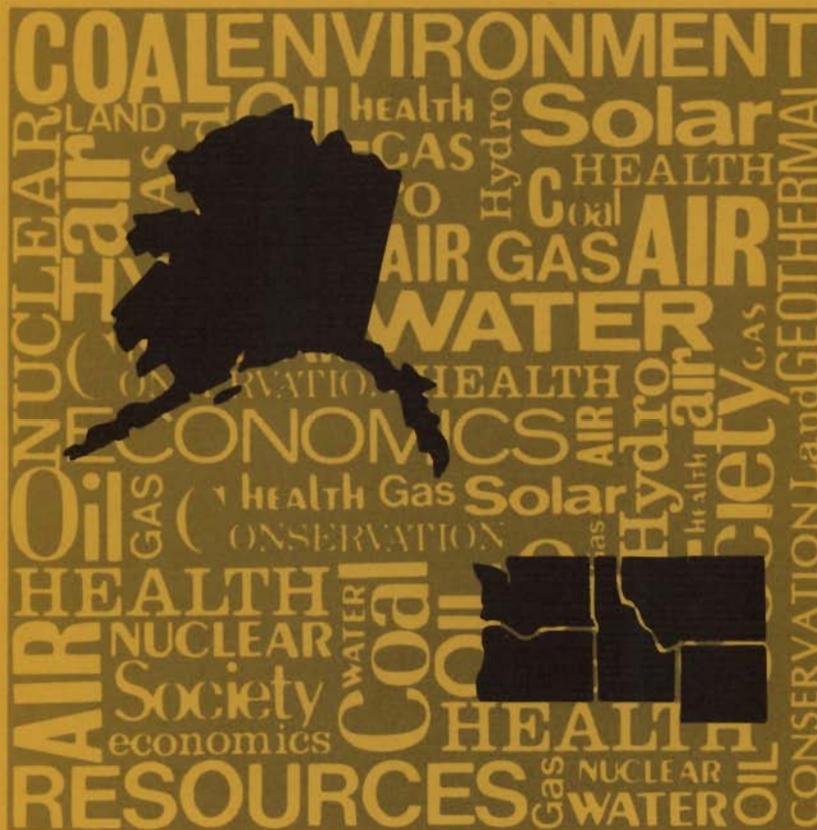


**Pacific Northwest Energy Related  
Regional Assessment Program**

**Regional Air Quality Assessment for  
Probable Near-Term Coal-Related  
Energy Development in the Northwest**



**October 1976**

Prepared for the U.S. Energy  
Research and Development Administration  
under contract AT(45-1):1830

## NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

PACIFIC NORTHWEST LABORATORY  
*operated by*  
BATTELLE  
*for the*  
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION  
*Under Contract EY-76-C-06-1830*

Printed in the United States of America  
Available from

National Technical Information Service  
U.S. Department of Commerce  
5285 Port Royal Road  
Springfield, Virginia 22151

Price: Printed Copy \$\_\_\_\_\*; Microfiche \$3.00

*Pages	NTIS Selling Price
001-025	\$4.50
026-050	\$5.00
051-075	\$5.50
076-100	\$6.00
101-125	\$6.50
126-150	\$7.00
151-175	\$7.75
176-200	\$8.50
201-225	\$8.75
226-250	\$9.00
251-275	\$10.00
276-300	\$10.25

**3 3679 00062 6442**

REGIONAL AIR QUALITY ASSESSMENT FOR PROBABLE  
NEAR-TERM COAL-RELATED ENERGY DEVELOPMENT IN  
THE NORTHWEST

by  
David S. Renne  
Dennis L. Elliott

October 1976

BATTELLE  
Pacific Northwest Laboratories  
Richland, Washington 99352

## SUMMARY

Regional impacts associated with the "possible" near-term scenario of coal-fired electrical generation and coal gasification development in the Pacific Northwest have been analyzed. This analysis is based on Federal New Source Performance Standards (NSPS) and a regional scale transport, transformation and removal model for SO<sub>2</sub>, sulfates, particulates, and NO<sub>x</sub>. Results show the following:

- With respect to the National Ambient Air Quality Standards (NAAQS), no significant incremental amounts of SO<sub>2</sub>, particulates, or NO<sub>x</sub> are added to the background level of regional air concentrations beyond the immediate vicinity of the plant. National standards have not been established for sulfates, although the State of Montana has established its own standards. Here, the modeling shows that the amounts added by new coal-fired power plants, in addition to all existing sulfur emitters, may approach the limit set for maximum allowable sulfate concentrations if emissions are as high as the NSPS. NSPS limits SO<sub>2</sub> emissions to less than 1.2 lb/10<sup>6</sup> Btu fired. In actual practice, emissions may be considerably less either due to the combustion of low sulfur coal or the application of control technology. This result has important implications on the siting of future additional plants in this state.
- There were generally higher air concentrations of all pollutants in July and October, mainly due to lower mean wind speeds. Air concentrations are generally lower in April and December because of greater mean wind speeds and precipitation scavenging.
- Topography influences the concentration patterns of all pollutants. Mostly, these patterns reflect the wind flow characteristics in the vicinity of the source but are modified by wet and dry removal processes.
- Sulfate concentrations and depositions decrease much more slowly with distance from the source than SO<sub>2</sub> concentrations and depositions, primarily due to the time lag involved in the chemical transformation and

to differences in the removal mechanisms. Beyond distances of 50 to 100 km, sulfate concentrations generally exceed  $\text{SO}_2$  concentrations.

- Concentration patterns of  $\text{NO}_x$  resemble those of  $\text{SO}_2$ , whereas concentration patterns of particulates resemble those of sulfate. Removal rates for  $\text{NO}_x$  are assumed to be similar to those of  $\text{SO}_2$ , while the removal rates for particulates are assumed to be similar to those of sulfates.
- For sulfur sources located in basins bordered or surrounded by mountainous terrain (e.g., Puget Sound, Columbia Basin, Snake River Valley), a major portion of the sulfur emissions are deposited onto the terrestrial environment as  $\text{SO}_2$  and sulfates. Over the Great Plains of Montana and Wyoming, there is considerably less deposition and a larger portion of the  $\text{SO}_2$  emitted remains in the air as sulfate to be transported out of the region.
- The fraction of  $\text{SO}_2$  deposited is substantially different between the July and December periods, primarily as a result of the seasonal variations in precipitation. In dry regions, approximately 45 to 60% of the  $\text{SO}_2$  emitted is deposited as  $\text{SO}_2$  (depending on the surrounding terrain), while in wet regions 75% or more may be deposited.
- As much as  $1 \text{ g/m}^2\text{-yr}$  or more, which is approximately 10 lb/acre-yr, of sulfur (in the form of both  $\text{SO}_2$  and sulfates), can be deposited onto the terrestrial environment in the vicinity of a large power plant.
- The most significant increases in ambient air concentrations and surface deposition resulting from the "possible" near-term development scenario will be in the northern Great Plains, the Snake River Valley,<sup>(a)</sup> and in eastern Washington and Oregon.

---

(a) The impact in the Snake River Valley is due to the proposed Pioneer Power Plant. However, recently the Idaho Public Utilities Commission denied a construction permit for this facility.

## CONTENTS

SUMMARY. . . . .	ii
ACKNOWLEDGMENTS. . . . .	viii
1. INTRODUCTION . . . . .	1
2. REGIONAL MODELING . . . . .	4
3. REGIONAL EMISSION INVENTORY . . . . .	7
4. ADAPTATION OF THE REGIONAL MODEL TO THE NORTHWEST . . . . .	11
4.1 UPPER AIR DATA. . . . .	11
4.2 TOPOGRAPHY. . . . .	14
4.3 SUMMARY OF MODEL INPUT. . . . .	16
5. RESULTS. . . . .	18
5.1 SO <sub>2</sub> CONCENTRATIONS. . . . .	18
5.2 SULFATE CONCENTRATIONS. . . . .	22
5.3 SO <sub>2</sub> DEPOSITION. . . . .	23
5.4 SULFATE DEPOSITION. . . . .	24
5.5 PARTICULATES . . . . .	26
5.6 NITROGEN OXIDES . . . . .	27
6. MODEL APPLICATION TO ASSESS PROPOSED CLEAN AIR ACT AMENDMENT . . . . .	29
7. RECOMMENDATIONS. . . . .	35
8. REFERENCES . . . . .	37
APPENDIX A: COMPARISONS OF 1974 DATA TO CLIMATIC AVERAGES . . . . .	A-1

## FIGURES

1	Plume Positions Shown at 12-hour Intervals from Six Existing and Proposed Coal-Fired Power Plants for a Release Starting at 0000 GMT April 2, 1974 . . . . .	5
2	Distribution of Major Existing and Proposed Coal-Fired Power Plants ( $\geq 100$ MWe) and Proposed Coal Gasification Plants in the Northwest and Sulfur Dioxide Emission Estimates Based on New Source Performance Standards . . . . .	9
3	U.S. and Canadian Meteorological Stations Used for Interpolating the Winds . . . . .	12
4	Gross Terrain Features over the Northwest Grid Used in Approximating Spatial Variations in Dry Deposition Velocities . . . . .	16
5	Annual Average Ground-Level Air Concentrations of $SO_2$ for Existing Plants Based on New Source Performance Standards . . . . .	19
6	Annual Average Ground-Level Air Concentrations of $SO_2$ for Existing and Proposed Plants Based on New Source Performance Standards . . . . .	19
7	Ground-Level Air Concentrations of $SO_2$ for July 1974 for Existing and Proposed Plants Based on New Source Performance Standards . . . . .	21
8	Ground-Level Air Concentrations of $SO_2$ for December 1-17, 1974, for Existing and Proposed Plants Based on New Source Performance Standards . . . . .	21
9	Annual Average Sulfate Concentrations for Existing and Proposed Plants Based on Emissions at New Source Performance Standards . . . . .	22
10	Annual Total $SO_2$ Deposition from Existing and Proposed Plants Based on New Source Performance Standards . . . . .	24
11	Annual Total Sulfate Deposition from Existing and Proposed Plants Based on New Source Performance Standards . . . . .	25
12	Annual Average Particulates Concentrations for Existing and Proposed Plants Based on New Source Performance Standards . . . . .	27
13	Annual Average $NO_x$ Concentrations for Existing and Proposed Plants Based on New Source Performance Standards . . . . .	28
14	All Possible Class I Exclusion Areas and Estimated Annual $SO_2$ Concentrations for the "Possible" Near-Term Scenario Based on New Source Performance Standards . . . . .	33

TABLES

1	Emissions from Coal-Fired Power Plants in the Northwest (Based on New Source Performance Standards) . . . . .	8
2	Emissions from Possible Gasification Plants and Total Coal-Related Emissions . . . . .	9
3	Meteorological Stations Utilized in the Interpolation Scheme . . .	13
4	National Ambient Air Quality Standards for Sulfur Dioxides, Total Suspended Particulates, and Nitrogen Oxides . . . . .	18
5	Seasonal Comparisons of Total SO <sub>2</sub> -Sulfate Budgets within the Northwest Grid . . . . .	26
6	Allowable Air Quality Increments Under Alternative Significant Deterioration Proposals (µg/m <sup>3</sup> ) . . . . .	30
7	Summary of Major Differences of Alternative Approaches to Significant Deterioration . . . . .	31

## ACKNOWLEDGMENTS

The authors thank the Puget Sound Air Pollution Control Agency for supplying meteorological data from the Seattle pilot balloon station. We also thank Terry Fox, Dave Powell, and Larry Wendell of the Atmospheric Sciences Department, Battelle, Pacific Northwest Laboratories, for their assistance in the model application and in preparation of meteorological data tapes, and Rick Cederwall of Brookhaven National Laboratories for providing upper air data tapes. Review comments by Ward Swift and John Burnham of Battelle are greatly appreciated.

This work was performed under Contract E-(45-1)-1830 with the Energy Research and Development Administration.

REGIONAL AIR QUALITY ASSESSMENT FOR PROBABLE NEAR-TERM  
COAL-RELATED ENERGY DEVELOPMENT IN THE NORTHWEST

David S. Renne and Dennis L. Elliott

*The combined impacts on regional air quality and terrestrial environments in the Pacific Northwest of the United States from SO<sub>2</sub>, sulfates, particulates, and NO<sub>x</sub> emissions associated with a "possible" near-term scenario of coal-fired electrical generation development has been initially assessed. This assessment is based on Federal New Source Performance Standards and uses a regional scale transport model. Dry deposition, precipitation scavenging, and chemical transformation processes are incorporated into the model. The effects of surface roughness and topography on dry removal rates are simulated by varying the deposition velocity over different terrain types. The analysis of ground level air concentrations and surface depositions from major existing and proposed coal-fired power plants and gasification plants is based on approximately 1 month's wind data for each season in 1974. Results show no significant amounts of SO<sub>2</sub>, particulates, or NO<sub>x</sub> added to the background levels within the region with respect to the National Ambient Air Quality Standards. Most of the SO<sub>2</sub> emitted is either deposited within the region or transported out of the region as sulfates. The model shows largest average concentrations for the summer and fall periods, primarily due to lighter wind speeds. Seasonal variations in the transport patterns and topographical influences are apparent from the analyses. The "possible" developmental sequence over the next decade shows the largest increases in air concentration and surface deposition due to new coal-fired facilities to occur in the northern Great Plains, the Snake River Valley, and in eastern Washington and Oregon.*

1. INTRODUCTION

The Northwest holds many large energy resources and could become one of the major energy-producing sectors of the country. Large, relatively untapped low-sulfur coal reserves exist in Montana, Wyoming, and Alaska; an abundance of hydroelectric power has already been exploited in Washington, Oregon and Idaho; sites for large nuclear/fossil power parks are under development or proposed in the Columbia Basin Region; and the trans-Alaskan pipeline will

soon be transporting crude oil to southern ports in Alaska to be transported and refined in the lower 48 states. Nevertheless, this seemingly abundant energy picture is complicated by a rapid population growth in certain regions, continued development of energy-intensive industries, potential curtailment of Canadian crude oil and natural gas supplies to the region, nuclear and hydroelectric moratoriums, and delays in fossil power plant production. The situation is further complicated by a strong desire to preserve, as much as possible, the natural environment of the diverse and spectacular scenery and lifestyle of this sector of the United States. This complex energy picture is being examined at the Battelle, Pacific Northwest Laboratories through the Regional Assessment Program for the six-state region (Alaska, Washington, Oregon, Idaho, Montana and Wyoming). The environmental consequences of these various energy development scenarios are being studied as a major component of the program.

One objective of the air quality portion of this regional study is to develop emission estimates to the year 2020 for various development scenarios and to apply the geographic distribution of these emissions to a regional scale transport, transformation and removal model. With an emphasis on providing information for a coal utilization assessment, the first phase of this continuing program has concentrated on regional impacts associated with emissions from existing and proposed coal-fired power plants. An initial air quality assessment of the regional impacts due to coal-related sulfur emissions has been described previously.<sup>(1)</sup> Since then, revisions and refinements in the modeling capability, analytical techniques, and emissions inventory have been added. For example, topography effects have been better incorporated by increasing the density of the upper air network utilized by the model, by examining the flow characteristics at each meteorological station to determine the most representative layer for regional pollutant transport (some of the stations may be in restricted valleys or sheltered locations), and by varying the deposition velocity over different terrain features. Further, 4 months of upper air data, one in each season of 1974, have been used to estimate annual average concentrations.

Ground-level air concentrations and surface depositions of four pollutants--sulfur dioxide ( $\text{SO}_2$ ), sulfates ( $\text{SO}_4$ ), nitrogen oxides ( $\text{NO}_x$ ), and particulates--have been computed for existing and proposed coal-fired power plants and coal gasification in the Northwest (excluding Alaska). Federal New Source Performance Standards (NSPS) are the upper limit on permissible emissions.

This paper focuses on the modeling techniques and model results of the impacts on regional air quality and the terrestrial environment expected from a "possible" near-term coal electric generation development in the next decade. It also assesses the effects of proposed amendments to the Federal Clean Air Act on coal development and utilization within the region.

