Oregon Caves National Monument
Subsurface Management Plan – Environmental Assessment

National Park Service
U.S. Department of the Interior

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Environmental Assessment of Subsurface Management Plan

Summary

This document is an environmental assessment (EA) of Oregon Caves National Monument's draft subsurface management plan which is attached to this document as an appendix. The plan provides National Park Service (NPS) management with the necessary framework to guide subsurface management within the Monument for the next 15 years. The plan is intended to be a useful long-term decision-making tool, providing NPS managers with a logical and trackable rationale for decisions about the protection and public use of the Monument's subsurface resources.

Since the Monument's enabling legislation was intended primarily to protect a showcave called Oregon Caves (hereinafter referred as the Caves) and, by implication, about 6 other, much smaller caves within the Monument, it is imperative that an environmental assessment of the Monument's subsurface be done in order to determine whether a Finding of No Significant Impact (FONSI) or an Environmental Impact Statement (EIS) is warranted.

At the beginning of the planning process for this assessment, a series of federal manager and public scoping meetings were held and letters sent to interested parties to present the purpose and need for an environmental assessment of the Monument's subsurface plan, to present the purpose and significance of the Monument to the public, to outline Monument mission goals, and to present issues that will be addressed in the plan. Input was solicited from the public and other governmental agencies to discern if there were other issues that needed to be addressed in the plan which were not initially listed. Among the issues brought up during the public scoping process was the need for more studies of cave processes, the need for greater protection of cave processes and other cave resources, and the need for more experienced cave managers and interpreters.

In response to these issues, and cognizant of the mission goals established for the Monument, this subsurface management plan EA emphasizes the ratio of studies versus other subsurface management actions and subsurface management versus surface management projects and actions by providing five alternative approaches for the protection, public use, and management of Monument subsurface resources. The following alternatives were developed:

Alternative A is the "No Action Alternative." Alternative A would involve a continuation of existing conditions, including about an equal emphasis on subsurface management compared to the rest of resource management in the Monument but would only involve research and other actions that involve public tours on paved trails.

Alternative B constitutes the preferred alternative. Alternative B would increase the emphasis on subsurface management but would balance the emphasis on subsurface research and non-research actions.

Baseline and monitoring studies would continue to occur, such as new photos at photo-monitoring points, water and air quality sampling, and monitoring of changeable attributes of a room-by-room inventory.

Monitoring would also evaluate ongoing restoration and mitigation. Actions would include subsurface restoration and mitigation, training of park staff, inventory and monitoring based on the vital signs and park cluster concepts, and offering public tours that would vary in both time and distance covered both on and off the Caves' paved trail.

Cave restoration would include removing rubble, lint, tracked in dirt, non-historic infrastructure, and non-paved trails, installing tarps or cement ridges to trap human-caused particulates, controlling non-native species, repairing cave formations, installing emergency toilets, and altering entrances or passages so that their cross-sectional areas are similar to what existed prior to the historic discovery of the Caves. Alternative B is considered the environmentally preferred alternative.

Alternative C would decrease the emphasis on subsurface management. The emphasis would be on surface management and subsurface management would be about evenly split between research and non-research actions.

Alternative D would increase the emphasis on baseline and monitoring studies.

Alternative E would decrease the emphasis placed on baseline and monitoring studies. Major actions would include subsurface restoration, mitigation and prevention of human impacts.

These alternatives and the draft subsurface management plan are presented to the public in order to receive input in regards to the public's choice of alternatives, the addition of subject matter expertise, and in making both the subsurface management plan and this document more effective, factual, understandable, and transparent.

Actions common to all alternatives include implementation of previous relevant environmental assessments and environmental impact statements, protection of the Oregon Caves Historic District, ongoing consultation with both cavers and non-cavers with subject matter expertise, and regional cooperation on various issues such as fire management, surface edge and fragmentation effects, and the effects of tourism.

Acronyms and other abbreviations in this document are spelled out initially and include:

Caves………Monument's main cave and its only showcave
CFR………..Code of Federal Regulations
EIS…………Environmental Impact Statement

FCRPA….…Federal Cave Resources Protection Act
DOI………...Department of Interior

EIS………....Environmental Impact Statement
GMP……….General Management Plan

Monument….Oregon Caves National Monument
NHPA……...National Historic Preservation Act

NEPA……...National Environmental Preservation Act
NPS..………National Park Service

RMP……….Resource Management Plan
U.S.C………United States Code
USDA……..United States Department of Agriculture

Several text changes, corrections and additions were made throughout revisions of this document, including the Purpose and Need, Affected Environment, and Environmental Consequences chapters of the document, as a result of input from the public and government agencies. A summary chart of actions for each alternative is included in the document.

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CHAPTER 1 – PURPOSE AND NEED

1. 1 BACKGROUND

The Caves were discovered in 1874 by a Euro-American hunter. In 1907, four sections of land, encompassing approximately 2,560 acres were withdrawn from the operation of the public land laws of the United States, apparently for the purposes of establishing the Monument. Two years later, a 480 acre Monument was established by proclamation of President William H. Taft. The proclamation was intended primarily to protect the showcave on the Monument Oregon Caves (hereinafter referred as the Caves) and, by implication, about 6 other, much smaller caves within the Monument.

The U.S. Forest Service began the first guided cave tours at Oregon Caves in 1911. It was one of the first uses of federal interpreters in what would later become a NPS area in 1934. In 1922 a private concession took over the guiding of the cave tours. The 1998 Oregon Caves National Monument General Management Plan/Environmental Impact Statement (GMP) recommended changing the tours by having park rangers guide public cave tours. This was based on public comments on the GMP, restoration of a historic function (federal interpreters), providing higher quality services for the public, and better conformance with NPS policies regarding the use of federal staff in interpreting core park themes. This change to park rangers guiding public cave tours was initiated in the spring of 2001. This change resulted in greater training of cave guides by cave management staff in terms of cave science, conservation, and restoration, the significance of the Monument and other park areas (especially caves), and other cave and information management related topics and concerns. Based on written visitor comments, annual surveys, and a 2002 visitor use survey, this change was well received by a large majority of Monument visitors.

1.2 PURPOSE AND NEED FOR FEDERAL ACTION

The 1909 proclamation that established Oregon Caves National Monument states that:

> "Whereas, certain natural caves, known as the Oregon Caves, which are situated upon unsurveyed land within the Siskiyou National Forest in the state of Oregon, are of unusual scientific interest and importance, and it appears that the public interests will be promoted by reserving these caves with as much land as may be necessary for the proper protection thereof, as a National Monument."

The Caves were the reason for the establishment of the Monument. However, the establishment of the Monument on the surface as well in 1909 implicitly recognized the importance of protecting processes directly above or otherwise near the cave. Other underground sites within the Monument are closely connected by geology, air, water, organic, dissolved minerals, and/or genetic flow to Monument caves and need to be protected in their own right. Therefore, it's important to formulate a subsurface management plan for the Monument rather, than just a cave management plan. The separation of resource management plans into subsurface and surface/ above the surface makes more sense in terms of geology and ecology than does relying on plans divided by anthropogenic definitions of the subsurface into cave and non-cave areas. The focus of monitoring, and the mitigation and prevention of human impacts still remains in the Caves because of the enabling legislation, the relative ease of sampling the subsurface via caves, and the concentration of park staff and the visiting public in the Monument's Caves.

The need for a subsurface management plan was reiterated by visitors who took part in a visitor use survey in 2002 (Hoger, Littlejohn & Hollenhorst 2003). In that report visitors were asked which of eleven selected attributes at the Monument were important to the preservation of the park for future generations. The attributes receiving the highest "extremely important" and "very important" ratings were cave features/environment (95%) and clean air/water (93%). Clean air and water are also important parts of the quality of the Monument's subsurface environment besides that of the Caves..

The NPS proposes to conduct management actions that affect the subsurface of the Monument. These include actions that occur on the surface which may affect conditions in the subsurface. This action is needed to continue implementation of the approved 1998 Oregon Caves National Monument General Management Plan/Environmental Impact Statement (GMP).

The final revised Subsurface Management Plan will also be in accord with other relevant park plans such as the Oregon Caves Safety Plan, Resource Management Plan, Surface Management Plan, Hazardous Spill Plan, Resource Management Plan, Museum Collections Management Plan, Scope of Collections Plan, Integrated Pest Management Plan, Library Acquisition Plan, Standard Operating Procedures, and Emergency Operations, or will surpass them in its emphasis on and likelihood of implementing appropriate cave restoration, protection, mitigation, education, and research.

The main focus in resource protection should involve a variety of research projects, actions and non-actions involving mitigation and prevention of human impacts in the subsurface in such a way that research can determine if those projects, actions, and non-actions will or will not cause major impacts on the subsurface or on other resources in the Monument.

This environmental assessment addresses the need to better protect the Monument's subsurface through mitigation or prevention of human impacts and better understanding of how both natural and human-caused processes (including subsurface management actions or non-actions) affect the Monument's subsurface.

This environmental assessment has been developed consistent with NPS and other legal mandates. The intent of most of the mandates and commitments is to establish sustainable conservation and to avoid major human-caused impacts on NPS lands. As a result, park management actions and visitor use can occur only to the extent that it is not likely to significantly adversely affect the Monument and its natural and cultural resources.

This programmatic Environmental Assessment (EA) documents the potential effects of several alternative approaches to subsurface mgmt of the Monument. As this EA provides for only a general, programmatic level of environmental impact analysis, any future projects to improve infrastructure, accomplish research studies or extensive monitoring, other surface-disturbing activities proposed to be implemented would first be subject to site- and\or project-specific environmental compliance (with appropriate opportunities for public comment).

1.1 AUTHORITIES AND GUIDELINES

The NPS and its mandates are authorized under the NPS Act of 1916 (Public Law (P.L.) 64-235; 16 United States Congress (USC) 1, 2-4), also known as the NPS Organic Act, and the General Authorities Act (16 USC 1a-8). These acts direct the agency to conserve scenery, natural and historic objects, and wildlife, and to provide for the enjoyment of those resources in such a manner as to leave them unimpaired for future generations. Amending the NPS Organic Act of 1916, the Redwood Act (March

27, 1978, 16 USC 1a-1) was passed. In this Act, Congress reaffirmed the mandates of the Organic Act and provided additional guidance on NPS management:

> "The authorization of activities shall be construed and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established."

According to Senate Report No. 95-528, page 7, the restatement of these principles of park management in the Redwoods Act intended to serve as the basis for any judicial resolution of competing private and public values and interests in the National Park System (U.S. Senate 1976).

