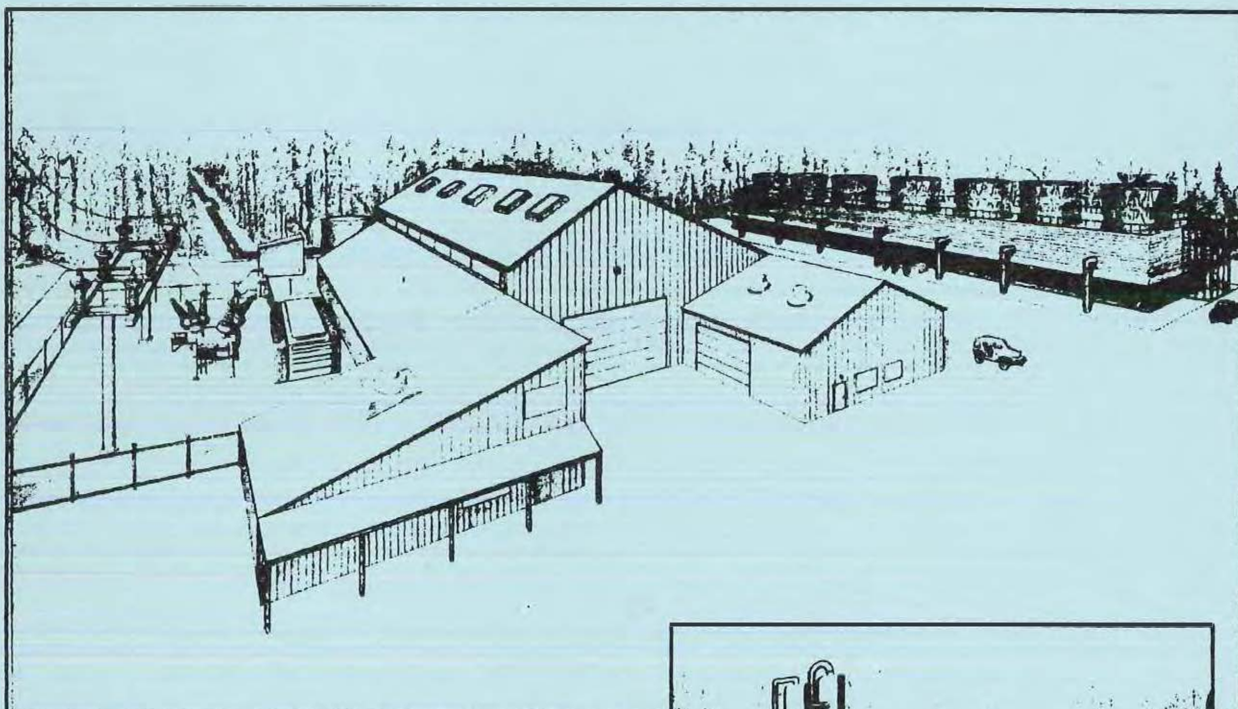
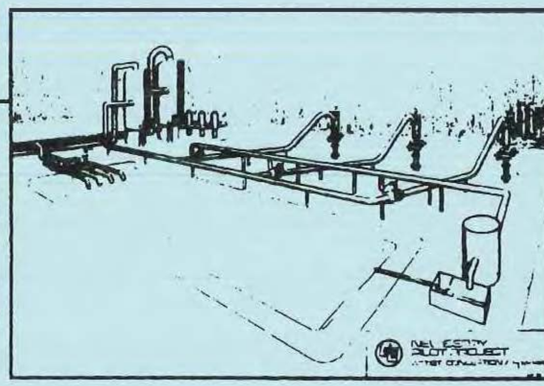
DOE/EIS - 0207
June 1994

Appendices:
Newberry Geothermal Pilot Project
Final Environmental Impact Statement





CE Exploration Company of Portland, Oregon has submitted a proposal to build and operate a 33-megawatt geothermal power plant in the Deschutes National Forest in Central Oregon. This is the draft version of the environmental analysis of the proposed project, prepared by the U.S. Forest Service, the U.S. Bureau of Land Management, and Bonneville Power Administration.

U.S. Forest Service

Bonneville POWER ADMINISTRATION

U.S. Bureau of Land Management

Newberry Geothermal Pilot Project

Final Enviromental Impact Statement

Appendices

Deschutes National Forest
Deschutes County, Oregon
June 1994

Lead Agency
USDA Forest Service

Cooperating Agencies
Bureau of Land Management, Prineville, Oregon
Bonneville Power Administration, Portland, Oregon

APPENDIX A
SCOPING PROCESS

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The agencies and CEE and EWEB have conducted an extensive scoping process for this project. The Newberry Geothermal Project is unique because it is a "pilot" project, selected by the Bonneville Power Administration to participate in a regional geothermal demonstration program. The Newberry Geothermal Pilot Project seeks to achieve an unprecedented level of public involvement by both the agencies and the project proponent in order to fully inform the public about the first commercial geothermal power generation project in Oregon.

The first step in the scoping process was to publish in the Federal Register a Notice of Intent (NOI) to prepare an EIS for the proposed project. The NOI announced the approximate time and place for the scoping meetings. Specific information packets on the scoping meetings for the Newberry Geothermal Pilot Project EIS were mailed to government agencies, Native American tribes, and interested groups and individuals which were known or expected to have an interest in the proposed project. A total of 760 information packets were initially mailed. The meetings were also announced in an update which was mailed the third week of January 1993, to the same agencies, tribes, groups, and individuals as above.

Paid advertisements announcing the scoping meetings were placed in the following newspapers: *The Eugene Register Guard, The Oregonian, The Bend Bulletin, The Sisters Nugget, The Bend View*, and *Frontier Advertising* in LaPine. Press releases and media packages were sent to radio and television stations throughout the project region.

All scoping meetings were conducted in an "open house" format. Representatives from the U.S. Forest Service, BPA, BLM, CEE, EWEB, and the EIS consultant were on hand to discuss the proposed project and answer questions. Displays describing the proposed project and the EIS process were also available. Public scoping meetings were held from 5:00 p.m. to 8:00 p.m. on the 9th, 10th, 16th, 17th, and 18th of February 1993 in Eugene, Portland, Sunriver, LaPine, and Bend, respectively. Agency scoping meetings were held on the 10th and 18th of February in Portland and Bend. The meeting locations were selected to provide an opportunity for local residents and users from other areas to participate in the process.

Court reporters were present at all five public scoping meetings, and provided verbatim transcripts. Detailed notes were taken by the EIS consultant during the agency scoping meetings. The transcripts, notes, and all written comments were reviewed and categorized as to general subject (such as air quality, visual resources, water quality, etc.). Copies of all original comments for each general subject were provided to the technical experts responsible for preparation of that part of the scoping report. Each expert reviewed and prepared a concise description of each issue, which in some cases resulted in combinations of several identical or similar comments.

A summary of each comment was entered into a Paradox database and given an individual identification number. Issues and mitigation measures identified by the various technical experts beyond the public and agency comments were identified. This material was compiled into a document called a Scoping Report (WCC 1993).

CEE and EWEB Public Involvement Efforts

The project proponents, CEE and EWEB, recognize that the public most concerned about the development is the Central Oregon community. As part of their project, CEE and EWEB have been conducting a public involvement program to bring early recognition of community concerns surrounding development of geothermal energy at the proposed Newberry location. CEE and EWEB invited a broad range of local constituencies to nominate individuals to serve on a 15-member Central Oregon Geothermal Citizens Working Group (COGWG).

The purpose of this citizen's group is to assist the project sponsors in planning for an environmentally responsible geothermal facility. The project sponsors expect to hear their independent ideas and perspectives, to develop a better understanding of the local perspective in seeking solutions to any potential conflicts. The concerns and issues from the COGWG group have been incorporated into the agencies' scoping efforts. Their concerns are included in the Scoping Report.

The CEE/EWEB public involvement program is designed to be an addition to agency-sponsored public forums associated with the NEPA review. The COGWG meets once per month to discuss various topics. The first six meetings were based on an informational format to describe what the geothermal industry is and how it works. Several workshop-type sessions were subsequently held to explore specific subjects and issues of concern, such as hazardous waste, hydrology, development of the resource, air quality, and cultural resources.

The group sponsored two tours to existing geothermal field at The Geysers in California and several visits to the proposed sites at Newberry.

Scoping Issues

The issues raised during scoping are addressed in the project scoping report and the executive summary of the scoping report. The major issues raised are summarized in Chapter 1.

DEIS Review and Comment Process

A significant part of the EIS public involvement process is the Draft EIS review and comment period. The DEIS was mailed on January 21 - 26 to 425 agencies, libraries, organizations and individuals for a 45-day review and comment period which commenced on February 4, 1994 when the notice of availability to review the DEIS was published in the Federal Register.

During this review period, a series of four open houses were held in Sun River, LaPine, and Bend on February 22, 23, and 24 to further acquaint the public with the project and the DEIS and to give them audience with the three agencies' representatives and the project proponents. Copies of the DEIS and Executive Summary were available at these meetings and written comments were accepted.

The review period concluded on April 18, 1994 and a total of 59 letters were received by the USFS, the lead agency, in response. The responses were generally favorable towards the project. The letters have been analyzed and categorized by specific individual comments, of which there were 586. The original letters and a more complete analysis of the comments with specific responses and categorization is available in the Comment Report, a separate document. For copies of this report, contact the USFS.

APPENDIX B
AGENCIES/ORGANIZATIONS AND PERSONS CONSULTED

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AGENCIES/ORGANIZATIONS AND PERSONS CONSULTED

City of Bend
Mike Beyers, Senior Planner
Lt. Maniscalo
Roger Powell, Assistant Water Supervisor

Bend, City of Fire Department
John Niendorf, Fire Marshall

Bend Chamber of Commerce
Jackie French, Director of Tourism

Bend-La Pine Public School District
John Rexford, Auxiliary Services Manager

CE Exploration (CEE)
David McClain, Project Manager

Central Oregon Economic Development Council (COEDC)

Deschutes County
Helen Rastovich, Tax Collector

Deschutes County Assessors Office
Kim Worrell, County Assessor

High Desert Ecology
Caroline Lindstedt, Biologist

La Pine Fire Department
Dan Hoffman, Firemedic

Leitner and Leitner Biological Consulting
Barbara Leitner, Biologist

Oregon Department of Environmental Quality (DEQ)
Linda Wishart, Air Quality Division

The Nature Conservancy
Oregon Natural Heritage Program

Oregon Department of Fish and Wildlife
Ted Wise

Oregon Department of Geology and Mineral Industries (DOGAMI)
Dan Wermiel, Petroleum Geologist

Science Applications International Corporation (SAIC)
Jalal Heydarpour, Consultant

U.S. Fish and Wildlife Service
Ron Garst, Biologist

Wildlife Dynamics
David Smith, Biologist

APPENDIX C
BIOLOGICAL SURVEY METHODS

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A. WILDLIFE SURVEY METHODS

Prior to the initiation of the wildlife field work, an information review was conducted which included site specific wildlife species observations, seasonal wildlife use information, habitat characteristics, and potential significant habitats. Protocols for nest and habitat surveys were reviewed with regulatory agency personnel and representatives of the EIS author to assure acceptable data collection methods that would determine potential effects to suitable habitat and wildlife utilization.

All wildlife studies for this project, except the herpetofauna surveys, were conducted in the area encompassing the drill pads and plant site and the two alternative transmission line area. The transmission line area was defined as 1/2 mile wide with the line as the center. Both proposed lines surveyed were located near the 9735 Road and their survey areas overlapped for the entire length of the corridor.

The following methods were used to achieve the main objectives of this wildlife resources study.

Winter Wildlife Surveys

Winter wildlife surveys were conducted on snowmobiles and by foot by two observers on April 12 and 18, 1993. Surveys were conducted using the regional ODFW snow track survey methodology as a guideline. The surveys performed for this study differed only in survey routes searched and the number of times the surveys were done. Observers during this study did reconnaissance-level surveys (one survey day on each route) along edges of clear-cut areas as well as the major snowmobile routes. No portion of the routes were sampled twice.

All wildlife tracks encountered were identified, if possible, and recorded on ODFW snow track survey forms. To reduce recording of duplicate tracks, observers followed all intercepted tracks a short distance off of the snowmobile routes to confirm the animal's travel direction.

Determining Habitat Types

During the information review period, the 1991 ortho-photos and -quads and the corresponding infrared photos, obtained from the U.S. Forest Service and CEE, were used for the preliminary habitat cover typing. The study area was cover typed on the ortho-photos and then digitized with AutoCAD to create a base map. The cover typing was done primarily by dominant over-story vegetative species and stand structure. The base map was used in the field to verify and describe the designated polygons and to assist in determining areas of suitable habitat for species of concern.

40-Acre Drill Pad Block Surveys

The U.S. Forest Service and ODFW required that intensive field surveys be completed on 40 acres surrounding all drill pad locations and the plant site. Forty-acre blocks, centered on the latitude and longitude of each pad and plant site, were overlaid on the cover type base map to assist in the field surveys.

Drill pad locations were located in the field with the assistance of a Global Positioning System (GPS, Magellan Model M-105), topographical maps, and existing survey flagging and stakes. Intensive surveys were completed using three biologist spaced evenly along one side of the 40-acre block and walking parallel through the block. The GPS was used to determine when the observers were 1/8 mile from the center of the pad site which marked the beginning of the block. The center observer carried the GPS and announced when the center of the pad block had been reached (Note: In many instances the pad site's center survey stake was intercepted). The observers continued through the block until the GPS indicated the observers were 1/8 mile past the center. The distance was sometimes paced by one of the observers when the GPS accuracy was deficient due to satellite position, topography, or canopy closure. Each observer was responsible for 13.3 acres and recorded detailed notes on specific habitat conditions, using ocular estimates, on their portion of the block. The observers completed the first three pad blocks walking throughout the block in a group to standardize the methodology and discuss the ocular estimates of the variables being estimated. After the survey was completed the observers discussed the habitat components within their portion of the block and then jointly completed a single data sheet that typified the entire block.

Data collected at each of the 40-acre drill pad blocks:

- field verification of habitat cover types
- suitability of habitat for species of concern
- locations of all caves and look for evidence of bat use
- snag densities and size classes by cover type
- canopy closure by cover type
- the # of canopy layers by cover type
- average dbh, by layer, by cover type
- dead/down logs and root wads for potential marten habitat by cover type
- areas within pad locations that should be avoided when the 5-acre pads or roads are constructed

Transmission Line Area Surveys

All habitat cover type polygons delineated on the base map within the transmission line area were field surveyed. The same data information gathered for pad site blocks were estimated for each of the polygons within the transmission line. Polygons that were determined to be similar in their habitat components were grouped together and described.

Determining Suitability of the Habitat for the Species of Concern

The U.S. Forest Service required that the extent of the suitable reproductive habitat for species of concern be determined by aerial photo interpretation with 25 percent ground truthing. Habitat suitability criteria was given by the U.S. Forest Service - Fort Rock district wildlife biologist during the information review (Becker, pers., comm., June 6, 1993). The following is a list of criteria used for determining suitability.

Flammulated owl:
Mixed conifer with white fir and lodgepole.

- must be at least pole-sized timber
- not pure hemlock stands
- snags must be present and be >12" dbh
- canopy can be clumpy distribution
- stands can be as small as 5 acres
- Note: Look at stands where flammulated owls were located in the U.S. Forest Service 1989/1990 owl surveys
- Note: Since the surveys were completed, new information indicates that flammulated owls will use ponderosa pine. Additional surveys would be required in 1994 to survey this cover type.

Northern goshawk:
Any tree species mix, including pure lodgepole.

- at least some of the trees must be >12" dbh and 40 ft tall to provide potential nest trees
- canopy closure must be >50%

Great gray owl:
Mostly the same habitat as flammulated owl; pole-sized mixed conifer and/or lodgepole stands if >12" dbh.

Three-toed woodpecker:
Mainly lodgepole stands but some mixed conifer if a lodgepole component is present.

- no stand size limit and includes clearcuts if at least 2 snags per acre are present

Pacific western big-eared bat:
Concerned with the presence of caves. If caves are located, record:

- location and size
- if it has full-dark zones
- if there is evidence of use (e.g., droppings or insect parts)

American marten:
Mostly mature and old growth stands of mixed conifer.

- At least 50% canopy closure
- presence of some large diameter snags
- abundant downed log component, preferably larger diameter and with root wads

Herpetofauna Surveys

A field reconnaissance was conducted on 17 June 1993 between 0900 and 1700 hours by two people under warm (daytime air temperature high of 23° Centigrade or 73° Fahrenheit), sunny conditions. Based on the heavy winter precipitation during 1992-93, the survey date and conditions were considered ideal for detecting amphibians and reptiles within the survey area. This date fell within the anticipated reproductive interval for most of the amphibians and reptiles that occur in this elevational range.

Survey routes were established at: (1) the area north of Paulina Creek just below the 1830 m (6000 feet) contour northward through the north half of Section 33, the west half of Section 28, and the southwest quarter of Section 21 (T21S, R12E); (2) a 0.5 km (0.3 miles) reach of Paulina Creek from 1.5 km (0.9 miles) below Paulina Creek Falls in an upstream direction; (3) Paulina Creek from just above Paulina Creek Falls to the outflow of Paulina Lake; (4) the edge of Paulina Lake just north of its outflow into Paulina Creek northward to a point along the lakeshore 0.5 km north of Paulina Creek Campground; (5) the edge of Paulina Lake south and east of its outflow in Paulina Creek to a point along the lakeshore 1.0 km (0.6 mile) east of Paulina Creek Campground; (6) Lost Lake; (7) Paulina Creek at its intersection with Paulina Creek Road (at Horse Camp Trailhead); and (8) Paulina Creek at its intersection with Newberry Road.

All aquatic sites were sampled with the aid of a kick net. Stillwater areas having submergent or low emergent vegetation were examined for larval amphibians by systematically sweeping through the vegetated edge at intervals. In stream areas, the kick net was used as a Surber sample; one individual placed the net as flush to the bottom as possible, while the other person rubbed individual rocks together upstream. Drifting organisms were then caught in the net.

The count, species, and life history stage were recorded for all observed amphibians and reptiles. Additional data, such as reproductive condition or food items (removed from snakes by palpation), were also recorded wherever these might assist interpretation of onsite conditions. Key structural and vegetative features of each site were also recorded. Miscellaneous observations of other organisms utilizing the same habitats as amphibians and reptiles were also noted.

Databases for museum collections with material from the region were examined for the most proximate records of various sensitive amphibian and reptile species. Databases examined were for collections at: California Academy of Sciences (CAS); Museum of Vertebrate Zoology at Berkeley (MVZ); Oregon State University (OSU); Portland State University (PSU); United States National Museum, Washington (USNM); University of Kansas (UK); and University of Michigan (UMMZ). Local Oregon Department of Fish and Wildlife (ODFW) biologists, Chris Carey and Walt Weber; an archeological volunteer in the Newberry National Monument work, June Tilman; Maurita Smyth, an environmental consultant; and WCC biologists provided key details about sensitive species records for the region, fish plantings, and features of the Paulina Lake/Creek system. John Paul Leeming assisted with field surveys.

Species of Concern Calling Surveys

Wildlife calling stations were determined in the field during the third and fourth field visits (June 6 and 19, 1993) and were located in areas that contained at least some habitat components suitable for reproductive habitat for the three species being surveyed for -- northern goshawk, great gray owl and flammulated owl. All calling stations were located on U.S. Forest Service roads within the study area. Calling techniques for the three species followed the general guidelines of the modified Region 6 Spotted Owl Inventory and Monitoring Handbook (1989 Barss). Calling was not done if it was raining or if the wind speed was greater than 15 mph.

Surveys for goshawk were conducted on July 3-5, and 17, 1993 during the daylight between 0800 - 1830 hrs. A goshawk tape (Sullivan Recordings, Ashland, OR) of "alarm" and "wailing" calls were broadcast alternately with a Johnny Steward Wildlife Caller. Calling was done at each station for 5 to 10 minutes and all responses were recorded.

Owl surveys were conducted on July 2, 15-18, and 28, 1993 after dark between 2300 - 0300 hrs. Due to surveying conditions, calling was only conducted at station 2 on July 2, 1993. Only flammulated owls were surveyed for on July 15 and 16, 1993. The National Geographic Birds of the Western United States calls of the flammulated and great gray owls were re-recorded repetitively. The tape was broadcasted on a Johnny Steward Wildlife Caller. Although it was likely to be too late for calling to locate great gray owl nest sites, calling was done anyway. Calling was done at each station for 5 to 10 minutes and all responses were recorded.

Wildlife Sightings

A standardized survey for a wildlife species account was not conducted for this study. All wildlife or their recognizable sign was documented during field activities to gather a species account by cover type for the project site. Areas in the project study area where big game were frequently sighted or areas of high use were noted. Observations of any species of concern were recorded on the base map.

Two spotlight surveys were conducted while travelling between owl calling stations in July 1993. All species observed within the study area during the spotlighting were recorded.

B. SENSITIVE PLANTS SURVEY METHOD

The field survey for Threatened, Endangered and Sensitive (TES) plant species was designed to confirm any previous sensitive plant sightings and to detect new occurrences within the proposed project area. The area was surveyed for TES species on the current Regional Forester's sensitive species list (FSM 2670.44, Region 6, Interim Directive No. 90-1), March 1991) which are documented or suspected to occur within the Deschutes National Forest.

Prior to the field survey, a Pre-Field Review was prepared by personnel at the Fort Rock Ranger District, Deschutes National Forest. The Review determined what TES species could potentially occur within the proposed project area.

Approximately 496 hectares (1,226 acres) within the proposed project area were surveyed in addition to two 7.2-km (4.5-mile) linear corridors along proposed transmission lines. All survey routes were marked on USGS 7.5-minute quadrangle maps during the course of the survey and subsequently submitted to the U.S. Forest Service personnel for review. A Sensitive Plant Survey Record for Deschutes National Forest was completed for every area unit surveyed. The "random meander" technique was used within the proposed project area, whereby plant associations were noted and areas located in habitat more likely to support TES species were surveyed more intensely to the perimeters of the habitat type. For surveying the proposed transmission line areas, compass direction was used.

Every plant encountered was identified in order to make a complete list of vascular plant species in the project area. Sensitive plant sighting forms were completed for each sensitive plant population encountered. Photographs were taken to document sensitive plant occurrences.

APPENDIX D
ARCHAEOLOGICAL SURVEY METHODS

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As part of the initial information gathering process, the cultural resources records of the following agencies were reviewed by personnel from Far Western Anthropological Research Group (Far Western) for known cultural resources sites and surveys within the study area and for a one mile area surrounding the study area perimeter:

- Fort Rock Ranger District, Deschutes National Forest
- Prineville District Office, Bureau of Land Management
- Oregon State Office of Historic Preservation

The results of the records search revealed that several cultural resources surveys have been conducted entirely or partially within the study area. These surveys were performed as investigations for a variety of activities including timber sales, geothermal development and natural gas pipeline construction. The nature and extent of these surveys with reference to the proposed project is discussed below. Based on guidance from cultural resources personnel with the Fort Rock Ranger District of the Deschutes National Forest, 492 hectares (1,215 acres) were identified within the study area for an intensive (Class III) pedestrian cultural resources survey. The results of this inventory, performed by Far Western, are provided in a Cultural Resources Technical Report (Gilreath and Wohlgemuth 1993) on file with the Deschutes National Forest.

APPENDIX E
AIR QUALITY REGULATORY REVIEW

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Air Quality Regulations

Ambient air quality standards have been set by the U.S. EPA under the Federal Clean Air Act (1990) and by the state of Oregon DEQ. For sources that emit significant levels of pollutants into the air, a permit is required and all applicable emission and air quality standards must be met. The type of permit required for a new source depends on the amounts and types of pollutants emitted.

The Federal Clean Air Act is designed to protect human health and welfare from air pollution. National Ambient Air Quality Standards (NAAQS) are defined in the Clean Air Act as levels of pollutants above which detrimental effects on human health or welfare may result. NAAQS have been established for the following air pollutants:

- Particulate matter (PM_{10})
- Sulfur dioxide (SO_2)
- Nitrogen dioxide (NO_2)
- Ozone (O_3)
- Carbon monoxide (CO)
- Lead (Pb)

Most of Oregon's ambient air standards are the same as the Federal ambient air standards, except for (1) total suspended particulates, which was dropped as a Federal criteria pollutant in 1987 but was retained by Oregon, and (2) sulfur dioxide, which has stricter standards for annual mean and 24-hour average in Oregon.

The basic permit required for air emissions in Oregon is called an Air Contaminant Discharge Permit. Other permits and rules that may apply to this project include Notice of Construction and Approval of Plans (OAR340-20-202), Emission Standards for Hazardous Air Contaminants (OAR 340-20-450), Highest and Best Practicable Treatment and Control (OAR 340-20-001), and Standards of Performance for New Stationary Sources (OAR 340-25-505). Applicability to this project would be determined by DEQ after an application has been submitted by CEE.

Another provision of the Clean Air Act and Oregon regulations is Prevention of Significant Deterioration or PSD. The premise behind the PSD provisions is to prevent areas that currently have clean air from being polluted to the maximum extent allowed by the NAAQS. Three air quality classes were established, Class I, Class II, and Class III. Class I areas are subject to the highest restrictions on how much additional pollution (usually called an "increment") can be added to the air. All remaining areas of the U.S. are designated Class II areas, where somewhat greater degradation is allowed, although never exceeding NAAQS. There are no Class III areas in the U.S.

Emissions criteria used to determine PSD permit applicability vary depending on the type of facility. Generally, a PSD review is not required for facilities that emit less than 250 tons per year of a regulated pollutant. The PSD criterion is 100 tons per year for a specific list of source types that are not expected to be included in CEE's plans. Anticipated daily and annual emission values have been evaluated for the proposed project and are based upon data available for similar geothermal resources. These levels are below that which would require a PSD permit. This determination would be confirmed by DEQ based on actual emissions data to be supplied by the applicant. Thus, the project is not expected to require a PSD permit (see Table 3.8.1-1).

Hazardous air pollutants and criteria pollutants are regulated by EPA and DEQ according to the Clean Air Act and are summarized in Table 3.2.6-1. Hazardous air pollutants are one of any 189 listed air pollutants determined to be hazardous to human health by the EPA. Major sources which emit hazardous air pollutants are subject to certain emission and control standards and restrictions. Those hazardous air pollutants that could be relevant to this project include: antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), lead (Pb), and radon-222 (Rn222). If any of the hazardous air pollutants are emitted by the project in significant amounts, a permit under Title V of the Clean Air Act Amendments of 1990 would be applicable. Anticipated levels of hazardous air pollutant emissions based upon data available for similar geothermal resources have been evaluated. These estimates are well below current levels which would trigger a Title V Permit or Title III compliance under the Clean Air Act. The actual amounts and types of air emissions cannot be fully determined until the wells have begun operating and specific data is available. Applicability of hazardous air pollutant requirements will be confirmed later by DEQ as the requirements develop and emissions data become available for the project. DEQ has the authority to require a source to demonstrate that "highest and best practicable" emission controls are being used, whether or not they are subject to toxic air pollutant controls. If Significant Emission Rates (SERs) are exceeded, DEQ would perform a control technology review and health effect assessment.

APPENDIX F-1
BACKGROUND CONCENTRATION OF AIR POLLUTANTS AND VISIBILITY AT THE NEWBERRY CRATER SITE

Prepared by Science Applications International Corporation (SAIC) for CEE, October 1993

1. Background Concentration of Air Pollutants and Visibility at the Newberry Crater Site

The CE Exploration Company's Newberry Geothermal Pilot Project site is located in the Deschutes National Forest in Deschutes County approximately 32 km south of Bend. It is within 1700 meters of the Newberry Crater National Volcanic Monument at its nearest boundary, and is 43.5 km from the Three Sisters Wilderness (the nearest Class I area). Deschutes County is located on the eastern slopes of the Cascade mountain range and extends into the high desert. Much of the land is managed either by the Bureau of Land Management or the National Forest Service for forest product, rangeland, or recreational uses. The area is by all definitions rural, with the possible exceptions of Bend and Redmond (approximately 32 km and 60 km north of the site, respectively). The principal existing sources of baseline air pollution near the site are wind-blown or road dust and infrequent slash burning events. The Oregon Department of Environmental Quality has tabulated emission inventory data by county (reference 1). Consistent with its rural setting, Deschutes County is responsible for only approximately 2 to 3% of Oregon's total traditional air pollutant emissions (Table 1).

Mean background concentrations of (1) federal criteria pollutants, (2) relevant hazardous air pollutants (HAP) as defined by title III of the Clean Air Act Amendments of 1990, and (3) other miscellaneous pollutants which are associated with the geothermal industry were estimated. The federal criteria pollutants are particles with aerodynamic diameters less than 10 microns (PM_{10}), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), and lead (Pb). The relevant HAP are antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), lead (Pb), and radon-222 (^{222}Rn). The miscellaneous pollutants which were taken into consideration are boron (B), hydrogen sulfide (H_2S), ammonia (NH_3), volatile organic compounds (VOC), and total suspended particles (TSP). Hydrogen sulfide is the principal air pollutant associated with the geothermal industry, in large part due to its low olfactory threshold (3.9 ppb or 5.5 $\mu g/m^3$, reference 2). Boron, ammonia, and volatile organic compounds are associated to a lesser degree with the geothermal industry and were included for that reason. In addition, VOC is responsible in part for atmospheric ozone production and may as a category contain organic HAP. The State of Oregon maintains a TSP standard and the prevention of significant deterioration (PSD) increments for particles are in terms of TSP, hence an estimate of TSP background was made.

Mean background levels of PM_{10}, SO_2, and Pb were estimated from Crater Lake monitoring data for the July 1991 to June 1992 time period (reference 3). Ozone estimates for the Three Sisters Wilderness area have been made by the National Forest Service (reference 4). Unpolluted background levels typical of the western United States were used for the CO, NO_2, H_2S, NH_3, and VOC values. Soil gas measurements have been made for Hg and ^{222}Rn as part of the geothermal exploration that has been conducted in the Newberry Crater area (references 5 and 6). It should be noted that neither the Hg or ^{222}Rn soil gas values were very high as compared to typical soil values. (Hg values averaged about 2.5 times higher than the mean and ^{222}Rn values were about 0.6 lower.) From the soil estimates, typical atmospheric Hg and ^{222}Rn (references 7 and 8) were scaled to provide an estimated atmospheric value for the Newberry Crater area. Except for Pb and Hg, the atmospheric concentrations of the other HAP metals and boron will be primarily controlled by the amount of dust in the air. (Even in a rural airshed the primary source of Pb is vehicular exhaust from vehicles using leaded gasoline, and mercury vapor emanating from subsurface geothermal features will be more significant than mercury contained in soil particles). Since the predominant soil type in the project area is composed of 7500-year-old Mazama ash (references 5 and 9) with an estimated 2% organic fraction (references 9 and 10), dacitic volcanic ash compositional data

Table 1 Air Pollutant Emissions in Deschutes County[1]

Area	PM_{10}	SO_x	NO_x	CO	VOC
Deschutes County	5443	1340	4815	45,283	6089
Oregon Total	200,726	69,995	213,189	1,537,526	219,639
% Deschutes County of Total Oregon	2.7%	1.9%	2.2%	2.9%	2.8%

[1]Tons per year

(references 11-13) combined with the soil fraction of PM_{10} that could be estimated from Crater Lake monitoring data allowed for the calculation of average Sb, As, Be, Cd, Cr, Co, Mn, Ni, Se, and B atmospheric levels. Average TSP levels were estimated from the Crater Lake PM10 monitoring data and the size distribution typical of soil (references 14 and 15).

Estimated mean background levels for each pollutant, along with the relevant standards, acceptable ambient levels (AAL) and PSD incremental values are provided in Table 2. Standards and AAL are provided for comparison purpose with background and predicted impact values. Acceptable ambient levels were calculated for those pollutants for which appropriate federal or state standards were not available. AAL values were calculated from occupational exposure levels by the method described in reference 16 and noted by footnote in Table 2.

It has been observed that short-term impacts from slash burning have created fine particulate levels in the 20 $\mu g/m^3$ range in the region (reference 11) and particulate levels in excess of the 24-hour PM_{10} and TSP standards can be expected adjacent to dirt roads during the months of July through September throughout eastern Oregon. The particulate material from slash burning will contain about 90% organic compounds, 10% elemental carbon, and traces of geological material. In regard to H_2S, it has been noted that the odor of H_2S is occasionally detectable near the fumaroles near the Big Obsidian Flow. The 50% olfactory threshold for H_2S is 5.5 $\mu g/m^3$ (3.9 ppb) (reference 2).

Considerable visibility monitoring has been conducted in the Cascade wilderness areas and at Crater Lake National Park (references 1, 17, and 18). Most relevant to the Newberry Crater area is data for the Three Sisters Wilderness (Huckleberry Mountain). Table 3 illustrates the historic visual range data for the Three Sisters Wilderness site. As can be seen from the data in Table 3, the 90th percentile value for the time period 1986 through 1990 averaged 254 km. The 90th percentile value is used both in the visibility modeling and the quantitative determination as to if there is "any humanly perceptible impairment of visibility" as specified in section 169A of the Clean Air Act.

Table 2. Background Air Pollutant Levels, Standards, Acceptable Ambient Levels, and PSD Increments

Pollutant	Chemical Symbol or Abbreviation	Category	Estimated Mean Background Concentration	Standards or AAL and PSD Increments	References Used in Background Estimates
Particles less than 10 μ	PM_{10}	Criteria	9.45 μg/m³	50 μg/m³ annual[1] 150 μg/m³ 24-hour[1]	3
Sulfur dioxide	SO_2	Criteria	0.457 μg/m³ (1.75×10^{-4} ppm)	0.03 ppm annual[1] 0.14 ppm 24-hour[1] 0.5 ppm 3-hour[1] 2 μg/m³ Class I, annual increment[2] 5 μg/m³ Class I, 24-hour max.[2] 25 μg/m³ Class I, 3-hour max.[2] 20 μg/m³ Class II, annual incr.[2] 91 μg/m³ Class II, 24-hour max.[2] 512 μg/m³ Class II, 3-hour max.[2]	3
Carbon monoxide	CO	Criteria	0.1 ppm	9 ppm 8-hour[1] 35 ppm 1-hour[1]	19
Ozone	O_3	Criteria	0.025-0.030 ppm[10]	0.12 ppm 1-hour[1]	4
Nitrogen dioxide	NO_2	Criteria	0.001 ppm	0.053 ppm annual[1]	19
Lead	Pb	Criteria and HAP	1.2×10^{-3} μg/m³	1.5 μg/m³ calendar quarter [1]	3
Antimony	Sb	HAP	$<9 \times 10^{-7}$ μg/m³	1.7 μg/m³ AAL[3]	9, 10, 11
Arsenic	As	HAP	6×10^{-6} μg/m³	0.7 μg/m³ AAL[3]	9, 10, 11
Beryllium	Be	HAP	6×10^{-6} μg/m³	0.007 μg/m³ AAL[3]	9, 10, 11
Cadmium	Cd	HAP	$<4 \times 10^{-7}$ μg/m³	0.033 μg/m³ AAL[3]	9, 10, 11
Chromium	Cr	HAP	2×10^{-4} μg/m³	1.7 μg/m³ AAL[3]	9, 10, 11
Cobalt	Co	HAP	7×10^{-5} μg/m³	0.17 μg/m³ AAL[3]	9, 10, 13
Manganese	Mn	HAP	2×10^{-3} μg/m³	17 μg/m³ AAL[3]	9, 10, 11
Mercury	Hg	HAP	0.01 μg/m³	0.17 μg/m³ AAL[3,4]	5, 7
Nickel	Ni	HAP	2×10^{-5} μg/m³	3.3 μg/m³ AAL[3]	9, 10, 12
Selenium	Se	HAP	$<4 \times 10^{-6}$ μg/m³	4 μg/m³ AAL[3]	9, 10, 11

Table 2. Background Air Pollutant Levels, Standards, Acceptable Ambient Levels, and PSD Increments (continued)

Pollutant	Chemical Symbol or Abbreviation	Category	Estimated Mean Background Concentration	Standards or AAL and PSD Increments	References Used in Background Estimates
Radon-222	^{222}Rn	HAP	0.13 pCi/l	4 pCi/l[5]	6, 8
Boron	B	Geothermal pollutant	7×10^{-5} µg/m³	33 µg/m³ AAL[3,6]	9, 10, 13
Hydrogen sulfide	H_2S	Geothermal pollutant	0.2 ppb (0.28 µg/m³)	30 ppb[7] (41.7 µg/m³)	20
Ammonia	NH_3	Geothermal pollutant	0.01 ppm	3.1 ppm[8]	19
Volatile organic compounds	VOC	Many HAPS are VOC- & O_3-producing	200 ppb	NA	19
Total suspended particles	TSP	Oregon State air pollutant and PSD incremental parameter	13.1 µg/m³	60 µg/m³ annual geometric mean[9] 150 µg/m³ 24-hour[9] 5 µg/m³ Class I, annual increment[2] 10 µg/m³ Class I, 24-hour max.[2] 19 µg/m³, Class II, annual increment[2] 37 µg/m³ Class II, 24-hour max.[2]	3

1. Federal standard.
2. OAR 340-31-110, annual TSP is geometric mean, annual SO_2 in arithmetic mean.
3. Acceptable ambient levels (AAL) = Occupational Threshold Limit Values (TLV) for time-weighted averages (TWA) for an 8-hour workday and a 40-hour work week divided by 300, i.e., AAL = $TLV_{TWA}/300$
4. Mercury vapor standard.
5. Federal indoor air standard.
6. Boron oxide.
7. California 1-hour standard.
8. Alaska 1-hour standard.
9. Oregon standard.
10. May through October, hourly average, Three Sisters.

Table 3. Standard Visual Range, Three Sisters Wilderness Area[1]

Year	Number of Obs.	10th Percentile	50th Percentile	90th Percentile
1986	785	90	163	295
1987	287	97	157	254
1988	276	95	176	247
1989	214	78	137	228
1990	269	82	142	248

1. Huckleberry Mountain; values are in kilometers; summer and fall months only.

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APPENDIX F-2
EVALUATION OF ATMOSPHERIC CONCENTRATIONS OF POLLUTANTS ORIGINATING FROM THE PROPOSED GEOTHERMAL DEVELOPMENT

Prepared by Science Applications International Corporation (SAIC) for CEE, November 1993

The Evaluation of Atmospheric Concentrations of Pollutants Originating from the Proposed Geothermal Development

The impacts of air pollutants were assessed by estimating emission factors from geothermal activities in areas with similar resources as Newberry Crater and conducting dispersion modeling with EPA guideline models. Meteorological data collected at the proposed CE Exploration Newberry Crater geothermal site were used for the modeling. Baseline concentrations of pollutants were estimated from literature reports of monitoring at Crater Lake National Park, from typical western atmospheric background levels or from geological related reports on soil mercury, radon emanation and regional soil chemistry. (Baseline concentrations of air pollutants and a detailed discussion on the methods used to estimate their levels have been provided in a companion document.) Total atmospheric concentrations were estimated by adding the worst-case impact values to typical baseline concentrations. In all cases the sum of the worst-case impact values and the typical baseline values were well below applicable standards or threshold levels. Two plant operational scenarios were modeled and it was found that the worst-case upset condition (with unabated emissions) had the highest impacts for all pollutants, at the two nearest class I and class II receptor points considered in this study.

A complete description of the dispersion modeling approach used along with a discussion on the meteorological data base and geothermal exploration, development and power plant operation scenarios have been provided in another companion document for hydrogen sulfide (H_2S) impact assessment. (The hydrogen sulfide impact analysis was done separately due to the fact that hydrogen sulfide has historically been the single major air quality issue associated with the geothermal industry.)

The impact of pollutants other than hydrogen sulfide were determined either by using the results of the previous H_2S modeling in the case of SO_2 or by running two new sets of models. The COMPLEX-1 model was used to predict impacts in each case. The use of a complex terrain model was required since the nearest class II receptor (the nearest Newberry Crater National Volcanic Monument boundary) and the nearest class I receptor (the nearest Three Sisters Wilderness boundary) are located at elevations higher than the project site. A map provided in this report shows the location of all sensitive receptors used in the previous and present modeling including the nearest Newberry National Volcanic Monument boundary (receptor No. 18) and the nearest Three Sisters Wilderness Class I boundary (receptor No. 16). Note that these two receptor points are labelled MONUMENT (rank 9) and CLASS1N (rank 8), respectively, in the model output printouts given in the appendices. The reference on the map to Table 4 corresponds to the companion report describing hydrogen sulfide impacts from the proposed geothermal plant.

The new modeling was conducted for two classes of pollutants: those that are predominately in the particulate phase and those that are predominately in the gas phase and are unaffected by the H_2S control equipment. Appendix A gives the modeling computer printout for the former class (as illustrated by TSP modeling) and Appendix B gives the modeling computer printout for the latter class (as illustrated by NH_3). The previous modeling results for H_2S were used, with adjustment for the change in molecular weight, for SO_2 impacts as it was assumed for worst-case scenario that all of the H_2S emitted was instantaneously converted to SO_2 in the atmosphere after it left the stacks or silencers. Since the distribution of all other pollutants between the various point sources (wellhead silencer, cooling tower, sulferox vessel and plant silencer) is similar to either NH_3 or TSP, their impact at receptor points was directly calculated by using the ratio of their emission rate to that of one of these two pollutants.

The modeling was performed for both the normal operation (plant normal operation including emissions from a cooling tower, a sulferox vessel and two wells being fully vented through wellhead silencers), and the worst-case upset condition (including emissions from six wells being fully vented through the plant silencer and two wells being fully vented through wellhead silencers). For both classes of pollutants, discussed above, it was found that the worst-case upset scenario had the highest impact at receptor points. In this study, we retained impacts from the worst-case upset condition (referred to as case 4 at 0-hour in the previously prepared documents). It should be emphasized that this is a rare event. Records form a similar CE Exploration geothermal facility in California shows that unabated upset conditions occurred for an hour or less only 12 times over a six month period. In addition well venting will not be conducted during periods of inclement weather and deep snow cover.

The results of the calculation of emission factors for all criteria pollutants, hazardous air pollutants (HAP) that are reasonably associated with geothermal emissions as well as miscellaneous pollutants often identified with geothermal emissions are provided in Table 1. The emissions of carbon monoxide, ozone and nitrogen dioxide at geothermal facilities are negligible as compared to standards and deleterious environmental levels and due to that fact no estimates of emission factors associated with the geothermal industry could be found in the literature for them and hence their impacts were not modelled. As previously noted the SO_2 emission factor was based on the emission of H_2S. It was simply assumed for the worst-case scenario that all H_2S was instantaneously converted to SO_2 at the point of entry into the atmosphere. In actuality, the typical lifetime of H_2S in the atmosphere before it is converted to SO_2 is 4 days. To provide worst-case conservative values when the emissions factors for PM_{10} and TSP were estimated it was assumed that all particulate emissions were either in the PM_{10} or TSP size categories, respectively, for use when the modeling was done for either pollutant. The emission factors for the remaining pollutants were either estimated from Medicine Lake or COSO geothermal chemical data or actual air pollutant measurements in a geothermal cooling tower plume (reference 1).

The predicted impacts, baseline concentrations and total atmospheric concentrations (the sum of impacts plus baseline) are contrasted to relevant standards or acceptable ambient levels (AAL) in Table 2) and to class I and class II prevention of significant deterioration (PSD) increments Table 3. In all cases the predicted ambient concentrations are well below standards, AAL or PSD increments. As previously noted, the nearest sensitive receptor (also class II receptor) was considered to be the nearest monument boundary to the proposed plant site (1.7 km from site) and the nearest class I receptor was the nearest Three Sisters Wilderness boundary (43.5 km from the site).