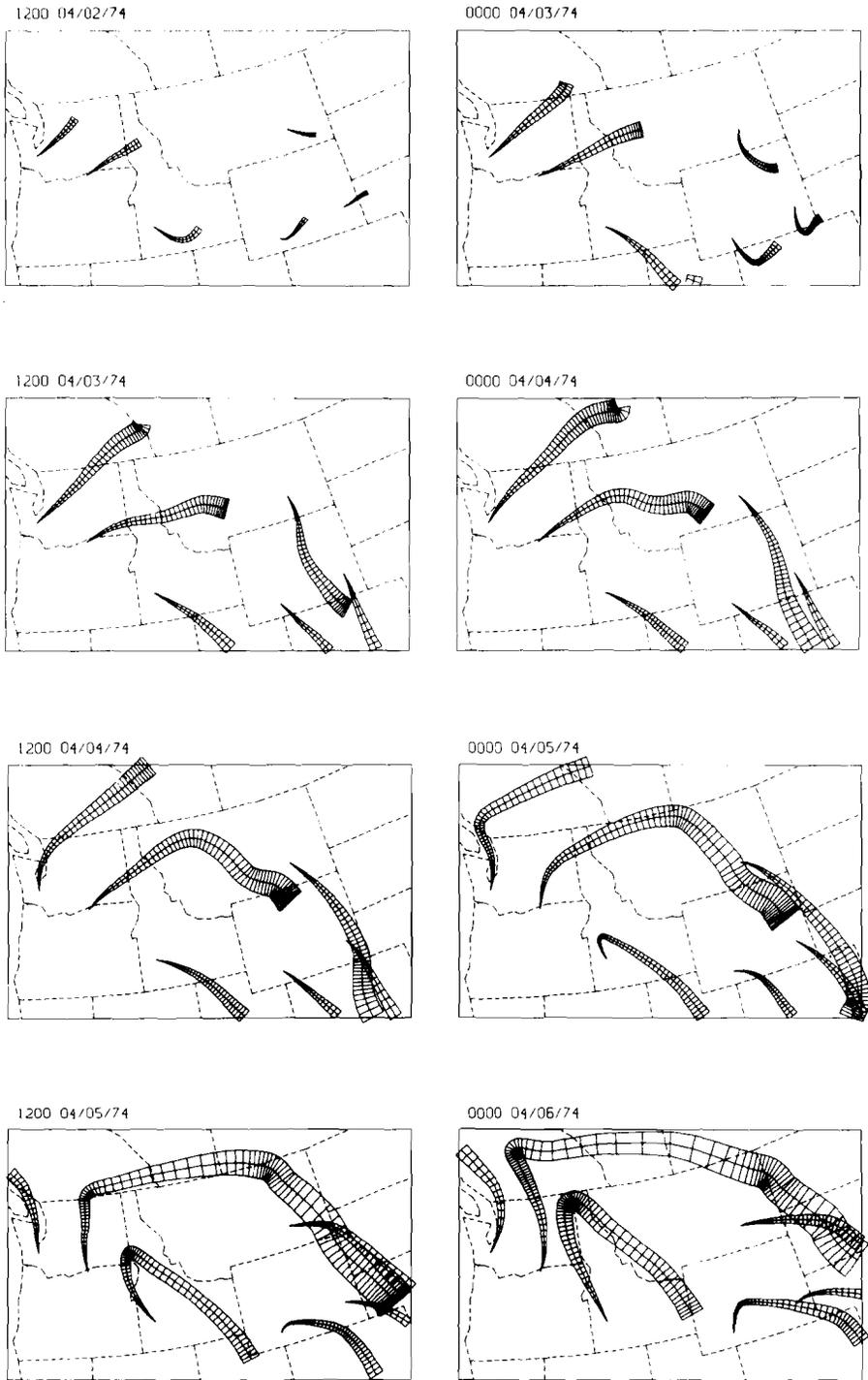
## 2. REGIONAL MODELING

A regional scale transport, transformation, and removal model developed by Wendell, et al.<sup>(2)</sup> is being utilized to obtain estimates of ground-level air concentrations and surface deposition of  $\text{SO}_2$ ,  $\text{SO}_4$ ,  $\text{NO}_x$  and particulates for the Northwest. The model has been modified to incorporate multiple source locations throughout the Northwest so that air quality impacts from any combination of scenarios, e.g., emission strengths and source locations, may be evaluated.

Transport of the effluents is determined from the spatial and temporal variations of the observed upper level rawinsonde and pibal winds interpolated to a uniformly spaced grid over the region. The winds are averaged over any given specified layer to provide a "layered-average" transport, and gridded wind fields are produced for each hour by interpolating between the routine 12-hour observations. Pollutant transport is simulated by a continuous plume centerline approximated by a series of massless particles released 1/hour from selected source locations. An example of computer plots of simulated plumes is shown in Figure 1. Average ground-level air concentrations and surface depositions are computed by sampling the plumes over an array of grid squares.

The vertical dispersion parameter,  $\sigma_z$ , is estimated from Briggs' formulations,<sup>(3)</sup> which are modified in this regional assessment to limit the vertical diffusion over long travel distances. As an option, a lid to the vertical mixing such as that imposed by an elevated inversion may be specified. A model version is currently being developed which will account for diurnal changes in the mixing height and stability.

Horizontal dispersion about the plume centerline is accounted for by the spatial and temporal variations in the wind field, using the techniques of previous investigations.<sup>(4)</sup> However, the model has the option of approximating the horizontal dispersion parameter as a function of travel distance and stability class, although use of this capability increases computer time by a factor of four.



**FIGURE 1.** Plume Positions Shown at 12-hour Intervals from Six Existing and Proposed Coal-Fired Power Plants for a Release Starting at 0000 GMT April 2, 1974

A linear oxidation reaction rate is assumed for the transformation of SO<sub>2</sub> to sulfate. This reaction rate is specified as model input. As more experimental data become available, the effects of nonlinear factors such as relative humidity on the transformation rate will be considered for incorporation in the model.

Removal of pollutants by dry deposition depends on many factors, such as roughness height, vegetation surfaces, and wind speed. However, insufficient experimental data exist to account properly for these processes in the model, so that deposition velocities for each pollutant are specified as model input. The model utilizes the techniques of source depletion, a somewhat less realistic but nevertheless simpler method than the techniques of surface depletion.<sup>(5)</sup>

Scavenging of airborne SO<sub>2</sub> and sulfate is determined from:

$$\psi = e^{-\Lambda t} \quad (1)$$

where  $\psi$  is the reduction of the source emission rate due to precipitation scavenging,  $\Lambda$  is the washout coefficient and  $t$  is the plume travel time during the precipitation episode. The washout coefficient is directly proportional to the precipitation rate. Thus, pollutant scavenging is estimated by a source depletion term in a manner similar to dry deposition. The model is designed to use either time-averaged or gridded hourly precipitation data. Although the more realistic approach is to use hourly precipitation data, these data are not currently available in a form that can be readily converted for use in a long-term assessment model. The effects of real-time versus time-averaged precipitation rates on SO<sub>2</sub> and sulfate removal have previously been examined,<sup>(6)</sup> and the results indicate that there is more total removal with time-averaged precipitation data but greater wet deposition in localized areas with hourly precipitation data.

Although topographic effects on plume transport are not incorporated into the model explicitly, the synoptic scale wind does reflect implicitly large-scale topographic features. More realistic methods of approximating the effects of topography on the transport and deposition of pollutants over the complex terrain of the Northwest are explained later in this report.

### 3. REGIONAL EMISSION INVENTORY

A sulfur emission inventory is being developed for the Pacific Northwest Region. Air quality impacts of the Regional Assessment Program have thus far dealt with concentrations and depositions caused by large point coal-related emission sources. Future assessments will include other large sources in the region such as smelters and refineries.

Emissions from the existing and proposed power plants have been estimated by assuming that all facilities will operate at the New Source Performance Standards (NSPS) promulgated by the Environmental Protection Agency.<sup>(7)</sup> These standards stipulate the following maximum allowable emissions for power plants:

SO <sub>2</sub> :	1.2 lb/10 <sup>6</sup> Btu
Particulate:	0.1 lb/10 <sup>6</sup> Btu
NO <sub>x</sub> :	0.7 lb/10 <sup>6</sup> Btu

State standards may be more stringent than these and would result in emissions less than the NSPS. Alternatively, coals with lower sulfur contents may be utilized or additional control technology may be applied. In this study the thermal generating capacity of the facilities is estimated by assuming a 75% plant load factor and a 33% thermal conversion efficiency.

Emission estimates for coal gasification plants were obtained following the procedure given in the Northern Great Plains Resource Program report.<sup>(8)</sup> A gasification plant size of 250 million standard cubic feet of gas production per day and an associated steam plant with a 325 MW equivalent capacity were assumed. A plant load factor of 91% was used in estimating the emissions.

Capacity and emission rates, based on NSPS, are given in Table 1 for major existing and proposed Northwest coal-fired power plants and in Table 2 for proposed coal gasification plants. Figure 2 shows the distribution throughout the Northwest of the existing and proposed coal-related energy generation emitters and their relative size in terms of SO<sub>2</sub> emissions. Emissions from sources near the same location (e.g., Wyodak power plant and Gillette gasification plant) are combined for this regional air quality

TABLE 1. Emissions from Coal-Fired Power Plants in the Northwest  
(Based on New Source Performance Standards)

Power Plant	Capacity (MWe)	Emissions ( $10^3$ tons/yr)		
		SO <sub>2</sub>	Particulates	NO <sub>x</sub>
Washington				
Centralia	1390	56.1	4.9	32.7
Oregon				
Carty (Proposed)	500	20.2	1.7	11.8
Eden Ridge (Proposed)	100	4.0	0.3	2.4
Idaho				
Pioneer (Proposed) <sup>(a)</sup>	1500	60.5	5.0	35.3
Montana				
J. E. Colette	173	7.0	0.6	4.1
Colstrip 1&2	660	26.6	2.2	15.5
Colstrip 3&4 (Proposed) <sup>(b)</sup>	1400	56.5	4.7	33.0
Wyoming				
Jim Bridger	2034	82.1	6.8	47.9
Dave Johnston	750	30.3	2.5	17.7
Naughton	707	28.5	2.4	16.6
Wyodak Simpson	358	14.4	1.2	8.5
Laramie River (Proposed)	1500	60.5	5.0	35.3
Naughton (Proposed)	860	34.7	2.9	20.2
Total				
Existing	6072	245.0	20.6	143.0
Proposed	5860	236.4	19.6	138.0
Existing and Proposed	11932	481.4	40.2	281.0

(a) Permit to construct has recently been denied by the Idaho Public Utilities Commission.

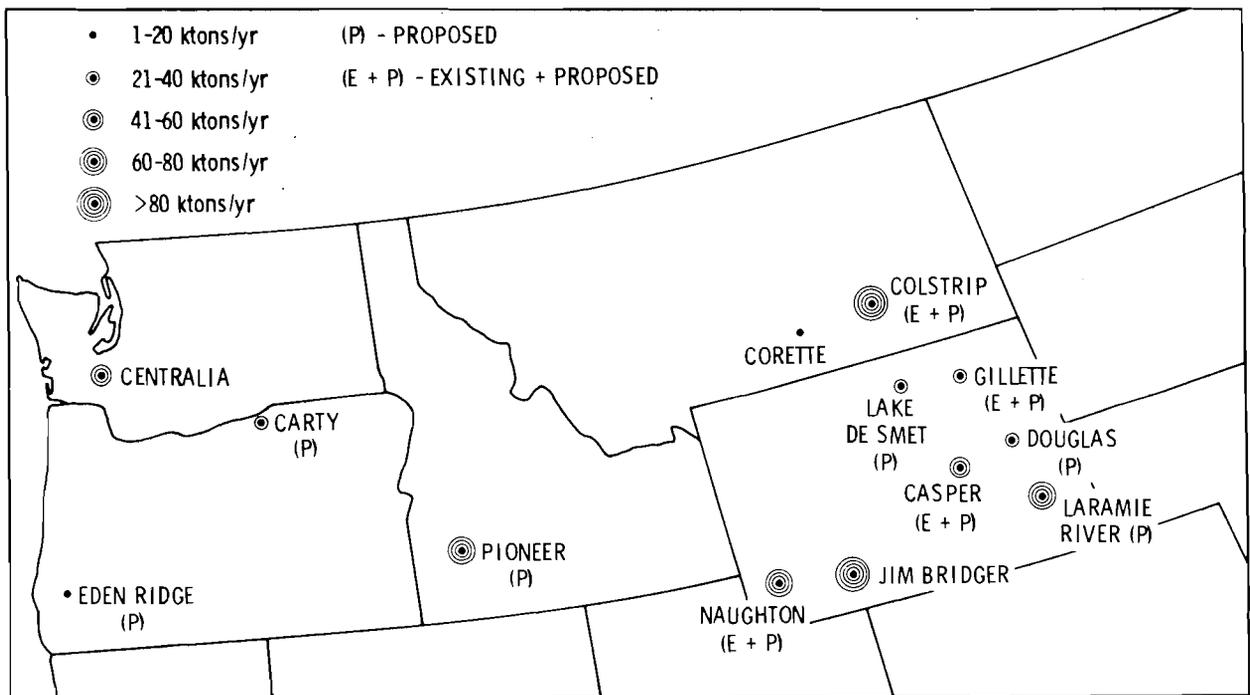
(b) Permit to build was recently issued.

**TABLE 2.** Emissions from Possible Gasification Plants and Total Coal-Related Emissions

Possible Gasification Plants	Capacity (MMSCFD)	Emissions ( $10^3$ tons/yr)		
		SO <sub>2</sub>	Particulates	NO <sub>x</sub>
<b>Wyoming</b>				
Casper	250	21.5	1.9	10.4
Douglas	250	21.5	1.9	10.4
Gillette	250	21.5	1.9	10.4
Lake DeSmet	250	21.5	1.9	10.4
<b>Total</b>	<b>1000</b>	<b>86.0</b>	<b>7.6</b>	<b>41.6</b>

Total Coal-Related Emissions (Existing + Proposed Power Plants + Possible Gasification Plants)

SO<sub>2</sub>: 567,400 tons/yr  
 Particulates: 47,800 tons/yr  
 NO<sub>x</sub>: 322,600 tons/yr



**FIGURE 2.** Distribution of Major Existing and Proposed Coal-Fired Power Plants (>100 MWe) and Proposed Coal Gasification Plants in the Northwest and Sulfur Dioxide Emission Estimates Based on New Source Performance Standards

assessment. As seen from Figure 2, a major portion of the existing and proposed coal-related emissions extend from the Great Plains of southeast Montana through eastern Wyoming and into southwest Wyoming.

An inventory of actual emissions data<sup>(8,9)</sup> for existing coal-fired power plants shows enormous variations in emissions, in some cases an order of magnitude for plants of approximately the same generating capacity. This is most likely due to no high efficiency control devices at some of the older power plants. For this assessment, however, since some of the existing plants may have modified their emission control devices after the publication of the emission inventories, emissions based on NSPS were used to obtain conservative (high) concentration estimates for all sources until more updated emissions data can be acquired.

As this model is refined and energy development scenarios for the Northwest are examined, future emissions will be computed directly from the energy conversion, transportation and consumption estimates of the simulation program projected to the year 2020. This present study concentrates on air quality impacts associated with the combined long-range transport of the existing major coal-fired power plants in the Northwest, and the incremental effects of a "possible" coal-fired electric generation and coal gasification development scenario projected about 10 years into the future.

#### 4. ADAPTATION OF THE REGIONAL MODEL TO THE NORTHWEST

In adapting the regional model to the Northwest, particular attention should be given to the air transport analysis, a major component of air quality assessment. Upper air data and the topographic features of the Northwest are important inputs to the regional model and are discussed below.

