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To: S.PRESTWICH (DOE1020)
To: M.REED (DOE4418)
To: P.WRIGHT (DOE4433)
To: S.STIGER (DOE4467)
Cc: J.RENNER (DOE4437)
From: J.RENNER (DOE4437) Delivered: Thu 17-Sep-87 14:12 EDT Sys 164 (22
)
Subject: CECI Crater Lake status
Mail Id: IPM-164-870917-127830235
Acknowledgment Sent

--More--

The Department of the Interior Office of the Regional Solicitor in Portland, Oregon has received the Appellant's Statement of Reasons in the Sierra Club, et al appeal of the FONSI and Decision Record prepared by the Bureau of Land Management (BLM) regarding the request by California Energy Company, Inc. (CECI) to deepen the temperature gradient well near Crater Lake and to drill without circulation. A copy of the Statement will be sent to INEL 17 September 1987.

The Solictor has thirty days to respond to the statement and will be able to request an extension if needed. The Solicitor expects that the Sierra Club, et al will request thirty days to respond to the Solicitor's brief. At that point the Interior Board of Land Appeals (IBLA) will begin to review the case. IBLA generally takes from twelve to eighteen months to render a decision. Hence, it is likely that drilling will not be possible during the 1988 field season even if IBLA renders a decision favorable to BLM and CECI. IBLA sometimes will expedite their decision if another Agency requests it. The Department of Energy is also welcome to assist the Solicitor in the preparation of his brief.

Disposition: d

To: S.PRESTWICH (DOE1020)
To: P.WRIGHT (DOE4433)
To: J.RENNER (DOE4437)
To: S.STIGER (DOE4467)
Cc: M.REED (DOE4418)
From: M.REED (DOE4418) Delivered: Fri 18-Sep-87 10:09 EDT Sys 164 (25)
Subject: CRATER LAKE CASE
Mail Id: IPM-164-870918-091430436

Dear Joel, Sue, Sue, Mike:

The Geothermal Technology Division has decided to avoid any contact or appearance of interferMnce with the proceedings of the IBLA appeal on drilling near Crater Lake. Please be circumspect in your inquiries or contacts with the Department of Interior Solicitor or with the IBLA itself. The Department of Energy and its geothermal contractors will not assist the Solicitor in this case unless a request for assistance is approved at the assistant secretary level in DOE. We will of course assist the BLM and USFS with anything they request Rf we can, but all legal contact should be between them and the Solicitor!

DOE Headquarters (GTD) and IDO have stated to Cal Energy that they have our full support and continuing interest in the drilling of the core hole. If the drilling activity is allowed to continue, we will participate as we have agreed. The decision to resume drilling will be up to CECI if they get IBLA approval.

Keep your ear to the ground, and don't stick your neck out.

Yours,
Marshall

Disposition: d

To: S.PRESTWICH (DOE1020)
To: M.REED (DOE4418)
To: P.WRIGHT (DOE4433)
To: J.RENNER (DOE4437)
To: S.STIGER (DOE4467)
From: J.RENNER (DOE4437) Delivered: Fri 18-Sep-87 14:29 EDT Sys 164 (65
)
Subject: work statement
Mail Id: IPM-164-870918-130360995
Acknowledgment Sent

Marshall:
Here is the remainder of the work statement. It more or less paraphrases a statement of work on the Cascades which Mike already sent you.

Mike:
If this causes grief, give Marshall a call.

CALDERA RESERVOIR INVESTIGATIONS

UURI will provide technical assistance as requested by DOE and track the progress of the remaining coring in the Cascades program. UURI will disseminate the data collected by industry and will supplement the data package by completing acquisition of critical items of information that are missing. They will write a case history of each coring and data acquisition project.

UURI will synthesize the data generated by the Cascades project and interpret it in the light of structure, chemical and mechanical properties of the rocks, and potential and observed hydrothermal effects to help determine the conditions for formation of geothermal reservoirs in the Cascades.

UURI will characterize, through mineralogical and physical property studies in the laboratory, both high-temperature and low-temperature alteration suites in Cascades rocks using available drill core samples. They will also utilize core and chip samples from the Valles Caldera, Long Valley, and Los Azufres. By measuring the physical properties of these rocks, particularly their electrical properties, UURI hopes to determine differences between the high- and low-temperature suites which can be differentiated geophysically.

INEL will review the literature available on the fracture geometry of geothermal systems and analogous hydrothermal ore deposits. The study will result in description of fracture systems and suggestions for further research.

Two wells drilled in the Long Valley caldera have provided samples that UURI will utilize to characterize hydrothermal alteration in the caldera. The compositions of fluids contained in microscopic inclusions in the minerals of the core will be determined. URRI will also use these inclusion studies to determine the temperature of formation of individual minerals and the isotopic composition of the fluids. This data and downhole geophysical data will be used to develop an initial model of fluid circulation patterns. This model will be used to examine expected electrical geophysical responses from the system for comparison with the observed response.

COOPERATIVE RESEARCH / GEOTHERMAL TECHNOLOGY ORGANIZATION (GTO)

INEL will manage a program of cooperative technological development with the GTO, an organization composed of members of the geothermal industry. Research will have a high probability of yielding near-term benefits. INEL will advise DOE on the appropriateness of research suggested by GTO, issue the contracts necessary to accomplish the work, monitor the progress of the contracted work, and report the results to both DOE and GTO.

CRATER LAKE WORKSHOP

February 24th & 25th, 1987

Marriott Hotel, Portland, Oregon

Tuesday February 24th:

8:00-9:00 AM.. Registration

9:00-9:15........................... Al Waibel, Columbia Geoscience

9:15-9:45.. C. Bacon, U.S.G.S.

9:45-10:45........................... J. LaFleur, Calif. Energy Co.

10:45-11:00... Break

11:00-11:30.................................... D. Williams, U.S.G.S.

11:30-12:00..................................... D. Blackwell, S.M.U.

12:00-1:30 PM.. Lunch, hosted

1:30-2:45..................................... M. Nathenson, U.S.G.S.

2:45-3:15.. H. Nelson, U.S.G.S.

3:15-3:30... Break

3:30-4:00.. A. Johnson, P.S.U.

4:00-4:30.. M. Cummings, P.S.U.

Wednesday, February 25th

9:00-9:30 AM............................. D. Larson, Army Corp. Eng.

9:30-10:30....................................... R. Collier, O.S.U.

10:30-11:30...................................... I. Barns, U.S.G.S.

11:30-1:00 PM...................................... Lunch, no host

1:00-3:00.................................Round-Table discussion

federal register

Friday
February 13, 1987

Part II

Department of the Interior

National Park Service

Significant Thermal Features Within Units of the National Park System; Notice of Proposed Listing

DEPARTMENT OF THE INTERIOR

National Park Service

Significant Thermal Features Within Units of the National Park System

AGENCY: National Park Service/U.S. Department of the Interior.

ACTION: Notice of proposed list of significant thermal features within units of the National Park System.

SUMMARY: In accordance with section 115 of the Department of the Interior and Related Agencies Appropriations Act for 1987, Pub. L. 99-591, the National Park Service (NPS) is publishing for public review and comment a proposed list of significant thermal features within twenty-two (22) units of the National Park System. This list may be revised after public comments are received in response to this Notice or as new information becomes available. A final list, including all public comments and rationale for additions to or deletions from the proposed list, will be sent to Congress in April 1987. No geothermal leases may be issued by the Secretary of the Interior until the final list is transmitted to Congress. Also, future geothermal leasing, pursuant to the Geothermal Steam Act of 1970, as amended, is dependent on determinations of whether or not proposals to explore for, develop, produce, or use geothermal resources surrounding the listed features are "likely to result in significant adverse effects" on the listed features.

The NPS welcomes a thorough review of the proposed listed features and the information serving as the bases for determining listed features as significant. The NPS seeks data or information that can assist in preparing a final list of significant thermal features within the specified units of the National Park System. NPS is also interested in receiving nominations for listing additional thermal features or recommendations for deleting thermal features, as proposed. All nominations for listing additional areas of significant thermal features and recommendations for deleting areas from the proposed list should be accompanied by background information on the thermal feature discussed and a supporting rationale for the recommended action.

After transmitting the final list of significant thermal features within units of the National Park System to the Congress, the NPS will publish the same list as sent to Congress in the **Federal Register** as a Final Notice. Copies of public comments received in response to this Notice will also be available for public review according to the specifications of the Final Notice.

DATES: Nominations, recommendations, and supporting comments must be received on or before March 16, 1987, to be assured of receiving consideration.

ADDRESS: Mail comments, recommendations, and nominations to Director, NPS, ATTN: Energy, Mining and Minerals Division (WASO 480, Room 3223, Main Interior Building), National Park Service, P.O. Box 37127, Washington, DC 20013-7127.

FOR FURTHER INFORMATION CONTACT: Ms. Pam Matthes, Energy, Mining and Minerals Division (Room 3223 Main Interior Building), National Park Service, P.O. Box 37127, Washington, DC 20013-7127, (202) 343-4639.

SUPPLEMENTARY INFORMATION: The Department of the Interior and Related Agencies Appropriations Act, Pub. L. 99-591, (hereinafter referred to as the Act) was passed by Congress and signed into law October 30, 1986.

Paragraph 2(a) of § 115 of the General Provisions for the Act, directs the Secretary to collect and publish in the **Federal Register**, within 120 days, a proposed list of significant thermal features in the following twenty-two (22) units of the National Park System:

Mount Rainier National Park, Washington;
Lassen Volcanic National Park, California;
Yellowstone National Park, Wyoming, Montana, and Idaho;
Bering Land Bridge National Preserve, Alaska;
Gates of the Arctic National Park and Preserve, Alaska;
Yukon-Charley Rivers National Preserve, Alaska;
Katmai National Park, Alaska;
Aniakchak National Monument and Preserve, Alaska;
Wrangell-St. Elias National Park and Preserve, Alaska;
Glacier Bay National Park and Preserve, Alaska;
Denali National Park and Preserve, Alaska;
Lake Clark National Park and Preserve, Alaska;
Hot Springs National Park, Arkansas;
Sequoia National Park, California;
Hawaii Volcanoes National Park, Hawaii;
Lake Mead National Recreation Area, Arizona and Nevada;
Big Bend National Park, Texas;
Olympic National Park, Washington;
Grand Teton National Park, Wyoming;
John D. Rockefeller, Jr. Memorial Parkway, Wyoming;
Haleakala National Park, Hawaii; and,
Crater Lake National Park, Oregon.

The NPS has been designated by the Department as the lead agency for preparation and publication of the list of significant thermal features. In making an overall determination of significance, the Act specifically requires four criteria to be applied to each thermal feature identified within the twenty-two (22) units of the National Park System. These four criteria are listed below, along with a brief discussion of the factors contributing to the determination of whether or not the identified feature(s) qualify as "significant" under each criterion:

(1) Size, extent, and uniqueness—NPS establishes neither lower nor upper limits on the size or extent of a feature. Each feature is identified according to its existing surface dimensions. However, for a feature to be considered significant under criterion #1, it is identified as unique to the unit, the Region, the Nation, or, in some cases, the World.

(2) Scientific and geologic significance—Under this criterion, a feature qualifies as "significant" when the feature has been identified as contributing to scientific or geologic data, to the understanding of thermal regimes, or to the history or origin of the feature within the unit, the Region, or the Nation.

(3) The extent to which such features remain in a natural, undisturbed condition—Under this criterion, NPS reports on the existing condition of identified features. Where applicable, NPS addresses whether disturbances or developments, if any, have affected the subsurface thermal regime.

(4) Significance of thermal features to the authorized purposes for which the National Park System unit was created—Features specifically identified within the enabling legislation for the unit or features used in a manner consistent with the stated purposes for which the unit was created are significant.

Thus, NPS has listed thermal features that were the basis for establishing the unit in the first instance (e.g., Yellowstone National Park) and thermal features that now significantly contribute to the statutory purposes for which the area was set aside by Congress (e.g., Lake Mead National Recreation Area).

In most every case, each feature listed as significant within this Notice has met all of the significance criteria, unequivocably. However, there are a few features proposed for listing where one or more of the significance criteria are met marginally or where the significance is not known at this time.

Such features are clearly identified in an introductory paragraph preceding the discussion of the significance criteria. Specific discussions for each of these features explain the rationale behind proposing these features as significant. NPS welcomes additional information that can assist in the final determinations for these features.

All thermal features initially determined to be or proposed as significant by the NPS under these criteria are listed within this Notice. The Act authorizes the Secretary to make additions to or deletions from the list based on public comments received in response to this Proposed Notice. Further, the Act requires that within 60 days of publishing the proposed list, the Secretary must transmit to Congress a final list together with copies of all public comments received. The transmittal to Congress will indicate any additions to or deleting from the proposed list, including a statement of the reasons for the action. Therefore, the NPS requests that any comments, recommendations for deletion from, or nominations for adding thermal features to the proposed list be supported by a rationale and specific information that addresses each of the above significance criteria.

The Act directs that the Secretary of the Interior shall not issue any geothermal leases under the Geothermal Steam Act of 1970, as amended (30 U.S.C. 1001), until after the list of significant thermal features within units of the National Park System is transmitted to Congress.

Paragraph 2(b) of the Act directs the Secretary of the Interior to establish and maintain a monitoring program for each of the significant thermal features included on the final list transmitted to Congress. The existing data characterizing each listed thermal feature and any data collected as a result of the monitoring program will serve as baseline data upon which the potential effects of future geothermal leasing and development on the listed features will be assessed.

The Act requires that, "Upon receipt of an application for a geothermal lease the Secretary shall determine on the basis of scientific evidence if exploration, development, or utilization of the lands subject to the geothermal lease application is reasonably likely to result in a significant adverse effect on a significant thermal feature listed." All such determinations "shall be subject to notice and public comment", and will be published in the **Federal Register** for public review and comment. Also, the Secretary of Agriculture must consider the effects on the listed thermal features when determining whether to consent to geothermal leases on national forest lands or any other lands under the jurisdiction of the Department of Agriculture. No geothermal lease can be issued, if the Secretary determines that the exploration, development, or utilization of the land subject to the lease application is "reasonably likely to result in a *significant adverse effect* on a listed thermal feature" (emphasis added). In addition, the areas within such proposed lease appplications that are likely to result in significant adverse impacts to listed features must be withdrawn from leasing under the Geothermal Steam Act.

Future proposals to explore for, develop, produce, or use geothermal resources that are determined as "reasonably likely to *adversely affect* such significant features" (emphasis added) within units of the National Park System, may be considered for leasing. If leases are issued in such areas, the "Secretary shall include stipulations in leases necessary to protect significant thermal features." If, in these areas, the Secretary later "determines that ongoing exploration, development, or utilization activities are having a significant adverse effect on significant thermal features" listed, among other things, all activity on the lease must be suspended, "temporarily or permanently" until the significant adverse effect is eliminated.

As previously mentioned, the Act specifically requires the Secretary of the Interior and the Secretary of Agriculture to determine the effects of proposed geothermal leases and future operations on each of the listed significant thermal features in units of the National Park System. The Act further requires that such determinations on lands under the jurisdiction of the Department of the Interior and/or the Department of Agriculture must be made available for public review and comment on a case-by-case basis. In response to this requirement of the Act and to assist in clarifying where future geothermal leasing may be considered, the Department of the Interior proposes to identify the affected States in which geothermal leasing proposals will be evaluated on a case-by-case basis under the public review requirements of the Act. The purpose of this proposal also is to obtain public comment for the balance of Federal lands not contained within the list of affected States so that geothermal leasing can proceed under the requirements of the Geothermal Steam Act without imposing the case-by-case public review provisions of the Act.

The States containing the specified units of the National Park System, as listed within this Notice, comprise the list of affected States. In addition, the NPS proposes to list the State of Utah as an affected State because of its proximity to Lake Mead National Recreation Area, in which the NPS proposes to list thermal features as significant. Therefore, applications for geothermal leases in the following States will be evaluated under the provisions of the Geothermal Steam Act as well as under the explicit public review requirements of the Act: Alaska, Arizona, Arkansas, California, Hawaii, Idaho, Montana, Nevada, Oregon, Texas, Utah, Washington, and Wyoming.

The provisions of the Act are designed to protect significant thermal features within units of the National Park System from the potential adverse effects of exploration, development, or utilization of geothermal resources and will remain in effect until Congress specifically directs otherwise. Therefore, it is important that the following proposed list be given the benefit of a thorough review so that information to supplement, refine, or further delineate significant features presented in this Notice can be added to the data that is transmitted to Congress.

Summary Analysis of Thermal Features in Units of the National Park System

The twenty-two (22) units of the National Park System specified by Congress in the Act are located within five (5) NPS Regions. The following table summarizes the information collected by the NPS on thermal features within each of the specified park units:

SUMMARY TABLE

NPSRegion: park units evaluated	Number of features identified	Identified features qualify as significant under the Act
Pacific Northwest Region:		
Mount Rainier National Park (Washington).	1	Yes
Crater Lake National Park (Oregon).	1	Yes.
Olympic National Park (Washington).	2	1 = Yes/ 1 = No
Rocky Mountain Region:		
Yellowstone National Park (Wyoming, Idaho, and Montana).	1	Yes.
Grand Teton National Park (Wyoming).	5	No
John D. Rockefeller, Jr. Memorial Parkway (Wyoming).	1	No
Alaska Region:		
Bering Land Bridge, National Preserve.	1	Yes.
Gates of the Arctic, National Park and Preserve.	1	Yes
Yukon-Charley Rivers, National Preserve.	None	Not Applicable
Katmai National Park	1	Yes
Aniakchak National Monument and Preserve.	1	Yes.
Wrangell-St. Elias, National Park and Preserve.	2	Yes

SUMMARY TABLE—Continued

NPSRegion, park units evaluated	Number of features identified	Identified features qualify as significant under the Act
Glacier Bay National Park and Preserve	None	Not Applicable.
Denali National Park and Preserve.	None	Not Applicable.
Lake Clark National Park and Preserve.	2	Yes.
Southwest Region:		
Hot Springs National Park (Arkansas).	1	Yes.
Big Bend National Park (Texas).	3	Yes.
Western Region:		
Lassen Volcanic National Park (California).	1	Yes.
Sequoia National Park (California).	2	Yes.
Hawaii Volcanoes National Park (Hawaii).	10	Yes.
Haleakala National Park (Hawaii).	1	Yes.
Lake Mead National Recreation Area (Arizona and Nevada).	3	Yes.

Maps showing the location of identified thermal features (if any) within all units are available for public inspection in Washington, DC at the following address:

Energy, Mining and Minerals Division, National Park Service, Room 3223, Main Interior Building, 18th and C Streets NW., Washington, DC 20240

Maps of units showing the location of identified thermal features (if any) are available for public inspection at each of the NPS Regional Offices responsible for administering the unit of interest at the following addresses:

Pacific Northwest Regional Office, National Park Service, 83 South King Street, Library, Seattle, Washington 98104
Rocky Mountain Regional Office, National Park Service, (Attn: Cecil Lewis), 655 Parfet Street, Denver, Colorado 80225
Alaska Regional Office, National Park Service, 2525 Gambell Street, Room 107, Anchorage, Alaska 99503
Southwest Regional Office, National Park Service, Public Affairs Office, 1100 Old Santa Fe Trail, Santa Fe, New Mexico 87504–0728
Western Regional Office, National Park Service, (Attn: Ray Murray), 450 Golden Gate Avenue, San Francisco, California 94102.

The NPS proposes to list features as significant within seventeen (17) units. The following subsection entitled "Proposed List of Significant Thermal Features in Units of the National Park System" describes each of the thermal features identified within each unit and provides information that addresses each of the four significance criteria identified by the Act.

Further, the NPS proposes to list no thermal features as "significant" within six (6) of the twenty-two (22) specified units. Features are not listed either because no thermal features are identified or because those features identified do not meet the significance criteria of the Act. The subsection entitled "Specified Units Within the National Park System With No Significant Thermal Features" explains the rationale for each of the six (6) units of the National Park System that are not proposed for inclusion on the list of significant thermal features to be transmitted to Congress.

Proposed List of Significant Thermal Features in Units of the National Park System

The thermal features identified in this Notice are named from terms describing the surface manifestations of subsurface thermal activity. Heat within the earth is manifested at the earth's surface as a result of different types of thermal activity. Any or all of the surface features described may be expressions of a thermal system or thermal feature.

Hydrothermal systems are the anomalous concentrations of high temperatures at shallow depths caused by the upward movement of water and/or steam. In addition to convective heat transfer by moving fluids, some hydrothermal systems also involve an anomalously shallow heat source caused either by a volcanic system that has moved magma to a shallow level or by high regional heat flow. Surface manifestations of hydrothermal systems are geysers, hot springs, warm springs, mud pots, fumaroles, and steaming ground.

Volcanic thermal activity may be expressed on the surface in the form of molten rock (magma or lava), ash, or thermal fluids such as water (steam), mud, and gas. Geysers, hot springs, warm springs, gas vents, and fumaroles result when water, steam, mud, and gases are heated by the molten rock below the earth's surface and then ejected at the surface. Volcanoes, craters, and calderas are formed on the surface from the eruption of molten rock and associated gases and ash. The conical shape of volcanoes is produced by the ejected material. Craters are a rimmed structure, similar to a basin, usually at the summit of a volcanic cone. A caldera is a large basin-shaped feature formed by one or more volcanic vents. Volcanoes, craters, and calderas, as surface manifestations of either active or dormant heat sources, are indications of active subsurface thermal activity.

The following features are proposed as "significant" thermal features to be forwarded to Congress in April 1987.

Mount Rainier National Park

Feature: Mount Rainier

Significance criteria: 1. Size—Approximately 176,000 acres.

Extent—Mountain area of volcanic origin.

Uniqueness—Mount Rainier is the largest Northern American stratovolcano south of Alaska that contains an active thermal system and is the largest and highest (14,410′) volcano in the Cascade Range.

2. Scientific and geologic significance—This feature is an ideal example of a large stratovolcano and the thermal features at the summit and the upper slopes above 10,000 feet provide excellent study opportunities. Mount Rainier is part of what is commonly referred to as the Pacific Rim of Fire. Ohanapecosh and Longmire thermal springs exist on the flanks of Mount Rainier and their presence are indicators of subsurface thermal activity.

3. The extent to which the feature remains in a natural, undisturbed condition—The volcano itself is primarily undisturbed. Longmire and Ohanapecosh Springs are significantly altered by development that occurred prior to the establishment of the park. There are other disturbances to the flanks of the volcano from the construction of roads and visitor facilities; however, these developments do not alter the thermal feature.

4. Significance of the feature to the authorized purposes for which the unit was created—Mount Rainier, the volcano, is the central feature of the park and Mount Rainier National Park was established in 1899 to preserve this feature. (16 U.S.C. 91)

Crater Lake National Park

Feature: Crater Lake

Significance Criteria: 1. Size—48 square kilometers.

Extent—Hydrothermal vents are located on the south central floor of the basin of Crater Lake at approximately 1500 feet depth. 30–150 liters per second inflow of thermal water is estimated to enter Crater Lake.

Uniqueness—Crater Lake is among the highest, largest, and deepest caldera lakes in the world. It is known for its blue color, nearly pure optical properties, and extreme water clarity.

2. Scientific and geologic significance—Studies indicate that thermal springs feed the lake from the vents located on the floor of the basin. Bathymetric and temperature surveys are needed to characterize the

contribution of these vents to the lake's water quality. Crater Lake resembles the primitive ocean. It is ideal for limnological studies and is a prime example of a caldera lake. It is an isolated system which approximates a closed system and provides a laboratory to investigate environmental disturbances from outside influences, such as atmospheric fallout.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Crater Lake National Park was established in 1902 to preserve the caldera lake and to assure the retention of the lake's superb water quality. (16 U.S.C. 121)

Olympic National Park

Feature: Sol Duc Hot Springs

NPS determines that this feature is marginally significant, mainly because of the lack of scientific interest or significance to the unit or to the Region.

However, these springs are extensively used by the public for recreational purposes as a spa. The NPS recognizes the recreational significance of this feature and has assisted in developments to accommodate increased visitor use. The value of its current recreational use is dependent upon the thermal flow of the springs. Recreational use is consistent with the authorized purpose for which the unit was created. Thus, NPS proposes to list this feature as a significant thermal feature within Olympic National Park.

Significance Criteria: 1. Size—Approximately one acre.

Extent—Sol Duc Springs are a series of seeps occurring next to the Soleduck River.

Uniqueness—The springs are unique in that hot springs are rarely found on the Olympic Peninsula and is one of two springs found within the unit. These hot springs indicates the presence of a thermal system within the confines of the Olympic Mountains.

2. Scientific and geologic significance—Sol Duc Hot Springs, located on the inactive Calawah fault zone, have not been identified as an area of scientific interest and is significant to the geology of the unit in that they serve as an indicator of a subsurface thermal regime.

3. The extent to which the feature remains in a natural, undisturbed condition—None of the seeps exist in a natural state as the springs have been extensively altered to accommodate commercial development, which is now a major concession offering all the facilities of a spa. The development of Sol Duc Hot Springs into a commercial spa is used extensively by the public for recreation and therapeutic purposes.

4. Significance of the feature to the authorized purposes for which the unit was created—In 1938, Congress established the Olympic National Park. The enabling legislation states that the lands within the unit were "set apart as a public park for the benefit and enjoyment of the people of the United States". Although not recognized within the enabling legislation, the Sol Duc Hot Springs existed as a commercial resort at the time the unit was considered for establishment by Congress. The resort has since been developed extensively to accommodate increased visitor use as a spa. The NPS recognizes the recreational significance of this feature and its thermal flow remains significant to the public's enjoyment of the springs. (16 U.S.C. 251)

Yellowstone National Park

Old Faithful and approximately 10,000 geysers and hot springs make Yellowstone National Park the world's greatest thermal area. NPS proposes to list the entire hydrothermal system within Yellowstone National Park as one significant thermal feature comprised of the identified one hundred fourteen (114) hot springs and seven (7) gas vents. Each of the features listed are part of and in total comprise the Yellowstone hydrothermal system within the boundaries of the park. The following significance criteria have been analyzed for each feature listed and have been found to be applicable to every feature within the Yellowstone thermal system.

Feature: Yellowstone National Park

Significance Criteria: 1. Size—Approximately 2,220,000 acres.

Extent—(a) 10 travertine hot springs in Mt. Holmes, Mammoth, Tower Junction, Abiathar, Madison Junction, Firehole Lake, and Huckleberry Mountain Quadrangles.

(b) 41 acid-sulfate hot springs in Obsidian Lake, Mt. Washburn, Amethyst Mountain, Madison Junction, Norris Junction, Solfatara Plateau, Canyon Village, Ponuntpa Springs, Pelican Cone, Juniper Creek, Beach Lake, Lake Junction, Steamboat Point, Buffalo Lake, Summit Lake, Shoshone Geyser Basin and Huckleberry Mountain Quandrangles.

(c) 18 neutral-chloride hot springs in Norris Junction, Ponuntpa Springs, Firehole Lake, Buffalo Lake, Warm River Butte, Old Faithful, Ragged Falls, and Lewis Lake West Quadrangles. This feature includes the Upper and Lower Geyser Basins.

(d) 1 neutral-dilute spring in Warm River Butte Quadrangle.

(e) 6 neutral-alkaline dilute springs in Lewis Lake West, Grassy Lake Reservoir, Huckleberry Mountain, and Mt. Hancock Quadrangles.

(f) 21 springs having a mixture of the above types in the following quadrangles: Obsidian Lake, Amethyst Mountain, Madison Junction, Norris Junction, Canyon Village, Pelican Cone, Firehole Lake, Juniper Creek, Steamboat Point, Old Faithful, West Thumb, Shoshone Geyser Basin, and Lewis Lake East.

(g) 1 Bicarbonate spring located in the Obsidian Lake Quadrangle.

(h) 16 springs of undetermined dominate chemistry located in Amethyst Mountain, Madison Junction, Norris Junction, Solfatara Plateau, Canyon Village, Ponuntpa Springs, Pelican Cone, Juniper Creek, Steamboat Point, and Lewis Lake West Quadrangles.

(i) 7 gas vents located in Amethyst Mountain, Abiathar Peak, Solfatara, Pelican Cone, and Eagle Peak (Brimstone Basin) Quadrangles.

Uniqueness—The Yellowstone thermal system is the world's greatest hydrothermal system and geyser area and is recognized as an outstanding natural feature of the world.

2. Scientific and geologic significance—Yellowstone contains thousands of thermal features and the park is widely known as the preeminent hydrothermal area of the world. The entire Yellowstone hydrothermal system provides numerous opportunities to study and characterize a large, undisturbed geyser system.

3. The extent to which the features remain in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the features to the authorized purposes for which the unit was created—Yellowstone National Park was created in 1872 to preserve and protect all natural curiosities or wonders within the park and to retain each of the features in their natural condition. The thermal features of the park are one of the natural wonders of the park and comprise the preeminent hydrothermal area of the world. (16 U.S.C. 21)

Bering Land Bridge National Preserve

Feature: Serpentine Hot Springs

Significance Criteria: 1. Size—Approximately 0.5 square miles.

Extent—Serpentine Hot Springs is a group of hot springs providing the only indication of thermal regime within the unit.

Uniqueness—These springs are the warmest springs in the region and is the only indicator of thermal activity in the Preserve.

2. Scientific and geologic significance—As the warmest springs in the region, Serpentine Hot Springs are the only indicator of thermal activity in the Preserve.

3. The extent to which the feature remain in a natural, undisturbed condition—The main pool has undergone some disturbance. Bath and bunk houses have been moved to the site to facilitate public visits and water has been piped to the bathing pool. These surface disturbances have not altered the thermal regime of the feature.

4. Significance of the feature to the authorized purposes for which the unit was created—The Bering Land Bridge National Preserve was established to protect and interpret volcanic lava flows, ash explosions, coastal formations and other geologic processes. Also, the recreational significance of the Serpentine Hot Springs was recognized in the enabling legislation. (16 U.S.C. 410hh)

Gates of the Arctic National Park and Preserve

Feature: Reed River Hot Springs

Significance Criteria: 1. Size—Complex of springs approximately 0.25 miles in length.

Extent—0.25 mile section along the east side of Reed River.

Uniqueness—Reed River Hot Springs is the largest known thermal feature in the park and is one of the few large hot springs in the region.

2. Scientific and geologic significance—As one of the few large warm springs in the Brooks Range of Alaska, Reed River Hot Springs has been proposed for listing in the National Register of Natural Landmarks and for designation as a State Ecological Preserve.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—The Alaska National Interest Lands Conservation Act of 1980 (ANILCA) established Gates of the Arctic National Park and Preserve as a new park unit within the National Park System. ANILCA states that the purpose of the unit is to "preserve unrivaled scenic and geologic values" with the mandate to manage the unit "to maintain the wild and undeveloped character of the area" and its "ecological integrity" (16 U.S.C. 410hh). The natural, undisturbed character of the one of the few warm springs in the Brooks Range, as found in the Reed River Hot Springs, is a significant thermal feature for this unit.

Katmai National Park and Preserve

Feature: Novarupta and vicinity

Significance Criteria: 1. Size—800 square miles.

Extent—Six volcanoes, all in the vicinity of Novarupta, are east of the Bruin Bay fault and between Mount Martin and coast of Kamishak Bay, north of Mount Douglas.

Uniqueness—The volcanoes, active since 1912, have only erupted once and, consequently, has a simple structure conducive to study. There is no other site in the world where an ash eruption of comparable size has occurred at a terrestrial, rather than marine, site and where the ejects are accessible.

2. Scientific and geologic significance—The structure beneath Novarupta, including the magma body, is of major scientific interest and significance. It is hypothesized that the proximity and relative locations of the six active volcanoes may have created heat so intense that the earth's rhyolitic crust, in addition to the mantle, was melted.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Katmai National Monument was established originally to protect the volcanism that created the identified thermal features. ANILCA further expanded the unit to protect, among other features, the existing geological features, which include the volcanoes within the unit. (16 U.S.C. 410hh-1)

Aniakchak National Monument and Preserve

Feature: Aniakchak Caldera

Significance Criteria: 1. Size—Approximately 28 square miles.

Extent—The caldera is a volcanically active, flat-floored, ash-filled bowl that is 2,500 feet deep.

Uniqueness—The Aniakchak caldera is one of the largest calderas in Alaska, exhibits recent volcanic activity, and is essentially dry-bottomed.

2. Scientific and geologic significance—The area is acclaimed as one of the largest and most accessible ice-free calderas on the Alaska Peninsula.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Aniakchak's enabling legislation states the unit must be managed to "maintain the caldera and its associated volcanic features and landscapes in their natural state." Therefore, the identified feature is a significant feature serving as the basis for the unit's creation. (16 U.S.C. 410)

Wrangell-St. Elias National Park and Preserve

Feature: Mineral Springs (mud volcanoes)

Significance Criteria: 1. Size—The three springs occupy approximately 310 acres.

Extent—This feature is comprised of three widely spaced thermal areas located on the flanks of Mt. Drum. One of the sites has no appreciable water flow and largely vegetated. Another site consists of a spring of approximately 10 acres. The third site is approximately 300 acres.

Uniqueness—The three identified springs are mineral springs, which is an unusual phenomenon in Alaska.

2. Scientific and geologic significance—The unique thermal activity associated with these springs provides opportunities for scientific investigations.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—ANILCA identifies the general purpose for which various Alaska units were established as one "to preserve unrivaled scenic and geological values associated with natural landscapes." The mud volcanoes identified are unique and are of significant geologic value within the unit and to the geology of the region. (16 U.S.C. 410hh)

Feature: Wrangell Volcanoes

Significance Criteria: 1. Size—Mt. Wrangell 14,153 feet; Mt. Drum 12,010 feet; Mt. Sanford 16,237 feet; and Mt. Blackburn 16,390 feet.

Extent—The four volcanoes are central features of the park.

Uniqueness—The four active volcanoes are prominent within the park which includes the greatest assemblage of mountain peaks in any park in the Nation.

2. Scientific and geologic significance—The Wrangells are collectively referred to as a group of large shield and composite volcanoes. Geologically, they are relatively young and have had major eruptions as recently as 1,500 years ago. Their size, recent eruptions, and current activity provide significant opportunities for scientific investigations, including glaciological and volcanic studies. A long-term monitoring program of Mt. Wrangell has been ongoing for over 15 years. The Wrangells are one of the greatest assemblages of mountain peaks in the Nation, some of which are volcanoes, both active and inactive. The Wrangells are the origin for some of the longest glaciers on the North American continent.

3. The extent to which the feature remains in a natural, undisturbed condition—The foothills and lowlands that form the outer fringe of this mountain range have been the sites for a few small mining operations. The mining operations with developed access routes have created some disturbances to these areas; however, disturbances to the lower surrounding mountains is minimal.

4. Significance of the feature to the authorized purposes for which the unit was created—ANILCA identifies the general purpose for which various Alaska units were established as one of preserving unrivaled scenic and geological values associated with natural landscapes. The primary purposes of Wrangell-St. Elias National Park and Preserve are to maintain unimpaired the scenic beauty and quality of high mountain peaks, foothills, glacial system, lakes, and streams in their natural state and to provide reasonable access for mountain climbing, mountaineering, and other wilderness recreational activities. These high peaks are significant features serving as the basis for the creation of the unit. (16 U.S.C. 410hh)

Lake Clark National Park and Preserve

Feature: Redoubt Volcano

Significance Criteria: 1. Size—38,000 acres.

Extent—The small vents in the cone of Redoubt Volcano.

Uniqueness—Redoubt Volcano is the second highest of the 76 volcanoes of the Alaska Peninsula and Aleutian Islands and is an active, heavily glaciated stratovolcano.