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Table 1. Air Pollutant Emission Factors

Pollutant	Chemical Symbol or Abbreviation	Well through Silencer (g/sec)	Sulferox (g/sec)	Cooling Tower (g/sec)	Comments
Particles < 10 μ	PM_{10}	3.9×10^{-2}	5×10^{-4}	5×10^{-3}	Assumes all particulate emissions are PM_{10}
Sulfur dioxide	SO_2	6.64×10^{-1}	9.49×10^{-3}	3.09×10^{-2}	Assumes all H_2S converted to SO_2
Carbon monoxide	CO	trace	trace	trace	Insignificant CO emissions
Ozone	O_3	trace	trace	trace	Insignificant O_3 emissions
Nitrogen dioxide	NO_2	trace	trace	trace	Insignificant NO_x emissions
Lead	Pb	9.35×10^{-7}	1.19×10^{-8}	1.19×10^{-7}	Medicine Lake data & reference 1
Antimony	Sb	1.52×10^{-6}	1.95×10^{-8}	1.95×10^{-7}	COSO data
Arsenic	As	7.14×10^{-7}	9.15×10^{-9}	9.15×10^{-8}	Medicine Lake data
Beryllium	Be	8.56×10^{-7}	1.09×10^{-8}	1.09×10^{-7}	Medicine Lake data and crustal ratios (reference 2)
Cadmium	Cd	9.35×10^{-7}	1.19×10^{-8}	1.19×10^{-7}	Medicine Lake data and reference 1
Chromium	Cr	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	Medicine Lake data and reference 1
Cobalt	Co	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	Medicine Lake data and reference 1
Manganese	Mn	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	Medicine Lake data and reference 1
Mercury	Hg	1.7×10^{-5}	9×10^{-5}	1×10^{-5}	COSO data (reference 3)
Nickel	Ni	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	Medicine Lake data and reference 1
Selenium	Se	1.3×10^{-6}	1.7×10^{-8}	1.7×10^{-7}	COSO data
Radon-222	^{222}Rn	2.7×10^{-10} Ci/sec*	1.4×10^{-9} Ci/sec*	1.6×10^{-10} Ci/sec*	Medicine Lake data
Boron	B	1.4×10^{-4}	1.9×10^{-6}	1.9×10^{-5}	Medicine Lake data
Ammonia	NH_3	2.71×10^{-3}	1.4×10^{-2}	1.6×10^{-3}	COSO data
Volatile Organic Compounds	VOC	4.44×10^{-7}	2.46×10^{-6}	2.67×10^{-7}	Medicine Lake data
Total Suspended Particles	TSP	3.9×10^{-2}	5×10^{-4}	5×10^{-3}	Assumes all particulate emission are TSP

*Units for ^{222}Rn are Curries per second

Table 2. Highest model predicted hourly impacts and total concentrations at the Newberry Crater Monument boundary for worst-case scenario (Case-4, unabated emissions)

Pollutant	Chemical Symbol or Abbreviation	Highest Hourly Impact	Estimated Mean Baseline Concentration	Total Hourly Concentration (unless otherwise noted)	Standards or AAL
Particles less than 10 μ	PM_{10}	6.19 $\mu g/m^3$	9.45 $\mu g/m^3$	1- hr: 15.64 $\mu g/m^3$ 24-hr: 10.09 $\mu g/m^3$ Annual 9.52 $\mu g/m^3$	150 $\mu g/m^3$ 24-hour[1] 50 $\mu g/m^3$ annual[1]
Sulfur dioxide	SO_2	130.0 $\mu g/m^3$ (0.05 ppm)[2]	0.457 $\mu g/m^3$ (1.75 $\times$ 10^{-4} ppm)	1-hr: 130.46 $\mu g/m^3$ (0.05 ppm) 3-hr: 87 $\mu g/m^3$ (0.03 ppm) 24-hr: 14 $\mu g/m^3$ (.005 ppm) Annual: 1.4 $\mu g/m^3$ (.0005 ppm)	0.5 ppm 3-hour[1] 0.14 ppm 24-hour[1] 0.03 ppm annual[1]
Carbon monoxide	CO	Trace	0.1 ppm	0.1 ppm	35 ppm 1-hour[1] 9 ppm 8-hour[1]
Ozone	O_3	Trace	0.025-0.030 ppm[10]	0.03 ppm	0.12 ppm 1-hour[1]
Nitrogen dioxide	NO_2	Trace	0.001 ppm	0.001 ppm	0.053 ppm annual[1]
Lead	Pb	<0.01 $\mu g/m^3$	1.2 $\times$ 10^{-3} $\mu g/m^3$	<0.01 $\mu g/m^3$	1.5 $\mu g/m^3$ calendar quarter [1]
Antimony	Sb	<0.01 $\mu g/m^3$	<9 $\times$ 10^{-7} $\mu g/m^3$	<0.01 $\mu g/m^3$	1.7 $\mu g/m^3$ AAL[3]
Arsenic	As	<0.01 $\mu g/m^3$	6 $\times$ 10^{-6} $\mu g/m^3$	<0.01 $\mu g/m^3$	0.7 $\mu g/m^3$ AAL[3]

Table 2. (continued)

Pollutant	Chemical Symbol or Abbreviation	Highest Hourly Impact	Estimated Mean Baseline Concentration	Total Hourly Concentration (unless otherwise noted)	Standards or AAL
Beryllium	Be	<0.01 $\mu g/m^3$	6×10^{-6} $\mu g/m^3$	<0.01 $\mu g/m^3$	0.007 $\mu g/m^3$ AAL[3]
Cadmium	Cd	<0.01 $\mu g/m^3$	$<4 \times 10^{-7}$ $\mu g/m^3$	<0.01 $\mu g/m^3$	0.033 $\mu g/m^3$ AAL[3]
Chromium	Cr	<0.01 $\mu g/m^3$	2×10^{-4} $\mu g/m^3$	<0.01 $\mu g/m^3$	1.7 $\mu g/m^3$ AAL[3]
Cobalt	Co	<0.01 $\mu g/m^3$	7×10^{-5} $\mu g/m^3$	<0.01 $\mu g/m^3$	0.17 $\mu g/m^3$ AAL[3]
Manganese	Mn	<0.01 $\mu g/m^3$	2×10^{-3} $\mu g/m^3$	<0.01 $\mu g/m^3$	17 $\mu g/m^3$ AAL[3]
Mercury	Hg	<0.01 $\mu g/m^3$	0.01 $\mu g/m^3$	0.02 $\mu g/m^3$ [7]	0.17 $\mu g/m^3$ AAL[3,4]
Nickel	Ni	<0.01 $\mu g/m^3$	2×10^{-5} $\mu g/m^3$	<0.01 $\mu g/m^3$	3.3 $\mu g/m^3$ AAL[3]
Selenium	Se	<0.01 $\mu g/m^3$	$<4 \times 10^{-6}$ $\mu g/m^3$	<0.01 $\mu g/m^3$	4 $\mu g/m^3$ AAL[3]
Radon-222	^{222}Rn	<0.01 pCi/l	0.13 pCi/l	0.13 pCi/l	4 pCi/l[5]
Boron	B	0.02 $\mu g/m^3$	7×10^{-5} $\mu g/m^3$	0.02 $\mu g/m^3$	33 $\mu g/m^3$ AAL[3,6]

Table 2. (continued)

Pollutant	Chemical Symbol or Abbreviation	Highest Hourly Impact	Estimated Mean Baseline Concentration	Total Hourly Concentration (unless otherwise noted)	Standards or AAL
Ammonia	NH_3	0.43 $\mu g/m^3$ (6×10^{-4} ppm)	0.01 ppm	0.01 ppm	3.1 ppm[8]
Volatile organic compounds	VOC	<0.01 $\mu g/m^3$ (<2 ppb)	200 ppb	202 ppb [11]	NA
Total suspended particles	TSP	6.19 $\mu g/m^3$	13.1 $\mu g/m^3$	1-hr: 19.3 $\mu g/m^3$ 24-hr: 13.7 $\mu g/m^3$ Annual: 13.2 $\mu g/m^3$	150 $\mu g/m^3$ 24-hour[9] 60 $\mu g/m^3$ annual geometric mean[9]

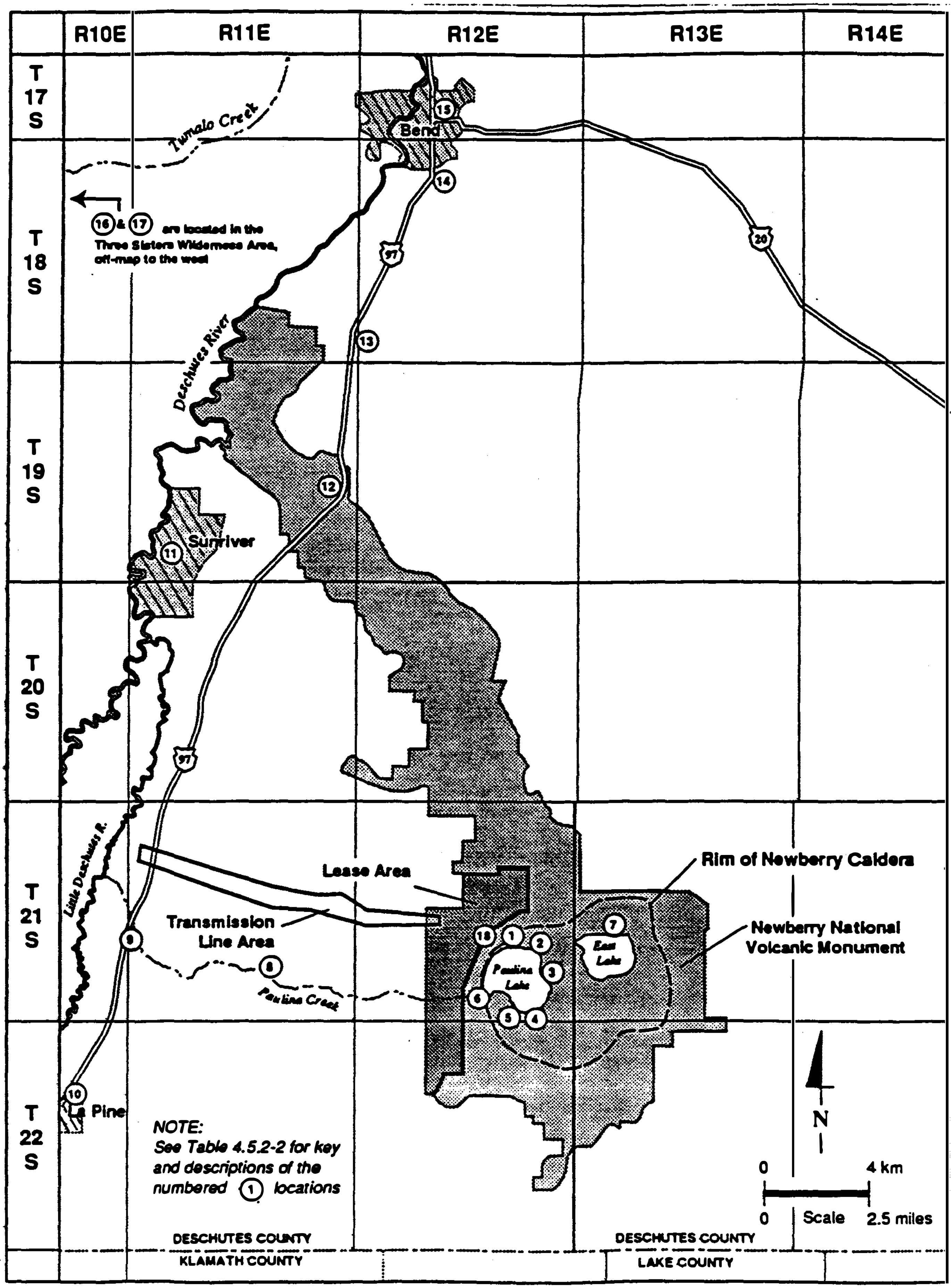
1. Federal standard.
2. Assumed all H_2S converted to SO_2 at exit from stacks and silencers.
3. Acceptable ambient levels (AAL) = Occupational Threshold Limit Values (TLV) for time-weighted averages (TWA) for an 8-hour workday and a 40-hour work week divided by 300, i.e., AAL = $TLV_{TWA}/300$
4. Mercury vapor standard.
5. Federal indoor air standard.
6. Boron oxide.
7. Assumed hourly impact is at maximum, i.e. = 0.01 $\mu g/m^3$
8. Alaska 1-hour standard.
9. Oregon standard.
10. May through October, hourly average, Three Sisters.
11. Assumed hourly impact is at maximum, i.e. = 2 ppb

Table 3. Highest model predicted impacts at class I (Three Sisters) and class II (Newberry Crater Monument) boundaries (Case-4, unabated emissions)

Pollutant	Chemical Symbol or Abbreviation	Highest hourly impact Class-I	Standards for Class I Increments	Highest hourly impact Class-II	Standards for Class II Increments
Total suspended particles	TSP	1-hr: 0.03 $\mu g/m^3$ 24-hr: <0.01 $\mu g/m^3$ Annual: <0.01 $\mu g/m^3$	10 $\mu g/m^3$ Class I, 24-hour 5 $\mu g/m^3$ Class I, annual	1-hr:6.19 $\mu g/m^3$ 24-hr:0.64 $\mu g/m^3$ Annual:0.07 $\mu g/m^3$	37 $\mu g/m^3$ Class II, 24-hour 19 $\mu g/m^3$, Class II, annual
Sulfur dioxide[1]	SO_2	1-hr: 0.60 $\mu g/m^3$ 3-hr: 0.32 $\mu g/m^3$ 24-hr:0.08 $\mu g/m^3$ Annual: <0.01 $\mu g/m^3$	25 $\mu g/m^3$ Class I, 3-hour 5 $\mu g/m^3$ Class I, 24-hour 2 $\mu g/m^3$ Class I, annual	1-hr: 130 $\mu g/m^3$ 3-hr: 87 $\mu g/m^3$ 24-hr: 14 $\mu g/m^3$ Annual: 1.4 $\mu g/m^3$	512 $\mu g/m^3$ Class II, 3-hour 91 $\mu g/m^3$ Class II, 24-hour 20 $\mu g/m^3$ Class II, annual

1. Assumed all H_2S converted to SO_2 at exit from stacks and wellhead silencers.

NEWBERRY GEOTHERMAL PILOT PROJECT Deschutes National Forest, Oregon	Location of Sensitive Receptors Used in Refined Modeling	



APPENDIX F-3
EVALUATION OF POTENTIAL PLUME VISIBILITY IMPACTS AT THE THREE SISTERS WILDERNESS-NEWBERRY GEOTHERMAL PILOT PROJECT

Prepared by Science Applications International Corporation (SAIC) for CEE, November 1993

Evaluation of Potential Plume Visibility Impacts at the Three Sisters Wilderness Newberry Geothermal Pilot Project

Introduction

This is a summary report of the results of our level 2 visibility screening modeling of the Newberry Pilot Project air emission plumes. The nearest class 1 area to the project site is the Three Sisters Wilderness located at approximately 45 km to the west of the site (Figure 1). Visibility in the central Cascade wilderness areas and the Crater Lake National Park have been monitored by the Oregon Department of Environmental Quality (ODEQ) (reference 1 and 2), and regulations have been promulgated for visibility protection of Class 1 areas (OAR 340-20-047 Section 5.2) (reference 3).

Model Description

The VISCREEN model has been designed to predict if the emissions from a given source, under worst-case meteorological dispersion conditions, will be perceivable by an observer stationed at the nearest point on the boundary of a class 1 area. Emissions considered by VISCREEN are particles, nitrogen oxides (NO_x), primary nitrogen dioxide (NO_2), soot and primary sulfate ($SO_4^=$). The model considers two criteria for the plume to be visible. The first is the color difference (delta E parameter) between the plume and the background (sky or terrain). The second is the contrast (green, red and blue contrast parameters) between the plume and the background (sky or terrain). The VISCREEN numeric values for these two criteria are 2.0 for delta-E and 0.05 for the green contrast. It is assumed that if any of these criteria are exceeded, the plume will be perceivable.

The model assumes a specific plume geometry considered to cause the worst-case visibility impact. The plume is assumed to cover, horizontally, a 22.5° sector centered at the source with its edge being adjacent to the observer. The plume centerline offset angle from the source-observer line will then be 11.25° (see Figure 1). Calculations are performed for up to 37 observer lines of sight at a 5° increment, covering an azimuth of 0° to 160° starting from the source. Two different sun angles for both sky and terrain background are considered in the calculations. The sun angles used are 10° (sun located in front of observer behind the plume) and 140° (sun located behind the observer). The model output results for these two angles are labelled "forward" and "backward", respectively.

The model allows for two levels of screening. In level 1 screening the default worst-case dispersion conditions (stability class F=6 and wind speed 1 m/s) are used. The level 2 screening involves the frequency analysis of real meteorological data that can result in the choice of a less conservative dispersion condition. The model assumes (in both screening levels) that the worst-case dispersion condition will persist up to 12 hours.

The model provides tabulated results and determines model criteria exceedances. The tabulated results are automatically converted into graphs by using a spreadsheet software.

Level 2 Screening

Our level 1 visibility screening analysis showed that under VISCREEN level 1 assumptions, the plume may be perceivable. Therefore a more refined approach (VISCREEN level 2 screening) was used. We summarize herein the results of our level 2 analysis.

Model Input Data

Four plant operational scenarios are considered:

Case 1. Plant normal operation, including emissions from cooling tower and sulferox vessel (2 sources).

Case 2. Normal operation plus two wells venting into the atmosphere (4 sources). The two wells closest to the plant were selected.

Case 3. Drilling phase: two wells venting into the atmosphere (2 sources).

Case 4. Plant upset condition with six wells venting through the plant silencer and two wells venting directly into the atmosphere (3 sources). This case also has three sub-scenarios:

Full emission rate starting at time 0 hr (1-hr duration)
50% emission rate starting at time 1 hr (5-hr duration)
25% emission rate starting at time 6 hr

The model input data for the project four operational scenarios are shown in Table 1.

The particulate values in Table 1 were calculated from the total dissolved solids contained in the water droplets escaping from the cooling tower, sulferox vessel, plant and wellhead silencers.

The model only considers primary sulfate because, as explained in the VISCREEN manual (reference 4), "over short distances (<200 km) and stable plume transport conditions typical of plume visual impact screening, secondary sulfate ($SO_4^=$) is not formed to a significant degree in plumes". In the present analysis, however, we decided to be conservative and we input the secondary sulfate data into the model, since, if H_2S is converted to SO_2 which is in turn converted to $SO_4^=$, the secondary sulfate thus formed would be the major contributor to visibility degradation.

As Table 1 shows, two emission rates are calculated for secondary $SO_4^=$ based on 100% and 11.8% H_2S conversion rates. VISCREEN assumes that the worst-case dispersion condition persists no longer than 12 hours. As described later in this report, based on conservative assumptions, a maximum of 11.8% of the initial H_2S emissions will theoretically convert to sulfates within 12 hours. Therefore, in our first modeling attempt we will use the secondary sulfate emission rates calculated with the assumption that 11.8% of the H_2S emissions will convert to sulfate (Table 1 last column).

From the ODEQ report entitled "Visibility in Oregon's Wilderness and National Park Lands- 1990 Program Report" (reference 2) it was found that the Three Sisters Wilderness area visibility range in 1990 was from 82 km (10th percentile), to 248 km (90th percentile). The 90th percentile value of 248 km was selected as the background visibility range for the modeling. A VISCREEN manual chart gives a value of 110 km for the project area background visibility range (reference 4).

All model default values other than stability class and wind speed were retained for our Level 2 modeling. These two parameters were found by the meteorological data frequency analysis described below.

Frequency Analysis of the Meteorological Data

Based on the procedures described in the VISCREEN user manual, the approximately one year meteorological data, which was collected at the Newberry Crater site, was analyzed for the frequencies of dispersion conditions. Frequencies were found for four daily 6-hour periods, as specified by the model level 2 procedures. A Fortran program was specifically written for this analysis. The appendix includes output tables of this program. The wind directions ranging from 78.7° to 168.8° which encompass the entire Three Sister Wilderness area were selected. A summary table was prepared listing the frequencies (in percent) of occurrences of wind speeds and stability classes (Appendix A).

Based on the results of the analysis, the worst dispersion condition corresponding to 1 percent total frequency is the combination E,2 (stability class E, wind speed 2 m/s). Therefore, our level 2 analysis will be based on the stability class E and the wind speed of 2 m/s.

VISCREEN Model Results

The VISCREEN model graphic results of our first modeling attempt are shown in Figure 2 through 7. These results are based on the assumption that 11.8% of the initial H_2S emissions are converted to $SO_4^=$ within 12 hours of worst-case dispersion condition persistence and based on an H_2S half-life of 4 days. For each operational scenario there are two plots showing the delta E (perceptibility) and the green contrast values at observer lines of sight ranging from 0° to 160° azimuth. Larger azimuth values correspond to plume greater distances from the source. Each plot shows four curves: plume against sky (forward and backward sun angles), plume against terrain (forward and backward). The letters **F** and B in the plot legends stand for forward and backward.

Discussion

The level 1 modeling effort has shown that the emission of particles and the primary sulfates will not cause the VISCREEN model visibility criteria to be exceeded. The following discussion is therefore limited to the secondary sulfates theoretically generated by H_2S.

Based on reviewed literature, the average lifetime of H_2S before it is converted to SO_2 is conservatively estimated as 18 hours (reference 5), and 2 days (reference 6). On the other hand, the average lifetime of SO_2 before it is converted to $SO_4^=$ is estimated as four days (reference 6). Based on these numbers and the fact that the conversion of H_2S to $SO_4^=$ is a consecutive reaction i.e. H_2S to SO_2 followed by SO_2 to $SO_4^=$, the average lifetime of H_2S before it is converted to $SO_4^=$ is greater than four days. The half-life ($t_{1/2}$) is related to average life (t) by the following formula:

$$t_{1/2} = 0.693\ t$$

Based on this equation and a 4-day average life, the half-life of H_2S to be converted to $SO_4^=$ can be conservatively calculated as (0.693)(24 hours/day)(4 days)= 66.5 hours.

Table 1. Input data for the VISCREEN model Level-2 analysis.

Emission Source Name	Particulate Matter (g/s)			Primary Sulfate (g/s)	Primary NOx (g/s)	Secondary Sulfate (g/s)					
						100% conversion			11.8% conversion		
Case 1: Normal Operation											
Cooling Tower	0.005			Trace	Trace	0.045					
Sulferox Vessel	Trace			Trace	Trace	0.013					
Total	0.005					0.058			0.007		
Case 2: Normal Operation & Two Wells Venting											
Cooling Tower	0.005			Trace	Trace	0.045					
Sulferox Vessel	Trace			Trace	Trace	0.013					
2 Wellhead Silencers	0.078			Trace	Trace	1.982					
Total	0.083					2.040			0.241		
Case 3: Two Wells Venting											
2 Wellhead Silencers	0.078			Trace	Trace	1.982			0.234		
Case 4: Plant Upset Condition (8 Wells Venting)											
	0-hr	1-hr	6-hr			0-hr	1-hr	6-hr	0-hr	1-hr	6-hr
Plant Silencer (6 wells)	0.234	0.117	0.059	Trace	Trace	7.940	3.970	1.985			
2 Wellhead Silencers	0.078	0.039	0.020	Trace	Trace	1.982	0.991	0.495			
Total	0.312	0.156	0.079			9.922	4.961	2.480	1.171	0.585	0.293

Based on the $t_{1/2}$=66.5 hours, and an exponential half-life trend, we can calculate the rate of H_2S conversion to sulfate as follows:

Hours	% converted	Hours	% converted
0	0.0		
1	1.0	7	7.0
2	2.1	8	8.0
3	3.1	9	9.0
4	4.1	10	9.9
5	5.1	11	10.8
6	6.1	12	11.8

Note that the model assumes the worst-case dispersion condition will persist no longer than 12 hours. In the following discussion and wherever necessary, based on the above conversion percentages, we will rerun the model iteratively to obtain more and more realistic predictions.

The modeling results are discussed below for each operational scenario.

Case 1: Normal Operation.

As Figure 2 shows, for case 1 there are no exceedances of the model criteria (delta E=2.0, green contrast=0.05 absolute value) for all backgrounds (sky, terrain) and sun angles (backward, forward).

Case 2: Normal Operation and Two Wells Venting.

As shown in Figure 3, the model visibility criteria are only exceeded at viewing angles (azimuth) less than 4.0° which corresponds to a distance of 10.8 km. Note that at this distance the plume is outside the Class 1 area.

Under the selected worst-case dispersion condition (stability class=E, wind speed=2 m/s) the wind speed actually varies between 1 m/s and 2 m/s with an average of 1.5 m/s (see tables in Appendix A). It takes the plume 2.0 hours to travel the distance of 10.8 km. Based on the above conversion percentages, within 2.0 hours a maximum of 2.1% of H_2S is expected to be converted to $SO_4^=$. Rerunning the model for a 2.1% smaller emission rate of (2.04 g/s)(2.1%/100) = 0.043 g/s will show no model criteria exceedance beyond 1 km from the source. The iterative modeling results are shown below.

Modeling Attempt	Emission Rate (g/s)	Exceedance up to (km)	Travel Time (hrs)	% H_2S Converted	New Emission Rate (g/s)
1	0.241	10.8	2.0	2.1	0.043
2	0.043	<1.0			

Case 3: Two Wells Venting.

The overall emission rate in this scenario is smaller than for the previous case. Therefore no model criteria exceedance can be expected.

Case 4: Plant Upset Condition.

The model was run for the three following sub-scenarios.

0-hr: Within the first hour of the start of upset condition when wells are venting at full unabated rates.

As Figure 5 shows, based on 11.8% H_2S conversion, the model criteria are exceeded within azimuth angles smaller than 80.0° which corresponds to a distance of 42.8 km (outside the Class 1 area). By using the iterative modeling as per Case 2, we gradually approach a smaller and more realistic value for the distance at which model criteria are exceeded. The iterative modeling results are summarized below:

Modeling Attempt	Emission Rate (g/s)	Exceedance up to (km)	Travel Time (hrs)	% H_2S Converted	New Emission Rate (g/s)
1	1.171	42.8	8.0	8.0	0.794
2	0.794	32.2	6.0	6.1	0.605
3	0.605	25.5	4.7	4.8	0.476
4	0.476	19.5	3.6	3.7	0.367
5	0.367	14.0	2.6	2.7	0.268
6	0.268	12.6	2.3	2.4	0.238
7	0.238	12.3	2.3	2.4	

It is found that the exceedance of model criteria occurs within a distance of 12.3 km.

1-hr: Between the first hour and the 6th hour after the start of upset condition when emissions are reduced to 50% of the initial unabated rates.

As Figure 6 shows, based on 11.8% H_2S conversion, the model criteria are exceeded within an azimuth of 10.8° which corresponds to a distance of 21.5 km. Iterative modeling will show the following results.

Modeling Attempt	Emission Rate (g/s)	Exceedance up to (km)	Travel Time (hrs)	% H_2S Converted	New Emission Rate (g/s)
1	0.585	21.5	4.0	4.1	0.202
2	0.202	10.6	2.0	2.1	0.102
3	0.102	6.9	1.3	1.3	0.064
4	0.064	3.9	0.7	0.7	0.036
5	0.036	<1.0			

It is found that the exceedance of model criteria will only occur within a distance of 1 km from the source.

6-hr: After 6-hours of the start of the upset condition when the wells are vented at only 25% of the original unabated rate.

The emission rates in this scenario are 50% smaller than in the previous scenario, therefore the real exceedance distance will be smaller than 1 km.

Conclusion

It is concluded that no visibility impact would occur within the Three Sisters Class 1 area.

The worst-case scenario of case 4 (plant upset condition with unabated emission rates) would, however, cause visibility impact outside the Three Sisters Class 1 area, within a distance of 12.3 km from the source. Based on the following observations such exceedance is highly infrequent.

The probability of the occurrence of the upset condition is estimated to be approximately 24 events in one year based on actual observation in similar plants. The probability of a 1-hr emission (assumed to cause a visibility impact) at each plant upset event is ((24 x 1 hrs)/(365 days x 24 hrs)) x 100% = 0.27%. The probability of occurrence of the worst-case dispersion condition for level 2 screening (as discussed above) is 1%. The probability of the 1-hr upset condition occurring at the same time as the worst-case dispersion condition is simply the product of the two previous probabilities: 0.27% x 1% = 0.003% which is extremely low.

References

1. Oregon Department of Environmental Quality, Visibility in Oregon's Wilderness and National Park Lands (1982-1984), 1985.

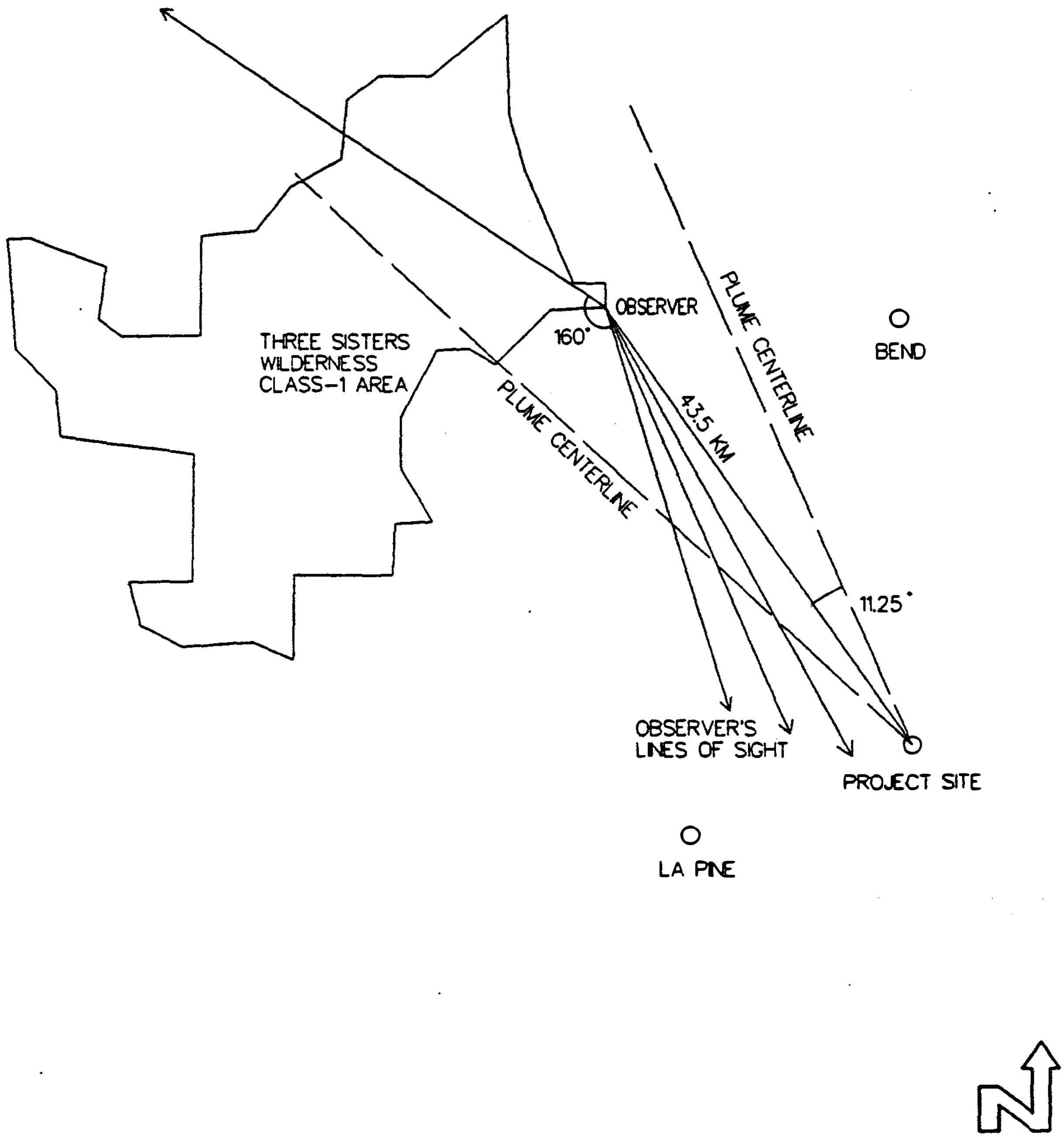
2. Oregon Department of Environmental Quality, Visibility in Oregon's Wilderness and National Park Lands- 1990 Program Report, 1991.

3. Oregon Department of Environmental Quality, Visibility Protection Plan for Class I Areas (OAR 340-20-047, Section 5.2)- Draft of February 6, 1992.

4. USEPA, Workbook for Plume Visual Impact Screening and Analysis, 1988.

5. Thompson, Ray, Behavior of Hydrogen Sulfide in the Atmosphere and Its Effects on Vegetation, in Geothermal Environmental Seminar-'76, 1976.

6. Stern, Arthur C., et al, Fundamental of Air Pollution, Academic Press, 1973.

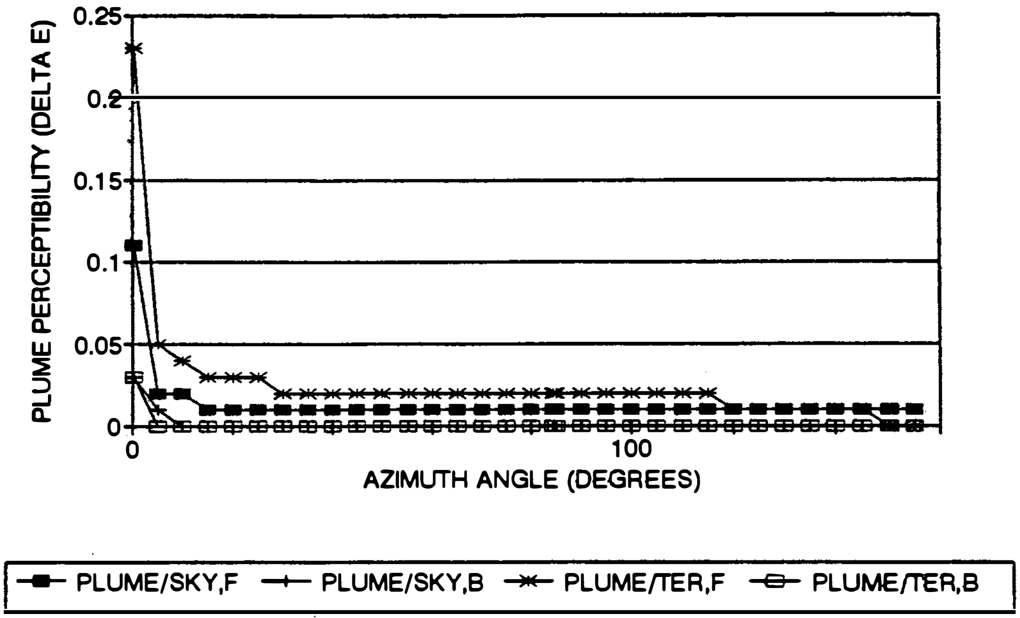


SAIC Science Applications International Corporation An Employee-Owned Company	Figure 1. VISCREEN Level-2 geometry setting	Project No: 05-2730-100
		Date: Sept. 20, 1993
	Newberry Pilot Project Newberry, Oregon	Scale: N/A
		Drawn by: JH / Checked by: JH

CEE2.GCD

PLUME PERCEPTIBILITY VS. AZIMUTH

Case 1: Normal operation (SO4=.007 g/s)



GREEN CONTRAST VS. AZIMUTH

Case 1: Normal operation (SO4=.007 g/s)

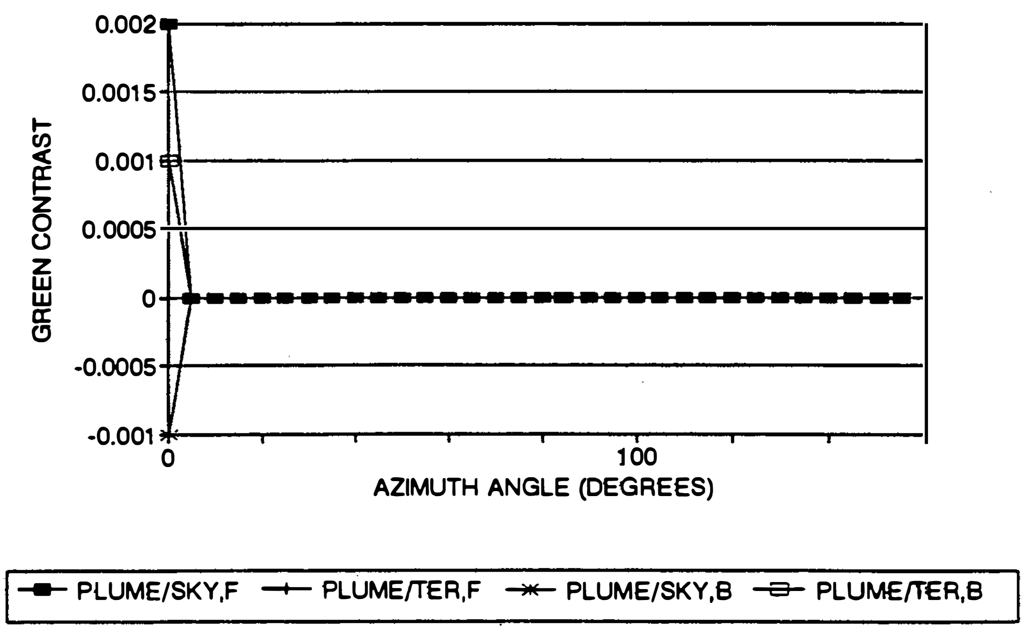
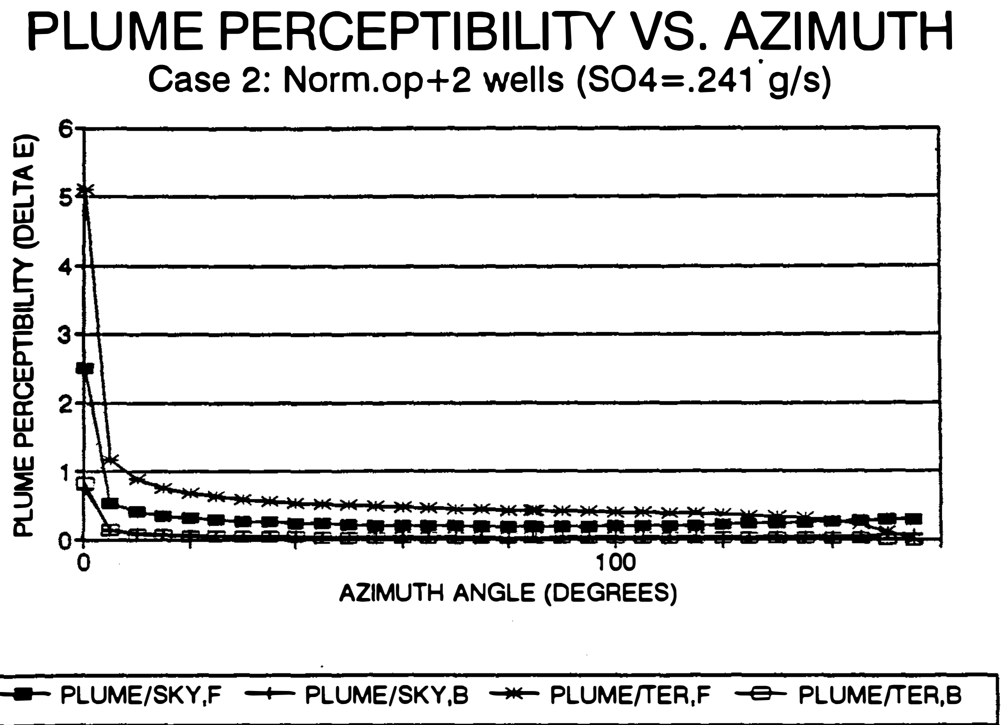


Figure 2.


PLUME PERCEPTIBILITY VS. AZIMUTH
Case 2: Norm.op+2 wells (SO4=.241 g/s)
PLUME PERCEPTIBILITY (DELTA E)
0
1
2
3
4
5
6
0
100
AZIMUTH ANGLE (DEGREES)
PLUME/SKY,F
PLUME/SKY,B
PLUME/TER,F
PLUME/TER,B

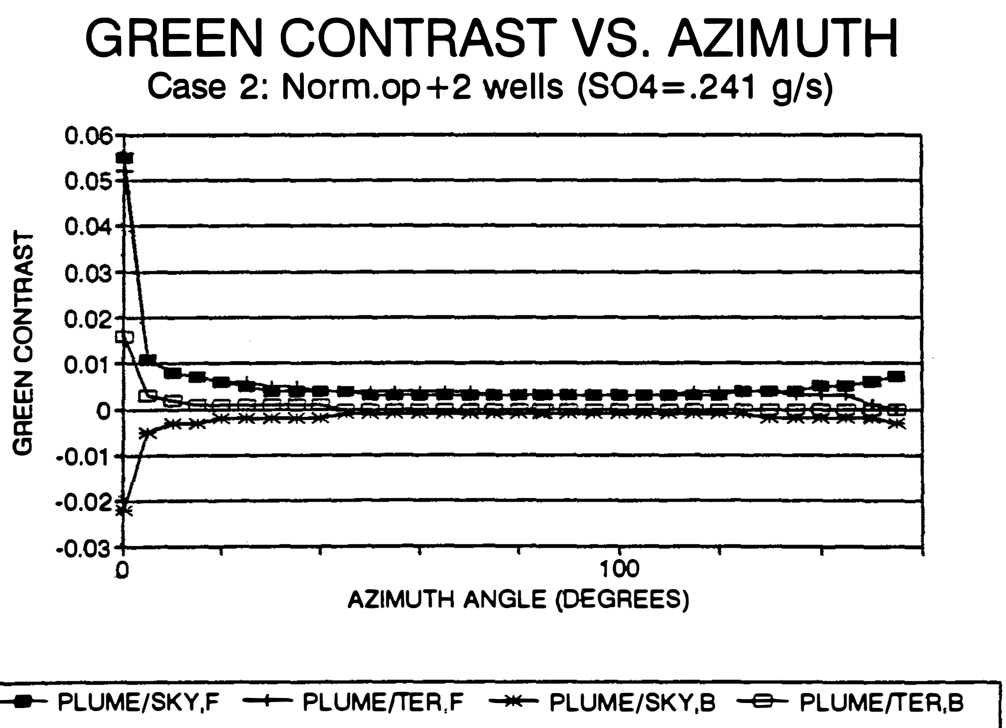
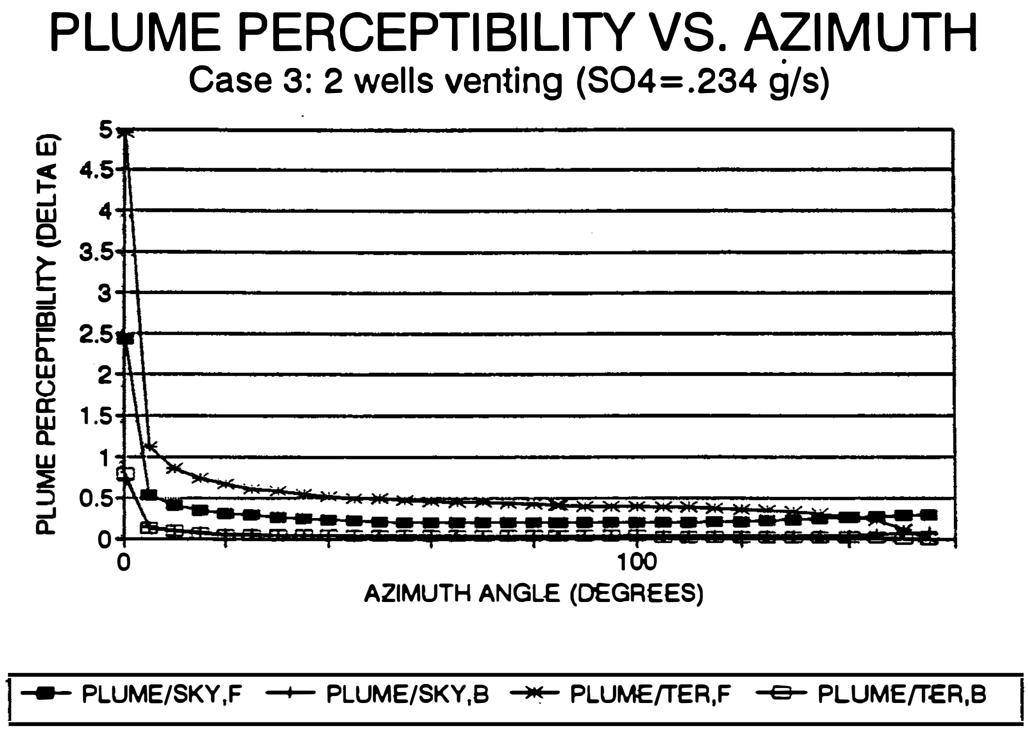

GREEN CONTRAST VS. AZIMUTH
Case 2: Norm.op+2 wells (SO4=.241 g/s)
GREEN CONTRAST
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
100
AZIMUTH ANGLE (DEGREES)
PLUME/SKY,F
PLUME/TER,F
PLUME/SKY,B
PLUME/TER,B

Figure 3.


PLUME PERCEPTIBILITY VS. AZIMUTH
Case 3: 2 wells venting (SO4=.234 g/s)
PLUME PERCEPTIBILITY (DELTA E)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
100
AZIMUTH ANGLE (DEGREES)
PLUME/SKY,F
PLUME/SKY,B
PLUME/TER,F
PLUME/TER,B

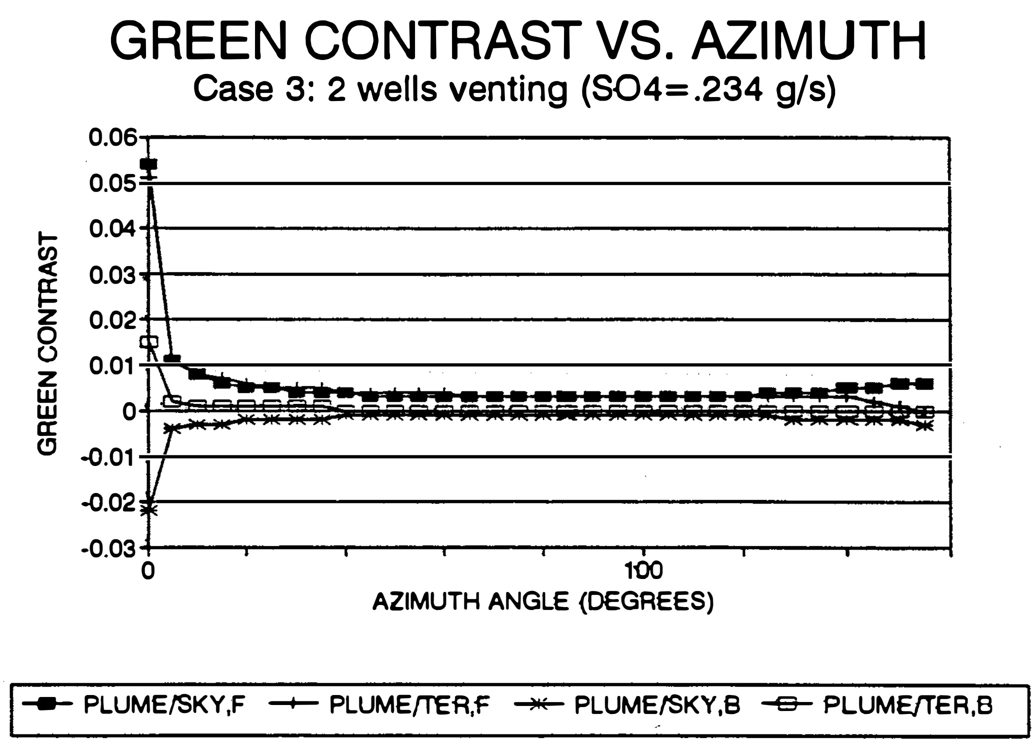
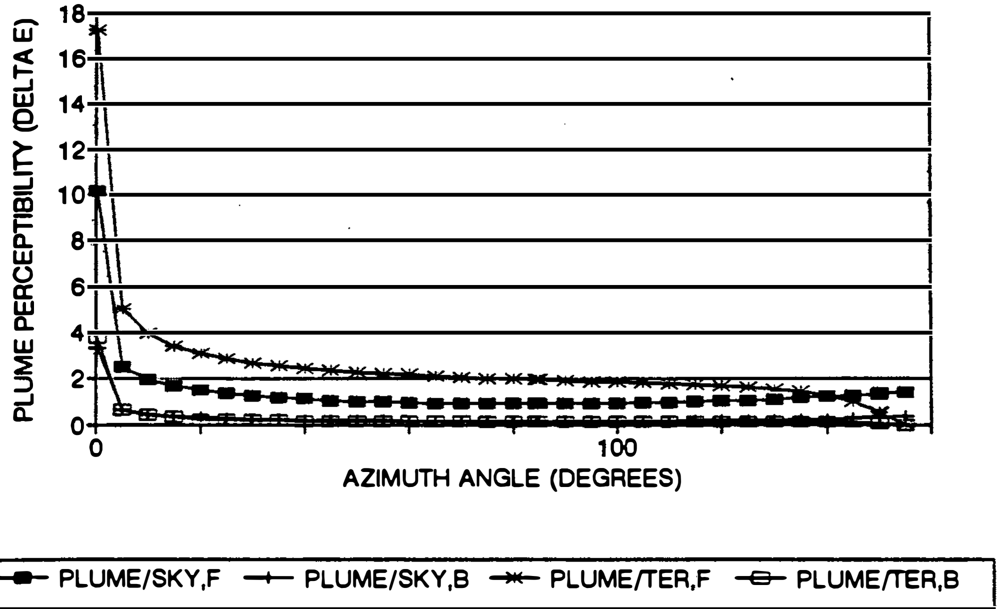

GREEN CONTRAST VS. AZIMUTH
Case 3: 2 wells venting (SO4=.234 g/s)
GREEN CONTRAST
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
100
AZIMUTH ANGLE (DEGREES)
PLUME/SKY,F
PLUME/TER,F
PLUME/SKY,B
PLUME/TER,B

Figure 4.

PLUME PERCEPTIBILITY VS. AZIMUTH

Case 4: Upset condition.0hr (SO4=1.171)



GREEN CONTRAST VS. AZIMUTH

Case 4: Upset condition.0hr (SO4=1.171)

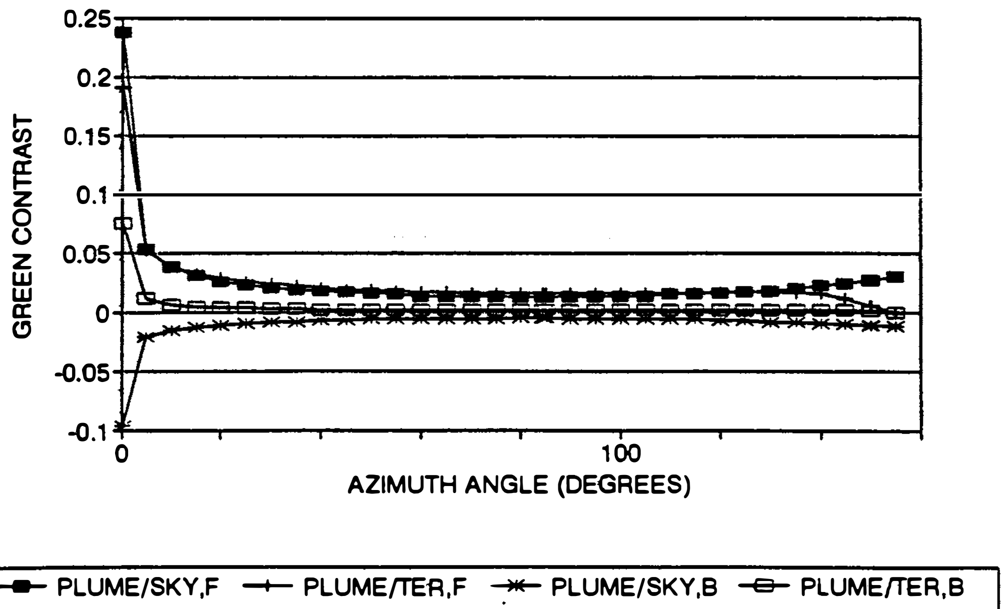
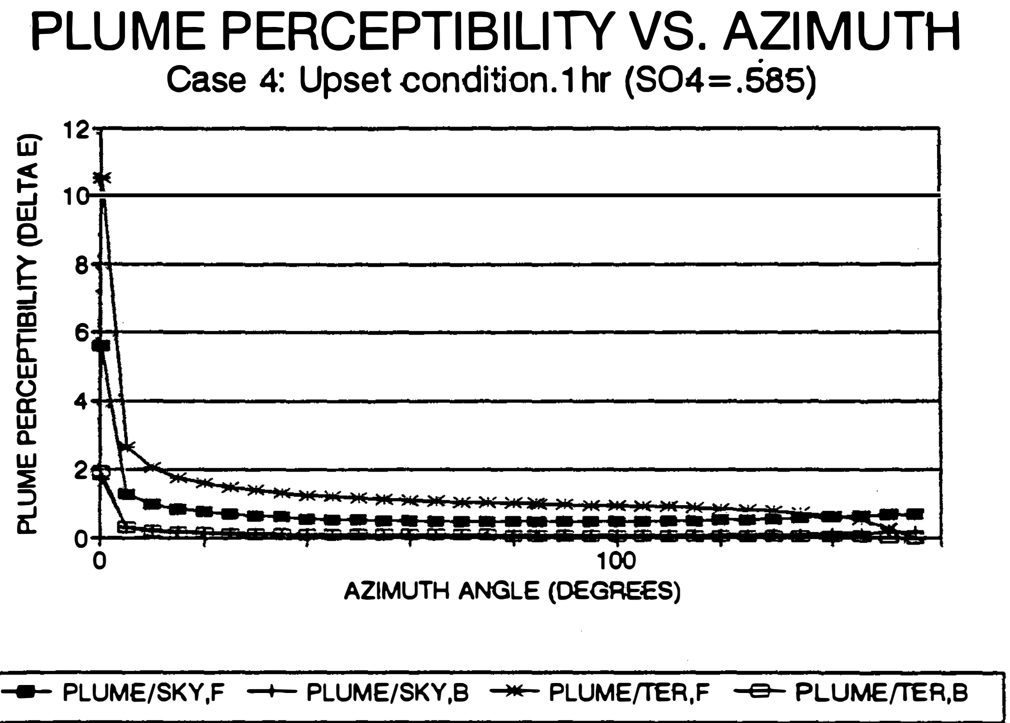
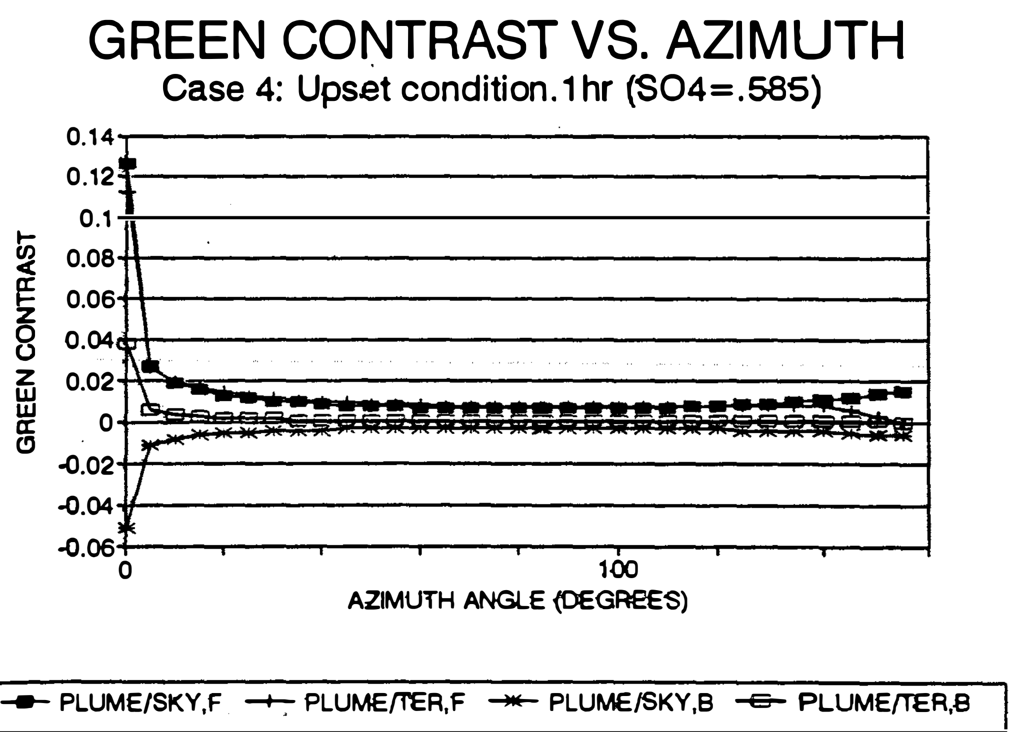


Figure 5.