##### 4.1 UPPER AIR DATA

Over large regions of complex terrain, such as the Northwest, caution must be used in interpolating gridded winds from upper air stations which are separated from emission sources by physical topographic barriers. These barriers cause wind characteristics significantly different from those near the source. Large-scale topographic influences on the wind field, such as channeling or sheltering effects, are often apparent 1000 m or more above the mean surface. For this reason, a study was conducted to determine how the atmospheric transport analysis could be improved over the Northwest, particularly for areas like Puget Sound in western Washington, the Columbia Basin of north-central Oregon, and the high plateau of southwest Wyoming. These are areas where large coal-fired power plants either exist or are proposed, but where standard upper air data at 0000 GMT and 1200 GMT are not available.

Two techniques were used in this study. The first was to increase the network density of upper air observations by incorporating those stations with upper air pilot balloon wind observations (pibals) at 0600 GMT and/or 1800 GMT. Figure 3 shows the upper air network of rawinsonde and pibal stations used in this assessment. Station names are given in Table 3. Some of the pibal stations, e.g., GRF, SEA, PDT, CPR, and BIL, are close (within 10 to 70 km) to specified emission sources where major topographical influences on the wind fields exist. Pibal stations which are located in mountain valleys or sheltered locations and not near any existing or proposed coal-fired power plant (e.g., Missoula, Montana and Wendover, Utah) were not used for this analysis.

Observations at 0600 GMT were included with those at 0000 GMT for computing the gridded winds at 0000 GMT. Likewise, 1800 GMT observations were

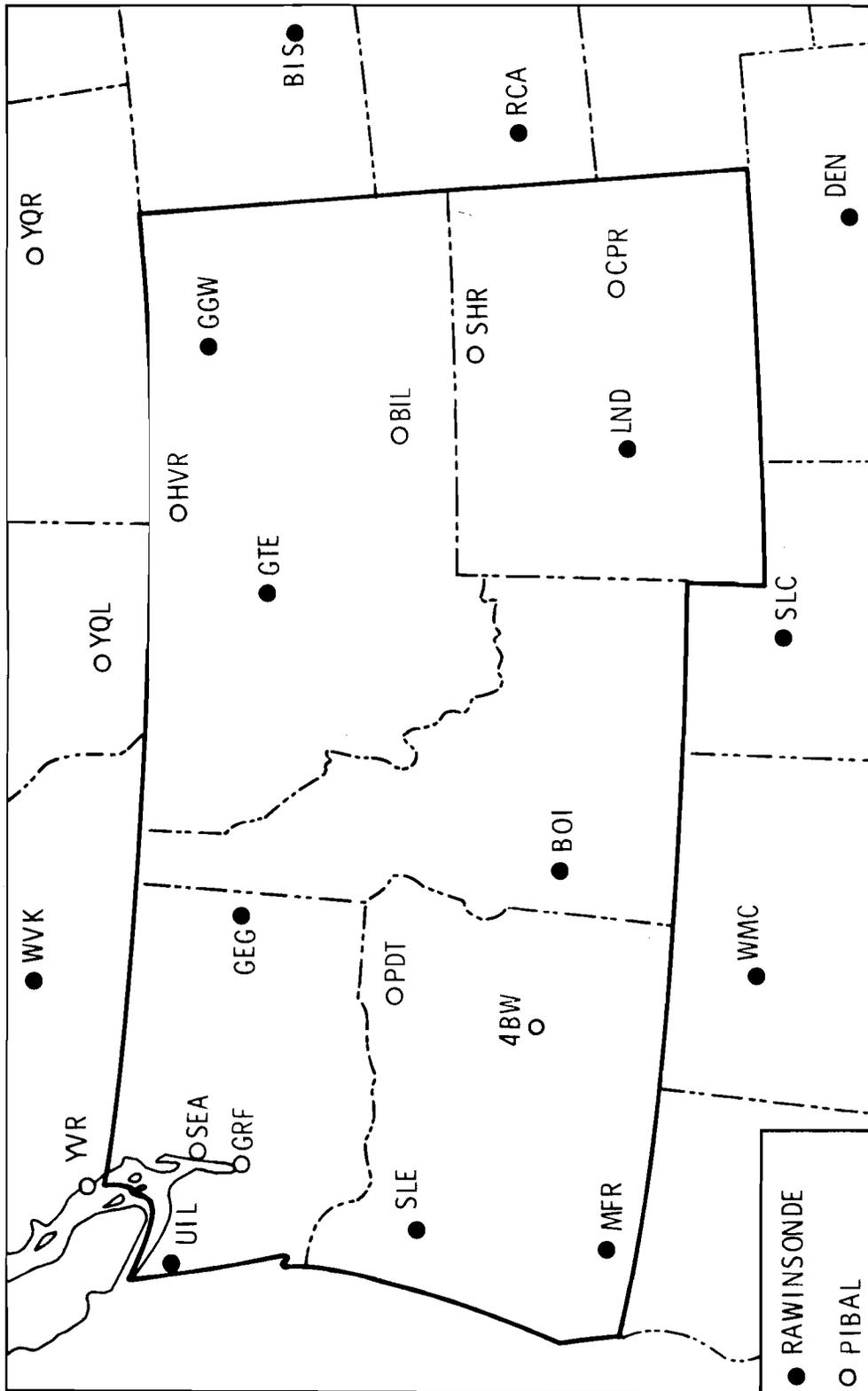


FIGURE 3. U.S. and Canadian Meteorological Stations Used for Interpolating the Winds. Additional stations off the grid are used for interpolating winds near the grid boundaries.

TABLE 3. Meteorological Stations Utilized  
in the Interpolation Scheme

<u>Station Number</u>	<u>Station Symbol</u>	<u>Station Name</u>	<u>Layer-Averaged Winds Specified(a)</u>
72451	DDC	Dodge City, KS	1
72469	DEN	Denver, CO	1
72476	GJT	Grand Junction, CO	2
72486	ELY	Ely, NV	1
72562	LBF	North Platte, NB	1
72569	CPR	Casper, WY	1
72572	SLC	Salt Lake City, UT	2
72576	LND	Lander, WY	2
72583	WMC	Winnemucca, NV	1
72597	MFR	Medford, OR	2
72654	HON	Huron, SD	1
72662	RCA	Rapid City, SD	1
72666	SHR	Sheridan, WY	1
72677	BIL	Billings, MT	1
72681	BOI	Boise, ID	1
72683	4BW	Burns, OR	1
72688	PDT	Pendleton, OR	1
72694	SLE	Salem, OR	1
72764	BIS	Bismarck, ND	1
72768	GGW	Glasgow, MT	1
72775	GTE	Great Falls, MT	1
72777	HVR	Havre, MT	1
72785	GEG	Spokane, WA	1
72793	SEA	Seattle, WA	1
72797	UIL	Quillayute, WA	1
72852	YWG	Winnipeg, Mani.	1
72853	YBR	Brandon, Mani.	1
72863	YQR	Regina, Sask.	1
72874	YQL	Lethbridge, Alb.	1
72892	YVR	Vancouver, BC	1
74109	YZT	Port Hardy, BC	1
74115	WVK	Vernon, BC	2
74207	GRF	Tacoma, WA	1

(a) 1 = 100 m to 1000 m layer  
2 = 1000 m to 2000 m layer.

included with 1200 GMT observations for estimating gridded winds at 1200 GMT. Some of the pibal stations (e.g., Sheridan, Wyoming) occasionally take observations at two consecutive 6-hour periods, such as 1200 GMT and 1800 GMT. In this case, the 1200 GMT observation was selected.

An investigation shows no significant difference in the long-term transport patterns if different time period combinations, such as the inclusion of 0600 GMT observations with 1200 GMT observations and 1800 GMT with 0000 GMT, are used. For this reason, more elaborate interpolation schemes were not considered. In regions of complex terrain, the effects of topography on the long-term regional transport patterns appear to overwhelm the effects of short-term (6-hour) temporal variations.

The second technique involved specifying the appropriate layer of winds for transporting the pollutant. For example, the emission source may be located on a broad plateau while the nearest upper air station is in a confined valley. In this case, a higher layer of wind data may be used so that the winds in the interpolation scheme are above the influence of local topography.

For the majority of stations, winds averaged over a layer between 100 and 1000 m above the ground were used to estimate the pollutant transport. However, for rawinsonde stations located in mountain valleys or sheltered locations away from the emission sources, e.g., MFR, WVK, LND, and GJT, 1000 to 2000 m layered winds were used to get above the influence of local topography. Also, the 1000 to 2000 m layered winds over SLC were used to obtain better transport estimates for the Naughton and Jim Bridger coal-fired power plants. These facilities are located in the southwest Wyoming basin which is an elevation about 600 to 700 m higher than the Salt Lake basin. The layer-averaged winds specified for each station are given in Table 3.

#### 4.2 TOPOGRAPHY

An additional feature of the modeling used in this study is the capability to vary the dry removal rates over different terrain types. Terrain

features over the Northwest grid were classified into four general types, shown in Figure 4. Smooth terrain types include large water bodies and gently rolling to hilly terrain composed of grasslands and small shrubs, typical of a steppe climate. All nonmountainous terrain east of the Cascade Mountains has been classified in this category. Flat forested areas in the Northwest are confined to the marine climate of western Oregon and Washington. As seen in Figure 4, a major portion of the Northwest is mountainous and very mountainous terrain. The mountainous terrain type includes very hilly areas (e.g., the coastal ranges of Washington and Oregon). The large extensive mountain ranges (mainly the Rockies and Cascades), which act as major barriers to regional transport of pollutants, have been designated as very mountainous terrain.

For each pollutant, dry removal rates are specified as model input for each terrain class. While insufficient data exist on deposition velocities over forested and mountainous terrain, it is generally accepted that dry removal rates are greater over these surface features primarily due to increased roughness and to the ability of vegetation to take up gaseous and particulate pollutants. Model predictions<sup>(10,11)</sup> and wind tunnel experiments<sup>(12)</sup> show an increase in deposition velocities with increased roughness heights; however, there is also considerable variation in these predicted deposition velocities.

Over mountainous terrain, additional factors such as plume impaction against the steeper slopes, increased roughness heights due to greater height variations of the terrain surface, and greater plume dilution due to terrain induced turbulence, complicate the problem of specifying deposition velocities. We assumed here that dry removal rates are significantly higher over mountainous terrain than over forested regions. Start et al.<sup>(13)</sup> investigated effluent transport over mountainous terrain and observed dilution factors averaging 4 to 15 times that predicted for smooth, flat terrain under similar atmospheric conditions. However, there is no way to account for the fraction of the observed dilution which can be attributed to plume impaction against the elevated terrain and the fraction attributed to enhanced mechanical turbulence. Greatest dilutions were observed under

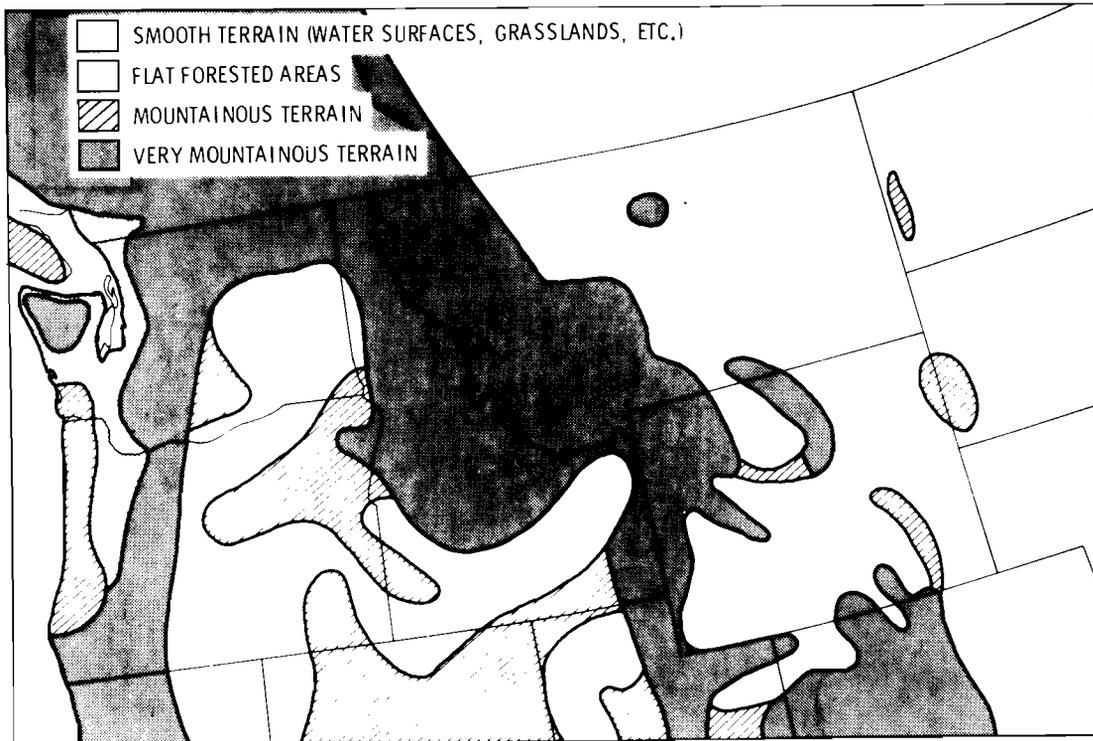


FIGURE 4. Gross Terrain Features over the Northwest Grid Used in Approximating Spatial Variations in Dry Deposition Velocities

strong inversion conditions and smallest during lapse conditions, in contrast to what is typically observed over flat terrain. Yet, since these measurements were taken primarily within 10 km of release points very near or within mountainous terrain, the applicability of these results to long-range transport over mountainous terrain is difficult to infer.

#### 4.3 SUMMARY OF MODEL INPUT

Upper air data for computing layer average gridded winds were used in this assessment for the following periods in 1974: April 1-30, July 1-31, October 1-31, and December 1-19. Thus, each season was represented so that seasonal variations in transport patterns throughout the Northwest could be examined. In Appendix A, a discussion of the comparison of 1974 meteorology with climatic averages is provided.

A 38.5 km grid spacing was used in the analysis, giving a grid area, and consequently a computational resolution, of approximately 1500 km<sup>2</sup> over which the concentrations and depositions were averaged. Neutral stability conditions were assumed for the diffusion calculations in each period. According to the diffusion formulation used,  $\sigma_z$  (the vertical dispersion coefficient) approaches an asymptotic limit of 3000 m for neutral stability. An effective stack height of 400 m was assumed for all sources.

Dry deposition velocities for smooth, flat terrain were specified as 1 cm/sec for SO<sub>2</sub> and NO<sub>x</sub> and 0.1 cm/sec for sulfates and particulates. Deposition velocities were increased by a factor of 2 for forested terrain, a factor of 5 for mountainous terrain, and a factor of 10 for very mountainous terrain. A transformation rate from SO<sub>2</sub> to sulfate was set at 5%/hr. For NO<sub>x</sub> and particulates, no transformation was assumed. The washout coefficients,  $\Lambda$ , for wet removal were specified as follows:

$$\Lambda_1 = P/2/\text{hr for SO}_2 \text{ and NO}_x$$

$$\Lambda_2 = P/20/\text{hr for sulfates and particulates}$$

where P is the rainfall rate in mm/hr. Spatial variations in the rainfall rate were determined by interpolating the mean monthly precipitation data (obtained from mean monthly precipitation maps) to the same size grid squares over which the concentrations and deposition were computed.

## 5. RESULTS

Average ground-level air concentrations and surface deposition of SO<sub>2</sub>, sulfates, particulates, and NO<sub>x</sub> from major existing and proposed coal-fired power plants and coal gasification plants were computed for each of the four 1-month periods. Annual average concentrations and depositions were computed from these four periods. Each period was weighted equally to obtain annual average estimates, regardless of the number of days in each period. That is to say, the average concentration for the 19-day period in December is considered representative of the winter season, the average concentration for the 30-day period in April is considered representative for the spring season, and so forth. Deposition was normalized to an annual cumulative amount deposited on the surface. Maximum allowable annual average air concentrations allowed under the National Ambient Air Quality Standards (NAAQS) are given in Table 4. State standards must at least meet the NAAQS and may be more restrictive.