Federal regulations that can be specifically applied to the subsurface at the Monument are listed in the "Code of Federal Regulations, Part 36, Parks, Forests, and Public Property." These include:

- Section 2.1 (1) re: preservation of natural, cultural and archeological resources
- Section 2.1(3) re: throwing rocks inside caves
- Section 2.10(1) re: camping outside designated sites or areas
- Section 2.21(b) re: smoking prohibition in caves

Current guidance for underground management in NPS-77 states that the major objectives of a park's underground management program should include:

Protection and perpetuation of natural cave, karst, and hydrological systems;

Opportunities for scientific studies and research in or about cave and karst resources and systems;

Detailed inventory of resources within cave systems;

Provision of educational and recreational opportunities for a broad spectrum of park visitors to discover, explore, study, respect, appreciate, and enjoy caves at their individual levels of interest and abilities; and

Establishment of regulations, guidelines, and/or permit stipulations that will ensure maximum safety of the cave visitor and conservation of cave resources.

1.4 ISSUES AND IMPACT TOPICS

Issues and concerns affecting this proposal were identified from the park's GMP and input from other state and/or federal agencies. The major impact topics and relevant laws, regulations, and park or other policies that apply to all topics and those that apply to specific impact topics follows:

All or Most Topics: Director's Order #2 (Park Planning), #6 (Interpretation), #7 (Volunteers in Parks), #9 (Law Enforcement Program), #12 (Conservation Planning, Environmental Impact Analysis and Decision Making), #14 (Resource Damage Assessment and Restoration), #20 (Agreements), #24 Museum Collections Management), #25 (Land Protection), 42 (Accessibility for Visitors with Disabilities in NPS Programs, Facilities and Services), #48A (Concession Management), #48B (Commercial Use Authorizations), #50D (Smoking Policy), 52C (Park Signage), 53 (Special Park

Uses), #55 (Interpreting the NPS Organic Act), #66 (Freedom of Information Act and Protected Resource Information), #74 (Studies and Collecting), #75 (Media Relations), #75A Civic Engagement and Public Involvement), #77 (Natural Resource Protection), #77-6 (Comprehensive Research and Development Agreements), #84 (Library Management), #90 (Value Analysis), #92 (Human Resources), #93 (Conflict Resolution).

National Parks and Recreation Act of 1978 (P.L. 95-625); Federal Caves Resources Protection Act (P.L. 100-691); Lechuguilla Cave Protection Act of 1993 (P.L. 103-169); National Parks and Recreation Act of 1978 (P.L. 95-625); National Environmental Policy Act of 1969 (1970) (P. L. 91-184); Federal Advisory Committee Act; NPS Organic Act; General Authorities Act (16 USC 1a-8).

Air Quality: Clean Air Act (33USC 1251 et seq.); Director's Order #47 (Sound Preservation and Noise Management

Cave Formations: Federal Caves Resources Protection Act (P.L. 100-691)

Cultural Values: Archaeological Resources Protection Act of 1979 (P.L. 96-95): Historic Sites Act of 1935 (P.L. 86-523); Director's Orders #28B (Archeology), #28 (Cultural Resource Management), #71A (Relationships with Indian Tribes), and#78 (Social Science); Native American Graves Protection and Repatriation Act of 1990 (P.L. 101-601)

Education: Director's Orders #6 (Interpretation), #29 (Ethnography Program), #52A (Communicating the NPS Mission), 52B (Graphic Design Standards), #70 (Internet and Intranet Publishing), #78 (Social Science), and #82 (Public Use Reporting); National Parks and Recreation Act of 1978 (P.L. 95-625); NPS-77

Fossils: NPS Organic Act; General Authorities Act (16 USC 1a-8); NPS-77
Mineralogy: Federal Caves Resources Protection Act (P.L. 100-691)

Safety: Director's Order #50B (Occupational Safety and Health Program, #51 (Emergency Medical Services), #59 (Search and Rescue), #83 (Public Health Program)

Sediments: Federal Caves Resources Protection Act (P.L. 100-691)
Water Quality & Quantity: Clean Water Act (33USC 1251 et seq.)

Wildlife: Endangered Species Act of 1973 (P.L. 93-205, amended 1982; Director's Orders #47 (Sound Preservation and Noise Management), #77-5 (Animal Capture/ Eradication), #77-7 (Integrated Pest Management), #77-8 (Endangered Species), #77-9 (In-Park Borrow Material)

1.5 TOPICS DISMISSED FROM FURTHER CONSIDERATION

Resource topics that were considered but dismissed from further consideration are listed below, including a brief rationale for dismissal.

Ethnology – There are no known ethnographic resources except for limited accounts of the first explorations of the area. The recent initiation of a cultural affiliation study and funding of a Euro-American ethnographic study could change this assessment.

Vegetation – There is none in the Caves or other Monument caves except for small amounts of algae near entrances to the surface and around electric lights. A seed could fall from a visitor's clothing and germinate in the cave but this would have a negligible effect ecologically as nearly all plants in caves beyond the twilight zone die shortly after germination. Indirect effects of vegetation on the cave are discussed under wildlife and geology.

Wilderness - No portion of Monument caves or other subsurface areas are designated as wilderness.

CHAPTER 2 - DESCRIPTION OF ALTERNATIVES

2.1 ALTERNATIVE A – No Action

Under the No Action alternative there would be few management actions, compared to most of the other alternatives, within Oregon Caves, other subsurface areas, or in surface areas that would likely affect Oregon Caves. Existing public uses of the cave and most current conditions would largely continue as they are under current management.

In May of 2004 the Monument completed an environmental assessment of special cave tours which resulted in a Finding of No Significant Impact with the following findings: “The selected program consists of the following elements (in addition to the basic tours which have traditionally been offered at the park and will continue): the park will conduct lantern tours, geology tours, and children’s tours. A three-hour long introductory caving tour for visitors may be considered after completion and approval of the Cave Management Plan.” The park’s cave management plan has been revised and subsumed under a more inclusive subsurface management plan and which is the subject of this EA.

As approved in the Special Cave Tour FONSI, tour size for the candlelight, children, and geology tours would be limited to 15 people per tour and would be available from late March to early September. The children and geology tours would be given as needed and funding staff levels permitted. None have been given as of September of 2005. The maximum number of candlelight tours conducted was one per day from late June to early September. There appears to have been an increase in visitation levels in the cave from these tours of at most a hundred people a year. However, this increase was more than offset by the year-to-date decrease in numbers for the general cave tour. The tour size for the off-trail caving tour would be limited to a maximum of six visitors and two park staff (guides). If approved in the FONSI for the park’s subsurface management plan, this tour would be offered for approximately 75 days per year from late June to early September with a maximum of one tour per day. The maximum increase in visitation to the cave from this tour would be 610 people, an increase of one percent compared to the approximately 61,000 who visited the main cave in fiscal year 2004.

No Action does not direct discontinuing any present actions or removing existing uses, development, or facilities. This alternative would only partly meet the purpose and need for a subsurface resource management plan as stated in the start of this document.

2.2 ALTERNATIVE B (Preferred Alternative) – Increase Emphasis on Subsurface Management, but Balance the Emphasis on Subsurface Research and Non-Research Actions

Management actions would be roughly balanced between restoration, mitigation, and research. Actions would include subsurface restoration and mitigation, training of park staff, inventory and monitoring based on the vital signs and park cluster concepts, and offering public tours that would vary in both time and distance covered and would be guided on and off the Cave’s paved trail.

Cave restoration would include removal of rubble, lint, tracked in dirt, and old trail trails, installing tarps or cement ridges to trap human-caused particulates, controlling non-native species, repairing cave formations, installing emergency toilets, and altering entrances or passages so that their cross-sectional areas are similar to what existed prior to the historic discovery of the Caves. Alternative B is considered the environmentally preferred alternative.

2.3 ALTERNATIVE C – Decrease Emphasis on Subsurface Management

Actions would include subsurface restoration and mitigation, training of park staff, inventory and monitoring based on the vital signs and park cluster concepts. There would be little cave restoration except for the removal of non-native plants and bacteria by sodium hypochlorite and/or hydrogen peroxide spraying.

2.4 ALTERNATIVE D – Increase Emphasis on Baseline and Monitoring Studies

Baseline studies would eventually include, in decreasing priority order; impact mapping of the paved trail, monitoring before and after effects of gate modification, present biodiversity effects of the paved cave trail using non-lethal pit traps, sediment mapping, identification of water contaminants, water quality study of major ions and nutrients, mineralogical, microbial, and stratigraphic pollen studies, magnetostratigraphy, cosmogenic dating of lava flows and quartz pebbles, removal of Pre-Pleistocene vertebrate bones for identification, radiolarian fossil extraction for stratigraphic dating, and additional studies as delineated in the Subsurface Management Plan. Priority emphasis will be on addressing what appear to be the most pressing resource management questions and/or concern in regards to prevention or mitigation of human-caused impacts.

2.5 ALTERNATIVE E – Decrease Emphasis Placed on Baseline and Monitoring Studies; Major Actions Would Include Subsurface Restoration, Mitigation and Prevention of Human Impacts.

Baseline studies would eventually include, in decreasing priority order; impact mapping of the paved trail, monitoring before and after effects of gate modification, and present biodiversity effects of the paved cave trail using non-lethal pit traps. Cave restoration would include rubble, lint, tracked in dirt, and trail removal, installing tarps or cement ridges to trap human-caused particulates, controlling non-native species, repairing cave formations, installing emergency toilets, and altering entrances or passages so that their cross-sectional areas are similar to what existed prior to the historic discovery of the Caves.

2.6 MITIGATING MEASURES UNDER ALL ALTERNATIVES

Subsurface management actions and non-actions that affect park interpretation and resource management will follow Director's Order #6 (Interpretation) and #11B (Ensuring Quality of Information Disseminated by the NPS). The latter order follows government-wide guidelines that "provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies."

All of the alternatives require well-selected, trained, and effective park staff in administration, subsurface resource management, interpretation and maintenance. Experience with caves, caving, subsurface conservation, and subsurface management would be one of the factors used to select employees.

All park staff that lead tours would undergo a minimum of two weeks of training that emphasizes subsurface conservation and preservation, safety, effective interpretive techniques, and appreciation of park resources. As recommended by visitor comments in the 2003 visitor use survey (Hoger, Littlejohn & Hollenhorst), safety messages that discuss bending requirements during travel through the Caves will be added to safety messages before visitors enter the Caves. Another effort will be to change the perception of 32% being "not aware" and 8% "not sure" that the Park Service was responsible for the Monument.

The goal is to have interpreters with enough credibility and knowledge to elicit appreciation of the subsurface and subsequent compliance from most tour members. Certification would be guided by the park's resource management and subsurface management plans. The emergency medical services/search and rescue coordinator, the natural resources specialist, or an experienced caver and conservationist designated by the park superintendent would complete certifications.

The Monument would seek to establish a job description and a Memorandum of Understanding with one or more caving groups in which experienced, knowledgeable cavers would participate in research, monitoring, inventories, and off-trail tours. This would provide an added measure of effective interpretation, safety and oversight of visitors while on the tour.