PLUME PERCEPTIBILITY VS. AZIMUTH
Case 4: Upset condition.1hr (SO4=.585)
PLUME PERCEPTIBILITY (DELTA E)
12
10
8
6
4
2
0
0
100
AZIMUTH ANGLE (DEGREES)
PLUME/SKY,F
PLUME/SKY,B
PLUME/TER,F
PLUME/TER,B

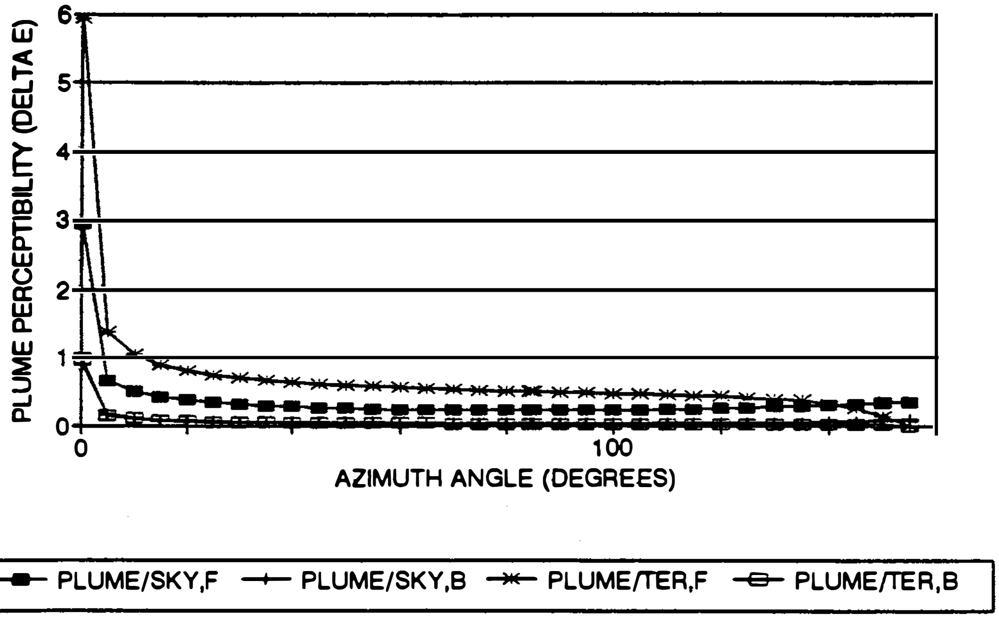


GREEN CONTRAST VS. AZIMUTH
Case 4: Upset condition.1hr (SO4=.585)
GREEN CONTRAST
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
100
AZIMUTH ANGLE (DEGREES)
PLUME/SKY,F
PLUME/TER,F
PLUME/SKY,B
PLUME/TER,B

Figure 6.

PLUME PERCEPTIBILITY VS. AZIMUTH

Case 4: Upset condition.6hr (SO4=.293)



GREEN CONTRAST VS. AZIMUTH

Case 4: Upset condition.6hr (SO4=.293)

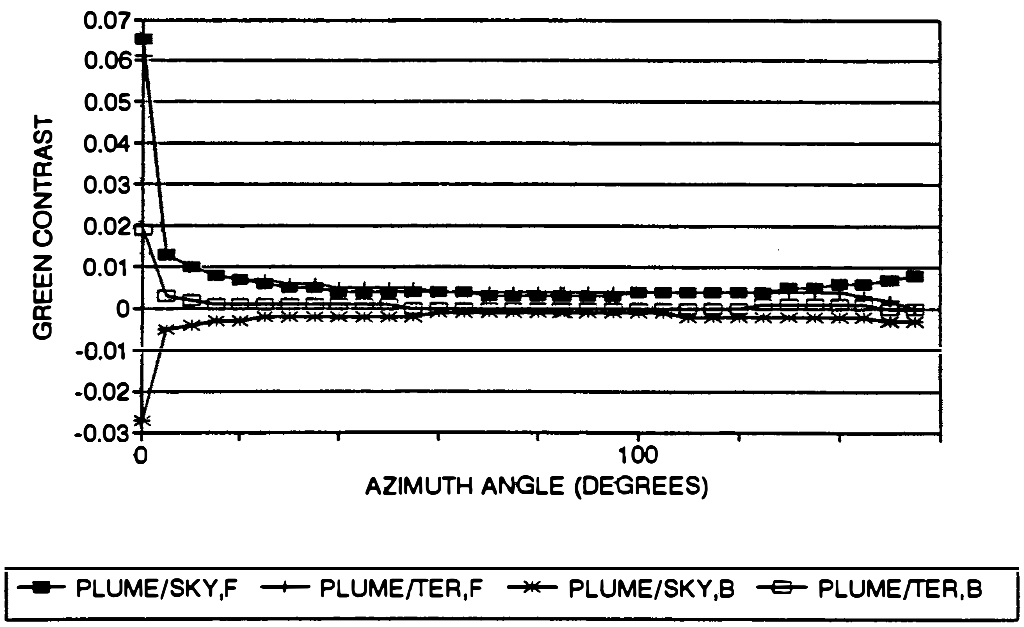


Figure 7

Meteorological data frequency analysis summary table

Stability /Wind Speed	σ_z u (m^2/s)	Transport Time (hrs)	Frequency (%) for Time of Day (hr)				Frequency & Cumulative Frequency (%)	
			0-6	6-12	12-18	18-24	f	cf
F,1	76	24*	.0	.0	.0	.0	.0	.0
E,1	150	24*	.0	.0	.0	.0	.0	.0
F,2	152	8	.0	.0	.0	.0	.0	.0
F,3	228	5	.1	.0	.0	.1	.1	.1
E,2	300	8	.9	.2	.0	.9	.9	1.0
F,4	304	3	.0	.0	.0	.0	.0	
D,1	310	24*	.0	.0	.0	.0	.0	
F,5	380	3	.0	.0	.0	.0	.0	
E,3	450	5	1.4	.4	.0	.9	1.4	

(*) Transport time longer than 12 hours (frequency not to be considered)
σ_z = Pasquill-Gifford vertical diffusion coefficient (m)
u = average class wind velocity in m/s (0.5 for class 0-1, etc.)

APPENDIX F-4
HYDROGEN SULFIDE IMPACT DUE TO PROPOSED GEOTHERMAL DEVELOPMENT

Prepared by Science Applications International Corporation (SAIC) for CEE, October 1993

Hydrogen Sulfide Impact Due to the Proposed Geothermal Development

Hydrogen sulfide (H_2S) impact has historically been the single major air quality issue associated with the geothermal industry. This is due, in a large part, to the low olfactory threshold of H_2S. There is no federal air quality standard (nor Oregon standard) for H_2S. The California state hourly standard of 30 ppb or 41.7 μ/m^3 has been used for impact evaluation in situations when there is no applicable state or local standard and has been used in that context for the Newberry Crater site. Hourly H_2S levels were predicted for the proposed facility using two U.S. Environmental Protection Agency (EPA) guideline dispersion models, COMPLEX-1 and ISCST-2.

Prior to conducting the modeling exercise an estimate of resource chemistry (namely H_2S concentration) was required since no production wells have yet been drilled at the site. An evaluation of western geothermal wells that are considered to represent the range of H_2S emissions that would reasonably be encountered at Newberry Crater are shown in Table 1. The data for Medicine Lake California is in the middle of the H_2S emission range. Medicine Lake is also in a similar geological setting as Newberry Crater. Due to these two reasons the data for Medicine Lake was used in the modeling to represent future Newberry Crater wells.

Four activity scenarios were modeled (Tables 2 and 3). These were (1) the normal operation of a 30 MW plant, (2) the normal operation of a 30 MW plant while two wells are venting (this would occur only during the summer and during the development phase of the well field), (3) two wells venting prior to plant construction again only during the summer, and (4) plant upset conditions while two wells are venting. The last scenario represents the absolute worst conditions with six wells to the plant venting unabated while two wells in the well field were being vented. CE Exploration developed an air quality response plan for upset conditions for another similar geothermal facility in California and an analogous plan would be submitted for the Newberry facility. The fundamentals of the response plan would include the following: (1) after one hour the wells would be shut back 50%, (2) after 6 hours they would be shut back another 50%, and (3) if after the second reduction air quality standards were being violated, the wells would be shut back to the point that air quality standards were met. To simulate the various stages of the upset control conditions, modeling was conducted at full emission rates (0 hr), at 50% of full emission rates (1 hr), and at 25% of full emission rates (6 hrs).

Meteorological data was collected from September 26, 1992 to August 13, 1993 near the proposed plant site for use with the dispersion models. Wind speed, wind direction, and sigma-theta (a measure of atmospheric stability) data were collected with sensors on a ten- meter tower. Temperature and relative humidity were also measured at the site. Wind roses for the data are contained in Appendix A. Interestingly, the wind data revealed a diurnal pattern in wind direction (Figure 1-4) with east and southeast wind occurring most frequently at night and winds from the west most frequently occurring during the day.

Sensitive receptors in the Newberry Crater airshed were selected (Table 4) and the impacts at the receptors were modeled under each scenario of emissions. The highest hourly H_2S values at each receptor under each emission scenario are shown in Tables 5 and 6. Standard computer output data for the COMPLEX-1 and ISCST-2 model are provided in Appendices B and C, respectively. The COMPLEX-1 model is used for receptors at higher elevations than the emission points and the ISCST-2 is used for receptors at lower elevations. Zero values in the table are in reality values less than 0.1 μ/m^3. As can be seen in reviewing the modeling results in Tables 5 and 6, only under upset conditions with no abatement and at the closest sensitive receptor is the California standard exceeded. It needs to be emphasized that the data in the tables are for highest hourly values which occur under infrequent meteorological conditions. For example, an analysis of the frequency of meteorological conditions that would cause the California standard to be exceeded at the nearest sensitive receptor under unabated upset conditions shows that these conditions will occur about 5% of the time. If the probability of a plant upset occurring is viewed as being independent of the occurrence of meteorological conditions that would produce a violation of the air quality standard, the combined probability of the two events occurring simultaneously is simply a product of their independent probability of occurrences. The operational records for a CE Exploration facility located in California that is similar to the facility planned for Newberry Crater showed that there were 12 upset events in a six-month period. Since only the first unabated hour of the upset would cause the California standard to be exceeded at the nearest receptor, the probability of occurrence of the unabated upset condition is (12 hrs/(182 days × 24 hrs)) × 100% = 0.27%. The probability of the unabated upset condition occurring during the same time as the meteorological conditions which would cause the California standard to be exceeded at the nearest sensitive receptor is 0.05 × 0.0027 × 100% = 0.014%. This value is a conservative estimate, because a number of the upset events in the California records were less than one hour in duration (those that were longer than one hour still only have 1 hour if unabated upset conditions because the stepwise reduction in emissions as specified in the control plan starts at one hour). Also, the occurrence of an upset is not strictly statistically independent of meteorological conditions. Severe meteorological conditions such as wind storms, ice storms, thunderstorms, and wintertime storms causing high snowfall could cause the plant to shut down, producing an "upset." Generally, severe meteorological events such as these produce good atmospheric dispersion conditions. Modeling under the most frequent daytime and nighttime sets of wind speed, wind direction, and stability class showed that under the most probable sets of conditions, the H_2S concentration at all receptors during the unabated upset condition is less than 0.1 μ/m^3 (Table 7).

Table 1. Example Unabated H_2S Emissions of Typical Western Geothermal Wells During Testing[1]

Location	H_2S (lb/hr)	H_2S (kg/hr)
Desert Peak, NV	1.30	0.59
Medicine Lake, CA	2.79	1.27
Coso, CA	3.46	1.57

1. 75% of maximum well capacity, assuming 400,000 lb/hr well production.

Table 2. Input data used for refined modeling.

Emission Source Name	Stack Height (ft)	Stack Diameter (ft)	Gas Exit Velocity (ft/s)	Gas Exit Temp. (°F)	H_2S Emission Rate (lb/hr)		
Case 1: Normal Operation							
Cooling Tower	50	58.20	57.0	80			0.13
Sulferox Vessel	60	1.17	37.0	110			0.04
Case 2: Normal Operation & Two Wells Venting							
Cooling Tower	50	58.20	57.0	80			0.13
Sulferox Vessel	60	1.17	37.0	110			0.04
Wellhead Silencer 1	24	12.00	30.0	297			2.79
Wellhead Silencer 2	24	12.00	30.0	297			2.79
Case 3: Two Wells Venting (Drilling Phase)							
Wellhead Silencer 1	24	12.00	30.0	297			2.79
Wellhead Silencer 2	24	12.00	30.0	297			2.79
Case 4: Plant Upset Condition							
					0 hr	1 hr	6 hr
Plant Silencer	28	12.00	30.0	297	22.32	11.16	5.58
Wellhead Silencer 1	24	12.00	30.0	297	2.79	1.40	0.70
Wellhead Silencer 2	24	12.00	30.0	297	2.79	1.40	0.70

Table 3. Operation and drilling phase scenarios used in refined modeling.

Scenario	Description	Sub-Scenarios
Case-1	Plant normal operation, including emissions from cooling tower and sulferox vessel (2 sources)	
Case-2	Normal operation plus two wells venting into the atmosphere (4 sources). The two wells closest to the plant were selected.	
Case-3	Drilling phase; two wells venting into the atmosphere (2 sources). The two wells closest to the plant were selected.	
Case-4	Plant upset condition with six wells venting through the plant silencer and two wells venting directly into the atmosphere (3 sources).	Three emission rates: 1. Full rate at 0 hr. 2. 50% rate at 1 hr. 3. 25% rate at 6 hr.

Table 4. Listing of sensitive receptors used in refined modeling.

No.	Receptor Name	Description	Distance (m)	Township/ Range	Section
1	CAMP1	North Cove Campground, north of Paulina Lake	3,000	21S/12E	26
2	CAMP2	Warm Springs Campground, northeast of Paulina Lake	4,200	21S/12E	25
3	CAMP3	Little Crater Campground, southeast of Paulina Lake	5,200	21S/12E	36
4	HOUSES	Summer houses, southeast of Paulina Lake	5,300	21S/12E	36
5	CAMP4	Camp/houses at south end of Paulina Lake	4,800	21S/12E	35
6	LODGE	Paulina Lodge, west end of Paulina Lake	3,100	21S/12E	34
7	BE-NEST	Bald Eagle nesting area, north of East Lake	7,000	21S/13E	19
8	MCKAY-CROSS	McKay Crossing Campground, 5 miles west of Paulina Lake	6,800	21S/11E	19
9	RESIDENCE	Residential area at intersection of 97 and 21	12,600	21S/11E	35
10	LAPINE	LaPine, Highways 97 and 22	18,000	22S/10E	14
11	SUNRIVER	Sunriver residential area, 11 miles north of LaPine	15,000	20S/11E	19
12	LAVA-VISIT	Lava Lands Visitors Center, 13 miles north of Paulina Lake	19,500	19S/11E	24
13	HD-MUSEUM	High Desert Museum, 6 miles south of Bend	25,500	18S/12E	31
14	BEND-1	Nearest Bend subdivision, 3.5 miles south of Bend	30,000	18S/12E	18
15	BEND-DT	Downtown Bend, Highways 97 and 20	36,000	17S/12E	33
16	CLASSI-N	Nearest Three Sisters Wilderness Area boundary, 15 miles west of Bend	43,500	17S/09E	36
17	CLASSI-S	Second-nearest Three Sisters Wilderness Area boundary, 21 miles northwest of LaPine	44,500	20S/08E	12
18	MONUMENT	Nearest Newberry Crater National Volcanic Monument boundary, west of Paulina Lake	1,700	21S/12E	22

Table 5. Complex and simple terrain refined modeling predicted highest hourly H_2S concentrations ($\mu g/m^3$), for cases 1, 2 and 3.

No.	Receptor name	Receptor Dist. (m)	Receptor Elev. (ft)	Case 1. Normal Operation (N.O.)	Case 2. N.O. plus 2 Wells Venting	Case 3. 2 Wells Venting (Drilling Phase)
	Complex Terrain (COMPLEX-1 MODEL):					
1	CAMP1	3,000	6,380	0.1	3.5	3.4
2	CAMP2	4,200	6,340	0.0	2.9	2.9
3	CAMP3	5,200	6,300	0.0	1.9	1.9
4	HOUSES	5,300	6,300	0.0	2.0	2.0
5	CAMP4	4,800	6,360	0.1	3.0	3.0
6	LODGE	3,100	6,340	0.1	3.9	3.9
7	BE-NEST	7,000	6,600	0.0	0.4	0.4
16	CLASS1-N	43,500	6,400	0.0	0.1	0.1
18	MONUMENT	1,700	6,500	0.1	8.6	8.6
	Simple Terrain (ISCST2 MODEL):					
8	MCKAY-CROSS	6,800	4,700	0.0	0.5	0.5
9	RESIDENCE	12,600	4,200	0.0	0.4	0.4
10	LAPINE	18,000	4,200	0.0	0.2	0.2
11	SUNRIVER	15,000	4,200	0.0	0.2	0.2
12	LAVA-VISIT	19,500	4,500	0.0	0.2	0.2
13	HD-MUSEUM	25,500	4,040	0.0	0.1	0.1
14	BEND-1	30,000	3,800	0.0	0.1	0.1
15	BEND-DT	36,000	3,600	0.0	0.1	0.1
17	CLASS1-S	44,500	4,800	0.0	0.1	0.1

Table 6. Complex and simple terrain refined modeling predicted highest hourly H_2S concentrations ($\mu g/m^3$), for case-4.

No.	Receptor name	Receptor Dist. (m)	Receptor Elev. (ft)	Case 4. Plant Upset condition		
				0-hr	1-Hr	6-hr
	Complex Terrain (COMPLEX-1 MODEL):					
1	CAMP1	3,000	6,380	29.4	14.7	7.3
2	CAMP2	4,200	6,340	19.2	9.6	4.8
3	CAMP3	5,200	6,300	12.2	6.1	3.0
4	HOUSES	5,300	6,300	12.6	6.3	3.1
5	CAMP4	4,800	6,360	18.7	9.4	4.7
6	LODGE	3,100	6,340	28.7	14.4	7.2
7	BE-NEST	7,000	6,600	1.9	0.9	0.5
16	CLASS1-N	43,500	6,400	0.3	0.2	0.1
18	MONUMENT	1,700	6,500	69.0	34.5	17.2
	Simple Terrain (ISCST2 MODEL):					
8	MCKAY-CROSS	6,800	4,700	2.5	1.2	0.6
9	RESIDENCE	12,600	4,200	2.0	1.0	0.5
10	LAPINE	18,000	4,200	0.9	0.4	0.2
11	SUNRIVER	15,000	4,200	1.2	0.6	0.3
12	LAVA-VISIT	19,500	4,500	1.0	0.5	0.2
13	HD-MUSEUM	25,500	4,040	0.6	0.3	0.2
14	BEND-1	30,000	3,800	0.7	0.4	0.2
15	BEND-DT	36,000	3,600	0.6	0.3	0.1
17	CLASS1-S	44,500	4,800	0.5	0.3	0.1

0-hr: Unabated emissions from 8 wells. 1-hr: Emissions reduced to 50% after 1 hour. 6-hr: Emissions reduced to 25% after 6 hours.

Table 7. Daytime and nighttime H_2S hourly impacts during the most probable wind speed, wind direction, and atmospheric stability conditions during plant upset condition[1].

No.	Receptor Name	Receptor Distance (m)	Receptor Elev. (ft)	Case 4. Plant Upset Condition		
				0-Hr	1-Hr	6-Hr
Daytime[2]						
1	CAMP1	3,000	6,380	0	0	0
2	CAMP2	4,200	6,340	0	0	0
3	CAMP3	5,200	6,300	0	0	0
4	HOUSES	5,300	6,300	0	0	0
5	CAMP4	4,800	6,360	0	0	0
6	LODGE	3,100	6,340	0	0	0
7	BE-NEST	7,000	6,600	0	0	0
16	CLASS1-N	43,500	6,400	0	0	0
18	MONUMENT	1,700	6,500	0	0	0
Nighttime[3]						
1	CAMP1	3,000	6,380	0	0	0
2	CAMP2	4,200	6,340	0	0	0
3	CAMP3	5,200	6,300	0	0	0
4	HOUSES	5,300	6,300	0	0	0
5	CAMP4	4,800	6,360	0	0	0
6	LODGE	3,100	6,340	0	0	0
7	BE-NEST	7,000	6,600	0	0	0
16	CLASS1-N	43,500	6,400	0	0	0
18	MONUMENT	1,700	6,500	0	0	0

1. These conditions represent the most probable wind direction, wind speed, and stability class during the daytime and nighttime over the course of the September 26, 1 2 to August 13, 1993 time period and average temperature during the conditions. These are not the same as the most frequent wind speed or wind direction alone, but are the most probable (frequent) combination of conditions.
2. Wind direction = 180°; Wind speed = 5.5 mph; Stability class = 1; Temperature = 5.25 °C.
3. Wind direction = 135°; Wind speed = 4.5 mph; Stability class = 5, Temperature - 2.83 °C.

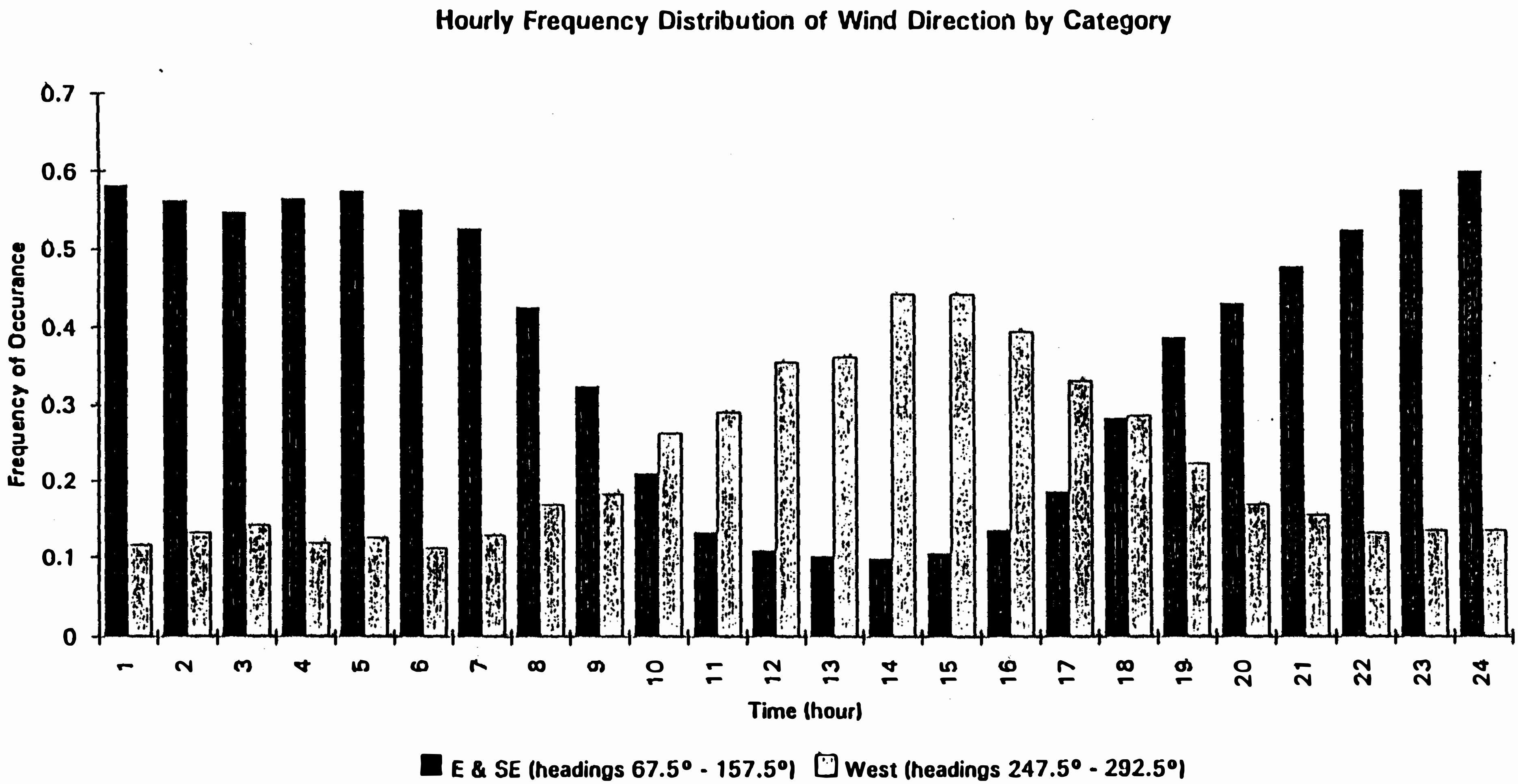


Figure 1. Hourly Frequency Distribution of Wind Direction by Category

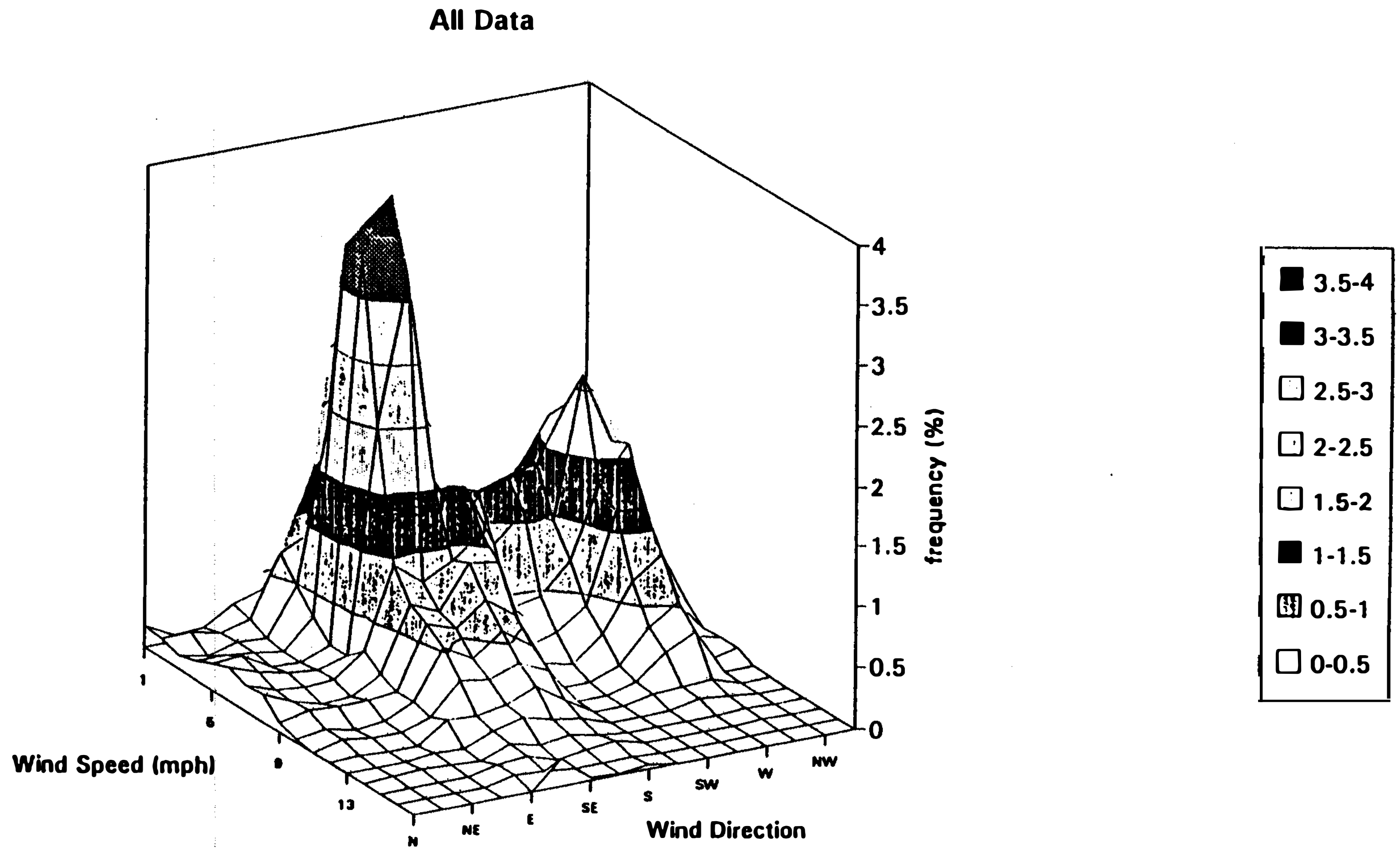


Figure 2. Frequency Distribution to Wind Speed and Direction, All Data

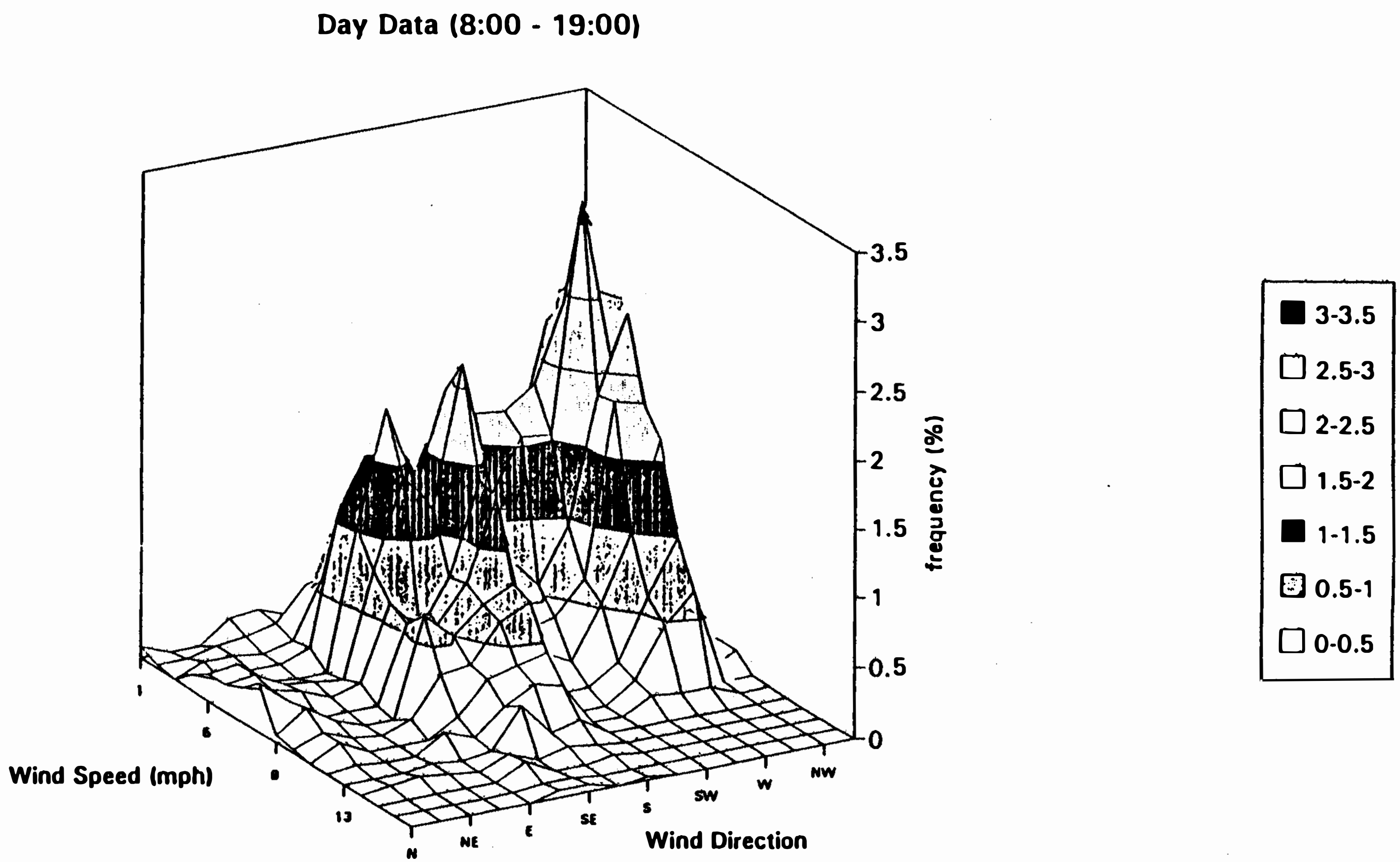


Figure 3. Frequency Distribution of Wind Speed and Direction, Daytime Data

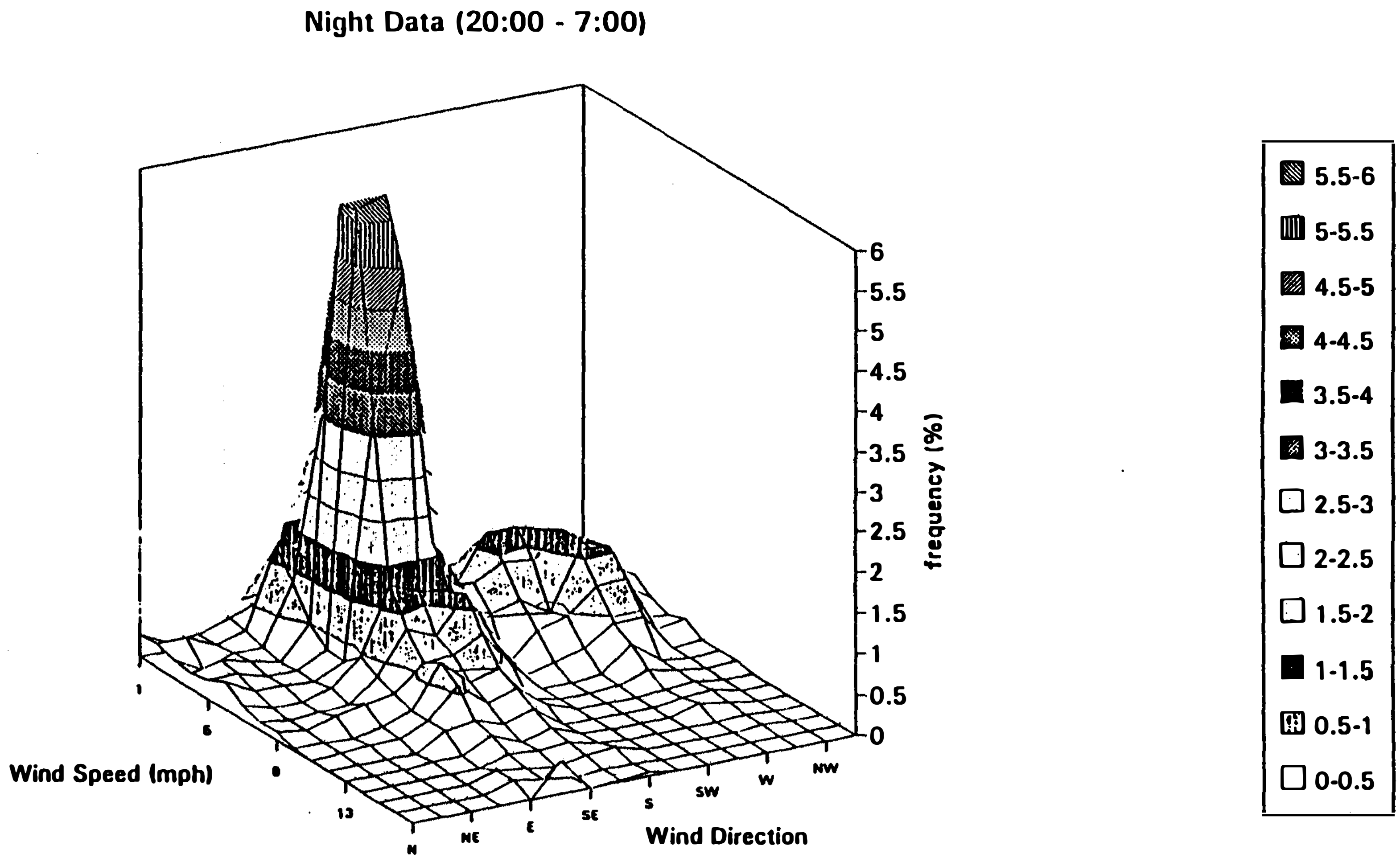
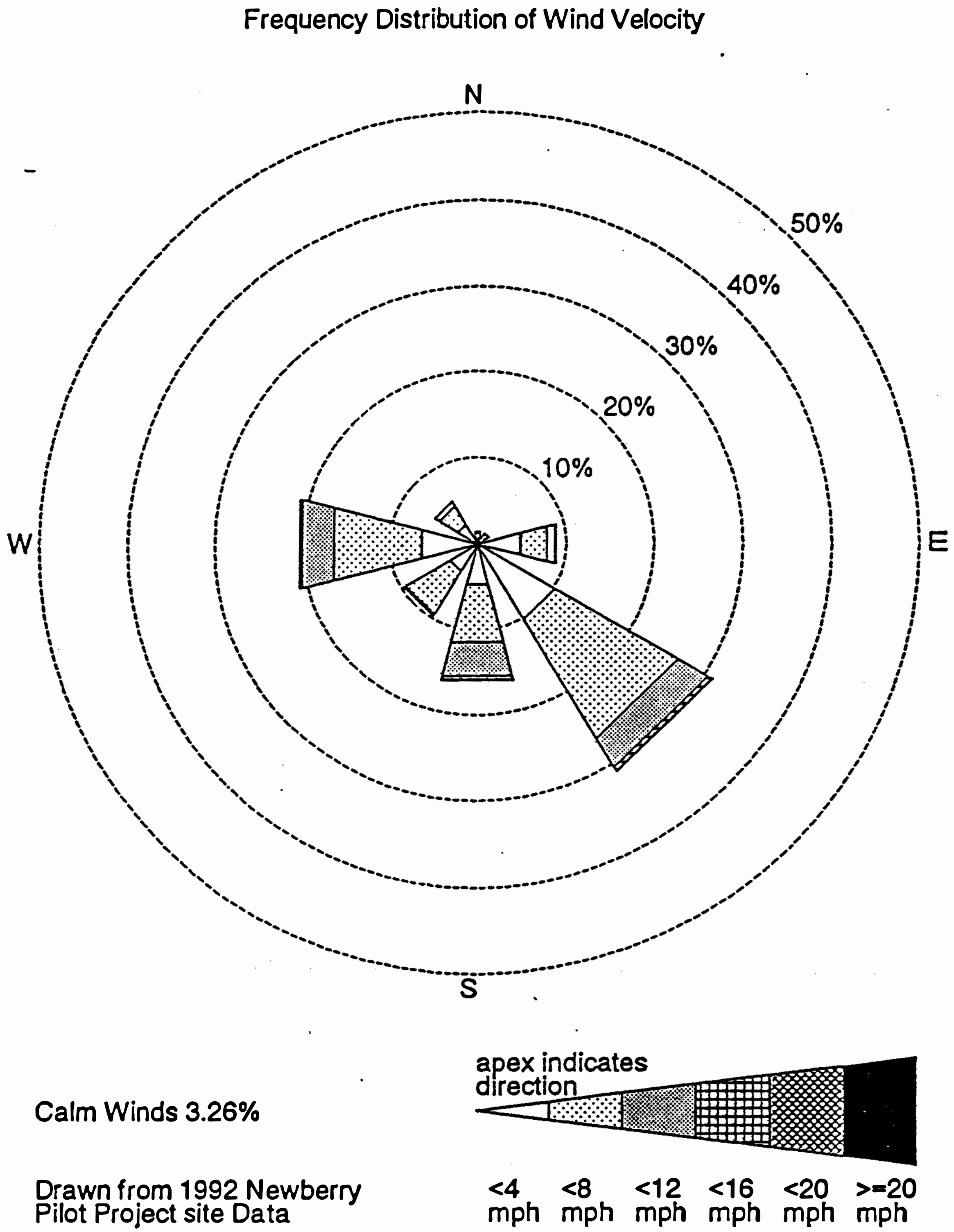


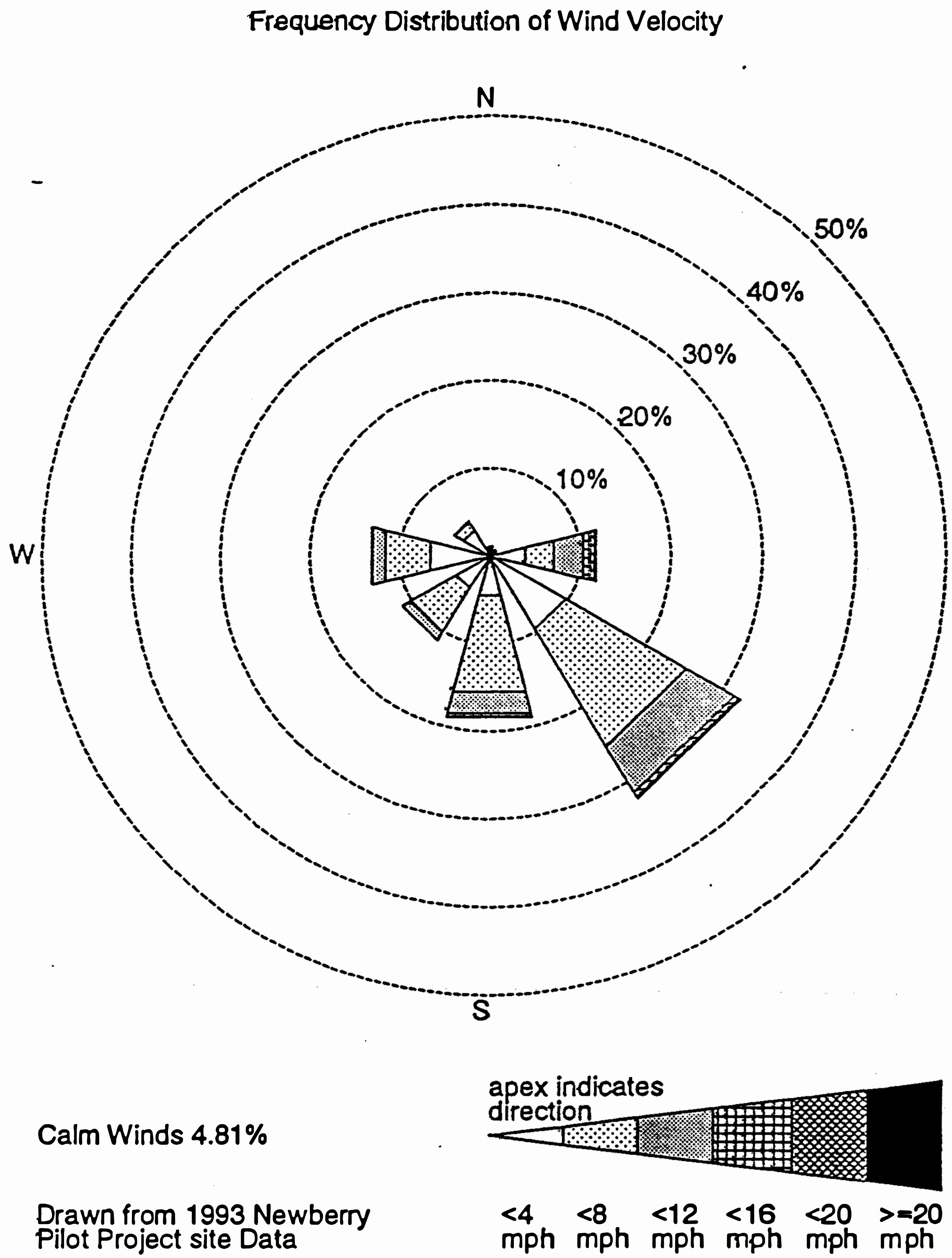
Figure 4. Frequency Distribution of Wind Speed and Direction, Night Data

Appendix A

Wind Roses for Meteorological Data Collection from September 26, 1992 through July 13, 1993

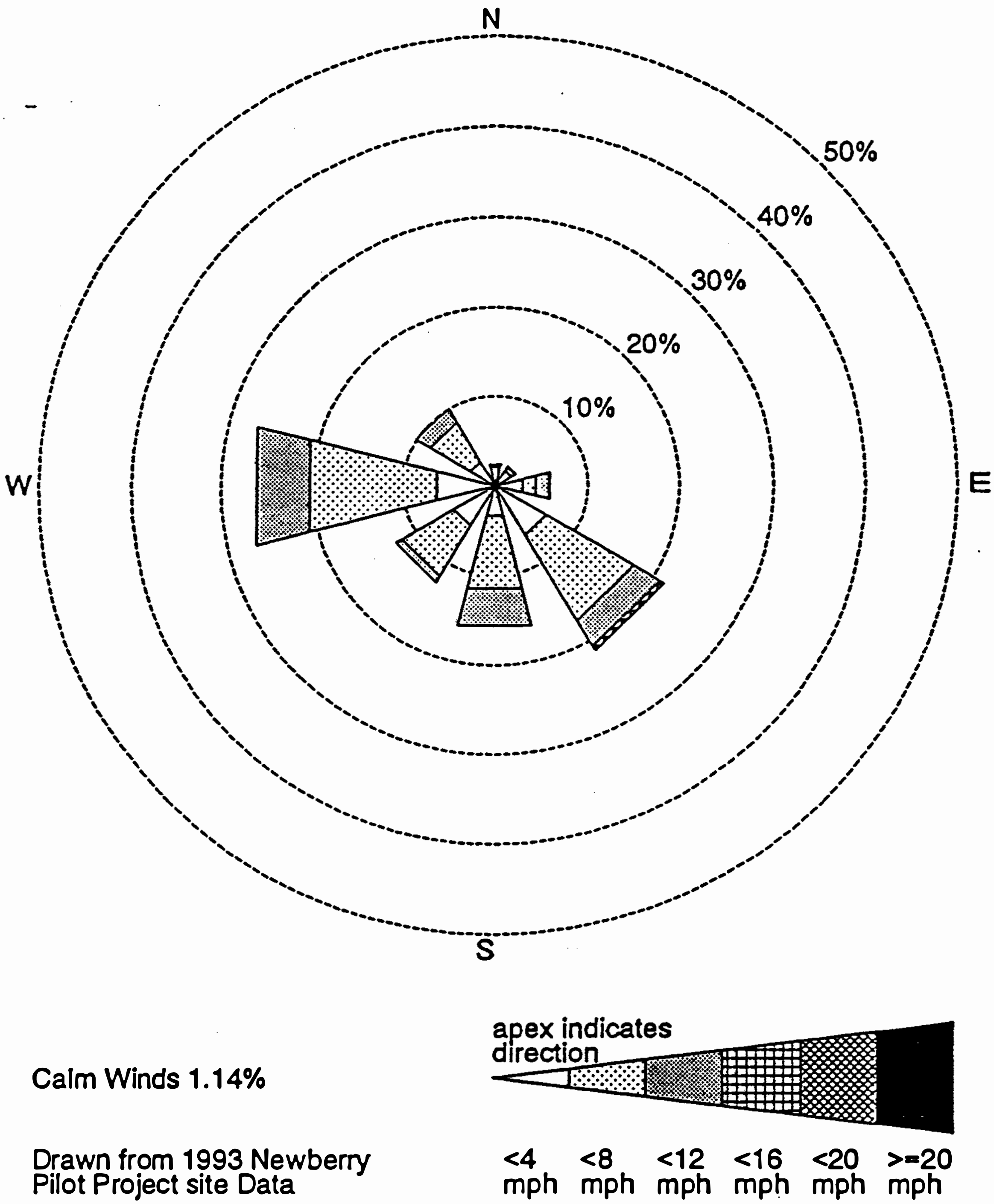


Fall 1992 (October, November & December) windrose of meteorological data gathered by SAIC at the Newberry Pilot Project site.



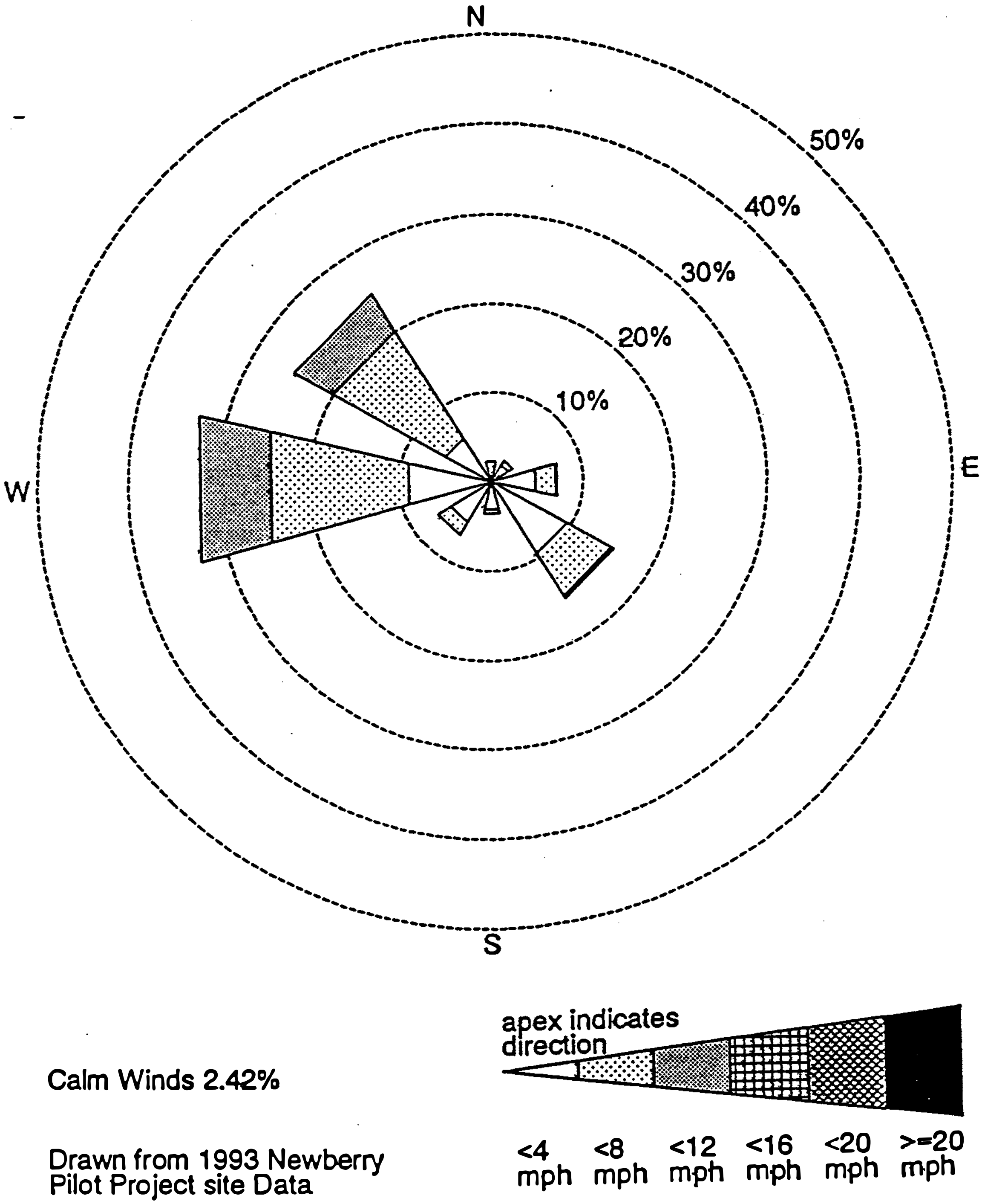
Winter 1993 (January, February & March) windrose of meteorological data gathered by SAIC at the Newberry Pilot Project site.