TABLE 4. National Ambient Air Quality Standards for Sulfur Dioxides, Total Suspended Particulates, and Nitrogen Oxides

<u>Pollutant</u>	<u>Maximum Allowable Annual Average Air Concentrations</u>	
	<u>Primary Standard</u>	<u>Secondary Standard</u>
Sulfur Oxides	80 g/m <sup>3</sup>	80 g/m <sup>3</sup>
Particulates	75 g/m <sup>3</sup>	60 g/m <sup>3</sup>
Nitrogen Oxides (as Nitrogen Dioxide)	100 g/m <sup>3</sup>	100 g/m <sup>3</sup>

### 5.1 SO<sub>2</sub> CONCENTRATIONS

Annual average concentrations of SO<sub>2</sub> are shown in Figure 5 for the existing plants and in Figure 6 for the existing plus proposed plants listed in Table 1. Except for the Centralia plant, located in western Washington, all the existing power plants are in Montana and Wyoming. Largest annual average SO<sub>2</sub> concentrations predicted by the model from coal-related emissions



FIGURE 5. Annual Average Ground-Level Air Concentrations of  $\text{SO}_2$  for Existing Plants Based on New Source Performance Standards



FIGURE 6. Annual Average Ground-Level Air Concentrations of  $\text{SO}_2$  for Existing and Proposed Plants Based on New Source Performance Standards

alone are approximately  $4 \mu\text{g}/\text{m}^3$ ,<sup>(a)</sup> which is well below the NAAQS ( $80 \mu\text{g}/\text{m}^3$ ) and state standards. However, since this value is an average for a  $1500 \text{ km}^2$  grid, much higher concentrations would be computed near the source using Gaussian plume type models. By comparing the area within  $1 \mu\text{g}/\text{m}^3$  contour interval in Figures 5 and 6, it can be seen that increased regional interactions of pollutants will occur over parts of Montana and Wyoming due to the proposed plants. For the existing power plants, the model shows there are presently no regional scale interactions of  $\text{SO}_2$  concentrations greater than  $1 \mu\text{g}/\text{m}^3$ ; however, there is considerable interaction of concentrations greater than this value with the addition of the proposed plants in Montana and Wyoming. While these incremental concentrations may seem insignificant, they could be quite important if they extend over areas where only small increases (i.e.,  $2 \mu\text{g}/\text{m}^3$ ) in air concentrations would be allowed under proposed amendments to the Federal Clean Air Act. This will be discussed in more detail in Section 6.

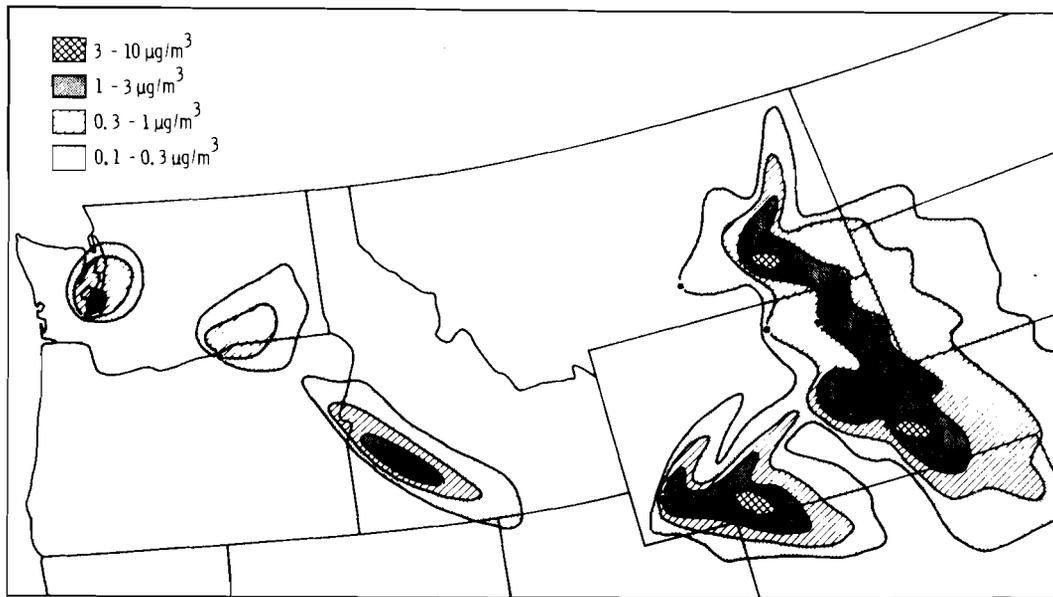
Seasonal variations between winter and summer concentrations and transport patterns can be seen by examining average concentrations for the July period in Figure 7 and for the December period in Figure 8. Several significant differences in the two periods are apparent: over the western half of the grid, largest  $\text{SO}_2$  concentrations are generally higher in July than in December due to less precipitation scavenging and lower wind speeds during summer. The most dramatic difference is at Centralia where the December precipitation averages over 6 inches whereas July precipitation averages less than 1 inch. With the exception of Centralia all the existing and proposed coal-fired power plants are in dry locations. However, seasonal variations in mean precipitation are pronounced with late spring and summer maximums east of the Rocky Mountains and winter maximums in Oregon and Washington. Nevertheless, over Montana and Wyoming, there are no significant differences between the largest concentrations for July and December. This is most likely

---

(a) Air quality is, by convention, normally expressed in  $\mu\text{g}/\text{m}^3$ . For purposes of comparison  $1 \mu\text{g}/\text{m}^3$  is approximately equal to  $0.38 \times 10^{-3}$  ppm for  $\text{SO}_2$  at  $25^\circ\text{C}$ .



**FIGURE 7.** Ground-Level Air Concentrations of  $\text{SO}_2$  for July 1974 for Existing and Proposed Plants Based on New Source Performance Standards



**FIGURE 8.** Ground-Level Air Concentrations of  $\text{SO}_2$  for December 1-17, 1974, for Existing and Proposed Plants Based on New Source Performance Standards

due to the fact that the effects of lower wind speeds in July are somewhat offset by greater precipitation, whereas in December the reverse is true.

The predominance of northwest winds in December and southeast winds in July over the Great Plains of Montana and Wyoming is apparent from a comparison of the concentration patterns for the two periods. In December the effluent is transported further into the bordering states of South Dakota, Nebraska, and Colorado, while in July there is more transport toward the northwest. These transport features over eastern Montana and eastern Wyoming agree well with the climatological surface flow patterns for the two periods, based on an examination of surface wind rose data. In addition, the influence of topography on effluent transport patterns is apparent in certain regions, such as the Snake River Valley of southwest Idaho and the Puget Sound-Willamette Trough of western Washington and Oregon.

## 5.2 SULFATE CONCENTRATIONS

Annual average sulfate concentrations for all existing and proposed power plants are shown in Figure 9. In contrast to the  $\text{SO}_2$  concentrations,



**FIGURE 9.** Annual Average Sulfate Concentrations for Existing and Proposed Plants Based on Emissions at New Source Performance Standards

the sulfate concentrations decrease much more slowly with distance from the source, primarily due to much smaller removal rates of sulfate for both precipitation scavenging and dry deposition. Largest annual sulfate concentrations are approximately  $2 \mu\text{g}/\text{m}^3$ . This estimate can be compared with measurements reported by Altshuller,<sup>(14)</sup> who showed measured sulfate concentrations at urban sites throughout the western U.S. averaging from 5 to  $9 \mu\text{g}/\text{m}^3$ , while measurements at nonurban sites indicate background levels of about  $1 \mu\text{g}/\text{m}^3$  or less. Although the maximum annual average sulfate concentrations estimated by the model are slightly less than the maximum for  $\text{SO}_2$ , the area with concentrations exceeding  $1 \mu\text{g}/\text{m}^3$  is substantially larger for sulfates than for  $\text{SO}_2$ , particularly over Montana and Wyoming. Here the combined wet and dry removal rate is less, leaving more  $\text{SO}_2$  in the atmosphere for chemical conversion to sulfates. Thus, sulfate concentrations hundreds of kilometers downwind of the source may be almost as large as they are near the source.

NAAQS for sulfates have not been established. However, air quality standards for sulfate have been adopted by the State of Montana, where the maximum allowable annual sulfate concentration is  $4 \mu\text{g}/\text{m}^3$ .<sup>(8)</sup> Since regional sulfate concentrations of 1 to  $3 \mu\text{g}/\text{m}^3$  are predicted for the coal generation development in Montana, the model results here indicate these standards could prove to be constraints upon energy development if emission levels up to the Federal New Source Performance Standards are permitted.

### 5.3 $\text{SO}_2$ DEPOSITION

Annual total deposition of  $\text{SO}_2$  for all existing and proposed plants is shown in Figure 10. The patterns are similar to the  $\text{SO}_2$  concentration patterns. However the deposition patterns are not as confined to the basins, indicating the greater wet and dry removal rates of  $\text{SO}_2$  over mountainous terrain. The analysis shows that  $1 \text{ g}/\text{m}^2$ , or 9 lb/acre, or more of  $\text{SO}_2$  can be deposited onto the terrestrial environment in the vicinity of a large power plant each year. Assuming that the top foot of a soil profile weighs roughly  $6 \times 10^6$  lb/acre, this would result in a sulfur concentration in the soil profile of 0.75 ppm.

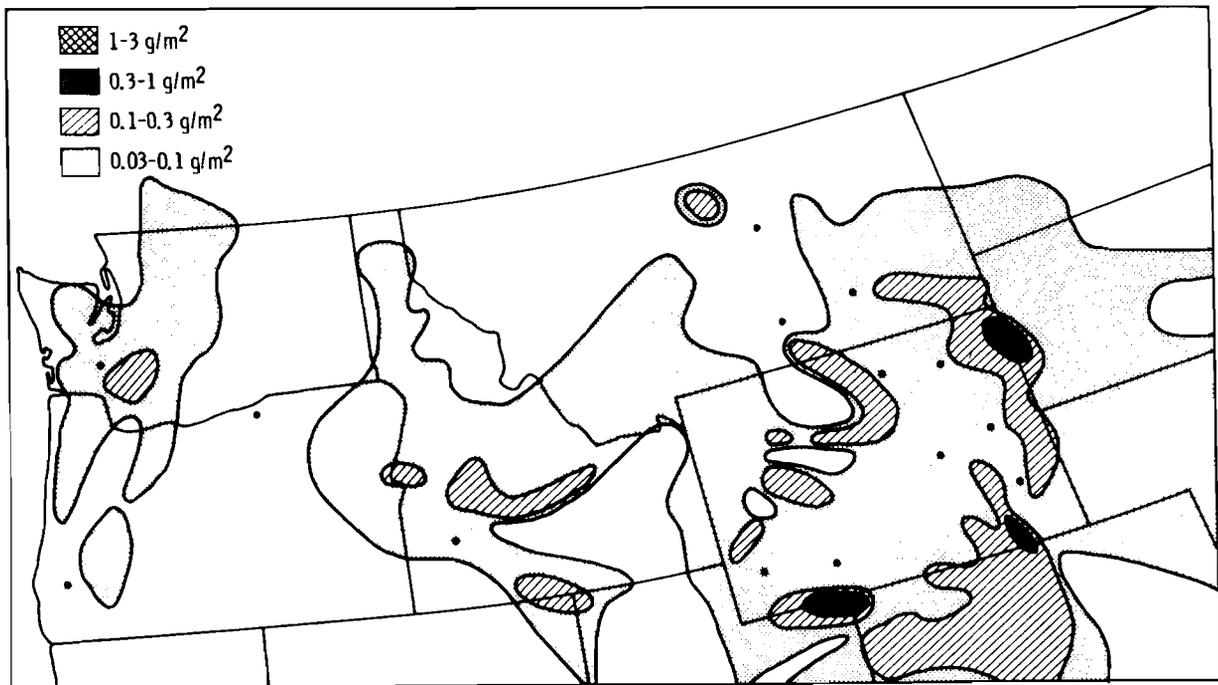


**FIGURE 10.** Annual Total  $\text{SO}_2$  Deposition from Existing and Proposed Plants Based on New Source Performance Standards

According to the U.S. Testing Company<sup>(15)</sup> as much as 60 lb/acre of sulfate needs to be applied to soil with no existing sulfur content in the Pacific Northwest for agricultural purposes. For soil with greater than 20 ppm sulfur, no additional applications are necessary. Thus, although damage could occur as the  $\text{SO}_2$  passes through the plant canopy to the soil, the increase of sulfur within the soil profile could benefit agriculture. Agriculture is an important activity in the Pacific Northwest, and research on the potential impacts that energy development may have on agricultural productivity should be pursued.

#### 5.4 SULFATE DEPOSITION

Annual total sulfate deposition for existing and proposed plants is shown in Figure 11. For the most part, largest sulfate depositions are roughly a factor of 5 to 10 smaller than  $\text{SO}_2$  depositions. This is primarily due to the smaller wet and dry removal rates for sulfates and the deposition



**FIGURE 11.** Annual Total Sulfate Deposition from Existing and Proposed Plants Based on New Source Performance Standards

of much of the  $\text{SO}_2$  before transformation occurs. The analysis shows that largest sulfate depositions are generally a considerable distance away from the source and often over mountainous terrain.

A comparison of the total regional  $\text{SO}_2$ -sulfate budgets for the July and December periods for a wet location (Centralia, in western Washington) and a dry location (Colstrip, in southeastern Montana) is given in Table 5. Overall, the majority of the  $\text{SO}_2$  released is either deposited as  $\text{SO}_2$  or transported beyond the grid as sulfate. The largest contrast in deposition between the two sites is during the December period when almost twice as much  $\text{SO}_2$  is deposited from Centralia (85%) as from Colstrip (44%). This difference primarily reflects the enormous variations in mean monthly precipitation for December between the two sites. During this season the region around Centralia receives nearly an order of magnitude more precipitation than the region around Colstrip.

TABLE 5. Seasonal Comparisons of Total SO<sub>2</sub>-Sulfate Budgets within the Northwest Grid

Period	Source	Left in Air Over Grid, Percent(a)		Deposited on Surface of Grid, Percent		Transported Beyond Grid, Percent		Total, Percent
		SO <sub>2</sub>	SO <sub>4</sub>	SO <sub>2</sub>	SO <sub>4</sub>	SO <sub>2</sub>	SO <sub>4</sub>	
July 1-30	Centralia, WA	0.8	2.4	67.0	21.1	0.2	8.6	100.0
	Colstrip, MT	1.3	4.9	52.2	15.3	1.0	25.4	100.0
Dec 1-17	Centralia, WA	0.8	0.6	84.6	6.8	0.4	6.9	100.0
	Colstrip, MT	1.9	1.6	44.4	4.5	8.5	39.1	100.0

(a) Percent of total emissions or transformed material remaining at end of computation period.

During July, which represents the summer season, the total SO<sub>2</sub> and sulfate deposited from Centralia again is greater than from Colstrip, even though the July precipitation is greater at Colstrip. This is mainly due to the terrain differences between the two regions. The forested and mountainous terrain near Centralia is assumed to cause much higher deposition velocities than the smooth grasslands near Colstrip.

As mentioned previously, wet removal by time-averaged precipitation overestimates the surface deposition of SO<sub>2</sub> by approximately 10 to 15%. If deposition occurs by dry processes only, approximately 35% of the total released is deposited as SO<sub>2</sub> and about 45% remains in the air as sulfate (assuming a uniform deposition velocity of 1 cm/sec). For a deposition velocity of 2 cm/sec (the model assumptions for forested terrain), the corresponding values are approximately 53% deposited as SO<sub>2</sub> and 33% remaining in the air as sulfate.

