations, the Prevention of Significant Air Quality Deterioration (PSD) provisions of the Clean Air Act Amendments of 1977 have limited the amount of air quality degradation allowed in a particular area.

The PSD regulations require that new major stationary sources would be subject to a new source review on the basis of potential to emit. In the case of the nuclear waste repository a PSD permit will be required if it has the potential to emit 250 tons/yr or more of any Clean Air Act (CAA) pollutant. Also, if the source has a potential to emit values equal or greater than those shown in Table 13, a PSD review will be required.

An overview of the requirements for sources subject to PSD review is as follows:

- Best Available Control Technology (BACT) must be applied for each pollutant subject to PSD review,
- preconstruction monitoring of ambient air quality should be provided,
- air quality analyses to show the source will not violate the NAAQS or PSD concentration increments for each pollutant subject to PSD review must be conducted,
- source impacts on soil, vegetation and visibility must be analyzed, and
- source will not significantly impact Class I areas and designated non-attainment areas must be demonstrated.

Presently PSD increments are established only for sulfur dioxide and particulate matter as shown in Table 14. The NTS area is considered a Class II area.

This summary oversimplifies the PSD requirements. Specifications of the regulations are contained in the Federal Register, Vo., 45, No 154 (August 7, 1980).

TABLE 13

SIGNIFICANT NET EMISSIONS INCREASE

Pollutant	Ton/year
CO	100
NO_x (as NO_2)	40
SO_2	40
Particulate matter	25
Ozone	40 of volatile organic compounds
Lead	0.6
Asbestos	0.007
Beryllium	0.0004
Mercury	0.1
Vinyl Chloride	1
Fluorides	3
Sulfuric acid mist	7
Hydrogen sulfide	10
Total reduced sulfur	10
Reduced sulfur compounds	10
Other CAA pollutants	>0

TABLE 14

PSD INCREMENTS FOR SO_2 AND TSP

Pollutant	Class 1 $\mu g/m^3$	Class II $\mu g/m^3$	Class III $\mu g/m^3$
Sulfur Dioxide			
Annual Arithmetic Mean	2	20	40
24-hour maximum	5	91	182
3-hour maximum	25	512	700
Particulate Matter			
Annual Geometric Mean	5	19	37
24-hour maximum	10	37	75

* Nevada has only one Class I area, Jarbidge National Wilderness Area located in the northeast corner of the state.

B. NEVADA REGULATIONS

A registration certificate is required for each new source before the commencement of construction. Although specific exemptions are listed within the regulations, a certificate is required if topsoil greater than eight hectacres (20 acres) including road construction and spoil piles is disturbed. Application forms for requesting the issuance of a certificate can be obtained from the Director, Department of Conservation and Natural Resources, Carson City, Nevada. A $10.00 fee is charged for each initial certificate.

The regulation states that the director shall determine if any additional information is needed within five working days after receiving an application for registration. Within 15 days after receiving adequate information, the director shall make a preliminary determination to issue or deny issuance of a registration certificate, and within 75 days after receiving adequate information, the director shall issue or deny issuance of a registration certificate. The registration certificate expires if construction is not commenced within one year from the date of issuance or if construction of the facility is delayed for one year after initiation.

1. Operating Permit

A separate operating permit is required for each new or existing single source. Request for an application of an initial operating permit can be obtained from the director of the Department of Conservation and Natural Resources, Carson City, Nevada, with a $50.00 fee.

The director will grant an operating permit if he finds from a stack emission test or other appropriate test and other relevant information that use of the source will not result in any violation of the Air Quality Regulations, New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants. The director may revoke an operating permit upon determining that there has been a violation of these regulations. The operating permit expires and is subject to renewal in five years.

VIII. SUMMARY AND CONCLUSIONS

The findings of the atmospheric overview for a nuclear waste repository on NTS are summarized in this section.

1. The climate within the last one million years has changed between glacial and interglacial periods. In Nevada, this meant changes between a moist, cool climate with pluvial lakes and a dry, warm climate during which the lakes disappeared. On NTS, pluvial lakes probably did not occur although the drainage from Jackass Flats may have been into Lake Manley (in Death Valley). Glaciers did not directly affect NTS.