Frequency Distribution of Wind Velocity

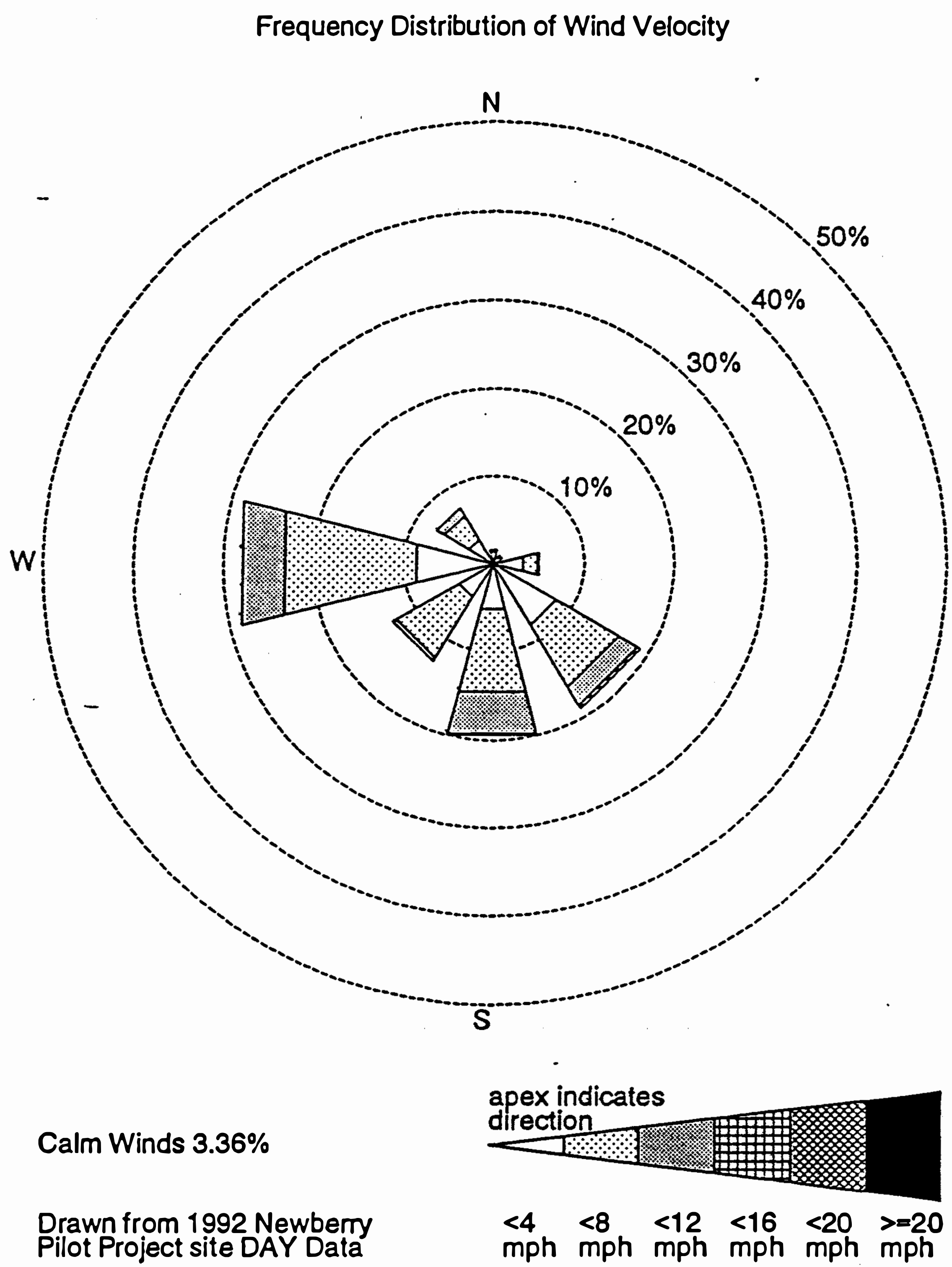


Spring 1993 (April, May & June) windrose of meteorological data gathered by SAIC at the Newberry Pilot Project site.

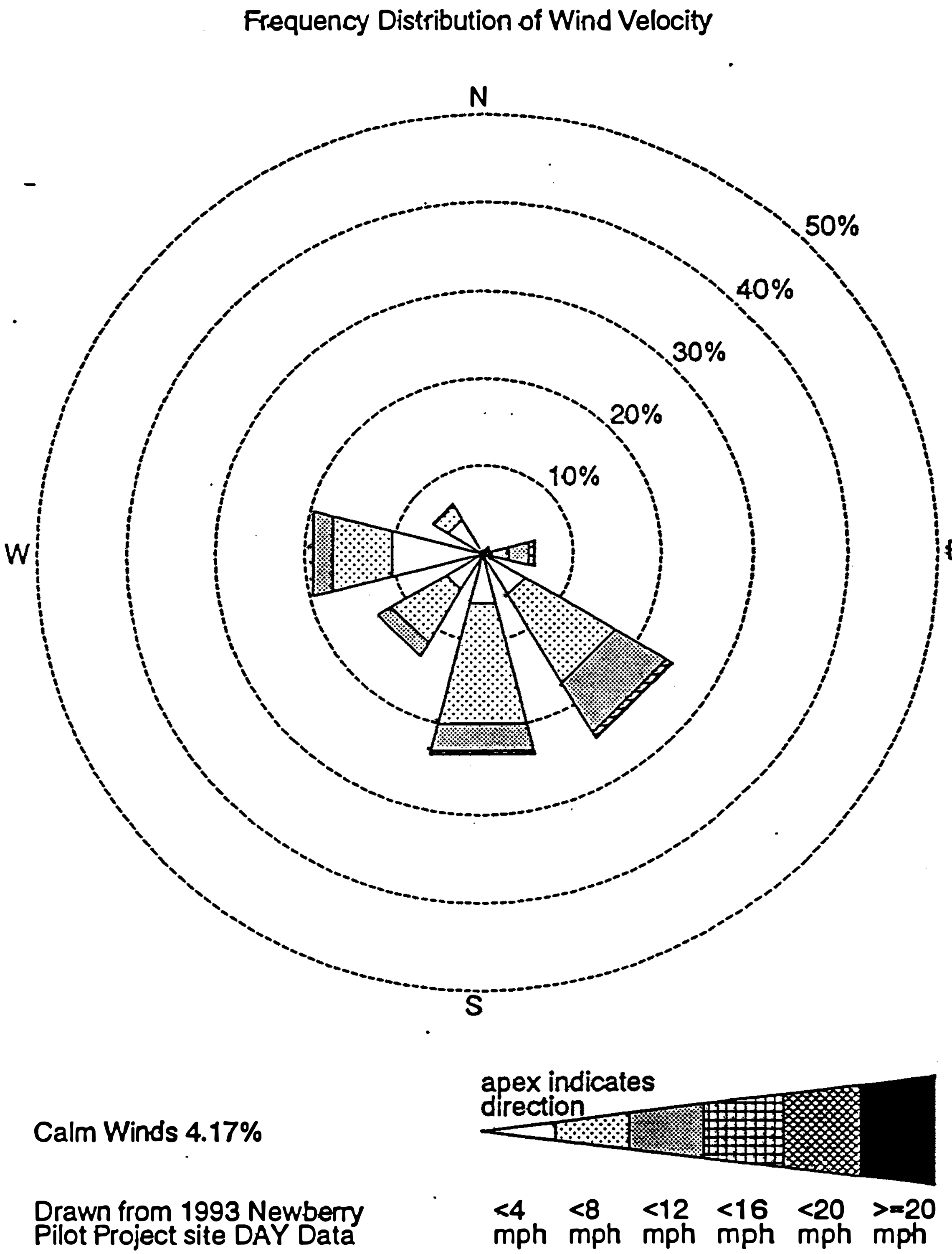
Frequency Distribution of Wind Velocity



Summer 1993 (July 1 through July 23, 1993) windrose of meteorological data gathered by SAIC at the Newberry Pilot Project site.

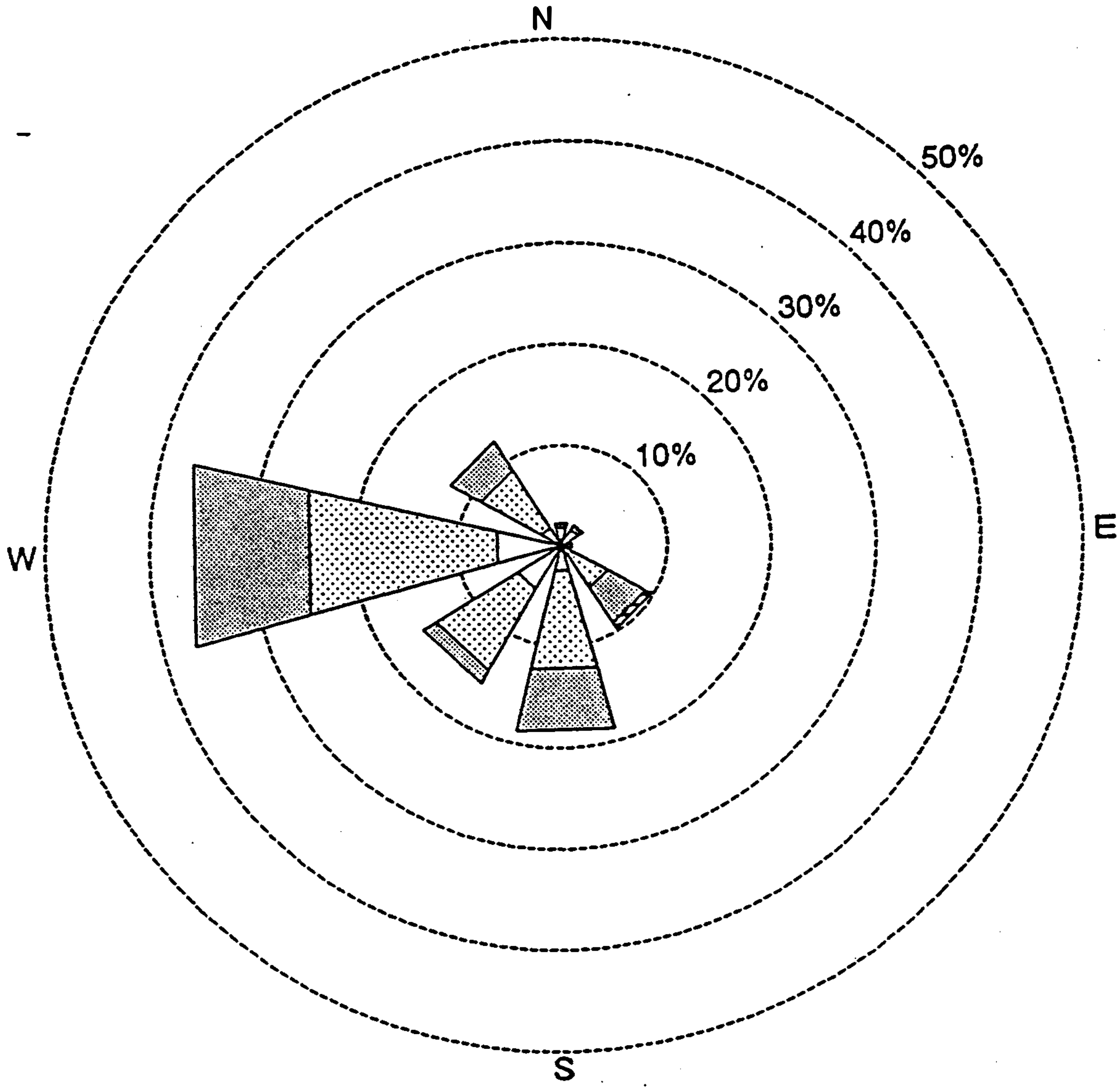


Fall 1992 (October, November & December) windrose of "day" (8:00 - 19:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.



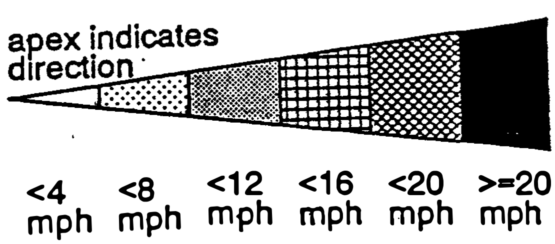
Winter 1993 (January, February and March) windrose of "day" (8:00 - 19:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.

Frequency Distribution of Wind Velocity



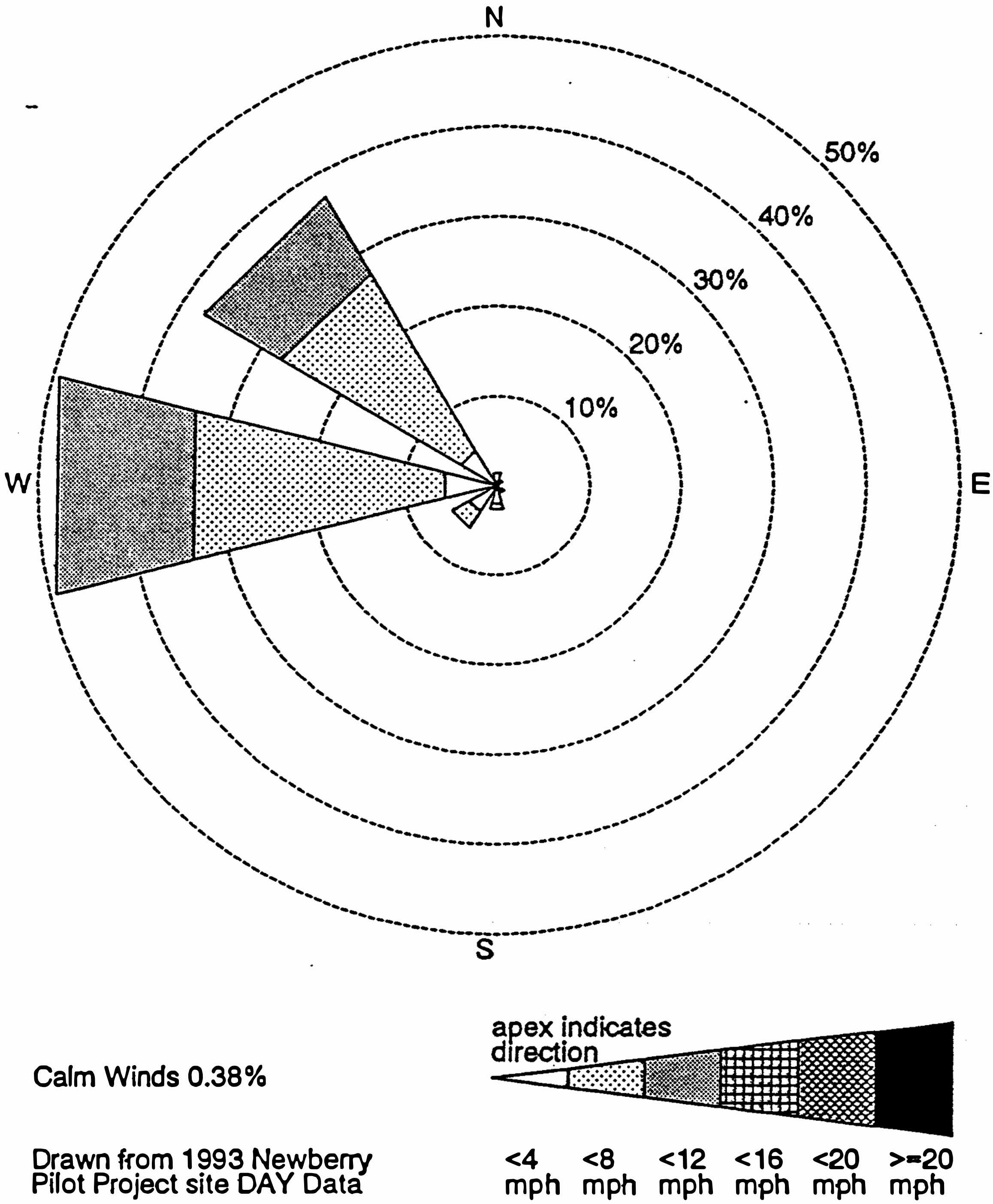
Calm Winds 0.18%

Drawn from 1993 Newberry Pilot Project site DAY Data

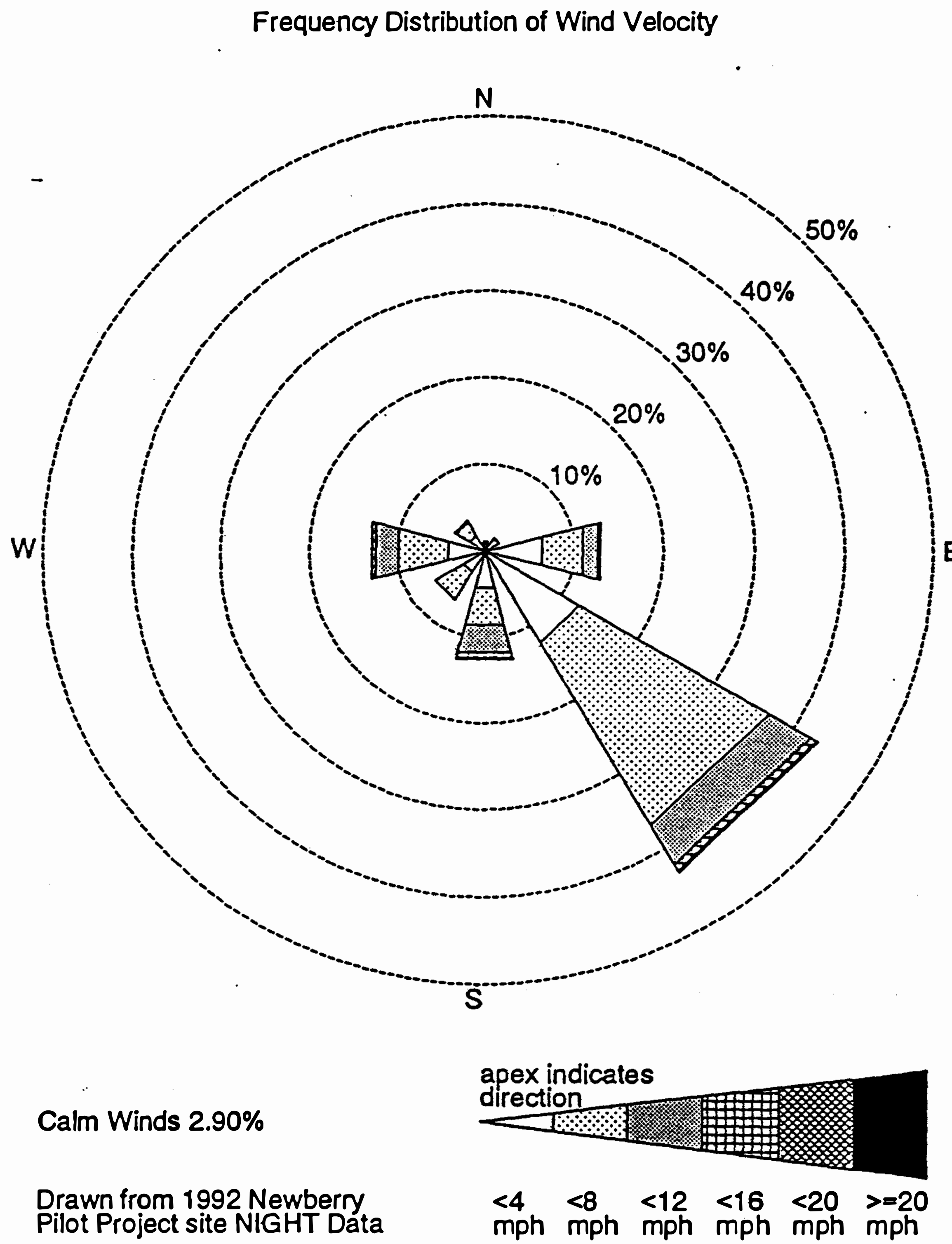


Spring 1993 (April, May & June) windrose of "day" (8:00 - 19:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.

Frequency Distribution of Wind Velocity

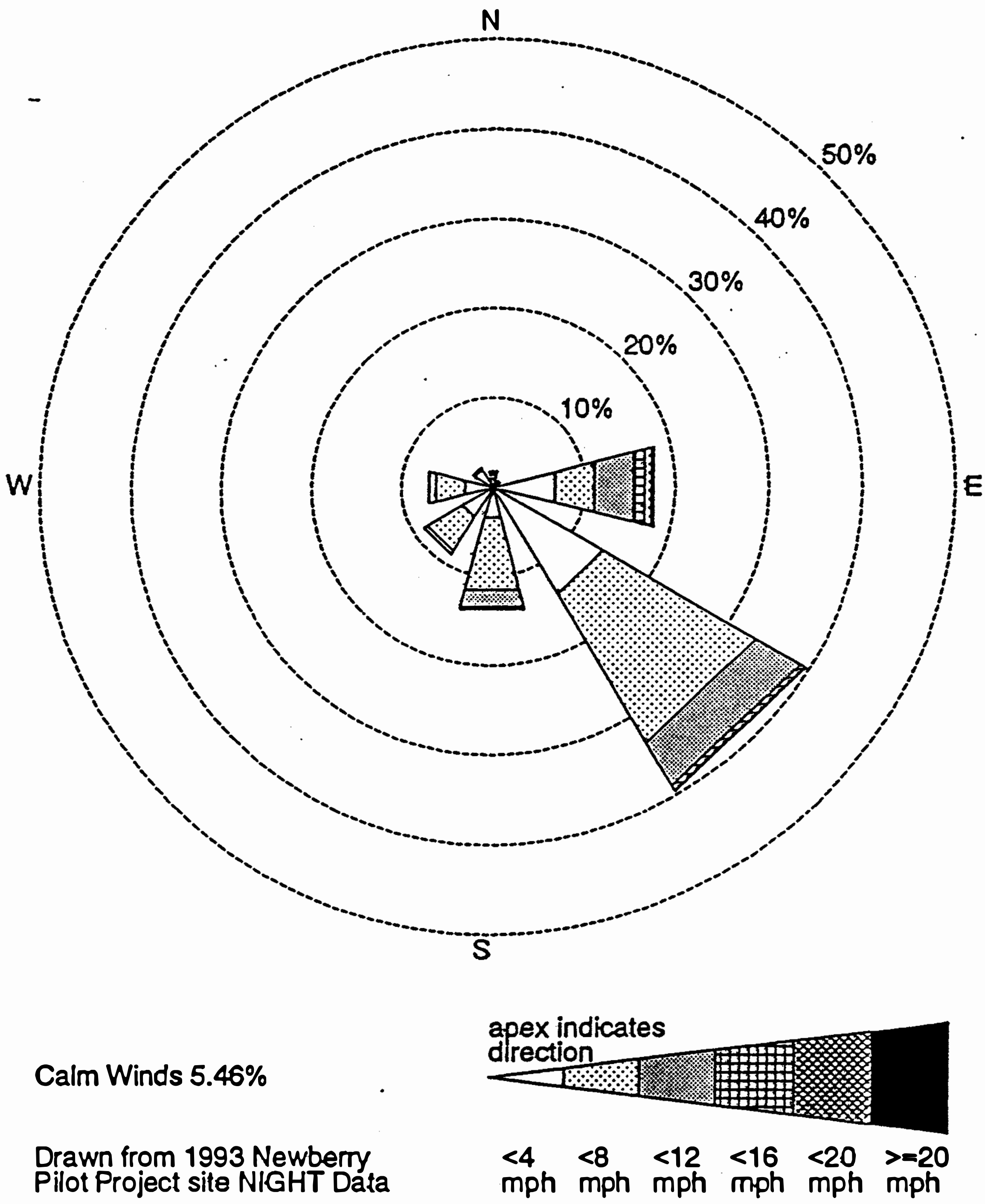


Summer 1993 (July 1 through July 13, 1993) windrose of "day" (8:00 - 19:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.

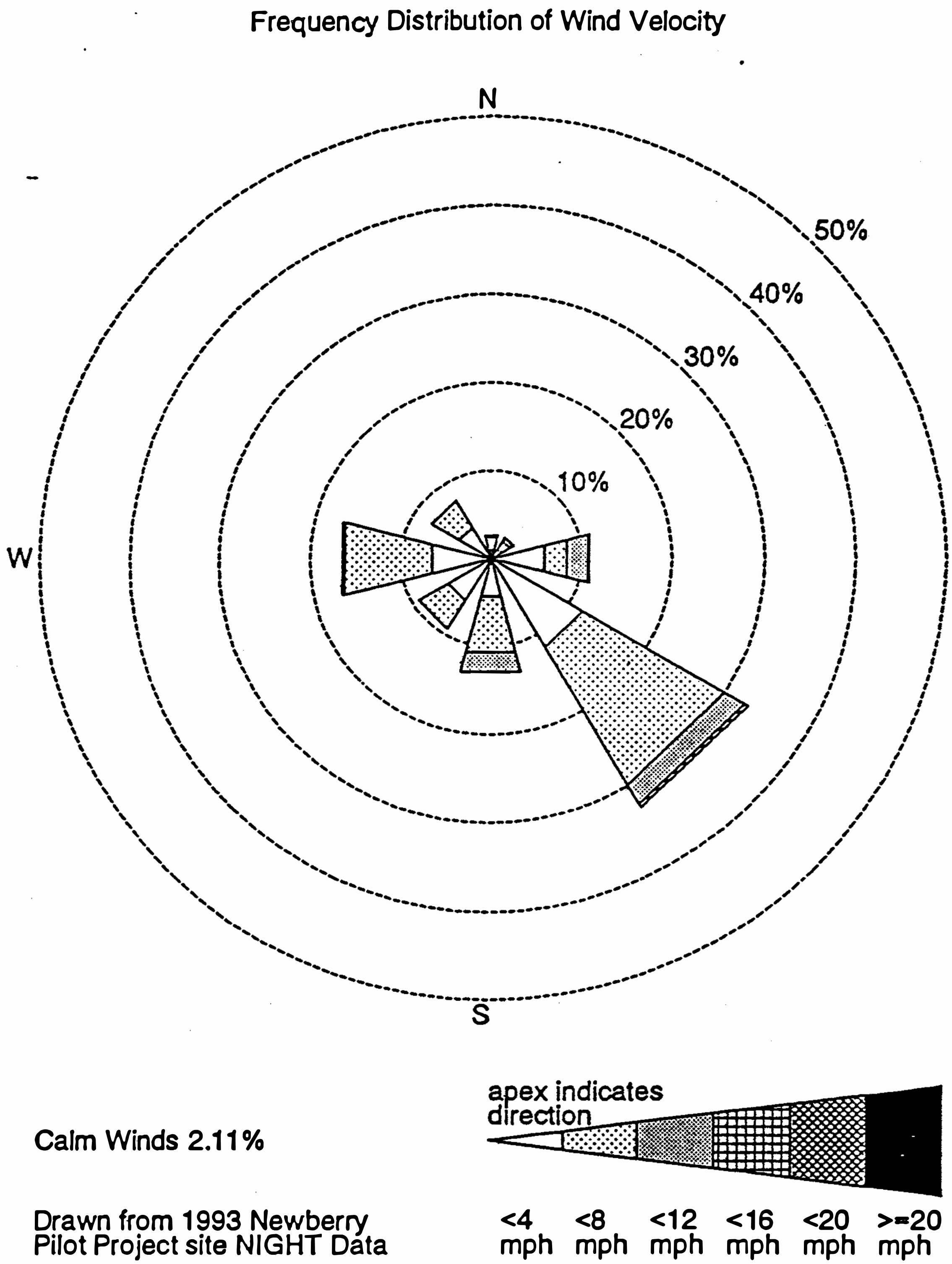


Fall 1992 (October, November & December) windrose of "night" (20:00 - 7:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.

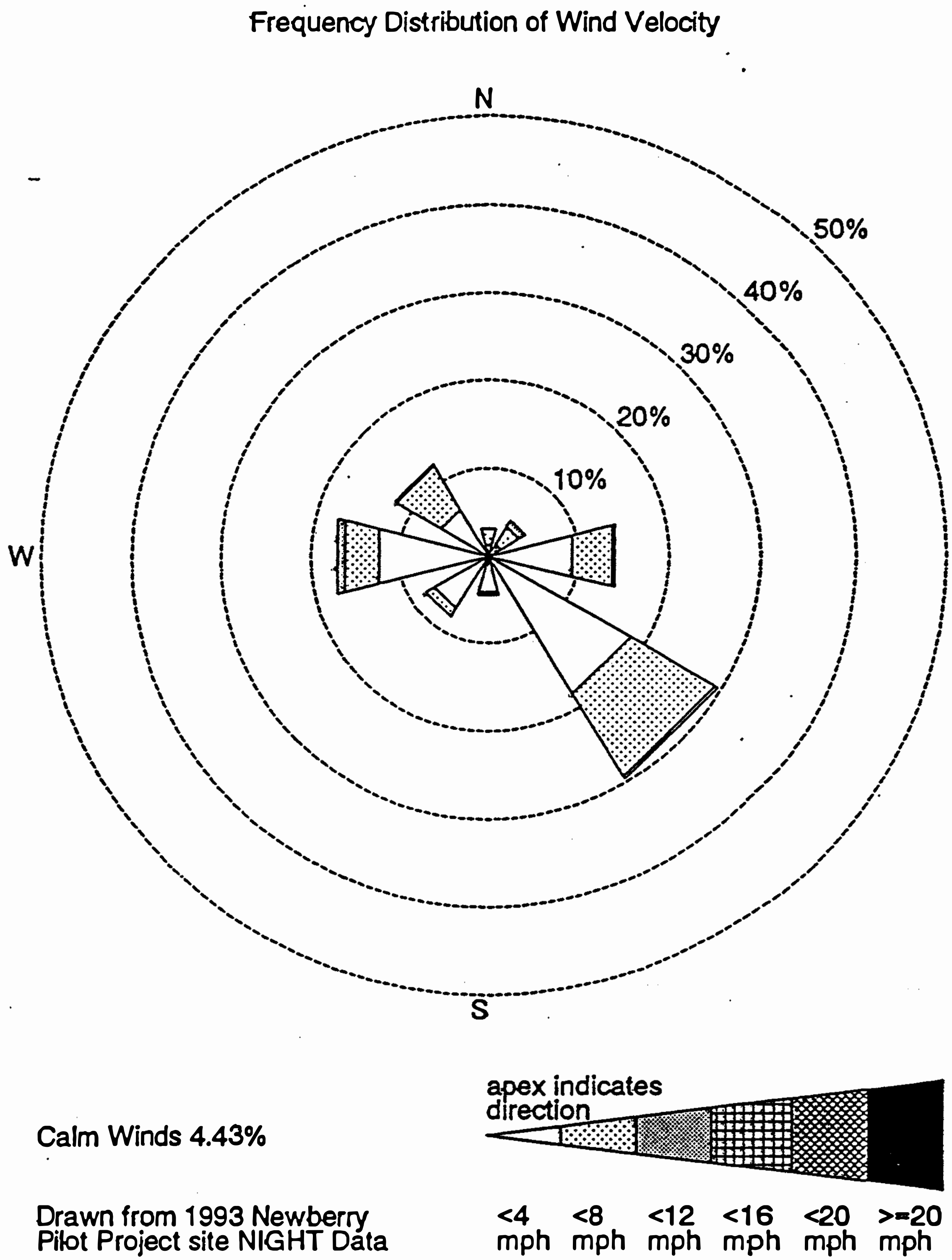
Frequency Distribution of Wind Velocity



Winter 1993 (January, February and March) windrose of "night" (20:00 - 7:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.



Spring 1993 (April, May & June) windrose of "night" (20:00 - 7:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.



Summer 1993 (July 1 through July 13, 1993) windrose of "night" (20:00 - 7:00) meteorological data gathered by SAIC at the Newberry Pilot Project site.

APPENDIX F-5
ANALYSIS OF DEPOSITION IMPACTS FROM EMISSIONS OF NEWBERRY GEOTHERMAL PROJECT ON NEWBERRY CRATER LAKES AND FROM COOLING TOWER PLUME DRIFT

Prepared by Science Applications International Corporation (SAIC) for CEE, November 1993

Analysis of Deposition Impacts from Emissions of Newberry Geothermal Project on Newberry Crater Lakes and from Cooling Tower Plume Drift

1 Introduction

This report is written to quantify the potential impacts on the Newberry Crater Lakes from the deposition of material estimated to be emitted from the Newberry Geothermal power plant project. The pollutants of concern are mainly hydrogen sulfide which converts into acid, and other elements associated with the geothermal industry such as various heavy metals, arsenic, boron, selenium and beryllium. With the exception of H_2S and mercury unmitigated (uncontrolled) emission rates were estimated for use with the modeling and deposition calculation.

Control efficiency for H_2S removal by the Sulferox system was taken into consideration in estimating H_2S emission rates. Since 90% of the incoming mercury is removed by the Sulferox system and is contained in the sulfur "cake" product and the mercury content makes the sulfur cake unmarketable, a charcoal filter system will be placed before the Sulferox system to remove the mercury. The measured mercury removal efficiency of the charcoal filter system at CE Explorations COSO geothermal facility is 97.7%.

A similar system would be used at the proposed Newberry geothermal and the 97.7% central efficiency was taken into consideration when the plant emission rates for mercury were estimated. It should be noted that the mercury content of the newberry Center resources is thought to be very low (lower than the COSO mercury data used for estimating emission rates here) and that the charcoal filter system may not be needed for either economic or environmental reasons at the Newberry Plant.

The source of pollutants for this evaluation is the Newberry Geothermal power plant (and associated wells) which is proposed for the Newberry Crater, Deschutes County, Oregon. The receptor for this analysis is the Newberry Crater Lakes watershed, which is located approximately 1.25 miles southeast of the proposed plant. The Newberry Crater Lakes watershed is approximately 17.4 square miles in area. Within the watershed are located the two Newberry Crater Lakes, Paulina Lake and East Lake. The majority of the watershed area is made up of forested area (approximately 67%); 12% of the watershed is considered open land (lava flows, deforested land, grassland, etc.), and 21% is actual water surface.

Because of the proximity of the watershed and the potentially different impact on the two lakes, the deposition impacts are evaluated for each lake separately. The Paulina Lake watershed is larger (10.2 sq.mi) and has an exit point, where the Paulina Creek starts. The East Lake watershed is smaller (7.3 sq.mi) and does not have a surface exit.

The soil types and climates of the Deschutes National Forest including the Newberry Crater, are described in reference 1. Other than areas covered with lava flows where soil is lacking, the soils consist of well drained coarse pumice and volcanic ash. Surface soils are typically pumiceous loamy sands with a high permeability over undifferentiated materials. The pH of soil samples collected from soil units that form the Newberry Crater lands vary from 5.5 to 7.0, mostly in the range of 6 to 6.5 which indicates low acidity. The types of soil become important in the sensitivity associated with acid precipitation and the ability of the soil to respond to the sulfuric acid deposition.

The average annual precipitation within the Newberry crater is approximately 30 inches. The mean annual lake evaporation is estimated to be 28-34 inches.

2 Emission and Atmospheric Impact Assessment

2.1 Modeling Procedures

To evaluate the potential impacts of the project plant on the Newberry Crater Lakes, the COMPLEX-1 model was used to determine the annual H_2S average impacts at ten receptors located within the watershed at various locations representative of the type of land coverage (water, open land, forest). The average annual impact of other pollutants were calculated based on the ratios of their annual emission rates to that of hydrogen sulfide.

The COMPLEX-1 model was used because the land elevations within the watershed are generally higher than the project site, and complex terrain modeling must be performed. Figure 1 shows the watershed map, the various land coverage and the locations of receptor points. One year of meteorological data collected at the project site (1992-1993) were used for this modeling.

2.2 Average Annual Emission Rate Calculation

The H_2S average annual emissions were calculated for each source based on the assumption that the normal plant operation will go on throughout the year. The emissions due to well venting and testing and due to plant upset conditions were also accounted for as discussed below. The actual observed data at other similar plants were used for the calculations (see our previous report on the Newberry project H_2S emission impacts, for source emission rates).

Cooling tower: Based on continuous plant normal operation, the annual average H_2S emission rate is 0.1270 lb/hr or 0.0160 g/s.

Sulferox vessel: The H_2S average annual emission rate for the sulferox vessel is 0.0365 lb/hr or 0.0046 g/s, based on continuous operation.

Wellhead Silencer: Based on 6 wells being vented 4 times/year and 24 hours each time, and one well being tested for an average of 30 days/year, the mean annual H_2S emission rate can be calculated. The H_2S emission rate from one well being fully vented is 2.79 lb/hr or 0.351 g/s.

$$(0.351 \text{ g/s}) ((6 \text{ wells} \times 4 \text{ days}) + (1 \text{ well} \times 30 \text{ days})) / (365 \text{ days/yr})$$
$$= (0.351 \text{ g/s}) (54/365) = 0.0520 \text{ g/s}$$

Plant Silencer: Based on observed data at a similar plant, the number of plant upset and shut-down events is 12 during a 6-month period, totalling 105.05 hours. The average upset/shut-down event duration is 105.05/12 = 8.75 or 9 hours. Conservatively assuming that all events relate to plant upset condition, and assuming full emission rate during the first hour, 50% emission rate during the following 5 hours and 25% emission rate during the remaining 3 hours, the average emission rate can be calculated as follows. The H_2S full emission rate from the plant silencer is 22.32 lb/hr or 2.8120 g/s.

Average emission rate at each upset event:

(2.8120 g/s) ((1 hr x 1.0)+(5 hr x 0.5)+(3 hr x 0.25))/(9 hr))
= 2.8120 g/s x 0.472 = 1.328 g/s

Average annual emission rate:

1.328 g/s x ((24 events/yr x 9 hr) / (365 days/yr x 24 hrs/day))
= 1.328 g/s x 0.0247 = 0.0328 g/s

The overall average annual H_2S emission rate is the sum of emissions from each source:

0.0160 + 0.0046 + 0.0520 + 0.0328 = 0.1054 g/s

Note that the sources data were individually input in the COMPLEX-1 model. For simplification, however, wellhead emissions were represented by a single source located closest to the plant.

The emission rates for H_2S and other pollutants were estimated from typical western geothermal wells during testing at similar size plants as described in our hydrogen sulfide and other pollutant impact studies.

A summary of all the emission rates is shown in Table 1. These emission rates were used to evaluate the yearly impact on the Newberry Crater Lakes watershed.

2.3 Modeling Results

Table 2 lists the model predicted average annual impacts for H_2S at all the ten receptor points. The COMPLEX-1 model output printout is presented in Appendix A.

As discussed, the impact of other pollutants are calculated based on the ratio of their annual emission rates (see Table 1) to that of H_2S.

3 Deposition of Material

The potential for deposition of a pollutant depends on the concentration of the pollutant in the atmosphere, and for dry deposition, the deposition velocity. Material is deposited either by wet deposition, where water "scrubs" the pollutants out of the air, or by dry deposition, where sorption of pollutants occurs onto and into plants, soil, and surface waters, as well as into inert materials such as asphalt and concrete. It is recognized that dry deposition equals or exceeds wet deposition rates (reference 2). In this study we will calculate the potential annual dry deposition rates within the watershed. The wet deposition rates are conservatively assumed to be of the same magnitude and to obtain the total deposition rates the calculated dry deposition rates are doubled.

Considerable research has been conducted on pollutant deposition processes and their impact on watersheds (references 3-16). In dry deposition, the flux of the pollutants into the surface is most simply stated as the product of the depositional velocity (v_g) and the predicted concentration (mass/volume). Determining the precise depositional velocities is a complex task and is beyond the scope of this report.

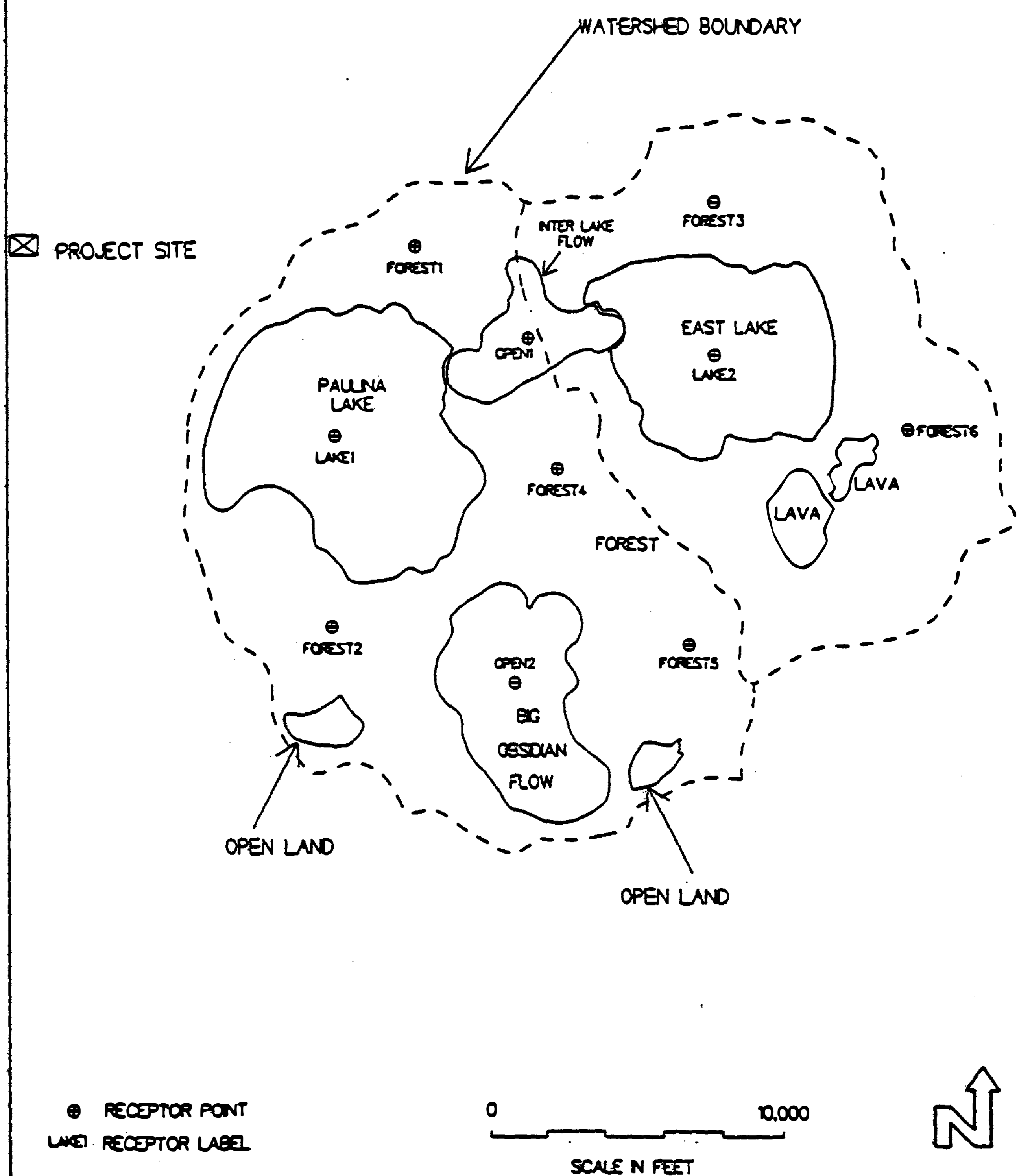


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Figure 1.
Newberry Lakes Watershed

Newberry Pilot Project
Newberry, Oregon

Project No:	05-2820-100
Date:	Nov. 10, 1993
Scale:	As shown
Drawn by: JH	Checked: JH

CEE3.CGO

Table 1. Pollutant average annual emission rates.

Pollutant Name	Pollutant Symbol	Mean Annual Emission Rate (g/sec)
Hydrogen Sulfide	H_2S	0.1054
Lead	Pb	3.59-07
Antimony	Sb	5.85E-07
Arsenic	As	2.79E-07
Beryllium	Be	3.29E-07
Cadmium	Cd	3.59E-07
Chromium	Cr	3.41E-08
Cobalt	Co	3.41E-08
Manganese	Mn	3.41E-08
Mercury	Hg	6.3E-06
Nickel	Ni	3.41E-08
Selenium	Se	5.04E-07
Boron	B	5.51E-05

Table 2. Average annual H_2S model predicted impacts at receptors within the Newberry Lake watershed.

Receptor Number	Receptor Label	Mean Annual Impact ($\mu g/m^3$)
1	LAKE1	0.015
2	LAKE2	0.002
3	OPEN1	0.005
4	OPEN2	0.007
5	FOREST1	0.002
6	FOREST2	0.004
7	FOREST3	0.001
8	FOREST4	0.013
9	FOREST5	0.010
10	FOREST6	0.003

However, values for deposition of various gases and small particles have been estimated in studies done by various researchers. Some factors tend to enhance deposition in a forest and grassland when compared to a flat surface; among them are relatively large foliage area, greater turbulent mixing, and the direct exposure of the leaves to high wind speeds. Vertical turbulent transfer tends to decrease rapidly downward in a forest, preventing foliage at lower levels from reaching its potential as a sink. A study by the Meteorological Assessment Division, Environmental Sciences Research Laboratory, Research Triangle Park (reference 14), indicated that deposition velocity, v_g, is relatively insensitive to canopy height, shape, roughness, length, and extinction coefficients, but is relatively sensitive to atmospheric stability, zero-plane displacement, surface resistance, leaf area index, and friction velocity. Using reasonable parameter choices, predictions by the methods described in the previous study agree well with empirical observations, yielding in the neighborhood of 1 cm/sec over grass for SO_2 and other gases and a value of two to three times that in forested areas. We have chosen to be conservative and to use rates for depositions of 1 cm/sec in water, 2 cm/sec in open lands, and 3 cm/sec in the forested areas for all particles and gas.

The deposition calculations for gases and particles were carried out separately for each of the two lake watersheds. For each surface type within the watersheds, the concentration corresponding to the receptor with highest impact was chosen for calculation. The concentration values ($\mu g/m^3$) retained for each surface area, along with the receptor name, are given below for the two watersheds.

	Paulina Lake	East Lake
Water	LAKE1=0.015	LAKE2=0.002
Open Land	OPEN2=0.007	OPEN1=0.005
Forest Land	FOREST4=0.013	FOREST4=0.013

The results of deposition calculations are presented in Tables 3 and 4. These numbers are found by multiplying the ambient concentration for each surface type (above) by the deposition velocity corresponding to the surface type to obtain the mass per area deposited in a year.

The surface area types for each lake watershed is shown in Table 5.

3.1 Hydrogen Sulfide

A detrimental impact of the hydrogen sulfide emission can be caused by its conversion into sulfuric acid. Acidic deposition is of particular concern in areas where, due to the chemical composition of the watershed, acid cannot be effectively neutralized and the pH of the ecosystem is changed to a level that has detrimental effects on the plant and animal life. For instance, it is well documented that reduction of the pH in the aquatic ecosystems can kill the fish in lakes and streams and the decrease in pH in the terrestrial environment plays a significant role in reduction of the system's productivity.

Many studies have been done on the effects of acid precipitation on lowering the pH of lakes and subsequent killing of aquatic life sensitive to pH changes.

In the atmosphere, hydrogen sulfide is partly converted to sulfur dioxide which in turn is converted to sulfur trioxide by catalytic processes. Sulfur trioxide is immediately converted to sulfuric acid in the presence of moisture. The degree of oxidation of hydrogen sulfide and sulfur dioxide in the atmosphere

Table 3. Annual deposition of pollutants from geothermal development on the Paulina Lake watershed.

Pollutant	Deposition on Water (lb/acre/yr)	Deposition on Open Lands (lb/acre/yr)	Deposition on Forest Lands (lb/acre/yr)
H_2S	0.0422	0.0394	0.1098
Pb	1.4E-07	1.3E-07	3.7E-07
Sb	2.4E-07	2.2E-07	6.1E-07
As	1.1E-07	1.0E-07	2.9E-07
Be	1.3E-07	1.2E-07	3.4E-07
Cd	1.4E-07	1.3E-07	3.7E-07
Cr	1.4E-08	1.3E-08	3.6E-08
Co	1.4E-08	1.3E-08	3.6E-08
Mn	1.4E-08	1.3E-08	3.6E-08
Hg	2.6E-06	2.4E-06	6.7E-06
Ni	1.4E-08	1.3E-08	3.6E-08
Se	2.0E-07	1.9E-07	5.3E-07
B	2.2E-05	2.1E-05	5.7E-05

a. Deposition (lb/acre/yr) = [Ambient Concentration (μg/m³)] × [Deposition Velocity (cm/sec)] × .01 m/cm × 4,046.87 m²/acre × 31,536,000 sec/yr × 2.205E-9 lb/μg.

Table 4. Annual deposition of pollutants from geothermal development on the East Lake watershed.

Pollutant	Deposition on Water (lb/acre/yr)	Deposition on Open Lands (lb/acre/yr)	Deposition on Forest Lands (lb/acre/yr)
H_2S	0.0056	0.0281	0.1098
Pb	1.9E-08	9.6E-08	3.7E-07
Sb	3.1E-08	1.6E-07	6.1E-07
As	1.5E-08	7.4E-08	2.9E-07
Be	1.8E-08	8.8E-08	3.4E-07
Cd	1.9E-08	9.6E-08	3.7E-07
Cr	1.8E-09	9.1E-09	3.6E-08
Co	1.8E-09	9.1E-09	3.6E-08
Mn	1.8E-09	9.1E-09	3.6E-08
Hg	3.4E-07	1.7E-06	6.7E-06
Ni	1.8E-09	9.1E-09	3.6E-08
Se	2.7E-08	1.3E-07	5.3E-07
B	2.9E-06	1.5E-05	5.7E-05

a. Deposition (lb/acre/yr) = [Ambient Concentration ($\mu g/m^3$)] × [Deposition Velocity (cm/.sec)] × .01 m/cm × 4,046.87 m^2/acre × 31,536,000 sec/yr × 2.205E-9 lb/µg.

Table 5. Surface area types for Paulina Lake and East Lake watersheds.

Watershed	Surface type	Surface area (acres)
Paulina Lake	Water	1,384
	Open Land	1,019
	Forest	4,094
	Total	6,497
East Lake	Water	983
	Open Land	303
	Forest	3,351
	Total	4,637

is primarily dependent on resident time, moisture, and intensity and duration of sunlight. The Newberry Crater watershed is approximately 10 km from the project site at its farthest point. Even at a very low wind speed of 1 m/s (2.25 mph), H_2S would be in the air only 2.8 hours, consequently conversion from H_2S to SO_2 and then to SO_3 and H_2SO_4 would be limited. We will assume for purposes of this analysis that all the H_2S will be converted to H_2SO_4 in the airshed and will be directed to the water so that an absolute maximum concentration would be calculated.