2. Scientific and Geologic Significance—Redoubt Volcano is an excellent example of a classic stratovolcano which exhibits areas of steam venting and sulfur vents. The feature is marked by erosion from glaciers and other processes exposing cross-sections of the volcano. Exposures illustrate the relationships of various lava flows and pyroclastic rocks of which the stratovolcano is composed.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—The enabling legslation for Lake Clark National Park and Preserve states that the purposes of the unit are, among others, to "maintain unimpaired the scenic beauty and quality of portions of the Alaska Range, including active volcanoes". (16 U.S.C. 410hh)

Feature: Iliamna Volcano

Significance Criteria: 1. Size—33,900 acres.

Extent—Thermal activity consists of two small sulphur vents located at about 9,000 feet near the summit on the eastern face of the volcano.

Uniqueness—Iliamna Volcano is a broad cone-shaped active volcano deeply dissected by erosional processes.

2. Scientific and geologic significance—The composition and appearance of the Iliamna Volcano offers opportunities to study its unique history.

3. The extent to which such features remain in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—The enabling legislation for Lake Clark National Park and Preserve states that the purposes of the unit are, among others, to "maintain unimpaired the scenic beauty and quality of portions of the Alaska Range, including active volcanoes". (16 U.S.C. 410hh)

Hot Springs National Park

Feature: Hot Springs

Significance Criteria: 1. Size—0.3 mile long section of the southwest base of Hot Springs Mountain.

Extent—These springs are comprised of 47 individual springs along the southwest toe of Hot Springs Mountain.

Uniqueness—The average temperature of 143 °F of the spring waters are unique and the combined flow of 23 of the monitored springs is 600,000 gallons per day. These springs are credited with advancing the bathhouse health spa ethic in this region of the United States.

2. Scientific and geologic significance—The springs have been studied to differing levels of sophistication over the past 150 years. Monitoring equipment to be installed will provide base information to monitor temperatures and flow as a measure of adverse effects and hydrologic changes. Studies are being conducted to affirm the subsurface geology and the groundwater flow network.

3. The extent to which the feature remains in a natural, undisturbed condition—The natural environment of the springs has been extensively altered with the construction of bathhouses and the city's Central Avenue business district. The springs themselves have been walled in and capped to prevent surface-borne contamination. Twenty-three (23) of the springs have had plumbing installed to collect and distribute the waters to a central reservoir.

4. Significance of the feature to the authorized purposes for which the unit was created—The Act of April 20, 1832, initially set aside this area, including the Hot Springs, as a Federal reserve in the Territory of Arkansas. Since the initial Act, there have been over 50 additional Federal statutes specifically addressing the management of the Hot Springs. NPS recognizes the cultural significance of the evolution of the bathing regime into the elegant bathhouses and the thermal flows remain of primary significance to Hot Springs National Park. (16 U.S.C. 361)

Big Bend National Park

Feature: Spring No. 1

Significance Criteria: 1. Size and Extent—Small developed hot spring along the Rio Grande River.

Uniqueness—Approximately 7–9 gallons per minute are being pumped to supply water for the endangered fish species *Gambusia gaigei*.

2. Scientific and geologic significance—Spring No. 1 along the Rio Grande River is the water supply for an endangered fish species and is an important source for water samples to make temperature measurements for monitoring hydrologic changes.

3. The extent to which the feature remains in a natural, undisturbed condition—The spring has been enclosed and a pumphouse has been installed.

4. Significance of the feature to the authorized purposes for which the unit was created—Big Bend National Park was established in 1935 primarily "as a

public park for the benefit and enjoyment of the people". Also, the enabling legislation provides for the administration and protection of the park to be exercised under the provisions of the Organic Act of the National Park Service of August 25, 1916. The Organic Act provides for the National Park Service to promote and regulate the use of Federal lands within the National Park System in a manner to conserve natural objects and wildlife therein (16 U.S.C. 1). Although this spring is not used for the purpose of public recreation, its primary use is for the maintenance of an endangered wildlife species. Thus, the purposes for establishing Big Bend National Park include preservation of endangered species. (16 U.S.C. 156)

Feature: Spring No. 4

Significance Criteria: 1. Size and Extent—Developed hot spring along the Rio Grande River.

Uniqueness—The spring has a flow of approximately 75 gallons per minute. The spring supplies potable water for Rio Grande Village and serves as a water source for the endangered species *Gambusia gaigei*.

2. Scientific and geologic significance—Spring No. 4 along the Rio Grande River serves as a water source for an endangered fish species and is an important source for water samples and to take temperature measurements for monitoring water temperature and flow as a measure of hydrologic changes.

3. The extent to which the feature remains in a natural, undisturbed condition—The spring has been enclosed and pumphouses installed. A 4 inch pipe is used to produce water flow that simulates natural flow for endangered species.

4. Significance of the feature to the authorized purposes for which the unit was created—As stated previously for Spring No. 1, this feature's use is primarily for maintaining an endangered wildlife species. The purposes for which Big Bend National Park was established include preservation of endangered species. (16 U.S.C. 156)

Feature: Hot Springs

Significance Criteria: 1. Size and Extent—Developed hot spring along the Rio Grande River.

Uniqueness—The spring supplies a bathhouse that is used by park visitors.

2. Scientific and geologic significance—The Hot Springs is a site contributing to Regional studies being conducted to monitor temperature and flow as a measure of hydrologic changes.

3. The extent to which the feature remains in a natural, undisturbed condition—The spring has been altered by development of a bathhouse built in 1910. The walls of the bathhouse still remain.

4. Significance of the feature to the authorized purposes for which the unit was created—Hot Springs, historically and currently, serves as a therapeutic hot spring. The spring is the focal point of Hot Springs National Register Historic District and is used by the public for recreational purposes. Thus, its use is of significance to the purposes for which the unit was created. (16 U.S.C. 156)

Lassen Volcanic National Park

There are six areas within Lassen National Volcanic Park that contain surface manifestations of a single thermal system. As all of these areas are connected to a single thermal system, NPS proposes to list the Lassen thermal system as one significant feature. The following significance criteria have been analyzed for each feature listed and have been found to be applicable to every feature within the Lassen thermal system.

Feature: Lassen thermal System

Significance Criteria: 1. Size—10 to 70 square kilometers.

Extent—Bumpass Hell, Little Hot Springs Valley, Sulphur Works, Devils Kitchen, Boiling Springs Lake—Drakesbad Hot Springs, and Terminal Geyser are the six features comprising the Lassen thermal system. The system is a two-phase, vapor dominated system approximately 500–600 meters thick. Surficial expression varies from superheated fumaroles at Bumpass Hall to acid-sulfate springs and mudpots at Sulfur Works and Devils Kitchen.

2. Scientific and geologic significance—The Lassen thermal system constitutes the only known extensive vapor-dominated thermal system in the Cascade Range. Only one other vapor-dominated system of equal thermal energy is known in the Western United States (the Geysers in California).

3. The extent to which the feature remains in a natural, undisturbed condition—Except for one well sited at Terminal Geyser, the system has not been tapped by deep drilling activity and there has been no depletion of thermal energy. Surface features at Bumpass Hell, Sulphur Works, and Devils Kitchen have been only slightly altered by the installation of trails and boardwalks for the safety of visitors.

4. Significance of the feature to the authorized purposes for which the unit was created—Lassen Volcanic National Park was established in 1916 as a "public park and pleasuring ground for the benefit of the people of the United States" and to be managed "for the preservation from injury or spoilation of all timber, mineral deposits, and natural curiosities or wonders within said park and their retention in a natural condition".

The thermal features in the park represents an outstanding example of Cascade volcanism and the thermal system and its surface manifestations are a significant part of the continuing volcanic activity in the area. (16 U.S.C. 201)

Sequoia National Park

Both of the identified thermal features within Sequoia National Park are determined as marginally significant, mainly because the scientific and geologic, significance of these features are unknown at this time. These springs represent surface manifestations of active subsurface thermal activity and both remain in a natural condition. One spring is located in a heavily used area and the other in a lightly used area of the backcountry within the unit. Combined visitation frequency is not known. These features are considered as natural curiosities within the unit and as such must be retained in their natural condition. In spite of their unknown geologic or scientific significance, these features are proposed by the NPS as significant thermal features within Sequoia National Park.

Feature: Kern Hot Springs

Significance Criteria: 1. Size and Extent—Kern Hot Springs is an extremely small spring approximately 2 meters in diameter.

Uniqueness—Kern Hot Springs is the only spring in the park with temperatures over 100° Fahrenheit and its presence serves as an indicator of active subsurface thermal activity.

2. Scientific and geologic significance—Unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—Kern Hot Springs is in a heavily used area of the backcountry, and the spring itself appears to be in a natural condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Sequoia National Park was established by an Act of Congress in 1890 and has as its purposes, among others, to preserve "from injury of all . . . natural curiosities or wonders within said park". Also, subsequent Acts of Congress that expand the

boundaries of the park require the curiosities and wonders of the park to be retained in their natural condition. Although the scientific and geologic significance of this feature is unknown, Kern Hot Springs is considered a natural curiosity of the unit as it is the only spring in the park representing active subsurface thermal activity. (16 U.S.C. 41)

Feature: Whitney Warm Springs

Significance Criteria: 1. Size and Extent—This spring is approximately 10 meters in diameter.

Uniqueness—Whitney Warm Springs is the only spring in the park with temperature ranging in the mid-80° Fahrenheit and as such is an indicator of active subsurface thermal activity. It could have a biotic community dependent on the thermal characteristics of the feature that are different from other park waters.

2. Scientific and geologic significance—Unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—Whitney Warm Springs is in a lightly used area of the backcountry and the spring itself appears to be in a natural condition. The only intrusion is an occasional wader and several rocks have been arranged around the shore of the springs.

4. Significance of the feature to the authorized purposes for which the unit was created—Sequoia National Park was created by an Act of Congress in 1890 and its purposes, among others, are to preserve "from injury of all . . . natural curiosities or wonders within said park". Also, subsequent Acts of Congress that expand the boundaries of the park require the curiosities or wonders of the park to be retained in their natural condition. Even though the scientific and geologic significance of this thermal feature is unknown, Whitney Warm Springs is considered a natural curiosity of the unit as it is the only spring in the park with temperatures in the mid-80° Fahrenheit range that could support biotic communities. Until more information is available on the significance of this feature, it is proposed for listing as a significant thermal feature within Sequoia National Park. (16 U.S.C. 41)

Hawaii Volcanoes National Park

The NPS proposes to list the following ten (10) thermal features as significant within the Hawaii Volcanoes National Park. Significance criteria #4 requires analysis of the significance of the feature to the authorized purposes for which the unit was created. Hawaii Volcanoes National Park was established as part of Hawaii National Park in 1916 and later redesignated as Hawaii Volcanoes National Park in 1961. The enabling legislation for this unit states that the purpose of the unit is to "provide for the preservation from injury of all . . . natural curiosities and wonders within said park, and their retention in their natural condition as nearly as possible". As the identified features within Hawaii Volcanoes National Park are unique natural thermal features of known scientific and geologic significance to the region, NPS has determined that each feature is a natural wonder of the unit. Many of the identified features are named as features for which the unit was created and as such are significant thermal features for this unit (16 U.S.C. 391). Criteria #4 is fully met and is applicable to each listed feature within the park.

Feature: Kilauea Caldera and Halemaumau

Significance Criteria: 1. Size and Extent—3 square miles (3 miles long by 1 mile wide).

Uniqueness—Kilauea Caldera and Halemaumau is the world's most active volcano.

2. Scientific and geologic significance—As the world's most active volcano, this feature offers extensive opportunites for scientific and geologic investigations of the active thermal activity manifested in steaming ground.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Chain of Craters

Significance Criteria: 1. Size and Extent—Approximately 12 square miles (12 miles long by 1 mile wide).

Uniqueness—This chain of craters is a very active thermal zone.

2. Scientific and geologic significance—This feature is an active intrusive zone with many collapse caldera features or pit craters and steaming ground.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: East Rift Zone

Significance Criteria: 1. Size and Extent—Approximately 20 square miles (13 miles long by 1.5 miles wide).

Uniqueness—The East Rift Zone is the world's most active volcanic rift zone and exhibits steaming ground.

2. Scientific and geologic significance—This feature is the world's most active volcanic rift zone and as such offers opportunities for scientific and geologic investigation.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Great Crack and Southwest Rift

Significance Criteria: 1. Size and Extent—Approximately 10 square miles (20 miles long by ½ mile wide).

Uniqueness—Major fault area of Kilauea is an artifact and indicator of active thermal activity.

2. Scientific and geologic significance—This feature is the major fault structural feature of Kilauea, which is an indicator of active thermal activity and offers opportunities for scientific and geologic investigation.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Thurston Lava Tube

Significance Criteria: 1. Size and Extent—½ mile long by 100 yards wide.

Uniqueness—Volcanic lava tube which is an easily accessible artifact of volcanic activity.

2. Scientific and geologic significance—This feature is one of the few accessible lava tubes formed by a volcano and is the site of a popular visitor trail. This feature, because of its accessibility offers opportunities for investigation of its volcanic history.

3. The extent to which the feature remains in a natural, undisturbed condition—The area is the site of a developed visitor trail; however, these trails have not altered the integrity of the active thermal activity which characterizes the unit and the region.

Feature: Steaming Bluff and Sulphur Banks

Significance Criteria: 1. Size and Extent—Approximately 2 square miles (two miles long by one mile wide).

Uniqueness—Active steaming fumaroles.

2. Scientific and geologic significance—This feature is the site where the active steaming fumaroles may easily be viewed.

3. The extent to which the feature remains in a natural, undisturbed condition—The area is the site of developed visitor trails; however, these trails have not altered the integrity of the thermal feature.

Feature: Kilauea Iki Crater

Significance Criteria: 1. Size and Extent—1 mile long by ½ mile wide.

Uniqueness—Cooling lava pond.

2. Scientific and geologic significance—This feature is the site of current lava pond cooling rate studies.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Puu Do

Significance Criteria: 1. Size and Extent—2 square miles (2 miles long by 1 mile wide).

Uniqueness—Continuously active volcanic vent.

2. Scientific and geologic significance—This area is under study for activity of a continuously active volcanic vent and its resultant magmatic activity.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Mauna Ulu

Significance Criteria: 1. Size and Extent—4 square miles (two miles long by two miles wide). Uniqueness—Continuously active volcanic vent.

2. Scientific and geologic significance—Major active volcanic feature formed recently in the 1970's.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Mokuaweoweo Caldera

Significance Criteria: 1. Size and Extent—4 square miles (4 miles long by 1 mile wide).

Uniqueness—This feature is the major caldera of Mauno Loa.

2. Scientific and geologic significance—This feature is the site of significant caldera studies.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Haleakala National Park

Feature: Haleakala Crater

Significance Criteria: 1. Size—17,130 acres.

Extent—Haleakala Crater and adjacent outer slopes around the summit of the crater.

Uniqueness—Haleakala Crater is between 5,000 and 6,000 feet deep and is part of the Hawaiian "hotspot". The summit of the crater and a great many sites within are considered to be sacred by Native Hawaiians and contains many sites of archeological value, including royal burial sites.

2. Scientific and geologic significance—The entire Haleakala Crater (2½ miles by 7½ miles) is one large thermal feature containing many smaller thermal features. The crater is a huge erosional scar carved out of the heart of the volcano by water which has been subsequently refilled by half with new lava flows and topped off with numerous multi-colored cinder cones. The crater and its adjacent areas have been the site of volcanic and geologic studies.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural condition except for very few roads, trails, and buildings provided to serve the public. These developments have not altered the integrity of the thermal feature.

4. Significance of the feature to the authorized purposes for which the unit was created—The legislative history supporting the Act of August 10, 1916, which created the Haleakala National Park as an isolated extension of Hawaii Volcanoes National Park, emphasizes that the craters within the proposed boundaries are among the most remarkable of natural wonders and among the largest and most spectacular in the world. Scientifically and popularly, these volcanoes are a national rather than a local asset and Congress recognized that legislation was necessary to protect these and other curiosities that were being damaged at the time the legislation was being considered. The purposes of Haleakala National Park are, among others, to preserve the area's volcanoes and other wonders and curiosities for public enjoyment and scientific study. (16 U.S.C. 396b)

Lake Mead National Recreation Area

Feature: Black Canyon Hotsprings

Significance Criteria: 1. Size—Five (5) hotsprings have their source in a four-mile stretch of the river.

Extent—Three of the five springs flow from the Nevada side, the other two springs flow from the Arizona side of the river.

Uniqueness—The temperatures of the springs have been recorded as high as 124° Fahrenheit. Two of the five hot springs discharge a volume of water sufficient to maintain a flow on the surface for approximately ¼ mile. The area is unique in that these springs are the only ones that flow water at the surface at temperatures higher than 100° Fahrenheit within the unit. Their presence serve as indicators of active thermal activity. Also, waters from one of the springs is used to support a refugium for the endangered Devils Hole Pupfish.

2. Scientific and geologic significance—The waters from one of the springs serve as habitat for an endangered fish species. Much of the geology in this area is volcanic in origin from the bottom of side canyons to the Colorado River. Also, Black Canyon has been identified by the NPS in its General Management Plan for the unit as an outstanding natural feature for its geologic beauty and the existence of the unique hot springs.

3. The extent to which the feature remains in a natural, undisturbed condition—The areas surrounding the springs have minor alterations and impacts from recreational use; however, the springs themselves remain in a natural condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Lake Mead National Recreation Area was established for the primary purpose of preserving and enhancing public recreation opportunities within the unit. These springs are used extensively by hikers and boaters on a regular basis for recreational and therapeutic purposes. Pools are created by stacking rocks and sand allowing visitors to immerse themselves in the pools. Public visits to the Black Canyon Hotsprings are estimated at 7,000 annually. Also, protection of endangered species is consistent with the authorized purposes for which the unit was established. (16 U.S.C. 460n)

The remaining two of the three identified features within Lake Mead National Recreation Area are connected to the same regional flow system, but otherwise their geologic significance are not known at this time. In spite of their unknown geologic significance, the NPS proposes to list the Blue Point Spring and the Rogers Spring as significant thermal features because of their value to the public for recreational purposes. The primary purpose of Lake Mead National Recreation Area is to provide for and enhance public recreational opportunities within its boundaries. As these springs are used extensively by the public as "spas" and as the value of their use is dependent on the thermal qualities of the springs, these features are proposed as significant thermal features within Lake Mead National Recreation Area.

Feature: Blue Point Spring

Significance Criteria: 1. Size—Approximately 0.3 mile long.

Extent—Small spring located in the Nevada portion of the NRA at the junction of two faults near Mississippian limestone.

Uniqueness—The discharge rate is approximately 400 gallons per minute with temperatures at the spring source measuring around 85° Fahrenheit. The presence of these warm springs are indicators of a subsurface thermal regime.

2. Scientific and Geologic Significance—This spring, at one time, was being considered as a refugium for the endangered *Moapa coriacez*. Upon investigation of the chemical properties of the waters, it was found that, although the Spring is in the same regional flow system as Moapa River headwaters springs (where the endangered species occur naturally), the ionic constituents of the waters of the spring make the area unsuitable as a refugium. The waters discharging at the spring are part of a regional flow system and represent a combination of deep and shallow water circulation in the recharge area where moisture availability is rated as intermediate. The bedrock is relatively permeable. Even though the area has been the site of scientific interest and study, the geologic significance of the area is unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—The channels have been altered for commercial and recreational uses.

4. Significance of the feature to the authorized purposes for which the unit was created—Lake Mead, formed by Hoover Dam and Lake Mohave, and by Davis Dam on the Colorado River comprise this first national recreation area established by an Act of Congress in 1964. The enabling legislation states that the NRA "shall be administered . . . for general purposes of public recreation, benefit, and use, and in a manner that will preserve, develop, and enhance . . . the recreational potential, and in a manner that will preserve the scenic, historic, scientific, and other important features of the area". Blue Point Spring is a part of the regional flow system that serves as a major recreation facility used extensively by the public, with recorded visits to Blue Point Spring and Rogers Spring (listed below) estimated at 5,000 annually. As this feature is of major recreational value to the unit, the NPS proposes this feature as a significant thermal feature within the NRA. (16 U.S.C. 460n)

Feature: Rogers Spring

Significance Criteria: 1. Size—Approximately 0.75 miles long.

Extent—Rogers Spring is located in the Nevada portion of the NRA at the junction of two faults near Mississippian limestone at an elevation of 1580 feet and is in the same general vicinity as Blue Point Springs.

Uniqueness—The discharge rate is approximately three second feet and temperature at the source is measured at 87° Fahrenheit. The presence of the warm springs is an indicator of active subsurface thermal activity.

2. Scientific and geologic significance—Waters discharging at Rogers Spring are part of the same regional flow system as those of Blue Point Spring. The discharge goes directly into a man-made pond that is used by the recreating public as a swimming area. The geologic significance of the area is unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—The channels of Rogers Spring have been altered over the years for either commercial purposes or recreational enhancement. Picknicking facilities have been developed adjacent to the spring for recreational use. Neither the discharge point nor underground system of the springs have been altered.

4. Significance of the feature to the authorized purposes for which the unit was created—As stated above for Blue Point Springs, Lake Mead National Recreation Area was established for the expressed purpose of preserving and enhancing public recreation opportunities within the unit. Public visits to both Rogers Spring and Blue Point Spring is estimated at 5,000 annually, with the heaviest public use centering around Rogers Spring. NPS recognizes the recreational significance of Rogers Spring and proposes its listing as a significant thermal features within the unit. (16 U.S.C. 460n)

Specified Units Within the National Park System With No Significant Thermal Features

The NPS has identified no known thermal features within the following three units of the National Park System located in Alaska:

Yukon-Charley Rivers National Preserve;

Glacier Bay National Park and Preserve; and,

Denali National Park and Preserve.

Thus, determinations of "significance" are not applicable and the three units listed above are not proposed for inclusion on the final list of significant thermal features to be forwarded to Congress in April 1987.

Thermal features were identified within the boundaries of the following three units of the National Park System; however, none of the features identified have been determined as "significant" by the NPS under the criteria of the Act. Thus, the features listed below are not proposed for inclusion on the final list of significant thermal features to be forwarded to Congress in April 1987.

Olympic National Park

Feature: Olympic Hot Springs

Significance Criteria: 1. Size—Approximately two (2) acres.

Extent—These springs consist of twenty-one (21) seeps along Boulder Creek.

Uniqueness—Olympic Hot Springs are unique because hot springs are rarely found on the Olympic Peninsula.

2. Scientific and geologic significance—Olympic Hot Springs has no apparent relationship with the area's volcanic history and has not been identified as significant in terms of the peninsula's geology. The mineral content of the waters varies little with that of surface waters and the scientific significance of the area is unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—The Olympic Hot Springs have been extensively altered to accommodate commercial operations and many have been formed into pools that have been used for bathing. The impounded water frequently fails to meet water quality standards. The resort around these springs no longer exist. None of the seeps exist in a natural state.

4. Significance of the feature to the authorized purposes for which the unit was created—Olympic National Park was established in 1938 as a public park for the benefit and enjoyment of the people of the United States. The Olympic Hot Springs do not attract extensive visitor use and are not considered a major public recreational resource within the unit. Also, as these springs were not used as rationale for establishing the unit and are not used today by the public for recreation, these springs are not considered as a significant thermal feature within the unit. (16 U.S.C. 251)

John D. Rockefeller, Jr. Memorial Parkway

Feature: Huckleberry Hotsprings

Significance Criteria: 1. Size and Extent—This feature consists of several springs located one mile west of Flagg Ranch.

Uniqueness—This feature is not unique and is in fact relatively commonplace for the area.

2. Scientific and geologic Significance—The combined flow of this feature is estimated at 350,000 gallons per day with temperatures over 100

°Fahrenheit. The waters from these springs are slightly radioactive and have not been identified as having any scientific or geologic significance.

3. The extent to which the feature remains in a natural, undisturbed condition—These springs have been highly altered and were developed into a public swimming pool facility in the early 1960's. The facility was abandoned in 1984. Extensive rehabilitation is planned for the area to restore it to more natural conditions. However, alterations to the thermal feature may not be reparable.

4. Significance of the feature to the authorized purposes for which the unit was created—This identified feature was not used as rationale for the establishment of the unit and is not recognized as a significant thermal feature within the unit.

Grand Teton National Park

Feature: Steamboat Mountain Fumarole

Significance Criteria: 1. Size and Extent—This fumarole is a small thermal vent near the summit of Steamboat Mountain.

Uniqueness—This feature is not unique because the activity of the fumarole has been declining for many years. Thermal characteristics are perceptable only in winter months.

2. Scientific and Geologic Significance—The Steamboat Mountain Fumarole has such little remaining activity that it can be considered essentially extinct and has little to no significance at this time.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is relatively unmodified but is almost extinct.

4. Significance of the feature to the authorized purposes for which the unit was created—Grand Teton National Park was established by Congress in 1929 with the expressed purpose of setting apart the lands within the boundaries "as a public park or pleasure ground for the benefit and enjoyment of the people of the United States". These springs have not been the site of recreation by the public and do not exhibit any unique characteristics related to the authorized purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Jackson Lake Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a series of springs along the northwest shoreline of Jackson Lake.

Uniqueness—Used to be completely inundated by Jackson Lake and not considered unique.

2. Scientific and geologic significance—This feature used to be completely submerged by the enlargement of Jackson Lake in 1910, but are now above water due to the temporary restriction of the lake level. This area has not been identified as an area of scientific or geologic interest; however, there is very little information available on these springs.

3. The extent to which the feature remains in a natural, undisturbed condition—This feature has been altered and is often under water.

4. Significance of the feature to the authorized purposes for which the unit was created—These springs have not been used nor are they currently being used by the public and do not exhibit any unique characteristics related to the purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Kelly Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a large spring located one mile north of Kelly, Wyoming.

Uniqueness—None.

2. Scientific and geologic significance—Kelly Springs has been highly modified to increase its flow for irrigation and stock watering. Its current flow is estimated between five and seven million gallons per day with temperatures measured at 75 °Fahrenheit. Both temperature and water chemistry data suggest this spring may be associated with the same geologic structures as Teton Valley Ranch Warmsprings and Abercrombie Warmsprings identified below. This spring contains dense populations of native and exotic fish but has not been identified as having scientific or geologic significance to the region.

3. The extent to which the feature remains in a natural, undisturbed condition—This thermal feature has been extensively modified for irrigation, stock watering, and public recreation.

4. Significance of the feature to the authorized purposes for which the unit was created—These springs have been highly modified for recreation and for domestic sources of water and were not used as rationale for establishing the unit. These springs do not exhibit any unique characteristics related to the purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Teton Valley Ranch Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a group of small springs located north of the Gros Ventre River, which is east of Kelly, Wyoming.

Uniqueness—Relatively small and commonplace.

2. Scientific and geologic significance—These springs create a marshy area on the floodplain which is heavily grazed by livestock. No flow or water quality data are available from these springs. These springs have not been identified as having any scientific or geologic significance.

3. The extent to which the feature remains in a natural, undisturbed condition—This feature may have been modified by past irrigation development.

4. Significance of the feature to the authorized purposes for which the unit was created—This feature is not used for recreation and was not used as rationale for the establishment of the unit. These springs do not exhibit any unique characteristics related to the purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Abercrombie Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a relatively small spring located near the south boundary of the unit.

Uniqueness—This feature is *considered commonplace*, rather than unique.

2. Scientific and geologic significance—This feature was developed as a swimming pool in the 1940's and has since been removed. The spring's flow is estimated at 60,000 gallons per day with temperatures measured at 75 °Fahrenheit. In 1986, the area has been partially rehabilitated. The area has no scientific or geologic significance to the region.

3. The extent to which the feature remains in a natural, undisturbed condition—The area has been highly modified with former development and subsequent partial rehabilitation.

4. Significance of the feature to the authorized purposes for which the unit was created—This feature is not used for public recreation and was not used as rationale for the establishment of the unit. (16 U.S.C. 406d).

Dated: February 9, 1987.

Signed:

William P. Horn,

Assistant Secretary for Fish and Wildlife and Parks.

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DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Chemical Analyses of Waters from Crater Lake, Oregon, and Nearby Springs

by

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Abstract

Crater Lake, Oregon, has no surface outlet and loses its inflow by evaporation and leakage. In order to understand the hydrology of the lake and the leakage of the lake in relation to nearby cold springs, water samples were collected for chemical and isotopic analyses. No spring analyzed had evidence of more than ten percent Crater Lake water. One spring, Crater Spring, has higher than usual chloride concentrations and slightly heavier isotopes than average meteoric water. If these are caused by Crater Lake water, then the calculated fraction of Crater Lake water is near seven percent. Chemical and isotopic analyses show that Crater Lake is well mixed. Crater Lake also has anomalously high chloride, boron, lithium, sulfate, and silica concentrations compared to nearby Diamond Lake and to cold springs discharging on the flanks of Mount Mazama. This elevated chloride may be caused by input of thermal water. Weight ratios of Cl/Li are within the range of western United States hot springs and significantly below those for surrounding cold spring waters. Estimates of total heat flow out of the lake bottom range from 670 to 1380 mW/m^2, also suggesting addition of thermal water to the lake bottom.

Introduction

Crater Lake, Oregon, is located in the 6800 year old caldera of Mount Mazama (Bacon, 1983). The lake receives 85 percent of its inflow by direct precipitation with the remainder coming as inflow from the surrounding drainage area. The lake covers 78 percent of its drainage area. The lake has no surface outlet, but loses 72 percent of its inflow by leakage and 28 percent by evaporation (Phillips, 1968). Van Denburgh (1968) recognized that chloride and sulfate and perhaps silica and sodium were anomalously high in the lake and suggested that these constituents may be contributed by thermal springs at depth in the lake. Based on unpublished analyses, Van Denburgh also suggested that the lake is quite uniform in chemical quality both areally and vertically.

The purpose of this paper is to present chemical and isotopic data for Crater Lake and cold springs emanating on the flanks of Mount Mazama in order to understand questions concerning the lake dynamics and the relationship of the lake water to nearby cold springs. The pertinent questions are: 1) Are the lake chemistry and isotopic composition anomalous compared to nearby cold springs? 2) If so, are there any springs that show a significant component of Crater Lake water mixed with shallow ground water? 3) How well mixed chemically and isotopically is the water in Crater Lake? and 4) Do the dissolved chemical constitiuents in Crater Lake water indicate an input of thermal water?

Table 1 contains the complete chemical and isotopic data previously discussed in Thompson and White (1983), Salinas and others (1984), and White and others (1985). These abstracts contained only preliminary answers to the questions posed above. Additionally, inconsistencies in some of the previously reported data have been identified, and the values have been redetermined and are given in Table 1. A complete study of the methods of chloride analysis was also made in order to calculate the accuracy and precision of various methods of analysis.

Sampling and Analysis

Spring waters were collected using methods similar to those described in Thompson (1975). Temperatures of springs were determined using a conventional, total immersion, mercury-in-glass thermometer. In 1981 and 1982 field measurements of the spring water pH were made with non-bleeding, low-ionic-strength, pH-indicating dyes (E. M. Colorphast pH strips*). Beginning in 1983 all field pH measurements were made with a gel-filled pH electrode and a portable pH meter. Temperature and pH were generally determined at each spring site. The alkalinity of the 1984 and the few 1985 samples was also determined in the field. At each spring site a filtered, unacidified (FU) water sample for anion analysis was collected by passing the water through a 0.45 μm membrane filter. Additionally, a filtered, acidified sample (FA) for cation analysis was collected by adding concentrated, trace-metal quality HCl to the filtered water. An untreated sample for deuterium and oxygen-18 analysis was also collected at each site.

Samples of lake water were collected in 2 liter Van Dorn sample bottles attached to a metal cable and retrieved either by hand (1981 samples) or mechanically (all others). The depth of sampling in 1983 was limited to 300 m by the available cable; in 1984 the winch and cable were replaced, permitting us to retrieve samples from the bottom of the lake. Samples were collected and treated similar to the spring water ones: one bottle for anion analysis, FU, another for cation analysis, FA, and a third for isotopic analysis, untreated. In 1985 a one-liter raw sample was collected and evaporated to approximately 50 mL for B and Li analysis.

Laboratory Analyses

Silica was analyzed at 640 nm by a modification of the molybdenum blue spectrophotometric procedure described by Shapiro and Brannock (1956) using 10 mL of the filtered acidified spring water.

Boron was determined spectrophotometrically using the carmin procedure at 600 nm (Brown and others, 1970).

Bicarbonate was determined titrimetrically as alkalinity using a constant-drive buret, a combination pH glass electrode, a specific ion - pH meter, a strip chart recorder, and standardized sulfuric acid (0.05N). The laboratory pH was taken as the pH at the start of the alkalinity titration. If bicarbonate was analyzed in the field, the analysis was not repeated in the laboratory.

Sulfate was determined by a turbidimetric procedure using $BaCl_2$ to precipitate $BaSO_4$. The 1983 samples of lake water were determined by ion chromatography (Fishman and Pyen, 1979).

Chloride was determined by four procedures: a) the colorimetric ferric thiocyanate method (Fishman and Friedman, 1985); b) the manual mercurimetric titration procedure (Brown and others, 1970), c) an ion chromatographic procedure using a HCO_3 - CO_3 eluent and conductivity detection (Dionex

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* Brand names used are for information purposes only and do not constitute a recommendation by the U.S. Geological Survey.

model 16), and d) an automated $AgNO_3$ titration (Brinkman, model 682). Results of the various chloride analyses are reported in table 2.

Fluoride was determined by an Orion ion specific electrode; TISAB II was mixed 1:1 with all samples and standards. The 1983 samples were analyzed by ion chromatography (Fishman and Pyen, 1979).

Sodium and lithium were determined simultaneously by flame emission spectroscopy (FES) in a fuel-rich, air-acetylene flame with added potassium ion (0.1 percent v/v) at 589.0 nm and 670.8 nm, respectively.

Potassium was determined by FES in a stoichiometric air-acetylene flame with added cesium ion (0.1 percent v/v) at 766.6 nm.

Calcium and magnesium were determined simultaneously by atomic absorption spectroscopy (AAS) in a stoichiometric air-acetylene flame with added La(III) (1.0 percent v/v) at 422.7 and 285.2 nm, respectively.

Specific Conductance was determined following the procedure described in Brown and others (1970).

Deuterium analyses were made following the procedure of Bigeleisen and others (1952).

Oxygen-18 analyses were made following the procedure of Epstein and Mayeda (1953).

Cold-Spring Waters

Water samples of cold springs were collected in the Crater Lake area from 1981 through 1985 at the locations shown in figure 1. An effort was made to sample all large discharging springs searching for evidence of Crater Lake water. Major-ion concentrations and water isotopes for cold-spring waters are reported in table 1a.

The cold spring waters discharging on the flanks on Mount Mazama have low total dissolved solids and are essentially a sodium-calcium-magnesium bicarbonate water (table 1a). Generally, the waters are neutral to slightly alkaline. The waters contain much less than 10 mg/L of dissolved sulfate and chloride and less than 1 mg/L of dissolved boron and lithium. Fluoride is just above the detection limit (0.1 mg/L). Dissolved silica in the waters is higher than would be expected for quartz solubility control. Quartz is not a common mineral in this area. Aluminosilicates and glassy volcanic rocks may be the source of the SiO_2 in the cold-spring waters (C. R. Bacon, oral communication, 1987).

In general, spring waters discharging above the surface elevation of Crater Lake are remarkably similar to those discharging below it. Few chemical differences exist between intracaldera spring water and extracaldera spring water. However, in the vicinity of Chaski Slide, a large piece of hydrothermally altered volcanic rock that failed sometime after the climactic eruption, water passing over the slide material is relatively enriched in calcium and sulfate (Samples JCL 81-14 and 81-15 on figure 1). Not all waters discharging from the caldera walls were analyzed for deuterium and oxygen-18, because samples were not collected at the spring orifice and the effects of evaporation were unknown.