Mitigation of subsurface impacts includes lint, rubble, and non-native plant removal. Removal of exiting compacted dirt trails is likely to offset any additional compaction impacts of dirt trails by the public or park staff, as documented in the EA on special tours for Oregon Caves.

The most important mitigation, prevention, restoration, and research protocols, procedures, and priorities will follow the best available practices in regard to reducing impact and deriving the most information on the subject or other beneficial effects and ensuring that the positive value gained is not offset by likely impacts.

2.7 ALTERNATIVES CONSIDERED BUT REJECTED

One alternative recommended by public comments on the park's initial scoping letter was apparently to do no prioritizing of research and inventory studies. This was considered but rejected because, since many major research projects are not funded by the park's base account, these projects are approved or not approved based on such criteria as applicability, timeliness, significance of associated resources, practicality, etc. Giving equal weight to all studies would result in the funding of fewer or no studies. However, baseline studies should be emphasized in most alternatives even if a particular baseline study may not be considered critical for resource management decisions and actions. Only the baseline and subsequent monitoring to contrast that baseline with current conditions may determine whether a particular type of resource is being impacted and how that impact can be mitigated or prevented.

Another suggestion recommended by public comments on the park's initial scoping letter was to do no mitigation, restoration, or public or park management off-trail trips until all baseline studies had been done, including but not limited to karstography, mineralogy, hydrology, pedology, paleontology, archaeology, vertebrate and invertebrate biology, bacteriology, meteorology, and the like (Halliday 2003). This was considered but rejected because studies can be subdivided indefinitely, studies from some disciplines are more important for detecting impacts than others, research methodologies and individuals with subject matter expertise are more easily located for some disciplines and not for others, and because of the need to mitigate or prevent on-going human impacts both within the Caves and from impacts affecting the subsurface from outside the Monument. Doing all these baseline studies would also run counter to a comprehensive inventory and monitoring program being developed at the network level that includes Oregon Caves and Lava Beds National Monuments, Whiskeytown National Recreation Area, and Crater Lake, Redwood, and Lassen Volcanic National Parks. However, Alternatives D and B partly address both the completion and topical comprehensiveness by increasing the amount of effort devoted to baseline and monitoring studies.

2.8 ENVIRONMENTALLY PREFERRED ALTERNATIVE

Environmentally Preferable is defined as the alternative that will promote the national environmental policy as expressed in the National Environmental Policy Act. Section 101 of the Act states that "… it is the continuing responsibility of the Federal government to …

1. "Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations." – Assuming that cave visitation levels remains about the same or declines compared to previous years, all alternatives will not likely impair resources. However, since Alternative B focuses on cave mitigation and prevention of impacts while a balance of research and monitoring ensures that such efforts themselves do not degrade resources, this alternative best fulfills the responsibility of the National Park Service to keep the Monument unimpaired.

2. "Assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings." – Caving tours under Alternative B would allow access to wilderness areas of the cave which for most attendants would likely be healthy, safe, and aesthetically and culturally pleasing. Mitigation of human impacts under the guidance of a balance of research in Alternative B would most likely best maintain aesthetically and culturally pleasing surroundings.

3. "Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences." – Alternatives B and E probably provides the widest range of beneficial uses while adopting Alternatives A or E would likely reduce the Park Service's ability to detect undesirable and unintended consequences of human actions, including management actions.

3. "Preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity, and variety of individual choice." – Alternative B and E provide the greatest variety of individual choice but Alternative B does the best preservation overall because it strikes a more even balance among mitigation, restoration, and prevention and understanding the impacts that these human actions and others are having on the subsurface.

5. "Achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities." – Alternative B probably provides the widest sharing of life's amenities because it will allow more alternatives to the traditional cave tour without degrading cave resources.

6. "Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources." **-** Alternative B and D probably provide the widest enhancement of quality of renewable resources. Alternative B provides the best education for recycling because it balances monitoring and mitigation. The use of rechargeable light batteries with low power usage on all cave tours should increase recycling by example.

The NPS has determined that the environmentally preferable alternative is Alternative B because it surpasses the other alternatives in realizing the full range of national environmental policy goals, as stated in Section 101 of the National Environmental Policy Act, and it is the alternative most likely to fulfill the purpose and need of a subsurface management plan as stated at the start of this document.

CHAPTER 3 – AFFECTED ENVIRONMENT

3.1 SUMMARY

Oregon Caves National Monument's 484 acres are located in southwestern Oregon just north of the California border. Elevation ranges from 3,680 to 5,480 feet above mean sea level for the main part of the Monument and an elevation of 1,800 feet for a four-acre site (visitor center) located in the town of Cave Junction 19 miles from the main part of the Monument. The three-mile Caves is the only cave on the Monument in which tours are given. The largest room, the Ghost Room, is about the size of a football field. There are approximately 25 other rooms of lesser size and many narrow passageways. Of the five known openings to the Caves, four are natural openings that have been modified and one is a human-made exit tunnel. Some passages deeper in the Caves have been artificially enlarged to accommodate walking instead of kneeling or crawling tours; three tunnels are human-made.

Human impacts on the cave were first documented by reports of vandalism in the first half of the twentieth century and by a listing of green species growing by lights in 1977 (Cordero 1977). Restoration or mitigation activities in the Caves since 1985 have included algae and cyanobacteria control, removal of lint, obsolete utilities, trails, walls, and 1,400 tons of rubble, installation of airlocks and bat gates, and replacement of the trail and lighting system.

The summary description of subsurface resources that follows illustrates the challenge of protecting such a diverse collection of resources (both object and process) and effectively interpreting those resources in such a way that major human-caused impacts of resources does not occur and most visitors will not only reduce their impacts while within the Caves but will continue to appreciate and protect the Caves after their visit.

3.2 GEOLOGY

3.2.1 Bedrock

All geology involves changes to Earth, changes either in place or on the move. Movement occurs through 1) erosion, or wearing down the land; 2) deposits, such as lava erupting or muddy water settling into clay; 3) rock folding like silly putty and 4) rock broken along faults. Rocks melt and then crystallize into igneous rocks. They break apart from erosion and cement into sedimentary rock. In between the temperature and pressure conditions of sedimentary and igneous rocks are metamorphics, rocks changed by heat or pressure short of being entirely melted.

Although variations in these rock types and processes are typically scattered globally, most of the world's major rock types and evidence of the processes that formed them occur within the Caves, a microcosm of the Klamath Mountain Geologic Province's geologic diversity in part because the Caves preserves evidence of processes, species, and deposits now missing from the surface. These include past precipitation and temperature amounts and seasonality, vegetation and soil patterns, wind particulates and direction, flowstone (water/air inclusions and radon), the age and quality of cave water, the size of cave entrances, fossils, relict species, and historic artifacts. Cycles likely detectable in flowstone or sediments include:

fire (Briles 2003),
forest composition(Briles 2003),
magnetic fluctuations and reversals (Latham et al. 1987),

solar luminosity (11, 100, 900 years – Shopov 2003),
Milankovitch (20,000 to 100,000 years – Stoykova et al. 2003),
cosmic ray flux (Shopov 2003),
El Nino and La Nina (3-7 years),
Dansgaard-Oeschger Event (1,500 years),
Heinrich Event (10,000 years),
and the Pacific Decadal Oscillation (20-30 years) (Serefiddin 2003).

The history and explanation of the most important geologic processes and features of the Caves and other subsurface areas that follows illustrate how each of the Cave's three main features (wallrock, erosion shapes, and cave deposits) and processes (air, water and rock movement (tectonics)) show superbly how some of the planet's most diverse and concentrated geology was preserved and/or exposed by faulting, uplift, cave formation, and deposition. The Monument's surface geology is summarized by Furtney (2002). The subsurface geology is summarized in a cave guide for tour guides that is updated at least yearly.

Most of the world's major rock types occur in the Caves and each major rock type tends to span its full spectrum, from peridotite to granite in igneous rocks, from high grade (contact metamorphism) to low grade (regional metamorphism) in metamorphics ranging from serpentine to meta-argillite and marble, and sedimentary rock ranging from chemical (Caves' limestone) to rock fragments (conglomerates, bone & dike breccias, sandstones) to deep (chert) and shallow water (lagoonal and subtidal limestones). Sediments range from volcanic ash (Bowen 1969), redeposited glacial loess, to mylonite (rock smashed to powder by faulting), debris flows, stream deposits, rockfall, and sediments apparently heavily weathered by warmer climates than what occurs today. Of the world's major types of geologic deposits, only those of arid and semi-arid lands and some in-situ glacial deposits may be absent.

Processes in the Caves are even more diverse than the rocks and sediments. Rock movement includes most major types of tectonic interactions among large crustal slabs of rock, including continent to continent and continent to ocean crust collisions, separations, and rotations (Achache et al. 1982). Rock movement includes not only large scale (tectonics) but smaller scale erosion and deposits. All major types of erosion and weathering occur (glacial, salt, wind, ice, chemical, etc.), including surface and subsurface karst and karren with enlargement from protocaves to young caves, to mature caves, to those infilled or partly destroyed by erosion.

Water moves in complex patterns both on the surface and underground along faults, bedding planes, joints, pools, and streams. Past formation of the Caves was so complex and took so long that as many as five major types of cave shape patterns (Ford 2000; Palmer 2000; Klimchouk & Ford 2000 (confined, anastomotic maze, curvilinear, reflooded and water table) may overlay one another and change in their emphasis in solutional intensity, space, time, and depth in the Caves). Water and air movement in the Caves, on the surface and above the Monument is driven by tectonic, astronomical, and biogenic climate changes that in turn determine frequencies, duration, and seasonal occurrences of storm events, weather oscillations, and many biotic interactions. For example, El Nino events may be increasing in frequency and intensity due to global warming. Since Oregon Caves lies in between El Nino drying to the north and increased precipitation from El Nino to the south, this can result in an increase, decrease, or no change in Monument precipitation. More birds may nest at the Caves' entrances because El Nino favors breeding success due to better winter food supplies down south before the migrants fly north (Wildlifenews.co.uk 2000). A paleoclimate study at Oregon Caves should result in a better understanding of El Nino events (Frappier et al. 2002).

Monument rock likely has been faulted into the Rattlesnake Creek Terrane, a mostly 230 to 171 million year old volcanic arc on top of an ocean crust slab (Furtney 2002). This terrane spans much time, is old, and is at a plate margin that for the past half a billion years enlarged western North America by alternately expanding and compressing basins and adding incoming volcanic islands, micro-continents, seamounts, and spreading ridges to the continent. Therefore, many things affected the Rattlesnake Creek marine basin and adjacent past and future basins during formation, deformation, and afterwards, resulting in great geologic complexity (Donato et al. 1996). Based on nearby fossils (Irwin & Bloome 2004), the marble mass may be around 210 million years old while other portions of the terrane exposed at the Monument are much younger or much older.