The conclusion from a comparison of the results of many other studies (Figure 2) is that annual sulfate loading of 13 to 15 lb/acre/yr would be unlikely to degrade lakes that are considered less sensitive (based on the availability of buffering components) to acid precipitation. More sensitive lakes would not be affected at an annual loading rate of 8 to 10 lb/acre/yr. If all the H_2S deposited on the water and land were converted to SO_4^{-2} the resultant loading on each lake would be the following (see calculations in Appendix B):

Paulina Lake	1.12	lb/acre/yr
East Lake	1.10	lb/acre/yr

These loadings are too small to degrade even the most sensitive lake.

3.2 Elemental Deposition

The toxicity of various metals and other elements is determined by the forms that they take in the environment, and those forms are determined by chemical, physical, and biological factors as well as the rate of deposition from the atmosphere into the soil and water. Metals and other elements tend to accumulate in soils and do so primarily by exchange reactions with organic matter or clays. Organic materials in soil absorb many metals and elements, forming stable complexes. In the aquatic environment, factors affecting the solubility of metals and other elements include pH, water hardness, alkalinity, organic matter content, nutrient content, and oxidation-reduction potential.

Table 6 represents the predicted concentrations of selected elements in the top one-foot layer of lake water assuming that all the elemental emissions from the geothermal development were solubilized or contained in a suspension (see Appendix B for sample calculations). This of course does not happen, due to the formation of insoluble compounds and complexes which do not reach the lakes. Also since the mixing layer of the two lakes is greater than one foot, the one-foot assumption produces very conservative values. However as can be seen in Table 6, based on worst-case assumptions, the highest levels attained for all elements except mercury are a fraction of a percent of the Maximum Contaminant Level (MCL) for drinking water and of surface water quality criteria.

The calculated mercury concentration in lake water was well below MCL; however, it was conincidentally identical to the mercury surface water quality chronic criteria value of 1.2E-5 mg/l. It must be emphasized that the concentration values calculated from the air quality model and deposition theory were very conservative. For example, it was assumed that the mixing depth at East and Paulina Lakes was a constant 1 foot throughout thge entire year. In actuality, both East and Paulina Lakes are dimitic, i.e., the deep mixing occurs twice a year, once in the fall when the air temperatures cool and once in the spring after the ice breaks up. In addition, a well-defined thermocline forms by early summer which stabilizes at a depth of 35 to 40 feet (references 24 and 25). Based on these data, near surface water mercury

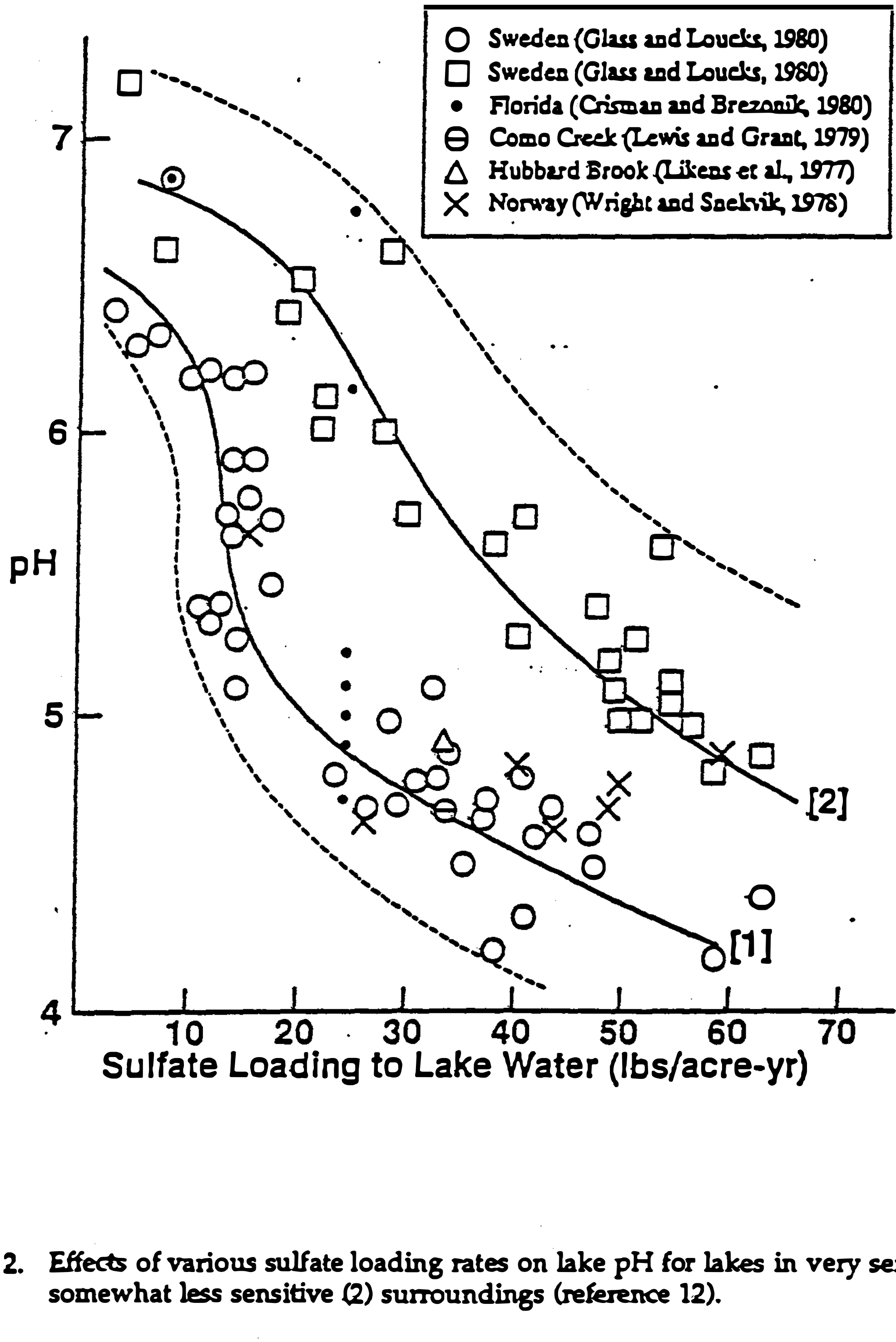

Figure 2. Effects of various sulfate loading rates on lake pH for lakes in very sensitive (1) and somewhat less sensitive (2) surroundings (reference 12).

Table 6. Elemental concentrations in a one-foot thick surface layer of lake water if all metals solubilized.

Metal	Concentration (mg/l)		Federal Drinking Water Standards (mg/l)	Surface Water Quality — Fresh Chronic Criteria (mg/l)
	Paulina Lake	East Lake		
Pb	6.5E-07	6.5-07	0.05	0.0032
Sb	1.1E-06	1.1E-06	0.005	1.6
As	5.0E-07	5.0E-07	0.05	0.19[c]
Be	5.9E-07	6.0E-07	0.001	0.0053
Cd	6.5E-07	6.5E-07	0.005	0.0011[d]
Cr	6.1E-08	6.2E-08	0.10	0.21[a]
Co	6.1E-08	6.2E-08	NA	NA
Mn	6.1E-08	6.2E-08	0.05	NA
Hg[f]	1.2E-05	1.2E-05	0.002	1.2E-05
Ni	6.1E-08	6.2E-08	0.10	0.16[e]
Se	9.1E-07	9.1E-07	0.05	0.035
B	9.9E-05	1.0E-04	NA	NA[b]

a. Trivalent Cr.

b. Mean value 0.1 mg/l, maximum value 0.5 mg/l for samples of river and lake waters in the U.S.

c. 4-day avg. concentration of inorganic As, not to be exceeded more than once every 3 years on average.

d. Insufficient data to develop criteria.
Value presented is LOEL - Lowest Observed Effect Level.

e. Hardness dependent criteria (100 mg/l used)

f. See Section 3.2 of text.

content would be one to two orders of magnitude lower than the water quality chronic criteria value depending on the time of the year.

4 Power Plant Cooling Tower and Wellhead Silencers Particulate Drift

The particulate emissions originating from the dissolved solid content of the geothermal steam and the cooling tower circulating water have been estimated to be 0.0050 g/s for the cooling tower, 0.0005 g/s for the sulferox vessel, and 0.039 g/s for each well being tested (see our reports on the visibility impacts, and on the impacts of non-H_2S pollutants). Based on the mean annual scenario assumptions discussed earlier in this report (considering the emissions during plant normal operation and plant upset conditions) the mean annual total emission rate for particulate matter is 0.0150 g/s. This emission rate corresponds to a total annual particulate emission of (0.0150 g/s) x (31,536,000 s/yr) / (453.5 g/lb) = 1,043 lb/year.
It is estimated that 84% of the cooling tower drifting particles have a diameter below 200 microns. These particles are small enough to have insignificant settling rates. The remaining percentage (16%) will be particles of the size that may fall out in the areas surrounding the plant. The corresponding estimated mass of particulates greater than 200 microns for the project plant will be 16 percent of 1,043 lb/year or 167 lb/year.

Boron deposition has been associated with vegetative stress and it is estimated that a boron deposition rate of 60 lb/acre in irrigation water will cause such vegetation stress. If we make a conservative assumption that the vegetation stress from aerial deposition starts at one-tenth of this number, the foliar toxicity may be produced at a deposition rate 6 lb/acre.

Depending on the evaporation rate, the wind speed and other meteorological conditions, the plume height and speed may vary and cause the fall out to impact a smaller or larger area around the plant. Analysis of plume drift for proposed geothermal development in the Vale, Oregon area found that the plume drift impact would be insignificant at distances greater than 500 m (reference 17). A maximum fallout rate of 167 lb/year over the corresponding 0.785 km^2 area [π x $(0.5\ km)^2$] or 196 acres is equivalent to 0.85 lb/acre of total particulate mass. Therefore, it is not expected that the particulate drift will cause significant damage to plants surrounding the project area.

5 Conclusions

In this analysis we have assumed that all the hydrogen sulfide was converted to sulfuric acid, and then analyzed the sulfate loading on the lake and compared that with known data on sulfate loading versus pH change, and found it would have no significant effect on even the most sensitive of lakes. The analysis was performed for the two Newberry crater lakes (Paulina Lake and East Lake) separately.

We analyzed the emissions of metals and other elements associated with geothermal fluids from the proposed geothermal development which are deposited on the watersheds of East and Paulina Lakes. Assuming that all the metals and other elements were solubilized or in suspension and restricted to the top one-foot layer of lake water, the results showed that increased concentrations (except for mercury) were significantly below federal drinking water standards and water quality chronic criteria.

Values for mercury were below MCL, but coincidentally identical to the water quality chronic water values. Since both East and Paulina Lakes are subject to deep mixing twice per year and a deep thermocline forms, it is estimated that the near surface values of mercury are one to two orders of magnitude lower than the very conservative values provided by the modeling.

It is therefore concluded that, the emissions from the Newberry Geothermal plant will not significantly impact the water quality of East or Paulina Lakes.

Our plume drift study showed that no significant damage to plants surrounding the project area is expected.

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APPENDIX F-6
ESTIMATION OF TOTAL ANNUAL MASS EMISSIONS OF AIR POLLUTANTS FROM THE PROPOSED NEWBERRY GEOTHERMAL PROJECT

Prepared by Science Applications International Corporation (SAIC) for CEE, October 1993

Estimation of Total Annual Mass Emissions of Air Pollutants from the Proposed Newberry Geothermal Project

The calculation of the annual masses of pollutants originating from the proposed power plant is based on an average plant operation scenario. Actual operation data collected at a similar size plant in California (COSO) have been used for this analysis. Emission data were estimated from similar geothermal resources such as Medicine Lake, COSO, etc. Please refer to our previous reports describing the emission sources, emission rates, plant operating scenarios, and the impacts of H_2S and other pollutants. The average scenario used for this analysis is described below.

Power Plant

Based on COSO plant operation records during 1992, the plant is expected to be in normal operation 97.3% of the time. During normal operation, the plant emissions originate only from the cooling tower and the sulferox vessel. A quarter of the remaining 2.7% of the year (0.675%) corresponds to the plant upset condition and three quarters (2.025%) relate to plant shut-down for maintenance.

During 0.675% of the year, when the plant is in an upset condition, the emission control system is not in use and steam is venting through the plant silencer. During this time, only the plant silencer is operating. This operation corresponds to approximately 60 hours/year. Assuming 30 plant upset events per year, each event will last approximately 2 hours. Based on the proposed control procedures, which call for a 50% reduction within the first two hours and an additional 50% reduction within the first six hours, it is conservatively assumed that from 60 hours/year upset venting, 30 hours will be at full emission rate and 30 hours at 50% emission rate. This scenario is equivalent to 45 hours of venting at full rate.

Well Field

Well Bleeding During Plant Maintenance

During 2.025% of the year when the plant is shut down for maintenance, wells are kept at minimal bleed which corresponds to less than 1/3 of a well normal venting rate. The emissions will be originating from 6 wellhead silencers. This operation corresponds to approximately 177 hours/year at 1/3 full rate or 177/3= 59 hours at full rate for 6 wells or 59 x 6 = 354 hours for one well.

Well Venting and Testing

Based on the observed data, it is assumed that 6 wells will be venting 4 times per year for 24 hours or one well for 6 x 4 x 24 = 576 hours. Also, it is assumed that one replacement well per year will be tested in average for 30 days, corresponding to 30 x 24 = 720 hours. The total will be 576 + 720 = 1,296 hours.

Average Annual Emission Rate Calculation

Based on the above data, an emission factor can be calculated for each of the four emission sources to convert the source full emission rate to average annual emission rate, as described below.

Cooling Tower

The emission factor is simply the 97.3 percentage rate, or 0.973.

Sulferox Vessel

The emission factor is the same as for the cooling tower, or 0.973.

Plant Silencer

The emission factor is:

(45 hrs/yr) / (365 days/yr x 24 hrs/day) = 0.0051

Wellhead Silencers

The emission factor is:

(1,296 hrs/yr well venting/testing + 354 hrs/yr well bleeding)/
(365 days/yr x 24 hrs/day) = 1650/8760 = 0.1885

The mean annual total emission rate for each pollutant is the sum of emission rates for each source after being reduced by their respective factors. For example, the mean annual emission rate for H_2S is:

Cooling tower	(0.0160 g/s x 0.9730) +
Sulferox vessel	(0.0046 g/s x 0.9730) +
Plant silencer	(2.8100 g/s x 0.0051) +
Wellhead silencer	(0.3510 g/s x 0.1885)
	= 0.1006 g/s

Total Annual Emission Masses

The total annual emission mass of each pollutant is calculated by simply multiplying the average annual emission rate in g/s by the number of seconds in a year and convert the result to ton/year.

Table 1 shows the total annual emission masses of all pollutants including hydrogen sulfide. The results are presented both in metric and english tons. It must be noted that the calculations for Radon are performed using emission rates both in g/s and in Curies. The SO_2 emission rates are based on the emission rates of H_2S, assuming that all H_2S is converted to SO_2 at the point of entry into the atmosphere. In actuality, the typical lifetime of H_2S in the atmosphere before it is converted to SO_2 is 4 days. Emissions rates for PM_{10} and TSP are estimated based on the assumption that all particulate emissions are either in the PM_{10} or TSP size categories.

Table 1 also presents the full emission rates for three sources, namely a wellhead silencer, the sulferox vessel and the cooling tower. Note that the emission rate for the plant silencer which is active during plant upset condition is equivalent of 8 times that of a wellhead silencer (0.351 x 8 = 2.810 g/s for H_2S, for example).

Table 1. Air Pollutant Emission Rates and Mean Annual Total Masses

Pollutant	Chemical Symbol or Abbreviation	Source Full Emission Rate (g/sec) [3]			Average Annual Emission Rate (g/sec)	Tons/Year (Metric)	Tons/Year (English)
		Wellhead Silencer	Sulferox	Cooling Tower			
Hydrogen Sulfide	H_2S	0.3510	0.0046	0.0160	0.1006	3.17	3.50
Particles <10 μ	PM_{10} [1]	0.0390	0.0005	0.0050	0.0143	0.45	0.50
Sulfur dioxide	SO_2 [2]	0.664	0.0095	0.0309	0.1918	6.05	6.67
Carbon monoxide	CO	trace	trace	trace	trace	--	--
Ozone	O_3	trace	trace	trace	trace	--	--
Nitrogen dioxide	NO_2	trace	trace	trace	trace	--	--
Lead	Pb	9.35×10^{-7}	1.19×10^{-8}	1.19×10^{-7}	3.42×10^{-7}	1.08×10^{-5}	1.19×10^{-5}
Antimony	Sb	1.52×10^{-6}	1.95×10^{-8}	1.95×10^{-7}	5.58×10^{-7}	1.76×10^{-5}	1.94×10^{-5}
Arsenic	As	7.14×10^{-7}	9.15×10^{-9}	9.15×10^{-8}	2.62×10^{-7}	8.26×10^{-6}	9.11×10^{-6}
Beryllium	Be	8.56×10^{-7}	1.09×10^{-8}	1.09×10^{-7}	3.13×10^{-7}	9.88×10^{-6}	1.09×10^{-5}
Cadmium	Cd	9.35×10^{-7}	1.19×10^{-8}	1.19×10^{-7}	3.42×10^{-7}	1.08×10^{-5}	1.19×10^{-5}
Chromium	Cr	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	$<3.24 \times 10^{-8}$	$<1.02 \times 10^{-6}$	$<1.13 \times 10^{-6}$
Cobalt	Co	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	$<3.24 \times 10^{-8}$	$<1.02 \times 10^{-6}$	$<1.13 \times 10^{-6}$
Manganese	Mn	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	$<3.24 \times 10^{-8}$	$<1.02 \times 10^{-6}$	$<1.13 \times 10^{-6}$
Mercury	Hg	1.7×10^{-5}	9×10^{-5}	1×10^{-5}	1.01×10^{-4}	3.19×10^{-3}	3.52×10^{-3}
Nickel	Ni	$<9.0 \times 10^{-8}$	$<1.1 \times 10^{-9}$	$<1.1 \times 10^{-8}$	$<3.24 \times 10^{-8}$	$<1.02 \times 10^{-6}$	$<1.13 \times 10^{-6}$
Selenium	Se	1.3×10^{-6}	1.7×10^{-8}	1.7×10^{-7}	4.80×10^{-7}	1.52×10^{-5}	1.67×10^{-5}

Table 1. (continued)

Pollutant	Chemical Symbol or Abbreviation	Source Full Emission Rate (g/sec) [3]			Average Annual Emission Rate (g/sec)	Tons/Year (Metric)	Tons/Year (English)
		Wellhead Silencer	Sulferox	Cooling Tower			
Radon-222	^{222}Rn (Curies)	2.7×10^{-10} Ci	1.4×10^{-9} Ci	1.6×10^{-10} Ci	1.58×10^{-9} Ci	4.98×10^{-2} [4]	--
Radon-222	^{222}Rn (g/sec)	1.8×10^{-15}	9.1×10^{-15}	1.0×10^{-15}	1.03×10^{-14}	3.24×10^{-13}	3.57×10^{-13}
Boron	B	1.4×10^{-4}	1.9×10^{-6}	1.9×10^{-5}	5.25×10^{-5}	1.66×10^{-3}	1.82×10^{-3}
Ammonia	NH_3	2.71×10^{-3}	1.4×10^{-2}	1.6×10^{-3}	0.0158	0.50	0.55
Volatile Organic Compounds	VOC	4.44×10^{-7}	2.46×10^{-6}	2.67×10^{-7}	2.76×10^{-6}	8.69×10^{-5}	9.58×10^{-5}
Total Suspended Particles	TSP [1]	0.0390	0.0005	0.0050	0.0143	0.45	0.50

1. Assumed all particles are either in the PM_{10} or TSP size categories.
2. Assumed all H_2S converted to SO_2 at exit from stacks and silencers.
3. The emission rates from the Plant silencer are 8 times those from a wellhead silencer.
4. Expressed as the total number of Curies per year.

F-80

APPENDIX F-7
ANALYSIS OF POTENTIAL DEPOSITION AND PLUME DRIFT IMPACTS ON NEAR-PLANT VEGETATION — NEWBERRY GEOTHERMAL PROJECT

Prepared by Science Applications International Corporation (SAIC) for CEE, November 1993

Analysis of Potential Deposition and Plume Drift Impacts on Near-Plant Vegetation - Newberry Geothermal Project

This summary report is prepared to quantify the potential impacts on the vegetation near the proposed plant site from the deposition of material from air emissions. Effects of both direct plum contact and particulate fallout (plume drift) deposition are taken into account. The pollutants studied are: hydrogen sulfide (H_2S), boron (B), arsenic (As), and mercury (Hg).

Detailed description of emission sources, plant operation scenarios, and impacts of H_2S and other air pollutants can be found in SAIC's previous reports.

Average Annual Emission Rates

The emission rate calculation is based on an average annual plant operation scenario which includes emissions from the cooling tower and the sulferox vessel which operate during pant normal operation, and from the plant silencer which operates only during plant upset events. The average annual emission rates from the cooling tower and sulferox vessel are calculated based on plant normal operation during 97.3% of a year. The plant silencer average annual emission rate is based on being operational during 0.675% of the year or approximately 60 hours/year (the remaining 2.025% of the year corresponds to plant shutdown for maintenance). Conservatively assuming 30 hours of venting at full emission rate and 30 hours at 50% emission rate, leads to an equivalent of 45 hours of venting at full rate. These data are the result of one year observation at the CE Exploration Coso plant in California. Table 1 summarizes the pollutant average annual emission rates for each source. The table also includes TSP (Total Suspended Particles) which will be used for plume drift estimations. Note that the emission rates in Table 1 are calculated by multiplying the full emission rate for each source by the source frequency of operation at full rate. For example, the average annual emission rate of H_2S for the plant silencer is (2.810 g/s) x ((45 hr/yr)/(8,760 hr/yr)) = 2.810 g/s x 0.0051 = 0.0143 g/s.

Table 1. Average Annual Source Emission Rates

Pollutant	Chemical Symbol or Abbreviation	Source Average Annual Emission Rate (g/sec)		
		Cooling Tower	Sulferox Vessel	Plant Silencer
Hydrogen Sulfide	H_2S	1.56×10^{-2}	4.48×10^{-3}	1.43×10^{-2}
Arsenic	As	8.90×10^{-8}	8.90×10^{-9}	2.91×10^{-8}
Mercury	Hg	9.73×10^{-6}	8.76×10^{-5}	6.94×10^{-7}
Boron	B	1.85×10^{-5}	1.85×10^{-6}	5.71×10^{-6}
Total Suspended Particles	TSP	4.87×10^{-3}	4.87×10^{-4}	1.59×10^{-3}

Average Annual Concentrations at Selected Receptors

To estimate the deposition impacts, a total of nine receptor points along three dominant wind directions were considered. The three dominant wind directions, based on one year meteorological data collected at the project site, are from South, West and Southeast (toward North, East and Northwest). Along each dominant wind direction, were considered three receptor points located at 500 m, 1000 m and 1500 m from the project site. The receptors are labelled N500, N1000, N1500, E500, E1000, E1500, NW500, NW1000 and NW1500. Refer to SAIC's report on H_2S emission impacts titled: "Hydrogen Sulfide Impact Due to Proposed Geothermal Development", which includes project site windroses.

Six of the receptors (N1000, N1500, E500, E1000, and E1500) are located at elevations above the highest stack top elevation, for which a complex terrain model must be used. COMPLEX-1 model was used to estimate the mean annual concentrations at these points. The remaining receptor points, N500, NW500, NW1000 and NW1500, are located at elevations equal to or below the project site elevation, for which a simple terrain model must be used. ISCST2 model was used to estimate the average pollutant impacts at these four points. One year of real meteorological data collected at the site was used for modeling.

Since the emission distribution among the three sources were not similar for all pollutants, three model runs were performed for H_2S, mercury and boron. The impacts of arsenic and TSP, which had a similar distribution to that of boron, were calculated by multiplying the results for boron by the ratio of their respective emission rates.

The average annual pollutant concentrations at receptor points, predicted by one of the two models (COMPLEX-1 and ISCST2) are given in Table 2. Appendix A, presents the model output printouts.

Annual Dry and Wet Deposition at the Receptors

Based on a conservative dry deposition rate of 3 cm/sec, the average annual concentrations, predicted by modeling, were used to calculate the annual dry deposition at each receptor point. The wet deposition was conservatively assumed to be equal to the calculated dry deposition and thus, the dry deposition was doubled to give the total wet and dry deposition. Calculations are based on the following formula:

Total Annual Deposition (lb/acres/yr) = 2 x [Ambient Concentration ($\mu g/m^3$)] x [Deposition Velocity (cm/sec)] x .01 m/cm x 4,046.87 m^2/acre x 31,536,000 sec/yr x 2.205E-9 lb/μg)

Annual Plume Drift Deposition

The average annual emission rate of suspended particles (TSP) originating from the total dissolved solid content of geothermal steam and cooling tower circulating water (as shown in Table 2), is the sum of emissions from the three sources or 0.00487 + 0.00049 + 0.00159 = 0.00695 or 0.007 g/s. This emission rate corresponds to a total annual particulate emission of (0.007 g/s) x (31,536,000 s/yr) / (453.5 g/lb) = 487 lb/year.

If we conservatively assume that 50 percent of the drifting droplets have a diameter greater than 200 microns which would fall out in the plant surrounding area, then the mass of settling particles will be 487 x 0.5 = 244 lb/year. Analysis of plume drift for a similar proposed geothermal development in the Vale, Oregon area indicated that the impact would be insignificant beyond a distance of 500 m from the plant site (Cooper, J.A. et al., 1980). The nearest receptors considered in the present study which are at a distance of 500 m from the plant site are, therefore, not expected to be impacted by the plume drift deposition. However, if we assume a uniform fallout over the corresponding surface area (π x (0.5 km)^2 = 0.785 km^2 or 196 acres) the impact of drift deposition on the nearest receptors would be (487 lb/yr)/(196 acres) = 2.48 lb/acre/year.

According to an estimate of geothermal fluid and cooling tower circulating water chemical constituents for the Coso plants in California (Goddard & Goddard, 1988) the approximate percentage of boron, arsenic and mercury in the total dissolved solid content of the cooling tower circulating water is 9.8%, 0.02% and 0.02%, respectively. Based on these numbers, the drift deposition corresponding to these elements can be estimated, as follows:

Boron	2.48 lb/acre/yr x 0.098 = 0.24 lb/acre/yr
Arsenic	2.48 lb/acre/yr x 0.0002 =0.0005 lb/acre/yr
Mercury	2.48 lb/acre/yr x 0.0002 =0.0005 lb/acre/yr

These numbers, representing the annual drift deposition of B, As and Hg, will be added to the corresponding total wet and dry deposition values, calculated for the three nearest receptors (N500, E500 and NW500).

Table 2 summarizes the results of calculations. The average annual concentrations and total annual depositions are given at each receptor point.

Discussion and Conclusion

As can be seen in Table 2, average annual concentrations and total annual depositions of hydrogen sulfide, boron, arsenic and mercury, are very small values. It should be noted that the very conservative estimates of particulate fallout contribution (plume drift) dominate the deposition values for boron and arsenic, and a significant fraction of mercury values, at the 500 m receptor points. Based on a cursory review of vegetative damage thresholds (Leitner, 1984), it appears that vegetative impact from the proposed plant emissions will be insignificant at the 500 m receptor sites and beyond.

Table 2. Air Pollutant Emission Rates and Mean Annual Total Masses

Receptor	H_2S		Boron		Arsenic		Mercury	
	Average Annual Concentration ($\mu g/m^3$)	Total Annual Deposition (lb/acre)	Average Annual Concentration ($\mu g/m^3$)	Total Annual Deposition (lb/acre)	Average Annual Concentration ($\mu g/m^3$)	Total Annual Deposition (lb/acre)	Average Annual Concentration ($\mu g/m^3$)	Total Annual Deposition (lb/acre)
N500	1.66×10^{-3}	2.80×10^{-2}	6.80×10^{-7}	2.40×10^{-1}	3.32×10^{-9}	5.00×10^{-4}	3.00×10^{-5}	1.01×10^{-3}
N1000	6.30×10^{-4}	1.06×10^{-2}	3.30×10^{-7}	5.57×10^{-6}	1.61×10^{-9}	2.72×10^{-8}	5.43×10^{-6}	9.17×10^{-5}
N1500	3.60×10^{-4}	6.08×10^{-3}	1.80×10^{-7}	3.04×10^{-6}	8.78×10^{-10}	1.48×10^{-8}	2.48×10^{-6}	4.19×10^{-5}
E500	5.42×10^{-3}	9.15×10^{-2}	2.29×10^{-6}	2.40×10^{-1}	1.12×10^{-8}	5.00×10^{-4}	9.95×10^{-5}	2.18×10^{-3}
E1000	1.85×10^{-3}	3.12×10^{-2}	7.90×10^{-7}	1.33×10^{-5}	3.85×10^{-9}	6.51×10^{-8}	2.77×10^{-5}	4.68×10^{-4}
E1500	1.09×10^{-3}	1.84×10^{-2}	4.60×10^{-7}	7.77×10^{-6}	2.24×10^{-9}	3.79×10^{-8}	1.42×10^{-5}	2.40×10^{-4}
NW500	3.11×10^{-3}	5.25×10^{-2}	1.28×10^{-6}	2.40×10^{-1}	6.24×10^{-9}	5.00×10^{-4}	6.04×10^{-5}	1.52×10^{-3}
NW1000	1.34×10^{-3}	2.26×10^{-2}	6.00×10^{-7}	1.01×10^{-5}	2.93×10^{-9}	4.94×10^{-8}	1.67×10^{-5}	2.82×10^{-4}
NW1500	7.70×10^{-4}	1.30×10^{-2}	3.60×10^{-7}	6.08×10^{-6}	1.76×10^{-9}	2.97×10^{-8}	7.72×10^{-6}	1.30×10^{-4}

References

Cooper, J.A. et al., Oregon Geothermal Overview Study, Oregon Graduate Center report to Lawrence Livermore Laboratory, 1980

Goddard & Goddard Engineering, Air Quality Impact and Health Effects Assessment in Support of Authority to Construct for BLM NWC #2 Geothermal Power Plant Units 1 and 2, 1988.

Leitner, B.M., An Assessment of Operational Effects on Vegetation, China Lake Joint Venture Geothermal Power Plant Project, submitted to California Energy Company, Santa Rosa, CA., 1984

APPENDIX F-8
PREDICTION OF COOLING TOWER PLUME DIMENSIONS USING THE EPRI COOLING TOWER PLUME PREDICTION MODEL (SACTI)-NEWBERRY GEOTHERMAL PILOT PROJECT

Prediction of Cooling Tower Plume Dimensions Using the EPRI Cooling Tower Plume Prediction Model (SACTI) Newberry Geothermal Pilot Project

Introduction

This report summarizes the results of our modeling of the Newberry Pilot Project cooling tower plume.

The EPRI model "Cooling Tower Plume Prediction Code", also known as SACTI (Seasonal and Annual Cooling Tower Impacts), was used to predict the probable dimensions of visible cooling tower plume. The model was developed by Argonne National Laboratory in the early 1980s on behalf of EPRI. The IBM personal computer version of the model was used.

The model consists of four components or sub-models which run individually. The first component (PREPROCESSOR) reads and analyses the meteorological data and prepares the input met data file for the next component. The main program (PLUME or MULT) reads the user input data and the processed meteorological data and generates output files. A third component (TABLES) converts the output data into frequency tables and, finally, the fourth program prepares contour plots of the tabulated data.

Meteorological Data

The model SACTI requires at least one year of meteorological data, but can also run with fewer days of data. The hourly meteorological data collected at the Newberry project site from 9-26-92 to 8-13-93 were used (approximately 320 days).

The model requires the ambient temperature, the wind speed and direction, the relative humidity, and the mixing heights. The Newberry site meteorological data file included these data except for mixing heights. The daily mixing height data was generated by using published monthly values. The meteorological data needed to be prepared in two specifically formatted files.

Model Input Data

All input data used for this modeling were provided by CE Exploration project documentation and from CE Exploration personnel. Some model input parameters were calculated from these data.

The main input parameters required by the model and their corresponding data are listed below.

Land data:	
Site latitude and longitude	44, 121
The land roughness height	283 (for trees)
Insolation data:	
12 monthly clearness index	(data from model manual)
12 daily insolation for each month	(data from model manual)

Cooling Tower Data:

Type of cooling tower	Linear Mechanical Draft
Tower effective height	15.2 m
Tower effective exit diameter	17.73 m
Tower effective heat rejection	198 MW
Tower effective air flow	4963 kg/s
Number of cooling tower Cells	7
Length/width of cooling tower Housing	106.7 m / 15.2 m

A coordinate system was considered with its origin located at the center of the site. The X and Y coordinates of the center of the cooling tower and each cell were input into the model. Also three representative wind directions at 0, 45, and 90 degrees from north, relative to the cooling tower housing orientation, were considered. A distance of 10,000 m was input as the maximum distance for calculations.

The input data for clearness and insolation are provided in the model manual for a number of cities in the United States. The data for the city of Boise (Idaho) were judged to be most representative of the project site area.

The model was set up to predict the plume dimensions for the entire length of the meteorological data. Due to missing relative humidity data for a number of days, it was not possible to run the model for specific seasons of the year. However, for comparison purposes, the model was also run separately for two months of July and January representing summer and winter.

Modeling Results

From analyzing the meteorological data, SACTI recognizes a number of meteorological categories which will generate a given plume with specific dimensions. From the Newberry meteorological data, 28 such categories were found.

The first model tabulated output is three tables giving the predicted plume dimensions for the three representative wind directions (at 0, 45, and 90 degrees). The model also outputs the frequency of the categories by wind directions, and other tables summarizing the meteorological conditions.

The model output also consists of a number of tables providing the frequencies of the plume being greater than a certain length, height, or radius. The plume length is measured horizontally; the height is measured vertically from the top of the cooling tower and the plume radius represents half of its vertical thickness. The tables give the frequency as a function of wind direction and distance from the cooling tower or height from the tower.

The frequency tables along with some other tables giving the hours of shadowing, etc. are included following this document.

The following frequency tables are also presented in contour graphic form:

Plume length frequency:	the probability that the visible plume will be longer than a given distance
Hours of plume shadowing:	the number of hours of plume shadowing at a given distance
Total solar energy loss:	total solar energy lost on a horizontal surface (in MJ/m^2) at a given distance

Discussion

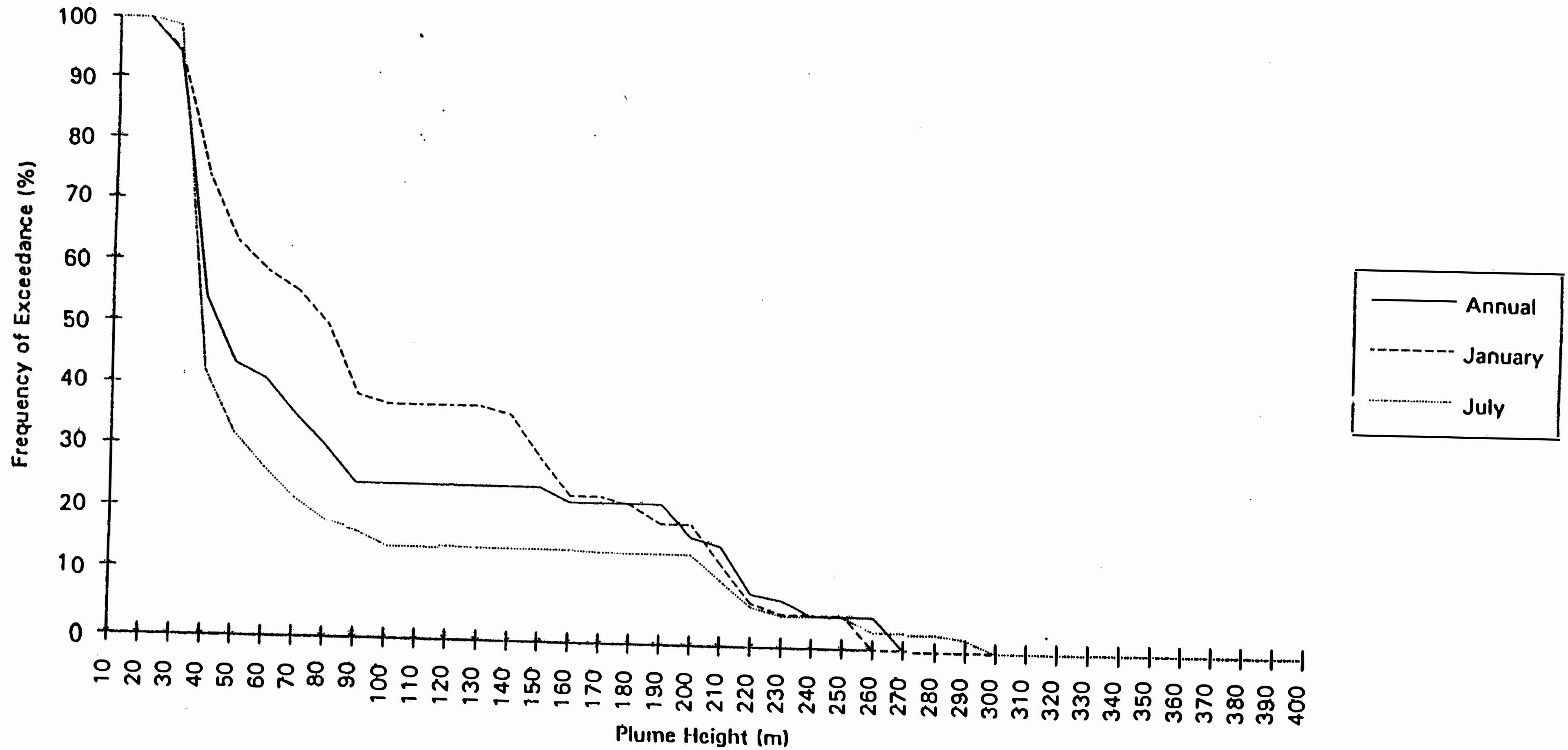
From the model output tables, the following plots have also been generated:

Figure 1.	The plume height exceedance frequency for the entire observation period (annual) and for a winter (January) and a summer (July) month.
Figures 2, 3, 4.	Same data plotted as plume height frequency for 10 m, 100 m, and 150 m (histograms) height categories.

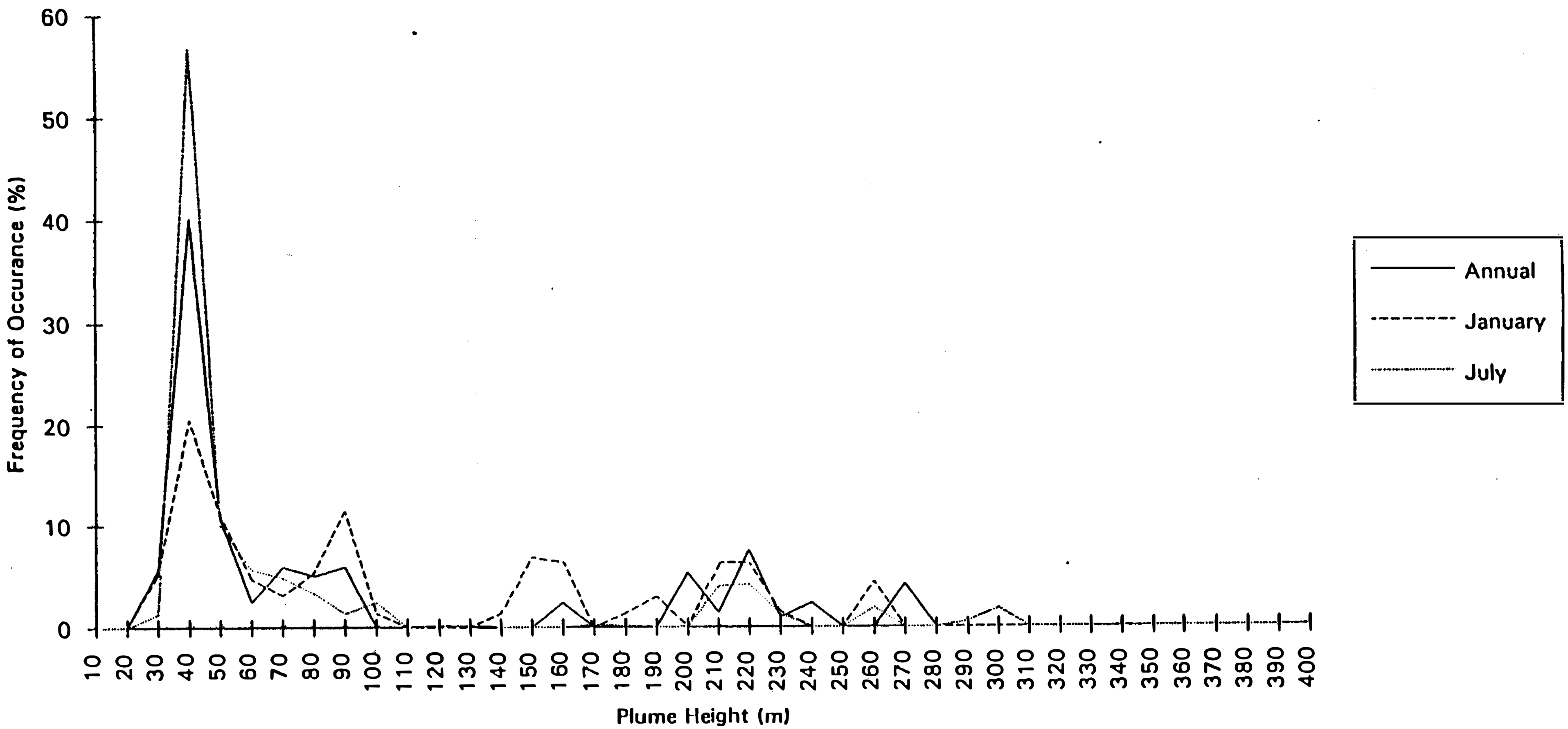
As Figures 1 through 4 show, the frequency of the plume to exceed a given height is above the annual curve in winter and below the annual curve in summer. It must be noted that the data for July corresponds to an exceptionally wet summer. Thus, the plume height frequency in an average summer may be expected to be generally lower.

From Figure 1 it can be estimated that there is a 90% chance that the plume height will be below 210 m. The median value of the series is approximately 45 m (corresponding to 50% frequency).

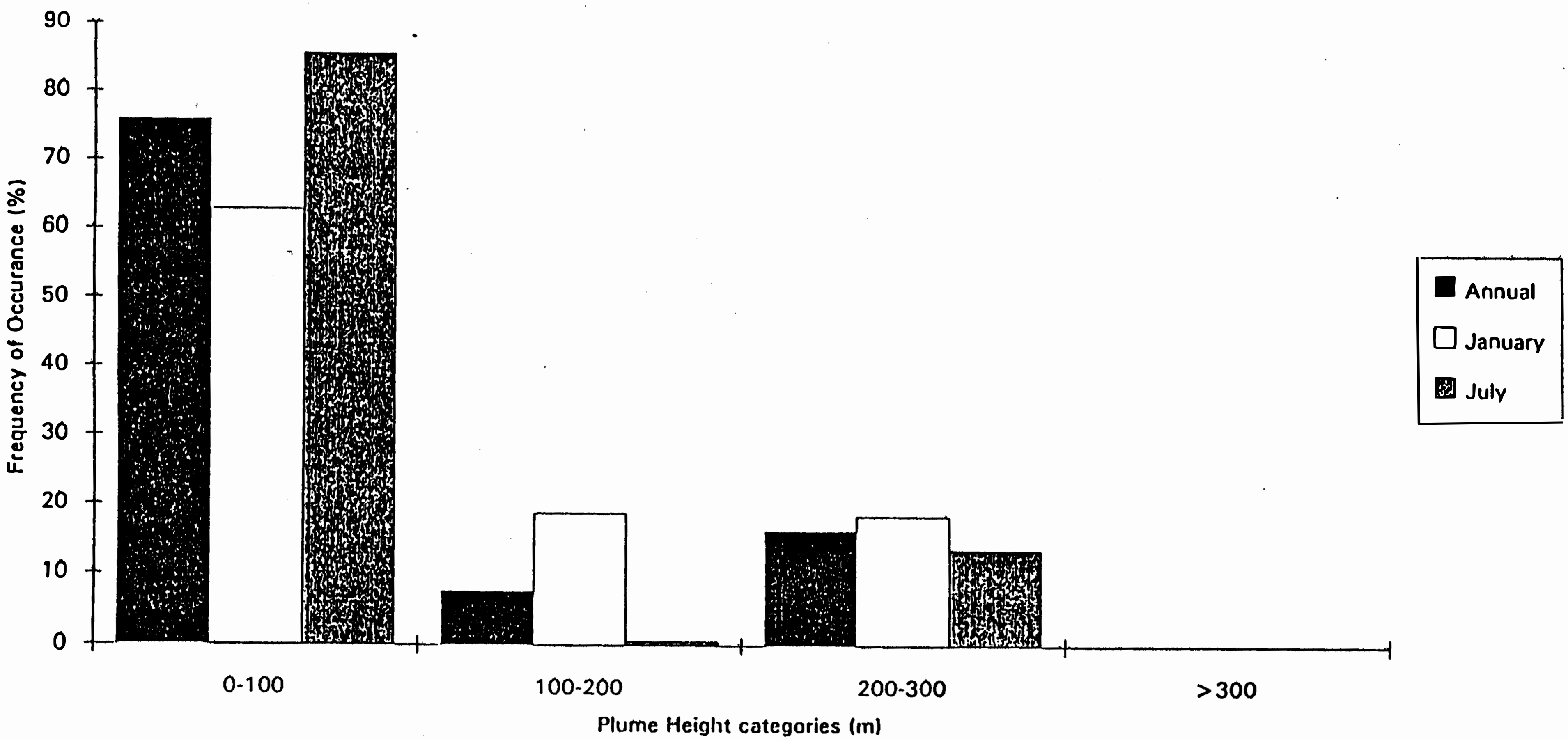
Plume Height Exceedance Frequency

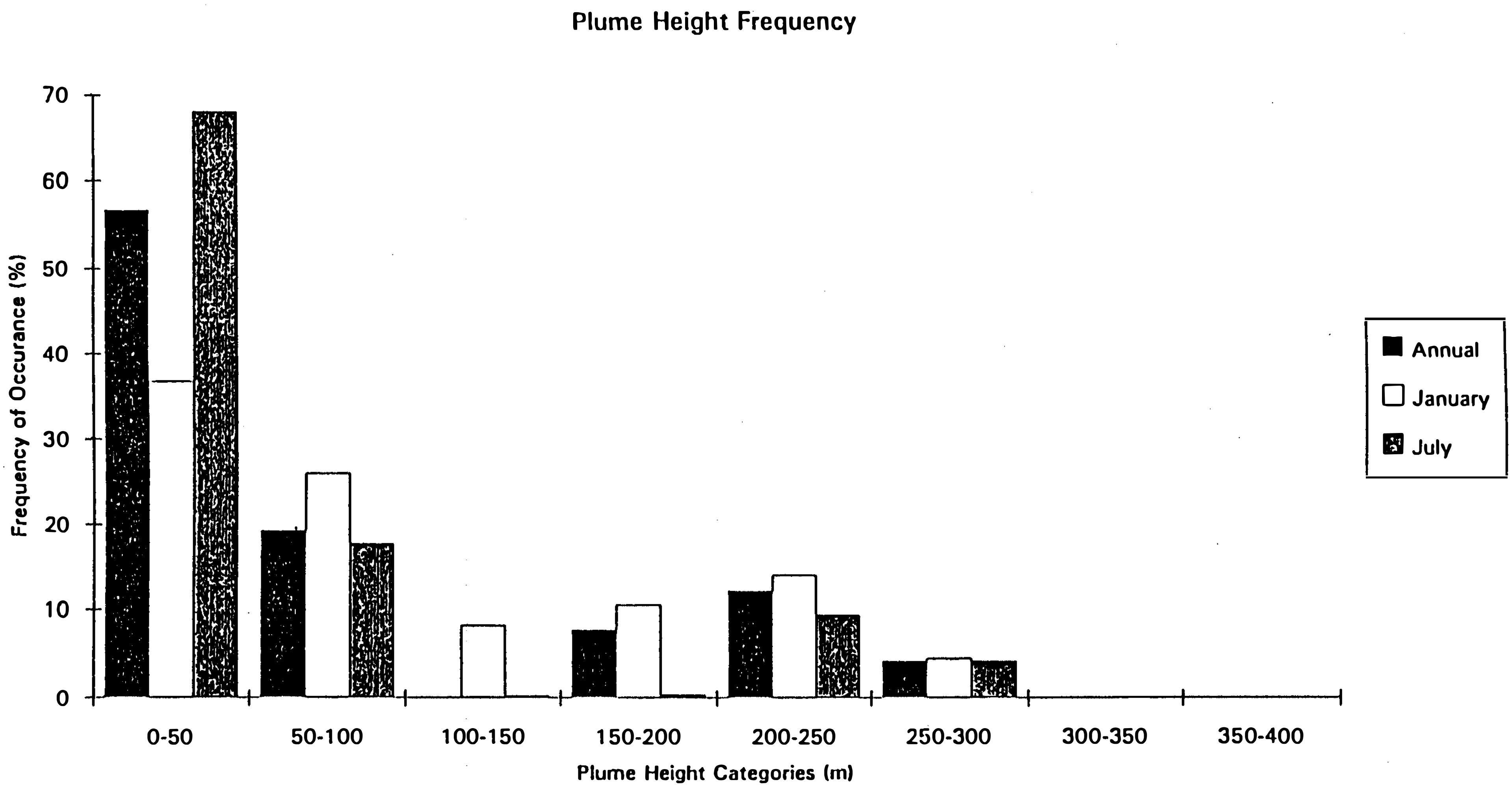


Plume Height Frequency



Plume Height Frequency




Plume Height Frequency
Frequency of Occurance (%)
0
10
20
30
40
50
60
70
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
Plume Height Categories (m)
Annual
January
July

APPENDIX G
METHODS FOR HYDROLOGIC BASELINE DATA COLLECTION

APPENDIX G
METHODS FOR HYDROLOGIC BASELINE DATA COLLECTION

NEWBERRY HYDROLOGY BASELINE STUDY METHODOLOGY
Dames & Moore, Portland, Oregon

Task 1: Data Collection and Data Report

Available hydrogeologic data for the area was compiled and collated to provide a summary data report of findings, including a map illustrating the location of any known domestic, agricultural, public, and geothermal wells; a series of tables describing hydrologic and geothermal data based on well logs; a bibliography of pertinent publications on the project area; and a listing of information sources and contacts. Data on groundwater levels and groundwater quality in addition to well depth and screened intervals were recorded. A field reconnaissance was performed to gain a better understanding of the locations of geothermal features, USGS monitoring points, groundwater wells, and general hydrogeologic and geologic conditions.