Springs above the lake all have chloride concentrations less than 0.4 mg/L whereas the lake has a chloride concentration of 10 mg/L (figure 2). The chloride concentration in the cold springs is similar to that measured in precipitation in western Oregon (Junge and Werbe, 1958), so that the chloride in the cold springs appears to be that which was in the water as precipitation. Because the lake loses 28 percent of its inflow by evaporation, the chloride concentration of the cold-spring water and direct precipitation into the lake can be raised by evaporation by no more than 40 percent. Thus the chloride concentration in the lake is quite anomalous compared to the available water supply.

Both Crater Lake and Diamond Lake show the effect of evaporation on their isotopic contents, and they have distinctly different values from cold-spring samples both above and below the surface elevation of Crater Lake (figure 3). The evaporation trend is the empirical slope of five reported by Craig (1961). It is possible to use values for the isotopes to calculate this evaporation trend (e.g. Gonfiantini, 1986); however, there are a number of free parameters that have not been measured that are required to perform such a calculation. Mixing between Crater Lake water and other waters would be along a straight line in this diagram. Based on the isotopes, there is no single cold spring with a significant fraction of Crater Lake water.

When deuterium is compared to chloride for Crater Lake and the cold-spring samples, a few samples show elevated chlorides, but the combination of mixing in the isotope plot of figure 3 and figure 4 permits some of these to be ruled out as containing a large fraction of Crater Lake water. Based solely on Cl and δD, the spring on Hamaker Creek (Spring 84-11 on Figure 1, with Cl = 4.2 mg/L, $\delta D = -90$ $^{o}/oo$) could be a mixture of 40 percent normal spring water and 60 percent Crater Lake water (Figure 4). However, its plotted value in Figure 3 is near the meteoric water line, indicating that it has no more than a small percentage of Crater Lake water. The six data points below the lines on Figure 4 appear to have similar isotopes with varying amounts of chloride; they cluster together on Figure 3 with similar values of deuterium and oxygen-18 isotopes. They do not appear to contain any significant fraction of Crater Lake water. These springs are located southeast of Crater Lake (figure 2). These springs may be dissolving chloride and boron from sediments of the receding Agency Lake. One of these springs, the source of the Wood River, was initially thought to be a good candidate for containing a significant fraction of Crater Lake water because of its high chloride concentration (Williams and Von Herzen, 1983); however, the isotopic data show that this is unlikely. Several springs have somewhat elevated chloride concentrations and isotopes that are in the correct range to have a few percent of Crater Lake water (Annie Spring 1984 sample, Ranger, Crater, and Fourmile springs); however, none of these have a sufficiently high concentration of chloride to have a clearly demonstrated contribution from Crater Lake. Ranger and Fourmile Springs are located far south and probably in a separate drainage area and are unlikely to contain any significant Crater Lake water. Crater Spring plots slightly along a mixing trend in figure 3 (shown as a filled square) and along a δD - Cl trend in figure 4 and, thus, may contain some lake water. Crater Spring, however, cannot contain more than seven percent Crater Lake water. Other springs could have small fractions of Crater Lake water as shown by their position on Figure 4. No single spring is convincingly demonstrated to contain a substantial amount of Crater Lake water. This is not surprising as the total flow of springs discharging on Mount Mazama is many times the 89 cfs seepage from Crater Lake calculated by Phillips (1968).

Crater Lake Water

Crater Lake can be characterized as being a low total-dissolved-solids, sodium-calcium-magnesium bicarbonate-chloride-sulfate water containing less than 1.0 mg/L boron and less than 0.1 mg/L lithium. Using the 1981 east basin samples (table 1b) as an example, the concentrations of SiO_2, Mg, Na, K, Li, HCO_3, Cl, and F and conductivity are almost identical between surface and bottom waters, and the concentrations of Ca, SO_4 and B are approximately the same. The concentrations of any of these constituents usually do not vary by more than the error of the determination, which generally does not exceed 10 percent.

Using the 1981 east basin surface and bottom samples again, the deuterium values are essentially identical whereas the oxygen-18 values are nearly the same. The reported isotopic values do not vary by more than 2 standard deviations on replicate samples. These data clearly indicate that Crater Lake is well mixed (figures 5 - 9). This essentially constant composition of lake water as a function of depth is also observed in the 1983 and 1984 point samples. Yearly variation, most likely analytical error, between samples is shown in figure 9. As is observed from figure 3, Crater Lake water is not on the meteoric water line, but rather plots along an evaporation line having a slope of 5, which is typical of such waters (Craig, 1961). Diamond Lake also plots along this line.

Silica analyses of Crater Lake bottom and surface water samples in 1981, point samples collected from the east basin and the southwest basin at 50 m intervals to 300 m depth in 1983, and point samples collected from the southwest basin at about 100 m intervals to the bottom in 1984 all indicate Crater Lake is well mixed with respect to silica (figure 5 - 8). Published SiO_2 values of Salinas and others (1984) for 1983 samples contained lower SiO_2 concentrations compared to those reported in Larson (1984, Table 5) for his 1983 samples and found for our 1984 samples. For that reason the 1983 lake water samples were reanalyzed for SiO_2. The corrected values are reported in table 1b; however, they may be questionable since the redeterminations were made in 1987. The source of this error in the original values is currently unknown and tentatively is considered to be analyst error. However, the chlorophyl and dissolved oxygen values reported by Salinas and others (1984) are correct. The corrected SiO_2 values are similar to those reported by Larson (1984) and the 1984 samples of the lake water (table 1b).

The degree of mixing of Crater Lake, as shown by major-ion chemistry and light stable isotopes, may be clarified using the tritium data of Simpson (1970) (figure 10). Except for the near-surface samples, the tritium content of the deeper lake water is constant at 24 TU from 50 m to total depth. In the seven months previous to the date of sampling the lake, the tritium concentration of precipitation averaged 171 TU. It seems likely that this recent precipitation is the source of the peak concentration of 31 TU (figure 10). Assuming that precipitation with 171 TU was added to the lake already at a tritium concentration of 24 TU to produce the peak concentration of 31 TU, the recent-precipitation would be diluted by 20 parts of low tritium-containing Crater Lake water. This much dilution cannot be detected by the other chemical or stable isotopic data that we have, because the techniques are not sensitive enough to show it. For example, precipitation with a chloride concentration of 0.2 mg/L added to 20 parts Crater Lake water with 10 mg/L chloride would have a resulting concentration of 9.5 mg/L. This small difference is well within the analytical uncertainty of chloride determinations.

Comparing Crater Lake water to other cold-spring waters and to Diamond Lake water, a lake about 20 km (12 miles) north of Crater Lake and 300 m (1000 ft) lower in elevation, Crater Lake has higher Cl, SO_4, HCO_3, Ca, Mg, Na, Li, and B concentrations (table 1a and 1b). Crater Lake, at such a high elevation, should contain either less chloride than a typical lower elevation lake and nearby cold springs or a similar chloride, but not more. Both lakes are significantly lower in dissolved SiO_2 than surrounding cold-spring waters. For Diamond Lake, which is quite a productive lake, this is probably a result of diatom metabolism. For Crater Lake, diatoms also consume silica, but its silica concentration is actually anomalously high. The inflow of spring and ground water measured by Phillips (1968) is 15 percent of the total inflow to Crater Lake. Precipitation carries negligible silica whereas the cold springs above Crater Lake carry about 35 mg/L. Using the assumptions in Phillips (1968), the inflow from the cold springs would yield a silica concentration of only 7.5 mg/L in Crater Lake whereas the measured concentration is 18 mg/L. This extra silica must be provided by the same inflow that supplies the added chloride and sodium calculated by Nathenson (1987, written communication).

The anomalous constituents in Crater Lake led Van Denburgh (1968) to the interpretation that the enrichment of Cl and SO_4, and perhaps SiO_2 and Na, "... may have been contributed to the lake by thermal springs or fumaroles ..." This suggestion, which is supported by the heat flow data of Williams and Von Herzen (1983), has caused much controversy. However, if the interpretation of Williams and Von Herzen's heat flow data is correct, it provides a mechanism for the relatively uniform chemical and isotopic composition of the lake, namely Rayleigh convection. They reported a Rayleigh number of 6.3×10^{14}, whereas 1000 is sufficient to initiate convection.

Chloride Analyses of Crater Lake Water

Because of inconsistencies in chloride values from two methods that became apparent when analyzing the last samples collected, we reanalyzed our Crater Lake water samples by at least two, and generally three, different methods for dissolved Cl (table 2). From the data in table 2, different analytical methods yield different Cl concentrations. Some measured Cl concentrations differ more than 1 mg/L.

These determinations pointed out the requirement for more information on both the precision and accuracy of the chloride procedures followed. To address this analytical problem, we prepared two different experiments. The first was to reanalyze the 1981, 1983, and 1984 lake water samples using analytical techniques not initially employed. The second was to prepare four solutions containing 5, 10, 15, and 20 mg/L Cl and then to analyze each of the four solutions three times by each analytical method employed: ion chromatography, an automated $AgNO_3$ titration, and a manual $Hg(NO_3)_2$ titration. The results of these analyses are reported in table 3.

To standardize the titrants for the two titration procedures, we used the method described by Fishman and Friedman (1985). After standardization of the titrant, the various standards were titrated 3 times and each individual concentration calculated (table 3). The mean and standard deviation are also reported in table 3. Because preparing standards for the ion chromatographic procedure is essentially a repeat of preparing the four standard Cl solutions, the error for this method was the variations in the peak heights. As can be observed from the RSDs calculated in table 3, some values are quite precise but others have significant variations.

The regression that passes nearest the origin using mean values is the ion chromatographic line, intercept a = -.014. Using the total data set, the best regression line is that for the automated $AgNO_3$ titration, a = .545. Using the mean values, the $Hg(NO_3)_2$ titration has good overall precision, but the worst intercept, a = 2.08. The method of choice seems to be the automated $AgNO_3$ titration because it is easy, rapid, and accurate. The Cl concentrations reported in table 1b for Crater Lake water samples collected since 1982 were determined using the automated $AgNO_3$ titration. The 1981 samples apparently evaporated too much for an adequate comparison.

Fishman and Pyen (1979) reported results of ion chromatographic (IC) and automated colorimetric (AC) Cl analyses for numerous surface waters. Assuming that the AC method is correct, the mean difference between the IC and AC is -0.76 (std. dev. = 1.30) for samples containing less than 20 mg/L Cl. A similar comparison can be made for our 1983 Crater Lake data in table 2. Assuming the $AgNO_3$ procedure is correct, the mean difference between methods is 0.95 (std dev = .34). This suggests a constant error of about 1 mg/L between the IC method and any other method.

Chemical Evidence of Thermal Components in Crater Lake Water

Elevated concentrations of boron and lithium are typically found in thermal waters of volcanic origin (e.g., White and others, 1976, Ellis and Mahon, 1977, p. 58-116). Because Crater Lake water is enriched in boron and lithium compared to local meteoric water and because the concentration of boron and lithium is either at or below the detection limit for these dissolved constituents in the cold spring waters, we evaporated water from 8 cold spring and 2 lake water profiles, collected at 100 m intervals, from 1 liter to approximately 50 mL. This reduced volume was then analyzed for boron and lithium. The concentration of lithium and boron were then significantly above the detection limits and are reported in table 4.

The concentrations of boron (tables 1 and 4) in Crater Lake water is at least twice that of the cold-spring water, and the lithium concentration is at least 10 times that of the cold springs. If the chloride, boron, and lithium are derived from a thermal source, then the Cl/B and Cl/Li weight ratios would be expected to be similar to ratios from known hot springs in volcanic areas (table 4). Unfortunately, the cold water Cl/B ratios range from 6 to 33 and the lake water ratios range from 17 to 31. This overlap invalidates the use of the Cl/B ratio for identifying thermal components in the lake waters.

The Cl/Li ratio appears to be more diagnostic. In cold-spring waters the Cl/Li ranges from 540 to 4600, and in Crater Lake the ratio ranges from 220 to 280 (mean = 242, std. dev. = 20)(table 4). The Cl/Li weight ratio is substantially lower in lake water than in cold-spring water. Typical Cl/Li weight ratios for thermal waters from other volcanic areas range from 80 to 410 (mean = 246, std. dev. = 115)(table 4). The Crater Lake Cl/Li weight ratios are near the mean Cl/Li ratios for a variety of volcanic settings in the western United States. This also suggests that the additional chloride may be contributed by a thermal water.

Of the other anionic indicators of thermal waters, SO_4 and HCO_3, SO_4 can arise from biogenic oxidation of sulfur and sulfides (Schoen, 1969; Schoen and Rye, 1970; and Brock and Mosser, 1975), and atmospheric CO_2 can also dissolve in the lake. We do not have the requisite isotopic data to determine the fraction of HCO_3 and SO_4 contributed by this deep thermal fluid.

Crater Lake is a slightly alkaline (pH~7.5) sodium chloride-sulfate lake. This observation negates the possibility that acidic fumarolic gases such as HCl and H_2S are being discharged into the lake bottom as was suggested by Van Denburgh (1968). If HCl were being added to the lake, then the ionization of the HCl would make the lake acidic ($pH<7$). The oxidation of H_2S, which generates sulfuric acid, also would tend to make the lake acidic. Thus, Na^+ and Cl^- appear to enter the lake together, probably dissolved in water. NaCl is not transported in a low temperature ($t<150°C$), low pressure ($P<15$ bars) gas. Additionally, the excess SiO_2 discussed earlier suggests transport of SiO_2 in water because little SiO_2 is transported in a vapor phase.

Conclusions

Compared to nearby cold springs and Diamond Lake to the north, Crater Lake has anomalously high concentrations of dissolved Na, Li, Cl, SO_4, and B. Additionally, the δD and $\delta^{18}O$ values for the lake water are significantly higher (heavier) than for cold-spring waters. The isotopic difference between lake water and cold-spring water is caused by evaporation. The water isotopes, δD and $\delta^{18}O$, determine an evaporation line between Annie Spring and Crater Lake water having a slope of five, which is typical for evaporated waters. Diamond Lake also plots along this evaporation line. The chemical enrichments in Crater Lake, however, cannot be explained by evaporation.

No one spring was identified as being the outlet of Crater Lake. We see no evidence for any spring containing more than ten percent lake water. Crater Spring in the NW part of the park (see figure 1 and 2) may contain some Crater Lake water. The evidence for this is that Crater Spring plots along a mixing line between Crater Lake water and the meteoric water line and also that it contains some Cl and plots along a δD - Cl mixing line between Crater Lake and dilute spring waters. If Crater Spring does contain Crater Lake water, it cannot contain more than seven percent lake water. Oasis Spring, in the same vicinity, may also contain some Crater Lake water.

Crater Lake appears to be well mixed based on chemical and isotopic analyses. The concentrations of SiO_2, Cl, Na, Li, SO_4, and B do not vary significantly as a function of depth. The δD and $\delta^{18}O$ values are remarkably uniform throughout the lake water. Tritium data indicate that recent precipitation rapidly mixes with many volumes of lake water in the near surface. The heat flow values reported by Williams and Von Herzen (1983) are sufficient to cause small density gradients that allow the lake to convect in the deeper levels. This Rayleigh convection is apparently able to mix the lake water thoroughly over a 1-year period because there are no major ion chemical gradients found in Crater Lake (Simpson, 1970).

Thermal water generally contains moderate to high concentrations of dissolved boron, chloride, and lithium. Crater Lake also appears to have an anomalously high Li concentration compared to other waters in this area. As is observed from table 1a and table 4, other cold springs can have somewhat elevated chloride concentrations and similar Cl/B weight ratios thus negating their overall usefulness. The Cl/Li weight ratio may be useful in assessing if the Cl is also derived from a thermal water. The mean Cl/Li weight ratio for Crater Lake is calculated to be 242, which is comparable to thermal waters from volcanic environments, 81 - 410, and is substanially lower than the lowest cold-spring ratio (550) at Annie Spring. This supports the hypothesis that Crater Lake contains thermal water and also explains the elevated Na, Li, Cl, SO_4, and B concentrations. With the present data it is not possible to assess a) the amount of, b) the temperature of, or c) the composition of this inferred thermal water.

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Table 1a. Chemical Analyses of Springs in the Vicinity of Mount Mazama

Sample Numbers	Name or Locality	Date	pH	SiO_2	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B	Cond. (μMHOS)	Water T. °C	$\delta^{18}O$	δD
			←						in mg/L					→				
									1981 Samples									
JCL-81-1	Annie Spring	8 Aug 81	7.2	38	2.9	1.0	2.6	0.8	<0.01	15	4	0.4	0.17	0.1	144	4	-13.89	-99.4
JCL-81-2	Diamond Lake, S End	9 Aug 81	7.3	3.6	1.7	1.0	3.2	0.8	<0.01	30	1	0.2	0.13	0.1	121	22.5	-10.85	-83.2
JCL-81-3	Boundary Springs	9 Aug 81	7.6	34	4.3	2.4	3.3	.5	<0.01	25	3	0.2	0.15	<0.1	120	5	-13.76	-98.1
JCL-81-4	Lightning Springs	9 Aug 81	7.1	26	1.7	.25	1.5	.8	<0.01	12	1	0.2	0.13	0.1	84	4	-14.23	-96.6
JCL-81-5	Lodgepole Picnic area	9 Aug 81	7.2	36	1.9	.48	2.8	1.5	<0.01	17	<0.5	0.3	0.14	<0.1	102	5	--	--
JCL-81-6	Maklaks Spring	10 Aug 81	6.9	24	1.8	.41	1.8	.8	<0.01	12	1	0.2	0.14	<0.1	105	10.5	--	--
JCL-81-7	Headwater of Lost Creek	10 Aug 81	7.2	32	1.8	.61	1.9	.4	<0.01	22	1	0.3	0.15	<0.1	109	7.5	--	--
JCL-81-8	Vidae Falls	10 Aug 81	7.1	34	2.1	.70	2.0	.8	<0.01	16	<0.5	0.2	0.15	0.2	117	9	--	--
JCL-81-9	Thousand Springs	11 Aug 81	7.3	34	4.8	2.5	2.5	1.1	<0.01	27	2	0.2	0.16	<0.1	129	5	-13.70	-99.2
JCL-81-10	Source of Wood River	11 Aug 81	7.3	40	5.6	2.7	6.1	1.0	.01	34	5	3.2	0.18	.2	132	9.5	-14.87	-107.6
JCL-81-11	Steel Bay, C.L.	13 Aug 81	7.0	26	.4	.30	1.9	.4	<0.01	14	2	0.3	0.18	<0.1	105	18	-13.75	-101.7
JCL-81-12	N. 'Pumice Castle' C.L.	13 Aug 81	8.6	36	1.6	.83	2.5	.6	.01	18	<0.5	0.3	0.24	<0.1	102	9	--	--
JCL-81-13	S. 'Pumice Castle' C.L.	13 Aug 81	8.2	40	1.6	1.1	2.7	1.0	<0.01	27	1	0.4	0.19	<0.1	110	6.5	-15.45	-110.5
JCL-81-14	'Chaski Slide-E', C.L.	13 Aug 81	7.06	26	4.9	1.7	2.0	.9	<0.01	19	12	0.1	0.19	<0.1	125	12	--	--
JCL-81-15	'Chaski Slide-W', C.L.	13 Aug 81	6.2	22	10.1	3.2	3.3	.4	<0.01	20	26	0.2	0.20	<0.1	145	9.5	-13.88	-105.2
JCL-81-16	'The Watchman Spring'	13 Aug 81	6.6	34	1.6	.42	2.1	1.0	<0.01	16	<0.5	0.2	0.15	<0.1	110	5	--	--
JCL-81-17	Dutton Cliff	13 Aug 81	7.8	36	1.1	.92	4.2	.6	<0.01	21	1	0.2	0.16	<0.1	115	14	--	--
JCL-81-24	Spring near C. L. Lodge	17 Aug 81	6.3	30	2.0	.29	1.9	.7	<0.01	24	<0.5	0.3	0.17	0.2	107	6	--	--
									1982 Samples									
JCL-82-1	Cascade Spring	31 Aug 82	7.06	40.5	2.5	.90	2.9	1.4	<0.01	37	<0.2	0.2	0.03	0.4	--	3.5	-15.11	-108.4
JCL-82-2	Cattle Crossing Rest.	1 Sep 82	7.15	40.0	2.7	2.9	10.8	.7	<0.01	63	<0.2	0.2	0.13	1.1	--	COLD	-14.04	-101.1
									1983 Sample									
JCL-83-1	Crater Spring	7 Aug 83	6.34	35.1	3.0	1.1	3.0	1.6	<0.01	32	<2	0.8	0.1	<.1	--	3.0	-13.56	-97.4
									1984 Samples									
JCL-84-1	Annie Spring	3 Aug 84	5.39	40.5	2.0	1.4	3.0	2.2	<0.01	30	<1	1.2	0.7	0.2	44	3	-13.9	-99.5
JCL-84-2	Tecumseh Spring	3 Aug 84	7.88	34.2	7.46	1.8	12.5	1.4	<0.01	58	3.4	4.9	0.17	0.2	95.5	11	-14.7	-106.8
JCL-84-3	Source of Crooked Crk	3 Aug 84	7.90	36.3	8.03	2.4	15.6	1.9	<0.01	53	6.2	8.4	0.16	0.4	126	11	-14.7	-108.0
JCL-84-4	Source of Wood River	3 Aug 84	6.74	45.8	2.09	2.4	6.6	1.9	<0.01	47	1.8	2.8	0.10	0.2	50	12	-15.1	-105.5
JCL-84-5	Reservation Spring	3 Aug 84	7.58	39.5	15.7	1.9	10.8	2.1	.01	50	4.6	5.8	0.14	0.1	103	8	-14.6	-106.
JCL-84-6	Source of Spring Crk	3 Aug 84	7.51	40.8	3.22	1.8	8.5	1.3	<0.01	46	2.4	3.3	0.12	0.1	60	6	-14.3	-105
JCL-84-7	Annie Creek at boundary	3 Aug 84	N.R.	39.8	6.43	1.1	3.4	1.6	<0.01	32	1.8	0.5	<.1	0.2	50.3	10	-14.2	-98
JCL-84-8	Pothole Spring	4 Aug 84	6.68	42.7	2.68	0.90	2.9	1.7	<0.01	29	0.2	0.5	<.1	0.1	30	3	-15.1	-110
JCL-84-9	Unnamed spring nr road	4 Aug 84	6.79	45.4	2.99	1.3	3.6	2.1	<0.01	34	0.1	0.5	<.1	0.1	47	4	-15.2	-108
JCL-84-10	Unnamed spring, source of Crk 1/4 mi S of Scott Crk	4 Aug 84	6.94	31.4	17.8	0.53	2.4	1.4	<0.01	21	0.4	0.5	<.1	0.2	29	6	-15.0	-103
JCL-84-11	Unnamed spring on Hamaker Creek nr Soda spring	4 Aug 84	N.R.	98.6	23.7	5.1	89	9.7	.03	417	0.8	4.2	0.12	0.2	320	10	-13.2	-90.
JCL-84-12	Mare's Egg Spring	5 Aug 84	7.70	34.8	10.8	9.0	4.2	1.5	<0.01	55	0.3	0.5	0.05	0.2	77	4	-14.4	-101.
JCL-84-13	Four-mile Spring	5 Aug 84	7.96	31.7	6.01	2.4	4.4	1.5	<0.01	54	0.5	1.4	<.1	0.2	74	5	-14.1	-98.
JCL-84-14	Ranger Spring	5 Aug 84	N.R.	38.9	14.2	1.0	3.0	2.0	<0.01	34	<0.1	0.9	<.1	0.2	47	2	-13.6	-95.
JCL-84-15	Cedar Springs	5 Aug 84	6.37	39.2	11.6	1.2	3.4	1.6	<0.01	44	<0.1	0.5	<.1	<.1	60	7	-13.4	-101.
JCL-84-16	Geyser Spring	6 Aug 84	N.R.	30.7	7.52	2.7	3.3	1.2	<0.01	57	0.1	0.5	<.1	0.2	75	5	-12.9	-91
									1985 Sample									
JCL-85-7	Soda Spg on Hamaker Cr	6 Aug 85	5.31	71	271.	243	106.	31.5	0.06	2280	16.	17.7	0.04	0.43	3620	10	-14.3	-102

Table 1b. Chemical Analyses of Crater Lake Waters

Sample Numbers	Name or Locality	Date	f pH	SiO_2	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B	Specific Cond. (μMHOS)	Water T. °C	$\delta^{18}O$	δD
			←					in mg/L						→				
								1981 Samples										
JCL-81-18	E Basin, surface, C.L.	14 Aug 81	6.0	18.2	6.4	2.8	9.1	1.2	0.04	30	10	9.6	0.19	0.2	155	18	-9.40	-79.4
JCL-81-19	E Basin, 579 m, C.L.	14 Aug 81	7.2	17.6	7.4	2.9	9.2	1.3	0.04	30	8	9.6	0.22	0.3	154	--	-9.59	-79.6
JCL-81-20	SW Basin, 448 m, C.L.	14 Aug 81	8.6	17.8	7.8	2.8	9.5	1.1	0.04	34	8	9.9	0.20	0.3	156	--	-9.55	-78.2
JCL-81-21	SW Basin, 489 m, C.L.	15 Aug 81	7.9	18.2	7.4	3.0	9.7	1.2	0.04	30	7	9.6	0.21	0.2	157	--	-9.53	-79.9
JCL-81-22	SW Basin, 448 m, C.L.	16 Aug 81	7.4	17.4	7.5	2.7	9.6	1.2	0.04	24	8	9.4	0.21	0.2	140	--	-9.67	-79.9
JCL-81-23	SW Basin, 468 m, C.L.	16 Aug 81	7.0	19.6	7.6	2.8	9.9	1.7	0.04	33	5	9.4	0.22	0.2	155	--	-9.49	-79.6
								1983 Samples										
JCL-83-2	SW Basin, surface	8 Aug 83	7.24	20.5	6.48	2.4	9.4	1.6	0.03	39	10	10.0	0.11	0.4	--	14.5	- 9.84	-78.4
JCL-83-3	SW Basin, 50 m	8 Aug 83	7.77	18.8	6.72	2.4	9.2	1.6	0.03	42	10	10.1	0.10	0.4	--	11	-9.68	-79.1
JCL-83-4	SW Basin, 100 m	8 Aug 83	7.73	21.5	7.08	2.3	9.3	1.6	0.03	45	10	10.1	0.11	0.5	--	9	-9.74	-79.3
JCL-83-5	SW Basin, 150 m	8 Aug 83	7.65	19.1	6.75	2.3	9.2	1.6	0.03	42	10	10.1	0.12	0.4	--	10	-9.62	-78.9
JCL-83-6	SW Basin, 200 m	8 Aug 83	7.60	19.8	7.15	2.6	9.2	1.6	0.03	45	10	9.8	0.12	0.4	--	10	-9.86	-78.7
JCL-83-7	SW Basin, 250 m	8 Aug 83	7.57	24.4 ?	9.45	2.6	9.2	1.5	0.03	45	10	10.1	0.12	0.6	--	7	-9.67	-77.3
JCL-83-8	SW Basin, 300 m	8 Aug 83	7.66	20.0	7.52	2.6	9.0	1.6	0.03	31	10	9.8	0.11	0.6	--	7	-9.76	-78.6
JCL-83-15	E Basin, surface	8 Aug 83	7.55	19.3	5.49	3.7	9.3	1.7	0.04	47	10	10.4	0.10	0.6	--	16	-9.74	-78.2
JCL-83-11	E Basin, 50 m	8 Aug 83	7.82	17.8	5.58	3.7	9.3	1.8	0.03	37	10	10.3	0.12	0.4	--	9	-9.69	-78.3
JCL-83-12	E Basin, 100 m	8 Aug 83	7.77	18.5	5.98	3.7	9.2	1.7	0.03	32	10	10.1	0.11	0.4	--	8	-9.65	-78.3
JCL-83-9	E Basin, 150 m	8 Aug 83	7.64	18.3	6.99	2.6	9.2	1.8	0.03	39	10	9.9	0.12	0.5	--	8	-9.71	-77.6
JCL-83-10	E Basin, 200 m	8 Aug 83	7.82	17.9	7.09	2.5	9.1	1.6	0.04	47	10	10.2	0.11	0.5	--	8	-9.76	-78.0
JCL-83-13	E Basin, 250 m	8 Aug 83	7.68	18.5	5.91	3.8	9.3	1.7	0.03	39	10	10.2	0.12	0.4	--	8	-9.73	-77.9
JCL-83-14	E Basin, 300 m	8 Aug 83	7.57	20.3	6.40	3.8	9.3	1.6	0.04	42	10	10.0	0.11	0.3	--	8	-9.73	-77.9
								1984 Samples										
JCL-84-17	SW Basin, surface	7 Aug 84	7.12	18.8	5.77	2.3	10.4	1.7	0.05	41	8.	10.0	0.1	0.4	--	--	-9.6	-79.
JCL-84-22	SW Basin, 50 m	7 Aug 84	N.R.	19.6	6.49	2.4	10.2	1.5	0.05	38	8.	10.0	0.1	0.5	--	--	-9.8	-79.
JCL-84-21	SW Basin, 200 m	7 Aug 84	7.01	18.5	6.57	2.2	10.9	1.7	0.05	41	8.	9.8	0.1	0.4	--	--	-9.8	-79.
JCL-84-20	SW Basin, 300 m	7 Aug 84	6.66	18.9	5.49	2.2	10.2	1.5	0.05	42	8.	10.0	0.1	0.5	--	--	-9.7	-79.
JCL-84-19	SW Basin, 400 m	7 Aug 84	6.65	19.2	10.1	2.4	10.4	1.7	0.05	42	8.	10.1	0.1	0.6	--	--	-10.0	-80.
JCL-84-18	SW Basin, 500 m	7 Aug 84	6.72	19.7	13.8	2.6	10.6	1.8	0.05	42	8.	10.6	0.1	0.5	--	--	-9.8	-79.

Table 2. Chloride Analyses of Crater Lake Waters
(Conc. in mg/L)

Sample Numbers	Name or Locality	Date of Collection	Cl $AgNO_3$ Analysis date	Cl $Hg(NO_3)_2$ Analysis date	Cl I.C. Analysis date	Cl $Fe(SCN)^{2+}$ Analysis date
	1981 Samples					
			29 Mar 87	--	--	25 Aug 81
JCL-81-18	E Basin, surface, C.L.	14 Aug 81	--	--	--	9.6
JCL-81-19	E Basin, 579 m, C.L.	14 Aug 81	10.6	--	--	9.6
JCL-81-20	SW Basin, 448 m, C.L.	14 Aug 81	11.4	--	--	9.9
JCL-81-21	SW Basin, 489 m, C.L.	15 Aug 81	10.8	--	--	9.6
JCL-81-22	SW Basin, 448 m, C.L.	16 Aug 81	11.0	--	--	9.4
JCL-81-23	SW Basin, 468 m, C.L.	16 Aug 81	10.2	--	--	9.4
	1983 Samples					
			29 Mar 87	20 Jul 87	10 Aug 83	
JCL-83-2	SW Basin, surface	8 Aug 83	9.9	9.2	8.6	--
JCL-83-3	SW Basin, 50 m	8 Aug 83	10.1	9.5	8.4	--
JCL-83-4	SW Basin, 100 m	8 Aug 83	10.1	9.2	8.9	--
JCL-83-5	SW Basin, 150 m	8 Aug 83	10.1	9.9	9.2	--
JCL-83-6	SW Basin, 200 m	8 Aug 83	9.8	9.6	8.9	--
JCL-83-7	SW Basin, 250 m	8 Aug 83	10.1	9.2	8.8	--
JCL-83-8	SW Basin, 300 m	8 Aug 83	9.8	--	9.2	--
JCL-83-15	E Basin, surface	8 Aug 83	10.4	9.9	9.7	--
JCL-83-11	E Basin, 50 m	8 Aug 83	10.3	9.6	9.4	--
JCL-83-12	E Basin, 100 m	8 Aug 83	10.1	9.2	9.4	--
JCL-83-9	E Basin, 150 m	8 Aug 83	9.9	9.6	9.1	--
JCL-83-10	E Basin, 200 m	8 Aug 83	10.2	9.6	9.0	--
JCL-83-13	E Basin, 250 m	8 Aug 83	10.2	9.2	9.4	--
JCL-83-14	E Basin, 300 m	8 Aug 83	10.0	9.9	9.7	--
	1984 Samples					
			29 Mar 87	26 Feb 87	--	Jan 85
JCL-84-17	SW Basin, surface	7 Aug 84	10.0	8.7	--	7.1
JCL-84-22	SW Basin, 50 m	7 Aug 84	10.0	9.4	--	7.2
JCL-84-21	SW Basin, 200 m	7 Aug 84	9.8	9.7	--	6.9
JCL-84-20	SW Basin, 300 m	7 Aug 84	10.0	10.0	--	7.1
JCL-84-19	SW Basin, 400 m	7 Aug 84	10.1	9.7	--	7.2
JCL-84-18	SW Basin, 500 m	7 Aug 84	10.6	9.7	--	7.3

Table 3. *Comparison of mercuric nitrate and silver nitrate titrations and ion chromatography determinations for chloride*

	Concentration in mg/L 5	10	15	20
$Hg(NO_3)_2$ visual titration (concentrations)				
aliquot A	6.4	11.8	15.6	20.1
aliquot B	7.1	10.8	15.9	21.0
aliquot C	6.4	11.3	16.1	20.1
mean	6.6	11.3	15.9	20.4
RSD (percent)	6.0%	4.6%	1.6%	2.0%
relative error	33%	13%	6%	2%
$AgNO_3$ automatic potentiometeric titration (concentrations)				
aliquot A	5.50	9.96	15.12	19.41
aliquot B	5.44	9.83	14.85	20.02
aliquot C	5.16	10.15	15.12	19.43
mean	5.37	9.98	15.03	19.62
RSD (percent)	3.3%	1.6%	1.0%	1.8%
relative error	8%	0.2%	0.2%	1.9%
Ion Chromatograph (peak heights)				
aliquot A	0.53	1.17	1.68	2.04
aliquot B	0.48	1.18	2.09	2.25
aliquot C	0.51	1.15	1.70	2.34
mean	0.51	1.17	1.82	2.21
s dev	.025	.015	.231	.154
RSD (percent)	5.0	1.3	13.	7.0

Table 4. Analyses of B and Li in partially evaporated samples of lake water collected in 1985, recalculated to original concentrations, and values for other western U. S. Hot Springs

Source		Temp.	Cl	B (mg/L)	Li	Cl/B weight	Cl/Li ratio
Cold Spring Waters							
Mare's Egg Spring		5	1.1	0.18	0.0016	6.1	690
Fourmile Spring		12	0.9	.10	.0006	9.0	560
Tecumseh Spring		9.5	4.4	.21	.0029	21.	1500
Crooked Creek		10	11.1	.34	.0044	33	4600
Wood River		7	8.4	.37	.0130	23	650
Reservation Spring		8	6.4	.37	.0079	17	810
Castle Craig Spring		3	0.8	.14	.0008	6	1000
Annie Spring		2.5	1.2	.04	.0022	30	550
Crater Lake Waters							
Crater Lake, E Basin,	surface	--	9.5	.46	.041	21	230
	100 m	--	10.0	.49	.042	20	230
	200 m	--	11.4	.46	.041	25	280
	300 m	--	9.9	.58	.043	17	230
	400 m	--	10.0	.54	.043	18	230
	500 m	--	9.7	.51	.043	19	230
	590 m	--	10.3	.45	.043	23	240
Crater Lake, SW Basin,	surface	--	9.5	.42	.037	23	260
	100 m	--	9.8	.42	.043	23	230
	200 m	--	9.8	.42	.043	23	230
	300 m	--	9.9	.59	.045	17	220
	400 m	--	11.1	.36	.040	31	280
	500 m	--	11.6	.53	.046	22	260
Typical Thermal Waters							
Growler Hot Spring, Lassen N.F[1]		95	2430	71	7.7	34	320
Loowit Hot Springs, Mt St Helens[2]		84	395	2.0	.97	197	410
Geyser Spring, Seigler Hot Spg[3]		43	294	15	1.6	20	180
Long Valley, unnamed[4]		60	250	13	2.5	19	100
Ear Spring, Yellowstone[5]		93	414	4.2	5.1	99	81
Gamma Hot Springs, Mt Baker[6]		65	755	9.0	2.8	84	270
Ohanapecosh Hot Spring, Mt Rain[6]		48	880	12	2.9	73	300
Baker Hot Springs, Mt Baker[6]		44	110	2.7	.36	41	310

[1]Thompson, 1985
[2]unpublished, data of Thompson
[3]Thompson, Goff and Donnelly-Nolan, 1981
[4]Mariner and Willey, 1976
[5]Thompson and Yadav, 1979
[6]Mariner, Presser and Evans, 1982

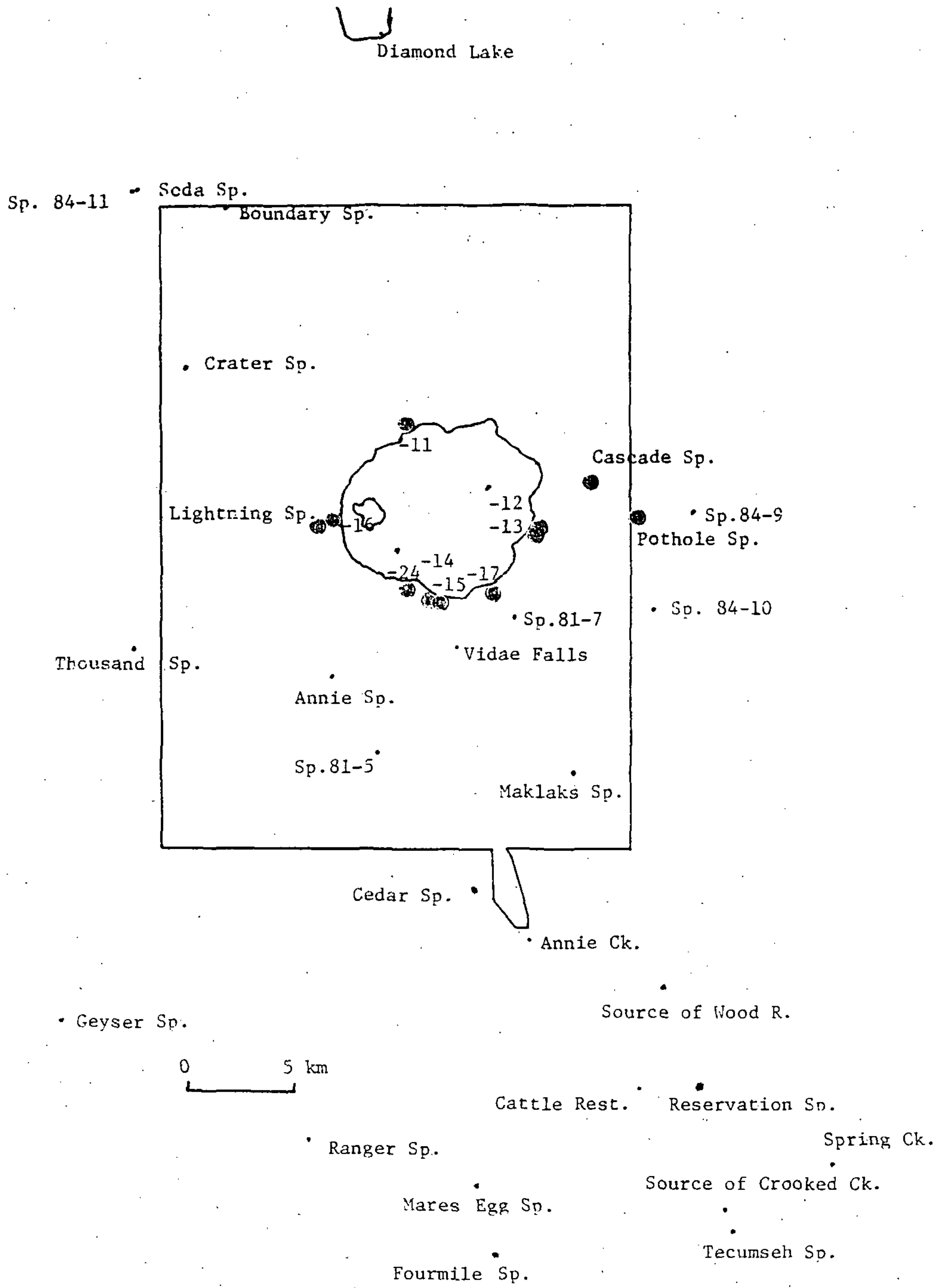

Figure 1. Locations of spring samples in the Crater Lake area. Large dots show spring locations that are higher in altitude than the surface of Crater Lake. Numbers around Crater Lake are last two digits of sample number series JCL 81-.