Once likely overlaying the Monument, the Josephine Ophiolite generated the granitic dikes in the Caves, and now likely underlies most of the Monument. It is one of the largest exposures of ultramafic rock in the world and one of the largest, best-preserved, and most complete North American ophiolite, a layered (peridotite, gabbro, sheeted dikes, pillow basalts, mudstones, chert and limestone) segment of ocean crust and underlying mantle that in this area was generated by a stretching back-arc basin (Barnes et al. 1992). Ultramafic refers to once melted (igneous) rocks heavy with iron, manganese and similar elements that lie on the other end of the igneous rock spectrum from whitish and relatively lightweight granite. Metamorphosing water-rich ultramafic peridotite rock creates serpentine. Most or all of the serpentine seen on the Monument likely squeezed up inside faults as the teardrop-shaped granitic (granite or granite-like) Grayback Batholith rose up.

All these rocks are exposed in the Caves or its tunnels. They illustrate that Oregon Caves is one of the few places on Earth with visible, accessible evidence of mid-ocean and continental transform (sideways), slanted, and vertical fault zones, sediments from old and new mountains and different climates, and cave wallrock illustrating fore-arcs, back-arcs, remnant volcanic arcs, interoceanic arcs, destroyed ocean basins, suturing to a continent, a continental basin (the Illinois Valley), and the many different ways that the Caves has enlarged, become decorated, and is being destroyed by erosion.

Great variations in the speed and orientation of crustal plates caused rock and sediment to be squeezed together, pulled apart or uplifted into mountains. Tectonic switching here and in most of the Klamath-Siskiyous occurred when long periods of crustal stretching from ocean plate (slab) slowing and rollback was interrupted by short periods of contraction. Stretching reduced the vertical pressure on rock and deepened back-arc basins that filled with continental crust sediments. Decompression of the sinking slab and expulsion of seawater from the slab allowed melting of overlying mantle peridotite that differentiated into basaltic melts. These masses of molten rock rose up and in turn melted overlying sediments so that the final batholiths and plutons were granitic. Now well illustrated in the Caves, this process more than doubled the width of Western North America (Collins 2002).

3.22 Speleogenesis

Bedding and Faults: Most passages in Oregon Caves formed along strike (defined as a straight line formed by the intersection of rock layers/bedding planes and a horizontal surface). Cracks usually form between bedding planes, especially those that have been faulted by sliding over one another, perhaps aided by graphite lubrication. The next major orientation follows faults steeper than most bedding planes (but often in the same orientation). The least important directions are down dip (direction you take if you slid down a bedding plane) and along vertical fissures. These latter fissures are more important for present day waterflow and in cave formation.

The Caves may have many passages because bedding tilts towards the Grayback Batholith. Rock may have faulted parallel to bedding towards the empty space created around the pluton as it shrunk while crystallizing. Bedding planes are also where water flow is concentrated because of a waterproof layer or where acids are released from sulphides (Lowe 1992; Rauch 1974). Steeply dipping bedding planes, as is the case in most of Oregon Caves, facilitates the flow of undersaturated water to depth. This allows solution of calcite to increase at depth, thus increasing the vertical extent of the Caves (Ewers 1972, 1982).

Oregon Caves is not as deep some caves because the cave is in a rather short marble block (but that increases the mazelike nature of the cave). The main passage orientation zigzags down under the surface, largely following perpendicular to surface contours (which is close to the direction of the hydraulic gradient and towards a spring outlet) but slightly changing direction when the main orientation of bedding planes or near-vertical faults and joints change direction. Thus cave development is a compromise between the fastest way water can go downhill and the easiest (along cracks). As cracks and conduits become more connected, the amount of water heading down the water gradient becomes more important than the size of cracks and there is a tendency for cave development to be more horizontal, as in the lower part of the cave**.**

Because of rapid erosion, uplift and uncovering of the marble, release of pressure likely caused fairly wide cracks (.2 mm.) along faults, bedding planes and joints near the surface where most of the cave formed. It would have taken several tens of thousands of years for such cracks to enlarge to the breakthrough time, when flow becomes turbulent and enlargement greatly increases (Breybrodt 2004; Dreybrodt & Eisenlohr 2000). Water becomes turbulent because, when cracks reach about 2 centimeters wide, the differences between rates of flow near the walls and in the middle of the channel become so great that eddies form and turbulence begins. Enlargement of a passage can lower its hydraulic gradient and thus the water pressure. This causes smaller passages with higher hydraulic gradients to flow into the larger conduit in what is known as cave piracy. With little water the small passages stop forming and the largest ones get larger**.**

Since Oregon Caves probably had a short breakthrough time (the time from initial crack enlargement to human-size passages, about 10,000 to 50,000 years), it may have only take from one to a few hundreds of thousands of year to create rooms the size of the South Room and Ghost Room. Further width enlargement probably occurred at about one to two feet every thousand years (Dreybrodt 1996; Dreybrodt & Eisenlohr 2000). Adding this to uranium/thorium flowstone ages (Turgeon 2001) yields a minimum cave age of about a million years. The cave is probably not much older than a few million as that supposedly is about the age of the Henley erosional surface and (assuming the slopes here were not recently steepened by uplift), older caves would have been mostly eroded away because the karstic processes elucidated for the Monument usually forms caves close to the surface and steep, wet terrains undergo rapid erosion. Some partly destroyed caves, also called grottoes, of unknown age can be seen on the walk between the cave and the main parking lot.

Cave Size: If the orientation of bedding, fault and joint cracks largely controlled cave passage direction, water volume largely controlled the Caves' size (Eners 1982) in part because most of the volume came from non-calcite surface areas and was very undersaturated with respect to calcite. Volume in turn was set by annual precipitation (now about 52") and the drainage basin size and direction. North-facing steep slope keep snow longer, allowing it to seep into caves instead of evaporating or running off as surface streams. The steep slopes also increased the speed and so the solution power of most water entering the Caves.

Water coming off argillite has little dissolved calcium and a fair amount of carbonic acid. Therefore it is aggressive, meaning it can dissolve much marble. Water near the main entrance is almost saturated with dissolved calcite and so cannot dissolve much more, possibly resulting in small rooms in the lower part of the Caves. However, because various flows join before they reach the exit, the higher flow volume should result in larger passages, as it does in most caves (Dreybrodt & Simers 2000; Ford et al. 2000). There is a tendency for convergence of flow toward the relatively low hydraulic head (pressure) of the major cave passages. The effect of increased flow does occur along the known length of the lower River Styx (the entrance area is the largest) but does not occur when compared to the Ghost Room and further upstream. This suggests that the lower cave became linked to the rest of the cave via stream piracy late in its history.

Complexity of passages was largely controlled by a high water pressure, a short block of marble, wide cracks, tilted bedding planes, and a lot of sediment (plugging up initial passages and so creating new ones). This helped produce three miles of passages beneath about ten acres of land. High passage sinuosity (waviness) likely results from intersecting fractures and local irregularities in dip or strike (Cathcart & Heller 1990), perhaps caused in part by the intrusion of the Grayback Batholith.

As many as five cave shape patterns may overlay one other. The Caves may have originally started forming before overlying argillite or metabasalts were eroded away. Numerous cracks allowed access to many parts of the marble instead of a branching network with one or a few large passages that out-compete smaller passages through stream piracy (Palmer 2000b). This coupled with a small block of marble and high water pressure due to steep slopes resulted in a cave with a high density of passages beneath a small surface area (Klimchouk 2003).

Further cave development after exposure of the marble resulted partly in an anastomotic maze, the cave type that normally forms with concentrated and variable discharge (sinking streams) moving along bedding planes and partly a curvilinear cave (= branchwork or dendritic like a bush) due to more limited and even discharge with a high water gradient often through sinkholes. Reflooding created dome pits and enlarged passages perpendicular to the main waterflow (Palmer 2000a). A water table and vadose cave or series of cave passages at the lowest known elevations in the Cave and vadose modifications in the South Room area and downstream of the Rimstone Room were among the last major erosional features to develop.

3.3.3 Cave formations

While the following lists cover most of the known cave formations (both speleothems and speleogens), it is still incomplete in part because cave-wide inventories did not list separately most subcategories of cave formations. The lists serve as a reference guide for discussions elsewhere in this document and they illustrate the need for training of cave tour guides by resource management staff so that the guides can better communicate to the public the value, significance and appreciation of the Caves' great geologic and biologic complexity.

Speleogens are erosional features in a cave, which in itself can be considered a large speleogen. Except for age and paleo-climates, speleogens often yield more information about the past history of a cave than do speleothems, which are non-sediment deposits and/or wall rock features that are exposed in a three dimensional wall by erosion. They include:

Air Pocket or **Bell**. Also called bell holes – An air space on the ceiling, especially one caused as air is squeezed into a space during back-flooding, when temporarily rising water level in a cave is caused by a downstream passage being too small to pass an abnormally high discharge. Such air can increase acid dew and enlarge the hole, usually with a more gradual upward extension than the more abrupt closure of most phreatic pockets and no obvious crack or tube that supplied aggressive water (Queen 2003). Some air pockets may form by local rising water driven by density (amount of dissolved calcite) differences

(Dogwiler 1998)

Anastomoses (also spelled anastomosies) **-** A network of curvilinear, irregular, braided tubes of circular or elliptical cross section. Anastomoses are commonly parallel to bedding planes or fractures. Commonly 100 mm in diameter & from initial cave development with phreatic/diffuse flow along bedding planes, joints, faults, etc. (Ewers 1965; Rogers 1980). Best seen where a foot cave joins the Exit Tunnel.

Bedding-plane and **Joint-plane Anastomoses.** Similar to two dimensional spongework, these meanders may form early on when the flow rate is small but the water pressure is high. They usually become inactive once a master passage has formed (Rogers 1980).

Boxwork: When palettes intersect from at least three directions. They appear to have formed relatively simply in Oregon Caves but have complex multistage development in other caves such as Jewel and Wind Caves (Palmer 1984; Stephenson 1990). They apparently are most common near faults at Oregon Caves.

Breakdown (rock fall accumulations) mostly occurs near entrances (just past the Dry Room) and in larger rooms (lack of ceiling support), especially rooms with much faulting and fractured rock and which have high overburden pressure because they are deep beneath the surface.

Cave Chimneys: Where a linear feature is contributing water to a water-filled cave passage, mixed corrosion may develop a long narrow chimney going upward.

Cave Ghosts: First described in 1967 (Lange 1967), their genesis has been partly understood only in the last 20 years. The whiteness of the ceiling formations appears at least partly due to acid dew and drying. Solution from acidic dew occurred along cleavage planes and between calcite crystals. Acid dew occurs when warm, moist air rising in a cave condenses on colder surfaces and, by absorbing carbon dioxide, forms carbonic acid that dissolves calcite. Edge patches or films are ceiling areas where condensation-corrosion films concentrate, as in the junction of a vertical wall and a relatively horizontal ceiling. The areas are relatively smooth but pitting can occur.