Task 2: Data and Impacts Evaluation

Based on the data collected in Task 1, additional data tables and geologic and hydrologic maps of the area were generated. These tables and maps display the spatial extent and variations in characteristics such as water levels, water quality, and other distinguishing physical parameters for identifiable water-bearing zones within the study area.

The tables, maps and other available data and interpretations were used to evaluate the potential interaction between the cold meteoric water system(s) and the geothermal system present within the study area. The evaluation focused on the characteristics which distinguish these systems such as temperature and water chemistry; characteristics which provide potential paths for communication or separation, such as faulting, vertical permeability and mineralized zones; and evidence for existing interaction such as the presence of chemically mixed waters or system hydraulics.

In addition, an evaluation was performed for the potential for interaction between the cold groundwater systems and the geothermal system as a result of exploitation of the geothermal system to supply a power plant. The evaluation included the impact of this interaction on the water quality and hydraulics of the cold groundwater system, as well as on the surface manifestations of the geothermal systems. The impact on key environmental issues identified in Task 1 was evaluated to the extent that data was available. In particular, the potential impacts which could affect the recreational, domestic or agricultural use of the cold groundwater system were identified.

Task 3: Preparation of Hydrology Baseline Report

The Hydrology Baseline Report was prepared, including:

- A compilation of existing data
- Collation of pertinent publicly available data interpretations
- Results of field review and ground truthing of existing data
- Identification of key environmental issues
- Tables and maps of reviewed geological and hydrological information
- Data analysis and interpretation including both existing and potential for interaction between the cold groundwater and geothermal systems resulting from geothermal development and the potential impact of interaction on environmental issues

APPENDIX H
HUMAN HEALTH AND SAFETY

Note: Material Safety Data Sheets (MSDSs) are not included here but are available for viewing in the project file.

TABLE H-6
Potential Materials and Waste Class
Sulferox-type Hydrogen Sulfide Abatement System

Material/Chemical Name	California Waste Class	Oregon Waste Class
Dow IC-110/chelate w/5% iron	Non-hazardous	Non-hazardous
Dow IC-210/chelate solution	Non-hazardous	Non-hazardous
Dow CA-100/degradation inhibitor/surfactant	Hazardous	Hazardous
Dow CA-2101/flocculent	Non-hazardous	Non-hazardous
Dow CS-299/surfactant	Hazardous	Non-hazardous
Caustic soda solution	Hazardous	Hazardous
Activated carbon	Non-hazardous	Non-hazardous

01-Jun-94

Table H-1

CHEMICALS USED & WASTE GENERATED BY A 33 MW GEOTHERMAL PLANT

DRILLING CHEMICALS (per 4000-foot-deep well, 60 days on location per well)

MATERIAL/CHEMICAL NAME/PACKAGING	UNITS	VOLUME	FREQUENCY	TRUCK DELIVERY SCHEDULE	TOTAL	WASTE CLASS HAZARDOUS(H) OR NON-HAZARDOUS(N) OREGON
M-I Gel/Bentonite (100# sacks)	lbs	169000	bi-monthly	2 trucks/mo.	169000	N
Tannathin/Lignite,Leonardite (50# sacks)	lbs	2350	"	1 truck/6 mo.	2350	N
Caustic Soda (50# sacks)	lbs	450	"	1 truck/year	450	N
Lime (50# sacks)	lbs	1450	"	1 truck/year	1450	N
Salt,NaCl,fine evaporated (100# sacks)	lbs	86500	"	1 truck/mo.	86500	N
Sodium Bicarbonate (100# sacks)	lbs	600	"	1 truck/year	600	N
Sulfotex PAI/Ammonium Alcohol Sulfate(drums)	gal	220	"	1 truck/6 mo.	220	N
SI 1000/Organic Phosphate Blend (drums)	gal	110	"	1 truck/6 mo.	110	N
Diesel fuel (tanker w/trailer:7500gal)	gal	6000	weekly	1 truck/week	48000	N
30-wt Engine Oil (drums)	gal	675	bi-monthly	1 truck/6 mo.	675	N
90-wt Gear Oil (drums)	gal	120	"	1 truck/6 mo.	120	N
Turbine Hydraulic Oil (drums)	gal	110	"	1 truck/6 mo.	110	N
Dextron-2 compressor oil (drums)	gal	55	"	1 truck/6 mo.	55	N
Kopr-Kote Thread Dope (5-gal buckets)	gal	60	"	1 truck/6 mo.	60	N
Lithium-Base EP Grease (14-oz tubes)	tube	120	"	1 truck/year	120	N
Anti-Freeze/Ethylene Glycol (drums)	gal	55	"	1 truck/6 mo.	55	N

STORAGE OF CHEMICALS & WASTES

All storage will be contained on drilling site. Drums and dry palletted chemicals will be set inside earth berms. Berms will also contain liquid runoff from rig generator and air compressor skids and will channel all to the clay-lined drilling sump.
Drums" refers to 55-gal size steel or plastic containers unless otherwise noted.
For chemicals that are used in smaller volumes (eg. 1-500 pounds per well), a delivery normally contains several types of chemicals to avoid excessive truck travel.

WASTE STREAM

MATERIAL/CHEMICAL NAME/PACKAGING	UNITS	VOLUME	FREQUENCY	TRUCK DELIVERY SCHEDULE	TOTAL	WASTE CLASS
Cuttings w/used drilling mud (if disposed of on-site and re-vegetated, no trucking would be necessary)	cu-ft	8100	bi-monthly	---	8100	N
Used Engine/Gear/Hydraulic Oil(by tank truck)	gal	480	bi-monthly	1 truck/3mo.	480	N
Municipal-Type dry waste (roll-off bins)	cu-yd	53	monthly	1.5 trucks/mo.	110	N
Empty drums (55 gal size)	each	12	bi-monthly	1 truck/3 mo.	12	

[redacted]un-9[redacted]

CHEMICALS USED & WASTE GENERATED BY A 33 MW GEOTHERMAL PLANT (MEDICINE LAKE OR NEWBERRY)
PLANT MAINTENANCE, INCLUDING TURBINES, COMPRESSORS, TRUCKS, CRANES & ROAD MAINTENANCE EQUIPMENT

MATERIAL/CHEMICAL NAME/PACKAGING	UNITS	VOLUME	FREQUENCY	TRUCK DELIVERY SCHEDULE	YEARLY TOTAL	WASTE CLASS HAZARDOUS(H) OR NON-HAZARDOUS(N) OREGON
Unleaded Gasoline (bulk 4000 gal tank)	gal	900	monthly	4000gal/ 4mo.	10800	N
Diesel Fuel (bulk 4000 gal tank)	gal	2000	"	4000gal/ 2mo.	24000	N
Shell Turbo 32 Oil (2000gal in 275 gal totes)	gal	100	"	1 truck/6 mo.	1200	N
Shell Turbo 68 Oil (5 gal pails)	gal	1	"	"	12	N
Shell Turbo 100 Oil (drums)	gal	12	"	"	144	N
Shell Turbo 150 Blower Oil(275gal totes)	gal	12	"	"	144	N
Shell Tellus 68 Oil (5 gal pails)	gal	1	"	"	12	N
Shell Rotella 15w40 Oil (275 gal totes)	gal	10	"	"	120	N
30wt Engine Oil (drums)	gal	50	"	"	600	N
Shell Kerosene Solvent (drum)	gal	5	"	"	60	N
Shell Donex TD Hydraulic Oil (drum)	gal	10	"	"	120	N
AW-46 Hydraulic Oil (drum)	gal	5	"	"	60	N
Chevron ISO-46 Hydraulic Oil (drum)	gal	5	"	"	60	N
Anti-Freeze/Ethylene Glycol (drums)	gal	7	"	"	84	N
Mobil Heavy Medium Oil (5 gal pails)	gal	1	"	"	6	N
Mobil 632 Gear Oil for Tower Gearboxes(drums)	gal	20	"	"	240	N
Summit SH-46 Air Compressor Oil (5 gal pails)	gal	2	"	"	24	N
LPS Cleaner/Degreaser Oil (20-oz cans)	each	20	"	"	240	N
Liquid Gasket Remover (20-oz cans)	each	1	"	"	12	N
Starting Fluid/Ether (20-oz cans)	each	1	"	"	12	N
Chevron EP Grease (14-oz tubes)	each	5	"	"	60	N
Shell Wheel Bearing Grease (5-gal bucket)	gal	0.4	"	"	5	N
Brake Fluid (5 gal can)	gal	0.1	"	"	1	N
Petroleum Distillate Degreaser (15-oz can)	each	1	"	"	12	N
Cleaning Solvent/petroleum distillate (drum)	gal	5	"	"	60	N
Automatic Transmission Fluid/Oil (drum)	gal	1	"	"	12	N
Battery Acid/Sulfuric Acid (5gal plastic pak)	gal	0.1	"	"	1	N
Sodium Bicarbonate (50 lb bag)	lb	50	"	"	600	N
Acetylene Gas, Welding (240cu-ft bottles)	cu-ft	240	"	"	2880	N
Oxygen Gas, Welding (240cu-ft bottles)	cu-ft	240	"	"	2880	N
Argon Gas, Welding (240cu-ft bottles)	cu-ft	240	"	"	2880	N
Nitrogen Gas, Welding (240cu-ft bottles)	cu-ft	240	"	"	2880	N
Go-Jo Hand Cleaner (4.5 lb container)	lb	4	"	"	48	N
Furniture Polish (20 oz. cans)	each	1	"	"	12	N
Floor Cleaner/Finish (1 gal jugs)	gal	1	"	"	12	N
Spray & Wipe Cleaner (1 gal jugs)	gal	0.5	"	"	6	N
Pine Odor Disinfectant (1 gal jugs)	gal	0.5	"	"	6	N
Blue Ammonia Glass Cleaner (1 gal jugs)	gal	1	"	"	12	N
Lemon Liquid Dishwashing Detergent (32 oz bottles)	each	0.5	"	"	6	N
Toilet Bowl Cleaner (1 gal jugs)	gal	1	"	"	12	N
Liquid Bleach (1 gal jugs)	gal	0.5	"	"	6	N
Floor Wax Stripper (1 gal jugs)	gal	0.5	"	"	6	N
Pink Liquid Hand Soap (1 gal jugs)	gal	1	"	"	12	N

STORAGE OF CHEMICALS AND WASTES

Fuels are to be stored in above-ground 4000 gal steel tanks stored in a concrete firewall/containment pad having 1.5 times the storage capacity of the largest tank. The 275-gal totes are to be stored either next to the blowers or inside the maintenance building near the door. Compressed gas bottles are to be chained upright to a rack fastened to the outside of a building. Sewage is to be handled by a buried septic tank system.

WASTE STREAM

Used Engine/Gear/Hydraulic Oil(by tank truck)	gal	60	monthly	1 truck/3 mo.	720	N
Municipal-Type dry waste (40 cu-yd roll-off bins)	cu-yd	24	"	1 truck/mo.	288	N
Empty Oil Drums (55 gal size drums)	each	3	"	1 truck/6 mo.	36	N

01-Jun-94

CHEMICALS USED & WASTE GENERATED BY A 33 MW GEOTHERMAL PLANT

Table H-3

PRODUCTION/FIELD GATHERING SYSTEM CHEMICALS

MATERIAL/CHEMICAL NAME/PACKAGING	UNITS	VOLUME	FREQ.	DELIVERY SCHEDULE	YEARLY TOTAL	WASTE CLASS HAZARDOUS(H) OR NON-HAZARDOUS(N) OREGON
Seaco 3530C/Polymaleic Acid (550gal totes)	gal	62	weekly	1 truck/4 mo.	3224	N
Seaco 3531/Dilute Polymaleic Acid (bulk tank)	gal	1944	monthly	**** see note	23328	N
Seaco 3550 Silica Inhibitor/Acrylate(275gal tote)	gal	69	"	1 truck/4 mo.	828	N
Seaco 2451/Corrosion Inhibitor/Imidiazoline & Isopropanol (275 gal totes)	gal	28	"	1 truck/9 mo.	336	N
Drew Biosperse 250/Dithiocarbamate (275 gal totes)	gal	80	"	1 truck/3 mo.	960	N
Caustic Flake (50 lb bags)	lbs	50	bi-monthly	1 truck/year	300	N

STORAGE OF CHEMICALS & WASTE

Polymaleic acid solution is to be stored in insulated 6000 gallon tanks housed in a centrally located building in the field gathering system. Chemicals from the tanks will be injected into the wells through insulated capillary tubing on the pipe supports that convey the well production flows to the plant.

*** Delivery of the 3531 is not applicable, as it can be diluted on site with water. Only the concentrate, Seaco 3530C, is brought in by truck. The totes are to be stored in heated buildings and are re-usable.

WASTE STREAM

All production chemicals are eventually disposed of in the injection wells as water is circulated through the gathering and plant piping. Paper waste is disposed of in the Plant Maintenance waste disposal bins. With the high wellbore temperature in the zone of injection and dilution with water, the injected chemicals break down to the following non-hazardous components:

Seaco 3531: goes to a maleate (carboxylate) compound
Seaco 3550: goes to an acrylic monomer
Seaco 2451: goes to a very low concentration ammonia compound
Drew Biosperse 250:
Caustic Soda: goes to dissociated Na and OH ions in water

Table H-4

01-Jun-94

CHEMICALS USED & WASTE GENERATED BY A 33 MW GEOTHERMAL PLANT

SULFEROX TYPE HYDROGEN SULFIDE ABATEMENT SYSTEM
(Based on 30,000 lb/hr of non-condensible gas, hydrogen sulfide content of 8,000 ppm by weight and 1.5 tons/day of elemental sulfur.)

MATERIAL/CHEMICAL NAME/PACKAGING	UNITS	VOLUME	FREQUENCY	TRUCK DELIVERY SCHEDULE	YEARLY TOTAL	WASTE CLASS HAZARDOUS(H) OR NON-HAZARDOUS(N) OREGON
Dow IC-110/Chelate w/5% iron (4000 gal. tank)	gal	140	daily	1 truck/mo.	51100	N
Dow IC-210/Chelate Solution (2500 gal. tank)	gal	75	"	"	27375	N
DowCA-100/Degradation Inhib./Surfactant(1000 tank)	gal	19	"	1 truck/3 mo.	6935	N
Dow CA-2101/Flocculent (500 gal tank)	gal	2	"	1 truck/6 mo.	730	N
Dow CS-299/Surfactant (500 gal. tank)	gal	2	"	1 truck/6 mo.	730	N
Caustic Soda Solution (500 gal tanker)	gal	45	weekly	1 truck/3 mo.	2340	N
Activated Carbon(IF NECESSARY) (drums)	lb	6000	per 18 mo.	1 truck/18mo.	4000	N

STORAGE OF CHEMICALS & WASTE

All Chemicals are to be stored in fiberglas bulk tanks inside a coated, concrete basin next to the Sulferox filter skid. The bulk storage tanks will be either enclosed in a building or heat-traced. The raw sulfur produced is non-hazardous and will pass from the filter skid directly into steel roll-off bins (25,000 lb gross weight) and then hauled off every 2 weeks for sale to farmers. Activated carbon is needed only if mercury is encountered in the produced gas and is shipped and stored in 30 re-usable 55 gal drums every 18 months.

WASTE STREAM

All chemicals are reacted in the process to form elemental sulfur and water. The sulfur will be sold to agricultural users as a soil amendment and the water will be partly recycled in the process and partly reinjected into disposal wells with the produced brine.

If mercury is encountered (and so far there is no evidence of mercury in the steam/gas/water production stream), then the used activated carbon will be hazardous in California (and probably in Oregon as well).

EXPECTED LABORATORY CHEMICAL INVENTORY FOR A 33 MW GENERATING FACILITY (AVERAGE CHEMICALS USED PER YEAR)

CHEMICAL NAME	QUANTITY	
Acetic acid	1.0	l
Acetic ananydride	1.0	l
Acetone	3.5	l
Aluminum potassium sulfate	500.0	g
Aminonaphathosulfonic acid	0.5	l
Ammonium chloride	0.5	l
Ammonium hydroxide	3.0	l
Ammonium molybdate	300.0	g
Bromphenol blue	10.0	g
Buffer for hardness 1	1.0	l
Buffer for hardness 2	0.25	l
Buffer solution pH4	3.0	l
Buffer solution pH7	1.5	l
Buffer solution pH10	0.8	l
Calcium indicator	400.0	g
Calmagite (hardness indicator)	25.0	g
Carmine (alum lake)	25.0	g
Chloride standard, various concs.	.5	l
Citric acid	200.0	g
EDTA	200.0	g
Ethyl alcohol	4.0	l
Hydrochloric acid, reagent grade	5.0	l
Hydrogen peroxide, 30%	1.6	l
Iodine solution, N/10	0.5	l
Isopropyl alcohol	2.0	l
Mercuric nitrate	4.0	l
Methyl orange indicator	0.5	l
Nitric acid, 30.3%	0.2	l
Nitric acid, reagent grade	5.0	l
Oxalic acid	400.0	g
Phenolphthalein indicator solution	0.3	l
Potassium chloride	2000.0	g
Potassium chromate indicator, 5%	0.4	l
Potassium dichromate	500.0	g
Potassium hydroxide	500.0	g
Potassium hydroxide, 0.1N	5.0	l
Potassium iodide	650.0	g
Potassium nitrate	0.05	l
Potassium permanganate, 5%	0.5	l
Silver nitrate	170.0	g
Silver nitrate	1.0	l
Silver nitrate sol., 10N	1.0	l
Sodium bisulfite	1000.0	g
Sodium chloride	400.0	g
Sodium chloride standard	1.0	l
Sodium hydroxide sol.	3.0	l
Sodium hydroxide	1000.0	g

CHEMICAL NAME	QUANTITY
Sodium nitrate	0.5 l
Sodium oxalate	125.0 g
Sodium silicate	200.0 g
Sodium thiosulfate, 0.25N	9.5 l
Starch indicator sol., 1%	1.0 l
Sulfuric acid, 46.3%	3.0 l
Sulfuric acid, 10N	6.0 l
Sym-diphenylcarbazone	10.0 g
Tricalcium phosphate	200.0 g
Xylene cyanol	100.0 g
Yttrium nitrate	20.0 g
Zinc	400.0 g

Note: Chemicals are diluted with approximately 60 gallons of water per day (15,000 gallons of water per year) and injected with brine into wells.

Much attention at present is focused on several recent reports suggesting that workers in certain electrical occupations and people living close to power lines have a small increased risk of leukemia and other cancers (Sagan, 1991). The evidence, however, does not conclusively prove that a cause-and-effect relationship between electric or magnetic fields and cancer exists.

A study in Denver, Colorado, (Wertheimer and Leeper, 1979) and one in Sweden (Tomenius, 1986) first reported that some cancer risks were about 2-3 times greater for children living near certain types of power lines assumed to be carrying high current. Those researchers suggested that the finding may be related to the magnetic fields of 2-3 mG produced in homes by such lines. The possibility could not be ruled out, however, that other factors, or chance, may be involved. If certain power lines actually do influence cancer rates, this would mean that 2 or 3 children out of 10,000 children exposed to such lines would develop cancer each year, compared to the normal rate of 1 in 10,000 per year (Ahlbom et al., 1987).

Another study from Denver (Savitz et al., 1988) indicated results that were generally consistent with the earlier work on childhood cancer by Wertheimer and Leeper (1979). However, the relative risk[1] in the new study (1.5) was smaller than that reported earlier (2-3). it was also on the borderline of statistical significance. Results of another study, from the Seattle area, found no association between power lines and leukemia in adults (Severson et al., 1988). An earlier power line study in Denver by Wertheimer and Leeper (1982) also found no increase in adult leukemia. However, the earlier Denver study did find an increased risk for some other types of adult cancers.

A study done in Los Angeles County, California, provided additional support for an association between childhood leukemia risk and high current power lines (London et al., 1991). The odds ratio for very high current lines compared to very low current and underground was 2.15. Associations with actual measured electric and magnetic fields, however, were weaker and not statistically significant.

A new study done in Sweden found that the relative risk for leukemia in children living near transmission lines was 3.8 where magnetic fields were greater than 3 mG (Feychting and Ahlbom, 1992). Preliminary information on a larger study done in Denmark indicates no increased risk of leukemia for children living near transmission lines in that country (Olsen, 1992). However, there was an elevated risk of lymphoma reported in the Danish study.

Studies in Rhode Island (Fulton et al., 1980), in Taiwan (Lin and Lu, 1989) and in England (Myers et al., 1985) found no significant association between childhood cancer and power lines. Other community studies in England found no consistent evidence to support a power line-cancer association (Coleman et al., 1985; McDowall, 1986).

A study in Washington State first reported that men in various "electrical occupations" had died more frequently from leukemia than men in other occupations (Milham, 1982). Other studies reported similar findings, suggesting an increased risk of around 20 to 50 percent (Savitz and Calle, 1987; Coleman and Beral, 1988). However, the studies were primarily based on

[1] Results of case-control studies are given in terms of relative risk (or odds ratio). A relative risk of 1.0 means that exposure to some factor (assumed to be EMF in this case) is the same for people with a disease (cases) as for people without the disease (controls). A value of 2 means cases were exposed to the factor twice as often as the controls. This establishes a "statistical association" between the disease and the factor. This may or may not represent a cause-and-effect association, however.

information only from death certificates (i.e., job title and cause of death). It, therefore, was not possible to determine whether the preliminary findings were related to electric and magnetic fields, or to other exposures such as those from chemicals.

Research on electric and magnetic fields and cancer was reviewed in a draft report by the U.S. Environmental Protection Agency (EPA, 1990). The EPA concluded that magnetic fields are a possible but unproven cause of cancer in humans and more research is needed. The EPA's Science Advisory Board (SAB) also reviewed the issue and reached a similar conclusion. The SAB, however, recommended that the EPA report should be rewritten to correct inconsistencies in the report (SAB, 1991).

In addition to research on humans and laboratory animals, several studies have investigated possible effects of transmission line electric and magnetic fields on plants, wildlife, and domestic animals (BPA, Lee et al., 1989). Crop growth is not noticeably affected by even the largest transmission lines. Trees that are allowed to grow too close to transmission line conductors can be damaged by the strong electric fields near the conductors. Normally, trees are not allowed close to conductors to prevent electrical flashover, i.e., spontaneous arcing of electrical current from lines to trees.

Studies have shown that honey bees in commercial hives can be adversely affected by strong transmission line electric fields. Shocks received by bees while in the hive cause decreased honey production and increased mortality. As a precaution, BPA recommends that bee hives not be placed directly on the transmission line right-of-way.

Wildlife do respond to effects (e.g., changes in food supply), of cleared rights-of-way. However, there is no evidence that their behavior is noticeably affected by the presence of electric and magnetic fields. Few studies have attempted to determine whether wildlife may be affected by long-term exposure to these fields. As noted above, some effects of electric and magnetic fields have been found in laboratory animal studies. It is not known whether such effects occur in wildlife similarly exposed to these fields.

Several studies have looked at the behavior and production of livestock raised near transmission lines. These studies found no indication that electric or magnetic fields have any major effects on livestock. Most of the studies were not designed to detect any subtle field effects, however, more detailed information on the potential health effects of electric and magnetic fields can be found in a BPA publication (incorporated here by reference): "Electrical and Biological Effects of Transmission Lines: A Review." 1993.

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APPENDIX I
MEMORANDUM OF UNDERSTANDING BETWEEN CE NEWBERRY, INC., THE BONNEVILLE POWER ADMINISTRATION, AND THE EUGENE WATER & ELECTRIC BOARD FOR NEWBERRY GEOTHERMAL PILOT PROJECT

MEMORANDUM OF UNDERSTANDING

Between

CE NEWBERRY, INC.,

and

the UNITED STATES OF AMERICA
Department of Energy
BONNEVILLE POWER ADMINISTRATION

and

the CITY OF EUGENE, OREGON
acting by and through the
EUGENE WATER & ELECTRIC BOARD

for

NEWBERRY GEOTHERMAL PILOT PROJECT

I. The Parties

The parties to this Memorandum of Understanding are CE NEWBERRY, INC. ("CE"), the United States of America, Department of Energy, BONNEVILLE POWER ADMINISTRATION ("BPA") and the City of Eugene, acting by and through the EUGENE WATER & ELECTRIC BOARD ("EWEB"), a municipal utility of the state of Oregon.

II. Introduction and Purpose

In July of 1991, BPA, as part of a geothermal pilot program, issued a Request for Proposals to supply electric power from geothermal generation projects. In response to that Request, CE and EWEB submitted a proposal to BPA for the development, construction and operation of a geothermal generating facility located approximately 30 miles south of Bend and 8 miles east of LaPine, Oregon.

BPA has approved the Project for inclusion in its Resource Acquisition Program under the Regional Power Act, P. L. 98-501, subject to the development of adequate definitive agreements and the approval of those agreements by the BPA Administrator.

The Parties have agreed that to further explore and analyze the feasibility and advisability of developing the Project, various matters must be definitively agreed upon between the Parties and certain actions should be taken to determine whether the Project can be developed in an environmentally acceptable and cost-effective manner.

The purpose of this Memorandum Of Understanding is to set forth proposed terms for the development of the Project and to provide definition for the respective roles and responsibilities of the Parties during the Project development period.

III. The Project

The Project will be a 33 megawatt (MW) gross geothermal power plant and supporting facilities at a centrally located site on Lease OR 45505 and Lease OR 45506 within the Deschutes Unit Area and the Newberry KGRA, Deschutes County, Oregon. The power plant will require up to 10 commercial production wells and 3 injection wells located on well pads within 3 miles of the plant site. The proposed plant is planned to be a "flash technology" modular plant with a condensing steam turbine and wet cooling tower. The turbine generator/condenser and supporting pumps and valves will be housed in a steel building with the cooling tower and H2S control systems being separate structures on the site. A 115 KV transmission line will be required to connect the proposed plant with the existing Midstate Electric/BPA substation in LaPine, Oregon.

The Project is more particularly described in Exhibits A and B.

IV. Owner/Operator

CE Newberry, Inc.

V. Total Amount Financed

Approximately 80% project debt issuance
Approximately 20% CE equity

VI. Proposed Financing Structure

As the proposed transaction is presently contemplated, the respective Parties will assume the following obligations subject to execution of definitive contracts, Exhibits A - C, upon approval of their governing boards or the Bonneville Power Administrator as appropriate.

A. CE agrees to finance and develop all Project facilities with a combination of project debt and CE equity.

B. BPA will execute a 20 megawatt (MW) 50-year output contract with CE prior to Project financing. The contract price structure and essential terms will be as described in Exhibit A (BPA-CE Power Purchase Agreement).

C. EWEB will execute a 10 MW 50-year output contract with CE prior to Project financing. The contract price structure and essential terms will be as described in Exhibit B (EWEB-CE Power Purchase Agreement).

D. Under both contracts, CE will receive a fixed and indexed payment as shown in Exhibits A and B.

E. EWEB and BPA will execute a Billing Credits Generation Agreement covering EWEB's share of the Project output as described in Exhibit C (BPA-EWEB Billing Credits Generation Agreement).

F. BPA will agree that if EWEB is unable to execute the EWEB-CE Power Purchase Agreement and the BPA-EWEB Billing Credits Generation Agreement, then BPA will purchase EWEB's share of project output under the terms of the BPA-CE Power Purchase Agreement, or will negotiate with CE in good faith to reach agreement on another structure.

G. EWEB will agree that all obligations incurred under the Billing Credits Generation Agreement and the Power Purchase Agreement shall be made binding to all successors and assigns to EWEB.

H. It is intended by the Parties that the pricing structure under the Power Purchase Agreements will allow CE to finance the Project on terms that will provide CE the financial return previously communicated to the other Parties in writing. In the event CE is unable to finance the Project in accordance with such contemplated financial returns and the pricing structures described in the Power Purchase agreements (Exhibits A and B), the Parties agree to enter into good faith negotiations to make changes to Exhibits A and B as may be required to accomplish financing. No party shall be bound to make any changes in Exhibits A or B without the express approval and consent of its governing Board or the administrator, as appropriate.

I. CE will make good faith efforts to seek Project financing for the longest term and lowest interest rate feasible.

VII. Clean Air Act Credits

CE and EWEB shall share in the economic benefits derived from the tradable credits produced by sale or resale of the Project's production to EWEB in accordance with the terms of the EWEB-CE Power Purchase agreement.

VIII. Option Rights

If CE or EWEB propose to develop further geothermal facilities within the Deschutes Unit Area, the entity proposing further developments will grant to the other entity the first right to participate on an equity or other joint action basis. This opportunity shall be offered under terms described in the EWEB-CE Power Purchase Agreement (Exhibit B). If the CE and EWEB choose to jointly proceed, CE shall be entitled to be the project developer. As project developer, CE shall exercise the same degree of control over project decisions as it exercises under the agreement applicable to the development of the Project.

IX. Joint Development Activities

A. During the development and construction period, CE and EWEB shall act in accordance with the EWEB-CE Joint Development Agreement (Exhibit D).

B. BPA will perform activities required by the National Environmental Policy Act (NEPA) including negotiating Memoranda of Understanding with the Bureau of Land Management, the United States Forest Service and other agencies which participate in preparation of any Environmental Impact Statement related to the

Project. BPA will coordinate environmental compliance activities with other entities and will use its best efforts to obtain prompt favorable resolution to siting, technical and environmental issues related to the Project. BPA will take an active supporting role in any public involvement program relating to the Project development and environmental permitting requirements. BPA will perform any transmission studies and assist in preparing any Plans of Interconnection necessary to connect the Project to the transmission grid.

C. BPA, CE and EWEB will take active roles in public involvement programs relating to Project development and environmental permitting requirements. EWEB will take the lead in public relations efforts.

D. When undertaking actions in connection with its supervisory responsibilities, CE shall not represent that it is the agent of EWEB or BPA and shall not enter into financial obligations in the name of EWEB or BPA. The incurrence of financial obligations shall be accomplished only through the express, written approval of EWEB or BPA.

E. The Development Agreement attached hereto as Exhibit D reflects a project structure whereby the financing for the Project will be accomplished by CE. If another financing alternative such as EWEB tax-exempt financing should prove both legally feasible and necessary to pursue the Project, then EWEB and BPA will consider such different financing alternatives. EWEB shall not be obligated to undertake such financing but shall be required only to discuss the alternatives with CE and BPA.

X. Alternative Locations

A. The planned location of the Project is the Deschutes Unit Area, Deschutes County, Oregon.

B. If the geothermal resources within the Deschutes Unit area are not capable of producing power on a cost-effective basis, CE will be entitled, subject to the deadlines in section 6 of the BPA-CE Power Purchase Agreement, to use an alternate location for the Power Purchase Agreements and other Project agreements without being subject to a BPA or EWEB competitive resource acquisition process.

C. Such alternate lease location must present the same advantages and economics to the Parties as does the Project. Movement of the location shall not economically disadvantage BPA or EWEB without approval of BPA and/or EWEB.

D. The Parties acknowledge that additional NEPA review may be required for the alternate location.

E. BPA and EWEB acknowledge that any definitive contracts may have to be amended to reflect CE's costs of developing such an alternative site and otherwise reflect changes in the contractual terms.

F. Such amendments shall be accomplished only upon the express written agreement of EWEB and/or BPA and neither EWEB nor BPA shall be obligated hereby to execute the same.

XI. <u>Termination Events Prior to Financing</u>

EWEB, BPA and CE agree to use their best efforts to proceed with the development of the Project, in the absence of the following events:

A. Failure to obtain required environmental approvals at Newberry and, if applicable, the alternate site.

B. Determination by CE of inadequate resource availability at Newberry and, if applicable, the alternate site.

C. Determination by CE to abandon the Project at its option if the expected financial returns become unacceptably low.

D. A determination following completion of the EIS process by any of the Parties not to execute the agreements attached hereto as Exhibits A - C, provided that such termination shall be effective as to the terminating Party only and the remaining Parties shall proceed to negotiate amendments in good faith to take account of such change in circumstances.

XII. <u>Confidentiality</u>

A. EWEB and BPA agree to keep strictly confidential the proprietary geological data, exploration techniques and other proprietary information developed by CE in its exploration and development activities and not to disclose such information to any third party or otherwise use or disclose such information without CE's written consent, unless otherwise required by law.

B. EWEB and BPA further acknowledge that CE is a publicly traded company subject to Securities and Exchange Commission disclosure regulations and accordingly agree that any press releases by such parties relating to the Project which can be reasonably anticipated to impact the public market for CE shares will be provided in advance to CE for review and comment.

XIII. Exhibits

The Exhibits listed below and attached hereto are part of this Memorandum of Understanding:

Exhibit A:	BPA-CE Power Purchase Agreement
Exhibit B:	EWEB-CE Power Purchase Agreement
Exhibit C:	BPA-EWEB Billing Credits Generation Agreement
Exhibit D:	CE-EWEB Joint Development Agreement
Exhibit E:	EWEB Board Resolution, dated August 10, 1992
Exhibit F:	Provisions Required by Law

XIV. Qualification and Authority

A. EWEB shall not be bound to any agreement until its Board has formally considered an agreement and specifically authorized its General Manager to execute an agreement and such agreement is executed by the General Manager. The EWEB Board has passed a Resolution (Exhibit E) authorizing its General Manager to sign this MOU and the CE-EWEB Development Agreement. EWEB does not represent that its Board will execute any other agreements, including any other Exhibit hereto, and any Party relying on such shall do so at its own risk.

B. CE and EWEB acknowledge that BPA must comply with NEPA, which requires that BPA evaluate the environmental impact, if any, of a major Federal action prior to making a final decision on such action, and that agreement regarding contract principles is not a commitment by BPA to make billing credit transfers to EWEB or otherwise to purchase power or facilitate the purchase of power from the Project. That obligation will arise, if at all, only upon the execution of formal written agreements.

XV. Duration of MOU and Termination

This Memorandum of Understanding shall continue until the various agreements detailed herein are signed, unless the Parties agree to suspend or terminate this agreement at an earlier date.

XVII. Modification

This Memorandum of Understanding may be modified only by written amendment executed by all of the Parties.

This Memorandum of Understanding will be effective as of the date when it is fully executed.

UNITED STATES OF AMERICA
Department of Energy
Bonneville Power Administration

By Sue F. Hickey
Assistant Administrator for
Energy Resources

Date 12/17/92

C.E. NEWBERRY, INC.

By [signature]
Vice President for Project
Development

Date 11/23/92

The CITY OF EUGENE
acting by and through
the EUGENE WATER & ELECTRIC BOARD

By Randy L. Berggren
General Manager

Date 11/24/92

APPENDIX J
FUGITIVE DUST MODELING FOR CONSTRUCTION/OPERATION SCENARIOS NEWBERRY GEOTHERMAL PILOT PROJECT

Prepared by AGI Technologies, May 11, 1994

Newberry Geothermal Pilot Project
Fugitive Dust Modeling

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James Houck

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541 NE 20th Avenue, Suite 103
Portland, OR 97232

May 11, 1994

1. Introduction

The fugitive dust impact was modeled using the U.S. EPA fugitive dust model (FDM 93070). The primary source of fugitive dust from the geothermal power plant project will be from vehicular traffic and construction activities. Existing background particulate levels were estimated from Crater Lake National Park monitoring data. Future impacts were estimated using construction/operation schedules provided by C.E. Exploration Company (CEE).

For short-term modeling purposes (24-hour maximum impact), the geothermal power plant project was divided into six different phases, each modeled independently. The modeling was done to predict the highest and second highest daily impact (the ambient standard is based on the second highest value per year). Daily emission rates were based on worst case construction/operation and meteorological conditions.

For long-term modeling (annual average impact), four representative years were used throughout the 50-year lifetime of the project. Emission rates were calculated based on the total emissions created per year by project activities. The modeling was conducted to estimate the annual impact of fugitive dust during each of the representative years.

2. Receptors

Receptors used in this modeling correspond to receptors used for modeling point source emissions at the site. A rectangular coordinate system was used with the origin being at the future plant site. Table 1 lists the receptors, their coordinates used for modeling, and their distance from the plant site.

Table 1. Receptor Coordinates and Distance from Plant Site

Receptor Name	Receptor number	Coordinates (meters)		Distance from Plant Site (meters)
		x - coordinate	y - coordinate	
North Cove Campground	1	3025	-949	3170
Warm Springs Campground	2	4409	-1142	4554
Little Crater Campground	3	4666	-3073	5587
Campground	4	4183	-3765	5628
Summer Houses	5	3475	-3829	5171
Paulina Lake Lodge	6	1899	-2848	3423
Bald Eagle Nest Site	7	7289	-467	7304
McKay Crossing Campground	8	-5985	-2671	6554
Intersection of Hwy 97 & Hwy 21	9	-12792	1271	12855
LaPine	10	-15977	-7353	17588
Monument Boundary	11	1014	-145	1024

3. Meteorological Data

One year of meteorological data were obtained for the time period of October 1, 1992 - October 1, 1993 from the SAIC operated 10-meter meteorological station at the approximate plant site. The station recorded hourly values of temperature, relative humidity, wind speed, wind direction, and sigma theta (wind stability). Precipitation data were obtained from the U.S. Forest Service meteorological monitoring station located at Paulina Lodge. Snow cover was assumed throughout the months of December, January, and February.

4. Emissions Associated with Construction and Operation of the Geothermal Power Plant

Short-Term Emissions

For short-term (daily impact) modeling purposes, the geothermal power plant project was divided into six different phases, each modeled independently. Each phase includes all activities which can be conducted concurrently. Worst case daily emissions (due to the highest level of activity that could conceivably occur) were used throughout the modeled year to find the worst case combination of project emissions and meteorological conditions. Emissions were all assumed to generated during the day (approximately 8:00 a.m. to 8:00 p.m.) since there will be no construction activities and little traffic during the night-time hours. The modeled estimates are conservative since the probability is low that the worst case emissions will occur on the day with worst case meteorological conditions.

Emissions from each of these phases were estimated using the U.S. EPA AP-42 guideline document and are based on construction time-lines, vehicle movements, and soil characteristics. Road watering procedures to control emissions which will be used by CEE were incorporated into the emission calculations. Emissions calculations for maximum daily impact did not take into account natural emission controls such as snow cover, precipitation, frozen soil, etc. Hence, the values that are calculated are conservative estimates of maximum daily impacts.

Phase 1: Drilling
The drilling phase includes activities associated with construction of exploration well pads and roads, and exploration well drilling. Worst case daily emissions assumed that two exploration wells were being cleared and two compliments of construction and well drilling equipment were delivered to the site in one day. Since this phase has the highest potential for fugitive dust emissions, a watering program will be used on the roads used by the project. Roads will be watered 3-4 times per day during dry, dusty periods. The control efficiency of fugitive dust emissions from vehicular traffic from this watering program will be at least 60%. Further control of dust will be achieved by watering exposed working areas during excavation. However, the control efficiency achieved by watering exposed areas of excavation were not taken into account for modeling estimates.

Phase 2: Site Excavation
Site excavation phase includes emissions due to transportation of construction equipment to the site and excavation of the plant site. Worst case daily emissions include emission from transportation of equipment to the plant site and daily excavation of the entire 18.5 acre plant site. The road watering program will be continued (3-4 times per day) and will achieve a control efficiency of at least 60%.

Phase 3: Plant Erection & Transmission Line Construction
This phase includes emissions from material deliveries and construction of the new road (between roads 500 and 600) and transmission lines. Worst case daily emissions included simultaneous delivery and construction of road/transmission line. Since much less fugitive emissions are expected during this phase, a less aggressive watering program will be used which will achieve a control efficiency of at least 40%.

Phase 4: Plant Start-up
Plant start-up includes emissions from crew busses and supervisor vehicles during plant start-up. Due to limited vehicular traffic, the road watering program will be discontinued during this phase of the project.

Phase 5: Plant Operation
Plant operation phase includes emissions from crew vehicles, vendor cars, delivery of materials,

well/well pad maintenance activities, and road maintenance (grading). Worst case daily emissions assumed all crews, material deliveries, and road maintenance occurred during one day. No road watering will be done during this phase.

Phase 6: Decommissioning
The decommissioning phase includes emissions from crew vehicles, equipment delivery, material removal, and site/well pad restoration. The watering program (2-3 times per day) will be continued for this phase and will achieve at least 40% control efficiency for road travel.

Long-Term Emissions

Calculation of long term (annual impact) emissions was done to model annual impact at each receptor. Total emissions from each phase were calculated and divided by the length of the phase to get an average daily emission rate for each phase. Natural emission controls (rainfall and snow-cover) were incorporated into the emission calculations. To model annual impact, the phases were then grouped into four representative years based on a projected construction/operation schedule as follows:

Year 1
The first representative year contains average emissions from phase 1 only. Phase 1 is expected to begin in September 1994 and last until December 1995 with a three month break during the winter months.

Year 2
The second representative year incorporates emissions from phase 2, phase 3, and phase 4.

Year 3
The third representative year incorporates average emissions from only the operation phase (phase 5).

Year 4
The fourth representative year incorporates emissions from both phase 5 and phase 6.

5. Modeling Results

Modeling was performed for both total suspended particles (TSP) and particulate matter less than 10 microns in aerodynamic diameter (PM_{10}) for the six short-term phases and the four long-term representative years. Tables 2-7 lists the highest and second highest modeled TSP/PM_{10} 24-hour impact at each receptor for phases 1-6 respectively. Tables 8-11 list the modeled annual TSP/PM_{10} impact for each receptor for each representative year respectively.

Table 12 lists the applicable standards for ambient TSP/PM_{10} and the estimated background particulate levels.

Table 2. Highest and Second Highest Daily Impacts for Phase 1

Receptor Name	Receptor number	TSP ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	
		highest	second highest	highest	second highest
North Cove Campground	1	63.0	49.3	45.1	35.2
Warm Springs Campground	2	45.5	35.2	32.8	25.0
Little Crater Campground	3	20.5	17.8	14.2	12.7
Campground	4	28.4	24.8	20.4	17.8
Summer Houses	5	19.6	18.6	14.1	13.3
Paulina Lake Lodge	6	25.1	23.6	18.0	16.4
Bald Eagle Nest Site	7	22.2	21.1	15.8	15.3
McKay Crossing Campground	8	12.7	9.7	9.1	7.1
Intersection of Hwy 97 & Hwy 21	9	11.0	8.1	7.7	5.9
LaPine	10	3.9	2.6	2.9	1.9
Monument Boundary	11	109.3	108.1	76.8	72.8

Table 3. Highest and Second Highest Daily Impacts for Phase 2

Receptor Name	Receptor number	TSP ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	
		highest	second highest	highest	second highest
North Cove Campground	1	41.6	30.1	34.0	24.3
Warm Springs Campground	2	28.8	21.5	23.2	17.3
Little Crater Campground	3	11.4	9.4	8.8	7.9
Campground	4	10.5	9.0	8.3	6.9
Summer Houses	5	6.8	6.4	4.8	4.8
Paulina Lake Lodge	6	14.7	8.8	14.1	7.2
Bald Eagle Nest Site	7	12.6	10.6	9.8	8.3
McKay Crossing Campground	8	6.9	4.5	4.9	3.4
Intersection of Hwy 97 & Hwy 21	9	9.7	8.7	7.1	6.3
LaPine	10	1.5	1.5	1.1	1.1
Monument Boundary	11	106.4	103.7	89.1	86.3

Table 4. Highest and Second Highest Daily Impacts for Phase 3

Receptor Name	Receptor number	TSP ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	
		highest	second highest	highest	second highest
North Cove Campground	1	44.9	32.9	32.5	23.5
Warm Springs Campground	2	33.3	24.3	24.1	17.4
Little Crater Campground	3	14.2	13.4	9.9	9.6
Campground	4	14.7	13.8	10.6	9.9
Summer Houses	5	11.1	11.0	8.0	7.7
Paulina Lake Lodge	6	14.9	12.1	10.4	8.8
Bald Eagle Nest Site	7	15.9	14.8	11.4	10.5
McKay Crossing Campground	8	10.3	6.3	7.4	4.5
Intersection of Hwy 97 & Hwy 21	9	12.8	12.7	9.2	9.2
LaPine	10	2.3	2.2	1.7	1.6
Monument Boundary	11	65.1	60.4	47.1	41.9

Table 5. Highest and Second Highest Daily Impacts for Phase 4

Receptor Name	Receptor number	TSP ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	
		highest	second highest	highest	second highest
North Cove Campground	1	2.9	2.4	2.1	1.7
Warm Springs Campground	2	2.2	1.9	1.6	1.3
Little Crater Campground	3	1.3	1.1	0.9	0.7
Campground	4	1.1	1.1	0.8	0.8
Summer Houses	5	1.0	1.0	0.8	0.7
Paulina Lake Lodge	6	2.0	1.8	1.4	1.3
Bald Eagle Nest Site	7	1.2	1.1	0.8	0.8
McKay Crossing Campground	8	0.6	0.4	0.4	0.3
Intersection of Hwy 97 & Hwy 21	9	0.6	0.6	0.4	0.4
LaPine	10	0.2	0.1	0.1	0.1
Monument Boundary	11	5.8	4.5	4.1	3.1

Table 6. Highest and Second Highest Daily Impacts for Phase 5

Receptor Name	Receptor number	TSP ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	
		highest	second highest	highest	second highest
North Cove Campground	1	9.6	7.8	8.0	6.3
Warm Springs Campground	2	6.9	5.4	5.7	4.5
Little Crater Campground	3	4.2	3.4	3.4	2.7
Campground	4	3.5	2.4	2.8	1.9
Summer Houses	5	3.5	3.4	2.8	2.8
Paulina Lake Lodge	6	5.9	5.6	4.7	4.3
Bald Eagle Nest Site	7	3.8	3.1	3.1	2.5
McKay Crossing Campground	8	2.1	1.9	1.7	1.7
Intersection of Hwy 97 & Hwy 21	9	3.0	2.4	2.5	2.0
LaPine	10	0.6	0.4	0.5	0.3
Monument Boundary	11	15.9	14.1	12.4	10.8

Table 7. Highest and Second Highest Daily Impacts for Phase 6

Receptor Name	Receptor number	TSP ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	
		highest	second highest	highest	second highest
North Cove Campground	1	20.5	16.1	15.5	12.2
Warm Springs Campground	2	14.1	11.4	10.7	8.3
Little Crater Campground	3	6.5	6.3	4.7	4.6
Campground	4	5.8	3.8	4.1	2.7
Summer Houses	5	5.7	5.2	4.0	3.8
Paulina Lake Lodge	6	7.7	7.5	5.4	5.4
Bald Eagle Nest Site	7	7.5	6.2	5.6	4.8
McKay Crossing Campground	8	4.7	3.7	3.4	2.7
Intersection of Hwy 97 & Hwy 21	9	6.9	5.6	4.9	4.0
LaPine	10	1.2	1.0	0.9	0.7
Monument Boundary	11	42.4	35.9	31.9	27.2

Table 8. Annual Impacts for Year 1

Receptor Name	Receptor number	TSP ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
North Cove Campground	1	2.8	1.7
Warm Springs Campground	2	1.8	1.1
Little Crater Campground	3	1.0	0.6
Campground	4	0.8	0.5
Summer Houses	5	0.8	0.5
Paulina Lake Lodge	6	1.7	1.0
Bald Eagle Nest Site	7	1.0	0.6
McKay Crossing Campground	8	0.2	0.2
Intersection of Hwy 97 & Hwy 21	9	0.2	0.1
LaPine	10	0.04	0.03
Monument Boundary	11	9.2	5.3

Table 9. Annual Impacts for Year 2

Receptor Name	Receptor number	TSP ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
North Cove Campground	1	1.0	0.7
Warm Springs Campground	2	0.7	0.5
Little Crater Campground	3	0.4	0.3
Campground	4	0.3	0.2
Summer Houses	5	0.3	0.2
Paulina Lake Lodge	6	0.6	0.4
Bald Eagle Nest Site	7	0.4	0.3
McKay Crossing Campground	8	0.2	0.1
Intersection of Hwy 97 & Hwy 21	9	0.2	0.1
LaPine	10	0.03	0.02
Monument Boundary	11	3.2	2.3

Table 10. Annual Impacts for Year 3

Receptor Name	Receptor number	TSP ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
North Cove Campground	1	0.4	0.2
Warm Springs Campground	2	0.3	0.2
Little Crater Campground	3	0.2	0.1
Campground	4	0.1	0.1
Summer Houses	5	0.1	0.1
Paulina Lake Lodge	6	0.3	0.2
Bald Eagle Nest Site	7	0.2	0.1
McKay Crossing Campground	8	0.04	0.03
Intersection of Hwy 97 & Hwy 21	9	0.04	0.03
LaPine	10	0.007	0.004
Monument Boundary	11	1.2	0.8

Table 11. Annual Impacts for Year 4

Receptor Name	Receptor number	TSP ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
North Cove Campground	1	0.6	0.4
Warm Springs Campground	2	0.4	0.3
Little Crater Campground	3	0.3	0.2
Campground	4	0.2	0.2
Summer Houses	5	0.2	0.2
Paulina Lake Lodge	6	0.4	0.3
Bald Eagle Nest Site	7	0.3	0.2
McKay Crossing Campground	8	0.1	0.1
Intersection of Hwy 97 & Hwy 21	9	0.1	0.1
LaPine	10	0.02	0.01
Monument Boundary	11	1.9	1.3

Table 12. Particulate Standards and Estimated Background Levels at Newberry Crater

Particulate Category	Second Highest 24-hour Value ($\mu g/m^3$)		Annual Average ($\mu g/m^3$)	
	Standard	Background[a]	Standard	Background[a]
TSP	150	31	60[b]	13
PM_{10}	150	22	50	9.5

a. estimated from Crater Lake data.
b. geometric mean.

6. Conclusions

As can be seen by comparing the estimated daily and annual impacts to the applicable standards, these standards are not expected to be exceeded even when the fugitive dust impact is added to the existing background levels.

This emission modeling exercise (as with all modeling) cannot take into account all scenarios, both man-made and natural, which may cause increased emissions. However, the modeling has demonstrated, excluding extraordinary events such as wildfires, dust storms, and intensive adjacent logging, that the construction and operation of the Newberry geothermal power plant will not contribute to a violation of ambient standards for particulate matter.