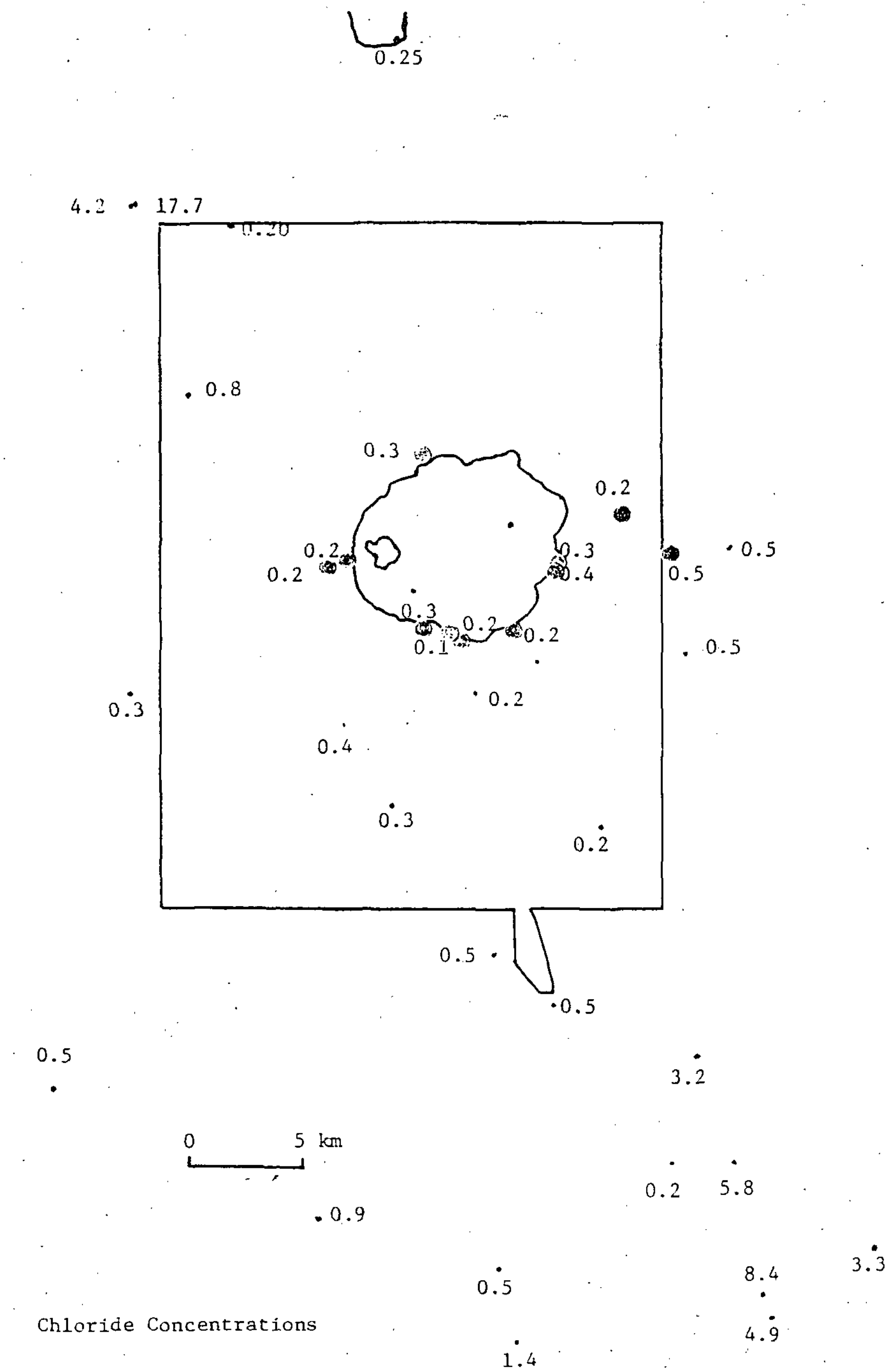

Figure 2. Chloride concentrations (mg/L) in spring waters from the Crater Lake area.

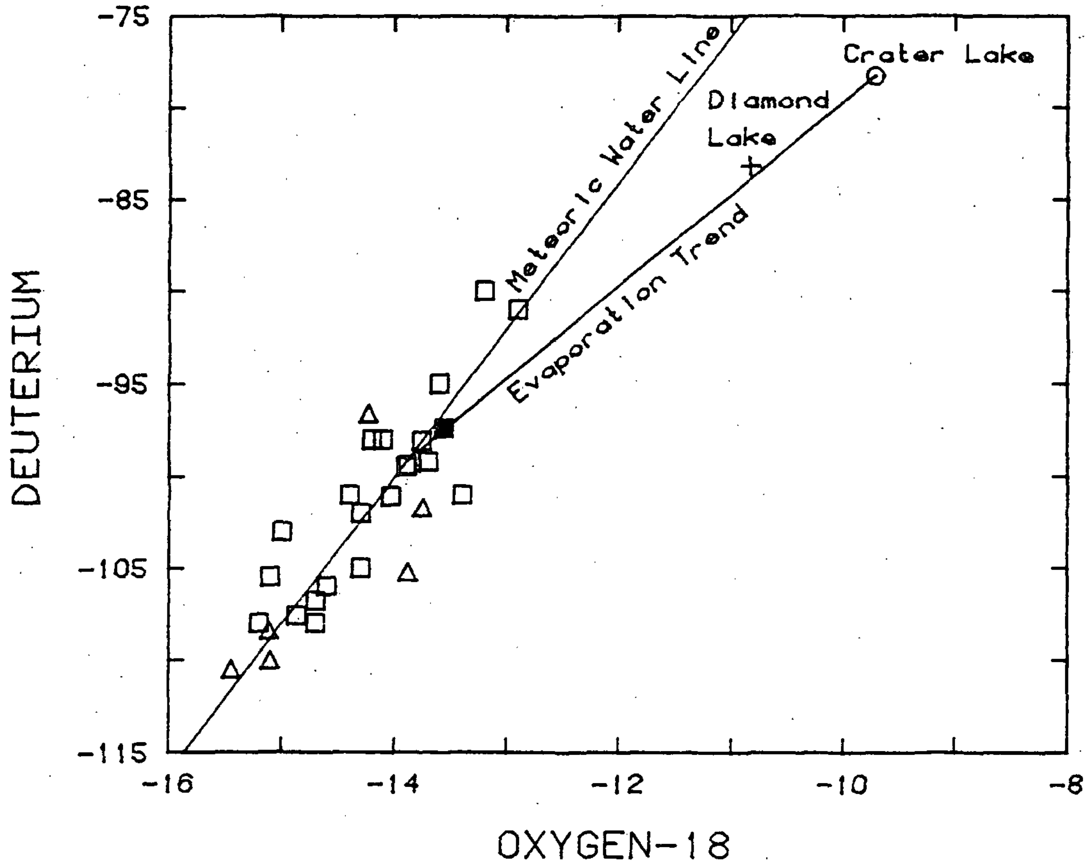

Figure 3. Values for deuterium versus oxygen 18 isotopes for Crater Lake (average of 1983 values) and Diamond Lake and nearby cold springs. Springs above the elevation of the surface of Crater Lake shown as triangles; springs below the surface elevation shown as squares. Crater Spring shown by filled square. Meteoric water line is $\delta D = 8\ \delta O^{18} + 12$ ‰, which has a slightly different intercept than the meteoric water line of Craig (1961). The evaporation trend line has a slope of 5, which is similar to results for other lakes (Craig, 1961).

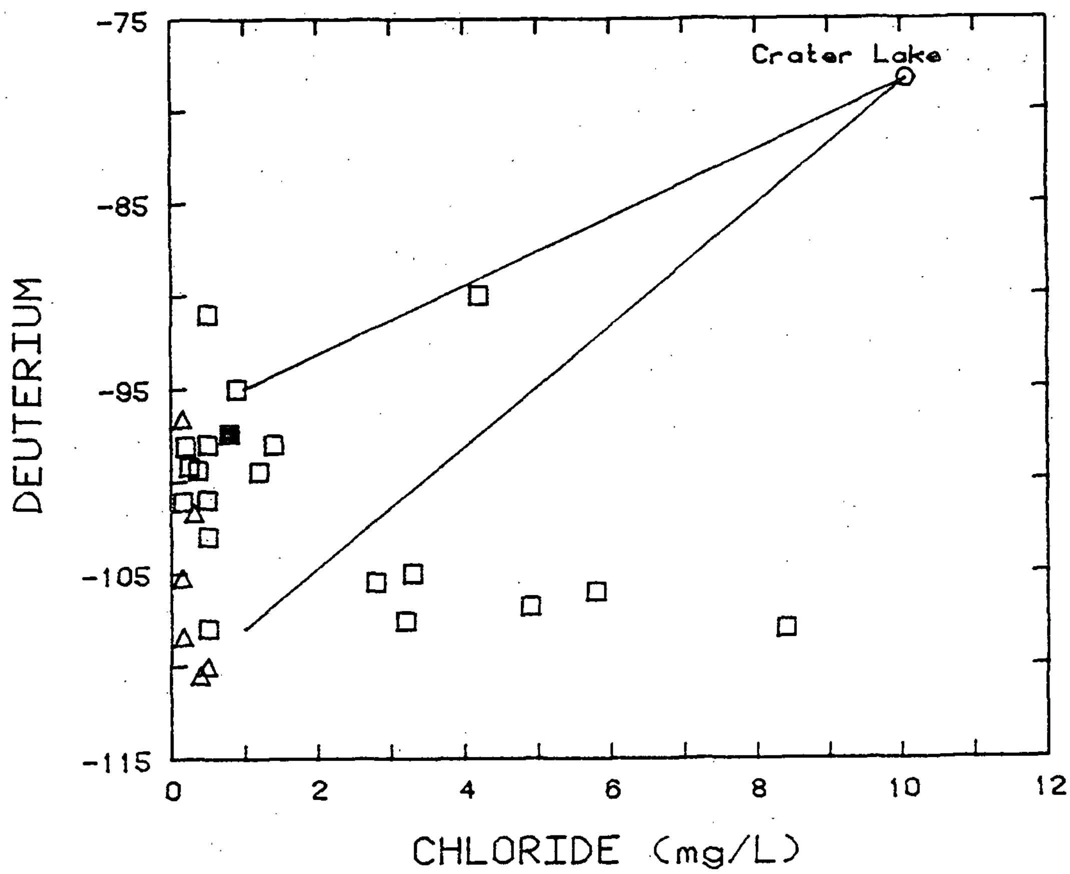

Figure 4. Deuterium versus chloride concentration for Crater Lake (average of 1983 values) and nearby cold springs. Springs above the elevation of the surface of Crater Lake shown as triangles; springs below the surface elevation shown as squares. Crater Spring shown by filled square. Lines shown are for mixing Crater Lake water with the available range of deuterium isotopes in cold-spring waters.

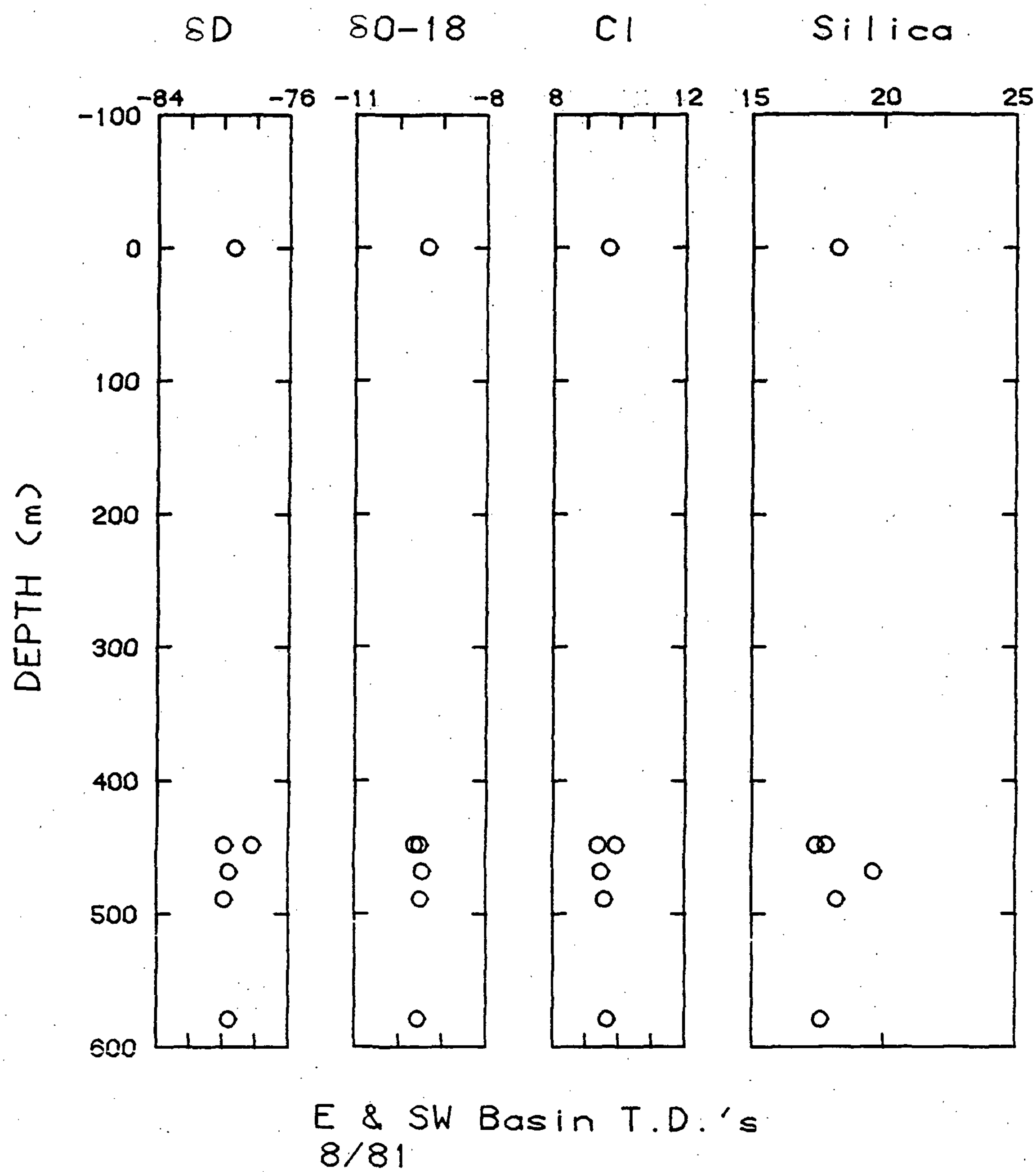

Figure 5. Isotope and chemical data for Crater Lake for surface and total depth samples in 1981 in the east and southwest basins.

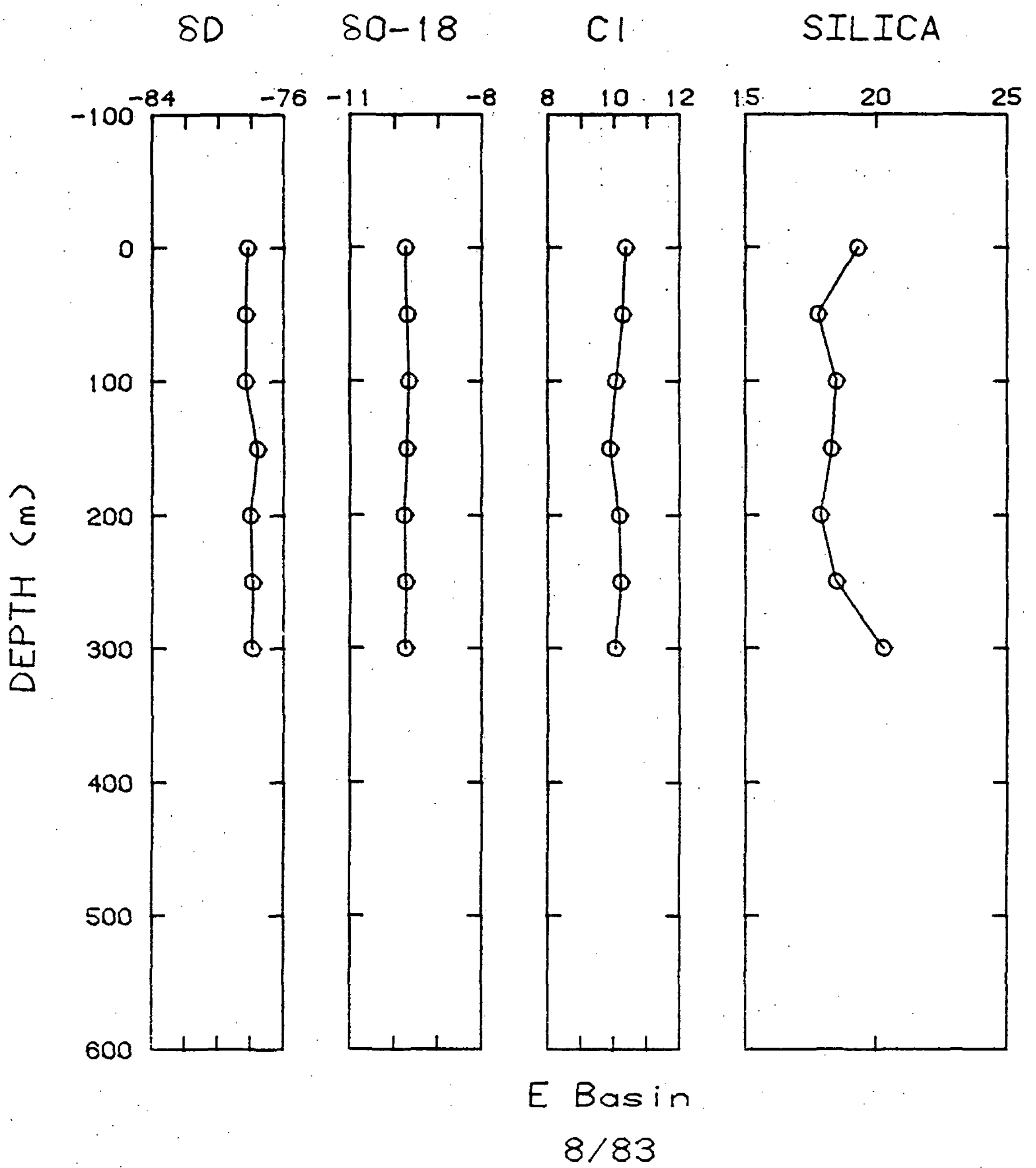

Figure 6. Profile of isotope and chemical data for Crater Lake for the east basin in 1983. Silica values shown were redetermined in 1987, and the variation is not necessarily real.

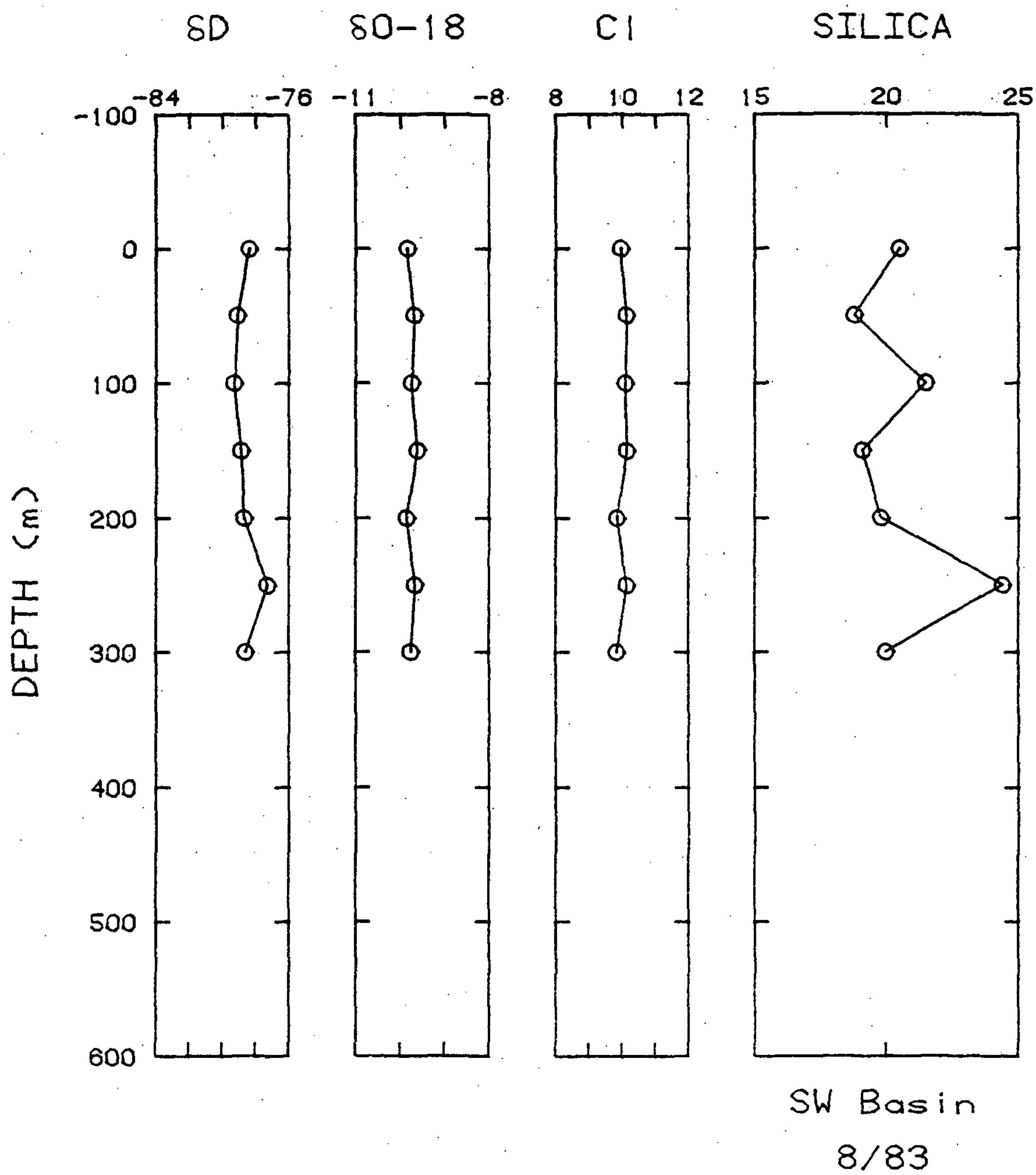

Figure 7. Profile of isotope and chemical data for Crater Lake for the southwest basin in 1983. Silica values shown were redetermined in 1987, and the variation is not necessarily real.

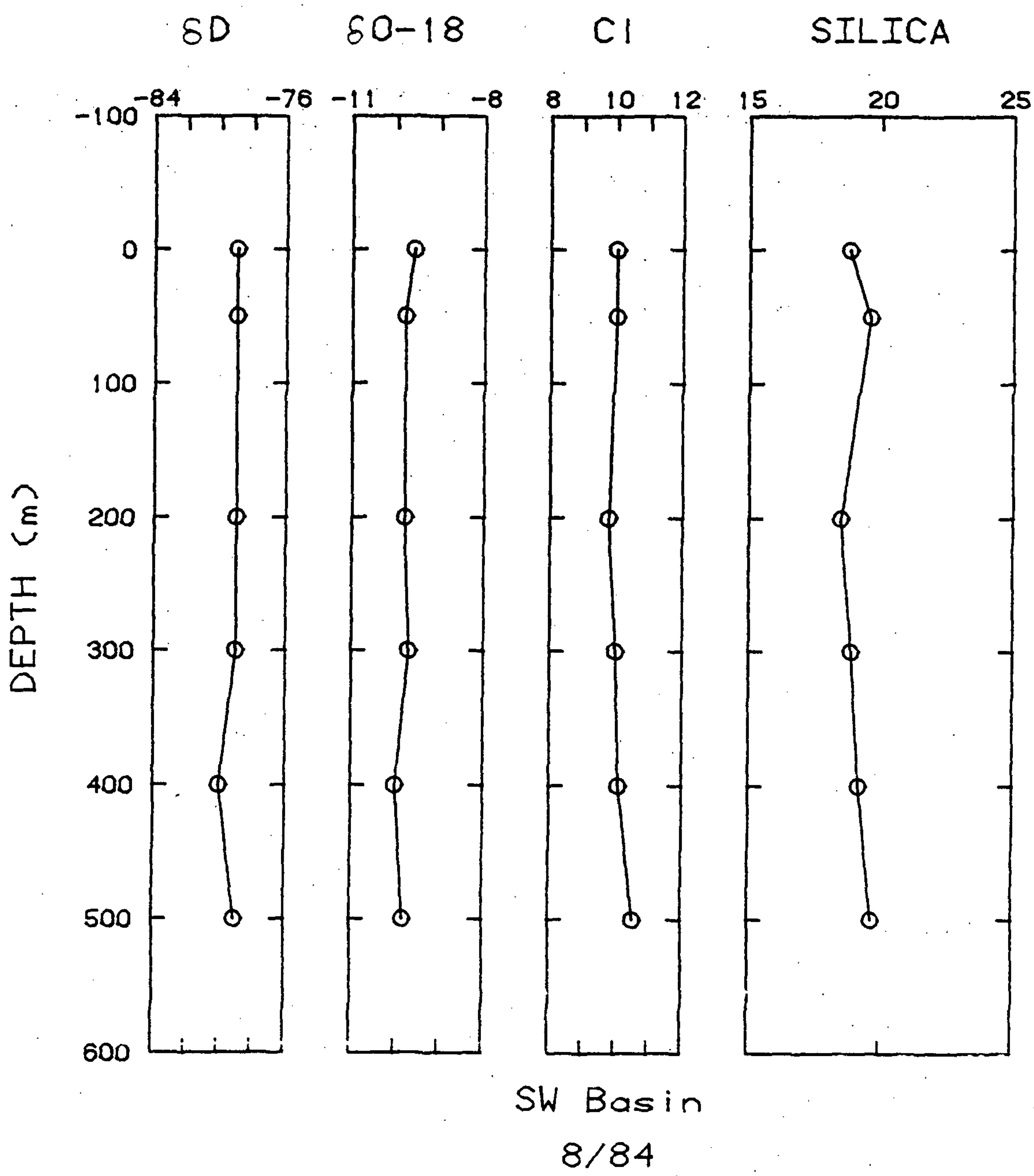

Figure 8. Profile of isotope and chemical data for Crater Lake for the southwest basin in 1984.

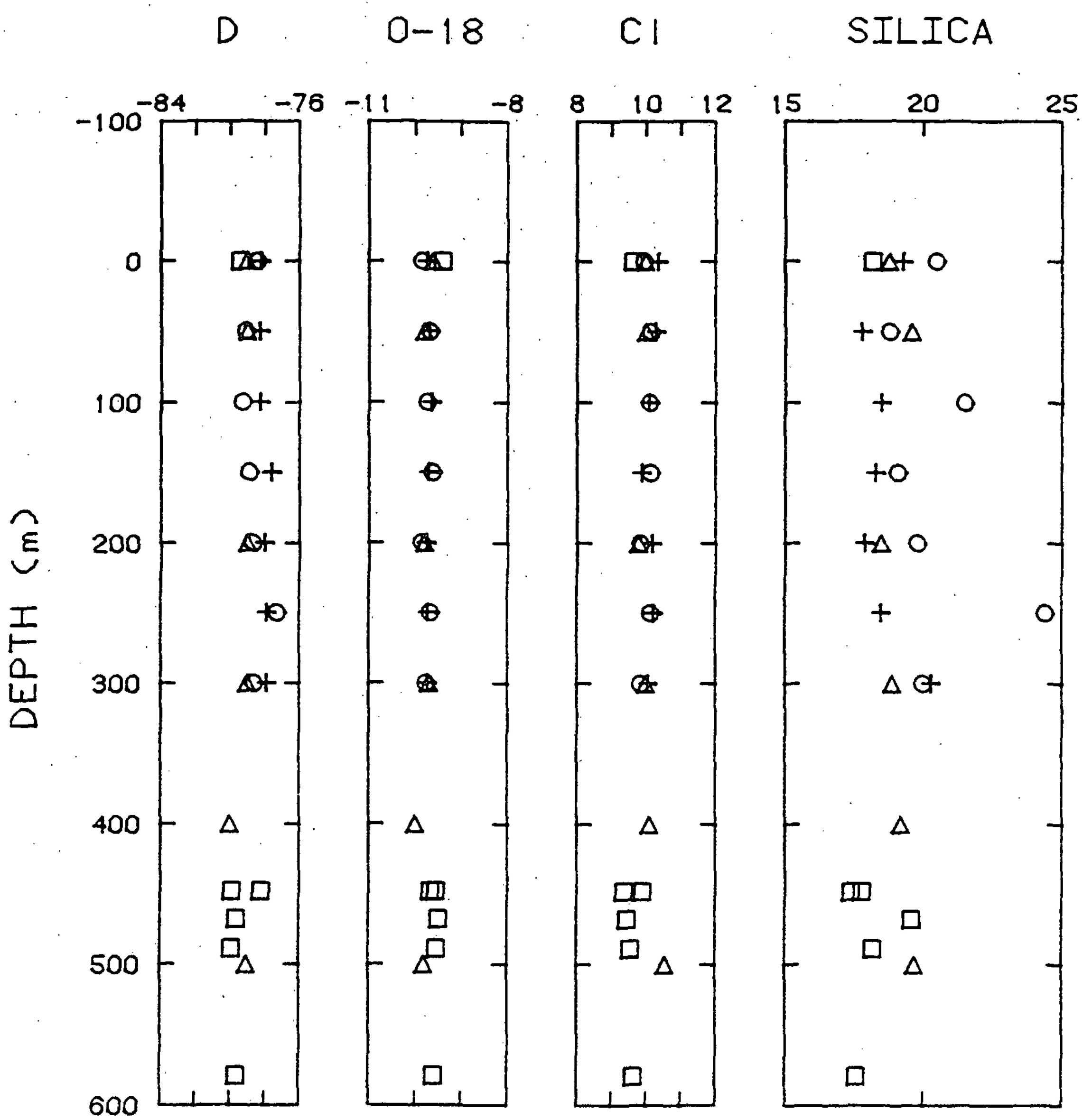

Figure 9. Isotope and chemical data for Crater Lake. Squares (1981), pluses (1983 east basin), circles (1983 southwest basin), and triangles (1984 southwest basin).