The convection is driven by a combined 1.5 degree F. geothermal gradient between the top and bottom of the Caves. Acid dew solution appears minor; the most is about a 4” thickness of calcite on some asymmetric flowstone. Condensation water still occurs in the highest and lowest parts of the cave in summer but large entrances now flush out much carbon dioxide. Global warming also heats the top part of the cave faster than the deepest part; this lowers the geothermal gradient. Both processes reduce acid dew.

Cave Passages – The orientation of bedding planes, faults to a lesser extent and joints to an even lesser extent control the orientation of most cave passages. Since bedding and faults are usually tilted, so are most rooms. Joints and some faults are vertical and so these rooms tend to be vertical, especially where erosion above the water saturated zone has cut a canyon.

Cave Scallops – Scallops are erosional features where turbulent water slows down near rock and vortices enlarge small idents in rock (Allen 1972; Goodchild & ford 1971). Small scallops indicate faster waterflow (Curl 1974). Based on scallop being smaller downward, stream flow was initially slower that at the present time but it increased later on during major flooding when outlets had enlarged and before the outlets became plugged with sediment. Scallop size indicate that passages in the lower part of the cave formed in the floodwater zone (epiphreatic), where passages may stay dry for long periods, but when active are completely water-filled and develop like phreatic tubes. The difference with phreatic tubes is that scallops are present and decrease in size on the ceiling (as in the Imagination Room) due to faster water flow at the top of the floodwaters. However some areas display larger scallops higher up (low, small ones in the Passageway of the Whale, larger ones just past the Dry Room). This likely indicates downstream constrictions (both passage size and sediment plug ups) slowed water flow at the highest flood stages.

Cockling: Where just a trickle of water runs down an almost vertical face, flutes don't form alone but are interspersed with horizontal ribs, scallops, or discontinuous rills, as in Miller's Chapel.

Corrosion Notch - Any substantial indentation in cave walls or cliffs. Includes waterline notches (see below), vadose wall notches (at blackout), and paragenetic wall notches (at Belly of the Whale) (Luaritzen & Lauritzen 1995).

Dome pits most likely formed from concentrated, aggressive (better able to dissolve calcite), fast moving inflowing water entering after the cave mostly drained. Dome pits are formed where there is a local input of water, as under the head of a stream valley, beneath the centers of sinkholes, or along a line where a layer of impermeable non-carbonate rock cover has been eroded off soluble carbonates (Herron 1990), as appears to be partly the case at the Caves.

Given the great thickness of flowstone, it is possible that most dome pits along the tour route formed at the start of older deglaciations when glacial and permafrost ice melted (125,000, 250,000, 350,000, 425,000 and/or 500,000 years ago) or are even older (Turgeon 2001). No pit below dome pits in the lower cave passages suggests that acid water drains away fairly quickly before it can dissolve & deepen the dome pit. Drainage may have been through a former stream but now is through interconnected cracks. This, along with much flowstone, indicates a mature karst, unlike the more recent and less mature karst in the upper end of the cave where dome pits are still actively deepening and there is little flowstone. With no large entrances to carbon dioxide, dome pit water can absorb carbon dioxide from the cave air and continue enlarging the pit (Herron 1990**)**. When surface soils and large entrances formed, most of the dome pits probably started depositing flowstone.

Drop dents –Acid dew, also called condensation-corrosion, in which the diameter is about the size of a water droplet and the relief is < 1-2 mm. Drop dents are often seen as summer dissolution of white crusts that possibly formed during past climates even drier than the one at present.

Earth fingers - Tiny earth pillars caused by rain or dripping water on clays, as in the 1st Clay Pocket**.**

Flutes – Vadose erosional runnels with the same orientation as water flow and, like scallops, with the steepest side facing down the water flow (Allen 1972; Blumberg 1970). 1. American Syn.: scallop. 2. Long grooves in cave walls (vertical flutes) formed as karren by raindrop impact and trickling water or underwater by eddies (thus related to scallops). The slope angle of the host rock surface appears to control flute length, with longer ones on vertical surfaces. Flute cross sections shape changes with slope angle and slope length.

Flat Ceilings (Laughdecke) Density driven convection currents rise upward and carry aggressive water (able to dissolve much calcite) to the walls (forming flat ceilings if everything is underwater) and notching them (Lauritzen & Lundberg. 2000). Even where bedding plane or other cracks are greatly tilted, flat ceilings may form because the lower parts of the ceiling are dissolved faster than the upper parts because convection currents there are likely to be less saturated with dissolved calcite. Kincaid's Dancehall is the best example near the paved trail.

Half(-)tubes - Trace of a ceiling channel or tube. Most form during incipient speleogenesis. Then the lower part of anastomoses or phreatic tubes along bedding planes are destroyed by vadose enlargement

(Ewers 1966). Some develop where a bed is more resistant but most carry the surviving flow through a passage that has become choked with sediment. Best seen just after the 110 Exit**.**

Subsoil Karren: The mushroom-shaped bedrock (more solution at the base) on the left just after the Rimstone Room and in the Wedding Cake Room likely resulted from an influx of acidic soil down passages above standing water. The cave likely drained soon after the sediment came in, allowing acids to migrate down to the base of the sediment where most of the solution of bedrock occurred.

Meander Niches are crescent shaped alcoves on the wall of a cave; formed by stream erosion, as in the area just after the first bridge over River Styx (Smart 1977).

Pendants: Bedrock projections. Some form in areas of rapid erosion, such as from very acidic or turbulent water in a stream, in a dome pit, along a bedding plane, or on the sides of the Ghost Room (mixed corrosion). The stream or dome pit cuts down into its floor so fast or the room drains so fast that sharp points are left high and dry before they can be eroded away.

Palettes: White lines of calcite on ceilings above the first bridge over the River Styx and on rock slabs in on the floor of the Ghost Room formed after graphite-gray marble formed and before recent organic brown limestone formed. Acid dew dissolved the surrounding marble, producing a type of petromorph. This is a term originally ascribed to cave shields.

Petromorphs: A cave formation that projects from bedrock and is part of the bedrock but differs from surrounding bedrock in terms of grain size, mineral composition, etc. Petromorphs include boxwork, palettes, granitic dikes, and much thinner quartz dikes.

Phreatic Loops – In the water-filled phreatic zone, passage enlargement can be largely independent of the water table and is directed by rock cracks, especially in Oregon Caves' bedding planes and faults. If one passage or crack becomes plugged with sediment, waterflow may move up or down to more open cracks or passages, thus creating loops.

Phreatic Passages – Formed completely underwater, they tend to be lenticular and oriented along a major rock weakness, especially bedding planes and faults (Dreybrodt & Gabrovsek 2000). The upper part of the Belly of the Whale is the best example along the tour route.

Phreatic Pockets – Where local input of water enters a cave passage, mixed corrosion will develop tubes or small domes going upward a few meters wide and deep.

Rills are a series of parallel, straight grooves on walls (Passageway of the Whale), ceilings (Ghost Room) and, rarely, on floors (first bridge over River Styx). They likely formed during backflooding with aggressive water, from mixing of cave air (both processes producing acid dew), splashing from dome pits, or as decantation rills from aggressive water moving out of cracks as the water level falls and the cave drains. Condensation rills or trails are sinuous or parallel karren grooves less than a few cm. wide. Rills are common here and in other wet, temperate caves with seasonal climates (Ford & Lundberg 1987).

Slanted Walls (Facetten) – Calcium-rich and therefore heavy water sinks alongside walls, progressively dissolving less calcite and thereby producing outward facing slopes before reaching the bottom of the passage and displacing lighter water that then moves upward and completes the cycle (Lauritzen & Lundberg. 2000).

Splash Pits – Form under waterfalls or drips and are equivalent to surface rain pits. Usually up to a few centimeters in width.

Vadose Canyons – When a canyon retreats by headward erosion of some erosion resistant area (a nickpoint) it is fairly straight, as in the case of most vadose canyons in Oregon Caves. The canyon stream is underfit, meaning that the stream does not occupy the entire floor of the canyon. This indicates a present-day decrease in streamflow compared to higher flows most likely occurring during past deglaciations. The canyons also tend to enlarge at the base, indicating that present and recent flow is unable to move out relatively insoluble stream pebbles and so those pebbles eroded the walls sideways during flooding.

Waterline Notches (also called solution or corrosion bevels) is the most common type of corrosion notches. They and some caves form at the top of a water surface because the width of cracks and the effect of the hydraulic gradient (the sloping surface that water runs down) tends to decrease with depth and therefore water flow is not as fast. Bevels also form at the water's surface due to absorption of carbon dioxide from the air and, to a lesser extent, from organics and mixed corrosion (when the mixing of two waters of different partial pressures of CO2 causes additional solution even if both waters were initially saturated with calcite). Some of the more irregular and less continuous notches in Oregon Caves may have formed by aggressive spring melt water on top of winter-frozen cave water.

Speleothems generally occur where non-sediment material is added to a cave. Speleothem growth in Oregon Caves progressively increased from one interglacial to the next (greater flushing of carbon dioxide from cave) but stopped during the height of glacials, the increase duration and severity of which increased the time that speleothems stopped growing (14,000, 2,000, 63,000 and 96,000 years) in intervals ranging from 14 to 102,000 years. Then, not only was groundwater frozen but the ice or periglacial/tundra material likely also plugged up entrances such as the one or ones in which a jaguar and grizzly entered. The higher carbon 13 (C^{13}) isotope values during the height of the glacials suggest reduced biological activity due to a lowering of treeline below that of the caves. Speleothem formation in Oregon Caves stopped very early during the transition from interglacial to glacial and began again at the very end of the glacial period. The periods of growth cessation got longer over time, indicating increased cold periods and/or continued uplift (Turgeon 2001).

Calcite is mostly deposited in a cave when there is an overlying soil, which apparently was lacking or reduced here during the height of the glacials and sometimes during interglacials (Turgeon 2001). When there is a soil, the amount of carbonic acid available for both dissolving a cave and for redepositing calcite in a drained cave increases as soil temperature and soil moisture increases (Qi & Xu 2001). Stalagmite growth in turn increases with temperature and increasing amounts of calcium in the dripwater but appears unaffected by drip rates except at low drip rates (less than 2 per second) (Genty, Baker & Vokal 2001).

Growth increased during the last half million years irrespective of the glacials, suggesting this resulted from larger cave openings or a decreased amount of rock over the Cave. Flowstone layers in the Cave with large crystals overlain by much smaller crystals support increased entrance size. The lowering of the treeline below the caves may have caused a change in carbon isotopes in Oregon Caves at this time (Turgeon 2001). Less amounts of light oxygen (O^{16}) indicates that evaporation was lower during cooler periods (Vacco 2003, Turgeon 2001).