2. At present NTS has a dry, warm climate with most variations caused by altitude. Its lower areas approach warm desert conditions while higher elevations are nearly boreal forest. A great deal of meteorological data has been collected on NTS since 1956, although only a few records have lasted for the entire period. These data show that wind, temperature, and precipitation depend on station altitude and local terrain. Wind tends to flow up and down slopes; temperature varies inversely with altitude except daily minimums in closed basins; and precipitation varies directly with altitude.

3. Future climatic changes will probably be similar to those of the past, although planned and inadvertent changes caused by man are uncertain at present. Various predictive schemes are not well enough developed to determine the effects of complicated interactions among natural and manmade forces.

4. Severe weather in the form of high winds, heavy precipitation, lightening and high temperatures will affect the construction and operation of the repository. The hundred-year wind at lower elevations of NTS is about 80 mph and has maximum gusts near 110 mph. Winds on exposed ridges are probably stronger. There is a low probability for tornadoes. Heavy precipitation and lightening are associated with summer thundershowers which occur on about 15% of the days in July and August. Lower elevations of NTS have summer temperature extremes over 100° F.

5. Present air quality, except for particulate and ozone concentrations, is probably good, although no air quality data have been collected on NTS. Wind-blown dust (TSP >100 $\mu g/m^3$) and high summer ozone concentrations (>100 ppb) which are common in remote regions of the Southwest desert, are likely to affect NTS. However, NTS is too far removed from sources of other pollutants to be affected.

6. Dispersion conditions are dependent on wind speed, stability, mixing height, and terrain. Wind speed and mixing height determine the volume of air into which a pollutant disperses. Stability governs the atmospheric mixing properties. Terrain influences wind direction and modifies turbulent diffusion. NTS meteorological data have included measurements of these quantities, although they are not in a form useful for pollutant dispersion. These NTS data may not have been collected at sites with enough similarity to the proposed repository site. Joint wind speed and direction frequency data, which comprise a major part of model input data are particularly dependent on local affects. It is recommended that site-specific meteorological data, oriented towards dispersion properties, be

collected at the proposed repository site. If this site is near a former NTS meteorological station, then the previously collected data would have to be analyzed to determine if atmospheric dispersion properties could be obtained.

7. Noise does not appear to be a problem to people off NTS. There may, however, be certain indigenous species near the repository site which are sensitive to noise.

8. The most comprehensive Environmental Impact Statement (EIS) for a nuclear waste repository would include monitoring and modeling requirements necessary to obtain a Prevention of Significant Deterioration (PSD) permit. Monitoring would develop a criteria pollutant (SO_2, NO_2, O_3, CO, TSP, Pb) baseline, and modeling would determine incremental increases caused by repository construction and operation of the repository. A thorough examination of repository effects, such as increased population, on the area surrounding NTS is also necessary. The EIS plans can be modified if a full PSD procedure is determined to more than necessary.

9. The regulatory agencies which enforce air quality regulations pertinent to a repository at NTS are the U.S. Environmental Protection Agency and the Nevada Department of Conservation and Natural Resources, Division of Environmental Protection. Federal regulations are concerned with either violations of National Ambient Air Quality Standards or requirements for PSD permitting. Nevada regulations cover soil disturbances associated with mining operations.

In conclusion, the effects of a nuclear waste repository on NTS and its environs will be similar to those of a mining operation. There will be gaseous and particulate emissions from machinary and fugitive dust emissions from tailing piles and dirt roads. Prediction of these effects requires knowledge of dispersion conditions and source emissions. The meteorological data collected on NTS since 1956 help determine dispersion conditions, although most are not directly applicable to dispersion prediction. Site-specific meteorological data, collected with emphasis toward dispersion, are necessary.

IX. REFERENCES

Angell, J.K. and D.H. Pack, 1961: Estimation of vertical air motions in desert terrain from tetroon flights. Mon. Wea. Rev, 89, 273-283.