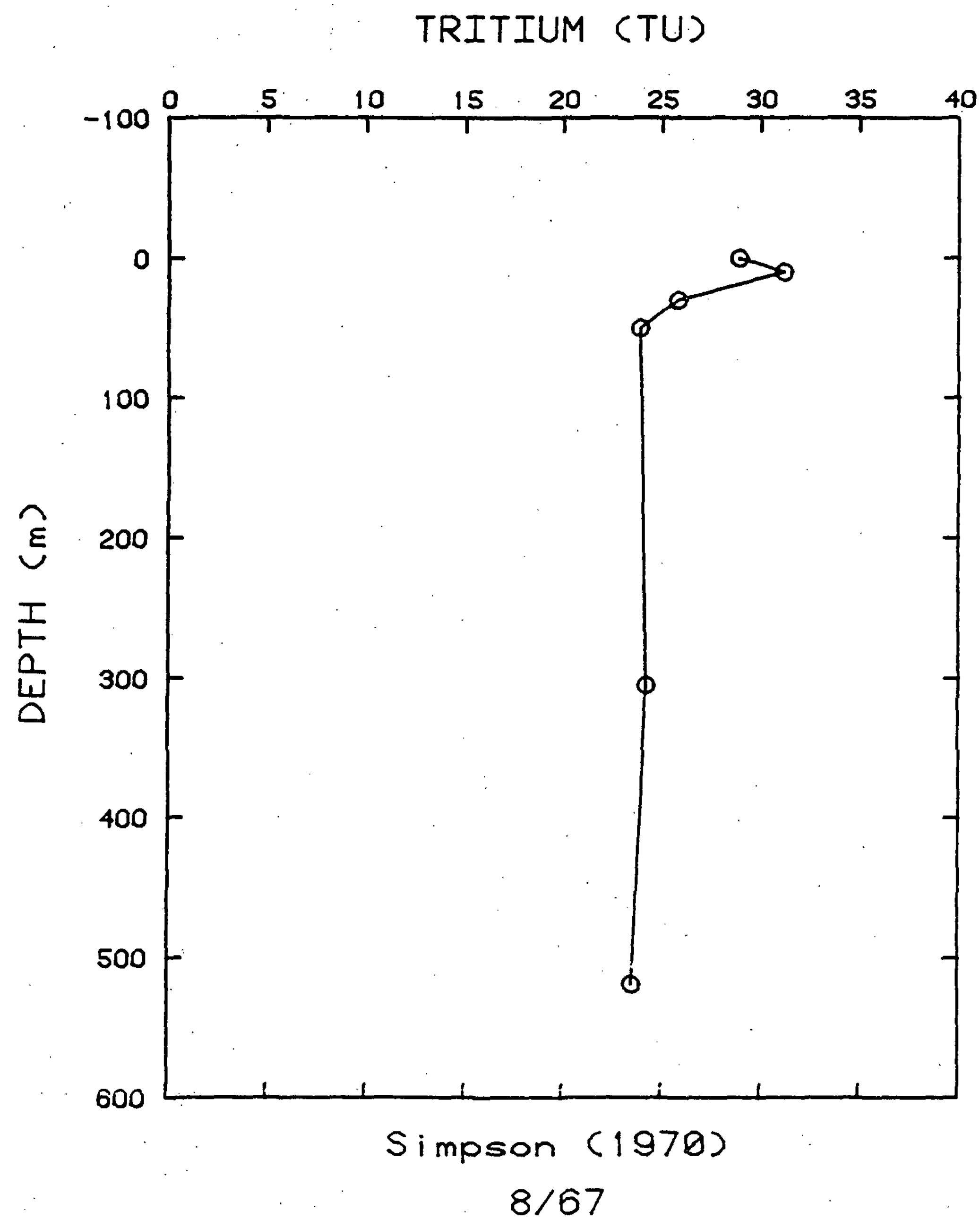

Figure 10. Tritium profile for Crater Lake obtained in 1967 by Simpson (1970).

nated for the purposes of acquisition as authorized in section (a).

(2) In addition to the sums made available under subsection (d)(1), there is authorized to be appropriated such sums as may be necessary to carry out the purposes of this section.

(e) The Secretary of the Interior shall transfer administrative jurisdiction over the Federal property, consisting of approximately 1 acre, known as the Broad Street site, to the Secretary of the Department in which the Coast Guard is operating, who shall transfer to the Secretary of the Interior, subject to such reservations, terms, and conditions as may be necessary for Coast Guard purposes, administrative jurisdiction over the Federal property, consisting of approximately 1 acre located near Fort Moultrie on Sullivan's Island for purposes of a maintenance workshop, storage, and seasonal housing in connection with the administration and protection of the Fort Sumter National Monument.

SEC. 115. (1) The primary term of any geothermal lease in effect as of July 27, 1984, issued pursuant to the Geothermal Act of 1970 (Public Law 91-581, 84 Stat. 1566, 30 U.S.C. 1001-1025) is hereby extended to December 31, 1988, if the Secretary of the Interior finds that—

(a) a bona fide sale of the geothermal resource, from a well capable of production, for delivery to or utilization by a facility or facilities, has not been completed (1) due to administrative delays by government entities, beyond the control of the lessee, or (2) such sale would be uneconomic;

(b) substantial investment in the development of or for the benefit of the lease has been made; and

(c) the lease would otherwise expire prior to December 31, 1988.

(2)(a) The Secretary of the Interior (hereinafter in this section referred to as "the Secretary" shall publish for public comment in the Federal Register within 120 days after the date of enactment of this section a proposed list of significant thermal features within the following units of the National Park System:

Mount Rainier National Park;
Lassen Volcanic National Park;
Yellowstone National Park;
Bering Land Bridge National Preserve;
Gates of the Arctic National Park and Preserve;
Yukon-Charley Rivers National Preserve;
Katmai National Park;
Aniakchak National Monument and Preserve;
Wrangell-St. Elias National Park and Preserve;
Glacier Bay National Park and Preserve;
Denali National Park and Preserve;
Lake Clark National Park and Preserve;
Hot Springs National Park;
Sequoia National Park;
Hawaii Volcanoes National Park;
Lake Mead National Recreation Area;
Big Bend National Park;
Olympic National Park;
Grand Teton National Park;
John D. Rockefeller, Jr. Memorial Parkway;
Haleakala National Park; and
Crater Lake National Park.

The Secretary shall include with such list the basis for his determination with respect to each thermal feature on the list. Based on public comment on such list, the Secretary is authorized to make additions to or deletions from the list. Not later than the 60th day from the date on which the proposed list was published in the Federal Register, the Secretary shall transmit the list to the Committee on Energy and Natural Resources of the Senate and the Committee on Interior and Insular Affairs of the House of Representatives together with copies of all public comments which he has received and indicating any additions to or deletions from the list with a statement of the reasons therefor and the basis for inclusion of each thermal feature on the list. The Secretary shall consider the following criteria in determining the significance of thermal features:

(1) size, extent, and uniqueness;
(2) scientific and geologic significance;
(3) the extent to which such features remain in a natural, undisturbed condition; and
(4) significance of thermal features to the authorized purposes for which the National Park System unit was created.

The Secretary shall not issue any geothermal lease pursuant to the Geothermal Steam Act of 1970 (Public Law 91-581, 84 Stat. 1566), as amended, until such time as the Secretary has transmitted the list to the Committees of Congress as provided in this section.

(b) The Secretary shall maintain a monitoring program for those significant thermal features listed pursuant to subsection (a) of this section.

(c) Upon receipt of an application for a geothermal lease the Secretary shall determine on the basis of scientific evidence if exploration, development, or utilization of the lands subject to the geothermal lease application is reasonably likely to result in a significant adverse effect on a significant thermal feature listed pursuant to subsection (a) of this section. Such determination shall be subject to notice and public comment. If the Secretary determines on the basis of scientific evidence that the exploration, development, or utilization of the land subject to the geothermal lease application is reasonably likely to result in a significant adverse effect on a significant thermal feature listed pursuant to subsection (a) of this section, the Secretary shall not issue such geothermal lease. In addition, the Secretary shall withdraw from leasing under the Geothermal Steam Act of 1970, as amended, those lands, or portion thereof, subject to the application for geothermal lease, the exploration, development, or utilization of which is reasonably likely to result, based on the Secretary's determination, in a significant adverse effect on a significant thermal feature listed pursuant to subsection (a) of this section.

(d) With respect to all geothermal leases issued after the date of enactment of this section the Secretary shall include stipulations in leases necessary to protect significant thermal features listed pursuant to subsection (a) of this section where a determination is made based on scientific evidence that the exploration, development, or utilization of the lands subject to the lease is reasonably likely to adversely affect such significant features. Such stipulations shall include, but are not limited to:

(1) requiring the lessee to reinject geothermal fluids into the rock formations from which they originate;
(2) requiring the lessee to report annually to the Secretary on its activities;
(3) requiring the lessee to continuously monitor geothermal production and injection wells; and
(4) requiring the lessee to suspend activity, temporarily or permanently, on the lease if the Secretary determines that ongoing exploration, development, or utilization activities are having a significant adverse effect on significant thermal features listed pursuant to subsection (a) of this section until such time as the significant adverse effect is eliminated.

(e) The Secretary of Agriculture shall consider the effects on significant thermal features of those units of the National Park System identified in subsection (a) of this section in determining whether to consent to leasing under the Geothermal Steam Act of 1970, as amended, on national forest or other lands administered by the Department of Agriculture available for leasing under the Geothermal Steam Act of 1970, as amended, including public, withdrawn, and acquired lands.

(f) Nothing contained in this section shall affect the ban on leasing under the Geothermal Steam Act of 1970, as amended, with respect to the Island Park Known Geothermal Resources Area, as provided for in Public Law 98-473 (98 Stat. 1837) and Public Law 99-190 (99 Stat. 1267).

(g) Except as provided herein, nothing contained in this section shall affect or modify the authorities or responsibilities of the Secretary under the Geothermal Steam Act of 1970, as amended, or any other provision of law.

(h) The provisions of this section shall remain in effect until Congress determines otherwise.

SEC. 116. (a) Section 1102(a) of the National Parks and Recreation Act of 1978 (Public Law 95-625) is amended by inserting the following after the second sentence: "In addition, the Secretary may acquire by any of the foregoing methods not to exceed ten acres outside the boundaries of the national river for an administrative headquarters site, and funds appropriated for land acquisition shall be available for the acquisition of the administrative headquarters site.".

(b) Section 1112 of Public Law 95-625 is amended by striking "$500,000" and inserting "$3,000,000".

SEC. 117. (1) The Women in Military Service for America Memorial Foundation is authorized to establish a memorial on Federal land in the District of Columbia and its environs to honor women who have served in the Armed Forces of the United States. Such memorial shall be established in accordance with the provisions of H.R. 4378, as approved by the Senate on September 10, 1986 (S. Rpt. 99-421).

(2) The organization or organizations approved by the Secretary shall establish the memorial with non-Federal funds.

SEC. 118. (1) The Black Revolutionary War Patriots Foundation is authorized to establish a memorial on Federal land in the District of Columbia and its environs to honor the estimated five thousand courageous slaves and free black persons who served as soldiers and sailors or provided civilian assistance during the American Revolution and to honor the countless black men, women, and children who ran away from slavery or filed petitions with courts and legislatures seeking their freedom. Such memorial shall be established in accordance with the provisions of H.R. 4378, as approved by the House of Representatives on September 29, 1986.

(2) The Black Revolutionary War Patriots Foundation shall establish the memorial with non-Federal funds.

SEC. 119. The Secretary of the Interior shall designate the visitor center to be associated with the headquarters of the Illinois and Michigan Canal National Heritage Corridor as the "George M. O'Brien Visitor Center" in recognition of the leadership and contributions of Representative George M. O'Brien with respect to the creation and establishment of this national heritage corridor.

SEC. 120. Notwithstanding any other provisions of the Land and Water Conservation Fund Act of 1965, Public Law 88-578, as amended, or other law, Land and Water Conservation Fund assisted land in Berkeley, Illinois, assisted under project No. 17-

P.L. 99-591 10/30/86

federal register

Friday
February 13, 1987

Part II

Department of the Interior

National Park Service

Significant Thermal Features Within Units of the National Park System; Notice of Proposed Listing

DEPARTMENT OF THE INTERIOR

National Park Service

Significant Thermal Features Within Units of the National Park System

AGENCY: National Park Service/U.S. Department of the Interior.

ACTION: Notice of proposed list of significant thermal features within units of the National Park System.

SUMMARY: In accordance with section 115 of the Department of the Interior and Related Agencies Appropriations Act for 1987, Pub. L. 99-591, the National Park Service (NPS) is publishing for public review and comment a proposed list of significant thermal features within twenty-two (22) units of the National Park System. This list may be revised after public comments are received in response to this Notice or as new information becomes available. A final list, including all public comments and rationale for additions to or deletions from the proposed list, will be sent to Congress in April 1987. No geothermal leases may be issued by the Secretary of the Interior until the final list is transmitted to Congress. Also, future geothermal leasing, pursuant to the Geothermal Steam Act of 1970, as amended, is dependent on determinations of whether or not proposals to explore for, develop, produce, or use geothermal resources surrounding the listed features are "likely to result in significant adverse effects" on the listed features.

The NPS welcomes a thorough review of the proposed listed features and the information serving as the bases for determining listed features as significant. The NPS seeks data or information that can assist in preparing a final list of significant thermal features within the specified units of the National Park System. NPS is also interested in receiving nominations for listing additional thermal features or recommendations for deleting thermal features, as proposed. All nominations for listing additional areas of significant thermal features and recommendations for deleting areas from the proposed list should be accompanied by background information on the thermal feature discussed and a supporting rationale for the recommended action.

After transmitting the final list of significant thermal features within units of the National Park System to the Congress, the NPS will publish the same list as sent to Congress in the **Federal Register** as a Final Notice. Copies of public comments received in response to this Notice will also be available for public review according to the specifications of the Final Notice.

DATES: Nominations, recommendations, and supporting comments must be received on or before March 16, 1987, to be assured of receiving consideration.

ADDRESS: Mail comments, recommendations, and nominations to Director, NPS, ATTN: Energy, Mining and Minerals Division (WASO 480, Room 3223, Main Interior Building), National Park Service, P.O. Box 37127, Washington, DC 20013-7127.

FOR FURTHER INFORMATION CONTACT: Ms. Pam Matthes, Energy, Mining and Minerals Division (Room 3223 Main Interior Building), National Park Service, P.O. Box 37127, Washington, DC 20013-7127, (202) 343-4639.

SUPPLEMENTARY INFORMATION: The Department of the Interior and Related Agencies Appropriations Act, Pub. L. 99-591, (hereinafter referred to as the Act) was passed by Congress and signed into law October 30, 1986.

Paragraph 2(a) of § 115 of the General Provisions for the Act, directs the Secretary to collect and publish in the **Federal Register**, within 120 days, a proposed list of significant thermal features in the following twenty-two (22) units of the National Park System:

- Mount Rainier National Park, Washington;
- Lassen Volcanic National Park, California;
- Yellowstone National Park, Wyoming, Montana, and Idaho;
- Bering Land Bridge National Preserve, Alaska;
- Gates of the Arctic National Park and Preserve, Alaska;
- Yukon-Charley Rivers National Preserve, Alaska;
- Katmai National Park, Alaska;
- Aniakchak National Monument and Preserve, Alaska;
- Wrangell-St. Elias National Park and Preserve, Alaska;
- Glacier Bay National Park and Preserve, Alaska;
- Denali National Park and Preserve, Alaska;
- Lake Clark National Park and Preserve, Alaska;
- Hot Springs National Park, Arkansas;
- Sequoia National Park, California;
- Hawaii Volcanoes National Park, Hawaii;
- Lake Mead National Recreation Area, Arizona and Nevada;
- Big Bend National Park, Texas;
- Olympic National Park, Washington;
- Grand Teton National Park, Wyoming;
- John D. Rockefeller, Jr. Memorial Parkway, Wyoming;
- Haleakala National Park, Hawaii; and,
- Crater Lake National Park, Oregon.

The NPS has been designated by the Department as the lead agency for preparation and publication of the list of significant thermal features. In making an overall determination of significance, the Act specifically requires four criteria to be applied to each thermal feature identified within the twenty-two (22) units of the National Park System. These four criteria are listed below, along with a brief discussion of the factors contributing to the determination of whether or not the identified feature(s) qualify as "significant" under each criterion:

(1) Size, extent, and uniqueness—NPS establishes neither lower nor upper limits on the size or extent of a feature. Each feature is identified according to its existing surface dimensions. However, for a feature to be considered significant under criterion #1, it is identified as unique to the unit, the Region, the Nation, or, in some cases, the World.

(2) Scientific and geologic significance—Under this criterion, a feature qualifies as "significant" when the feature has been identified as contributing to scientific or geologic data, to the understanding of thermal regimes, or to the history or origin of the feature within the unit, the Region, or the Nation.

(3) The extent to which such features remain in a natural, undisturbed condition—Under this criterion, NPS reports on the existing condition of identified features. Where applicable, NPS addresses whether disturbances or developments, if any, have affected the subsurface thermal regime.

(4) Significance of thermal features to the authorized purposes for which the National Park System unit was created—Features specifically identified within the enabling legislation for the unit or features used in a manner consistent with the stated purposes for which the unit was created are significant.

Thus, NPS has listed thermal features that were the basis for establishing the unit in the first instance (e.g., Yellowstone National Park) and thermal features that now significantly contribute to the statutory purposes for which the area was set aside by Congress (e.g., Lake Mead National Recreation Area).

In most every case, each feature listed as significant within this Notice has met all of the significance criteria, unequivocably. However, there are a few features proposed for listing where one or more of the significance criteria are met marginally or where the significance is not known at this time.

Such features are clearly identified in an introductory paragraph preceding the discussion of the significance criteria. Specific discussions for each of these features explain the rationale behind proposing these features as significant. NPS welcomes additional information that can assist in the final determinations for these features.

All thermal features initially determined to be or proposed as significant by the NPS under these criteria are listed within this Notice. The Act authorizes the Secretary to make additions to or deletions from the list based on public comments received in response to this Proposed Notice. Further, the Act requires that within 60 days of publishing the proposed list, the Secretary must transmit to Congress a final list together with copies of all public comments received. The transmittal to Congress will indicate any additions to or deleting from the proposed list, including a statement of the reasons for the action. Therefore, the NPS requests that any comments, recommendations for deletion from, or nominations for adding thermal features to the proposed list be supported by a rationale and specific information that addresses each of the above significance criteria.

The Act directs that the Secretary of the Interior shall not issue any geothermal leases under the Geothermal Steam Act of 1970, as amended (30 U.S.C. 1001), until after the list of significant thermal features within units of the National Park System is transmitted to Congress.

Paragraph 2(b) of the Act directs the Secretary of the Interior to establish and maintain a monitoring program for each of the significant thermal features included on the final list transmitted to Congress. The existing data characterizing each listed thermal feature and any data collected as a result of the monitoring program will serve as baseline data upon which the potential effects of future geothermal leasing and development on the listed features will be assessed.

The Act requires that, "Upon receipt of an application for a geothermal lease the Secretary shall determine on the basis of scientific evidence if exploration, development, or utilization of the lands subject to the geothermal lease application is reasonably likely to result in a significant adverse effect on a significant thermal feature listed." All such determinations "shall be subject to notice and public comment", and will be published in the **Federal Register** for public review and comment. Also, the Secretary of Agriculture must consider the effects on the listed thermal features when determining whether to consent to geothermal leases on national forest lands or any other lands under the jurisdiction of the Department of Agriculture. No geothermal lease can be issued, if the Secretary determines that the exploration, development, or utilization of the land subject to the lease application is "reasonably likely to result in a *significant adverse effect* on a listed thermal feature" (emphasis added). In addition, the areas within such proposed lease appplications that are likely to result in significant adverse impacts to listed features must be withdrawn from leasing under the Geothermal Steam Act.

Future proposals to explore for, develop, produce, or use geothermal resources that are determined as "reasonably likely to *adversely affect* such significant features" (emphasis added) within units of the National Park System, may be considered for leasing. If leases are issued in such areas, the "Secretary shall include stipulations in leases necessary to protect significant thermal features." If, in these areas, the Secretary later "determines that ongoing exploration, development, or utilization activities are having a significant adverse effect on significant thermal features" listed, among other things, all activity on the lease must be suspended, "temporarily or permanently" until the significant adverse effect is eliminated.

As previously mentioned, the Act specifically requires the Secretary of the Interior and the Secretary of Agriculture to determine the effects of proposed geothermal leases and future operations on each of the listed significant thermal features in units of the National Park System. The Act further requires that such determinations on lands under the jurisdiction of the Department of the Interior and/or the Department of Agriculture must be made available for public review and comment on a case-by-case basis. In response to this requirement of the Act and to assist in clarifying where future geothermal leasing may be considered, the Department of the Interior proposes to identify the affected States in which geothermal leasing proposals will be evaluated on a case-by-case basis under the public review requirements of the Act. The purpose of this proposal also is to obtain public comment for the balance of Federal lands not contained within the list of affected States so that geothermal leasing can proceed under the requirements of the Geothermal Steam Act without imposing the case-by-case public review provisions of the Act.

The States containing the specified units of the National Park System, as listed within this Notice, comprise the list of affected States. In addition, the NPS proposes to list the State of Utah as an affected State because of its proximity to Lake Mead National Recreation Area, in which the NPS proposes to list thermal features as significant. Therefore, applications for geothermal leases in the following States will be evaluated under the provisions of the Geothermal Steam Act as well as under the explicit public review requirements of the Act: Alaska, Arizona, Arkansas, California, Hawaii, Idaho, Montana, Nevada, Oregon, Texas, Utah, Washington, and Wyoming.

The provisions of the Act are designed to protect significant thermal features within units of the National Park System from the potential adverse effects of exploration, development, or utilization of geothermal resources and will remain in effect until Congress specifically directs otherwise. Therefore, it is important that the following proposed list be given the benefit of a thorough review so that information to supplement, refine, or further delineate significant features presented in this Notice can be added to the data that is transmitted to Congress.

Summary Analysis of Thermal Features in Units of the National Park System

The twenty-two (22) units of the National Park System specified by Congress in the Act are located within five (5) NPS Regions. The following table summarizes the information collected by the NPS on thermal features within each of the specified park units:

SUMMARY TABLE

NPSRegion: park units evaluated	Number of features identified	Identified features qualify as significant under the Act
Pacific Northwest Region:		
Mount Rainier National Park (Washington).	1	Yes.
Crater Lake National Park (Oregon).	1	Yes.
Olympic National Park (Washington).	2	1=Yes/1=No.
Rocky Mountain Region:		
Yellowstone National Park (Wyoming, Idaho, and Montana).	1	Yes.
Grand Teton National Park (Wyoming).	5	No.
John D. Rockefeller, Jr. Memorial Parkway (Wyoming).	1	No.
Alaska Region:		
Bering Land Bridge, National Preserve.	1	Yes.
Gates of the Arctic, National Park and Preserve.	1	Yes.
Yukon-Charley Rivers, National Preserve.	None	Not Applicable.
Katmai National Park	1	Yes.
Aniakchak National Monument and Preserve.	1	Yes.
Wrangell-St. Elias, National Park and Preserve.	2	Yes.

SUMMARY TABLE—Continued

NPSRegion: park units evaluated	Number of features identified	Identified features qualify as significant under the Act
Glacier Bay National Park and Preserve.	None	Not Applicable.
Denali National Park and Preserve.	None	Not Applicable.
Lake Clark National Park and Preserve.	2	Yes.
Southwest Region:		
Hot Springs National Park (Arkansas).	1	Yes.
Big Bend National Park (Texas).	3	Yes.
Western Region:		
Lassen Volcanic National Park (California).	1	Yes.
Sequoia National Park (California).	2	Yes.
Hawaii Volcanoes National Park (Hawaii).	10	Yes.
Haleakala National Park (Hawaii).	1	Yes.
Lake Mead National Recreation Area (Arizona and Nevada).	3	Yes.

Maps showing the location of identified thermal features (if any) within all units are available for public inspection in Washington, DC at the following address:

Energy, Mining and Minerals Division, National Park Service, Room 3223, Main Interior Building, 18th and C Streets NW., Washington, DC 20240

Maps of units showing the location of identified thermal features (if any) are available for public inspection at each of the NPS Regional Offices responsible for administering the unit of interest at the following addresses:

Pacific Northwest Regional Office, National Park Service, 83 South King Street, Library, Seattle, Washington 98104
Rocky Mountain Regional Office, National Park Service, (Attn: Cecil Lewis), 655 Parfet Street, Denver, Colorado 80225
Alaska Regional Office, National Park Service, 2525 Gambell Street, Room 107, Anchorage, Alaska 99503
Southwest Regional Office, National Park Service, Public Affairs Office, 1100 Old Santa Fe Trail, Santa Fe, New Mexico 87504-0728
Western Regional Office, National Park Service, (Attn: Ray Murray), 450 Golden Gate Avenue, San Francisco, California 94102.

The NPS proposes to list features as significant within seventeen (17) units. The following subsection entitled "Proposed List of Significant Thermal Features in Units of the National Park System" describes each of the thermal features identified within each unit and provides information that addresses each of the four significance criteria identified by the Act.

Further, the NPS proposes to list no thermal features as "significant" within six (6) of the twenty-two (22) specified units. Features are not listed either because no thermal features are identified or because those features identified do not meet the significance criteria of the Act. The subsection entitled "Specified Units Within the National Park System With No Significant Thermal Features" explains the rationale for each of the six (6) units of the National Park System that are not proposed for inclusion on the list of significant thermal features to be transmitted to Congress.

Proposed List of Significant Thermal Features in Units of the National Park System

The thermal features identified in this Notice are named from terms describing the surface manifestations of subsurface thermal activity. Heat within the earth is manifested at the earth's surface as a result of different types of thermal activity. Any or all of the surface features described may be expressions of a thermal system or thermal feature.

Hydrothermal systems are the anomalous concentrations of high temperatures at shallow depths caused by the upward movement of water and/or steam. In addition to convective heat transfer by moving fluids, some hydrothermal systems also involve an anomalously shallow heat source caused either by a volcanic system that has moved magma to a shallow level or by high regional heat flow. Surface manifestations of hydrothermal systems are geysers, hot springs, warm springs, mud pots, fumaroles, and steaming ground.

Volcanic thermal activity may be expressed on the surface in the form of molten rock (magma or lava), ash, or thermal fluids such as water (steam), mud, and gas. Geysers, hot springs, warm springs, gas vents, and fumaroles result when water, steam, mud, and gases are heated by the molten rock below the earth's surface and then ejected at the surface. Volcanoes, craters, and calderas are formed on the surface from the eruption of molten rock and associated gases and ash. The conical shape of volcanoes is produced by the ejected material. Craters are a rimmed structure, similar to a basin, usually at the summit of a volcanic cone. A caldera is a large basin-shaped feature formed by one or more volcanic vents. Volcanoes, craters, and calderas, as surface manifestations of either active or dormant heat sources, are indications of active subsurface thermal activity.

The following features are proposed as "significant" thermal features to be forwarded to Congress in April 1987.

Mount Rainier National Park

Feature: Mount Rainier

Significance criteria: 1. Size—Approximately 176,000 acres.

Extent—Mountain area of volcanic origin.

Uniqueness—Mount Rainier is the largest Northern American stratovolcano south of Alaska that contains an active thermal system and is the largest and highest (14,410′) volcano in the Cascade Range.

2. Scientific and geologic significance—This feature is an ideal example of a large stratovolcano and the thermal features at the summit and the upper slopes above 10,000 feet provide excellent study opportunities. Mount Rainier is part of what is commonly referred to as the Pacific Rim of Fire. Ohanapecosh and Longmire thermal springs exist on the flanks of Mount Rainier and their presence are indicators of subsurface thermal activity.

3. The extent to which the feature remains in a natural, undisturbed condition—The volcano itself is primarily undisturbed. Longmire and Ohanapecosh Springs are significantly altered by development that occurred prior to the establishment of the park. There are other disturbances to the flanks of the volcano from the construction of roads and visitor facilities; however, these developments do not alter the thermal feature.

4. Significance of the feature to the authorized purposes for which the unit was created—Mount Rainier, the volcano, is the central feature of the park and Mount Rainier National Park was established in 1899 to preserve this feature. (16 U.S.C. 91)

Crater Lake National Park

Feature: Crater Lake

Significance Criteria: 1. Size—48 square kilometers.

Extent—Hydrothermal vents are located on the south central floor of the basin of Crater Lake at approximately 1500 feet depth. 30–150 liters per second inflow of thermal water is estimated to enter Crater Lake.

Uniqueness—Crater Lake is among the highest, largest, and deepest caldera lakes in the world. It is known for its blue color, nearly pure optical properties, and extreme water clarity.

2. Scientific and geologic significance—Studies indicate that thermal springs feed the lake from the vents located on the floor of the basin. Bathymetric and temperature surveys are needed to characterize the

contribution of these vents to the lake's water quality. Crater Lake resembles the primitive ocean. It is ideal for limnological studies and is a prime example of a caldera lake. It is an isolated system which approximates a closed system and provides a laboratory to investigate environmental disturbances from outside influences, such as atmospheric fallout.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Crater Lake National Park was established in 1902 to preserve the caldera lake and to assure the retention of the lake's superb water quality. (16 U.S.C. 121)

Olympic National Park

Feature: Sol Duc Hot Springs

NPS determines that this feature is marginally significant, mainly because of the lack of scientific interest or significance to the unit or to the Region. However, these springs are extensively used by the public for recreational purposes as a spa. The NPS recognizes the recreational significance of this feature and has assisted in developments to accommodate increased visitor use. The value of its current recreational use is dependent upon the thermal flow of the springs. Recreational use is consistent with the authorized purpose for which the unit was created. Thus, NPS proposes to list this feature as a significant thermal feature within Olympic National Park.

Significance Criteria: 1. Size—Approximately one acre.

Extent—Sol Duc Springs are a series of seeps occurring next to the Soleduck River.

Uniqueness—The springs are unique in that hot springs are rarely found on the Olympic Peninsula and is one of two springs found within the unit. These hot springs indicates the presence of a thermal system within the confines of the Olympic Mountains.

2. Scientific and geologic significance—Sol Duc Hot Springs, located on the inactive Calawah fault zone, have not been identified as an area of scientific interest and is significant to the geology of the unit in that they serve as an indicator of a subsurface thermal regime.

3. The extent to which the feature remains in a natural, undisturbed condition—None of the seeps exist in a natural state as the springs have been extensively altered to accommodate commercial development, which is now a major concession offering all the facilities of a spa. The development of Sol Duc Hot Springs into a commercial spa is used extensively by the public for recreation and therapeutic purposes.

4. Significance of the feature to the authorized purposes for which the unit was created—In 1938, Congress established the Olympic National Park. The enabling legislation states that the lands within the unit were "set apart as a public park for the benefit and enjoyment of the people of the United States". Although not recognized within the enabling legislation, the Sol Duc Hot Springs existed as a commercial resort at the time the unit was considered for establishment by Congress. The resort has since been developed extensively to accommodate increased visitor use as a spa. The NPS recognizes the recreational significance of this feature and its thermal flow remains significant to the public's enjoyment of the springs. (16 U.S.C. 251)

Yellowstone National Park

Old Faithful and approximately 10,000 geysers and hot springs make Yellowstone National Park the world's greatest thermal area. NPS proposes to list the entire hydrothermal system within Yellowstone National Park as one significant thermal feature comprised of the identified one hundred fourteen (114) hot springs and seven (7) gas vents. Each of the features listed are part of and in total comprise the Yellowstone hydrothermal system within the boundaries of the park. The following significance criteria have been analyzed for each feature listed and have been found to be applicable to every feature within the Yellowstone thermal system.

Feature: Yellowstone National Park

Significance Criteria: 1. Size—Approximately 2,220,000 acres.

Extent—(a) 10 travertine hot springs in Mt. Holmes, Mammoth, Tower Junction, Abiathar, Madison Junction, Firehole Lake, and Huckleberry Mountain Quadrangles.

(b) 41 acid-sulfate hot springs in Obsidian Lake, Mt. Washburn, Amethyst Mountain, Madison Junction, Norris Junction, Solfatara Plateau, Canyon Village, Ponuntpa Springs, Pelican Cone, Juniper Creek, Beach Lake, Lake Junction, Steamboat Point, Buffalo Lake, Summit Lake, Shoshone Geyser Basin and Huckleberry Mountain Quadrangles.

(c) 18 neutral-chloride hot springs in Norris Junction, Ponuntpa Springs, Firehole Lake, Buffalo Lake, Warm River Butte, Old Faithful, Ragged Falls, and Lewis Lake West Quadrangles. This feature includes the Upper and Lower Geyser Basins.

(d) 1 neutral-dilute spring in Warm River Butte Quadrangle.

(e) 6 neutral-alkaline dilute springs in Lewis Lake West, Grassy Lake Reservoir, Huckleberry Mountain, and Mt. Hancock Quadrangles.

(f) 21 springs having a mixture of the above types in the following quadrangles: Obsidian Lake, Amethyst Mountain, Madison Junction, Norris Junction, Canyon Village, Pelican Cone, Firehole Lake, Juniper Creek, Steamboat Point, Old Faithful, West Thumb, Shoshone Geyser Basin, and Lewis Lake East.

(g) 1 Bicarbonate spring located in the Obsidian Lake Quadrangle.

(h) 16 springs of undetermined dominate chemistry located in Amethyst Mountain, Madison Junction, Norris Junction, Solfatara Plateau, Canyon Village, Ponuntpa Springs, Pelican Cone, Juniper Creek, Steamboat Point, and Lewis Lake West Quadrangles.

(i) 7 gas vents located in Amethyst Mountain, Abiathar Peak, Solfatara, Pelican Cone, and Eagle Peak (Brimstone Basin) Quadrangles.

Uniqueness—The Yellowstone thermal system is the world's greatest hydrothermal system and geyser area and is recognized as an outstanding natural feature of the world.

2. Scientific and geologic significance—Yellowstone contains thousands of thermal features and the park is widely known as the preeminent hydrothermal area of the world. The entire Yellowstone hydrothermal system provides numerous opportunities to study and characterize a large, undisturbed geyser system.

3. The extent to which the features remain in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the features to the authorized purposes for which the unit was created—Yellowstone National Park was created in 1872 to preserve and protect all natural curiosities or wonders within the park and to retain each of the features in their natural condition. The thermal features of the park are one of the natural wonders of the park and comprise the preeminent hydrothermal area of the world. (16 U.S.C. 21)

Bering Land Bridge National Preserve

Feature: Serpentine Hot Springs

Significance Criteria: 1. Size—Approximately 0.5 square miles.

Extent—Serpentine Hot Springs is a group of hot springs providing the only indication of thermal regime within the unit.

Uniqueness—These springs are the warmest springs in the region and is the only indicator of thermal activity in the Preserve.

2. Scientific and geologic significance—As the warmest springs in the region, Serpentine Hot Springs are the only indicator of thermal activity in the Preserve.

3. The extent to which the feature remain in a natural, undisturbed condition—The main pool has undergone some disturbance. Bath and bunk houses have been moved to the site to facilitate public visits and water has been piped to the bathing pool. These surface disturbances have not altered the thermal regime of the feature.

4. Significance of the feature to the authorized purposes for which the unit was created—The Bering Land Bridge National Preserve was established to protect and interpret volcanic lava flows, ash explosions, coastal formations and other geologic processes. Also, the recreational significance of the Serpentine Hot Springs was recognized in the enabling legislation. (16 U.S.C. 410hh)

Gates of the Arctic National Park and Preserve

Feature: Reed River Hot Springs

Significance Criteria: 1. Size—Complex of springs approximately 0.25 miles in length.

Extent—0.25 mile section along the east side of Reed River.

Uniqueness—Reed River Hot Springs is the largest known thermal feature in the park and is one of the few large hot springs in the region.