## 5.5 PARTICULATES

Annual average particulate concentrations for existing and proposed plants are shown in Figure 12. Largest concentrations are less than 1 µg/m<sup>3</sup>. The national average background particulate level is approximately 25 µg/m<sup>3</sup> and



**FIGURE 12.** Annual Average Particulates Concentrations for Existing and Proposed Plants Based on New Source Performance Standards

generally lower ( $10$  to  $20 \mu\text{g}/\text{m}^3$ ) for the northern Great Plains.<sup>(8)</sup> Thus, the concentration from coal power plants and gasification plants appears to be insignificant in the long-term assessment. A standard of  $75 \mu\text{g}/\text{m}^3$  has been established as the maximum allowable annual average of total suspended particulates. However, annual and/or 24-hour particulate standards are exceeded even in rural areas of the Northwest as a result of particulates formed by uncontrollable natural processes such as windblown dust.<sup>(16)</sup>

## 5.6 NITROGEN OXIDES

Annual average  $\text{NO}_x$  concentrations are shown in Figure 13. The patterns are similar to those for  $\text{SO}_2$ . Largest concentrations are in the range of  $1$  to  $3 \mu\text{g}/\text{m}^3$ , compared to the NAAQS of  $100 \mu\text{g}/\text{m}^3$ . This indicates that no significant long-term regional air concentrations of  $\text{NO}_x$  due to existing and proposed coal power and gasification plants are expected on a regional scale.

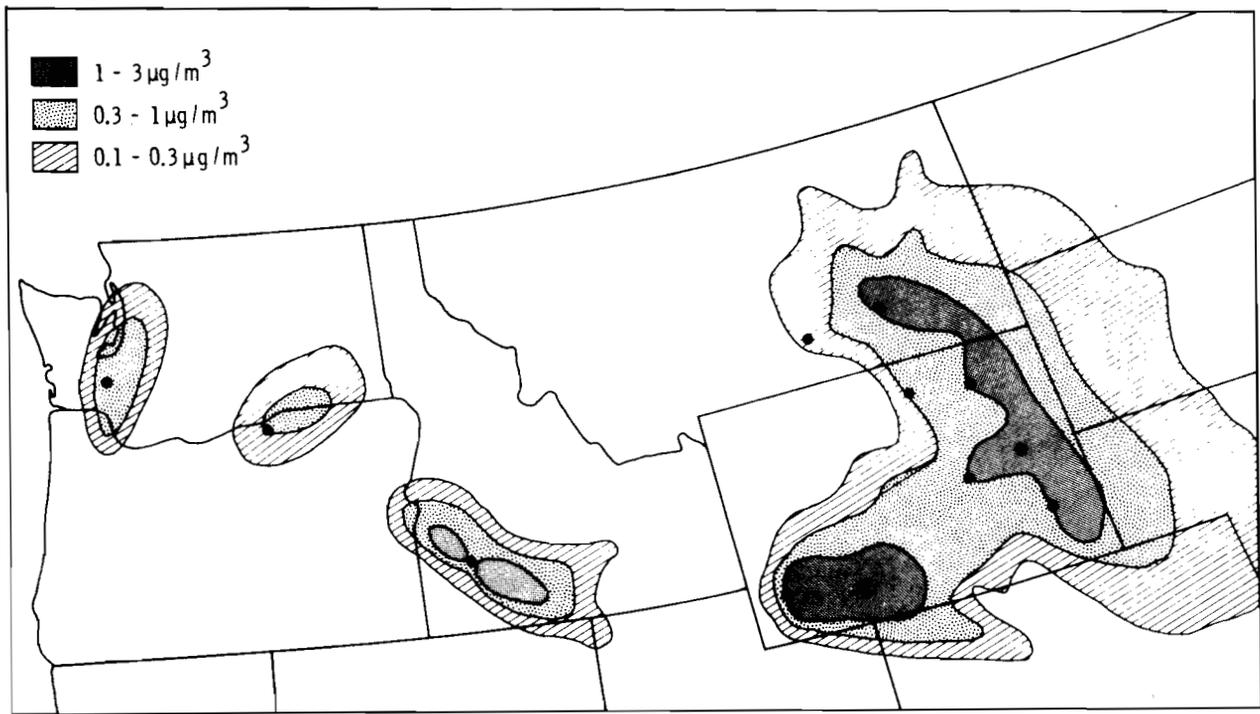


FIGURE 13. Annual Average NO<sub>x</sub> Concentrations for Existing and Proposed Plants Based on New Source Performance Standards

## 6. MODEL APPLICATION TO ASSESS PROPOSED CLEAN AIR ACT AMENDMENTS

One of the most controversial Federal air quality regulations to be passed in recent years deals with prevention of significant air quality deterioration. Those regulations were promulgated by the Environmental Protection Agency in December 1974<sup>(17)</sup> after a suit had been filed against the Administration in June of 1972 stating that no State Implementation Plan was designed to protect clean areas from significant air quality deterioration. The suit referred specifically to the Four Corners Project, which is a major coal-fired energy facility established in an area of very clean air. The EPA Significant Deterioration Regulation specifies that all states must designate all regions as either Class I (the air must remain almost as clean as presently exists), Class II (air quality can be degraded up to approximately 25% of the NAAQS), or Class III (air quality can be degraded up to the NAAQS).

These regulations generated immediate controversy. Industry considered them too stringent and oriented toward a no-growth policy. Conservation groups considered them too lenient, including the Sierra Club which claimed that the Class III designation would allow states to establish as much area as they wanted to be degraded up to the legal air quality limits. Furthermore, the regulations only allowed for total suspended particulates and SO<sub>2</sub>. Once again the Sierra Club sued the EPA, but this time Congress stepped in to clarify the issue by legislation rather than leaving it up to the courts to decide.

Separate proposals were developed by the Senate and the House. The allowable air quality increments under the various proposals are shown in Table 6, and a summary of the major differences among the proposals as they existed in late 1975 is given in Table 7. These tables were taken from an analysis prepared by the EPA<sup>(18)</sup> on the impact the various proposed regulations would have on the electric utilities. The analysis showed that, in general, the proposed regulations would have an impact on the electric utilities in siting new power plants, particularly in the west where much of the mandatory Class I land exists.

**TABLE 6.** Allowable Air Quality Increments Under Alternative Significant Deterioration Proposals ( $\mu\text{g}/\text{m}^3$ )

Source: EPA, 1975 (Reference 18)

Pollutant Standard	CLASS I			CLASS II			CLASS III		
	EPA Regs.	Senate Proposal	House Proposal (a)	EPA Regs.	Senate Proposal	House Proposal (a)	EPA Regs. (b)	Senate Proposal	House Proposal (b)
<u>Sulfur Dioxide</u>									
Annual	2	2	1.6	15	15	20	80	No	40
24-hour	5	5	7.3	100	100	91	365	Class III	183
3-hour	25	25	26	700	700	325	1300		50
<u>Total Suspended Particulates</u>									
Annual	5	5	7.5	10	10	19	75	No	38
24-hour	10	10	15	30	30	38	150	Class II	75

(a) The increments for the House proposal are based on limitations of 2% of NAAQS for Class I, 25% for Class II, and 50% for Class III, except that the limit for total suspended particulates in Class I is 10% of NAAQS. In addition, the House proposal stipulates that the concentration of all pollutants cannot exceed 75% of the national ambient air quality standards in any of the classes.

(b) EPA's Class III allows degradation up to the NAAQS (see Table 4).

TABLE 7. Summary of Major Differences of Alternative Approaches to Significant Deterioration

Source: EPA, 1975 (Reference 18)

Issues	EPA	House	Senate
Sources Covered	18 Source categories	Any facility emitting more than 100 tons/yr of any regulated pollutant	Major emitting facilities
Pollutants Covered	TSP (a) and SO <sub>2</sub>	All	TSP, SO <sub>2</sub> others to be established later
Control Technology Requirements	Equivalent to NSPS where NSPS exist, and determined on a case-by-case basis where NSPS does not exist	None specified	Maximum degree of emission control possible; determined on a case-by-case basis
Class I Areas	No mandatory (at state and Federal discretion with procedures for full public participation)	Designation of some areas as mandatory Class I and others as either Class I, II or III	Designation of some areas as mandatory Class I and others as either Class I or Class II
Class III Areas	Procedures for designation of areas as Class III	Procedures for designation of areas as Class III	No provision for Class III
Numeric Limitations for Class I, II and III	See Table 6	See Table 6	See Table 6
Maximum Allowed Concentration	National Ambient Air Quality Standards (NAAQS)	Three-fourths of NAAQS	NAAQS

(a) Total suspended particulates.

On August 2, 1976 the U.S. District Court of Appeals for the District of Columbia upheld the EPA's regulations, ruling against the Sierra Club suit. Three days later, on August 5, the Senate approved its version of the Prevention of Significant Air Quality Deterioration legislation, which was part of a package of proposed Clean Air Act Amendments (S 3219), by a vote of 78 to 13. Hearings on the House version of the Clean Air Act Amendments (HR 10498) began almost simultaneously, on August 4, and were approved a few weeks later. The amendments are presently before the full Congress.

We used the regional transport model to examine the effects those regulations will have on siting new electric generating facilities in the Northwest. The House and Senate versions, as well as the EPA regulations, specify that, at the least, emissions from new facilities must comply with the NSPS. Furthermore, the House and Senate versions specify mandatory and discretionary Class I exclusion areas, where very little air quality deterioration is permitted. Under the present Senate version, for example, National Parks and Wilderness Areas will be mandatory Class I areas, while many other types of Federal lands, such as National Forests, National Wildlife Refuges, and Indian Reservations, could be designated Class I upon agreement with the appropriate Federal land manager and state officials. (a)

Figure 14 shows all possible Class I exclusion areas under the present version of the proposed regulations. Included in this figure are the contours for the 1 and 3  $\mu\text{g}/\text{m}^3$  annual  $\text{SO}_2$  concentration predicted by the model for existing and proposed energy generating facilities in the region. These contour intervals essentially envelop the allowed  $\text{SO}_2$  degradation permitted by both the House and Senate versions of the proposed significant deterioration regulations (Table 6). This analysis shows that very few possible Class I exclusion areas will be affected by the "possible" near-term development scenario. Exceptions could be the Flaming Gorge National Recreation Area in

---

(a) The Northern Cheyenne Indian Reservation has requested that the air quality classification for their Reservation be established at Class I. The Colstrip complex (2060 MWe) is about 15 miles from the Reservation.

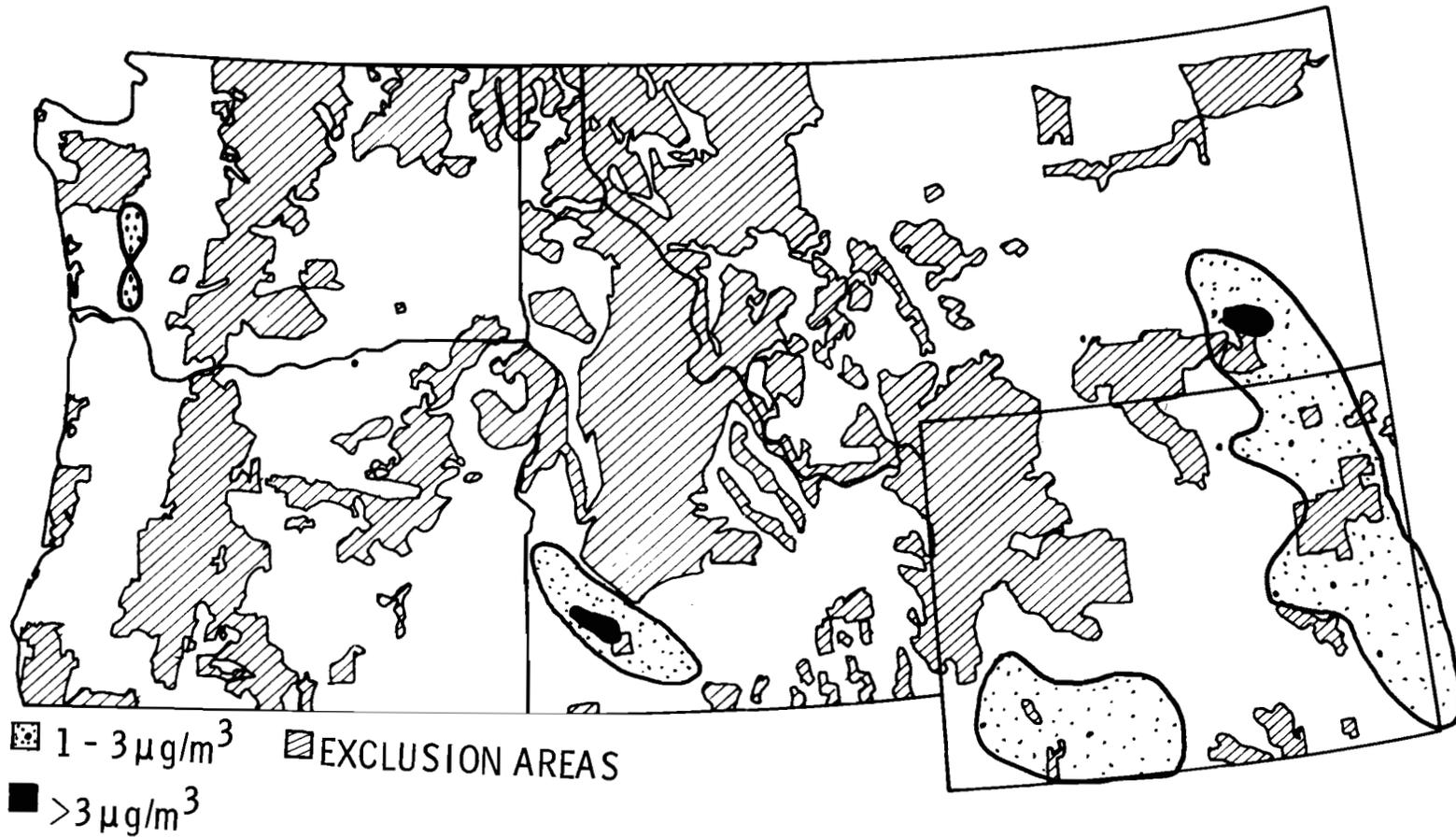


FIGURE 14. All Possible Class I Exclusion Areas and Estimated Annual SO<sub>2</sub> Concentrations for the "Possible" Near-Term Scenario Based on New Source Performance Standards

southwest Wyoming and northwest Colorado, and the Northern Cheyenne Indian Reservation in southeast Montana.

This analysis is not to provide a detailed assessment of the proposed regulations for the Prevention of Significant Air Quality deterioration, but rather to demonstrate the utility of applying regional transport models to these kinds of assessments. It is intended that, as the modeling program proceeds and proposed Clean Air Act Amendments are signed into law, the effects of these regulations on the electric utilities in the Northwest will be assessed as a component of the Regional Assessment Program.

## 7. RECOMMENDATIONS

There are many facets to air quality assessments besides long-range pollutant transport. Modeling of individual proposed facilities, estimating visibility reductions, examining secondary air quality impacts, and regional and global climatic impacts are just some of the assessments being considered under the Regional Assessment Program. However, much work is still required on the regional modeling program to provide more realistic assessments of long-range pollutant transport processes. Recommendations for this continued effort are listed below:

- There is a need to incorporate improved techniques to account for the effects of regional topography on the transport and diffusion properties of the atmosphere.
- More experimental studies on dry deposition velocities over mountainous terrain are required.
- More realistic dry removal methods in the model are necessary, including a surface depletion instead of a source depletion scheme.
- Techniques need to be developed to incorporate the effects of diurnal and seasonal variations in stability and mixing height into the regional modeling.
- A more thorough seasonal and annual assessment should be performed using a complete year's meteorological data, including hourly precipitation data to more accurately estimate temporal and spatial variabilities in precipitation scavenging.
- More complete information on background air quality levels of the various pollutants throughout the region are required to fully evaluate air quality impacts from existing and proposed facilities.
- A more complete emission inventory, including large nonenergy sulfur emitters, needs to be incorporated into the modeling effort.

- The effect of biogenic sources of sulfur on the sulfate budget in the Northwest needs to be studied, similar to a study performed in the eastern U.S. by Hitchcock.<sup>(19)</sup>

These types of studies are currently underway in the Regional Assessment Program as well as other programs sponsored by various agencies, including ERDA. As improved methodologies become available they will be incorporated into the assessment program to provide a more realistic picture of the regional environmental trade-offs to be expected with future energy development scenarios.