APPENDIX K
SOIL AND LAND TYPE INFORMATION FOR PROJECT AREA

SELECTED INFORMATION FROM: LARSEN D.M., 1976, SOIL AND RESEARCH INVENTORY DESCHUTES NATIONAL FOREST, PACIFIC NORTHWEST REGION, NATIONAL FOREST SERVICE, 381 PP.

APPENDIX K TABLE OF CONTENTS

The following materials are from the Larsen, D.M., 1976, Soil and Resource Inventory Deschutes National Forest, Pacific Northwest Region, National Forest Service, 381pp.

MAPPING UNIT 73

Mapping Unit 73 consists of 70 percent or more of Landtype 73 and may have inclusions of Landtypes 17, 19, 6H, and 15.

Landtype 73 occurs on smooth to slightly uneven lava plains. Slope gradients are typically less than 15 percent. Elevation ranges from 4,800 to 5,800 feet, and the annual precipitation is about 25 to 40 inches.

Vegetation includes lodgepole pine, currant, sedges, lupine, and needlegrass. White fir is sometimes present in the understory, and some mountain hemlock occurs at the upper elevation range of this landtype. Productivity is estimated at cubic foot Site Class 5 and Site Index 40 to 50 for lodgepole pine.

This landtype has well to excessively drained soils formed from a moderately thick layer of pumiceous volcanic ash over an older soil on basalts and andesites. Surface soils are typically loamy sands, and buried soils are cobbly sandy loams. Permeability is very rapid in the surface soils and rapid in the buried soil. Depth to bedrock is 24 to 50 inches.

Bedrock consists of black to gray, highly to moderately fractured, blocky basalts and andesites. It is hard and competent.

Landtype 73 is similar to Landtype 19 except it is underlain by bedrock instead of glacial till. It is similar to Landtype 7E except for ground vegetation. Landtype 6H is similar except it supports more white fir than Landtype 73 and generally is more sloping.

Range of Soil Characteristics of Landtype 73

Litter:	Needles, leaves, twigs, cones, and decomposing organic matter; 0.25 to 2.0 inches thick.
Surface Layers:	Very dark grayish brown to dark brown sandy loam to loamy sand; weak, fine, crumb structure; 2 to 20 percent pumice coarse fragments; nonsticky, nonplastic; pH 6.0 to 6.5; 2 to 6 inches thick.
Sub-surface Layers:	Brown to yellowish brown pumiceous loamy sand to sand; massive to single grain; 2 to 30 percent pumice coarse fragments and blocky gravels and cobbles by volume; nonsticky, nonplastic; pH 6.0 to 7.0; 18 to 30 inches thick.
Buried Soil:	Dark brown to brown loamy fine sand to loam; massive; 20 to 70 percent blocky cobbles, stones, and gravels by volume; nonsticky to slightly sticky, nonplastic to slightly plastic; pH 6.2 to 6.8; 6 to 24 inches thick.

MAPPING UNIT 4A

Mapping Unit 4A consists of 70 percent or more of Landtype 4A and may have inclusions of Landtypes 19, 42, and 7F.

Landtype 4A occurs on gently sloping plateaus and glacial outwash plains. Slope gradients are generally less than 10 percent but may range up to 30 percent. Elevation ranges from 5,500 to 6,200 feet, and the annual precipitation is about 25 to 30 inches.

Vegetation is composed dominantly of lodgepole pine and lupine. Productivity is estimated at cubic foot Site Class 5 to 6 and Site Index 30 to 40 for ponderosa pine.

This landtype has excessively drained soils formed from a moderately thick layer of pumiceous volcanic ash over an older soil on sands and gravels. Surface soils are typically pumiceous loamy sands, and buried soils are sandy loams and sandy gravels. Permeability is very rapid in the surface soils and rapid to very rapid in the buried soils.

Landtype 4A is similar to Landtypes 19 and 73 except for underlying material. It is similar to Landtype 42 except for vegetation.

Range of Soil Characteristics of Landtype 4A

Litter:	Needles, leaves, twigs, cones, and decomposing organic matter; 0.5 to 1 inch thick.
Surface Layers:	Very dark grayish brown to dark brown sandy loam to loamy sand; weak, fine, crumb structure; 0 to 15 percent pumice fragments and gravel; nonsticky, nonplastic; pH 6.0 to 6.8; 2 to 6 inches thick.
Sub-surface Layers:	Brown to yellowish brown pumiceous loamy sand to sand; massive or single grain; 5 to 10 percent pumice coarse fragments and rounded gravels by volume; nonsticky, nonplastic; pH 6.0 to 7.8; 20 to 36 inches thick.
Buried Soil:	Brown to dark brown sandy loam to loamy sand; massive; 10 to 30 percent rounded gravels by volume; nonsticky to slightly sticky, nonplastic to slightly plastic; pH 6.2 to 6.8; 6 to 24 inches thick.
	Dark grayish brown gravelly loamy sand to sandy gravel; massive to single grain; 40 to 70 percent rounded and subrounded gravels by volume; nonsticky, nonplastic; pH 6.4 to 6.8; greater than 36 inches thick.

MAPPING UNIT 7F

Mapping Unit 7F consists of 70 percent or more of Landtype 7F and may have inclusions of Landtypes 17, 7E, and 85.

Landtype 7F occurs on lava plains and side slopes of shield volcanoes. Slopes are smooth to uneven with a gradient of 0 to 30 percent. Generally, the slopes are less than 20 percent. Elevation ranges from 6,200 to 6,800 feet, and the annual precipitation may range from about 30 to 60 inches.

Vegetation is composed dominantly of lodgepole pine with some mountain hemlock over sedges, needlegrass, and grouse huckleberry. This landtype has low potential for timber production.

This landtype has well to excessively drained soils formed from a moderately thick layer of pumice and volcanic ash over an older soil on basalts and andesites. Surface soils are typically pumiceous loamy sands, and buried soils are sandy loams. Permeability is very rapid in the surface soils and rapid to very rapid in the buried soils. Depth to bedrock is 24 to 50 inches.

Bedrock consists of black to dark gray, highly to moderately fractured, blocky basalts and andesites. It is hard and competent.

Landtype 7F is similar to Landtype 7E but occurs at higher elevations and has different vegetation. Landtype 85 is similar but supports a dominance of mountain hemlock over lodgepole pine and the slopes tend to be slightly steeper than on Landtype 7F. The soils of Landtype 7F are not as stony as Landtype 7A, and surface materials are different than in Landtype 7B.

Range of Soil Characteristics of Landtype 7F

Litter:	Needles, leaves, twigs, cones, and decomposing organic matter; 0.25 to 1 inch thick.
Surface Layers:	Dark grayish brown to dark brown sandy loam to loamy sand; weak, fine, crumb structure; 0 to 15 percent pumice fragments and gravel; nonsticky, nonplastic; pH 5.8 to 6.5; 2 to 6 inches thick.
Sub-surface Layers:	Brown to brownish yellow pumiceous loamy sand to sand; single grain to massive; 5 to 20 percent pumice coarse fragments and blocky gravels and cobbles; nonsticky, nonplastic; pH 6.0 to 6.8; 18 to 36 inches thick.
Buried Soil:	Dark yellowish brown to brown loamy sand to sandy loam; 20 to 80 percent blocky cobbles and stones by volume; nonsticky, nonplastic; pH 6.2 to 6.8; 6 to 20 inches thick.

SOIL RESOURCE INVENTORY
DESCHUTES NATIONAL FOREST

INTERPRETATIONS FOR ENGINEERING - PART 1

Land-type No.	Unified Classification	Suitability for Use as Topsoil Source	Suitability of Soil as Sand and/or Gravel Source	Suitability of Soil as a Possible Clay Source	Suitability of Bedrock for Road Rock	Limitations of Bedrock for Road Rock	Consideration for Road Location and Construction*	Method of Excavation	Cutbank & Ditch Erosion Potential	Susceptibility to Cutbank Sloughing and Ravelling
1	N/A	Unsuited	Unsuited	Unsuited	Good	Difficult to crush	Rocky, uneven land	Blasting and blading	Low	Moderate (rock fall)
2	Not rated	Unsuited	Unsuited	Unsuited	Variable	Nearness to streams limits quarrying	Avoid running roads parallel to streams in this unit. Provide adequate drainage facilities	Blading, some blasting	High	Low
3	N/A	Unsuited	Generally unsuited, but with some cinder deposits	Unsuited	Variable	Very steep slopes, some soft materials	Steep rocky slopes at high elevations	Blasting and blading	Low	High
4	Not rated	Unsuited	Unsuited	Unsuited	Poor to good	Some soft materials that break down readily	Climatic limitations due to high elevation.	Blading	High	N/A
5	Not rated	Suited on some locations	Generally unsuited	Suited on a few locations	N/A	N/K	Wet areas, some organic soils	Blading	N/A	N/A
6	Not rated	Unsuited	Unsuited	Unsuited	Good to fair	Some soft materials that k down readily brea	Steep, rocky slopes; side-cast waste damage potential to downslope soils	Blading, ripping, and blasting	High	High to moderate
7	SP-GW	Unsuited	May be suited on some locations	Unsuited	Good	Generally good where not underlain by gravels	N/A	Blading	N/A	N/A
8	Not rated due to variability	Unsuited	Suited on some sites	Unsuited	N/A	Watertable, depth of overburden	Provide adequate drainage and maintain a suitable buffer strip between roads and streams	Blading	N/A	N/A
9	GW-GP	Unsuited	Suited	Unsuited	Fair (cinders)	Tends to break down under logging traffic	Cutbanks will ravel; potential for high visual impacts	Blading	Low	High
10	Not rated	Unsuited	Unsuited	Unsuited	Unsuited to good	Some soft pyroclastic rocks	Sidecast material could cause water quality problems	Blading, ripping, and blasting	Low to moderate	High to moderate
11	N/A	Unsuited	Unsuited	Unsuited	Good	Difficult to blast and brush	Very stony land	Blading and blasting	Low	N/A
12	GM, SP, SM	Unsuited	Unsuited	Unsuited	Good	May be difficult to quarry	Moderate to steep, complex slopes; snowed in much of the year	Blading and blasting	Moderate	Low to moderate
13	Not rated	Unsuited	Unsuited	Unsuited	Good	Steep slopes at high elevations	It is unlikely that roads would be constructed in this landtype; snow slide hazard	Blasting and blading	Moderate to high	Moderate
14	Not rated	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry due to large size of blocks	Steep, stony slopes	Blasting and blading	Moderate to high	Moderate
15	GM, SP, SM, GP, GM	Unsuited	Unsuited	Unsuited	Generally good	Depth to bedrock is greater than 12 feet in some areas	No special considerations	Blading	Low	N/A
16	GM, SP, SW, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Avoid wet spots in this unit	Blading and ripping	Moderate	Moderate
17	GM, GM	Unsuited	Unsuited	Unsuited	N/A	Use restricted by depth to bedrock	No special considerations	Blading and ripping	Moderate	N/A
18	SM, SP, GM	Unsuited	Unsuited	Unsuited	Poor to good	Some soft materials are included	Most of this unit lies in Wilderness areas, avalanche tracks need special consideration	Blading, ripping, and blasting	High to moderate	Moderate to high
19	GM, SP, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	No special considerations	Blading and ripping	Moderate	N/A

* Dustiness is an item to consider on all roads except on rough, rocky land and wet areas. Surfacing or dust abatement materials should be applied when dust conflicts with other values.

INTERPRETATIONS FOR ENGINEERING - PART 2

Land-type No.	Probability of Cutbank Failures	Suggestions for Cutbank Stability Problems	Failure Potential on Road Waste and Fills	Erosion Potential on Road Waste and Fills	Suitability of Road Waste & Fill Slopes to Seeding	Limitations to Road Waste & Fill Slope Seeding	Suggestions for Road Waste & Fill Slope Seeding	Suitability of Cutbanks to Seeding	Limitations to Cutbank Seeding	Suggestions for Cutbank Seeding
1	I	N/A	Low	Low	Unsuited	Stoniness	N/A	Unsuited	Stoniness	N/A
2	I-II	N/A	Low to moderate	Moderate	Low to moderate	Coarse textured soils, high elevations, some steep slope	Use high elevation native species 1/	Low	Coarse soils, high elevation	Use high elevation native species 1/
3	III-V	Retaining walls	High	Low	Unsuited	Stoniness, lack of soil, severe climate	N/A	Unsuited	Stoniness, lack of soil	N/A
4	N/A	N/A	Low	Moderate	Low	Low fertility, coarse soils, frost heaving, cold climate	Use native species suited to high elevations, fertilize and mulch	Low	Low fertility, coarse soils, cold climate	Use native species suited to high elevations, fertilize and mulch
5	N/A	N/A	N/A	N/A	High	N/A	N/A	N/A	N/A	N/A
6	II-III	Retaining walls may have local application	Moderate	High	Low	High elevation, stony soils, steep slopes, exposed aspects	Avoid seeding rocky areas	Low	Rocky slopes, high elevation	Avoid seeding rocky areas
7	N/A	N/A	N/A	Low	Low	Frost pockets, coarse soils of low fertility	2/	N/A	N/A	N/A
8	N/A	N/A	N/A	Moderate to high	Fair to good	Local droughtiness	1/	N/A	N/A	N/A
9	III	Retaining walls	Low to moderate	Low	Unsuited	Lack of soil, coarse cinders, droughtiness	2/	Low to unsuited	Lack of soil, coarse cinders	Probability of success is so low that it is not feasible to seed these slopes unless top-soil is added
10	II-III	Retaining walls may have application locally	Moderate to low	Moderate	Poor to fair	South aspects are droughty, coarse textured soils of low fertility, soil ravelling	1/	Poor	Coarse soils, low fertility, ravelling, some droughty sites	Seed only where sufficient soil material is available
11	N/A	N/A	N/A	N/A	Unsuited	Lack of soil, lava flows	N/A	Unsuited	Lack of soil, lava flows	N/A
12	II-III	No special suggestions	Moderate to low	Moderate	Poor	Coarse soils, cold climate	1/	Poor	Coarse soils, low fertility, cold climate	1/
13	II	Retaining walls may be needed locally to prevent rock fall into the road	Moderate	Moderate	Poor	Coarse, stony soils at high elevations, harsh climate and low fertility	2/	Poor	Rocky slopes, high elevation	2/
14	I-II	No special suggestions	Low	Moderate to high	Poor to fair	Coarse soils, droughty	1/	Poor to fair	Coarse textured soils, droughty, ravelling	1/
15	N/A	N/A	N/A	Low	Poor	Frost pockets, climatic extremes and low soil fertility	2/	N/A	N/A	N/A
16	I-II	N/A	Low	Moderate	Poor to fair	Coarse textured soils of low fertility	1/, some 2/	Poor to fair	Coarse soils of low fertility, ravelling	1/, 2/
17	N/A	N/A	Low	Moderate	Fair	Coarse textured soils of low fertility	1/	Fair	Coarse textured soils of low fertility	1/
18	II-III	Retaining walls may be needed locally to prevent rock fall.	Moderate	Moderate	Poor	Steep slopes, high elevations, low fertility, stoniness	2/	Poor	Steep, rocky slopes; high elevation	2/
19	N/A	N/A	Low	Moderate	Fair	Coarse textured soils of low fertility	1/	Poor to fair	Coarse textured soils of low fertility, droughtiness and some ravelling	1/

1/ Prepare seed bed, fertilize, seed, and mulch, using species adapted to the climatic zone and moisture regime of the landtype. Periodic watering will be needed in many cases for grass establishment. Native shrubs should also be considered.

2/ Seeding success is questionable. Each site should be evaluated on a project basis for seeding recommendations. Native shrubs may be successful on some of these sites not suited for grasses.

INTERPRETATIONS FOR ENGINEERING - PART 2

Land-type No.	Probability of Cutbank Failures	Suggestions for Cutbank Stability Problems	Failure Potential on Road Waste and Fills	Erosion Potential on Road Waste and Fills	Suitability of Road Waste & Fill Slopes to Seeding	Limitations to Road Waste & Fill Slope Seeding	Suggestions for Road Waste & Fill Slope Seeding	Suitability of Cutbanks to Seeding	Limitations to Cutbank Seeding	Suggestions for Cutbank Seeding
79	I-II	Retaining structures may be applied locally	Low to moderate	Moderate to high	Good to fair	Low fertility, droughtiness	1/	Fair to good	Exposure of bedrock, steep slopes, some coarse soils	1/
80	II-III	Retaining structures may be applied	Moderate to low	Moderate	Poor to fair	Coarse textured, cindery soils; droughtiness	1/	Poor to unsuited	Coarse textured, cindery soils; droughtiness	1/, 2/
81	II-III	Retaining structures may be applied	Moderate to low	Moderate	Poor to fair	Coarse textured, cindery soils; droughtiness	1/	Poor to unsuited	Cindery soils, droughtiness	1/, 2/
82	II	Retaining structures may be applied	Low	Moderate	Poor	Coarse, cindery soils; low fertility	1/	Poor to unsuited	Cindery soils, ravelling	1/, 2/
83	II	Retaining structures may be applied	Moderate to low	High to moderate	Poor to unsuited	Cindery soil, low fertility, harsh climate	2/	Unsuited to poor	Cindery soil, low fertility, harsh climate, ravelling	2/
84	II-III	Retaining structures may be applied	Moderate	High to moderate	Poor to unsuited	Coarse textured soils, low fertility, harsh climate	2/	Unsuited to poor	Coarse textured soils, low fertility, harsh climate	2/
85	I	N/A	Low	Moderate to low	Poor	Coarse soils, low fertility, frost, dry summers	1/, 2/ Use sedges	Poor to unsuited	Coarse soils, low fertility, harsh climate, exposure of bedrock	1/, 2/ Use sedges
86	I-II	No special suggestions	Low	Moderate	Fair	Low fertility, droughty summers	1/	Fair to poor	Low fertility, bedrock exposures, droughty summers	1/
87	I-II	No special suggestions	Low	Moderate	Fair	Low fertility, droughtiness	1/	Fair to poor	Droughtiness, low fertility	1/
88	II-III	Retaining structures may be needed	Moderate	Moderate to high	Poor to fair	Low fertility, coarse soils, droughty	1/	Poor	Exposure of bedrock, low fertility, droughtiness	1/
89	II-IV	Retaining structures may be needed	Moderate to high	High to moderate	Fair to unsuited	Stony soils, low fertility, droughtiness	1/, 2/	Unsuited to poor	Exposure of bedrock, droughtiness	1/, 2/
90	II	Seed with grasses	Low to moderate	Moderate	Fair to good	Some coarse materials, droughtiness	1/	Fair	Droughtiness, low fertility	1/
91	I	No special suggestions	Low	Moderate to high	Fair to good	Droughtiness	1/	Fair	Droughtiness, exposure of bedrock	1/
92	I	N/A	Low	Low	Unsuited	Cindery soil, high elevation, frost heaving, low fertility	2/	Unsuited	Cindery soil, ravelling, frost heaving, high elevation, low fertility	2/
93	I	N/A	Low	Low	Unsuited to fair	Cindery soil, low fertility, droughtiness	1/, 2/	Unsuited	Cindery soil, ravelling, droughtiness	2/
94	N/A	N/A	N/A	High	Poor	Sandy soils, low fertility	1/	Poor	Sandy soils, low fertility, droughty summers	1/
95	N/A	N/A	N/A	High	Fair	Sandy soils, low fertility	1/	Poor to fair	Sandy soils, low fertility	1/
96	N/A	N/A	N/A	Moderate to low	Poor	Coarse pumice soils, low fertility, droughtiness	1/, 2/	Poor to unsuited	Coarse pumice soils, low fertility, droughtiness, ravelling	1/

1/ Prepare seed bed, fertilize, seed, and mulch, using species adapted to the climatic zone and moisture regime of the landtype. Periodic watering will be needed in many cases for grass establishment. Native shrubs should also be considered.

2/ Seeding success is questionable. Each site should be evaluated on a project basis for seeding recommendations. Native shrubs may be successful on some of these sites not suited for grasses.

INTERPRETATIONS FOR ENGINEERING - PART 1

Landtype No.	Unified Classification	Suitability for Use as Topsoil Source	Suitability of Soil as Sand and/or Gravel Source	Suitability of Soil as a Possible Clay Source	Suitability of Bedrock for Road Rock	Limitations of Bedrock for Road Rock	Consideration for Road Location and Construction*	Methods of Excavation	Cutbank & Ditch Erosion Potential	Susceptibility to Cutbank Sloughing and Ravelling
20	Not rated	Unsuited	Unsuited	Unsuited	Unsuited to good	Depth of overburden limits use over much of the area, some soft materials	Special measures must be taken to protect water quality	Blading, ripping, and blasting	Moderate	Low to moderate
21	SM, SP, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Road cuts and sidecast material may have high visual impacts	Blading and ripping	Moderate	Moderate
22	SM, SP, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Subsurface drainage over compact till is common on this landtype	Blading and ripping	Moderate	Moderate
23	SM, SP, GM	Unsuited	Unsuited	Unsuited	Some good	Depth of overburden	Steep slopes, subsurface drainage on compact till	Blading, ripping, and some blasting	High	Moderate
24	SM, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Avoid unstable spots as much as possible, provide adequate drainage of cutbanks	Blading and ripping	Moderate	Moderate
25	SM, SP, SM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Some wet spots may be present as well as subsurface flow over compact glacial till	Blading and ripping	Low to moderate	Moderate
26	SM, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Rapid runoff may occur on this landtype	Blading and ripping	Low to moderate	Low to moderate
27	SM, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Subsurface flow over compact till occurs on this landtype	Blading and ripping	Moderate	Low to moderate
28	SM, SP, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Moderate to steep, complex slopes; subsurface drainage	Blading and ripping	Moderate to high	Low to moderate
29	SM, SP, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	No special consideration	Blading and ripping	Moderate	N/A
30	SM, GW, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden, watertable	Proper drainage is very important	Blading	High to moderate	N/A
31	SM, SP	Unsuited	Unsuited	Unsuited	N/A (Some locally good material)	Depth of overburden	Drainages and wet spots are common along these steep slopes	Blading and ripping	Moderate to high	High
32	SM	Unsuited	May have some suitable deposits	Unsuited	N/A	Depth of overburden	No special considerations	Blading	Moderate	Low to moderate
33	SM, SP, GP	Unsuited	Suited	Unsuited	N/A	Depth of overburden	Cindery soils	Blading	Low to moderate	High
34	SM, SP, GP	Unsuited	Suited	Unsuited	N/A	Depth of overburden	Cindery soils on steep slopes	Blading	Low to moderate	High
35	SM	Unsuited	Suited	Unsuited	N/A	Depth of overburden	Steep slopes	Blading	Moderate	Moderate
36	SM, GP, GW	Unsuited	Suited	Unsuited	N/A	Depth of overburden	No special considerations	Blading	Low	N/A
37	SM, GP, GW	Unsuited	Suited	Unsuited	N/A	Depth of overburden	No special considerations	Blading	Low to moderate	N/A
38	SM, SW	Unsuited	Suited	Unsuited	N/A	Depth of overburden	Steep slopes	Blading	Moderate to high	Moderate
39	SM, ML, SP, MH	Suited	Unsuited	Unsuited (some thin bands of clay present)	N/A	Depth of overburden	Wet spots may be included in these areas	Blading	Low to moderate	N/A
40	SM, SW, ML, MH	Suited	Unsuited to suited	Unsuited to suited	N/A	Depth of overburden	Proper drainage is a major consideration	Blading	High to moderate	N/A
41	SM, SW	Unsuited	Suited	Unsuited	N/A	Depth of overburden	No special considerations	Blading	Moderate to low	Moderate

* Dustiness is an item to consider on all roads except on rough, rocky land and wet areas. Surfacing or dust abatement materials should be applied when dust conflicts with other values.

INTERPRETATIONS FOR ENGINEERING - PART 2

Land-type No.	Probability of Cutbank Failures	Suggestions for Cutbank Stability Problems	Failure Potential on Road Waste and Fills	Erosion Potential on Road Waste and Fills	Suitability of Road Waste & Fill Slopes to Seeding	Limitations to Road Waste & Fill Slope Seeding	Suggestions for Road Waste & Fill Slope Seeding	Suitability of Cutbanks to Seeding	Limitations to Cutbank Seeding	Suggestions for Cutbank Seeding
20	II	N/A	Low to moderate	Moderate	Fair	Low fertility, frost heaving	1/	Poor to fair	Low fertility, stoniness, climatic limitations	1/
21	II-III	May need local retaining walls	Moderate to low	Moderate	Fair	Coarse textured soils of low fertility, droughtiness, ravelling	1/	Poor to fair	Droughtiness, low fertility	1/
22	II-III	Provide adequate drainage along cutbanks	Low to moderate	Moderate	Fair	Coarse textured soils	1/	Fair to poor	Coarse soils, ravelling, some compact material	1/
23	II	Provide adequate drainage along cutbanks	Low to moderate	High	Poor to fair	Sandy soils, low fertility	1/	Poor	Sandy soils, steep slopes	1/
24	III-IV	Provide adequate drainage of cutbanks, retaining walls may have local application	Moderate	Moderate	Fair to good	Coarse textured soils of fairly low fertility	1/	Fair	Coarse soils, some compact material	1/
25	I-II	No special suggestions	Low	Moderate	Poor to fair	Coarse textured soils of low fertility	1/	Poor to fair	Coarse textured soils, low fertility, some compact materials	1/
26	I-II	Some retaining structures may be needed; provide adequate drainage	Low	Moderate	Fair	Coarse textured soils	1/	Fair	Some stony, compact materials; low fertility	1/
27	I-II	Provide adequate drainage	Low to moderate	Moderate	Fair to good	Low fertility, droughty on some sites	1/	Fair	Some stony, compact materials; droughty on some sites	1/
28	Low	Provide adequate drainage	Low	Moderate to high	Good to fair	Coarse soils, some drought problems and erosion	1/	Fair to good	Coarse soils, ravelling, some compact material	1/
29	N/A	No special suggestions	Low	Moderate to low	Good to fair	Coarse soils, some drought problems	1/	Fair to good	Coarse soils, ravelling, droughtiness	1/
30	N/A	N/A	N/A	High	Good	Some erosion, low fertility	1/	N/A	N/A	N/A
31	II	Provide adequate drainage	Low to moderate	Moderate	Poor	Coarse textured, pumice soils at high elevations	2/	Poor	Coarse textured soils, low fertility, high elevation, ravelling	2/
32	I	No special suggestions	Low	Moderate	Fair	Coarse textured soils, droughtiness, low fertility	1/	Fair	Coarse textured soils, low fertility, droughtiness	1/
33	I	Lay cutbanks fairly flat	Low	Low to moderate	Poor	Coarse textured, cindery soils	2/	Poor	Coarse textured, cindery soils	2/
34	I-II	No special suggestions	Low	Low	Poor	Coarse, cindery soils	2/	Poor	Coarse, cindery soils; ravelling	2/
35	I	No special suggestions	Low	Moderate	Fair	Coarse soils, droughtiness	1/	Fair to poor	Coarse soils, ravelling, droughtiness	1/
36	N/A	N/A	N/A	Low	Fair	Droughtiness	1/	Fair	Droughtiness	1/
37	N/A	N/A	Low	Low	Fair to good	Droughtiness, coarse soils	1/	Fair to good	Coarse soils, droughtiness	1/
38	I	Lay cutbanks back as flat as practical to reduce ravelling	Low	Moderate to high	Fair	Coarse soils, steep slopes	1/	Fair	Coarse soils, steep slopes, ravelling	1/
39	N/A	N/A	Low	Low to moderate	Fair to good	Droughtiness	1/	Fair to good	Droughtiness, low fertility	1/
40	N/A	N/A	N/A	High to moderate	Good	Periodic flooding, some coarse soils	1/	Good	N/A	1/
41	I	N/A	Low	Moderate	Fair	Coarse soils, droughtiness	1/	Fair	Coarse soils, droughtiness	1/

1/ Prepare seed bed, fertilize, seed, and mulch, using species adapted to the climatic zone and moisture regime of the landtype. Periodic watering will be needed in many cases for grass establishment. Native shrubs should also be considered.

2/ Seeding success is questionable. Each site should be evaluated on a project basis for seeding recommendations. Native shrubs may be successful on some of these sites not suited for grasses.

INTERPRETATIONS FOR ENGINEERING - PART I

Land-type No.	Unified Classification	Suitability for Use as Topsoil Source	Suitability of Soil as Sand and/or Gravel Source	Suitability of Soil as a Possible Clay Source	Suitability of Bedrock for Road Rock	Limitations of Bedrock for Road Rock	Consideration for Road Location and Construction*	Method of Excavation	Cutbank & Ditch Erosion Potential	Susceptibility to Cutbank Sloughing and Ravelling
62	SM, SC, ML	Suited at some locations, mostly unsuited	Unsuited	Unsuited	Good	N/A	Clayey soils may be encountered	Blading, ripping, and blasting	Moderate	Low
63	SM	Unsuited	Unsuited	Unsuited	Good	N/A	No special considerations	Blading and blasting	Moderate	Moderate
64	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Complex slopes with some rock outcrops	Blading and blasting	Moderate	Moderate
65	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Complex slopes with some rock outcrops	Blading and blasting	Moderate	Moderate
66	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good	N/A	No special considerations	Blading and blasting	Moderate	Moderate
67	SM, SW	Unsuited	Unsuited	Unsuited	Good	N/A	Depth to bedrock	Blading and blasting	Moderate	Moderate
68	SM, SW	Unsuited	Unsuited	Unsuited	Good	N/A	Steep slopes	Blading and blasting	Moderate to high	Moderate
69	SM, SW	Unsuited	Unsuited	Unsuited	Good	N/A	Steep slopes	Blading and blasting	Moderate to high	Moderate
70	SM, SP, SW, GP	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	No special considerations	Blading and blasting	Low to moderate	N/A
71	SM, ML	Unsuited	Unsuited	Unsuited	Good	N/A	Long steady slopes	Blading and blasting	Moderate to high	Low
72	SM	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Stoniness and rock outcrops are common	Blading and blasting	Moderate	N/A
73	SM	Unsuited	Unsuited	Unsuited	Good to fair	Some soft materials may be included	No special considerations	Blading and blasting	Moderate	Low to moderate
74	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good to fair	Density is below optimum on some of the material	Very stony land	Blading and blasting	Low to moderate	Low to moderate
75	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good to fair	Density is below optimum on some of the material	Very stony land	Blading and blasting	Low to moderate	Low to moderate
76	SM, SW, SP	Unsuited	Unsuited	Unsuited	Good to fair	Density is below optimum on some of the material	Very stony land	Blading and blasting	Moderate	Low to moderate
77	SM, SW, SP	Unsuited	Unsuited	Unsuited	Good to fair	Density is below optimum on some of the material	Very stony land	Blading and blasting	Moderate	Low to moderate
78	SM	Unsuited	Unsuited	Unsuited	Good	N/A	Steep slopes	Blading and blasting	Moderate	Low

* Dustiness is an item to consider on all roads except on rough, rocky land and wet areas. Surfacing or dust abatement materials should be applied when dust conflicts with other values.

INTERPRETATIONS FOR ENGINEERING - PART 2

Land-type No.	Probability of Cutbank Failures	Suggestions for Cutbank Stability Problems	Failure Potential on Road Waste and Fills	Erosion Potential on Road Waste and Fills	Suitability of Road Waste & Fill Slopes to Seeding	Limitations to Road Waste & Fill Slope Seeding	Suggestions for Road Waste & Fill Slope Seeding	Suitability of Cutbanks to Seeding	Limitations to Cutbank Seeding	Suggestions for Cutbank Seeding
62	1	N/A	Low	Moderate	Good	Droughtiness	1/	Good to fair	Some compact material of low fertility	1/
63	1	N/A	Low	Moderate	Fair	Coarse textured soils of low fertility, droughtiness	1/	Fair	Coarse textured soils of low fertility, droughtiness	1/
64	1	N/A	Low	Moderate to low	Fair	Coarse textured soils of low fertility, droughtiness	1/	Fair to poor	Coarse textured soils, low fertility, droughtiness, exposure of bedrock	1/
65	1	N/A	Low	Moderate to low	Fair	Coarse textured soils of low fertility	1/	Fair to poor	Coarse textured soils, low fertility, droughtiness, exposure of bedrock	1/
66	1	N/A	Low	Moderate to low	Fair	Coarse textured soils of low fertility	1/	Fair to poor	Coarse textured soils, low fertility, droughtiness, exposure of bedrock	1/
67	1	N/A	Low	Moderate to low	Fair	Coarse textured soils of low fertility	1/	Fair	Coarse textured soils, low fertility, droughtiness	1/
68	1	N/A	Low	Moderate	Fair	Coarse textured soils of low fertility, droughtiness	1/	Fair to poor	Coarse textured soils, low fertility, droughtiness	1/
69	1	N/A	Low	Moderate	Fair	Coarse textured soils, low fertility	1/	Fair	Coarse textured soils, low fertility	1/
70	1	N/A	N/A	Low to moderate	Poor	Coarse textured pumice soils, low fertility, frost, droughtiness	1/	Poor	Coarse textured soils of low fertility, frost heaving, droughtiness	1/
71	1	N/A	Low	Moderate to high	Fair to good	Droughtiness	1/	Fair to good	Droughtiness	1/
72	1	N/A	N/A	Moderate	Fair	Coarse textured soils, low fertility, droughtiness	1/	Fair	Coarse textured soils, low fertility, droughtiness, frost heaving	1/
73	1	N/A	Low	Moderate	Poor to fair	Coarse textured soils of low fertility, frost heaving	1/	Poor to fair	Coarse textured soils of low fertility	1/
74	1	N/A	Low	Low to moderate	Poor	Coarse textured, stony soils	2/	Poor	Coarse textured, stony soils	2/
75	1	N/A	Low	Low to moderate	Poor	Coarse textured, stony soils; droughtiness	2/	Poor	Coarse textured, stony soils; droughtiness	2/
76	1	N/A	Low	Moderate	Poor to fair	Coarse textured soils, low fertility, stony	1/, 2/	Poor	Coarse textured soils, low fertility, stoniness	2/
77	1	N/A	Low	Moderate	Poor	Coarse textured soils, low fertility, stoniness	2/	Poor	Stoniness, coarse textured soils, low fertility	2/
78	1	N/A	Low	Moderate	Fair to good	Some coarse textured soils of low fertility, droughtiness	1/	Fair	Droughtiness	1/

1/ Prepare seed bed, fertilize, seed, and mulch, using species adapted to the climatic zone and moisture regime of the landtype. Periodic watering will be needed in many cases for grass establishment. Native shrubs should also be considered.

2/ Seeding success is questionable. Each site should be evaluated on a project basis for seeding recommendations. Native shrubs may be successful on some of these sites not suited for grasses.

INTERPRETATIONS FOR ENGINEERING - PART 1

Land-type No.	Unified Classification	Suitability for Use as Topsoil Source	Suitability of Soil as Sand and/or Gravel Source	Suitability of Soil as a Possible Clay Source	Suitability of Bedrock for Road Rock	Limitations of Bedrock for Road Rock	Consideration for Road Location and Construction*	Method of Excavation	Cutbank & Ditch Erosion Potential	Susceptibility to Cutbank Sloughing and Ravelling
79	SMd	Unsuited	Unsuited	Unsuited	Good	N/A	Steep slopes	Blading and blasting	Moderate	Low
80	SMd, GW, GP	Unsuited	Suited (cinders)	Unsuited	Unsuited	N/A	Steep slopes on cinder cones	Blading	Low	High
81	SMd, GW, GP	Unsuited	Suited (cinders)	Unsuited	Unsuited	N/A	Steep slopes on cinder cones	Blading	Low	High
82	SMd, SW, SP, GW, GP	Unsuited	Suited (cinders)	Unsuited	Unsuited	N/A	Steep slopes on cinder cones	Blading	Moderate	High
83	SMd, SW, SP GW, GP	Unsuited	Suited (cinders)	Unsuited	Unsuited	N/A	Steep slopes on cinder cones	Blading	High to moderate	High
84	SMd, SW, SP	Unsuited	Unsuited, suited locally for cinders	Unsuited	Good to unsuited	Some material is too soft for road rock	Special precautions need to be taken to prevent damage from avalanches	Blading, ripping, and blasting	High	High to moderate
85	SMd, SP, SW	Unsuited	Unsuited, suited for cinders locally	Unsuited	Good to unsuited	Some of the material is too soft for road rock	No special considerations	Blading, ripping, and blasting	Moderate	Low
86	SMd	Unsuited	Unsuited, possible local cinder sources	Unsuited	Good to unsuited	Some of the material is too soft for road rock	Steep slopes	Blading, ripping, and blasting	Moderate	Low
87	SMd	Unsuited	Unsuited, possible local cinder sources	Unsuited	Good to unsuited	Some of the material is too soft for road rock	Steep slopes	Blading, ripping, and blasting	Moderate	Low
88	SMd, ML, SC, MH	Unsuited	Unsuited	Unsuited (Some deposits of diatomaceous earth)	Good to unsuited	Some materials are too soft for road rock	Materials are complex and detailed site investigation is necessary	Blading, ripping, and blasting	Moderate to high	Moderate to high
89	SMd, ML, SC, MH	Unsuited	Unsuited	Unsuited (some deposits of diatomaceous earth)	Good to unsuited	Some materials are too soft for road rock	Detailed site investigation is needed due to the complexity of the land.	Blading, ripping, and blasting	High	High
90	SMd, ML, SC	Unsuited	Suited locally, mostly unsuited	Unsuited	Fair to unsuited	Depth of overburden, materials too soft for road rock	Some clayey soil may be encountered	Blading, some ripping and blasting	Moderate	Low to moderate
91	SMd, ML	Unsuited	Unsuited	Unsuited	Good to fair	Some of the material is too soft for road rock	Steep slopes	Blading, ripping, and blasting	Moderate to high	Low
92	SMd, SW, SP, GP	Unsuited	Possible cinder source	Unsuited	Good	Depth of overburden	Cindery soils	Blading	Low	Moderate to high
93	SMd, SW, SP, GP	Unsuited	Possible cinder source	Unsuited	Good	Depth of overburden	Cindery soils	Blading	Low	Moderate to high
94	SMd, SP	Unsuited	Suited (sand)	Unsuited	Unsuited, some local spots may be suitable	Depth of overburden	Sandy soils	Blading, some blasting	High	N/A
95	SMd, SP	Unsuited	Suited (sand)	Unsuited	Unsuited	Depth of overburden	Sandy soils	Blading	High	N/A
96	SMd, SW, SP, GW	Unsuited	Suited	Unsuited	Unsuited	Depth of overburden	Pumice soils	Blading	Moderate to low	N/A

* Dustiness is an item to consider on all roads except on rough, rocky land and wet areas. Surfacing or dust abatement materials should be applied when dust conflicts with other values.

Land-type No.	Unified Classification	Suitability for Use as Topsoil Source	Suitability of Soil as Sand and/or Gravel Source	Suitability of Soil as a Possible Clay Source	Suitability of Bedrock for Road Rock	Limitations of Bedrock for Road Rock	Consideration for Road Location and Construction*	Method of Excavation	Cutbank & Ditch Erosion Potential	Susceptibility to Cutbank Sloughing and Ravelling
97	SM, SW, SP	Unsuited	Unsuited	Unsuited	Good	N/A	No special considerations	Blading and blasting	Moderate	Moderate
98	SM, SW, SP	Unsuited	Unsuited	Unsuited	Good	N/A	No special considerations	Blading and blasting	Moderate	Moderate
1A	Not rated	Unsuited	Unsuited	Unsuited	Good	N/A	Steep rocky slopes limit road construction	Blasting and blading	Moderate to high	Moderate
2A	SM, GP, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Coarse pumice surface soils	Blading	Low to moderate	N/A
2B	SM, SP, SW, GP	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Coarse pumice soils	Blading	Low to moderate	N/A
4A	SM, SW	Unsuited	Suited	Unsuited	N/A	Depth of overburden	No special considerations	Blading	Moderate	N/A
4C	SM	Unsuited	Some sites may be suitable	Unsuited	N/A	Depth of overburden	Flashy runoff occurs in this landtype	Blading	High	Moderate to low
5A	SM, SW, SP	Unsuited	Unsuited	Unsuited	Unsuited to fair	Most of the material is too soft for road rock	Steep slopes, potential for high visual impact	Blading, ripping, and blasting	Moderate to high	High to moderate
6A	SM	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	No special considerations	Blading and blasting	Low to moderate	N/A
6B	SM, SP	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Some stony sites	Blading and blasting	Low to moderate	N/A
6C	SMu, SM, ML	Some sites are suitable, mostly unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Some stony sites	Blading and blasting	Moderate	N/A
6E	SM	Unsuited	Unsuited	Unsuited	Unsuited (some good material may be found locally)	Depth of overburden	Some steep slopes, coarse pumice soil	Blading	Moderate	Moderate to high
6G	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	No special considerations	Blading	Low to moderate	N/A
6H	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	No special considerations	Blading, some blasting	Moderate	Low
6J	SM, SP, SW	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Some rock outcrops are present	Blading and blasting	Moderate	N/A
7A	SM, SP, (very stony)	Unsuited	Unsuited	Unsuited	Good to fair	Some soft materials	Rough, rocky land	Blading and blasting	Low	Moderate to low
7B	SM, GW, SW (very stony)	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Rough, rocky land	Blading and blasting	Low	Moderate

* Dustiness is an item to consider on all roads except on rough, rocky land and wet areas. Surfacing or dust abatement materials should be applied when dust conflicts with other values.

INTERPRETATIONS FOR ENGINEERING - PART 2

Land-type No.	Probability of Cutbank Failures	Suggestions for Cutbank Stability Problems	Failure Potential on Road Waste and Fills	Erosion Potential on Road Waste and Fills	Suitability of Road Waste & Fill Slopes to Seeding	Limitations to Road Waste & Fill Slope Seeding	Suggestions for Road Waste & Fill Slope Seeding	Suitability of Cutbanks to Seeding	Limitations to Cutbank Seeding	Suggestions for Cutbank Seeding
97	I	N/A	Low	Moderate	Poor	Coarse pumice soils, droughtiness	1/	Poor to unsuited	Coarse textured pumice soils, low fertility, rock exposure, ravelling	2/
98	I	N/A	Low	Moderate	Poor	Coarse pumice soils, low fertility	1/	Poor to unsuited	Coarse textured pumice soils, low fertility, exposure of bedrock, ravelling	2/
1A	II	Retaining walls to prevent rock fall	Low to moderate	Moderate to high	Poor to unsuited	Coarse textured soils, stoniness, harsh climate	2/	Unsuited to poor	Coarse textured soils, bedrock exposure, harsh climate	2/
2A	N/A	N/A	N/A	Moderate to low	Unsuited to poor	Coarse textured pumice soils, frost heaving, low fertility	2/	Unsuited to poor	Coarse textured pumice soil, frost, low fertility	2/
2B	N/A	N/A	N/A	Moderate to low	Unsuited to poor	Coarse pumice soils	2/	Unsuited to poor	Coarse pumice soils, frost, low fertility	2/
4A	N/A	N/A	N/A	Moderate	Poor to fair	Coarse textured soils, low fertility, frost heaving	1/	Poor	Coarse textured soils, low fertility, droughtiness	1/
4C	I-II	Provide adequate drainage facilities	Low	High	Fair	Droughtiness, gravelly soils	1/	Fair	Droughtiness, gravelly soils	1/
5A	II	Local application of retaining structures	Moderate	High to moderate	Poor to unsuited	Coarse textured soils, harsh climate	2/	Unsuited to poor	Exposure of bedrock, coarse soils, low fertility	2/
6A	I	N/A	N/A	Low to moderate	Fair	Droughtiness, coarse textured soils, low fertility	1/	Fair	Exposed bedrock, coarse textured soils, droughtiness	1/
6B	I	N/A	N/A	Low to moderate	Fair	Coarse textured soils, low fertility, droughtiness	1/	Fair	Exposed bedrock, coarse soils, low fertility, droughtiness	1/
6C	I	N/A	N/A	Moderate	Good to fair	Droughtiness	1/	Fair	Droughtiness	1/
6E	I	N/A	Low	Moderate	Poor	Coarse textured soils, harsh climate	1/, 2/	Poor to unsuited	Coarse textured soils, droughtiness, ravelling	1/, 2/
6G	N/A	N/A	N/A	Low to moderate	Fair	Sandy soils, low fertility, frost heaving, droughtiness	1/	N/A	N/A	N/A
6H	I	N/A	Low	Moderate	Fair to poor	Coarse textured soils, frost heaving, droughtiness	1/	Poor to fair	Coarse textured soils, low fertility, ravelling, droughtiness	1/
6J	N/A	N/A	N/A	Moderate	Fair	Coarse textured soils, low fertility, droughtiness, frost heaving	1/	Fair to poor	Coarse textured soils of low fertility, droughtiness, ravelling	1/
7A	I	N/A	Low	Low to moderate	Poor to unsuited	Very stony soils	2/ Shrubs could be used	Unsuited	Very stony	2/
7B	I	N/A	Low	Low to moderate	Unsuited to poor	Coarse textured soils, very stony, harsh climate	2/	Unsuited to poor	Very stony, coarse soils, ravelling, harsh climate	2/

1/ Prepare seed bed, fertilize, seed, and mulch, using species adapted to the climatic zone and moisture regime of the landtype. Periodic watering will be needed in many cases for grass establishment. Native shrubs should also be considered.

2/ Seeding success is questionable. Each site should be evaluated on a project basis for seeding recommendations. Native shrubs may be successful on some of these sites not suited for grasses.

INTERPRETATIONS FOR ENGINEERING - PART 1

Land-type No.	Unified Classification	Suitability for Use as Topsoil Source	Suitability of Soil as Sand and/or Gravel Source	Suitability of Soil as a Possible Clay Source	Suitability of Bedrock for Road Rock	Limitations of Bedrock for Road Rock	Consideration for Road Location and Construction*	Method of Excavation	Cutbank & Ditch Erosion Potential	Susceptibility to Cutbank Sloughing and Ravelling
7C	GP	Unsuited	Unsuited	Unsuited	Good	Difficult to quarry and crush	Rough, rocky land	Blasting and blading	Low	Moderate to high
7E	GM, SW, SP	Unsuited	Unsuited	Unsuited	Good to fair	Some soft pyroclastic material may be included	No special considerations	Blading and blasting	Moderate	Moderate to low
7F	GM, SW, SP	Unsuited	Unsuited	Unsuited	Good to fair	Some soft pyroclastic material may be included	High elevations, some rock outcrops	Blading and blasting	Moderate	Low
7G	GP, GW, GM	Unsuited	Unsuited (Possible some pumice gravel)	Unsuited	Unsuited to fair	Depth of overburden, soft materials	Likely to cause a high visual impact; light colored pumice soils	Blading, ripping, and blasting	Moderate	High
7H	GM, SM, SW	Unsuited	Unsuited	Unsuited	Good to poor	Some of the pyroclastic bedrock materials break down easily	Steep slopes	Blading, ripping, and blasting	Moderate to high	Low to moderate
7J	SM, GP, SP	Unsuited	Suited	Unsuited	N/A	Depth of overburden	No special considerations	Blading	Low	N/A
7K	GM, ML	Unsuited	Unsuited	Unsuited	Good	Some rock is difficult to quarry and crush	Steep slopes	Blading and blasting	Moderate to high	Low
7T	Not rated	Unsuited	Unsuited	Unsuited	Fair to good	Some pyroclastic material may be included	Narrow ridgetops	Blading and blasting	Moderate	Low
8A	GM, SW, SP	Unsuited	Unsuited	Unsuited	Good to fair	Some soft pyroclastic material may be included	Roads may have a high visual impact	Blading and blasting	Moderate to high	High to moderate
8B	GM, SP, SW	Unsuited	Unsuited	Unsuited	Good to unsuited	Some of the material is too soft for road rock	No special considerations	Blading, ripping, and blasting	Moderate	Moderate to low
8C	Not rated	Unsuited	Locally suited for cinders	Unsuited	Good to unsuited	Much of the bedrock is too soft for road rock	Potential impact to water quality, high visual impact	Blading, ripping, and blasting	Moderate to high	High to moderate
8E	Not rated	Unsuited	Unsuited	Unsuited	Unsuited to fair	Soft materials	High erosion potential	Blading and ripping, some blasting	High	High to moderate
8P	GW, GP	Unsuited	Suited	Unsuited	N/A	Depth of overburden	Coarse pumice soils on steep slopes, visual impact	Blading	Moderate	High
8T	Not rated	Unsuited	Unsuited	Unsuited	Unsuited to fair	Pyroclastic bedrock materials break down under traffic	Steep slopes, high potential for visual impact	Blading and ripping, some blasting	Moderate to high	Moderate to high
9A	GM, SW, SP, GP	Unsuited	Unsuited	Unsuited	Good to poor	Depth of overburden, some soft materials, stratified volcanics	Pumice soils, steep slopes	Blading and some blasting	High to moderate	High
9B	GM, GP, SW, SP	Unsuited	Unsuited	Unsuited	Unsuited to good	Depth of overburden, some soft materials, stratified volcanics	Steep slopes, pumice soils	Blading and some blasting	High to moderate	High
9C	GM, GP, SW, SP	Unsuited	Unsuited	Unsuited	Unsuited to good	Depth of overburden, stratified volcanics including some soft materials	Steep slope, pumice soils	Blading and some blasting	High to moderate	High
9F	GM, GP, SW, SP	Unsuited	Suited locally for outwash gravel or sand	Unsuited	N/A	Depth of overburden	Coarse pumice soils	Blading	Moderate	Moderate
9G	GW, SW, SP GM	Unsuited	Unsuited, locally for gravel	Unsuited	N/A	Depth of overburden	Some seepy spots over the compact glacial till	Blading and ripping	Moderate to high	Moderate
9J	GM, SW, SP, GM	Unsuited	Unsuited	Unsuited	N/A	Depth of overburden	Some seepy spots over the compact glacial till	Blading and ripping	High	Moderate to high

* Dustiness is an item to consider on all roads except on rough, rocky land and wet areas. Surfacing or dust abatement materials should be applied when dust conflicts with other values.