2. Scientific and geologic significance—As one of the few large warm springs in the Brooks Range of Alaska, Reed River Hot Springs has been proposed for listing in the National Register of Natural Landmarks and for designation as a State Ecological Preserve.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—The Alaska National Interest Lands Conservation Act of 1980 (ANILCA) established Gates of the Arctic National Park and Preserve as a new park unit within the National Park System. ANILCA states that the purpose of the unit is to "preserve unrivaled scenic and geologic values" with the mandate to manage the unit "to maintain the wild and undeveloped character of the area" and its "ecological integrity" (16 U.S.C. 410hh). The natural, undisturbed character of the one of the few warm springs in the Brooks Range, as found in the Reed River Hot Springs, is a significant thermal feature for this unit.

Katmai National Park and Preserve

Feature: Novarupta and vicinity

Significance Criteria: 1. Size—800 square miles.

Extent—Six volcanoes, all in the vicinity of Novarupta, are east of the Bruin Bay fault and between Mount Martin and coast of Kamishak Bay, north of Mount Douglas.

Uniqueness—The volcanoes, active since 1912, have only erupted once and, consequently, has a simple structure conducive to study. There is no other site in the world where an ash eruption of comparable size has occurred at a terrestrial, rather than marine, site and where the ejects are accessible.

2. Scientific and geologic significance—The structure beneath Novarupta, including the magma body, is of major scientific interest and significance. It is hypothesized that the proximity and relative locations of the six active volcanoes may have created heat so intense that the earth's rhyolitic crust, in addition to the mantle, was melted.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Katmai National Monument was established originally to protect the volcanism that created the identified thermal features. ANILCA further expanded the unit to protect, among other features, the existing geological features, which include the volcanoes within the unit. (16 U.S.C. 410hh-1)

Aniakchak National Monument and Preserve

Feature: Aniakchak Caldera

Significance Criteria: 1. Size—Approximately 28 square miles.

Extent—The caldera is a volcanically active, flat-floored, ash-filled bowl that is 2,500 feet deep.

Uniqueness—The Aniakchak caldera is one of the largest calderas in Alaska, exhibits recent volcanic activity, and is essentially dry-bottomed.

2. Scientific and geologic significance—The area is acclaimed as one of the largest and most accessible ice-free calderas on the Alaska Peninsula.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Aniakchak's enabling legislation states the unit must be managed to "maintain the caldera and its associated volcanic features and landscapes in their natural state." Therefore, the identified feature is a significant feature serving as the basis for the unit's creation. (16 U.S.C. 410)

Wrangell-St. Elias National Park and Preserve

Feature: Mineral Springs (mud volcanoes)

Significance Criteria: 1. Size—The three springs occupy approximately 310 acres.

Extent—This feature is comprised of three widely spaced thermal areas located on the flanks of Mt. Drum. One of the sites has no appreciable water flow and largely vegetated. Another site consists of a spring of approximately 10 acres. The third site is approximately 300 acres.

Uniqueness—The three identified springs are mineral springs, which is an unusual phenomenon in Alaska.

2. Scientific and geologic significance—The unique thermal activity associated with these springs provides opportunities for scientific investigations.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—ANILCA identifies the general purpose for which various Alaska units were established as one "to preserve unrivaled scenic and geological values associated with natural landscapes." The mud volcanoes identified are unique and are of significant geologic value within the unit and to the geology of the region. (16 U.S.C. 410hh)

Feature: Wrangell Volcanoes

Significance Criteria: 1. Size—Mt. Wrangell 14,153 feet; Mt. Drum 12,010 feet; Mt. Sanford 16,237 feet; and Mt. Blackburn 16,390 feet.

Extent—The four volcanoes are central features of the park.

Uniqueness—The four active volcanoes are prominent within the park which includes the greatest assemblage of mountain peaks in any park in the Nation.

2. Scientific and geologic significance—The Wrangells are collectively referred to as a group of large shield and composite volcanoes. Geologically, they are relatively young and have had major eruptions as recently as 1,500 years ago. Their size, recent eruptions, and current activity provide significant opportunities for scientific investigations, including glaciological and volcanic studies. A long-term monitoring program of Mt. Wrangell has been ongoing for over 15 years. The Wrangells are one of the greatest assemblages of mountain peaks in the Nation, some of which are volcanoes, both active and inactive. The Wrangells are the origin for some of the longest glaciers on the North American continent.

3. The extent to which the feature remains in a natural, undisturbed condition—The foothills and lowlands that form the outer fringe of this mountain range have been the sites for a few small mining operations. The mining operations with developed access routes have created some disturbances to these areas; however, disturbances to the lower surrounding mountains is minimal.

4. Significance of the feature to the authorized purposes for which the unit was created—ANILCA identifies the general purpose for which various Alaska units were established as one of preserving unrivaled scenic and geological values associated with natural landscapes. The primary purposes of Wrangell-St. Elias National Park and Preserve are to maintain unimpaired the scenic beauty and quality of high mountain peaks, foothills, glacial system, lakes, and streams in their natural state and to provide reasonable access for mountain climbing, mountaineering, and other wilderness recreational activities. These high peaks are significant features serving as the basis for the creation of the unit. (16 U.S.C. 410hh)

Lake Clark National Park and Preserve

Feature: Redoubt Volcano

Significance Criteria: 1. Size—38,000 acres.

Extent—The small vents in the cone of Redoubt Volcano.

Uniqueness—Redoubt Volcano is the second highest of the 76 volcanoes of the Alaska Peninsula and Aleutian Islands and is an active, heavily glaciated stratovolcano.

2. Scientific and Geologic Significance—Redoubt Volcano is an excellent example of a classic stratovolcano which exhibits areas of steam venting and sulfur vents. The feature is marked by erosion from glaciers and other processes exposing cross-sections of the volcano. Exposures illustrate the relationships of various lava flows and pyroclastic rocks of which the stratovolcano is composed.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—The enabling legslation for Lake Clark National Park and Preserve states that the purposes of the unit are, among others, to "maintain unimpaired the scenic beauty and quality of portions of the Alaska Range, including active volcanoes". (16 U.S.C. 410hh)

Feature: Iliamna Volcano

Significance Criteria: 1. Size—33,900 acres.

Extent—Thermal activity consists of two small sulphur vents located at about 9,000 feet near the summit on the eastern face of the volcano.

Uniqueness—Iliamna Volcano is a broad cone-shaped active volcano deeply dissected by erosional processes.

2. Scientific and geologic significance—The composition and appearance of the Iliamna Volcano offers opportunities to study its unique history.

3. The extent to which such features remain in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

4. Significance of the feature to the authorized purposes for which the unit was created—The enabling legislation for Lake Clark National Park and Preserve states that the purposes of the unit are, among others, to "maintain unimpaired the scenic beauty and quality of portions of the Alaska Range, including active volcanoes". (16 U.S.C. 410hh)

Hot Springs National Park

Feature: Hot Springs

Significance Criteria: 1. Size—0.3 mile long section of the southwest base of Hot Springs Mountain.

Extent—These springs are comprised of 47 individual springs along the southwest toe of Hot Springs Mountain.

Uniqueness—The average temperature of 143 °F of the spring waters are unique and the combined flow of 23 of the monitored springs is 600,000 gallons per day. These springs are credited with advancing the bathhouse health spa ethic in this region of the United States.

2. Scientific and geologic significance—The springs have been studied to differing levels of sophistication over the past 150 years. Monitoring equipment to be installed will provide base information to monitor temperatures and flow as a measure of adverse effects and hydrologic changes. Studies are being conducted to affirm the subsurface geology and the groundwater flow network.

3. The extent to which the feature remains in a natural, undisturbed condition—The natural environment of the springs has been extensively altered with the construction of bathhouses and the city's Central Avenue business district. The springs themselves have been walled in and capped to prevent surface-borne contamination. Twenty-three (23) of the springs have had plumbing installed to collect and distribute the waters to a central reservoir.

4. Significance of the feature to the authorized purposes for which the unit was created—The Act of April 20, 1832, initially set aside this area, including the Hot Springs, as a Federal reserve in the Territory of Arkansas. Since the initial Act, there have been over 50 additional Federal statutes specifically addressing the management of the Hot Springs. NPS recognizes the cultural significance of the evolution of the bathing regime into the elegant bathhouses and the thermal flows remain of primary significance to Hot Springs National Park. (16 U.S.C. 361)

Big Bend National Park

Feature: Spring No. 1

Significance Criteria: 1. Size and Extent—Small developed hot spring along the Rio Grande River.

Uniqueness—Approximately 7–9 gallons per minute are being pumped to supply water for the endangered fish species *Gambusia gaigei.*

2. Scientific and geologic significance—Spring No. 1 along the Rio Grande River is the water supply for an endangered fish species and is an important source for water samples to make temperature measurements for monitoring hydrologic changes.

3. The extent to which the feature remains in a natural, undisturbed condition—The spring has been enclosed and a pumphouse has been installed.

4. Significance of the feature to the authorized purposes for which the unit was created—Big Bend National Park was established in 1935 primarily "as a

public park for the benefit and enjoyment of the people". Also, the enabling legislation provides for the administration and protection of the park to be exercised under the provisions of the Organic Act of the National Park Service of August 25, 1916. The Organic Act provides for the National Park Service to promote and regulate the use of Federal lands within the National Park System in a manner to conserve natural objects and wildlife therein (16 U.S.C. 1). Although this spring is not used for the purpose of public recreation, its primary use is for the maintenance of an endangered wildlife species. Thus, the purposes for establishing Big Bend National Park include preservation of endangered species. (16 U.S.C. 156).

Feature: Spring No. 4

Significance Criteria: 1. Size and Extent—Developed hot spring along the Rio Grande River.

Uniqueness—The spring has a flow of approximately 75 gallons per minute. The spring supplies potable water for Rio Grande Village and serves as a water source for the endangered species *Gambusia gaigei.*

2. Scientific and geologic significance—Spring No. 4 along the Rio Grande River serves as a water source for an endangered fish species and is an important source for water samples and to take temperature measurements for monitoring water temperature and flow as a measure of hydrologic changes.

3. The extent to which the feature remains in a natural, undisturbed condition—The spring has been enclosed and pumphouses installed. A 4 inch pipe is used to produce water flow that simulates natural flow for endangered species.

4. Significance of the feature to the authorized purposes for which the unit was created—As stated previously for Spring No. 1, this feature's use is primarily for maintaining an endangered wildlife species. The purposes for which Big Bend National Park was established include preservation of endangered species. (16 U.S.C. 156)

Feature: Hot Springs

Significance Criteria: 1. Size and Extent—Developed hot spring along the Rio Grande River.

Uniqueness—The spring supplies a bathhouse that is used by park visitors.

2. Scientific and geologic significance—The Hot Springs is a site contributing to Regional studies being conducted to monitor temperature and flow as a measure of hydrologic changes.

3. The extent to which the feature remains in a natural, undisturbed condition—The spring has been altered by development of a bathhouse built in 1910. The walls of the bathhouse still remain.

4. Significance of the feature to the authorized purposes for which the unit was created—Hot Springs, historically and currently, serves as a therapeutic hot spring. The spring is the focal point of Hot Springs National Register Historic District and is used by the public for recreational purposes. Thus, its use is of significance to the purposes for which the unit was created. (16 U.S.C. 156)

Lassen Volcanic National Park

There are six areas within Lassen National Volcanic Park that contain surface manifestations of a single thermal system. As all of these areas are connected to a single thermal system, NPS proposes to list the Lassen thermal system as one significant feature. The following significance criteria have been analyzed for each feature listed and have been found to be applicable to every feature within the Lassen thermal system.

Feature: Lassen thermal System

Significance Criteria: 1. Size—10 to 70 square kilometers.

Extent—Bumpass Hell, Little Hot Springs Valley, Sulphur Works, Devils Kitchen, Boiling Springs Lake—Drakesbad Hot Springs, and Terminal Geyser are the six features comprising the Lassen thermal system. The system is a two-phase, vapor dominated system approximately 500–600 meters thick. Surficial expression varies from superheated fumaroles at Bumpass Hall to acid-sulfate springs and mudpots at Sulfur Works and Devils Kitchen.

2. Scientific and geologic significance—The Lassen thermal system constitutes the only known extensive vapor-dominated thermal system in the Cascade Range. Only one other vapor-dominated system of equal thermal energy is known in the Western United States (the Geysers in California).

3. The extent to which the feature remains in a natural, undisturbed condition—Except for one well sited at Terminal Geyser, the system has not been tapped by deep drilling activity and there has been no depletion of thermal energy. Surface features at Bumpass Hell, Sulphur Works, and Devils Kitchen have been only slightly altered by the installation of trails and boardwalks for the safety of visitors.

4. Significance of the feature to the authorized purposes for which the unit was created—Lassen Volcanic National Park was established in 1916 as a "public park and pleasuring ground for the benefit of the people of the United States" and to be managed "for the preservation from injury or spoilation of all timber, mineral deposits, and natural curiosities or wonders within said park and their retention in a natural condition".

The thermal features in the park represents an outstanding example of Cascade volcanism and the thermal system and its surface manifestations are a significant part of the continuing volcanic activity in the area. (16 U.S.C. 201)

Sequoia National Park

Both of the identified thermal features within Sequoia National Park are determined as marginally significant, mainly because the scientific and geologic, significance of these features are unknown at this time. These springs represent surface manifestations of active subsurface thermal activity and both remain in a natural condition. One spring is located in a heavily used area and the other in a lightly used area of the backcountry within the unit. Combined visitation frequency is not known. These features are considered as natural curiosities within the unit and as such must be retained in their natural condition. In spite of their unknown geologic or scientific significance, these features are proposed by the NPS as significant thermal features within Sequoia National Park.

Feature: Kern Hot Springs

Significance Criteria: 1. Size and Extent—Kern Hot Springs is an extremely small spring approximately 2 meters in diameter.

Uniqueness—Kern Hot Springs is the only spring in the park with temperatures over 100° Fahrenheit and its presence serves as an indicator of active subsurface thermal activity.

2. Scientific and geologic significance—Unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—Kern Hot Springs is in a heavily used area of the backcountry, and the spring itself appears to be in a natural condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Sequoia National Park was established by an Act of Congress in 1890 and has as its purposes, among others, to preserve "from injury of all . . . natural curiosities or wonders within said park". Also, subsequent Acts of Congress that expand the

boundaries of the park require the curiosities and wonders of the park to be retained in their natural condition. Although the scientific and geologic significance of this feature is unknown, Kern Hot Springs is considered a natural curiosity of the unit as it is the only spring in the park representing active subsurface thermal activity. (16 U.S.C. 41)

Feature: Whitney Warm Springs

Significance Criteria: 1. Size and Extent—This spring is approximately 10 meters in diameter.

Uniqueness—Whitney Warm Springs is the only spring in the park with temperature ranging in the mid-80° Fahrenheit and as such is an indicator of active subsurface thermal activity. It could have a biotic community dependent on the thermal characteristics of the feature that are different from other park waters.

2. Scientific and geologic significance—Unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—Whitney Warm Springs is in a lightly used area of the backcountry and the spring itself appears to be in a natural condition. The only intrusion is an occasional wader and several rocks have been arranged around the shore of the springs.

4. Significance of the feature to the authorized purposes for which the unit was created—Sequoia National Park was created by an Act of Congress in 1890 and its purposes, among others, are to preserve "from injury of all . . . natural curiosities or wonders within said park". Also, subsequent Acts of Congress that expand the boundaries of the park require the curiosities or wonders of the park to be retained in their natural condition. Even though the scientific and geologic significance of this thermal feature is unknown, Whitney Warm Springs is considered a natural curiosity of the unit as it is the only spring in the park with temperatures in the mid-80° Fahrenheit range that could support biotic communities. Until more information is available on the significance of this feature, it is proposed for listing as a significant thermal feature within Sequoia National Park. (16 U.S.C. 41)

Hawaii Volcanoes National Park

The NPS proposes to list the following ten (10) thermal features as significant within the Hawaii Volcanoes National Park. Significance criteria #4 requires analysis of the significance of the feature to the authorized purposes for which the unit was created. Hawaii Volcanoes National Park was established as part of Hawaii National Park in 1916 and later redesignated as Hawaii Volcanoes National Park in 1961. The enabling legislation for this unit states that the purpose of the unit is to "provide for the preservation from injury of all . . . natural curiosities and wonders within said park, and their retention in their natural condition as nearly as possible". As the identified features within Hawaii Volcanoes National Park are unique natural thermal features of known scientific and geologic significance to the region, NPS has determined that each feature is a natural wonder of the unit. Many of the identified features are named as features for which the unit was created and as such are significant thermal features for this unit (16 U.S.C. 391). Criteria #4 is fully met and is applicable to each listed feature within the park.

Feature: Kilauea Caldera and Halemaumau

Significance Criteria: 1. Size and Extent—3 square miles (3 miles long by 1 mile wide).

Uniqueness—Kilauea Caldera and Halemaumau is the world's most active volcano.

2. Scientific and geologic significance—As the world's most active volcano, this feature offers extensive opportunites for scientific and geologic investigations of the active thermal activity manifested in steaming ground.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Chain of Craters

Significance Criteria: 1. Size and Extent—Approximately 12 square miles (12 miles long by 1 mile wide).

Uniqueness—This chain of craters is a very active thermal zone.

2. Scientific and geologic significance—This feature is an active intrusive zone with many collapse caldera features or pit craters and steaming ground.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: East Rift Zone

Significance Criteria: 1. Size and Extent—Approximately 20 square miles (13 miles long by 1.5 miles wide).

Uniqueness—The East Rift Zone is the world's most active volcanic rift zone and exhibits steaming ground.

2. Scientific and geologic significance—This feature is the world's most active volcanic rift zone and as such offers opportunities for scientific and geologic investigation.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Great Crack and Southwest Rift

Significance Criteria: 1. Size and Extent—Approximately 10 square miles (20 miles long by ½ mile wide).

Uniqueness—Major fault area of Kilauea is an artifact and indicator of active thermal activity.

2. Scientific and geologic significance—This feature is the major fault structural feature of Kilauea, which is an indicator of active thermal activity and offers opportunities for scientific and geologic investigation.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Thurston Lava Tube

Significance Criteria: 1. Size and Extent—½ mile long by 100 yards wide.

Uniqueness—Volcanic lava tube which is an easily accessible artifact of volcanic activity.

2. Scientific and geologic significance—This feature is one of the few accessible lava tubes formed by a volcano and is the site of a popular visitor trail. This feature, because of its accessibility offers opportunities for investigation of its volcanic history.

3. The extent to which the feature remains in a natural, undisturbed condition—The area is the site of a developed visitor trail; however, these trails have not altered the integrity of the active thermal activity which characterizes the unit and the region.

Feature: Steaming Bluff and Sulphur Banks

Significance Criteria: 1. Size and Extent—Approximately 2 square miles (two miles long by one mile wide).

Uniqueness—Active steaming fumaroles.

2. Scientific and geologic significance—This feature is the site where the active steaming fumaroles may easily be viewed.

3. The extent to which the feature remains in a natural, undisturbed condition—The area is the site of developed visitor trails; however, these trails have not altered the integrity of the thermal feature.

Feature: Kilauea Iki Crater

Significance Criteria: 1. Size and Extent—1 mile long by ½ mile wide.

Uniqueness—Cooling lava pond.

2. Scientific and geologic significance—This feature is the site of current lava pond cooling rate studies.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Puu Oo

Significance Criteria: 1. Size and Extent—2 square miles (2 miles long by 1 mile wide).

Uniqueness—Continuously active volcanic vent.

2. Scientific and geologic significance—This area is under study for activity of a continuously active volcanic vent and its resultant magmatic activity.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Mauna Ulu

Significance Criteria: 1. Size and Extent—4 square miles (two miles long by two miles wide). Uniqueness—Continuously active volcanic vent.

2. Scientific and geologic significance—Major active volcanic feature formed recently in the 1970's.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Feature: Mokuaweoweo Caldera

Significance Criteria: 1. Size and Extent—4 square miles (4 miles long by 1 mile wide).

Uniqueness—This feature is the major caldera of Mauno Loa.

2. Scientific and geologic significance—This feature is the site of significant caldera studies.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural, undisturbed condition.

Haleakala National Park

Feature: Haleakala Crater

Significance Criteria: 1. Size—17,130 acres.

Extent—Haleakala Crater and adjacent outer slopes around the summit of the crater.

Uniqueness—Haleakala Crater is between 5,000 and 6,000 feet deep and is part of the Hawaiian "hotspot". The summit of the crater and a great many sites within are considered to be sacred by Native Hawaiians and contains many sites of archeological value, including royal burial sites.

2. Scientific and geologic significance—The entire Haleakala Crater (2½ miles by 7½ miles) is one large thermal feature containing many smaller thermal features. The crater is a huge erosional scar carved out of the heart of the volcano by water which has been subsequently refilled by half with new lava flows and topped off with numerous multi-colored cinder cones. The crater and its adjacent areas have been the site of volcanic and geologic studies.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is in a natural condition except for very few roads, trails, and buildings provided to serve the public. These developments have not altered the integrity of the thermal feature.

4. Significance of the feature to the authorized purposes for which the unit was created—The legislative history supporting the Act of August 10, 1916, which created the Haleakala National Park as an isolated extension of Hawaii Volcanoes National Park, emphasizes that the craters within the proposed boundaries are among the most remarkable of natural wonders and among the largest and most spectacular in the world. Scientifically and popularly, these volcanoes are a national rather than a local asset and Congress recognized that legislation was necessary to protect these and other curiosities that were being damaged at the time the legislation was being considered. The purposes of Haleakala National Park are, among others, to preserve the area's volcanoes and other wonders and curiosities for public enjoyment and scientific study. (16 U.S.C. 396b)

Lake Mead National Recreation Area

Feature: Black Canyon Hotsprings

Significance Criteria: 1. Size—Five (5) hotsprings have their source in a four-mile stretch of the river.

Extent—Three of the five springs flow from the Nevada side, the other two springs flow from the Arizona side of the river.

Uniqueness—The temperatures of the springs have been recorded as high as 124° Fahrenheit. Two of the five hot springs discharge a volume of water sufficient to maintain a flow on the surface for approximately ¼ mile. The area is unique in that these springs are the only ones that flow water at the surface at temperatures higher than 100° Fahrenheit within the unit. Their presence serve as indicators of active thermal activity. Also, waters from one of the springs is used to support a refugium for the endangered Devils Hole Pupfish.

2. Scientific and geologic significance—The waters from one of the springs serve as habitat for an endangered fish species. Much of the geology in this area is volcanic in origin from the bottom of side canyons to the Colorado River. Also, Black Canyon has been identified by the NPS in its General Management Plan for the unit as an outstanding natural feature for its geologic beauty and the existence of the unique hot springs.

3. The extent to which the feature remains in a natural, undisturbed condition—The areas surrounding the springs have minor alterations and impacts from recreational use; however, the springs themselves remain in a natural condition.

4. Significance of the feature to the authorized purposes for which the unit was created—Lake Mead National Recreation Area was established for the primary purpose of preserving and enhancing public recreation opportunities within the unit. These springs are used extensively by hikers and boaters on a regular basis for recreational and therapeutic purposes. Pools are created by stacking rocks and sand allowing visitors to immerse themselves in the pools. Public visits to the Black Canyon Hotsprings are estimated at 7,000 annually. Also, protection of endangered species is consistent with the authorized purposes for which the unit was established. (16 U.S.C. 460n)

The remaining two of the three identified features within Lake Mead National Recreation Area are connected to the same regional flow system, but otherwise their geologic significance are not known at this time. In spite of their unknown geologic significance, the NPS proposes to list the Blue Point Spring and the Rogers Spring as significant thermal features because of their value to the public for recreational purposes. The primary purpose of Lake Mead National Recreation Area is to provide for and enhance public recreational opportunities within its boundaries. As these springs are used extensively by the public as "spas" and as the value of their use is dependent on the thermal qualities of the springs, these features are proposed as significant thermal features within Lake Mead National Recreation Area.

Feature: Blue Point Spring

Significance Criteria: 1. Size—Approximately 0.3 mile long.

Extent—Small spring located in the Nevada portion of the NRA at the junction of two faults near Mississippian limestone.

Uniqueness—The discharge rate is approximately 400 gallons per minute with temperatures at the spring source measuring around 85° Fahrenheit. The presence of these warm springs are indicators of a subsurface thermal regime.

2. Scientific and Geologic Significance—This spring, at one time, was being considered as a refugium for the endangered *Moapa coriacez.* Upon investigation of the chemical properties of the waters, it was found that, although the Spring is in the same regional flow system as Moapa River headwaters springs (where the endangered species occur naturally), the ionic constituents of the waters of the spring make the area unsuitable as a refugium. The waters discharging at the spring are part of a regional flow system and represent a combination of deep and shallow water circulation in the recharge area where moisture availability is rated as intermediate. The bedrock is relatively permeable. Even though the area has been the site of scientific interest and study, the geologic significance of the area is unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—The channels have been altered for commercial and recreational uses.

4. Significance of the feature to the authorized purposes for which the unit was created—Lake Mead, formed by Hoover Dam and Lake Mohave, and by Davis Dam on the Colorado River comprise this first national recreation area established by an Act of Congress in 1964. The enabling legislation states that the NRA "shall be administered . . . for general purposes of public recreation, benefit, and use, and in a manner that will preserve, develop, and enhance . . . the recreational potential, and in a manner that will preserve the scenic, historic, scientific, and other important features of the area". Blue Point Spring is a part of the regional flow system that serves as a major recreation facility used extensively by the public, with recorded visits to Blue Point Spring and Rogers Spring (listed below) estimated at 5,000 annually. As this feature is of major recreational value to the unit, the NPS proposes this feature as a significant thermal feature within the NRA. (16 U.S.C. 460n)

Feature: Rogers Spring

Significance Criteria: 1. Size—Approximately 0.75 miles long.

Extent—Rogers Spring is located in the Nevada portion of the NRA at the junction of two faults near Mississippian limestone at an elevation of 1580 feet and is in the same general vicinity as Blue Point Springs.

Uniqueness—The discharge rate is approximately three second feet and temperature at the source is measured at 87° Fahrenheit. The presence of the warm springs is an indicator of active subsurface thermal activity.

2. Scientific and geologic significance—Waters discharging at Rogers Spring are part of the same regional flow system as those of Blue Point Spring. The discharge goes directly into a man-made pond that is used by the recreating public as a swimming area. The geologic significance of the area is unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—The channels of Rogers Spring have been altered over the years for either commercial purposes or recreational enhancement. Picknicking facilities have been developed adjacent to the spring for recreational use. Neither the discharge point nor underground system of the springs have been altered.

4. Significance of the feature to the authorized purposes for which the unit was created—As stated above for Blue Point Springs, Lake Mead National Recreation Area was established for the expressed purpose of preserving and enhancing public recreation opportunities within the unit. Public visits to both Rogers Spring and Blue Point Spring is estimated at 5,000 annually, with the heaviest public use centering around Rogers Spring. NPS recognizes the recreational significance of Rogers Spring and proposes its listing as a significant thermal features within the unit. (16 U.S.C. 460n)

Specified Units Within the National Park System With No Significant Thermal Features

The NPS has identified no known thermal features within the following three units of the National Park System located in Alaska:

Yukon-Charley Rivers National Preserve;

Glacier Bay National Park and Preserve; and,

Denali National Park and Preserve.

Thus, determinations of "significance" are not applicable and the three units listed above are not proposed for inclusion on the final list of significant thermal features to be forwarded to Congress in April 1987.

Thermal features were identified within the boundaries of the following three units of the National Park System; however, none of the features identified have been determined as "significant" by the NPS under the criteria of the Act. Thus, the features listed below are not proposed for inclusion on the final list of significant thermal features to be forwarded to Congress in April 1987.

Olympic National Park

Feature: Olympic Hot Springs

Significance Criteria: 1. Size—Approximately two (2) acres.

Extent—These springs consist of twenty-one (21) seeps along Boulder Creek.

Uniqueness—Olympic Hot Springs are unique because hot springs are rarely found on the Olympic Peninsula.

2. Scientific and geologic significance—Olympic Hot Springs has no apparent relationship with the area's volcanic history and has not been identified as significant in terms of the peninsula's geology. The mineral content of the waters varies little with that of surface waters and the scientific significance of the area is unknown.

3. The extent to which the feature remains in a natural, undisturbed condition—The Olympic Hot Springs have been extensively altered to accommodate commercial operations and many have been formed into pools that have been used for bathing. The impounded water frequently fails to meet water quality standards. The resort around these springs no longer exist. None of the seeps exist in a natural state.

4. Significance of the feature to the authorized purposes for which the unit was created—Olympic National Park was established in 1938 as a public park for the benefit and enjoyment of the people of the United States. The Olympic Hot Springs do not attract extensive visitor use and are not considered a major public recreational resource within the unit. Also, as these springs were not used as rationale for establishing the unit and are not used today by the public for recreation, these springs are not considered as a significant thermal feature within the unit. (16 U.S.C. 251)

John D. Rockefeller, Jr. Memorial Parkway

Feature: Huckleberry Hotsprings

Significance Criteria: 1. Size and Extent—This feature consists of several springs located one mile west of Flagg Ranch.

Uniqueness—This feature is not unique and is in fact relatively commonplace for the area.

2. Scientific and geologic Significance—The combined flow of this feature is estimated at 350,000 gallons per day with temperatures over 100

°Fahrenheit. The waters from these springs are slightly radioactive and have not been identified as having any scientific or geologic significance.

3. The extent to which the feature remains in a natural, undisturbed condition—These springs have been highly altered and were developed into a public swimming pool facility in the early 1960's. The facility was abandoned in 1984. Extensive rehabilitation is planned for the area to restore it to more natural conditions. However, alterations to the thermal feature may not be reparable.

4. Significance of the feature to the authorized purposes for which the unit was created—This identified feature was not used as rationale for the establishment of the unit and is not recognized as a significant thermal feature within the unit.

Grand Teton National Park

Feature: Steamboat Mountain Fumarole

Significance Criteria: 1. Size and Extent—This fumarole is a small thermal vent near the summit of Steamboat Mountain.

Uniqueness—This feature is not unique because the activity of the fumarole has been declining for many years. Thermal characteristics are perceptable only in winter months.

2. Scientific and Geologic Significance—The Steamboat Mountain Fumarole has such little remaining activity that it can be considered essentially extinct and has little to no significance at this time.

3. The extent to which the feature remains in a natural, undisturbed condition—The feature is relatively unmodified but is almost extinct.

4. Significance of the feature to the authorized purposes for which the unit was created—Grand Teton National Park was established by Congress in 1929 with the expressed purpose of setting apart the lands within the boundaries "as a public park or pleasure ground for the benefit and enjoyment of the people of the United States". These springs have not been the site of recreation by the public and do not exhibit any unique characteristics related to the authorized purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Jackson Lake Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a series of springs along the northwest shoreline of Jackson Lake.

Uniqueness—Used to be completely inundated by Jackson Lake and not considered unique.

2. Scientific and geologic significance—This feature used to be completely submerged by the enlargement of Jackson Lake in 1910, but are now above water due to the temporary restriction of the lake level. This area has not been identified as an area of scientific or geologic interest; however, there is very little information available on these springs.

3. The extent to which the feature remains in a natural, undisturbed condition—This feature has been altered and is often under water.

4. Significance of the feature to the authorized purposes for which the unit was created—These springs have not been used nor are they currently being used by the public and do not exhibit any unique characteristics related to the purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Kelly Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a large spring located one mile north of Kelly, Wyoming.

Uniqueness—None.

2. Scientific and geologic significance—Kelly Springs has been highly modified to increase its flow for irrigation and stock watering. Its current flow is estimated between five and seven million gallons per day with temperatures measured at 75 °Fahrenheit. Both temperature and water chemistry data suggest this spring may be associated with the same geologic structures as Teton Valley Ranch Warmsprings and Abercrombie Warmsprings identified below. This spring contains dense populations of native and exotic fish but has not been identified as having scientific or geologic significance to the region.

3. The extent to which the feature remains in a natural, undisturbed condition—This thermal feature has been extensively modified for irrigation, stock watering, and public recreation.

4. Significance of the feature to the authorized purposes for which the unit was created—These springs have been highly modified for recreation and for domestic sources of water and were not used as rationale for establishing the unit. These springs do not exhibit any unique characteristics related to the purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Teton Valley Ranch Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a group of small springs located north of the Gros Ventre River, which is east of Kelly, Wyoming.

Uniqueness—Relatively small and commonplace.

2. Scientific and geologic significance—These springs create a marshy area on the floodplain which is heavily grazed by livestock. No flow or water quality data are available from these springs. These springs have not been identified as having any scientific or geologic significance.

3. The extent to which the feature remains in a natural, undisturbed condition—This feature may have been modified by past irrigation development.

4. Significance of the feature to the authorized purposes for which the unit was created—This feature is not used for recreation and was not used as rationale for the establishment of the unit. These springs do not exhibit any unique characteristics related to the purposes for which the unit was created. (16 U.S.C. 406d)

Feature: Abercrombie Warmsprings

Significance Criteria: 1. Size and Extent—This feature is a relatively small spring located near the south boundary of the unit.

Uniqueness—This feature is considered commonplace, rather than unique.

2. Scientific and geologic significance—This feature was developed as a swimming pool in the 1940's and has since been removed. The spring's flow is estimated at 60,000 gallons per day with temperatures measured at 75 °Fahrenheit. In 1986, the area has been partially rehabilitated. The area has no scientific or geologic significance to the region.

3. The extent to which the feature remains in a natural, undisturbed condition—The area has been highly modified with former development and subsequent partial rehabilitation.

4. Significance of the feature to the authorized purposes for which the unit was created—This feature is not used for public recreation and was not used as rationale for the establishment of the unit. (16 U.S.C. 406d).

Dated: February 9, 1987.

Signed:

William P. Horn,

Assistant Secretary for Fish and Wildlife and Parks.

[FR Doc. 87-3064 Filed 2-12-87; 8:45 am]

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United States Department of the Interior

GEOLOGICAL SURVEY

Branch of Igneous and Geothermal Processes
345 Middlefield Road, Menlo Park, California 94025

05 March 1987

M E M O R A N D U M

To: Participants in the Geothermal Resources Council Meeting on Crater Lake

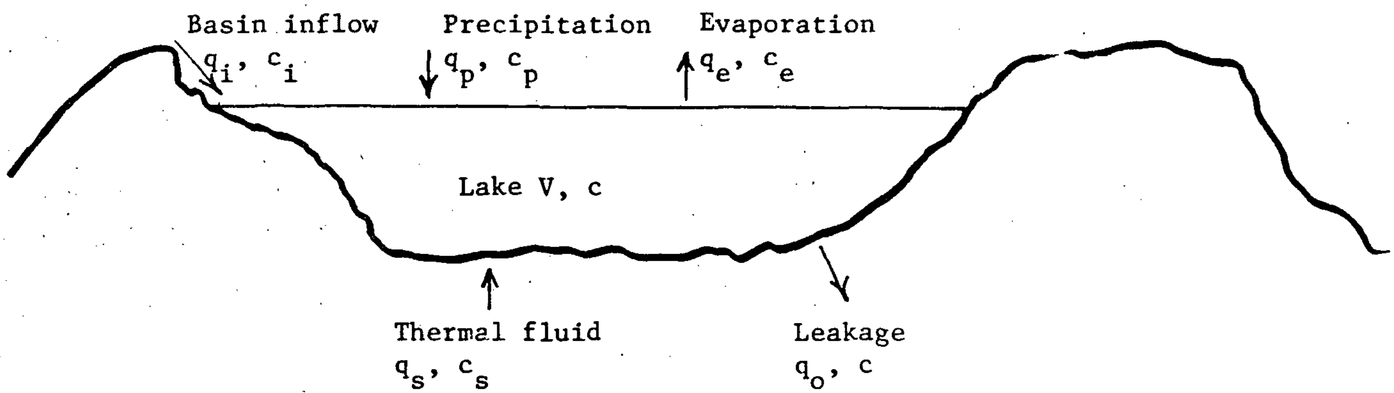
From: Manuel Nathenson *Manuel Nathenson*

Subject: Calculations on the time evolution of chloride

At the meeting, there was considerable discussion of my calculation of the evolution of chloride with time if there were no longer any input of higher-chloride (thermal) water into Crater Lake after some time. Because this calculation has not been presented previously, it was difficult for people to evaluate the assumptions and methodology in an oral presentation. There really is not time for me to write a formal discussion of this work before the public comment period for the list of thermal features has passed. In order to make the work more widely available, however, I have decided to distribute copies of the slides that concern this calculation to the participants. If you need to discuss the work further, please feel free to call me at (415)323-8111 X-4196.