## 8. REFERENCES

1. D. S. Renne and D. L. Elliott, "Regional Air Quality Assessment for Northwest Energy Scenarios." BNWL-SA-5660, presented at the 69th Annual Meeting of the Air Pollution Control Association, Portland, OR, June 1976, Battelle, Pacific Northwest Laboratories, Richland, WA, 1976.
2. L. L. Wendell, D. C. Powell and R. L. Drake, "A Regional Scale Model for Computing Deposition and Ground Level Air Concentration of SO<sub>2</sub> and SO<sub>4</sub> from Elevated and Ground Sources." Presented at the Third Symposium on Atmospheric Turbulence, Diffusion and Air Quality of the American Meteorological Society, Raleigh, NC, October 19-22, 1976.
3. G. A. Briggs, "Diffusion Estimates for Small Emissions." U.S. Dept. of Commerce, NOAA-ERL-ARATDL Contribution No. 79 (Draft), Oak Ridge, TN, May 1973.
4. B. Bolin and C. Persson, "Regional Dispersion and Deposition of Atmospheric Pollutants with Particular Application to Sulfur Pollution Over Western Europe." Tellus XVII, 3:281-310, 1975.
5. T. W. Horst, "A Surface Depletion Model for Deposition from a Gaussian Plume." BNWL-SA 5096, presented at the Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants Symposium - 1974, Richland, WA, AED Symposium Series CONF-740921, September 4-6, 1974.
6. L. L. Wendell and D. C. Powell, "An Examination of the Effects of Real Time versus Time Averaged Precipitation Data on SO<sub>2</sub> and SO<sub>4</sub> in the Regional Assessment Model." In: Pacific Northwest Laboratory Annual Report for 1975 to the ERDA Division of Biomedical and Environmental Research, Part 3, Atmospheric Sciences, BNWL-2000 PT3, Battelle, Pacific Northwest Laboratories, Richland, WA, March 1976.
7. Environmental Protection Agency, "New Source Performance Standards for Fossil Fuel-Fired Steam Generators." Federal Register, 36(247):24878, Part II, Subpart D, December 23, 1971.
8. Northern Great Plains Resource Program Atmospheric Aspects Work Group Report. NTIS PB-243 149, December 1974.
9. Environmental Protection Agency, "National Emissions Data System (NEDS)." Available upon request from National Air Data Branch, Research Triangle Park, NC.
10. W. G. N. Slinn, "Modeling Preliminary for Dry Deposition to a Canopy." In: Pacific Northwest Laboratory Annual Report for 1975 to the ERDA Division of Biomedical and Environmental Research, Part 3, Atmospheric Sciences, BNWL-2000 PT3, Battelle, Pacific Northwest Laboratories, Richland, WA, March 1976.

11. G. A. Sehmel, "Comparison of Deposition Velocities Predicted from Dimensional Analysis Correlations." In: Pacific Northwest Laboratory Annual Report for 1975 to the ERDA Division of Biomedical and Environmental Research, Part 3, Atmospheric Sciences, BNWL-2000 PT3, Battelle, Pacific Northwest Laboratories, Richland, WA, March 1976.
12. G. A. Sehmel, "Particle Deposition and Penetration Through Vegetation Canopies from Wind Tunnel Experiments." In: Pacific Northwest Laboratory Annual Report for 1975 to the ERDA Division of Biomedical and Environmental Research, Part 3, Atmospheric Sciences, BNWL-2000 PT3, Battelle, Pacific Northwest Laboratories, Richland, WA, March 1976.
13. G. E. Start, C. R. Dickson and N. R. Ricks, "Effluent Dilutions over Mountainous Terrain and Within Mountain Canyons." Symposium on Atmospheric Diffusion and Air Pollution, Santa Barbara, CA, Am. Meteorol. Soc., Boston, MA, pp. 226-232, September 9-13, 1974.
14. A. P. Altshuller, "Regional Transport and Transformation of Sulfur Dioxide to Sulfates in the U.S." J. Air Poll. Control Assoc. 26:318, 1976.
15. U.S. Testing Co., Inc. "Fertilizer Recommendations for the Pacific Northwest." Richland Laboratories, 2800 George Washington Way, Richland, WA, 1974.
16. P. F. Fennelly, "The Origin and Influence of Airborne Particulates." American Scientist, 64:46-56, 1976.
17. Environmental Protection Agency. "Regulations for the Prevention of Significant Air Quality Deterioration." Federal Register, Part III, 39(235):42510-42517, December 5, 1974.
18. Environmental Protection Agency. An Analysis of the Impact on the Electric Utility Industry of Alternative Approaches to Significant Deterioration. NTIS PB-247 385, October 1975.
19. D. R. Hitchcock, "Atmospheric Sulfates from Biological Sources." J. Air Poll. Control Assoc. 26:210, 1976.

APPENDIX A

COMPARISONS OF 1974 DATA TO CLIMATIC AVERAGES

## COMPARISONS OF 1974 DATA TO CLIMATIC AVERAGES

Anomalies of wind speed and direction, precipitation, and temperature were examined over the Northwest for April, July, October, and December 1974 to determine how representative each of the four periods in 1974 were of average conditions. Of primary concern are the extreme departures from the long-term averages (e.g., those that occur only once in 10 years or more), and not the normal deviations that are expected from year to year. The main purpose here is to investigate the anomalies of each period to assure the time period(s) used was not one of the windiest or calmest, rainiest or driest, or hottest or coldest periods on record in the Northwest.

For this regional air quality assessment, the only real time meteorological data used were wind speed and direction. Spatial variabilities in precipitation scavenging were approximated from gridded values of mean monthly precipitation, as previously described. Therefore, the most important parameters here are the temporal and spatial variations in the wind flow patterns (estimated from layer-averaged rawinsonde and pibal wind data) and the representativeness of these flow patterns with the mean flow. For the purposes of this comparison, we felt the use of surface wind data was sufficient. Thus, the monthly mean wind speeds for April, July, October, and December 1974 at first order weather stations<sup>(a)</sup> were compared with their corresponding monthly climatological averages.<sup>(b)</sup> A few of the stations could not be used in the comparison because of recent changes in instrument height or location. Precipitation and temperature anomalies are discussed nevertheless to provide additional information on the representativeness of 1974 with climatological averages.<sup>(c)</sup>

- 
- (a) Climatological Data, National Climatic Center, Environmental Data Service, Asheville, NC.
  - (b) Climates of the States, National Climatic Center, Environmental Data Service, Asheville, NC.
  - (c) Climatological Data, National Summary, National Climatic Center, Environmental Data Service, Asheville, NC.

## APRIL

Mean wind speeds for April 1974 were above normal (1 to 2 mph) over Idaho, eastern Washington, and eastern Oregon and near normal elsewhere. However no large departures from the mean prevailing flow patterns were evident. Precipitation for April was highly variable over the region, varying from 50 to 200% of normal (Figure A-1a). Except for temperature departures of 3 to 4°F above normal over much of Montana, April temperature averages were near normal over most of the Northwest (Figure A-1b). Overall, the weather during April 1974 was not extreme and appears representative of the average April in the Northwest.

## JULY

Mean wind speeds for July 1974 were near normal over most of the Northwest, with no extreme departures from normal. Precipitation was much above normal over much of Washington and Oregon, with some record amounts in western Washington and Oregon (Figure A-2a). This was due to a southward displacement of the mean storm track during this time. No extreme precipitation departures occurred over the remainder of the Northwest. Mean temperatures were about 2 to 4°F warmer than normal over Montana and Wyoming and about 2°F cooler over most of Washington (Figure A-2b). Thus, July 1974 appeared cooler and wetter than normal over most of Washington and Oregon and warmer than normal over Montana and Wyoming. However, the prevailing flow patterns appeared, for the most part, similar to the mean for July.

## OCTOBER

Mean wind speeds for October 1974 were 10 to 30% below normal. Conditions were drier than normal over Oregon, Washington, northern Idaho, and northwest Montana, with generally less than 50% of the normal precipitation, and wetter than normal over southern Idaho, Wyoming, and southeast Montana, with over 300% of the normal precipitation reported over parts of this area (Figure A-3a). Temperatures were 1 to 2°F above normal throughout most of the northwest (Figure A-3b). With the exception of a brief period at the

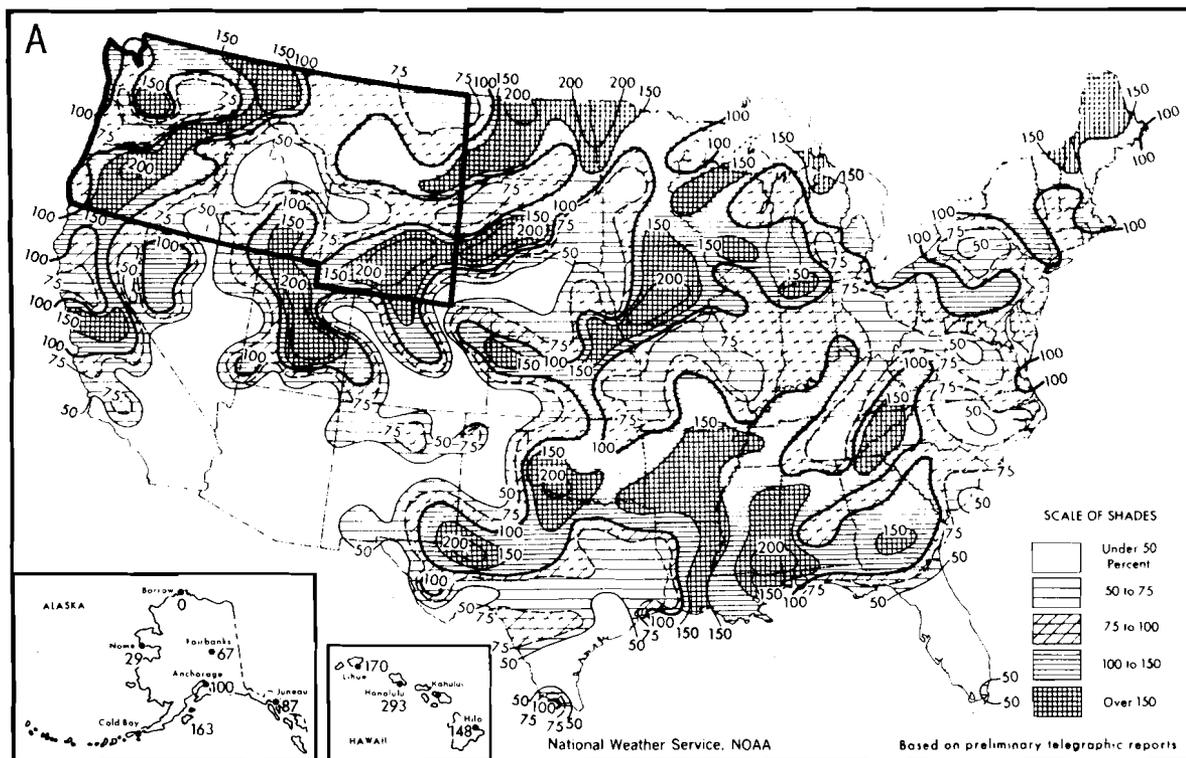


FIGURE A-1a. Precipitation Departure (%) from 30-Year Mean for April 1974.  
 Source: Climatological Data, National Summary, April 1974

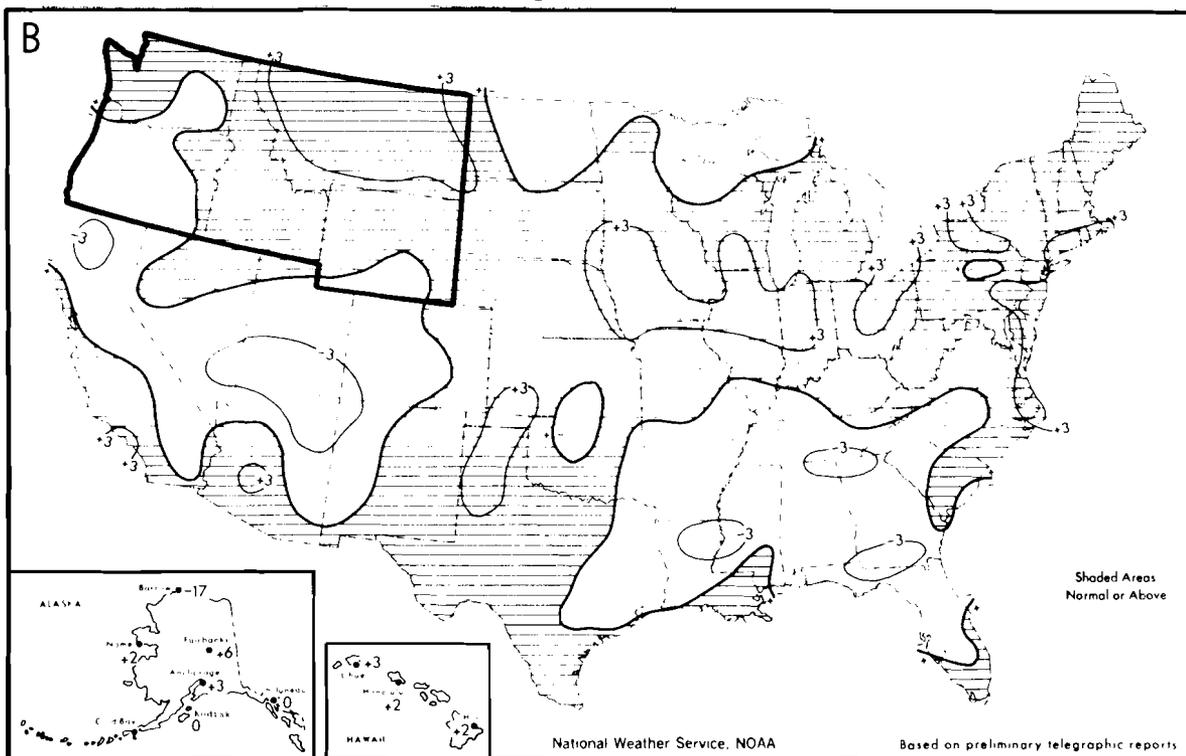


FIGURE A-1b. Temperature Departure (F°) from 30-Year Mean for April 1974.  
 Source: Climatological Data, National Summary, April 1974

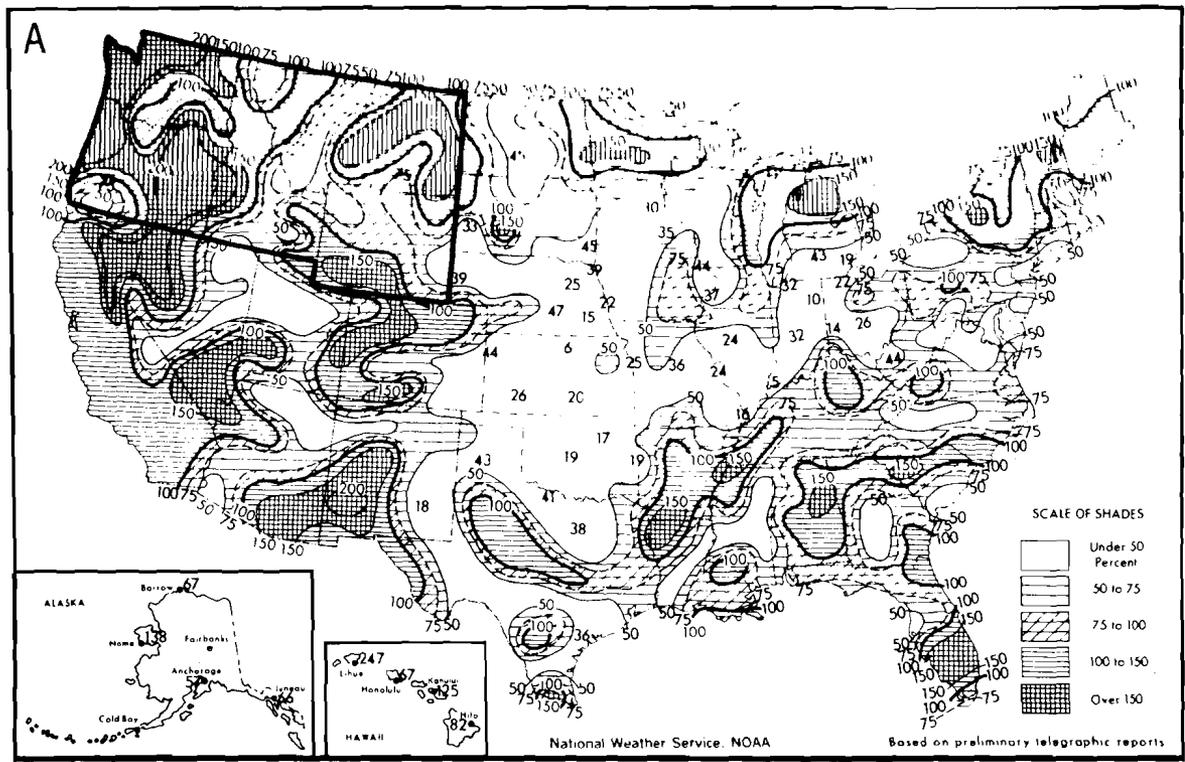


FIGURE A-2a. Precipitation Departure (%) from 30-Year Mean for July 1974.  
 Source: Climatological Data, National Summary, July 1974