Landtype No.	Probability of Cutbank Failures	Suggestions for Cutbank Stability Problems	Failure Potential on Road Waste and Fills	Erosion Potential on Road Waste and Fills	Suitability of Road Waste & Fill Slopes to Seeding	Limitations to Road Waste & Fill Slope Seeding	Suggestions for Road Waste & Fill Slope Seeding	Suitability of Cutbanks to Seeding	Limitations to Cutbank Seeding	Suggestions for Cutbank Seeding
7C	I	N/A	Low	Low	Unsuited	Coarse pumice soils	2/	Unsuited	Coarse pumice soil	2/
7E	I	N/A	Low	Moderate to low	Poor	Coarse textured soils, frost heaving, low fertility, droughty summers	1/	Poor	Coarse textured soils, low fertility, harsh climate	2/
7F	I	N/A	Low	Moderate	Poor	Coarse textured soils, low fertility	1/, 2/	Poor	Coarse textured soils, exposure of bedrock, low fertility	1/, 2/
7G	I-II	No special suggestions	Low	Moderate	Unsuited	Coarse textured pumice	2/	Unsuited	Coarse textured pumice, ravelling	2/
7H	I	N/A	Low	Moderate to high	Fair to good	Droughtiness, some coarse textured soils	1/	Fair	Coarse textured soils, droughtiness	1/
7J	N/A	N/A	N/A	Low	Poor	Coarse pumice soils	1/, 2/	Poor to unsuited	Coarse pumice soils	2/
7K	I	N/A	Low	Moderate to high	Fair	Droughtiness	1/	Fair	Droughtiness, exposure of bedrock	1/
7T	I	N/A	Low	Moderate to high	Fair	Droughtiness	1/	Fair	Droughtiness	1/
8A	I-II	No special suggestions	Moderate	Moderate to high	Unsuited to poor	Coarse pumice soils, low fertility	2/	Unsuited to poor	Coarse pumice soils, low fertility	2/
8B	I	N/A	Low	Moderate	Poor	Coarse soils, low fertility, frost heaving, droughty summers	1/, 2/	Poor to unsuited	Coarse soils, low fertility, exposure of bedrock	2/
8C	II-III	Retaining structures may be applied	Moderate	High to moderate	Unsuited to poor	Coarse soils, harsh climate, droughtiness	1/, 2/	Unsuited to poor	Coarse soils, low fertility, droughtiness, harsh climate	2/
8D	II-III	Retaining structures to reduce ravelling	Moderate	High	Poor to unsuited	Coarse soils, erosion potential, harsh climate	2/	Unsuited to poor	Coarse soils, erosion potential, harsh climate	2/
8P	II-III	Retaining structures to reduce ravel and sloughing	Low	Moderate	Unsuited	Coarse pumice soil	2/	Unsuited	Coarse pumice soil	2/
8T	II	Retaining structures to reduce ravel and sloughing	Low	Moderate	Fair to unsuited	Coarse pumice soils, low fertility, droughtiness, harsh climate	1/, 2/	Poor to unsuited	Coarse pumice soils, exposed bedrock	2/
9A	I-II	N/A	Low	High to moderate	Poor	Coarse textured pumice soils	1/, 2/	Poor	Coarse textured pumice soils	1/, 2/
9B	II	No special suggestions	Low to moderate	High	Poor	Coarse pumice soils	2/	Poor to unsuited	Coarse pumice soils, ravelling	2/
9C	I-II	No special suggestions	Low	High to moderate	Poor	Coarse pumice soils	2/	Poor to unsuited	Coarse pumice soils, ravelling	2/
9F	I	N/A	Low	Moderate	Fair to poor	Coarse pumice soils, frost heaving	1/, 2/	Poor	Coarse pumice soils	2/
9G	II	Provide adequate drainage facilities	Low	Moderate	Poor to fair	Coarse pumice soils	1/, 2/	Poor	Coarse pumice soils, some compact glacial till	2/
9J	II	Provide adequate drainage facilities	Low to moderate	High	Poor to fair	Coarse pumice soils	1/, 2/	Poor	Coarse pumice soils, exposure of compact glacial till	1/, 2/

1/ Prepare seed bed, fertilize, seed, and mulch, using species adapted to the climatic zone and moisture regime of the landtype. Periodic watering will be needed in many cases for grass establishment. Native shrubs should also be considered.

2/ Seeding success is questionable. Each site should be evaluated on a project basis for seeding recommendations. Native shrubs may be successful on some of these sites not suited for grasses.

3. ENGINEERING

Interpretations for engineering include characteristics for roads, foundations, bedrock, and some miscellaneous interpretations. These are presented in two tables: One table, "Characteristics Pertinent to Roads and Airfields," is a standard engineering table for road construction based on the Unified Soil Classification System. The other table, "General Engineering Interpretation," gives other engineering interpretations which will be useful to engineers and other resource managers. These interpretations are explained and defined in this section. Generally, the following interpretations and ratings are based on the entire landtype unit including soil, bedrock, and landform. Some interpretations are based only on the soil material or bedrock material. These are stated in the description for each interpretation. The interpretations pertaining to roads are based on standard Forest Service regulations and construction methods presently used.

Unified Classification

Each soil is classified as to its Unified Classification. Those soils with significant layers of different soil materials will have a classification for each layer designated. The classification will be made for some representative soils by laboratory testing. Those soils not tested will be classified by comparing their properties to those tested.

Suitability for Use as Topsoil Source

This rating evaluates each soil as to its suitability for use as topsoil. It does not specify any particular use of the topsoil. Ratings are based on soil characteristics.

> Suited - Soil texture ranges from sandy loam to clay loam. Gravel content is less than 35 percent and soil layer is at least 3 feet thick.
>
> Unsuited - This rating indicates the soils do not satisfy the requirements specified under "Suited." However, soils rated "Unsuited" may still satisfy a particular requirement. See the "Table of Soil Characteristics" for soil texture, thickness, and gravel content.

Suitability of Soil as Sand and/or Gravel Source

This interpretation indicates the suitability of each soil as a possible source of sand and/or gravel. It does not indicate the kind or quality of sand or gravel, or refer to any specific use of the sand and/or gravel.

> Suited - This rating indicates that sand and/or gravel is present and the following conditions are satisfied. There is a layer present which is composed of 80 percent, by volume, of sand and/or gravel. This layer is at least 4 feet.

Unsuited - This rating indicates that sand and/or gravel is generally not present in amounts which satisfy the requirements under "Suited." However, soils rated "Unsuited" may still satisfy a particular requirement. See the Table of Soil Characteristics for soil depth and gravel content.

Suitability of Soil as a Possible Clay Source

This rating indicates the suitability of each soil as a possible source of clay. It does not indicate the kind or quality of clay or refer to any specific use of the clay.

Suited - This rating indicates that the soil is a possible source of clay. Soils with this rating have the following: Texture ranges from clay loam to clay. Gravel content is less than 35 percent. This layer is at least 2 feet thick.

Unsuited - Soils with this rating generally are not possible sources for clay.

Suitability of Bedrock for Road Rock

This interpretation indicates the general suitability of rock when used as road rock for base course or wearing surface. These ratings are based on rock hardness, density, and susceptibility to weathering and breakdown. Soils are not rated when depth to bedrock is greater than 12 feet. (Cautionary note: This information is for broad planning purposes only. Specific onsite characterization data are required to accurately determine rock suitability.)

Unsuited - Rock is soft and breaks down rapidly under logging traffic.

Poor - Rock is only moderately hard and breaks down easily under logging traffic; usually in one or two years' time.

Fair - Rock is hard and dense, but tends to break down under logging traffic after about two to four years' use.

Good - Rock is hard, dense, and resists breakdown under logging traffic.

Limitations of Bedrock for Road Rock

This column indicates the major limitation of the bedrock for road rock use.

Consideration for Road Location and Construction

This column indicates the major considerations for road location and construction through each soil. The rating evaluates the impact of road construction on other resources and/or road construction problems likely to be encountered.

Method of Excavation

This interpretation refers to excavation methods most commonly used and required for each soil. This includes soil, bedrock, and cemented and/or compacted layers in the soil. Methods are blading, ripping, and/or blasting. (Cautionary note: These appraisals are subject to change as machinery capabilities change.)

Cutbank and Ditch Erosion Potential

This interpretation indicates the potential for subsoil erosion by running water on each soil. Subsoil refers to that material from approximately the 2-foot depth extending to bedrock. It includes erosion which takes place along road ditches and on cutslopes. Rating is of soil material only and does not apply when cutbank or ditch is in bedrock. Factors considered in making ratings are field observations, texture and structure of subsoil materials, permeability, compaction, and climate.

> Low - Factors indicate that little or no subsoil erosion is likely to occur.
>
> Moderate - Factors indicate that the subsoils have moderate erosion potential.
>
> High - Factors indicate that the subsoils are likely to erode severely.

Susceptibility to Cutbank Sloughing and Raveling

This rating evaluates each unit for its susceptibility to sloughing or raveling after excavation. Ratings are based on cutbanks at least 10 feet high. Factors include field observations, soil and bedrock characteristics, backslope ratio, frost action, climate and potential for revegetation.

> Low - Sloughing and/or raveling is a minor problem requiring occasional road maintenance.
>
> Moderate - Sloughing and/or raveling causes some damage. Annual road maintenance is usually adequate.
>
> High - Sloughing and raveling occur at a rate that often plugs culverts and fills inside ditches. Frequent road maintenance with heavy equipment such as front-end loader is required.

Probability of Cutbank Failures

This interpretation indicates the probability of failures in cutbanks following road construction or excavation for buildings. Failures are considered to be at least 5 cubic yards of material in volume. Ratings are based on cutbanks of at least 5 feet in height and refer to more than a 50-percent chance for failures. These ratings are the same as in the Mantle Stability Surveys.

I. Very Stable - Practically no probability of chance of cutbank failures.

II. Stable - Probability of no more than 3 failures per mile of road cutbank.

III. Moderately Stable - Probability of 4 to 8 failures per mile of road cutbank.

IV. Unstable - Probability of 9 to 15 failures per mile of road cutbank.

V. Very Unstable - Probability of more than 15 failures per mile of road cutbank.

Suggestions for Cutbank Stability Problems

This rating gives suggestions, when applicable, to increase stability of cutbanks or reduce damage from raveling and sloughing.

Failure Potential on Road Waste and Fills

This interpretation rates the soil units as to the susceptibility of failure occurring on fill and sidecast waste material and related damage to resources. Failures are defined as a loss or partial loss of road fill or sidecast material on the fill slope.

Considered are initial and subsequent failures cased by construction, erosion and additional sidecast during maintenance. Failures result in damage to various resources. Stream sedimentation levels are increased, resulting in an adverse effect on both water quality and fisheries. Timber growth potential is affected as fill slope areas no longer contribute to production. Occasionally, the failures do damage to the road itself. The ratings are based on current road construction practices and procedures and on type of soil materials, natural drainage of the site, landform, slope of the fill, and field observation.

Low - Failure on road waste and fills is sufficiently low to result in only minor damage to resource values.

Moderate - Failures on road waste and fills occur with sufficient frequency to cause moderate damage to resource values.

High - Failures on road waste and fills occur at a rate and magnitude sufficient to cause major damage to resource values.

Erosion Potential on Road Waste and Fills

This interpretation rates the soil units as to the susceptibility of erosion occurring on fill and sidecast waste material and related damage to resources. Erosion is a loss of surface soil from fill or sidecast.

This erosion contributes sedimentation to streams. Timber growth potential is affected as fill slope areas no longer contribute to production. The ratings are based on current road construction practices and procedures and on type of soil materials, natural drainage of the site, landform, slope of the fill, and field observation.

Low - Erosion on road waste and fills is sufficiently low to result in only minor damage to resource values.

Moderate - Erosion on road waste and fills occurs with sufficient magnitude to cause moderate damage to resource values.

High - Erosion on road waste and fills occurs at a magnitude sufficient to cause major damage to resource values.

Suitability of Road Waste and Fill Slopes to Seeding

This interpretation indicates the probable success of fill slope seeding. Factors considered in making ratings are soil characteristics, elevation, slope, climate, snowpack, and frost hazard. Ratings are based on current methods and practices of seeding, grass species, fertilizer application and time of seeding.

Poor - Probability of success is low. Seeding generally is not successful and requires three or more reseedings and special treatments.

Fair - Success is likely on about 50 percent of area treated. Requires one or two followup treatments. Seeding usually becomes well established within two years. Little followup seeding necessary.

Good - Probability of high success. Seeding usually becomes well established within two years. Little followup seeding is necessary.

Limitations to Cutbank Seeding

This indicates the major limitations to success of cutbank seeding.

Suggestions for Cutbank Seeding

This indicates special treatment to be given, when applicable, to increase the chance of success of cutbank seeding.

DESCHUTES NATIONAL FOREST

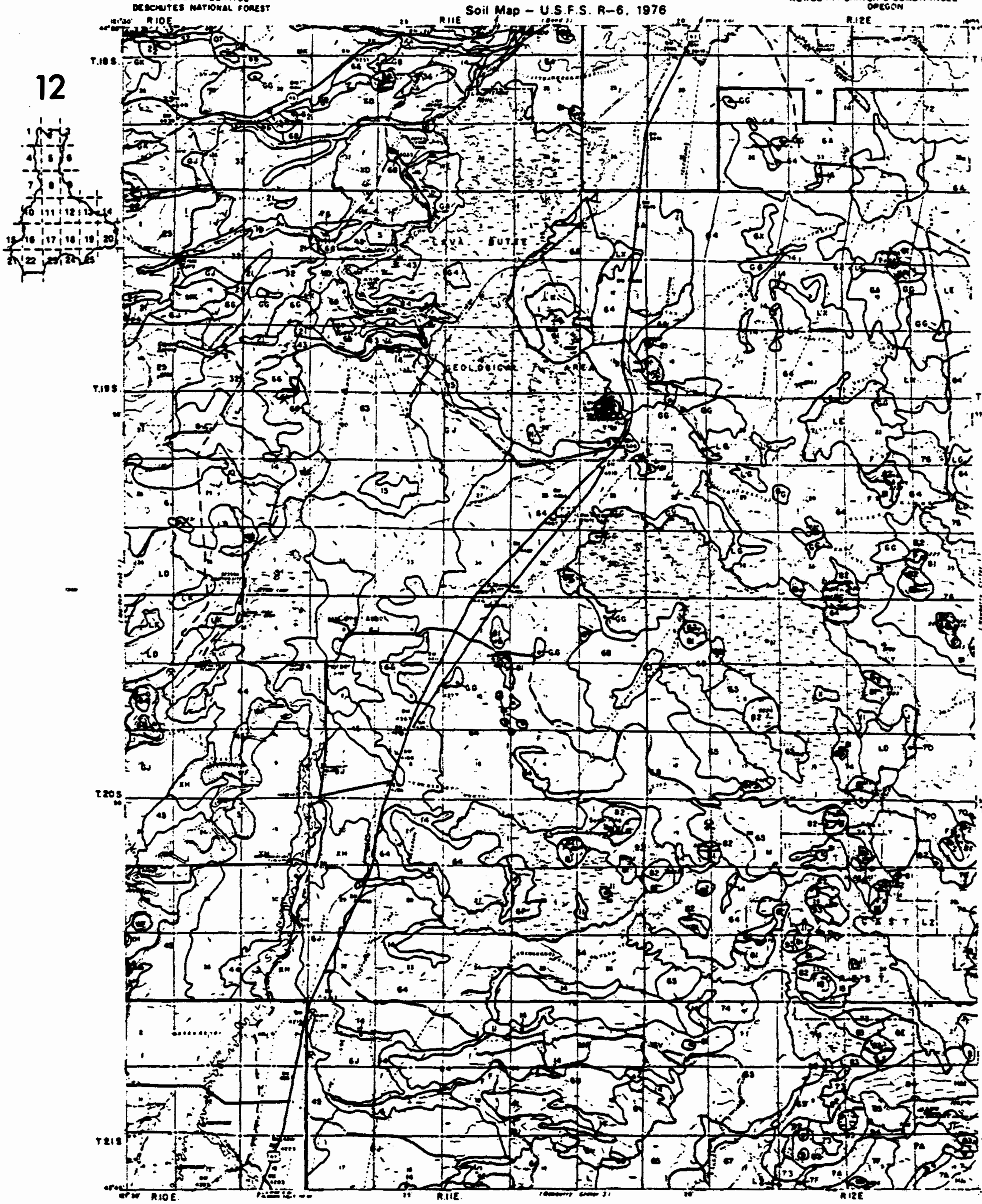
Soil Resource Inventory

Soil Map – U.S.F.S. R–6, 1976

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
DESCHUTES NATIONAL FOREST

NEWBERRY CRATER 2 QUADRANGLE
OREGON

12



Soil mapping by U.S.F.S. Soil Scientists Daniel M. Larsen and Robert A. Klink, Deschutes National Forest.
Mapping units are described in the Soil Resource Inventory Report.

- ROCK OUTCROP
- TALUS
- UNSTABLE AREA
- WET SPOT, SMALL MARSH OR POND
- AVALANCHE TRACK OR DEBRIS SLIDE
- FAULT ESCARPMENT, ROCK CLIFF
- CRATER
- GRAVEL OR CINDER PIT
- SANDSPOT, SAND BLOWOUT
- SMALL FROST POCKET
- SLUMP OR SLIDE ESCARPMENT, CIRQUE HEADWALL

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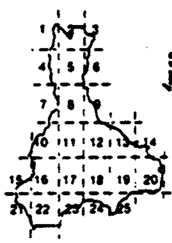
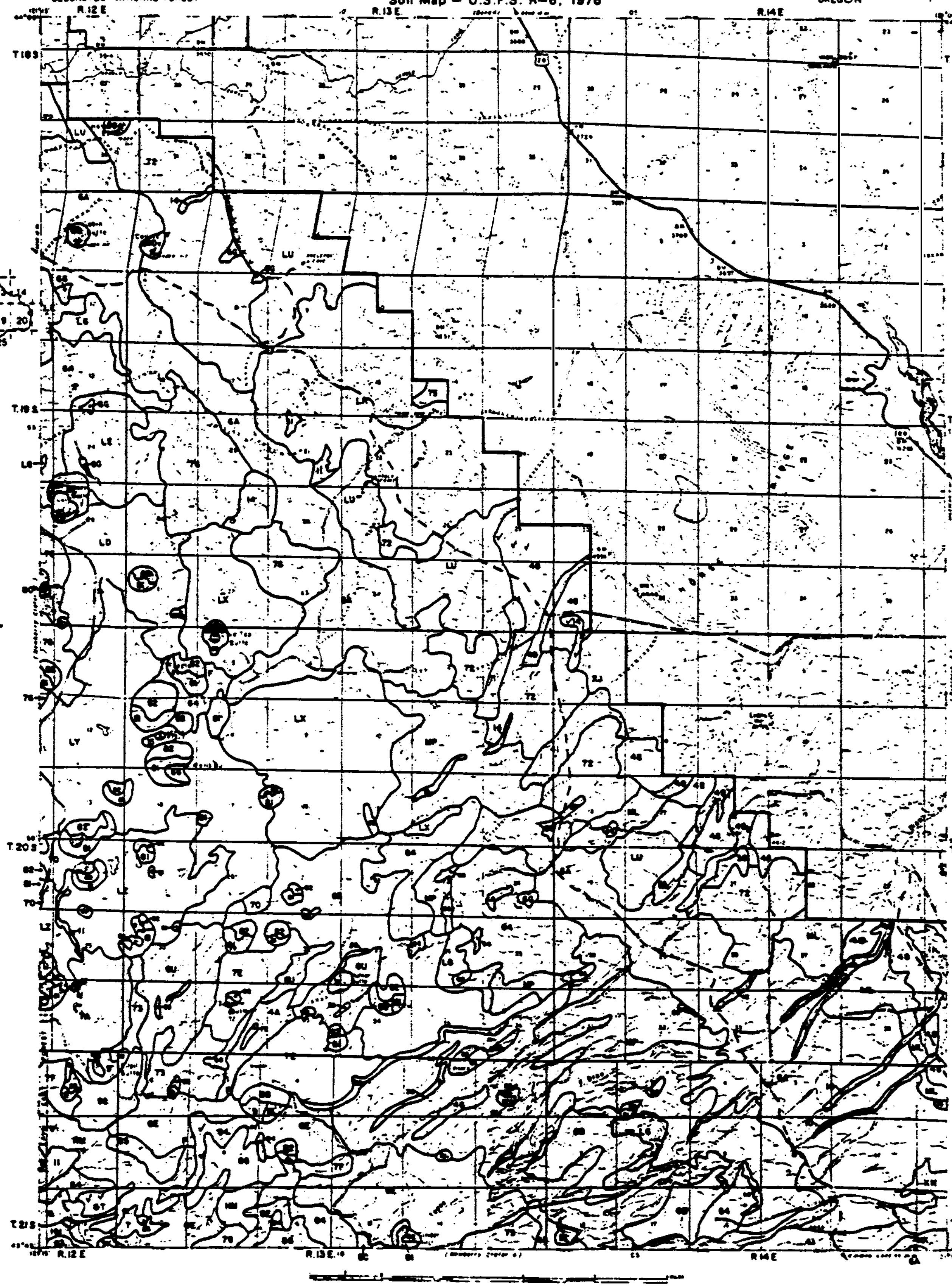
NEWBERRY CRATER 1 QUADRANGLE
OREGON

13





Soil mapping by U.S.F.S. Soil Scientists Daniel M. Larsen
and Robert A. Klink, Deschutes National Forest.
Mapping units are described in the Soil Resource Inventory Report.

ROCK OUTCROP	CRATER
TALUS	GRAVEL OR CINDER PIT
UNSTABLE AREA	SANDSPOT, SAND BLOWOUT
WET SPOT, SMALL MARSH OR POND	SMALL FROST POCKET
AVALANCHE TRACK OR DEBRIS SLIDE	SLUMP OR SLIDE ESCARPMENT, CIRQUE HEADWALL
FAULT ESCARPMENT, ROCK CLIFF	

DESCHUTES NATIONAL FOREST

Soil Resource Inventory

Soil Map— U.S.F.S. R–6, 1976

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NEWBERRY CRATER 3 QUADRANGLE
OREGON

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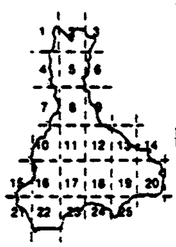

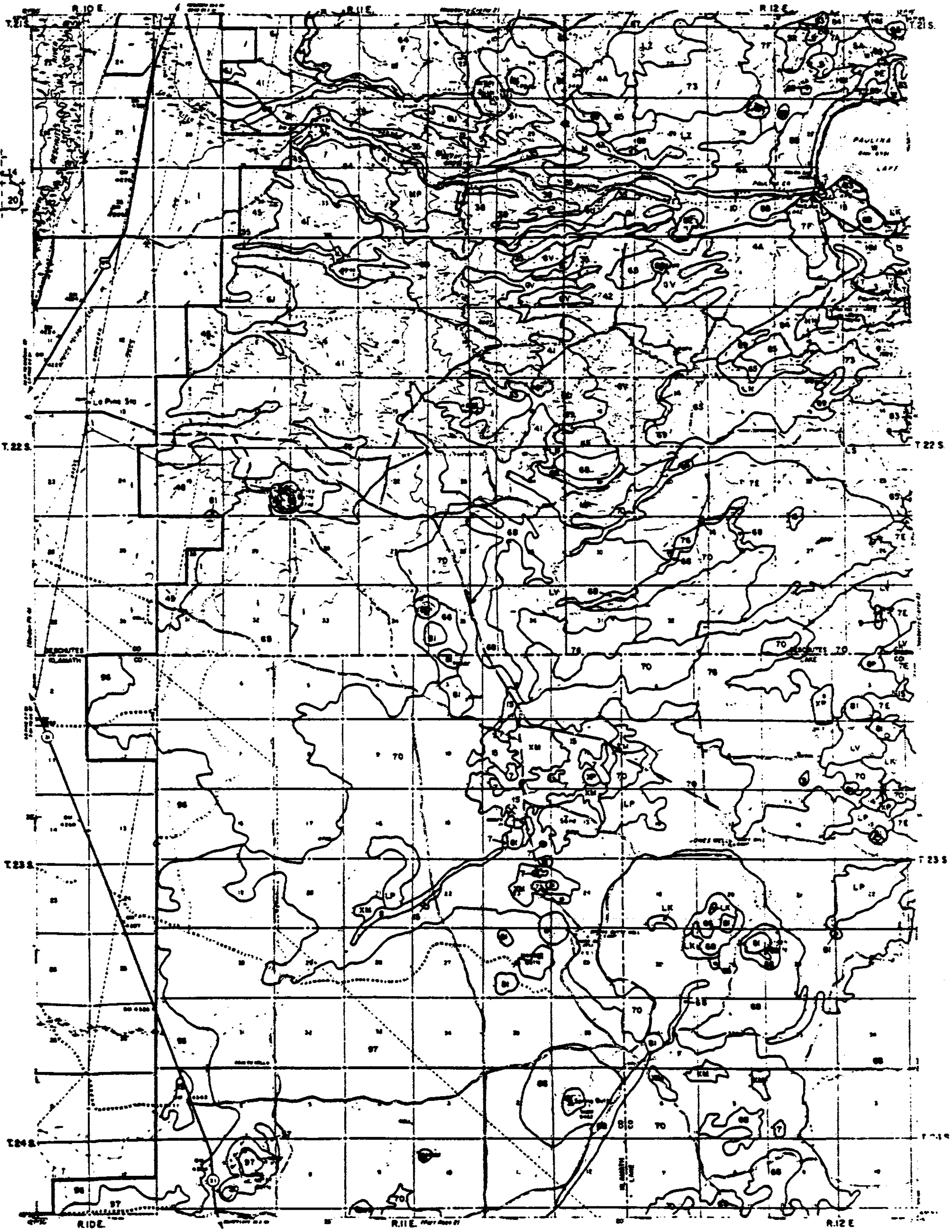

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- ROCK OUTCROP
- TALUS
- UNSTABLE AREA
- WET SPOT, SMALL MARSH OR POND
- AVALANCHE TRACK OR DEBRIS SLIDE
- FAULT ESCARPMENT, ROCK CLIFF
- CRATER
- GRAVEL OR CINDER PIT
- SANDSPOT, SAND BLOWOUT
- SMALL FROST POCKET
- SLUMP OR SLIDE ESCARPMENT, CIRQUE HEADWALL

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Soil Resource Inventory

Soil Map – U.S.F.S. R–6. 1976

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NEWBERRY CRATER 4 QUADRANGLE
OREGON

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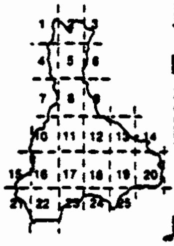

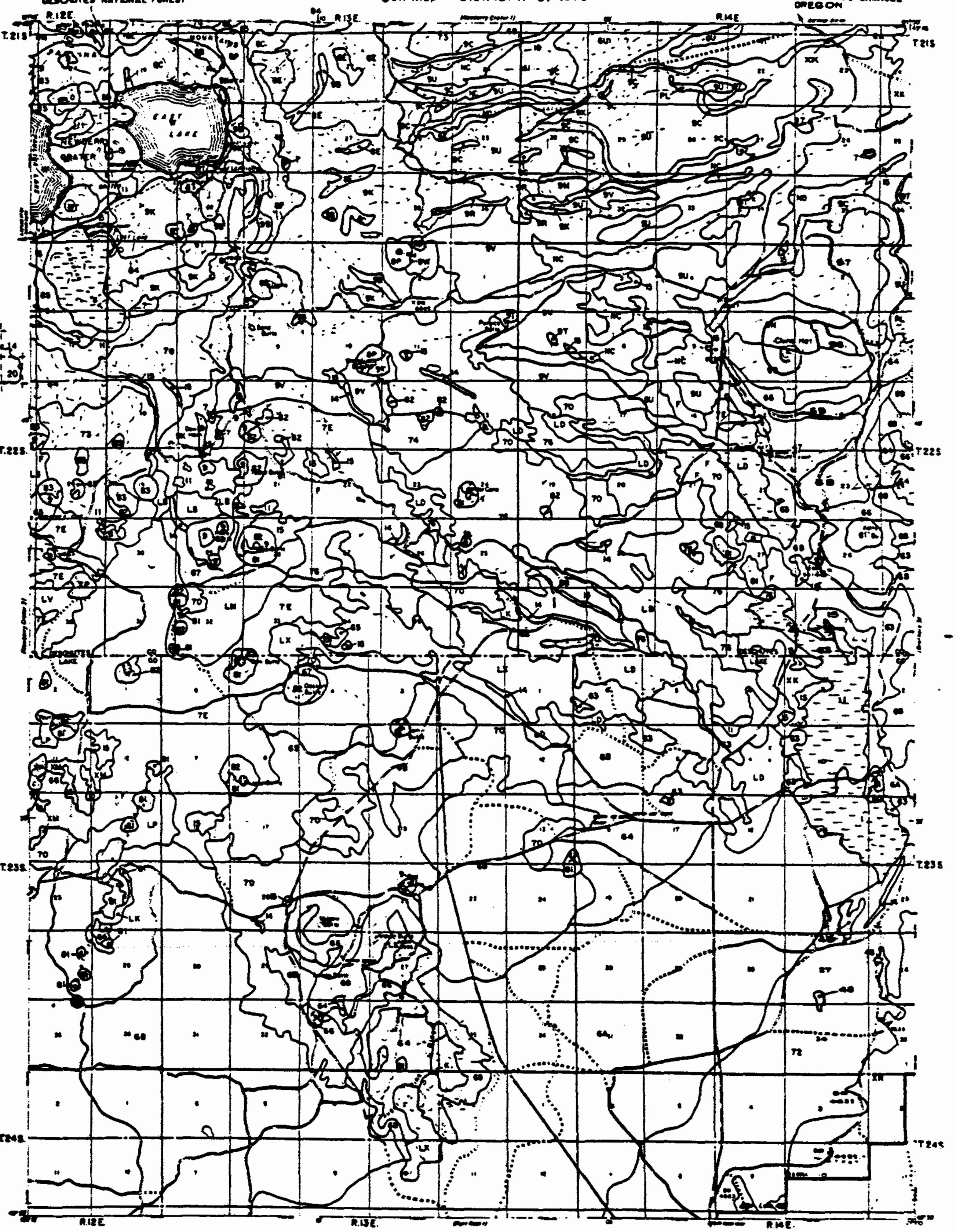

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CRATER
GRAVEL OR CINDER PIT
SANDSPOT, SAND BLOWOUT
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SLUMP OR SLIDE ESCARPMENT, CIRQUE HEADWALL

APPENDIX L
ANALYSIS OF ARSENIC, BORON AND MERCURY DEPOSITION FROM EMISSIONS OF NEWBERRY GEOTHERMAL PROJECT ON NEWBERRY CRATER LAKES

Prepared by AGI Technologies, May 11, 1994

Analysis of Arsenic, Boron, and Mercury Deposition from Emissions of Newberry Geothermal Project on Newberry Crater Lakes

Robert C. Palmquist
James Houck
AGI-Technologies
Portland, Oregon
May 11, 1994

1 Introduction

This report is written to quantify the potential impacts on the Newberry Crater Lakes from deposition of arsenic, boron, and mercury estimated to be emitted from the Newberry Geothermal power plant project. A previous study (Analysis of Depositional Impacts from Emissions of Newberry Geothermal Project on Newberry Crater Lakes and from Cooling Tower Plume Drift) estimated the annual deposition rate for these materials on the watershed to range between 1.5×10^{-08} and 2.9×10^{-7} pounds per acre/year (lbs/ac/yr) for arsenic, 2.9×10^{-06} and 5.7×10^{-05} lbs/ac/yr for boron, and 3.4×10^{-7} and 6.7×10^{-6} lbs/ac/yr for mercury. The potential impact of this deposition on the lakes was estimated for a worse case scenario which assumed:

- The elements were deposited over the entire watershed at the highest estimated rate (depositional rate in forests)
- The entire watershed drained into the lakes
- All deposited material was solubilized and transported to the lakes
- Within the lakes, the elements uniformly mixed with the upper one foot of water.

The resulting concentrations of arsenic and boron were below the fresh water chronic criteria, but the mercury concentration, approximately 1.2×10^{-5} milligrams per liter (mg/l), was identical to the chronic criteria for fresh water (chronic criteria).

This investigation incorporates the estimated depositional rates (Table 1) and the assumption of completely solubilized elements into appropriate mixing models to more realistically assess the potential their concentrations in the lakes. The concentrations were calculated for the proposed project life of 50 years and equilibrium conditions. The most appropriate models estimate the concentrations to be to between 10% and 20% of the chronic criteria at the end of the project period for mercury and to be less than 1 % of the chronic criteria for arsenic. No chronic level has been established for boron.

2 Physical Characteristics

The Newberry Crater Lakes watershed, which is located approximately 1.25 miles southeast of the proposed plant, contains two lakes—Paulina Lake and East Lake. It is approximately 17.4

square miles in area and has a cover consisting of forests, the two lakes, and open lands consisting of lava flows, grassland, and deforested land as described in Table 1.

The physical and chemical characteristics of the lakes are described in Reference 1. Paulina Lake is larger in area and volume than East Lake (Table 1) and is drained by Paulina Creek. Outflow from East Lake is by ground water seepage to Paulina Lake. Both lakes are dimictic and holomictic; that is, they have a distinct thermal stratification with fall and spring turnovers that affects the entire water column. Recent depth profiling by the US Geological Survey (USGS), as described in reference 2, indicates the upper layer (epilimnion) may reach thicknesses of 40 to 60 feet. Water levels vary seasonally a few feet being highest in the spring and lowest in late fall.

Their chemistry is unusual for lakes not in an evaporative basin. They have very high concentrations of major ions that are attributed to discharge of mineralized water from hot springs. The concentrations in the lakes differs with Paulina Lake generally having higher concentrations than East Lake. The lakes are fresh water and thus must have attained a balance between inflow and outflow.

The lakes receive water from direct precipitation, snow-melt runoff, ground water seepage, and hot springs. Not all of the topographic basin of East Lake may contribute runoff and ground water flow to it; rather a portion may drain outward to the flanks of the volcano.

Outflow from Paulina Lake is through Paulina Creek. Measurements by the USGS during the 1992 water year (ref. 2) indicates it has a mean discharge of 13 cubic feet per sec (cfs) with a maximum of 24 cfs in April and June and a minimum of 5.2 cfs in February. The total discharge was 9520 acre-feet. No data are available for ground water outflow from East Lake.

The soils and climate are described in reference 3. The soils are typically well drained loamy sand to sandy loam pumice with a Ph that varies between 5.5 to 7.0. The average annual precipitation is approximately 30 inches with a mean annual lake evaporation estimated to be 28 - 34 inches.

3 Background Concentrations

Background concentrations of arsenic, boron, and mercury for the lakes are presented in Table 1 for East lake and Lake Paulina. Mercury is a prospecting tool for geothermal reservoirs and extensive background data are available for it.

Elevated mercury concentrations are characteristic of soils, water, and rocks overlying active high-temperature hydrothermal systems as described in reference 4. However, mercury concentrations in the ground and surface waters of Newberry Crater, are below detection limits (0.0001 mg/l) which indicates the contribution of soluble mercury from rocks, soils, and thermal springs to surface water is small.

Mercury concentrations in soils of Newberry Crater are higher than those in surrounding areas. They were used to locate anomalies that may indicate actively circulating geothermal waters. Two of these anomalies with mercury concentrations in excess of 0.09 parts per million (ppm) underlie the north slopes of the caldera and extend to the shores of Paulina and East lakes.

Most of the caldera is underlain with soils with mercury concentrations between 0.03 and 0.05 ppm.

Mercury concentrations in ground water and hot springs vary greatly. Concentrations of 0.0003 mg/l were measured in East Lake Hot Springs in 1973 as described in reference 5. In 1991 and 1992, the USGS sampled water wells in the crater (ref. 2). Most samples (15 of 21) had mercury concentrations below detection level (0.0001 mg/l, or 0.0001 ppm) and the remaining six samples had concentrations below 0.0004 mg/l with a modal concentration of 0.0002 mg/l.

Mercury concentrations in surface water are generally below detection limits. The USGS sampled water at two locations each in East Lake and in Paulina Lake, and in Paulina Creek near its outflow from Paulina Lake. Only one of the eight samples had a mercury concentration exceeding detection; it was 0.0002 mg/l in Paulina Creek.

The non-detectable mercury concentrations in surface water and most ground water indicate that background mercury levels are very low and do not need to be considered in the following calculations. These very low levels indicate an insignificant mercury contribution from the leaching of rocks and soils and from mineralized hot springs.

4 Modeling

4.1 Modeling Procedures

The potential concentrations within the lakes can be assessed by an appropriate mixing model. As described in reference 6, a wide spectrum of models exist that range from the simplest one-box to the three-dimensional continuous model each of which provides a different spatial resolution. The choice of a model should be based on an analysis of the relative magnitude of the mixing and reaction rates. A simple model is appropriate if the reaction rate is significantly lower than the mixing rate, in which case, the system is "completely mixed" with respect to any spatial subdivision.

The assumption of completely solubilized elements makes them non-reactive and conservative substances. For conservative substances, the simplest approach, the completely mixed model is appropriate. The Newberry Crater Lakes are physically suited to simple modeling because their

- fall and spring turnovers mix shallow and deep waters,
- nearly constant water levels indicate water outflow and inflow are in balance and the lakes have a constant volume, and
- fresh water indicates that a chemical balance has been achieved between the input of chemical substances and their outflow in either subsurface or surface water.

The variation of the concentration (C) in a well-mixed box of constant water volume (V) can be derived from a simple mass balance equation (ref. 6) as described by equation 1, below. The terms on the are total input (J), loss through outlet (flow rate Q), and loss by reactions (R).

Equation 1:

$$V\frac{dC}{dt}=J-QC-R$$

The reaction term (R) drops out of the equation because of the solubilized assumption. Solving for the change in concentration simplifies it to equation 2 below. Equation 2 is appropriate to assess the cumulative effects of a constant input on lake concentrations as influenced by stream or ground water outflow.

Equation 2:

$$\frac{dC}{dt}=\frac{J-QC}{V}$$

The simplest approach is to determine the concentration at the end of the first year without outflow, which produces equation 3 below. This approach is an expansion of the one-foot mixing layer used in the initial investigation.

Equation 3:

$$C=\frac{J}{V}$$

The arsenic, boron, and mercury concentrations in Paulina and East Lakes were estimated using equations 2 and 3 in three uniform mixing models assuming completely solubilized elements. The models and their results are presented in Appendices A through C.

- Model 1 uses equation 3 to assess the effect of different loading rates on the mercury concentration at the end of the first year. This analysis was performed only for mercury.

- Model 2 uses equation 2 to investigate the cumulative impacts of arsenic, boron, and mercury deposition and was run for 500 years to determine the equilibrium concentrations for each lake in isolation. It uses the discharge data for Paulina Creek during the 1991-92 water year to calculate the mercury concentration in Paulina Lake (Model 2a). For East Lake, the impacts of three different three ground water discharge rates were investigated (Model 2b). Ground water discharge from East Lake contributes to the Paulina Creek discharge and its contribution was assumed to be proportional to the ratios of either watershed areas or lake volumes as described by the following three cases.

  Case 1: No ground water discharge, a worse-case scenario.

  Case 2: Ground water discharge assumed to be proportional to the watershed areas or 43% of Paulina Creek discharge.

  Case 3: Ground water discharge assumed to be proportional to lake volumes or 22% of Paulina Creek discharge.

- Model 3 considers the impact of ground water discharge from East Lake on the mercury concentrations in Paulina Lake. It uses equation 2 and the arsenic, boron, or mercury concentrations in ground water as described in case 2, Model 2b.

4.2 Modeling Results

4.2.1 Arsenic

The modeling results for arsenic are summarized in Table 2A and the results of each mixing model are presented in Appendix A. The results indicate that estimated arsenic concentrations in the lakes are significantly lower than the chronic criteria of 2.48x 10^{-5} mg/l at both the end of the 50-year contract period and at equilibrium.

In model 2, which considers each lake separately, the highest arsenic concentration occurs in East Lake with no discharge and it is less than 0.0001% of the chronic level at the end of the project life.

In model 3, which joins both lakes, the arsenic concentration in Lake Paulina reach 0.00006% of the chronic level and that in East Lake reaches 0.00005% of the chronic level.

4.2.2 Boron

The modeling results for boron are summarized in Table 2B and the results of each mixing model are presented in Appendix B. Chronic levels have not been established for boron and the estimated boron concentrations are compared to mean and maximum values from water samples collected in the United States.

The results indicate that estimated boron concentrations in the lakes are significantly lower than the mean value of 0.1x 10^{-1} mg/l at both the end of the 50-year contract period and at equilibrium.

In model 2, which considers each lake separately, the highest boron concentration occurs in East Lake with no discharge and it is only 0.05% of the national mean at the end of the project life.

In model 3, which joins both lakes, the boron concentration in Lake Paulina reaches 0.01% of the chronic level and that in East Lake reaches 0.02% of the national mean.

The modeling results for boron are summarized in Table 2B and the results of each mixing model are presented in Appendix B. The results indicate that estimated

4.2.3 Mercury

The modeling results for mercury are summarized in Table 2C and the results of each mixing model are presented in Appendix C. The results indicate that estimated mercury concentrations in the lakes are significantly lower than the chronic criteria of 1.2 x 10^{-5} mg/l at both the end of the 50-year contract period and at equilibrium.

According to Model 1, at the end of the first year, mercury concentrations in both lakes will range between 1.64 x 10^{-7} mg/l and 4.93 x 10^{-8} mg/l. These values are less than 2% of the chronic level. Their magnitude is not significantly affected by different loading rates. Of note, the mercury concentration in East Lake (1.64 x 10^{-7} mg/l) is 256% of that in Paulina Lake (6.41 x 10^{-8} mg/l) as a result of its smaller lake volume and similar mercury loading.

Model 2a indicates the cumulative effect of continued mercury deposition is to slowly increase the mercury concentrations until an equilibrium is attained between 100 and 200 years. In Paulina Lake equilibrium is achieved at approximately 145 years at a concentration of approximately 1.3 x 10^{-6} mg/l, which is 11% of the chronic level. At the end of the project, the cumulative mercury concentration in Paulina Lake is approximately 1.1 x 10^{-6} mg/l, or 9% of the chronic level.

Model 2b indicates the cumulative impact of mercury in East Lake is strongly dependent on the quantity of ground water outflow. In the unrealistic worse case which has no outflow from East Lake (case 1), the mercury concentration increases indefinitely but at the end of the 50-year project period, it is only 6.03 x 10^{-6} mg/l or 50 % of the chronic level. A ground water discharge (cases 2 and 3), produces equilibrium concentrations of 2.17 x 10^{-6} mg/l to 4.11 x 10^{-6} mg/l within 100 to 200 years which are less than 35% of the chronic level and project concentrations between 2.04 x 10^{-6} mg/l and 3.19 x 10^{-6}mg/l which are less than 27% of the chronic level.

Model 3 indicates that an additional mercury load in the ground water recharge from East Lake does not substantially change the mercury concentrations in Paulina Lake. Equilibrium is achieved within 173 years at a concentration of 2.19 x 10^{-6} mg/l, which is 19% of the chronic level.

4.3 Discussion

The mixing models do not estimate total concentrations of arsenic, boron, or mercury in the lakes which are the sum of the existing background concentrations and the model estimates. To do so, the existing background concentrations in the lakes must be known. The only water quality study (ref. 2) analyzed for boron in most samples but only a few samples in each lake for arsenic and mercury. The mercury concentrations in the lakes were below the detection level, 1.0 x 10^{-4} mg/l, of their analytical procedures.

The total concentration of arsenic in the lakes does not reach chronic levels. The background concentration of arsenic in the lakes is low (less than 3.0 x 10^{-03} mg/l in East lake) and when combined with the highest estimated concentration at the end of 50 years (1.13 x 10^{-06} mg/l for Lake Paulina, model 3) it remains at less than 1.5 x 10^{-03}mg/l, which is only 0.9% of the chronic level.

Boron concentrations in the lakes (8.9 x 10^{-01} mg/l) exceed the national mean of 1.0 x 10^{-01} mg/l. The addition of the greatest estimated boron concentration from the models (5.03 x 10^{-05} mg/l for East Lake, Model 2, case 1),increases this amount by only 0.00006%.

The mercury concentrations estimated by the models are unlikely to significantly increase background concentrations because they are only about 2% of the detection limit.

The arsenic, boron, and mercury concentrations estimated herein should be considered maximal values because:

1. The depositional rates were based on wet depositional rate for each surface type which is greater than dry depositional rates.

2. The assumption of complete solubilization does not allow for the absorption of the elements onto organic and mineral matter in soils, suspended in the lakes, or in the lake sediments. Such absorption will reduce their dissolved concentrations.

3. The timing of hydraulic events in the Paulina Lake watershed are ignored in the mixing models. In particular, these are:

   a. Particles deposited on snow are likely to be flushed from the watershed during the spring snow melt and not be solubilized.

   b. Summer and fall input to Paulina Lake will be to the epilimnon which discharges through Paulina Creek. The epilimnon is about 40 feet thick and completely mixed; concentration will become progressively higher than that of the deeper hypolimnon as the summer stagnation progresses. The higher concentration waters will be discharged from the lake prior to the fall overturn and reduce the rate of elemental increase in the lake.

4. The entire East Lake topographic watershed is considered to contribute elements to the lake. However, as noted in reference 1, portions of it are likely to contribute ground water that discharges externally. If so, the estimated loads to East Lake are excessive.

5 Conclusions

In this analysis we have assumed that arsenic, boron, and mercury are completely solubilized and deposited in the watershed as estimated in previous studies and described in the introduction. The background concentrations of arsenic are very low, whereas, those of boron are at the national average. Mercury concentrations in ground and surface water are generally below the detection limit of 0.0001 mg/l which indicates that it is being contributed to these waters in insignificant quantities by the leaching of rocks and soils and by thermal mineral springs.

Arsenic, boron, and mercury concentrations in Paulina and East Lakes were estimated based on a completely mixed lake model. This model is appropriate because the elements are assumed to be completely solubilized and the lakes undergo seasonal overturning. The modeling considered different mercury depositional and water discharge rates, as well as, different degrees of connection between Paulina and East Lakes. The models indicate that deposition of arsenic, boron, and mercury do not significantly increase background concentrations.

Table 1: Physical characteristics of the Newberry Crater Lakes, Deschutes County, Oregon.

Parameter	Paulina Lake	East Lake
Surface Areas		
Water	1,384 acres	983 acres
Open Land	1,019 acres	303 acres
Forest	4,094 acres	3,351 acres
Total Water Shed Area	6,497 acres	4,637 acres
Lake		
Volume	249,800 acre-feet	69,600 acre-feet
Area	1531 acres	1,044 acres
Mean Depth	163 feet	67 feet
Maximum Depth	250 feet	180 feet
Lake Discharge		
Paulina Creek	9,520 acre-feet	no data
Arsenic Depositional Rates		
Water	1.5×10^{-08} lbs/ac/yr	1.5×10^{-08} lbs/ac/yr
Open Land	7.4×10^{-08} lbs/ac/yr	7.4×10^{-08} lbs/ac/yr
Forest	2.9×10^{-07} lbs/ac/yr	2.9×10^{-07} lbs/ac/yr
Boron Depositional Rates		
Water	1.5×10^{-08} lbs/ac/yr	2.9×10^{-06} lbs/ac/yr
Open Land	1.5×10^{-08} lbs/ac/yr	1.5×10^{-06} lbs/ac/yr
Forest	1.5×10^{-08} lbs/ac/yr	5.7×10^{-06} lbs/ac/yr
Mercury Depositional Rates		
Water	2.6×10^{-6} lbs/ac/yr	3.4×10^{-7} lbs/ac/yr
Open Land	2.4×10^{-6} lbs/ac/yr	1.7×10^{-6} lbs/ac/yr
Forest	6.7×10^{-6} lbs/ac/yr	6.7×10^{-6} lbs/ac/yr
Background Concentrations		
Arsenic	1.5×10^{-03} mg/l	3.0×10^{-03} mg/l
Boron	8.9×10^{-01} mg/l	9.5×10^{-01} mg/l
Mercury	$<1.0 \times 10^{-04}$ mg/l	$<1.0 \times 10^{-04}$ mg/l

Table 2A. Summary of arsenic concentrations in Newberry Crater lakes using uniform mixing models with different arsenic inflow and outflow rates as described in Appendix A.

Model and Assumptions	Lake	Concentrations (mg/l)			
		First Year	50th Year	At Equilibrium	Year
Model 1 a: No discharge with estimated depositional rates	Paulina	NA	Not Applicable (NA)		
	East	NA			
Model 1b: No discharge with maximum depositional rate	Paulina	NA			
	East	NA			
Model 2: Discharge with estimated depositional rates	Paulina	NA	4.70×10^{-7}	5.57×10^{-6}	200
	East: Case 1		2.56×10^{-7}	NA	
	Case 2:		8.82×10^{-8}	9.39×10^{-8}	200
	Case 3:		1.37×10^{-7}	1.78×10^{-7}	200
Model 3: Discharge with ground water recharge	Paulina	NA	1.13×10^{-6}	1.33×10^{-6}	200

* Fresh water chronic level for arsenic = 1.9×10^{-1} mg/l

Table 2B. Summary of boron concentrations in Newberry Crater lakes using uniform mixing models with different boron inflow and outflow rates as described in Appendix B.

Model and Assumptions	Lake	Concentrations (mg/l)			
		First Year	50th Year	At Equilibrium	Year
Model 1 a: No discharge with estimated depositional rates	Paulina	NA	Not Applicable (NA)		
	East	NA			
Model 1b: No discharge with maximum depositional rate	Paulina	NA			
	East	NA			
Model 2: Discharge with estimated depositional rates	Paulina	NA	6.52×10^{-6}	7.66×10^{-6}	200
	East: Case 1		5.03×10^{-5}	NA	
	Case 2:		1.73×10^{-5}	1.85×10^{-5}	150
	Case 3:		2.69×10^{-5}	3.50×10^{-5}	250
Model 3: Discharge with ground water recharge	Paulina	NA	1.16×10^{-5}	1.53×10^{-5}	200

* Fresh water chronic level for boron has not been established: mean concentration in surface waters of US is 1.0×10^{-1} mg/l; maximum value is 5.0×10^{-1}mg/l.

Table 2C. Summary of mercury concentrations in Newberry Crater lakes using uniform mixing models with different mercury inflow and outflow rates as described in Appendix C.

Model and Assumptions	Lake	Concentrations (mg/l)			
		First Year	50th Year	At Equilibrium	Year
Model 1 a: No discharge with estimated depositional rates	Paulina	4.93×10^{-8}	Not Applicable		
	East	1.23×10^{-7}			
Model 1b: No discharge with maximum depositional rate	Paulina	6.41×10^{-8}			
	East	1.64×10^{-7}			
Model 2: Discharge with estimated depositional rates	Paulina	Not Applicable	1.10×10^{-6}	1.29×10^{-6}	145
	East: Case 1		6.03×10^{-6}	Not Applicable	
	Case 2:		2.04×10^{-6}	2.17×10^{-6}	114
	Case 3:		3.19×10^{-6}	4.11×10^{-6}	200
Model 3: Discharge with ground water recharge	Paulina	Not Applicable	1.72×10^{-6}	2.19×10^{-6}	173

* Fresh water chronic level for mercury = 1.2×10^{-5} mg/l

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