One point that was raised at the meeting is whether all of the chloride data were on the slide or not. I plotted only the literature data and the surface sample for 1981 obtained by Michael Thompson. I have enclosed a new figure that has all of his data for 1981 and 1983 and some of the data for 1984 samples (surface and deep samples). Chloride values of 7 mg/L and 8 mg/L were mentioned at the Portland meeting as being measured by Thompson. I was not aware of any such values in working with his basic data sheets. In reviewing materials that had been presented at poster sessions, Thompson and I found that a table used in his 1985 presentation at the American Geophysical Union contained several errors. The table of names and chloride concentrations that was posted (but not given in the abstract) contained the data for sulfate rather than chloride for Crater Lake, and some of the values for cold springs were listed for the wrong springs. Unfortunately, these incorrect numbers were copied down by those attending the AGU meeting. Mike and I regret the confusion that this may have caused.

I did some further research on chloride data for Crater Lake and found that the Water Resources Division of the USGS has measured chloride on a large number of samples over the last 21 years. I have included a plot with their data and the same theoretical curve (assuming $q_s c_s = 0$ starting in 1912) as shown in the top figure on the last page.

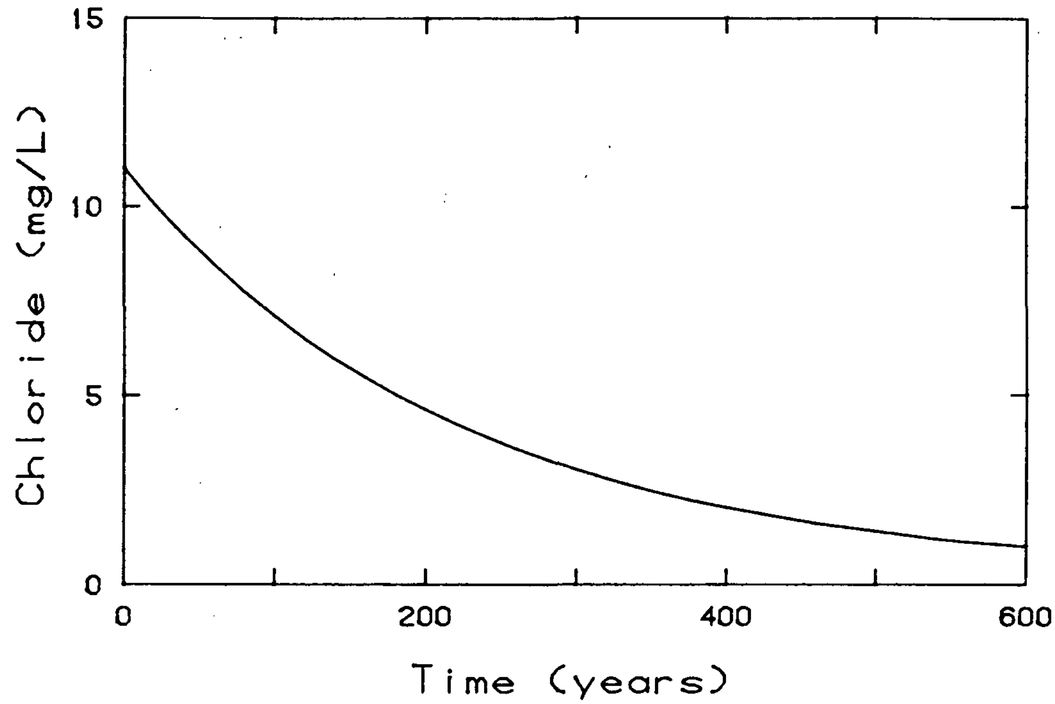


<u>**Evolution of chloride assuming that the lake is well mixed**</u>

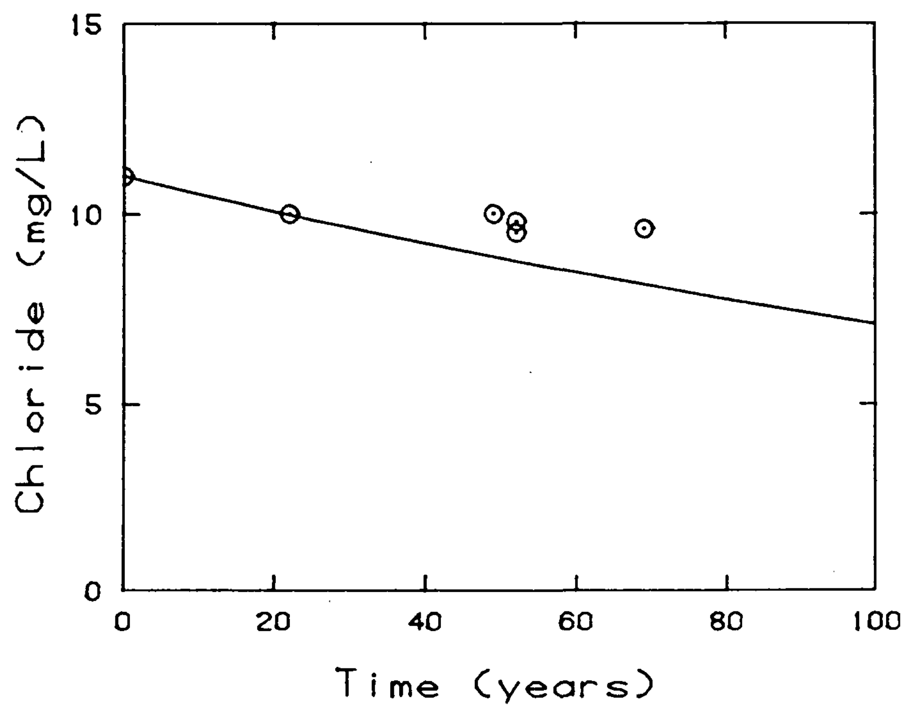
$$V \frac{dc}{dt} = (q_i + q_p)\, c_p + q_s\, c_s - q_o\, c$$

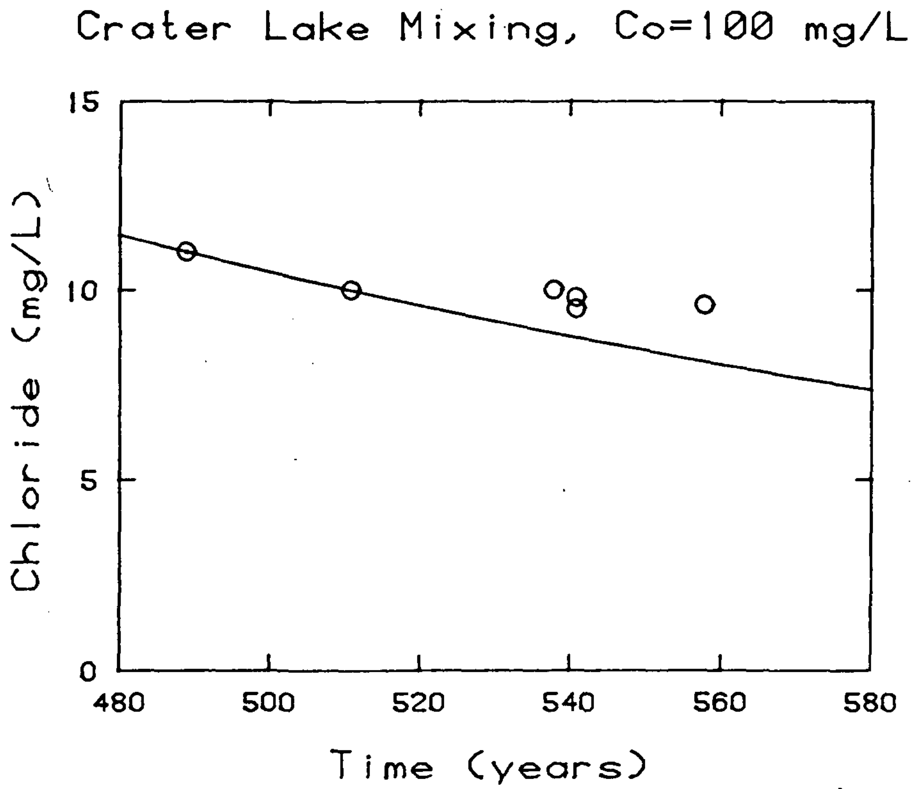
$$\frac{q_o\, c - (q_i + q_p)\, c_p - q_s\, c_s}{q_o\, C_o - (q_i + q_p)\, c_p - q_s\, c_s} = e^{\frac{-q_o t}{V}}$$

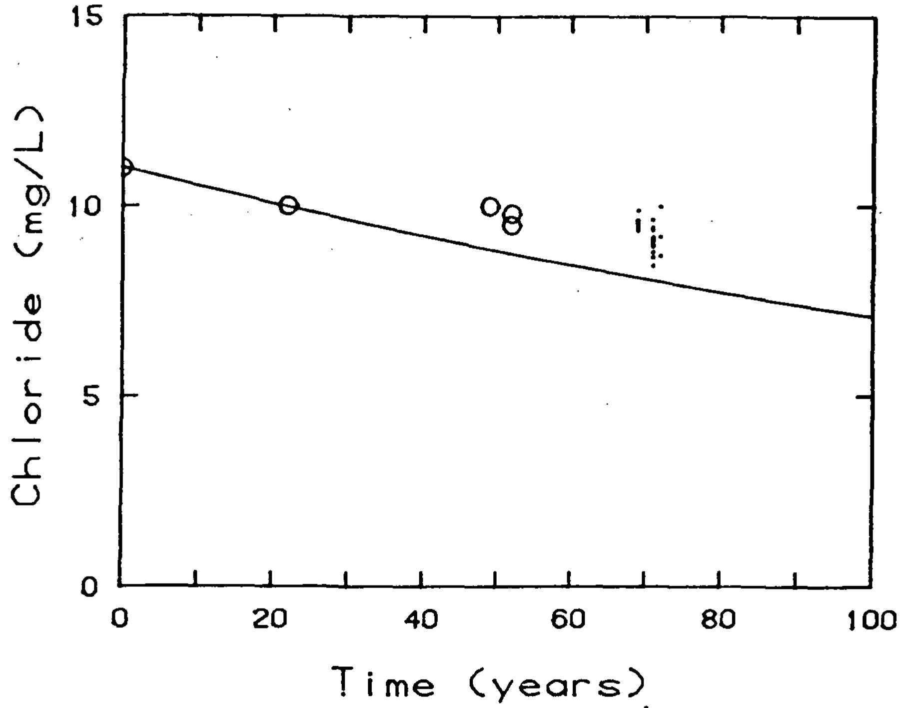
check



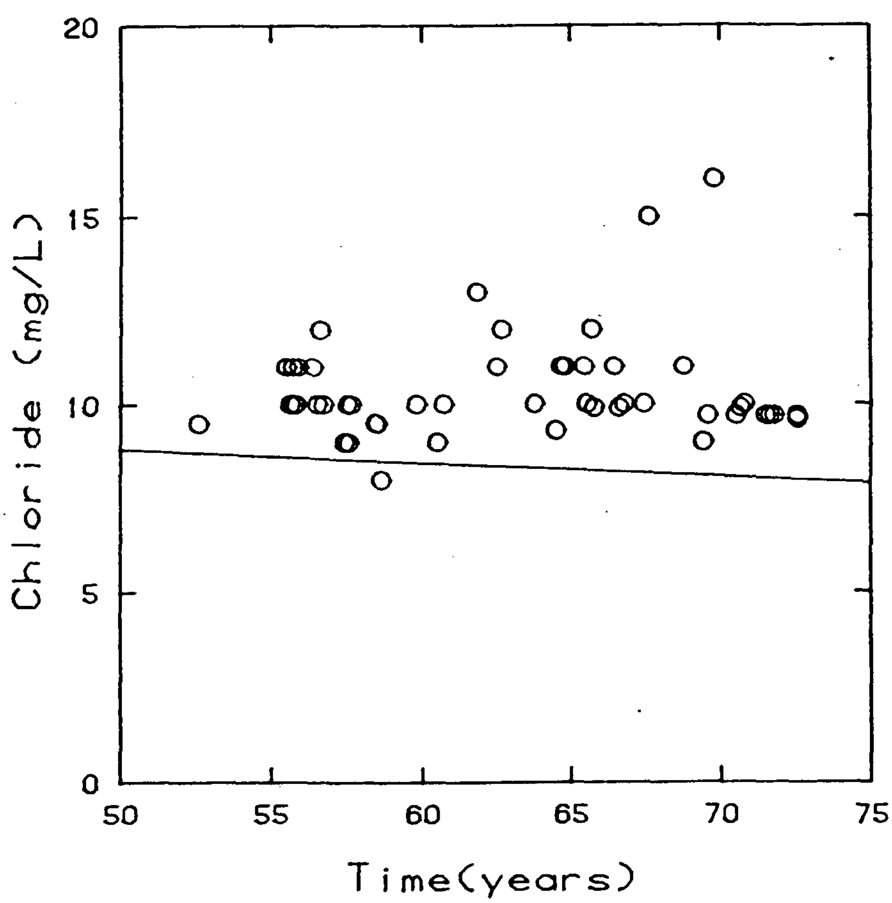
Crater Lake Mixing




Crater Lake Mixing, Co=100 mg/L
Chloride (mg/L)
15
10
5
0
480
500
520
540
560
580
Time (years)



Water Resources Data



$$V \frac{dc}{dt} = a - q_o c \qquad a = (q_i + q_p) C_p + q_s C_s$$

$$V\,dc = (a - q_o c)\,dt$$

$$\int_0^t dt = V \int_{c_o}^{c} \frac{dc}{a - q_o c} = \frac{-V}{q_o} \ln(a - q_o c) \Big|_{c_o}^{c}$$

$$t = \frac{-V}{q_o} \left[\ln(a - q_o c) - \ln(a - q_o c_o) \right]$$

$$\frac{-q_o t}{V} = \ln(a - q_o c - \ln(a - q_o c_o)$$

$$= \ln \frac{a - q_o c}{a - q_o c_o}$$

$$\frac{a - q_o c}{a - q_o c_o} = e^{-\frac{q_o t}{V}}$$

$$\frac{(q_i + q_p) C_p + q_s C_s - q_o C}{(q_i + q_p) C_p + q_s C_s - q_o C_o} = e^{-\frac{q_o t}{V}}$$

$$\frac{q_o C - [(q_i + q_p) C_p + q_s C_s]}{q_o C_o - [(q_i + q_p) C_p + q_s C_s]} = e^{-q_o t/V}$$

Taken from paper submitted for the 1987 GRC Annual Meeting, Sparks, NV, October 11-14, 1987.

An Analysis of the Hydrologic Effects of Proposed Test Drilling in the Winema National Forest Near Crater Lake, Oregon

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Abstract

The paper describes the results of a preliminary study on the hydrologic regime underlying the Crater Lake Caldera, Oregon. The study was performed to provide a basis for evaluating the potential for polluting Crater Lake by drilling exploratory boreholes on the flanks of the mountain. A simple conceptual model of the hydrologic regime was developed by synthesizing the data from the region surrounding the Caldera. Based on the conceptual model, a series of numerical simulations aimed at establishing the basic groundwater flow patterns under and surrounding the lake were performed. In addition to the numerical simulations, we used simple volumetric techniques for estimating the distance that drilling mud would migrate away from the borehole if drilling proceeded without drilling fluid returns.

Based on our calculations that show the regional flow of groundwater will oppose the flow of drilling mud toward the lake, and based on our volumetric estimate of drilling mud migration, our study concludes that drilling without returns will not pollute Crater Lake, nor will it affect the hydrologic regime in the immediate vicinity of the Crater Lake Caldera.

CONCLUSIONS

1. Two major driving forces are able to establish the fundamental nature of the ground-water flow beneath the Crater Lake caldera. These forces are the hydraulic head imposed by the water level in Crater Lake and the high pressures generated at large depths beneath the lake by high-temperature rocks. Both of these forces tend to move ground-water radially outward under the flanks of the mountain. Each would operate in the way shown by this study independently of the other, although the vertical extent of mass flow from either is highly dependent on the vertical permeability.

2. Temperatures at depths of 2.5 km or more beneath the lake are probably high in view of the volcanic history of Mt. Mazama, which includes an eruption as recently as 4000 years B.P., and by analogy to Newberry Volcano, a Cascade Range volcano of similar size, characteristics, and eruptive history.

3. On the basis of temperatures measured in the lake and the hydrologic evidence provided by the models, the hydraulic head in the lake appears to be the dominant hydrologic force in the shallow (less than 1.5 km depth) ground-water regime. In the areas of concern for this report, the directions and magnitudes of ground-water flow are determined largely by the potential differences (hydraulic head differences) between the lake and the local base levels of the Klamath Marsh to the east and the upper Klamath Lake valley to the south of Crater Lake. Simply put, the uppermost ground water body is principally controlled by gravitational forces that cause it to flow from high elevations to lower elevations.

4. The general direction of ground-water movement under the flanks of the mountain is not sensitive to assumptions of permeability and anisotropy in the models, although the magnitudes of flow and the details of flow directions are sensitive to these factors. The principal flow directions could not be reversed by the presence of rocks that differed from those modeled or by the existence of major structural features that were not modeled. The reason is simply the dominating effect of high-altitude recharge of water from precipitation and snow melt and the consequent seepage from the lake.

5. The fundamental nature of the flow system appears to be well established by the models, and it is clear that natural hydraulic forces in the flow system will oppose the flow of drilling fluids toward the lake at any point in the proposed drilling areas. Nevertheless, the analysis of impacts from the injection of drilling fluid does not depend only on the presence of radial outward ground-water flow. Calculations of volume displacement show that drilling fluid could not reach Crater Lake from proposed drilling sites even in the most extreme and unlikely cases considered.

6. In view of the ground-water flow directions determined by the modeling, which would oppose the flow of drilling fluid toward the lake, and in view of calculations that show the volume of injected fluid to be too small to reach the lake by simple volume displacement, we conclude that the loss-of-circulation while drilling does not pose a threat to Crater Lake or in any way affect the hydrologic system in the immediate vicinity of the Crater Lake caldera.

Sunrise, Mt. McKinley Ansel Adams

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BY CERTIFIED MAIL

September 11, 1987

United States Department of the Interior
Board of Land Appeals
4015 Wilson Boulevard
Arlington, Virginia 22203

Re: IBLA No. 87-735

Gentlemen:

Enclosed you will find Appellants' Statement of Reasons in this matter.

Very truly yours,

Victor M. Sher/dm

Victor M. Sher

VMS/dm

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To Mike Wright

Date ____________ From

VICTOR M._SHER
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Attorneys for Appellants

In Re Appeal of

Sierra Club, Inc., et al. | IBLA No. 87-735

APPELLANTS' STATEMENT OF REASONS

Sierra Club,Inc. (Sierra Club), Oregon Natural Resources Council (ONRC), and National Parks and Conservation Association (NPCA) (collectively, "appellants") submit this Statement of Reasons in support of their appeal of the decision dated July 1, 1987 to permit continued temperature gradient drilling in the Winema National Forest by California Energy Corporation, Inc. (CEC) without addressing potential impacts of the drilling project -- and proposed modifications to the project -- in an Environmental Impact Statement (EIS). By their decision, the responsible federal agencies (the Bureau of Land Management and the Forest Service) (collectively, BLM) approved CEC's modification of its drilling regimen to permit drilling without circulation, and to a depth increased from 4,000 to 5,500 feet. As explained below, the central issue raised by this appeal is the continued complete failure of the responsible federal agencies_ to address the risks of potentially disastrous consequences of the drilling.

I. PARTIES TO THE APPEAL

Sierra Club, Inc. (Sierra Club) is a non-profit corporation organized in 1892 under the laws of the State of California, with its principal place of business in San Francisco, California and other offices located throughout the nation. The Sierra Club is a national conservation organization with over 390,000 members. The stated corporate purposes of the Sierra Club include:

> ... to explore, enjoy and protect the wild places of the earth; to practice and promote the responsible use of the earth's ecosystems and resources; to educate and enlist humanity to protect and restore the quality of the natural and human environment; and to use all lawful means to carry out these objectives.

Members of the Sierra Club live, work and recreate throughout the United States, including in Oregon. Club members visit and use for a variety of purposes the public lands of the Winema National Forest and Crater Lake National Park. The Sierra Club and its members have a direct and profound interest in the proper management of the public lands in the United States, in protecting the natural resources of those lands, and in ensuring that applicable environmental laws are enforced and obeyed by public agencies.

Oregon Natural Resources Council (ONRC) is a nonprofit association of more than 90 local and statewide conservation, sportsmen, educational, business and outdoor recreational organizations, as well as over 2,500 individual members. ONRC coordinates public involvement in Oregon's natural resource management issues at the administrative, legal and legislative levels. The Council provides information and assistance to its members and other citizens concerned about the use of Oregon's lands, waters and natural resources.

The National Parks and Conservation Association (NPCA) is an independent conservation group established in 1919. NPCA is dedicated to the protection and preservation of the country's magnificent national parks. NPCA has approximately 55,000 members nationwide, who regularly visit and use for a variety of recreational, aesthetic, and other purposes the national parks and other public lands throughout the United States. NPCA regularly and actively participates in public decisionmaking with implications for public lands, including by public education and testimony before legislative bodies. As just one example, NPCA has testified before Congress recently concerning the Geothermal Steam Act Amendments, H.R. 2794, specifically addressing the potential impacts of geothermal development on national parks, including Crater Lake National Park.

II. FACTUAL SUMMARY

CEC currently holds geothermal leases on approximately 76,515 acres of federal land in the Winema National Forest. In 1984, CEC applied to the Oregon State Office of the Bureau of Land Management (which administers the subsurface resources related to geothermal leases) for permission to drill up to 24 temperature gradient holes on the leases. BLM prepared an Environmental Assessment (EA) on the proposed drilling, and ultimately approved a Finding of No Significant Impact (FONSI) for a modified project proposal that contemplated a plan of exploration for four (4) holes. Two holes have approved permits, and have been partially drilled.

Appellants' concern lies with BLM's failure to disclose and analyze potential risks that inhere in geothermal drilling in a unique and largely unknown environment, and so close to Crater Lake. Some of the drill sites are as close as 2,000 feet from the Park's east boundary. The consequences of errors in understanding potential adverse impacts -- even if the risks of such unintended consequences are remote -- could be disastrous for an irreplaceable ecological treasure.

As the National Park Service has said:

> Our primary concern about the proposed project is potential impacts on the main resource of Crater Lake National Park -- Crater Lake itself.

The unique ecological character of Crater Lake and the hydrothermal systems that surround it are well recognized,[1] but

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[1] The National Park Service recently summarized Crater Lake National Park as "a unique and beautiful national treasure. The aesthetic value of the lake and the surrounding lands are priceless to the park visitor experience. The park is world renown [sic] as a scientific field research laboratory for oceanographic, limnological and most recently geothermal processes."

It cannot be seriously disputed that Crater Lake is unique. As the Park Service stated, "The only other lake in the world known to have geothermal hot spring input with a depth comparable to Crater Lake is Lake Tanganyika in Tanzania, Africa. According to Dymond, Crater Lake's geothermal manifestations are unique because of their location in a lake of the size and depth of Crater Lake. It is among the highest (6,179 ft ASL), largest (48 sq km) and the deepest (589 m) caldera lake in the world."

poorly understood. Crater Lake National Park was established in 1902 as "an area ... set apart forever as a public park or pleasure ground for the benefit of the people of the United States." In 1974, 122,000 acres of the park were recommended for official wilderness designation. In 1979 Crater Lake was recommended as a scientific benchmark for limnological research. In 1982, Crater Lake National Park was identified as a potential International Biosphere Reserve. In September of 1982, PL 97-250 instructed the Secretary of Interior to "... immediately implement such actions as may be necessary to assure the retention of the Lake's pristine water quality." As Oregon's only national park and the destination of over 500,000 national and international visitors annually,the significance of Crater Lake National Park on a world scale cannot be overstated and potential impacts on the park, its resources and visitors must be considered. (See Comment Letter #1, National Park Service, 1984 EA.)

including preservation from oil slicks caused by submersibles

Crater Lake is such an important national ecological treasure, that if there is any risk to the hydrothermal system that supports it all such risks should at a minimum be fully and carefully analyzed and explored before a decision to proceed with the project is made. BLM's vice in this case is its acknowledgement that such risks exist, but its complete failure even to attempt to delineate their nature and scope.

There is no evidence for this

1. The 84 EA.

The following aspects of the 1984 EA and FONSI are particularly significant with respect to the instant appeal:

First, the 1984 EA failed entirely to address the potentially catastrophic effects of an uncontrolled blowout from one or more of the proposed drilling. Indeed, BLM specifically took the position that consideration of a blowout was "beyond the reach of NEPA". (Geothermal Exploration Briefing Paper.)

Second, the 1984 EA also failed to address the potential for water flowing within a hole between aquifers with different pressure heads, and the possibility of subsurface interzonal migration of fluids that could affect aquifers and nearby lakes and streams. However, the monitoring plan approved for the drilling specifically required monitoring of mud pit levels (used for circulation in the drilling), and provided that if drilling problems such as lost circulation were encountered, the lessee will be required to seal the zone of fluid inflow or fluid loss.

Third, in 1984 the National Park Service expressed concern about potential impacts on Crater Lake, pointing out that the temperature gradient holes drilled to 4000 feet would be 2,000 to 4,000 feet below the lake bottom, and expressing fear that the drilling of these holes could affect the geothermal input to the lake and therefore the limnological processes of the lake. (Comments on Environmental Assessment, comment 1.) In allaying this concern, BLM pointed out that the minimum depth to the top of the geothermal aquifer underlying Crater Lake was likely 5,000 to 6,500 feet below the bottom of the lake: "This places the bottom of the wells at least 1,000 feet above the top of the geothermal aquifer." (Response to Comments, Appendix C at 1.)

2. The 1987 Project Modification.

In 1987, CEC requested two major modifications to the parameters of its drilling. First, CEC requested permission to drill to a maximum depth of 5,500 feet. Second, CEC requested permission to drill even where the drilling loses circulation.

The decision to modify the project and to continue the exploratory drilling was highly controversial, and for good reason. Oregon newspapers ran several editorials, all of which opposed continued drilling because of fears regarding possible impacts on Crater Lake. The EA failed entirely even to mention this controversy. (Copies of a number of these editorials are attached as Exhibit A.)

Comments on the 1987 draft EA raised questions concerning the impacts of these proposed modifications on risks of blowouts and interzonal migrations of fluids. BLM failed completely to address either of these concerns.

For example, the Sierra Club commented that

> "A loss of circulation could increase the risk of blowout. Would this lead to fluid interchange between permeable formations? Would the blowout be stopped at the wellhead only to reach the surface with noise and effluent problems at another weak spot?"

While BLM's response admitted that a blowout could lead to a "temporary fluid interchange between permeable formations," and that surfacing of subsurface fluids at some location other than the wellhead "is possible", BLM neglected entirely to address the issue of risk, increased or otherwise, resulting from drilling without circulation.

The seriousness of this concern is demonstrated by the comment of John K. Dean, attached hereto as Exhibit B. Mr. Dean was a petroleum engineer for 15 years, and was "either responsible for or participated in the decisionmaking process on, literally, hundreds of wells". He states flatly that BLM's decision to allow wells to be drilled with total or even partial lost circulation "seems very strange and also very risky.... The fluids that circulate are very important in preventing blowouts and in allowing the drill pipe to [be] moved up and down the hole."[2]

Nor can BLM properly contend that risks of unintended but uncontrolled consequences of the drilling do not exist or are minimal. BLM itself acknowledges that blowouts and interzonal migrations of fluids are "possible,", but minimizes the likelihood of their occurrence. In addition, BLM artificially

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[2] The importance of maintaining circulation rests on a variety of reasons. First, mud returns remove cuttings from the drill hole, thus allowing drilling to proceed.

Second, analysis of returns tells the geologist where he is, what formation he's drilling through. This is important from a drilling engineering and geologist's viewpoint. The various casing strings must be below problem formations, so the driller needs good drilling cutting analysis to keep track of formations that have been passed.

Most importantly, drilling muds keep the drill hole full of fluid, providing pressure that controls geothermal formation fluids, helping to prevent blowouts. See generally, L. Capuano, "How Geysers Steam Wells Are Drilled And Equipped," World Oil (Feb. 1979) at 69-70; A. Woodyard, "Determining Blowout Risks for Producing Wells", World Oil (April 1981) at 87-90; S. Sherwood, Business Insurance (February 22, 1982), at 3 et seq.

reduces the range of possible consequences by assuming that any blowout or interzonal contamination would be quickly controlled. But blowouts at the Geyser fields in Northern California have been blowing out -- uncontrolled -- for two decades. BLM provides no reasonable assurances that temperature gradient wells cannot blow out; indeed, to the contrary, BLM states that there are "no guarantees" that such events will not occur. See, e.g., Briefing Paper on 1984 EA "Drilling Concerns".

The implications of such a blowout in the vicinity of Crater Lake are not difficult to envision. First, a blowout of any substantial duration would create substantial noise, dust, odors, and other disturbances. At the surface, such blowouts could result in degradation of the area's air quality, violating the federal Clean Air Act. BLM, however, never even mentions such a possibility.

Even more alarming, the Coordinator of the USGS Geothermal Research Program has recognized the possibility that pressure reduction in the hydrothermal system that feeds Crater Lake is entirely possible:

> Given that a geothermal system is found in the Winema National Forest and that such a system is shown to be part of the same hydrothermal system that supplies Crater Lake with its thermal water, the production of geothermal fluids could affect the flow of thermal water into Crater Lake. ... [T]he nearest drill hole would be four miles from the lake and the farthest twelve miles. Assuming that the thermal water going into Crater Lake comes from a hydrothermal system that has a reservoir that is continuous with one found under the Winema National Forest, propagating a pressure reduction over a distance of four miles is quite easy to do. In such a worst-case scenario, the flow of thermal water into Crater Lake would be

affected.

(See Exhibit C at 5.)

likewise there is no certainty that OSU will not create an oil slick

Finally, several comments, including those of the National Park Service, indicated that lake contamination is a distinct possibility. While the BLM has provided a computer simulation indicating the likelihood of such contamination is extremely low, the fact remains that, as BLM admits, the natures of the geo- and hydrothermal systems underlying Crater Lake and the Winema National Forest remains largely unknown, and it cannot be said with certainty that contamination could not occur.

Finally, concerns about possible impacts on Crater Lake's hydrothermal system are heightened by the confirmation this summer -- after preparation of the EA and BLM's adoption of the FONSI -- that hydrothermal vents exist in the lake bottom. BLM, however, has never addressed this significant new information, nor indicated how, if at all, it might affect its analysis of the hazards posed by the proposed drilling activity.

no exaggeration here

Any of the potential consequence of CEC's temperature gradient drilling would obviously represent an ecological disaster of immense magnitude. Yet BLM has neither provided assurances that they cannot occur, nor provided a basis for reasoned decisionmaking that takes the risks of such disasters into account.

III. VIOLATIONS OF OBLIGATIONS IMPOSED BY LAW

A. National Environmental Policy Act

1. Failure to Analyze Risks

BLM is required to comply with the National Environmental Policy Act (NEPA), 42 U.S.C. § 4332(2)(C) in approving geothermal lease activities such as the one at issue in this case. See, e.g., Idaho Natural Resources Legal Foundation, Inc., 96 IBLA19, 23 (1987). Unless a project is categorically exempt, which this one is not claimed to be, an EA must be prepared. 40 C.F.R. § 1501.4(b). Such an assessment must take a hard look at the issues, as opposed to setting forth bald conclusions, identify the relevant areas of environmental concern, and make a convincing case that environmental impact is insignificant if its conclusion that an EIS is not required is to be upheld. Id; Glacier-Two Medicine Alliance, 88 IBLA 133, 141 (1985); Sierra Club, 57 IBLA 79, 83 (1981). If a salient aspect of a program or project has not been assessed, and that aspect is within the Board's jurisdiction, it may not be implemented until an adequate analysis of all relevant factors has been prepared. SOCATS (On Reconsideration), 72 IBLA 9 (1983).

In this case, BLM has candidly admitted that it did not even attempt to analyze the risks associated with either a blowout or the potential for water flowing within a hole between aquifers with different pressure heads. In its briefing paper on the 1984 EA, BLM stated:

> Two drilling uncertainties are associated with any drilling alternative: the potential for water flowing

> within a hole between aquifers with different pressure heads; and the potential for a blowout (uncontrolled emissions of fluids and/or gases from a well).
>
> There are no guarantees that either event would not occur ....
>
> With respect to the uncertainty of a blowout, the EA did not discuss in detail the risks associated with such an event. A blowout would be considered an accident, and the U.S. Supreme Court has determined that "a risk of an accident is not an effect on the physical environment," and is therefore beyond the reach of NEPA (Metropolitan Edison v. People Against Nuclear Energy et al., no. 81-2399, decision of April 19, 1983).

This position represents a significant error of law. CEQ regulations generally require federal agencies to analyze in an EIS all "reasonably foreseeable" significant impacts on the environment; these include all actions that "will <u>or may</u> have an effect on [the environment]." 40 C.F.R. section 1508.3. In addition, 40 C.F.R. section 1502.22, adopted in 1986, specifically provides that "reasonably foreseeable includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason." With respect to such catastrophic consequences, the agency shall always make clear that it lacks complete information, and either must obtain the information or include within the EIS

> (1) A statement that such information is incomplete or unavailable; (2) a statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment; (3) a summary of existing credible scientific evidence which is relevant to

> evaluating the reasonably foreseeable *significant* adverse impacts on the human environment, and (4) the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community.

Nor does any conceivable interpretation of case law, including the Supreme Court decision cited by the BLM for the proposition that it need not address these impacts, in any way support BLM's position. Indeed, in Metropolitan Edison Co. v. People Against Nuclear Energy, 75 L.Ed.2d 534 (1983), the Supreme Court merely held that the psychological harm of an accident need not be considered an environmental effect under NEPA unless connected to an impact on the physical environment. In contrast to BLM's erroneous characterization of the case, the Supreme Court indicated that environmental risks are environmental effects that fall within NEPA. Other cases make this rule even clearer. See, e.g., City of New York v. United States Dept. of Transportation, 715 F.2d 732)2d Cir. 1983), cert. denied, 79 L. Ed.2d 730 (1984) (requiring risk analysis of possibility of accident while transporting radioactive materials through urban centers).[3]

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[3] See also, Save Our Ten Acres v. Kreger, 472 F.2d 463, 467 (5th Cir. 1973), in which the court stated:

> [W]here substantial questions are raised as to whether a project will have significant adverse impacts it is hardly reasonable for an agency to conclude, prior to study, that an EIS is not required. Accordingly, an EIS must be prepared whenever a project "may cause a significant degradation of some human environmental factor."