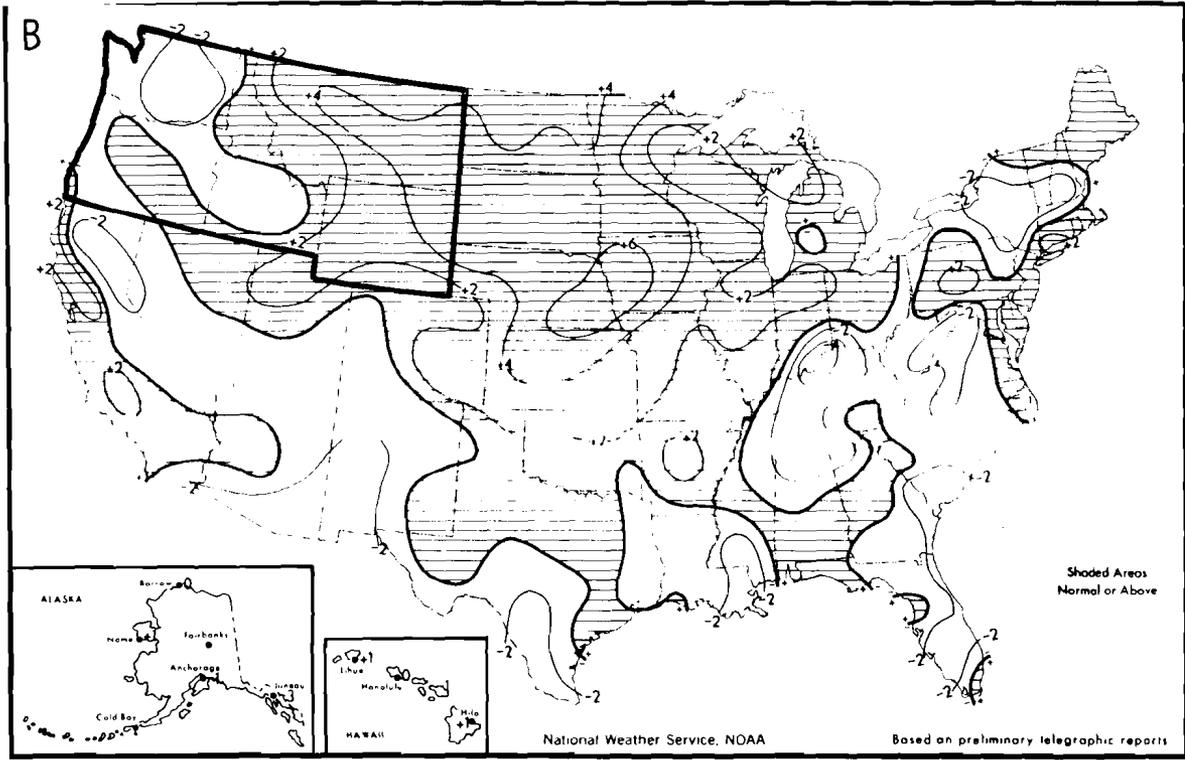


FIGURE A-2b. Temperature Departure (F°) from 30-Year Mean for July 1974  
 Source: Climatological Data, National Summary, July 1974

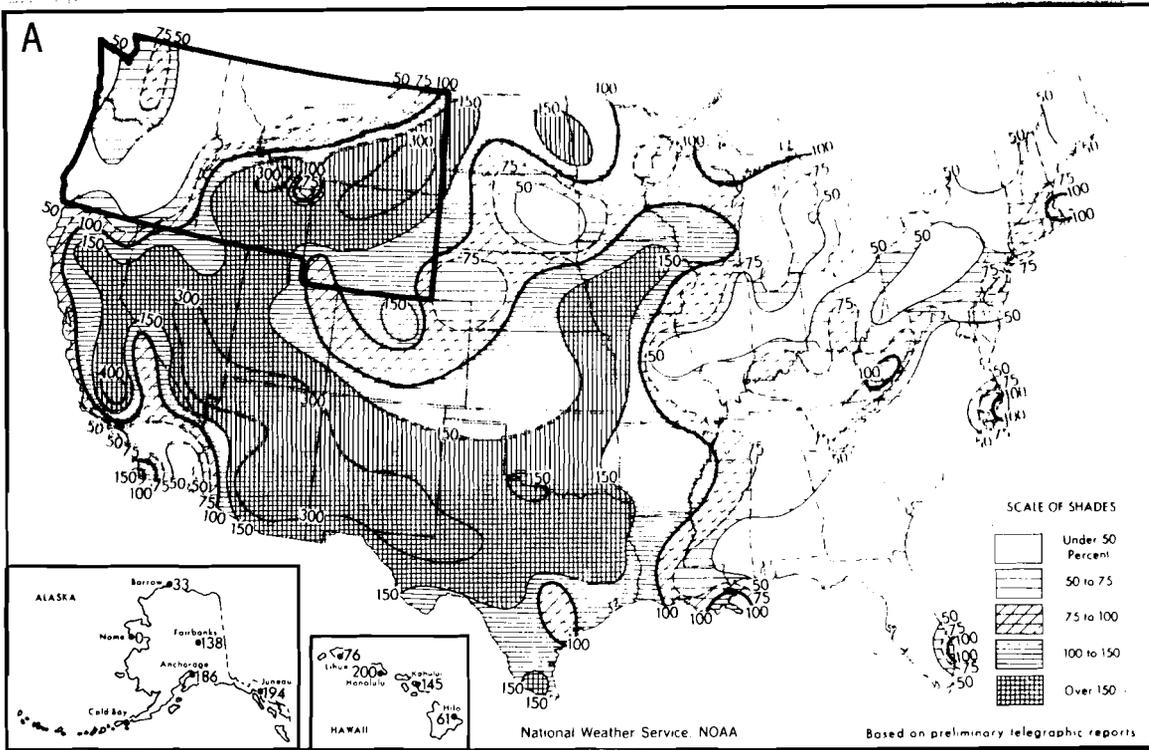


FIGURE A-3a. Precipitation Departure (%) from 30-Year Mean for October 1974.  
 Source: Climatological Data, National Summary, October 1974

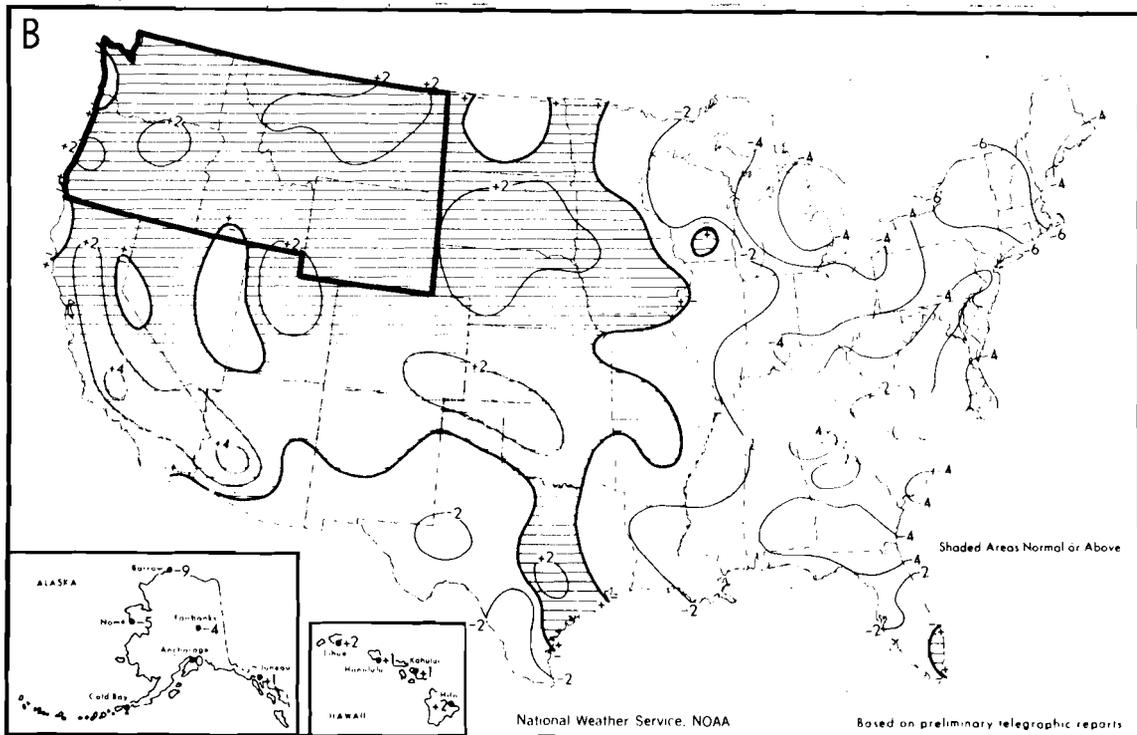


FIGURE A-3b. Temperature Departure (F°) from 30-Year Mean for October 1974.  
 Source: Climatological Data, National Summary, October 1974

end of the month, the storm track lay north of the region--perhaps further north than would normally be expected. In general, departures of meteorological parameters over the region during October were opposite those during July.

#### DECEMBER 1-19

Average wind speeds for the period December 1-19, 1974 showed no large departures from normal. However, the time period is too short for a good representation of the different types of flow patterns. Most of the region was drier (Figure A-4a) and warmer (Figure A-4b) than normal, particularly in northern Montana, with the storm track staying generally well to the north of the region.

#### SUMMARY

For the period as a whole, much of the region was generally warmer and drier than long-term averages. However, there were many regional exceptions to this. A wetter and stormier period in July was balanced by a drier period in October. These observations indicate qualitatively that many offsetting meteorological variations over the 4 months used in this study resulted in 1974 being a rather "typical" year compared with climatology.

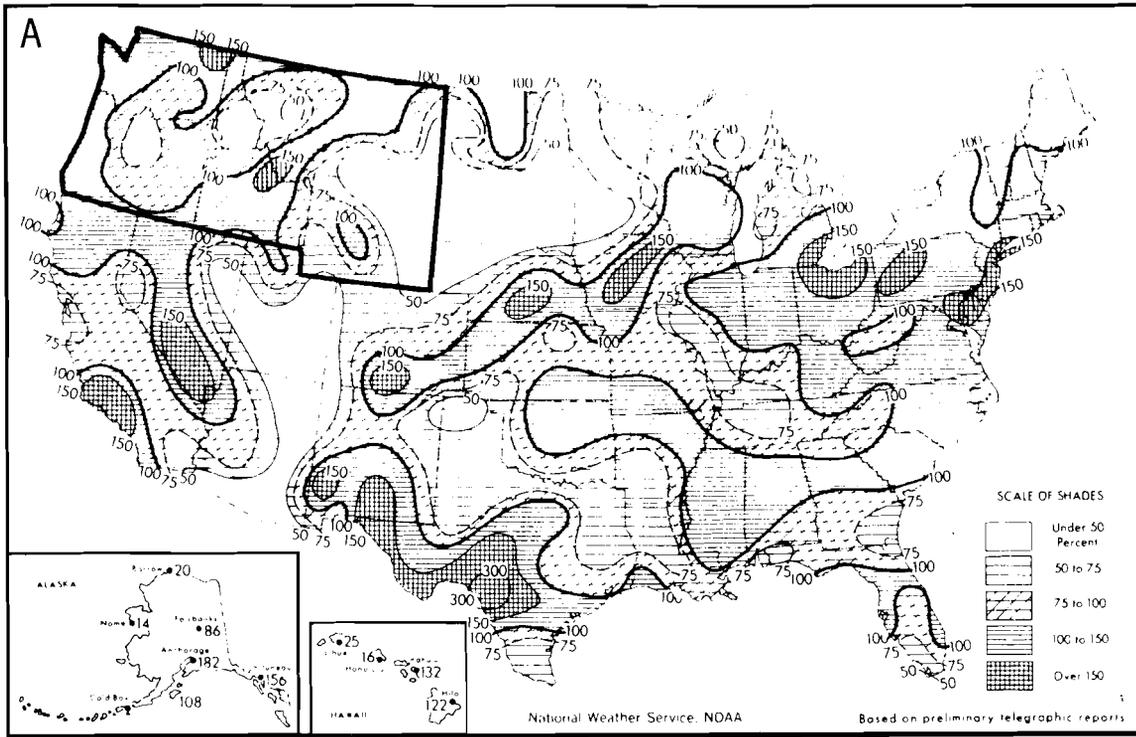


FIGURE A-4a. Precipitation Departure (%) from 30-Year Mean for December 1974. Source: Climatological Data, National Summary, December 1974

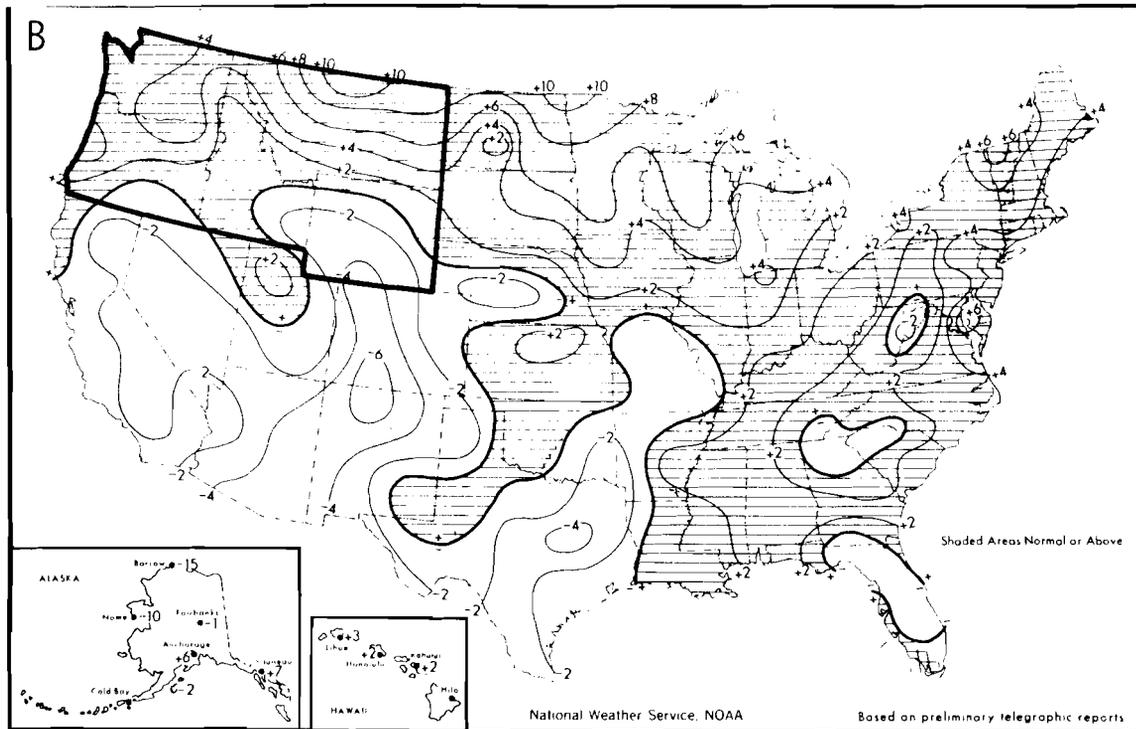


FIGURE A-4b. Temperature Departure (F°) from 30-Year Mean for December 1974. Source: Climatological Data, National Summary, December 1974