Most caves become well decorated only in middle age, when a sizeable entrance flushes carbon dioxide out of a cave. This makes it more likely that water will lose carbon dioxide to the cave atmosphere, thus reducing acid and precipitating calcite. The range of formations increases because some now are formed at least partly by evaporation, such as moonmilk, cave popcorn, and helictites. Many entrances indicate that a cave is nearing old age when erosion changes the cave into an open-air grotto. At least at one time, there were probably one or several natural entrances to Oregon Caves higher than the 110 Exit. The resulting chimney effect moved air through the cave that helped deposit much of the cave popcorn through evaporation and loss of carbon dioxide. However, smaller crystals and the lack of flowstone overlying popcorn or manganese/iron surficial layers suggests there has also been a general increase in dryness within the last ten thousand years due both to larger entrances and greater drought during the summer.

The abundance of speleothems in the Petrified Forest, after the 110 Exit and before the end of the Exit Tunnel indicates that they grow faster close to entrances (but beyond the freeze thaw and acid dew zones) due to higher flushing of carbon dioxide, The greater the difference between the amount of carbon dioxide dissolved in water and the amount in the air, the more carbon dioxide is bubbled off from the water to equalize concentrations. With the loss of carbon dioxide from the water, carbonic acid decreases until the amount of acid is not enough to keep all the calcite in solution. Calcite crystals then precipitate.

While not inclusive, the following list illustrates that Oregon Caves has many of the common cave formations as well as relatively rare or uncommon ones such as lizard skin popcorn, moonmilk microgours, calcified vermiculations, splattermites, toothed draperies with inverted “microgours” and “flexible flowstone.” Speleothems include:

Anemolites - A linear but bent eccentric stalactite ascribed to airflow and in which most are pointed within a 250 degree arc (Hill & Forti 1986). After a soda straw thickens, evaporation on one side from wind may deposit calcite in intercrystalline cracks, causing one side to lengthen & bend. They differ from helictites in that they usually don’t form dense clusters and the diameter tends to be bigger. A few occur near the main trail.

Canopies – Flowstone layers that extend out over open space (Hill & Forti 1986). Most canopies in Oregon Caves form on sediment that is later washed away by water or which becomes liquefied and flows from underneath flowstone during earthquake shaking. Both are called clastic canopies. A baldacchino canopy is one formed when downward growing flowstone meets a water surface (Hill & Forti 1986), apparently both ice and liquid surfaces in Oregon Caves.

Cave Coral – A type of coralloid with clumped clusters of visible crystals with sharp terminations (Hill & Forti 1986). Usually forms underwater or in areas of high humidity where there is very slight supersaturation. It may be a coralloid if it has a curved internal structure. Some clusters have been vandalized but there are at least ten small cave pools in Oregon Caves that are relatively undamaged.

Cave Crusts. Thin, generally flat layers of usually microcrystalline material deposited on cave walls. Flowstone tends to be thicker with larger crystals. Coatings are thinner than crusts (Hill & Forti 1986). Many crusts in Oregon Caves are from former moonmilk deposits but one in the Exit Tunnel thickened in places to become flowstone next to the same layer thin enough to be a coating.

Cave Popcorn usually forms through loss of carbon dioxide due to airflow (Thraikill 1976; Gonzales & Lohmann 1987) but evaporation can also help, especially with white-tipped cave popcorn between the main entrance and the 110 Exit. Cold air, especially during winters, nights and glacial periods, flows into the cave. As it moves into the cave, the air warms up and is therefore able to evaporate more water. This air is also, relative to other cave air, lower in carbon dioxide. Therefore, more carbon dioxide is going to be lost to this air from water in the cave in order to equalize the difference. Acid dew has dissolved some layers of stalagmites on those sides facing away from entrances.

Best seen in Petrified Forest and on the right wall just after the 110 Exit are small oriented knobs known as bumpy moonmilk where it is soft and lizard skin popcorn where it is hard. The resulting knobs oriented in a parallel fashion that remained after rilling or acid dew solution were sites of popcorn formation, presumably after the entrance became large and evaporation increased. This type of mixing of dissolving and precipitation of calcite in one place is rare; lizard skin popcorn and bumpy moonmilk apparently is known from only a few caves.

Coatings - A smooth thin speleothem layer usually less than a few millimeters thick. Calcite coatings often create capillary pressure needed for helictite growth. Includes manganese coatings (Potter & Rossman 1979**)**

Coralloids - Micro-crystalline, nodular, globular, botryoidal, or coral-like spheroid, dripstone, or pool speleothem with curved outer surfaces and curved internal structures (esp. laminations) (Hill & Forti 1986). Includes cave pearls (rare in Oregon Caves, not seen along tour route), cave popcorn, and some cave coral (those with curved internal structure**).**

Crennulations - Horizontal ridges on stalactites of both calcite and ice. They tend to have a wavelength of about 1cm, suggesting waves in water films may have a role. They may form when water flows over a slight bump in the surface. The water film thins as it passes over the bump, which increases evaporation, freezing, and/or carbon dioxide loss, thus more calcite or ice is deposited on the bump. Just below the bump the water pools up again, and below this small pool the water thins again due to surface tension, depositing more calcite or ice to form another ridge. Crennulations seem to be self-perpetuating below the initial bump (Despain 1994). Microgours in flowstone and the saw-tooth edge of some draperies may also be self-perpetuating in the same manner.

Crystal Clusters: Visible calcite crystals occur in cave pools (when clumped called cave coral), as part of shelfstone, where thick layers of flowstone have been broken (Wedding Cake Rm.) and where slow flow saturated with calcite favors slow growth and thus larger crystals (Angel Falls). The type of crystal habitat may depends on the amount of calcite saturation; the lowest saturation may produce branching crystals in cave pools, then crystal clusters, and then velvet flowstone, with the highest saturation forming cave popcorn.

Draperies – Curtain-like, linear flowstone from water droplets running down a wall or ceiling. Especially on low angle walls, small bumps in the bedrock cause the drapery to become slightly curved, and there is more deposition of calcite on the outside edge of each curved segment because there is more surface area for deposition and often a greater exposure to evaporation (Hill & Forti 1986). Most ceilings in Oregon Caves are very tilted and this may reduce the number of curved draperies.

Flowstone: Where water sheeting down a surface deposits calcite. Dogtooth spar crystals that individually cannot be seen can impart a soft look to what then is called velvet flowstone (Hill & Forti 1986), which if found along in the Clay Pockets. What appears to be spongy flowstone occurs near the Slab Crawl and may have only been reported in one other area, a cave in Alaska.

Helictites: Contorted more or less cylinders that may twist in any direction. Each helictite has a central canal and an outside surface through which water moves under capillary pressure. Growth is by calcite precipitation due to evaporation and degassing of capillary water at the tip. Crystal lattice distortions, the regular rotation of the crystallographic axis, stacking of wedge-shaped crystals, dry/wet cycles, &/or impurities cause changes in orientation of helictites (Francis 1982). Most in the Cave have been found in areas of very low airflow, suggesting that those in areas of somewhat higher airflow have been vandalized.

Microgours are like miniature rimstone dams on steep flowstone slopes or on the underside of draperies (both in Exit Tunnel) that probably produce frequent turbulent but very shallow flow (Finlayson & Li 1993). Microgours do not grade into rimstone dams size wise and each formation forms on different material, indicating that they probably form differently. Wavelets may deposit calcite lines by driving off carbon dioxide by way of increasing turbulence. Microgours with moonmilk now cemented into calcite crusts are a rare feature in the Caves and likely rare in the US as a whole.

Moonmilk: A white cave mud with the consistency of cream cheese when wet and milk powder when dry. Most of the Oregon Caves' moonmilk likely is Mundmilch, moonmilk with more than 95% calcite. Mundmilch is most common in caves close to freezing, as used to be the case in parts of Oregon Caves. In 1995, Oregon Caves moonmilk under the microscope yielded filamentous bacteria with sheaths of calcite around them. Another study in 2001 found yeasts and "probable" Corynebacterium, Runella and Actinomycetes in Oregon Caves moonmilk. The regularity of the sheaths suggests that they are purposely produced by the bacteria but it is possible that the sheaths are simply a precipitate inadvertently caused by the bacteria using carbon dioxide and/or organics and thus reducing the acidity of the water.

Patina - Thin, darkish coating, film or crust from the evaporative wicking and/or aquatic deposition of iron and manganese oxides (usually with some silicates). Incorporates atmospheric metals and may be stromatolitic (layers bound by bacterial activity) in origin and structure. Desert varnish (the name for surface patina especially in dry areas) in Hawaii and western US have biochemical compounds (siderophores) produced by microbes to solubilize otherwise insoluble iron oxides and oxyhydroxides. The activity of such microbes may control the iron content of such deposits.

Rimstone Dams (also called gours) have a dam and pool (sometimes dry). The basin side is usually slightly overhung (facing upstream), while the spillway side usually slopes downstream. This appears to be a compromise between growing up to the area of the most calcium ions (because water is evaporating and carbon dioxide is being lost at the water's surface) and growing into the direction that causes maximum turbulence and further loss of carbon dioxide (Hill & Forti 1986; LeJeune 1990). The slant probably becomes less as water flow decreases and as evaporation increases, as appears to be the case in the Rimstone Room.

Soda Straws are a type of stalactite that at least initially is hollow and is always tubular, usually with the diameter of the size of a water droplet (Hill & Forti 1986). However, skinnier soda straws called sub-minimum diameter stalactites do occur in Oregon Caves and other caves.

Since <1% of the soda straws in Oregon Caves show any re-growth, the average is <.0014/century or around .015"(.032mm) per 1,000 years. The bigger stalactites here grew a lot faster than that. The flowstone and dripstone sampled by Turgeon (2001) in Oregon Caves showed growth rates between 1.54 to 31.5 millimeters (about 1/15 of an inch to close to an inch and a half) per thousand years during about 11 early to mid-interglacial periods of the last 500,000 years. The difference between these growth rates probably means that with the intense summer drought that started at least 6,000 years ago, the growth rate in Oregon Caves has slowed down considerably (down a thousandfold). This may explain why the youngest speleothem dated by Vacco (2003) was 6,000 years old. Increases in both temperature and water film thickness (related to precipitation) increases growth in Oregon Caves (Turgeon 2001). Most forecasts of the effects of global warming for the Pacific Northwest indicate higher precipitation in the winter and and even lower precipitation in the summer, suggesting that human impacts will lower growth rates even more than what occurs at present**.** Snow pack for the Puget Sound area decreased by around 35% since 1950 (Scientific Consensus 2004) and similar decreases seem to have occurred in Oregon Caves since 1975. The result is that the 1980 and 1979 records of from 460 to 320 gallons per minute exiting from the

Cave have never been or have rarely been matched by spring melt-outs in the last fifteen years.