Brown, Merle, 1960: The climate of Nevada. In Climates of the States, Vol. II - Western States. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Burt, E.W., 1977: Valley Model User's Guide. EPA-450/2-77-018. OAQPS. Research Triangle Park, NC 27711

Burt, E.W. and H.H. Slater, 1977: Evaluation of the Valley Model. Presented at Joint AMS/APCA Conference on Applications of Air Pollution Meteorology. Nov. 29-Dec 2, 1977. Salt Lake City, UT.

Christensen, R.C. and N.E. Spahr, 1980: Flood potential of Topopah Wash and Tributaries, eastern part of Jackass Flats, Nevada Test Site, Southern Nevada. U.S. Geological Survey, Water Resources Investigations, Open-file report 80-963, Lakewood, CO, 22 pp.

Cowherd, C., Jr., K. Axetell, Jr., C.M. Guenther, and G.A. Jutze, 1974: Development of emission factors for fugitive dust sources. EPA-450/3-74-037, OAQPS, Research Triangle Park, NC, 172 pp.

Desert Research Institute, 1979: Final addendum for the Reid Gardner unit #4 air quality and meteorological analysis. Submitted as part of Nevada Power Company, Construction Permit Application.

Environmental Protection Agency, 1971: Noise from construction equipment and operations, building equipment and home appliances. Contract # 68-04-0047.

Environmental Protection Agency, 1974: Information on levels of environmental noise requisites to protect public health and welfare with an adequate margin of safety. EPA 550/9-74-004.

Environmental Protection Agency, 1976: Compilation of air pollution emission factors. AP-42 Second edition (Third printing with supplements 1-5), OAQPS, Research Triangle Park, NC 27711

Environmental Protection Agency, 1978: Guideline on air quality models. EPA-450/2-78-027, OAQPS, Research Triangle Park, NC 27711

Environmental Protection Agency, 1980a: Ambient monitoring guideline for prevention of significant deterioration (PSD). EPA-450/4-80-012, Research Triangle Park, NC.

Environmental Protection Agency, 1980b: Interim guidance for visibility monitoring. Draft. Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Environmental Protection Agency, 1980c: Guideline on air quality models. Proposed revisions Oct. 1980, OAQPS, Research Triangle Park, NC

Federal Register, 1980: Requirements for preparation, adoption, and submittal of implementation plans; approval and promulgation of implementation plans. Vo. 45, No. 154, August.

Fujita, T.T., 1973: Tornadoes around the world. Weatherwise, 26, 56-62, 78-83.

Gifford, F.A., 1961: Use of routine meteorological observations for estimating atmospheric dispersion. Nuclear Safety, 2, 47-51.

Hanna, S.R., G.A. Briggs, J. Deardorff, B.A. Egan, F.A. Gifford, and F. Pasquill, 1977: AMS Workshop on stability classification schemes and sigma curves - summary of recommendations. Bull. Am. Meteorol. Soc., 58, 1305-1309.

Hilst, G.R., 1978: Plume model validation. Workshop Summary Report. Electric Power Research Institute, EA-917-5Y, Palo Alto, CA

Holzworth, G.C., 1962: A study of air pollution potential for the western United States. J. Appl. Meteor., 1, 366-382.

Holzworth, G.C., 1972: Mixing heights, wind speeds, and potential for urban air pollution throughout the contiguous United States. Environmental Protection Agency, Research Triangle Park, NC, publication no. AP-101.

Holzworth, G.C., 1974: Meteorological episdoes of slowest dilution in contiguous United States. EPA-650/4-74-002, 84 pp.

Hosler, C.R., 1961: Low-level inversion frequency in the contiguous United States. Mon. Wea. Rev., 89, 319-339.

Houghton, J.B., 1969: Characteristics of rainfall in the Great Basin. Desert Research Institute, University of Nevada.

Houghton, J.B., C.M. Sakamoto, and R.O. Gifford, 1975: Nevada's Weather and Climate. Nevada Bureau of Mines and Geology. University of Nevada, Reno. 78 pp.