DISTRIBUTION

No. of  
Copies

No. of  
Copies

No. of  
Copies

OFFSITE

A. A. Churm  
ERDA Chicago Patent Group  
9800 South Cass Avenue  
Argonne, IL 60439

D. S. Ballantine  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

R. P. Blaunstein  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

W. W. Burr  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

R. L. Butenhoff  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

C. E. Carter  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

C. W. Edington  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

W. O. Forster  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

G. J. Rotariu  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

D. H. Slade  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

J. Swinebroad  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

W. H. Weyzen  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

R. W. Wood  
ERDA Division of Biomedical  
and Environmental Research  
Washington, DC 20545

W. E. Mott  
ERDA Division of Environmental  
Control Technology  
Washington, DC 20545

M. Reilly  
ERDA Division of Fossil Energy  
Washington, DC 20545

H. L. Hollister  
Deputy Assistant Administrator  
for Environment and Safety  
Washington, DC 20545

J. L. Liverman  
ERDA Assistant Administrator  
for Environment and Safety  
Washington, DC 20545

J. Coleman  
ERDA Office of Environment  
Policy Analysis  
Washington, DC 20545

B. W. Wachholz  
ERDA Office of Environmental  
Policy Analysis  
Washington, DC 20545

E. S. Burton  
ERDA Office of Planning,  
Analysis and Evaluation  
Washington, DC 20545

N. F. Barr  
ERDA Division of Technology  
Overview  
Washington, DC 20545

W. G. Belter  
ERDA Division of Technology  
Overview  
Washington, DC 20545

R. D. Cooper  
ERDA Division of Technology  
Overview  
Washington, DC 20545

P. H. Gearhart  
ERDA Division of Technology  
Overview  
Washington, DC 20545

R. R. Newton  
ERDA Division of Technology  
Overview  
Washington, DC 20545

H. R. Wasson  
ERDA Division of Technology  
Overview  
Washington, DC 20545

A. B. Joseph  
Office of Nuclear Regulatory  
Research  
U.S. Nuclear Regulatory  
Commission  
Washington, DC 20555

F. G. Lowman  
Office of Nuclear Regulatory  
Research  
U.S. Nuclear Regulatory  
Commission  
Washington, DC 20555

E. E. Held  
Office of Standards Development  
U.S. Nuclear Regulatory  
Commission  
Washington, DC 20555

27 ERDA Technical Information  
Center

J. B. Robertson  
Federal Energy Administration  
Room 1992  
Federal Building  
915 Second Avenue  
Seattle, WA 98174

L. E. Coate  
U.S. Environmental Protection  
Agency, Region X  
Seattle, WA 98101

E. Croke  
Argonne National Laboratory  
9700 South Cass Avenue  
Argonne, IL 60439

L. J. Hoover  
Argonne National Laboratory  
9700 South Cass Avenue  
Argonne, IL 60439

P. M. Meier  
Bldg. 475  
Brookhaven National Laboratory  
Upton, NY 11973

P. Palmedo  
Bldg. 475  
Brookhaven National Laboratory  
Upton, NY 11973

W. Siri  
University of California - LBL  
Lawrence Berkeley Laboratory  
Berkeley, CA 94720

<u>No. of Copies</u>	<u>No. of Copies</u>	<u>No. of Copies</u>
W. Robison University of California - LLL Lawrence Livermore Laboratory P.O. Box 808 Livermore, CA 94550	M. F. Thomas Regional Engineer Bureau of Power 555 Battery Street, Room 415 San Francisco, CA 94111	A. C. Tsao Energy Planning Division Department of Natural Resources and Conservation 32 South Ewing Helena, MT 59601
E. Hammil Los Alamos Scientific Laboratory P.O. Box 1663 Los Alamos, NM 87545	D. Guss Bureau of State Planning and Community Affairs State House Boise, ID 83720	H. Brauner Conservation and Development Commission 1175 Court Street N.E. Salem, OR 97301
R. Malenfant Los Alamos Scientific Laboratory University of California P.O. Box 1663 Los Alamos, NM 87545	K. D. Smith Public Utilities Commission 472 W. Washington Street Boise, ID 83720	Charles Davis Public Utility Commissioner Labor and Industries Bldg. Salem, OR 97310
S. J. Auerbach Oak Ridge National Laboratory P.O. Box X Oak Ridge TN 37830	R. J. Vissia Regional Director Pacific Northwest Region (Columbia River Basin) Federal Building, U.S. Court House 550 W. Fort Street Boise, ID 83724	Col. C. D. Gilkey District Engineer Portland District Corps of Engineers 2850 S.E. 82nd Ave. (97266) P.O. Box 2946 Portland, OR 97208
W. Fulkerson Oak Ridge National Laboratory P.O. Box X Oak Ridge, TN 37830	R. N. Wise Bureau of State Planning and Community Affairs State House Boise, ID 83720	Maj. Gen. W. E. Peel Division Engineer North Pacific Division Corps of Engineers 210 Custom House Portland, OR 97209
Col. Charles A. Debelius District Engineer Alaska District Corps of Engineers Anchorage, AK 99510	R. Hulme State Clearinghouse Office of Budget and Program Planning 232 Capitol Building Helena, MT 59601	F. D. Miller Oregon Department of Energy 528 Cottage, N.E. Salem, OR 97310
R. Estess State Clearinghouse Division of Policy Development and Planning Office of the Governor Pouch AD Juneau, AK 99801	M. O. Mortensen Energy Advisory Council c/o Lt. Governor's Office Capitol Building Helena, MT 59601	Dr. K. Woods Energy Facility Siting Division Department of Energy 528 Cottage, N.E. Salem, OR 97310
J. Lowell Jensen Public Utilities Commission 1100 MacKay Building 338 Denali Street Anchorage, AK 99501	J. Nybo Energy Advisory Council c/o Lt. Governor's Office Capitol Building Helena, MT 59601	W. Young Intergovernmental Relations Division Office of the Governor 240 Cottage Street, S.E. Salem, OR 97310
W. C. McConkey, Director Division of Energy and Power Development Department of Commerce and Economic Development MacKay Building 338 Denali Street Anchorage, AK 99501	W. Opitz Public Service Commission 1227 11th Avenue Helena, MT 59601	F. S. Adair Washington State Department of Commerce and Economic Development Olympia, WA 98504
G. Martin Department of Natural Resources 11th Floor, State Office Bldg. Pouch M Juneau, AK 99811	B. Roberts State Land Use Planning Bureau Department of Community Affairs Capitol Post Office Helena, MT 59601	Col. N. P. Conover District Engineer Walla Walla District Corps of Engineers Bldg. 602, City-County Airport Walla Walla, WA 99362

No. of  
Copies

Col. Raymond J. Eineigl  
District Engineer  
Seattle District  
Corps of Engineers  
1519 Alaskan Way South  
Seattle, WA 98134

N. Lewis  
Assistant Director  
Office of Program Planning  
and Fiscal Management  
State Planning Division  
House Office Building  
Olympia, WA 98504

R. Polson  
Energy Facilities Site  
Evaluation Council  
820 East Fifth Avenue  
Olympia, WA 98504

E. T. Shaw  
Utilities and Transportation  
Commission  
Highways-Licenses Building  
Olympia, WA 98504

E. Adams, Director  
Idaho Energy Office  
State House  
Boise, ID 83720

K. Sherman  
Washington State Energy Office  
1000 Cherry  
Olympia, WA 98504

M. Walsh  
Department of Ecology  
State of Washington  
Olympia, WA 98504

A. J. Eliopoulos  
Public Service Commission  
Supreme Court Building  
Cheyenne, WY 82002

D. B. Freudenthal  
State Planning Coordinator's  
Office  
Office of the Governor  
State Capitol  
Cheyenne, WY 82002

D. Hoffman  
Mineral Development Division  
Department of Economic Planning  
and Development  
720 West 18th Street  
Cheyenne, WY 82002

F. C. Blood  
Bonneville Power Administration  
P.O. Box 3621  
Portland, OR 97208

No. of  
Copies

R. S. Gens  
Bonneville Power Administration  
P.O. Box 3621  
Portland, OR 97208

J. Hoozen  
Bonneville Power Administration  
P.O. Box 3621  
Portland, OR 97208

J. C. Loosli  
Bonneville Power Administration  
P.O. Box 3621  
Portland, OR 97208

C. M. Moore  
Bonneville Power Administration  
P.O. Box 3621  
Portland, OR 97208

M. Katz  
Northwest Energy Policy Project  
1096 Lloyd Building  
700 N.E. Multnomah Street  
Portland, OR 97232

R. Lewis  
Northwest Energy Policy Project  
1096 Lloyd Building  
700 N.E. Multnomah Street  
Portland, OR 97232

W. E. Bruner  
Pacific Northwest Regional  
Commission  
1205 Washington  
Vancouver, WA 98660

D. J. Lane  
Pacific Northwest River Basins  
Commission  
1 Columbia River  
P.O. Box 908  
Vancouver, WA 98660

Dr. O. Osborne  
Oregon State University  
Electrical Engineering  
Department  
Corvallis, OR 97331

Dr. R. Wensink  
Oregon State University  
Agricultural Engineering  
Department  
Corvallis, OR 97331

Dr. J. Jaksch  
Corvallis Environmental  
Research Laboratory  
Corvallis Environmental  
Protection Agency  
Corvallis, OR 97331

No. of  
Copies

J. Brar  
Washington State University  
Pullman, WA 99163

G. Hinman  
Washington State University  
Pullman, WA 99163

R. T. Miller  
Vice President  
Engineering and Gas Control  
Northwest Natural Gas Company  
123 N.W. Flanders Street  
Portland, OR 97209

H. S. Johnson  
Portland General Electric Co.  
621 S.W. Alder Street  
Portland, OR 97205

G. A. Perrault  
Portland General Electric Co.  
621 S.W. Alder Street  
Portland, OR 97205

C. L. Sauvie  
Portland General Electric Co.  
621 S.W. Alder Street  
Portland, OR 97205

J. L. Williams  
Portland General Electric Co.  
621 S.W. Alder Street  
Portland, OR 97205

R. A. Duncan  
Coordination Engineer  
Northwest Power Pool  
920 S.W. 6th Ave., Rm. 1210  
Portland, OR 97204

H. Kosmata  
Washington Public Power Supply  
System  
3000 George Washington Way  
Richland, WA 99352

D. Renberger/G. F. Bailey  
Washington Public Power Supply  
System  
3000 George Washington Way  
Richland, WA 99352

R. Tillson  
Washington Public Power Supply  
System  
3000 George Washington Way  
Richland, WA 99352

R. Woodruff  
Washington Public Power Supply  
System  
3000 George Washington Way  
Richland, WA 99352

<u>No. of Copies</u>	<u>No. of Copies</u>	<u>No. of Copies</u>
D. N. Morris The Rand Corporation 1700 Main Street Santa Monica, CA 90406	S. Boris Teknekron Corp. 2118 Miluia Street Berkeley, CA 94704	H. G. Curtis Public Power Council P.O. Box 1307 Vancouver, WA 98660
J. W. Ellis Puget Sound Power and Light Company Puget Power Building Bellevue, WA 98009	J. W. LaFond City of Seattle Department of Lighting 1015 Third Avenue Seattle, WA 98104	Scott Alstrom Western States Water Council 220 South Second East, Suite 200 Salt Lake City, UT 84111
L. E. Hall Puget Sound Power and Light Company Puget Power Building Bellevue, WA 98009	R. Sheehan City of Seattle Department of Lighting 1015 Third Avenue Seattle, WA 98104	J. T. Stiles Pacific Power and Light Portland, OR 97204
B. C. Thomas Puget Sound Power and Light Company Puget Power Building Bellevue, WA 98009	J. McFadden Energy Inc. Box 736 Idaho Falls, ID 83401	W. Rogers, Jr. Western Interstate Nuclear Board P.O. Box 15038 Lakewood, CO 80215
T. E. Browne Electric Power Research Institute 3412 Hillview Avenue P.O. Box 10412 Palo Alto, CA 94304	K. Blackburn Old West Regional Commission Fratt Building, Suite 306A Billings, MT 59101	L. Harris Western Aluminum Producers Association P.O. Box 8484 Portland, OR 97207
R. Crow Electric Power Research Institute 3412 Hillview Avenue P.O. Box 10412 Palo Alto, CA 94304	G. Culp Culp, Dwyer, Guterson, and Grader Hoge Building Second and Cherry Seattle, WA 98104	W. L. Guy Western Governors' Regional Energy Policy Office 4730 Oakland St. Denver, CO 80239
M. Greenburger Electric Power Research Institute 3412 Hillview Avenue P.O. Box 10412 Palo Alto, CA 94304	B. Goldhammer Loyde Building 700 NE Multnomah Portland, OR 97232	K. Muller Northern Plains Resource Council 418 Stapleton Building Billings, MT 59101
L. Henning Electric Power Research Institute 3412 Hillview Avenue P.O. Box 10412 Palo Alto, CA 94304	H. C. Elmore Pacific Northwest Utilities Conference Committee P.O. Box 1231 Wenatchee, WA 98801	J. Binanado Regional Planner Bureau of Land Management P.O. Box 30157 Billings, MT 59107
H. A. Kornberg Electric Power Research Institute 3412 Hillview Avenue P.O. Box 10412 Palo Alto, CA 94304	D. J. Lewis Public Service Building 920 S.W. Sixth Portland, OR 97204	W. Tomlinson Environmental Library Rm 208A Natural Sciences University of Montana Missoula, MT 59801
M. Searle Electric Power Research Institute 3412 Hillview Avenue P.O. Box 10412 Palo Alto, CA 94304	R. A. Hofacker Montana Power Company 40 East Broadway Butte, MT 59701	R. Doell U.S. Geological Survey 354 Middlefield Road Menlo Park, CA 94025
	R. H. Bendio Idaho Power Company P.O. Box 70 Boise, ID 83721	Battelle-Northwest Human Affairs Research Center (HARC)
	H. W. Harding Washington Water Power Company P.O. Box 3727 Spokane, WA 99220	M. G. Curry M. Green J. A. Hebert S. M. Nealey M. Mertaugh D. J. Merwin M. E. Olsen R. E. Schuller

No. of  
Copies

ONSITE

ERDA Richland Operations Office

P. W. Gottschalk  
G. L. Liffick  
R. H. Lindsey  
B. J. Melton

117 Battelle-Northwest

W. J. Bair  
C. H. Bloomster  
J. B. Burnham (10)  
D. B. Cearlock  
L. L. Clark  
M. Clement  
B. W. Cone  
J. W. Currie  
D. E. Deonigi  
P. J. Dionne  
D. W. Dragnich  
D. L. Elliott (10)  
L. E. Erickson  
D. W. Fraley  
T. J. Foley  
J. C. Fox  
T. P. Harrington  
P. L. Hendrickson  
D. Hessel  
E. R. Hill  
J. J. Jacobsen  
J. King  
C. A. Knutsen  
T. P. Kula  
J. W. Litchfield  
K. A. McGinnis  
S. Marks  
E. L. Owzarski  
W. A. Reardon  
D. S. Renne (35)  
W. H. Rickard  
R. H. Sauer  
L. C. Schmid  
S. J. Shupe  
W. H. Swift  
W. L. Templeton  
D. W. Uresk  
B. E. Vaughan  
R. D. Widrig  
G. L. Wilfert  
K. E. Yandon  
J. R. Young  
Economics Library (20)  
Technical Information Files (3)  
Technical Publications