Accord, Minnesota Public Interest Research Group v. Butz, 498 F.2d 1314 (8th Cir. 1974). (An initial decision not to prepare

2. Failure to Address Public Controversy

In defining "significantly" for purposes of determining whether potential environmental impacts warrant preparation of an EIS, CEQ has provided that federal agencies must consider "The degree to which the effects on the quality of the human environment are likely to be highly controversial." 40 C.F.R. section 1508.27(b)(10); see, e.g., Foundation for North American Wild Sheep v. USDA, 681 F.2d 1172 (9th Cir. 1982). As the newspaper articles in Exhibit __ make clear, concern over any potential impact on Crater Lake is highly controversial. This controversy warrants preparation of an EIS.

3. Failure to Address Site Specific Concerns.

It is well-established that NEPA requires a hard look at the site-specific impacts of proposed federal actions. In this case, some of the proposed drill sites are located right next to the National Park boundaries, while others are located farther away. Yet BLM has never discussed the site-specific impacts of CEC's proposed drilling; rather, the EAs merely provide a generic

---

an EIS precludes the full consideration directed by Congress. In view of the concern for environmental disclosure present in NEPA, the agency's discretion as to whether an impact statement is required is properly exercised only within narrow bounds. Action which could have a significant effect on the environment should be covered by an impact statement.) SCRAP v. United States, 346 F.Supp. 189, 200-201 (D.D.C. 1972) (J. Skelly Wright, J., for three-judge court) ("it should be obvious that the NEPA requirements cannot be circumvented by so transparent a ruse [as a simple assertion that an agency's action would have no significant impact]. The main purpose of an impact statement is to force assessment of the environmental impact of the proposed action. Therefore, a statement is required whenever the action arguably will have an adverse environmental impact.")

discussion for all 24 potential drill sites. Because BLM has not indicated which sites will receive the remaining two drill holes, it is impossible to determine potential impacts. These include (for example), down valley groundwater contamination. In addition, while the EAs assert the drilling sites are all "pre-disturbed", the truth is that any prior disturbance rests entirely on the surface. Yet the drilling will be in (previously) undisturbed subsurface areas.

be very careful - God forbid we drill any exploratory wells anywhere into undisturbed subsurface.

4. Failure to address new information.

CEQ regulations require that new information be addressed in supplemental EISs. Although there has been significant new information concerning the existence of significant thermal features in Crater Lake, BLM has failed to address this information.

B. Violations of Public Law 99-591

Section 115 of P.L. 99-591 (1986) requires the Secretary of the Interior to prepare and transmit to Congress a list of significant thermal features within specified units of the National Park System. Section 115 also provides that until such a list is submitted to Congress, DOI "shall not issue any geothermal lease pursuant to the Geothermal Steam Act of 1970 (Public Law 91-581, 84 Stat. 1566) ... until such time as the Secretary has transmitted the list to the Committees of Congress ....."

In addition, Public Law 97-250, September 1982, directs the Secretary of the Interior "... to immediately implement such actions as may be <u>necessary to assure</u> the retention of the lake's natural pristine water quality."

On June 30, 1987, Secretary of the Interior Donald Hodel transmitted a report to Congress announcing the lifting of the general moratorium on new geothermal leases imposed by Public Law 99-591. However, with respect to potential geothermal features of Crater Lake, the Secretary reserved possible inclusion on the list until further studies are completed in the Fall 1987. The Secretary stated flatly:

"No geothermal leases will be issued for lands surrounding Crater Lake National Park until such time as a determination has been made and forwarded to [Congress]."

The next day, however, BLM announced approval of the lease <u>modifications</u> at issue in this appeal, on land immediately adjoining Crater Lake National Park. As explained above, the modification permits the lessor, California Energy Corporation, to increase the depth of its drilling by 1/3, and removes a significant lease condition -- that "circulation" be maintained. Public Law 99 581 is meaningless unless the term "geothermal leases" includes, along with entirely new leases, materially new leasing decisions. Because it constitutes just such a new leasing decision, this action violates PL 99-581 and, especially in light of DOI's representation to Congress, is arbitrary and capricious.

IV. CONCLUSION

For all the above reasons, BLM's FONSI should be set aside, and the responsible agencies should be directed to prepare an EIS concerning the proposed project.

DATED: September 11, 1987

Respectfully submitted,

Victor M. Sher/Dm

Victor M. Sher
Todd D. True
Attorneys for Appellants

EXHIBIT A

Viewpoints

Editorials

Don't take any chances with Crater Lake purity

Don't drill if there's any significant chance it could endanger Crater Lake's purity.

That should be the long and the short of it. The benefit of the doubt should go to the lake. Its water quality is nothing to take chances with.

Opponents of exploratory drilling for geothermal sources shouldn't have to prove drilling's a threat; rather, the drillers, California Energy Co., should have to prove that it's safe. Inability to do so should mean permanent shutdown.

In any serious conflict over the drilling's impact, give the benefit of the doubt to the lake.

Cal-Energy has been drilling near Mount Scott, just outside the park's eastern boundary, on Winema National Forest land. The operation currently is shut down, pending resolution of an appeal over the procedures used.

National Park Service personnel and others have expressed concern drilling might have an impact on Crater Lake's water quality. There have been indications that, over time, the lake's remarkably clear, blue waters have become more cloudy, though that apparently started before the Cal-Energy operation.

Last week, scientists sent a small, remotely operated camera vehicle on a dive in the 1,932-foot-deep lake and found a hot spring at the 1,500-foot level.

That reinforces the possibility that it or other geothermal springs might connect with geothermal aquifers outside the park which could cause deterioration of the water quality if involved with a geothermal heat project.

Joe LaFleur, Cal-Energy geologist, said vents could be recirculating lake water, but he doesn't believe there could be a connection outside.

That may be true, but let's not forget Crater Lake is a national treasure, a one-of-a-kind geologic masterpiece.

When the tests are done and the study completed, if there's any significant disagreement among scientists about the potential hazard to the lake, drilling should be permanently ended. It's that simple.

Scientific insensitivity

A couple of recent news reports are the kinds of items that give science a bad name.

In one case, a plant expert at Montana State University said he deliberately ignored federal regulations he thought were "almost ludicrous" and released genetically altered bacteria into the environment.

In another instance, a U.S. Geological Survey scientist was quoted as saying that the best way to determine the effects of hydrothermal development on Crater Lake would be to "produce a well" and see what it does to the lake.

Both instances show an insensitivity to a growing and valid public concern about scientific research: that a new Frankenstein's monster — even one the size of an altered gene — might be unleashed by a researcher not paying enough attention to the potentially harmful effects of an experiment. Science has gotten too deadly — too potentially destructive — to tolerate a cavalier attitude of let's just do it and see what happens.

Of the two cases, the action of Gary Strobel, a professor of plant pathology at Montana State University, is the more alarming. Strobel injected genetically altered bacteria into 14 elm trees as part of an experiment to fight Dutch elm disease. Strobel, who is well-known in his field, said gaining the necessary federal approval would have delayed his experiment by a year.

That kind of arrogance is likely to do more harm than good to scientists who feel federal regulations on release of genetically altered organisms into the environment are too restrictive and need to be eased. If scientists cannot be relied on to follow existing regulations, can they be trusted to anticipate adequately the range of potential results from their experiments — to evaluate the worst-case result?

Potentially not. That's why a system of peer review and regulatory agency approval is needed to ensure that a researcher's zeal does not cause the release of organisms that could proliferate and end up killing the wrong things. Efforts to develop biological controls are replete with examples of unintended side effects doing more harm than good. Killer bees are an example of research gone bad.

Many scientists are concerned that U.S. regulations in this area are unnecessarily cumbersome. The U.S. Department of Agriculture is developing guidelines for research under its jurisdiction. The guidelines shouldn't be more restrictive than necessary, but if Strobel's actions are any guide, public pressure where there is dispute should be for the department to err on the side of conservatism.

Crater Lake findings may be used to stop drilling

CRATER LAKE (AP) — Data collected in a e-day exploration of the bottom of Crater ke may be used to stop geothermal drilling the region, according to a National Park rvice official.

Scientists using a remote-controlled underater camera to survey the lake bottom were wn off the extinct volcano's caldera Saturay, confident they had located vents that are arming the lake's deep, clear waters.

The park service believes there is a connecon between the drilling and hydrothermal nts apparently located on the lake floor, said James Milestone, natural resources specialist for Crater Lake National Park.

Milestone said park officials hoped to use last week's findings to stop drilling just outside the park by California Energy Co., of Santa Rosa, which is planning to market thermal-generated power.

"Within five years they could have geothermal power plants all over the place," Milestone said.

On Friday, the fifth and final day of the lake bottom survey, researchers encountered some equipment problems.

One of the researchers, an Oregon State University oceanography professor, Jack Dymond, said: "I'm convinced we have some venting (of hot gases). There's a region (of the lake bottom) that's strongly influenced by venting."

He said the vehicle used to scan the lake's bottom recorded what looked like vents, but another device used to record temperature changes malfunctioned.

Both the visual evidence and the recorded temperature changes were needed to prove the vents had been located, Dymond said. The technical problems have left researchers with some doubts.

"Without the temperature data, we can't be sure," he said.

Dymond and a colleague from the oceanography department at Oregon State, Robert Collier, plan to present their preliminary findings in January to a joint national meeting of the American Geo-Physical Union and the American Society of Limnology and Oceanography.

A partial report on the findings will be presented to the National Park Service in September.

Editorials

Crater Lake drilling

Scheme is an outrage

Tempting the forces of nature is dangerous. To do so with malice at Crater Lake is foolhardy and should not be condoned or tolerated by thinking people.

What we need now are thinking people.

The land snaps, crackles and pops, like a good breakfast cereal, throughout Oregon.

Nowhere is this power more evident than in the High Cascades, those pristine sentinels to the east that flank the Willamette Valley. Geologic forces more powerful than most of us thought possible until, perhaps, Mount St. Helens self-destructed in 1980, cook and gurgle and brew below the surface of the Pacific Northwest.

The result of this magnificent witch's brew makes our region special.

The Cascades are a marvelous example of nature's engineering. Geologists describe the area as a subduction zone, a spot where two of the many plates that form the earth's crust push and churn and thrash in constant movement. In the Pacific off our shoreline, one of these plates is pushed beneath another; the resulting force moves molten rock inland and then upward, creating a volcanic mountain range.

We know these mountains by name: Hood, Jefferson, Washington, Three Fingered Jack, the Sisters peaks, Bachelor, Scott. But the greatest of all, perhaps, was a mountain that modern scientists call Mazama: It is Crater Lake today.

More than 6,800 years ago — mere ticks of the geologic clock — Mazama shocked the earth, rocked, and then blew. The peak was estimated at more than 12,000 feet, higher and considerably thicker than Mount Hood. When it finished spewing its insides across the Northwest and into Canada, so much of the mountain had been pushed skyward that what remained of the peak simply crashed into itself, forming a great caldera.

So much of Mazama's core was expended, in fact, that the ash and rock from the blast, if collected and stacked, would make almost five Mount Jeffersons. Geologists have found Mazamian ash 18 inches thick in Alberta, Canada, and on the southern slope of Mount Rainier in Washington. At least five inches of ash blanketed all of Oregon, most of the Northwest, and much of the western Canadian provinces.

Rain and snowmelt accumulated in the ... increasing in depth through the centuries that followed. The lake today remains at a steady 1,932 feet — one of the deepest in the world.

A couple thousand years after Mazama erupted, another gasp from the ticking volcano that lurks below the lake's surface pushed up a cinder cone that we now call Wizard Island.

Mazama is by no means through; like all of the High Cascades, it is a live wire of volcanic activity. Right now, it is rumbling and gurgling and bubbling below the placid surface of Crater Lake. Right now, the geologic forces that caused the mountain to blow 6,840 years ago are at work. Right now, this active volcano is brewing some more geologic mischief.

Right now, other mischief is afoot in southern Oregon.

The California Energy Co. of Santa Rosa has obtained permits from the U.S. Bureau of Land Management to drill deep test holes outside the southeast corner of the National Park that is Crater Lake. Their intent is to tap into the geothermal energy that abounds within the area. There is a fast buck to be made, no doubt.

National Park Service officials are angry — rightfully so — arguing that no one can be certain whether the drilling might be harmful to Crater Lake, either by altering its geothermal features or by polluting the water.

Oregonians should be angry as well. In fact we should be outraged.

We should insist that all drilling stop near Crater Lake. We should insist that those who allowed the drilling to begin should be required to enter another line of work — one where common sense is at least optional. And we surely should insist that the California Energy Co. return immediately to California — or to some other such unfortunate place where people don't really care what happens around them.

We care here in Oregon — certainly enough to protect so valuable a wonder as Crater Lake.

Tempting the forces of nature is dangerous. To do so willingly — and foolishly — at Crater Lake is idiotic and should not be tolerated by thinking people.

Join the thinkers, please; and then ask a friend or neighbor to do the same.

EXHIBIT B

221 Sixth Street
Lake Oswego, OR 97034
27-05-87

Mr. Lee Coonce
Forest Supervisor
Winema National Forest
2819 Dahlia St.
Klamath Falls, OR 97601

Re: Your Supplement to EA OR-010-84-28, regarding geothermal drilling in the Winema National Forest.

Dear Mr. Coonce

I am a member of the Sierra Club and have been following the Geothermal drilling issue since 1984-85. Mr Fred Hirsh also a member of the Sierra Club, and our Chapter Geothermal Coordinator suggested I write to you directly regarding your decision to allow wells to be drilled with total or even partial lost circulation.

This decision seems very strange and also very risky. My work experience, prior to moving to Oregon, was as Petroleum Engineer. During some 15 years of petroleum engineering I was either responsible for or participated in the decision making process on, literally, hundreds of wells. I do not remember a case where we planed to drill a well without circulation. The fluids that circulate are very important in preventing blowouts and in allowing the drill pipe to moved up and down the hole.

I think you should give great thought to reconsidering this decision as an accident next to one of great national parks would be a tremendous disaster.

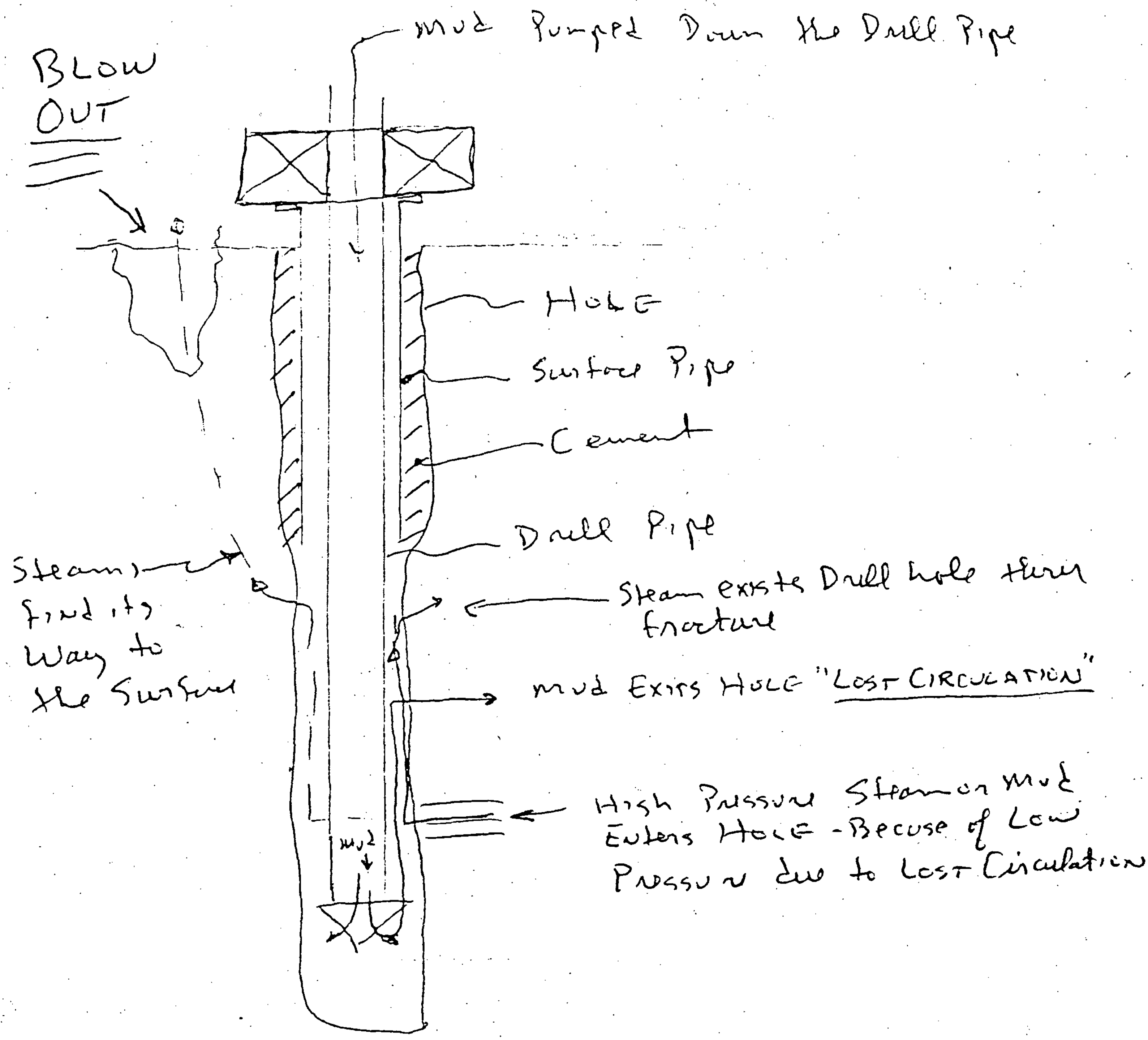
Sincerely yours,

John K. Dean

cc. Fred Hi8-05-87

TYPICAL LOST CIRCULATION

BLOW OUT



JKD
1.06.87

United States Department of the Interior

GEOLOGICAL SURVEY

Branch of Igneous and Geothermal Processes, MS-910
345 Middlefield Road, Menlo Park, California 94025

31 July 1986

AUG 1986 Received

Joseph G. LaFleur
Senior Geologist, Exploration
California Energy Company
3333 Mendocino Avenue
Santa Rosa, CA 95401

Dear Mr. LaFleur:

This letter is in response to your letter of 06 June 1986 raising questions concerning the scientific conclusions of personnel of the U.S. Geological Survey with regard to geothermal systems. Your letter specifically requests a USGS response to the 24 April 1986 statement of Destry Jarvis before the Senate Subcommittee on Natural Resources Development and Production. In addition, you raise a number of points about USGS investigations at Crater Lake, stating that many of the scientific conclusions of these investigations are speculation.

With regard to Mr. Jarvis' letter, I can comment on it only with regard to its accuracy in factual matters that fall within my expertise or experience.

- p. 2, l. 4-7: "Of the ten major geyser areas in the world, only three have been left undisturbed, including Yellowstone National Park. The other seven have either been severely, adversely affected or completely destroyed." True (White, 1979).
- p. 2, PP. 2, l. 1-5: "The most important determination to be made before the commencement of any geothermal development near any national park must be accurate and conclusive findings that <u>no</u> subterranean interconnection exist [sic] between the thermal features available for leasing and development outside park boundaries and those within the parks." This complex statement is Jarvis' opinion, not a statement of fact. If "accurate and conclusive findings" require a 100% guarantee, then geothermal development near a national park with thermal features is impossible. If "accurate and conclusive findings" are interpreted to mean something less rigorous, then geothermal development near a national park with thermal features might be possible. The U.S. Government has tussled with this question for many years; little consensus has been reached.
- p. 3, PP. 1, l. 1-2: "*** the advent extent, and subsidence of geothermal phenomenon is still a very ill-researched process." I do not understand this garbled sentence, and accordingly cannot comment.
- p. 3, PP. 1, l. 3-4: "Though hypotheses exist, too little work has been completed to date to predict with any accuracy the likely effects of nearby geothermal drilling." To some extent, true. Without some direct exploration by drilling of the thermal structure and the hydrologic properties of the specific sites in question, it is impossible to

predict with accuracy the likely effects of nearby geothermal drilling. Without drilling, one is restricted to inferences from geophysics, geochemistry, geology, and surface hydrology. In ideal situations (e.g., Lassen) one can make some reasonable predictions about the effect of development outside the park on the thermal features within the park. But in most other situations, the pertinent drilling data simply do not exist. Clearly a conundrum.

- p. 3, PP. 1, l. 4-6: "Even in Yellowstone National Park there is only a far from incomplete [sic] picture of the geothermal process." I think Jarvis means "far from complete." If so, I would debate his conclusion. Years of detailed study of the thermal features of Yellowstone has given us a good picture of the thermal processes there, but the picture is admittedly not complete (indeed, can it ever be?). The question boils down to how far from complete is acceptable for what purpose.
- p. 3, PP. 1, l. 6-10: "Within the past two weeks, for example, two brand new geysers have emerged in the Biscuit Basin area of the park, one with a 50 foot plume. These are the first new geysers to appear in Yellowstone since the major earthquake in 1959, when several of the park's thermal features were altered." Change is the rule in thermal areas. They evolve by a variety of natural means, one of which is the disruption of geyser conduits by earthquakes. I fail to see how Jarvis' statements are relevant.
- p. 3, PP. 3, l. 2-6: "One U.S.G.S. scientist has concluded, 'that natural discharge of water and heat is increased two-to-ten times by most exploitation programs (and), in general, we cannot exploit the geothermal energy of an area and also preserve its geysers.'" This summarizes a statement made by Donald E. White and is true (White, 1979).
- p. 3, PP. 4, l. 3 to p. 4, PP. 1, l. 4: "The Beowawe Geysers in Nevada (at one time second only to those of Yellowstone in North America) stopped flowing by 1961 after centuries of activity because wells were drilled nearby in the 1940s and 1950s and allowed to discharge. Steamboat Springs, Nevada has also suffered due to geothermal activity in the 1950s and 1960s." Mostly true. Wells were drilled at Beowawe in the late 1950s, not 1940s. The geysers stopped flowing in 1961 (White, 1979).
- p. 4, PP. 2, l. 7-10: "Two completed studies have not ruled out a potential structural <u>link</u> between the Yellowstone-Island Park Calderas; [and] have shown no evidence of structural <u>barriers</u> to fluid migration between the calderas ***." True, but on the other hand the studies have shown no evidence of a structural link and have not precluded the existence of barriers. How one interprets the studies depends on the conclusion one wishes to reach.
- p. 4, PP. 3, l. 4-8: "USGS studies still in progress, but reported in the Montana press have indicated evidence to support the belief that the water source for much of the Yellowstone geyser basins originates in the deep aquifers beneath the Gallatin National Forest." To some degree, this statement reflects lack of attention to important details in statements made to the press. Studies of oxygen isotopes do indicate that the Gallatin Range (which is only a part of the Gallatin National Forest) is likely to be the recharge area for waters that eventually

discharge in at least some of the geyser basins. No data in this study indicate that there are deep aquifers containing large volumes of recharge water.

- p. 7, PP. 2, l. 1-3: "The thermal features of Lassen Volcanic National Park in California could be seriously jeopardized as well including: Terminal geyser, Boiling Spring Lake, Devils Kitchen and Bumpass Hell." The U.S. Geological Survey has performed a study (Ingebritsen and Sorey, 1985) that shows how various scenarios of geothermal development south of Lassen Volcanic National Park might affect the fumaroles in the Park. Note, however, that the thermal features in Lassen Volcanic National Park do not include geysers. Terminal Geyser is a misnomer; it is not a geyser, but is steam-heated surface water.
- p. 8, PP. 1, l. 2-5: "At Crater Lake National Park, concern has been raised, since park research has indicated that one of the reasons why the lake is so clear and blue is that there is thermal input in the bottom of the lake, ***." The available data leave little doubt that there is thermal input in the bottom of the lake (see below). I know of no research or evidence that relates this thermal input to the clarity or color of the lake.

I now shall try to address some of the points you raised in your letter with respect to Crater Lake specifically (These comments are supplementary to the enclosed copy of a letter from the Director of the U.S. Geological Survey to William Leavell, State Director, Oregon State Office, Bureau of Land Management. The Director's policy statement for the USGS concerning potential impacts of phase 2 of California Energy's exploration program a very useful summary of many of the more important questions):

1. The scientific evidence for flow of thermal water into the floor of Crater Lake appears to be very strong. Williams and Von Herzen's (1983) study of heat flow in the sediments on the bottom of Crater Lake establishes unequivocally that there is an anomalous input of thermal energy into the lake. Based on an analogy to the work at oceanic spreading centers where similar anomalies have coincided with finding actual vents discharging hot spring water, they reasoned that Crater Lake must have vents discharging thermal fluid. This reasoning is strongly reinforced by (a) the thermal structure of the lake and (b) the chloride concentration in Crater Lake of 10 ppm. Comparing chloride concentrations of water found in other Cascade Lakes and in large-flow cold springs on the flanks of Mt. Mazama, it is unlikely that this concentration could be produced by leaching of material at low temperatures. The conclusion that there are vents discharging thermal fluid in Crater Lake appears rather strong to me; it certainly is far beyond mere speculation.

2. How much thermal water is coming into the Lake? Michael Sorey (1985) calculated that the flow is in the range 30 to 150 liter/sec. The basis for his calculation is two-fold. A chloride balance of the lake requires that the seepage loss from the lake containing an average concentration of 10 ppm chloride at a flow of 64,400 acre ft/yr (= 2500 liter/sec) be balanced by an inflow of thermal water at some unknown chloride concentration. This balance assumes that the lake is well

mixed and that the flows of water and chemicals are in approximate steady state. Based on data for other thermal waters in the Cascades, the input chloride concentration is likely to be in the range of 200 to 1000 ppm. This results in a flow of thermal water ranging from 125 to 25 liter/sec. The second calculation compares the estimates of convective heat flow into the lake to what flow of thermal water would be required to produce that heat flow. Williams and Von Herzen measured an average conductive heat flow per unit area of 3 HFU and estimated that the convective heat flow ranges from 13 to 30 HFU over the total area of the lake. Sorey used a more conservative range of 3 to 30 HFU for the convective heat flow. Balancing the convective heat flow of 3 to 30 HFU over the area of the lake against the energy in the flow of thermal water and assuming that the thermal water is at 80°C, results in a calculated range of 20 to 200 liter/sec. Other assumptions concerning the temperature of the thermal water are easily defended as long as they are reasonable. The point is that both analyses give similar numbers. No specific value can be defended, but the range seems reasonable.

3. The flow of thermal water affects the circulation pattern of the lake. As explained by Williams and Von Herzen (1983), the increasing temperatures below a depth of 295 m, the thermal anomalies found in water at great depth, and the fairly uniform chemical concentrations as a function of depth are not what one would expect in a deep lake such as this unless conditions are different from those normally found in deep lakes. The upper 200 to 300 m of the lake operate in the normal manner of spring heating causing stable stratification and fall cooling breaking up the stratification causing mixing in the upper layer. No evidence has been found that the lower portion of the lake turns over in the way found in many lakes, but the data support continuous convection caused by the input of heat into the lake. This turbulent convection is an efficient mechanism for distributing disolved chemicals and isotopes of water in the lake as found by Simpson (1970) and Salinas and others (1984).

4. Any connection between the color of Crater Lake and the input of thermal water is tenuous at best. The blue color of the lake is caused by light scattering in water with very low suspended particulate matter (e.g., Smith and others, 1973). Particulate matter can come into the lake either as suspended solids in streams or be generated in the lake as phytoplankton grow. Likely reasons for the low suspended solids are the large amount of inflow that arrives directly as precipitation rather than through streams, the low amount of nutrients available, and the cold temperatures in the surface waters for much of the year. Possibly, the circulation pattern developed by the input of thermal water enhances these factors, but no mechanism is obvious. Lake Tahoe, which is unlikely to have any input of thermal water, has a color similar to Crater Lake. In summary, I see no connection whatsoever between the thermal water coming into Crater Lake and the clarity and color of the lake. However, my opinion should be taken in the context that I am a geologist, not a limnologist.

5. Given that a geothermal system is found in the Winema National Forest and that such a system is shown to be part of the same hydrothermal system that supplies Crater Lake with its thermal water, the production of geothermal fluids could affect the flow of thermal water into Crater Lake. You point out that the nearest drill hole would be four miles from the lake and the farthest twelve miles. Assuming that the thermal water going into Crater Lake comes from a hydrothermal system that has a reservoir that is continuous with one found under the Winema National Forest, propagating a pressure reduction over a distance of four miles is quite easy to do. In such a worst-case scenario, the flow of thermal water into Crater Lake would be affected. But it seems to me that the thermal water flowing into the lake is irrelevant to the clarity and color of the lake. Furthermore, it represents only a small fraction of the total water input to the lake, most of which is from precipitation.

6. The possibility that the geothermal system at Klamath Falls may be partly supplied by hot water from either Crater Lake or Medicine Lake Volcano. This idea that the geothermal system at Klamath Falls may be partly supplied by hot water from Medicine Lake was presented in an abstract by Julie Donnelly-Nolan (1983). It is based on an analysis of structural trends at Medicine Lake Volcano and indeed was presented as speculation. Because it appears in an abstract, it is lot more visible than it will be if the idea is presented in a subsequent publication. It is likely to be a small part in the conclusion section of a long report and will be in a better context than its appearance as one sentence out of about 12 in the abstract. I cannot find any published statement by a member of the USGS stating that the geothermal system at Klamath Falls is supplied by water from Crater Lake.

I conclude that input of thermal water into Crater Lake has been established by accepted means of heat-flow measurement, the data and analysis are published in a definitive paper in a prestigious peer-reviewed scientific journal, and the conclusion is far stronger than mere speculation. Furthermore, two methods of calculation give consistent ranges for the amount of hot water that is coming into the bottom of the lake. In contrast, however, the connection between the color of Crater Lake and the input of thermal water appears to be tenuous at best. Even if production of geothermal resources outside of Crater Lake National Park reduced the input of thermal water into the lake, I cannot see how this could have a significant affect on the color and clarity of the lake. As you and I have discussed, anthropogenic material seems far more likely to affect the color and clarity of the lake.

Sincerely,

L. J. Patrick Muffler

L. J. Patrick Muffler
Coordinator, Geothermal Research Program

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CERTIFICATE OF SERVICE

I am a citizen of the United States and a resident of the District of Columbia. I am over 18 years of age and not a party to this action. My business address is 1531 P Street, N.W., Suite 200, Washington, D.C., 20005.

On September 11, 1987 I served a true copy of Appellants' Statement of Reasons on the person listed below by placing said copy in a sealed envelope with postage full prepaid, in a United States Postal Service mail box in Washington, D.C., addressed as follows:

Regional Solicitor
Pacific Northwest Region
U.S. Department of the Interior
Lloyd 500 Building, Suite 607
500 N.E. Multnomah Street
Portland, Oregon 97232

I, Dallas Motlagh, declare under penalty of perjury that the foregoing is true and correct.

Executed on this 11th day of September, 1987 at Washington, D.C..

Dallas Motlagh
Dallas Motlagh

Regional Solicitor in Portland with the reasons for their appeal. The appellants requested an extension for submittal of their documentation and transmitted their Statement of Reasons to the Department of the Interior Board of Land Appeals on September 11, 1987.

The Regional Solicitor in Portland, with the assistance of the Bureau of Land Management and the U. S. Forest Service, has prepared a draft of his response to the appeal and the Statement of Reasons and the draft is being reviewed by the Solicitor's Office in Washington. The Solicitor generally has about 30 days to respond to the appellant's reasons. However, he requested additional time.

CECI requested that they be allowed to intervene in this case and also that IBLA hold an evidentiary hearing. IBLA entered an order October 22 allowing CECI to intervene and will consider at a later time conducting an evidentiary hearing. The order also allowed the Solicitor thirty days from receipt of the order (until November 26) to complete his response to the appellant's reasons for the appeal. CECI will be allowed until about December 26 to file their evidence in the case.

These time extensions presumably will allow some time for the Department of Energy to enter the case, if they desire to do so.

Typically, the appellants file a response to the Solicitor's arguments. IBLA may request oral arguments or additional written statements if new information has become available between filing of the written briefs and ILBA making a decision. IBLA generally takes from twelve to eighteen months to render a decision. Hence, it is likely that drilling will not be possible during the 1988 field season even if IBLA renders a decision favorable to BLM and CECI. Sometimes the decision can be hastened if a Government agency makes a request for an expedited decision.

The BLM is currently preparing a decision on a request by CECI that operations on the effected leases be suspended pending the outcome of the appeal. The BLM will in all likelihood agree to the suspension, but has not decided the appropriate date to initiate the suspension.

r nomore hardcopy

To: M.REED (DOE4418)
To: P.WRIGHT (DOE4433)
Cc: J.RENNER (DOE4437)
From: J.RENNER (DOE4437) Delivered: Wed 28-Oct-87 15:32 EST Sys 164 (10
1)
Subject: chronology of CECI drilling decision appeal at IBLA
Mail Id: IPM-164-871028-139930239
Acknowledgment Sent

--More--

Following is a more or less un-editorialized chronology of the attempt of CECI to drill a thermal gradient with lost circulation and the ensuing appeal of the BLM decision to IBLA:

The U. S. Department of Energy entered into a cost-sharing agreement with California Energy Company, Inc. (CECI) during August, 1986 for the drilling of a thermal gradient hole near Crater Lake National Park. The hole is part of DOE's continuing research aimed at understanding the nature of the deep hydrothermal resource in the Cascades volcanic region of California, Oregon, and Washington. CECI is engaged in geothermal exploration south and east of Crater Lake National Park and agreed to allow DOE access, for research purposes, to a thermal gradient hole planned just to the east of the Park and about five miles from the nearest shore of Crater Lake.

During the Bureau of Land Management's (BLM) approval process for the proposed drilling of the cost-shared hole and other holes in CECI's drilling program near the National Park, a stipulation was attached to the drilling plan which required CECI to notify the BLM whenever circulation was lost during drilling. As is common when drilling in a volcanic environment, circulation was lost October 10, 1986 and could not be regained. The drilling rig was moved off location October 29, 1986 with the hole at 1354 feet, pending approval by the BLM of drilling ahead without circulation.

The BLM in conjunction with the U. S. Forest Service, surface manager at the hole location, decided that a supplemental environmental assessment was necessary before BLM could issue approval for drilling without return circulation. Because of DOE's interest in the results of the drillhole, DOE provided BLM with the assistance of reservoir modelling expertise at LBL in order to analyze the transport of drilling mud from the drillhole and to prepare a model of regional groundwater flow in the vicinity of the CECI drillhole. The results of the study were presented to the BLM for their use in preparation of the supplemental assessment and were also presented to the geothermal industry at the 1987 annual meeting of the Geothermal Resources Council (GRC). The calculations show that the regional flow of groundwater will oppose the flow of drilling mud toward the lake and that drilling without returns will not pollute Crater Lake, nor will it affect the hydrologic regime in the immediate vicinity of the Crater Lake Caldera. (A copy of the GRC paper is attached.)

The Bureau of Land Management received comments from seven groups on the supplemental environmental assessment. The most significant comments were submitted by various chapters of the Sierra Club, who are still concerned that lost circulation will have a negative effect on Crater Lake, despite further drilling with lost circulation be allowed this close to the lake since they consider the site unsuitable for development. The BLM responded to these comments and in early July issued the FONSI and decision record recommending that CECI be allowed to complete their Mt. Mazama thermal gradient hole without return circulation . The public was allowed to file appeals of that decision through July 31.

On July 31, Oregon Natural Resources Council, Sierra Club Legal Defense Fund, and National Parks and Conservation Association filed a joint appeal of the BLM decision to allow California Energy Co., Inc. (CECI) to continue drilling a thermal gradient hole near Crater Lake National Park. The appellants had 30 days from the date of appeal to provide the Department of Interior Board of Land Appeals (IBLA) and Interior's