Splattermites – May be the same as cave blades. The only one known from Oregon Caves probably formed from a combination of dissolution and deposition of calcite from water dripping from a long distance.

Stalagmites: High soil cover, dripwater calcium content and high temperatures increase the growth of stalagmites (Baker, Genty & Dreybrodt 1998; Dreybrodt & Lamprecht 1983). This likely is due to soil carbon dioxide production being primarily determined by surface temperature and soil moisture. Studies in caves with grasslands above indicate growth rate is only proportional to precipitation while increases in the solar constant (that is, temperature) increases fulvic acid amounts and its fluorescence (Baker, Genty & Smart 1998).

Studies in the dome pits of Oregon Caves suggest that surface temperature increases carbon dioxide available for carrying dissolved calcite into the cave. The large amounts of organics and thicker soils in forests compared to grasslands may hold the water in long enough to pick up carbon dioxide as the temperature increases in early summer. Solubility graphs of water in Oregon Caves indicate that there is little growth during winter. Most stalagmites in Oregon Caves are narrow or breast-like, the latter indicating a slow decrease in calcite deposition. The relative lack of stalagmites in Oregon Caves and their nearly ubiquitous resolution may indicate the lack of warm climates (Gascoyne 1977), erosional lowering of the surface, and/or great differences between summer and winter precipitation.

Vermiculations are thin, irregular, discontinuous deposits usually of clay or mud, likely formed from flocculation of drying, liquid films. Directed water flow with ripples may result in the tiger skin vermiculation and moonmilk ridges along vertical walls. A relatively high proportion of water and slower drying results in more complex forms. The colloidal mass (particles thousandth to a hundred thousandth of a millimeter) flocculates into shapes determined by particle size and amounts, bedrock irregularities, rate of evaporation, and electric charges (Bini et al. 1978). Simple, rounded or unbranched vermiculations have formed in a year or so on PVC piping in the cave whereas more complex forms using carbon from carbide lamps in Oregon Caves probably took decades to a century to form.

Welts: Like a linear helictites, water flows out under capillary pressure, but, unlike cave shields, the crack usually is sealed with calcite and the resulting formation is more irregular and smaller (Hill & Forti 1986). Usually found on speleothem columns, sometimes where settling and cracking has occurred from earthquakes.

3.3 CAVE CLIMATE

3.3.1 Airflow

Even before Oregon Caves had large entrances, warm air, caused by it being hotter the deeper you go in the earth, rose up and combined with carbon dioxide to etch ceilings with acid dew. Once the cave had large entrances, the biggest effects on airflow were elevation differences between entrances and in temperatures between the cave and surface (in both cases the greater the difference, the more airflow). If it is warmer outside than in most of the cave, cold, dense, outside air then will flow into the two main upper entrances and flow down to the lower entrances, what is known as a reverse chimney effect. Winter chimney effects occur when the outside temperatures are colder. Then the warmer air in the Caves rises up from the lower entrances to the upper entrances. Present low airflow indicates few undiscovered passages of much volume extent exist that connect with known Monument caves or passages.

At the end of the last ice age, the glacial anticyclone was weakened by the retreat of the continental ice sheet, allowing westerly storm tracks to move south (Tattershall 1999). Rainfall decreased and temperatures warmed up to ~4 degrees Centigrade over the Caves from 13,500 to 12,900 years ago. As a result of astronomical cycles, a higher-than-present summer insulation at this time (Briles 2003) and an increase in solar output (Shopov 2003) helped lead to the development of open woodland and even more frequent fires than before or at present. This was followed by a ~4 degrees Centigrade cooling and drought cycle 12,800 to 11,760 years ago, in what is known globally as the Younger Dryas period.

Oxygen isotopes of a caves' stalagmites indicate a temperature cycle of 190 years between ~13,500 and 9,500 years ago, most likely a solar luminosity cycle. Longer cycles during the last 145,000 years in central California have also been attributed to changes in the solar luminosity, once called the Solar Constant (Cannariato, 2002). Calcium salts of fulvic and humic acid from cave formations under grass-covered surfaces furnished some of the first records indicating that the Solar Constant has changed over time and that it is almost as important as the astronomical cycles in affecting global temperatures (Shopov 2003).

The Younger Dryas was followed by a ~3.5 degree Centigrade temperature increase (Vacco 2003) and drier conditions nearby beginning about 10,900 years ago (Briles, 2003).The temperature increased even more at higher elevations (Porinchu, 2002) in the Sierras, suggesting differential warming of higher elevations – perhaps resulting from a solar cycle. Summer insulation was greater than before or after this period, thus summers were drier and winters were colder. After 9,000 BP, astronomical cycles caused summer sunlight energy to decrease and winter sunlight to increase (Tattershall 1999). As a result, the northeastern Pacific subtropical high pressure system weakened, defusing monsoon circulation, resulting in more drought. A stalagmite from the central California coast indicates cooling started at 8,000 BP, in part as a result of the sun no longer being closest to the sun during summers in the Northern Hemisphere (Serefiddin 2003).

Peak warming was from 7,500 to 5,000 BP. Charcoal washing into the cave probably occurred to near the end of this fire-prone period. Cool, wet conditions starting about 4,500 years ago allowed fir and spruce (Picea) to become more abundant, resulting in lower fire frequency than before. Modern forests of Doug-fir (*Pseudotsuga*) and true fir (*Abies*) likely were established by around 2,100 years ago near the elevation of the Monument (Briles, 2003). Fire frequency increased in the area approximately 1,000 years BP, the same time as the Medieval Warm Period (1080 to 1200 AD). Likely from higher solar luminosity as a result of greater sunspot activity, warming also occurred in Europe, the Sierras, and the Rockies - though not in the Southeast (Briles 2003), suggesting again that higher solar luminosity affected higher elevations and perhaps latitudes more than lower elevations or latitudes.

Since there seems to be little or no evaporation occurring in the lower part of the Caves prior to 9,500 years ago (Vacco 2003), most of the directional cave popcorn in that area (such as between the Ghost Room and Miller's Chapel) may be largely formed due to the loss of carbon dioxide on one side of the popcorn rather than loss of water through evaporation. However, whitish cave popcorn and moonmilk likely was forming in the upper part of the Cave by about 4,000 years BP. Evaporation produced increasingly small crystals with lots of space between them (hence a whitish color) while acidic dew also helped produce a whitish color in these formations.

Aside from a few observations of temperature, the first quantitative studies of airflow (relative humidity, wind, temperature) in the cave began in the early 1970s (Eide 1972). Much more detailed studies were done in the late 1970s by cavers from a National Speleological Society chapter (grotto) and in the mid-1980s by Aley and Aley (1988).

3.3.2 Carbon Dioxide

Sampling of air in the cave indicates the carbon dioxide is about double in most places compared to the surface. Active dome pits in summer may have up to four times the concentration compared to the surface.

3.3.3 Radon

Radon daughters are atoms produced by the radioactive decay of radon. They adhere to dust and can deliver much alpha particle energy to lungs when inhaled. Studies of uranium miners in the 1950s and 1960s indicate that radon caused lung cancer, although there were other carcinogens, such as diesel exhaust and rock dust, in uranium mines. Moderately high concentrations of radon occur in caves with silicate sediments and low airflow. Consequently, those areas in the Caves with the highest radon are the areas between blackout lights and the end of the Connecting Tunnel, and the Ghost Room. The areas with the lowest radon are those areas with good airflow and near entrances, that is, the old (pre-1933) tour route between the main entrance and the 110 Exit.

3.4 SUBSURFACE HYDROLOGY

Cave hydrology at the Monument is summarized by Meiman (1996), the National Park Service (1998), and Salinas (2001-2, 2004). Water presently mainly gets into the cave through four ways, with water moving through vertical cracks (especially in the upper part of the cave) likely being the largest volume, through dome pits being the second most important in volume, through one or several surface streams being the next most important source and through bedding planes that have been faulted along the same orientation as the bedding planes. During formation of the cave, the last source was likely the most important.

Part of the stream comes from water seeping into the cave from Upper Cave Creek. The source of the upper part of the stream (Ghost Room) comes, in order of importance, as seepage through sediment-filled former entrances, faults, joints, and bedding planes. In the lower part of the cave, bedding planes may be a more important water source. Compared to the stream in the Ghost Room, there is less dissolved calcium in the water that leaves the cave. This and relatively high amounts of dissolved silica indicate that most of the water enters the stream between the Ghost Room and lower cave and it comes from a largely non-marble drainage (Upper Cave Creek). Therefore, unlike the Ghost Room stream, it is dissolving most of the year except during low flow in July (drought) and April (water still frozen?)

Based on surface geologic mapping, a fault that determined the major location of the surface drainage may shunt water past the cave through highly permeable parts of the fault. The difference between the fairly flat profile of the River Styx and the profile of the rest of the Caves suggests that the integration of the River Styx with the rest of the Caves was recent stream piracy. Also the water in River Styx has less dissolved calcite than water in most of the rest of the cave, suggesting that that there is only a weak water connection between the two areas and if both parts of the cave started forming at the same time, the lower part should have larger rooms than the upper part. In the fall of 1992, flow went down to just a few gallons per minute, the lowest ever recorded. It usually is 1.3 (spring snowmelt) to .2 cubic feet (before first fall rains, usually October) per second or 602 to 90 gallons per minute).

Waterflow in River Styx peaks in April or May, declines rapidly until August, then declines slowly or increases slowly depending upon surface precipitation during the fall. Surface rainfall increases flow after a lag of 24 to 36 hours (Salinas 2001-2, 2004).

Much of the water in the cave now comes from snowmelt in the largest meadow in the Monument. Flourescein dye takes about 50 hours for some of it to travel 1,000' from the surface to the stream exiting the cave. Despite summer long droughts, the stream runs all year, a result of water retention in old-growth, bedding planes, and in glacial silts above and in the Caves, a big "sponge" that keeps lower passages wet all year. Within a few months of the start of the summer drought, water drains through most cave passages within about 150 feet of the surface but below that passages remain wet year round because water from previous winters is still arriving.

Flooding in November of 1974 began in the cave 24 hours after a major rainfall. The water rose over a foot over the trail in Watson's Grotto. Flow usually increases within about two days after rain begins in the lower part of the Caves **(**Salinas 2001-2, 2004)**.**

Around twelve thousand years ago and during older deglaciations, silts and gravels shaped by frost heaving and meltwater raised the level of surface streams and the water table and, perhaps with glacial ice as well, blocked cave outlets to the surface and the deeper cave passages. Gravels were deposited in the cave during initial entry of surface streams into the cave and then, as exits were plugged or partly plugged by the gravels, slackwater silts and some volcanic ash were deposited during major floods on top of the gravels. Reopenings dumped gravel on top of some of the silts. Since the last Ice Age, reduced water flow and the cutting of surface streams below much of the cave has largely stopped enlargement of the Caves.