Hovind, E.L., M.W. Edelstein, and V.C. Sutherland, 1979: Workshop on atmospheric dispersion models in complex terrain. EPA-600/9-79-041, Research Triangle Park, NC

Johnson, W.B., W. Viezee, L.A. Cavanaugh, F.L. Ludwig, H.B. Singh, and E.F. Danielsen, 1979: Measurements of stratospheric ozone penetrations into the lower troposphere. Proc. Fourth Symp. Turbulence, Diffusion and Air Pollution, Reno, NV, 15-18 Jan 1979 (American Meteorological Society, Boston)

Keeling, C.D. and R.B. Bacastow, 1977: Impact of industrial gases on climate. In Energy and Climate, National Academy of Sciences, Washington, DC, 72-95.

Lamb, H.H., 1972: Climate: Present, Past and Future, Vol. 1 Fundamentals and Climate Now. Methuen and Co., London, 613 pp.

Lamb, H.H., 1977: Climate: Present, Past and Future. Vol. 2. Climate History and the Future. Methuen and Co., London, 835 pp.

Leitner, P. 1976: An environmental overview of geothermal development: The Geysers-Calistoga KGRA. Vol 3, Noise UCRL-5z496. Lawrence Livermore Laboratory, Univ. of CA, Livermore, CA

Leitner, P. 1980: An environmental overview of geothermal development: Northern Nevada. Chapter VIII Noise Effects, Mackay School of Mines, University of NV, Reno.

Macias, E.S., J.O. Zwicker, W.H. White, 1980: Regional haze in the southwestern United States: II. Source contributions. Presented at Conference on Plumes and Visibility, Grand Canyon, AZ, Nov 10-14, 1980.

McDonald, J.R., J.E. Minor, and K.C. Mehta, 1975: Development of a design basis tornado and structural design criteria for the Nevada Test Site. Lawrence Livermore Laboratory, UCRL-13668.

Mifflin, M.D. and M.M. Wheat, 1979: Pluvial lakes and estimated pluvial climates of Nevada. Nevada Bureau of Mines and Geology, Bull. 94, Mackay School of Mines, University of Nevada, Reno, 57 pp.

Milankovitch, M., 1930: Mathematische Klimalchre und astronomische Theorie der Klimashwankungen in Handbuch der Klimatologie, I, Teil A (ed. W. Koppen and R. Geiger), Berlin (Borntraeger).

Mitchell, A.E., Jr., and K.O. Timbre, 1979: Atmospheric stability class from horizontal wind fluctuations. Presented at 72nd Annual Meeting APCA, Cincinnati, June 24, 1979.

Morrison, R.B., 1965: Quaternary geology of the Great Basin. In Wright and Frey (1965), 265-285.

National Oceanic and Atmospheric Administration, 1972: 10-year Climatological Summary (1962-1971) Yucca Flat, Nevada - Nevada Test Site. Air Resources Laboratory, Las Vegas, NV, 1 p.

National Oceanic and Atmospheric Administration, 1980: Climatological data: Nevada. National Climatic Center, Asheville, NC.

Nevada Division of Water Resources, 1971: Water Resources and Inter-Basin Flows. Map prepared by State Engineers Office.

Nevada Department of Conservation and Natural Resources, Division of Environmental Protection, 1980: Air Quality Regulations, Carson City, NV.

Niemeyer, L.E., 1960: Forecasting air pollution potential. Mon. Wea. Rev, 88, 88-96.

Pacific Gas and Electric Company, 1977: Environmental Data Statement, Geysers Unit 16, San Francisco

Pasquill, F., 1961: The estimation of the dispersion of windborne material. Meteorol. Mag., 90, 33-49.

Pasquill, F., 1976: Atmospheric dispersion parameters in Gaussian plume modeling. Part II. Possible requirements for change in the Turner workbook values. EPA-600/4-76-0306, 53 pp.

Peterson, Kendall R., 1976: Diffusion climatology for hypothetical accidents in area 410 of Nevada Test site. Lawrence Livermore Laboratory, UCRL-52074.

Pitchford, A., M. Pitchford, W. Malm, R. Flocchini, T. Cahill and E. Walther, 1980: Regional analysis of factors affecting visual air quality. Presented at Conference on Plumes and Visibility, Grand Canyon, AZ, 10-14 Nov. 1980.

Pitchford, M., R.G. Flocchini, R.G. Draftz, T.A. Cahill, L.L. Ashbough, and R.A. Eldred, 1981: Silicon in submicron particles in the Southwest, Atmos. Environ, 15, 321-334.

Quiring, R.F., 1967: Climatological Data Applicable in the vicinity of Test Cell C (NRDS). Unpublished report Air Resources Field Research Office, ESSA, Las Vegas, 15 pp.

Quiring, R.F., 1968: Climatological Data - Nevada Test Site and Nuclear Rocket Development Station. ESSA Research Laboratories Technical Memorandum - ARL 7, Las Vegas, NV, 171 pp.

Quiring, R.F., 1969: BREN Tower Temperature Profiles. Extracted from semi-annual Research Report, June - December 1965, Air Resources Laboratory, Las Vegas, NV 4 pp.

Quiring, Ralph, 1971: NTS meteorological facilities - past and present: an historical record to January 1971. Air Resources Laboratory, Las Vegas, NV, unpublished report. 13 pp.

Quiring, R.F., 1972: Frequency of occurrence and duration of thunderstorms and associated phenomena at Yucca Flat, Nevada. Air Resources Laboratory, Las Vegas, NV, Unpublished report, June 2, 1972, 21 pp.

Quiring, R.F., 1973: Summary of inversion statistics. DOC/NOAA/ERL, Air Resources Laboratory, Las Vegas, NV. ARLV-351-37. 22 pp.

Quiring, R.F., 1979: Precipitation probability in relation to areal coverage at the Nevada Test Site. DOC/NOAA/NWS, Nuclear Support Office, Las Vegas, NV. WSNSO-351-73. 14 pp.

Randerson, Darryl, 1972: Temporal changes in horizontal diffusion parameters of a single nuclear debris cloud. J. App. Meteor., 11, 670-673.

Richter, Alden P. 1960: The climatology of the Nevada Test Site. Unpublished report, U.S. Weather Bureau Research Station, Las Vegas, NV, 37 pp.

Robinson, G.D., 1977: Effluents of energy production: particulates. In Energy and Climate, National Academy of Sciences, Washington, DC, 61-71.

Schaeffer, J.R., 1969: Climatology of the Tonopah Test Range, 1968. Sandia Laboratories, SC-M-69-488.

Shinn, Joseph H, 1976: Potential effects of geothermal energy conversion on Imperial Valley ecosystems. UCRL-52196. Lawrence Livermore Laboratory, Univ of CA.

Simpson, G.C. 1934: World climate during the Quaternary Period. Quart. J. Roy Met. Soc., 59, 425-471.

Slade, D.H., editor, 1968: Meteorology and atomic energy, 1968: U.S. Atomic Energy Commission. Div. of Technical Information Extension, Oak Ridge, TN.

Start, G.E., C.R. Dickson, and L.L. Wendell, 1975: Diffusion in a canyon within rough mountainous terrain. J. Appl. Meteoro., 14, 333-346.

Thom, H.C.S., 1959: Distribution of extreme winds in the United States. U.S. Weather Bureau Manuscript, quoted in Quiring (1968).

Thomas, C.E., C.M. Sakamoto, and V.L. Gupta, 1970: Annual climatological extremes in Nevada. Report No. 39, Dept. of Civil Engineering, University of Nevada, Reno.

Turner, D.B., 1970: Workbook of atmospheric dispersion estimates. EPA Pub. AP-26. Office of Air Programs, Research Triangle Park, NC, 84 pp.

Weather Bureau, 1959: Climatology of jackass Flats, Nevada Test Site. Unpublished report by U.S. Weather Bureau, Research Station, Las Vegas, NV, 29 pp.

Wright, H.E., and D.G. Frey, eds., 1965: The Quaternary of the United States: A review volume for the VIIth Congress of the International Association for Quaternary Research. Princeton University Press, Princeton, NJ, 922 pp.

U.S. Department of Interior, Geological Survey, 1976: guidelines for Acquiring Environmental Baseline Data on Federal Geothermal Leases. Menlo Park, CA.

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