Less is known about other subsurface water patterns compared to patterns in the Cave. Presumably, compared to the marble, the top of the zone of saturation is higher in the less permeable rocks of the Monument such as the argillite and granitic rock. Five small springs begin and flow most years in the Monument. The first becomes Upper Cave Creek. Most of these springs are feed by shallow groundwater moving along short flow curves and most occur where different rates of water flow in different adjacent types of rock forces water upward. Judging by the amount of dissolved calcium and water volume, the Caves and the next largest spring (near trail below Chateau) are likely coming from deeper groundwater with less angled flow curves. The main non-cave underground flow appears to flow in vertical joints of the first twenty or thirty feet of bedrock and then may largely move along steeply angled faults and bedding planes. Dye tracing indicates fairly rapid flow through poorly sorted sediments, as is the case with Upper Cave Creek.

Fire suppression (Agee 1991) likely has reduced water inflow into Oregon Caves due to an increase in evapo-transporation from a much higher density of small trees and shrubs than what would have occurred under prehistoric conditions. For example, chloride concentrations in rainwater and in the cave suggest that evapo-transporation over the main cave is over 90% in the summer. The overriding evolutionary pressure in cave-adapted animals in wet caves is to conserve energy, leading to the loss of waxy coverings (cuticles) and limb and body elongation (making finding food more efficient) (Culver 1995). These adaptations, though, make cave-adapted animals more susceptible to death by desiccation. Less waterflow into the cave likely results in reduced habitat for such animals, especially after winter rains. An ongoing study of water infiltration rates and chloride concentrations should answer whether prescribed burns on the surface increases waterflow into the cave.

3.5 SUBSURFACE BIOLOGY

3.5.1 Species Summary

A list of species from the Caves has been compiled as result of work by various biologists (summarized in Crawford 1993), by Dr. Crawford (1994, 1996) analysis of pit trap collections, by Dr. Tom Aley on diatoms, bacteria, and green algae in the 1980s, by microbiologist David Fuller in 1997 and by three mycologists from 2001 to 2003 (Carpenter 2003). Dr. Stewart Peck (2003) has determined that one beetle species known only from the main cave is likely to be found in nearby soils. A species list for Oregon Caves is in the attached Subsurface Management Plan and contains at least 260 live species. There are at least 78 likely species (mostly parasites of bats or woodrats) and 22 fossils or subfossils.

The list includes; amphibians (1 species, 4 fossils or subfossils); Ants (2 species); Bacteria (>24 species); Beetles (>13 species); Birds (2); Bristletails (2); Bugs (1, 2 likely parasites); Caddisflies (2 or > 2); Crickets (3); Diatoms (>22 species); Fleas (44 likely species); Flies (21, 1 parasite species likely); Fungi 59 (Carpenter 2003); Green Algae (7), Harvestmen (5); Mammals (28, most Recent fossils or sub-fossils); Millipedes (6); Mites (15, 17 parasite species likely); Moths (4); Mollusks (2); Pseudoscorpions (1); Reptiles (5, all except 1 fossils or subfossils); Spiders (8); Springtails (13); Worms (1, 14 likely parasites);

This compares with the 290 or so species from one of the most diverse if not the most diverse known cave fauna known in the world, Mammoth Cave. This diversity likely is related to the high diversity of subsurface and surface animals in the Monument's bioregion (DellaSala et al. 1999), as well as the geologic age of the bioregion. At least in terms of number of species per square area of cave, the Caves' list is one of the most extensive of compiled lists for a cave. However, judging from species ratios in other parts of the world, more work needs to be done as the list likely is very incomplete, especially with regard to bacteria, archaea, worms (flatworms, nematodes, parasites, annelids), and groundwater crustaceans.

The following illustrates the value of scientific studies on the Monument's cave species and the need for park rangers and others to be well trained in order to better interpret the Caves biology in its simplicity, diversity, and significance.

Groundwater crustaceans and annelids have not been sampled in Oregon Caves but have been observed coming in through dome pits. Diversity is likely to be low to moderate due to the limited accessibility of habitats, the relative homogeneity (that is the small number of different habitats and potential niches) of the environment and the low nutrient nature of most natural groundwaters. However, diversity can be moderate due to low competition with insects, ecological partitioning, barriers to migration that induce isolation-speciation, and even temperatures that decrease extinctions (Sket 1999).

Compared to the higher energy and acidity on the Earth's surface, subterranean habitats protect life from weather, competitors, predators and asteroids, preventing extinction and preserving traces of life. Most processes are slowed down, minimized or simplified – metabolism, competition, reproduction and evolution - thus facilitating great opportunities to study life's processes.

Subterranean species have developed many strategies to make a living, highlighting evolutionary processes. They often save energy, manage to live longer and have more efficient reproduction (few large eggs and long term caring of young). Many subterranean species have reduced or have eliminated eyes, pigments; and waterproof body coverings (cuticles) and in caves or large conduit groundwaters have developed long limbs, bodies, and antenna for running into food more quickly. Species may be stubby (if they are burrowers) or vermiform (worm-like) if they move between sediment particles. Loss of aggression, teeth, eyes, wings, size, pigments, and the development of water conserving skin coverings saves energy in order to survive the food-poor environment of most subterranean habitats. However it also prevents animals from leaving subterranean habitats because they can't fly, can't see, can't eat well, can't stay wet, can't protect themselves from the sun, or otherwise can't out-compete competitors topside. Stuck underground with small populations, they keep evolving into new endemics provided enough barriers exist between populations, as is the case with terrestrial cave species. That's because an individual with a new mutation is not as liable to dilute that mutation out of existence if he or she only interbreeds with a small population over successive generations rather than breeding with many individuals. The result is that those species confined to caves (troglobites) have the highest reported level of endemism of any taxonomic or ecological group of organisms in the United States (Culter et al. 2003).

Knowing the age of a cave can reveal how fast its endemic lifeforms are evolving. Caves present evolutionary experiments in travel, birth and death - repeated thousands of times – enabling us to learn about similarities, differences, and sequences, by showing us which animals got there first. Many groups in the Caves are derived from groundwater or soils and so tend to be primitive genera existing before the breakup of the supercontinent of Pangaea about 200 million years ago. Others from Australia or eastern Asia may have rafted here on mini-continents. Marine amphipods may have been trapped by incoming rock blocks, with subsequent evolution and adaptation to freshwater.

The size of a cave is critical in respect to evolution of some life forms. Large caves, as well as more caves per area, both increase biodiversity. Although there are not many caves in our region, those that do occur are found in short marble blocks under high water pressure, ideal for acidic water to dissolve out many passages with many habitats because the passages vary widely with respect to distance to the surface and this affects seasonal water flow, evaporation rates, organic concentrations, etc. The longer a cave is, or the more caves there are, the more likely animals are to find refuge during catastrophes, thus escaping extinction. A larger number of entrances in mountain caves versus low lying caves introduces more organics which may be crucial in preventing extinction during extended droughts. The Oregon Caves is big enough to provide refuges from competition, freezing or flooding, thus slowing extinction. Yet the Caves is also small enough, so that isolated populations are able to mutate into new species – as the mutations aren't diluted out of existence by interbreeding with larger populations.

The simplicity of most subsurface environments reduces most evolutionary selection pressures, resulting in more obvious adaptations to the few remaining pressures. Subterranean habitats yield many interesting adaptations to the darkness and lack of food. Woodrats sniff urine and cheek-scent trails. Cave crickets', amphipods' and springtails' elongated or enlarged antenna orient to: airflow, mates, and humidity, respectively. Planthoppers, salamanders, and amphipods evaluate more vibrations or chemicals than do their surface cousins. Some bats don't bother hunting after sensing a barometric drop, probably because so few bugs fly in storms.

In subterranean habitats, low migration, extinction, and population growth is often revealed more clearly than are such processes on the more complex, faster, and continuous surface. Physical parameters and boundaries are easily measured because the parameters don't vary as much as on the surface and because the surrounding rock clearly delineates habitats in both large passages and tiny cracks. Interactions among species in a food pyramid can best be studied when individuals are few, as in most subterranean habitats. In terms of cave adaptations, the Caves are in between areas to the north with many trogloxenes and areas to the south with the same species being troglophiles because the increased organics enables them to live in caves all year. Cave migrants find fewer competitors or predators, thus are more likely to escape extinction than are their surface brethren.

Unfortunately, the evolutionary strategies that made subterranean species successful also make them more vulnerable to human impacts. Due to climate change, fire suppression, and deforestation, the area above the Cave has more shrubs and relatively fewer big trees. The more numerous shrubs use more water than the trees do, so less moisture makes its way into caves, depriving the skinny animals trying to survive below. U.S. cave extinction is 1% per century, a hundredfold faster than averaged rates of extinction in the fossil record. Other adaptations, such as long life spans, make subterranean species more likely to absorb pollutants and accumulate them. This is similar to how old-growth forest species are at risk. Because many surface animals are at the top of long food chains; toxins become progressively more concentrated as they move up food chains. Many subterranean animals eat detritus that can be from these animals, thus concentrating pollutants even more. In addition, surface species capitalize on human impacts by utilizing organic matter or pollution brought into caves by humans. For example, the lights in the caves cause algae and bacteria to grow. Generally being more aggressive, faster or more numerous, surface species can then out-compete cave species. Excess nutrients can also resulting in explosions of groundwater bacteria, thus clogging nutrient and oxygen flow for crustaceans. Low birth rates and the inability to travel far prevent cave species from rebounding after depopulation.

Our region has at least 30 endemic cave arthropods, not surprising as caves may hold more rare animals than anywhere else. The Sierra Nevada and Klamath-Siskiyous were a single mountain range during the Jurassic reign of the dinosaurs. If rejoined, the combined regions hold enough species to be one of the six hotspots of cave biodiversity in the US. This number is increasing due to migrants, newly evolved endemics and low extinction rates. This region and the Appalachians hosts some of the highest levels of surface biodiversity in the U.S. Caves in both places may have afforded protection 65 million years ago from a meteor strike and subsequent fiery rock fall, forest burning, nuclear winter, and subsequent super-hot climate. Or, since mountains increase biodiversity because of their high geologic, climatic, and topographic diversity, both areas have even higher biodiversity than most other mountains since the Klamaths-Siskiyous and Appalachians are among the oldest extant mountain systems in North America. The Ice Ages also killed surface species but were mild enough here to leave cave survivors, as in certain springtails, ice crickets, beetles, crickets, and mites.

3.5.2 Bats

In part because of the length of time in which bat surveys have been done at Oregon Caves (Allbright 1959), the main investigator of bats in Oregon Caves for the past three decades considers the Monument's main cave as the most important bat research site in the Pacific Northwest (Cross, personal communication 2001)

Nine of the fifteen bat species found in Oregon occur in the Oregon Caves. Most bats seen by the main trail are big eared Townsend bats (*Corynorhinus townsendii*) (especially in winter), Yuma Bats (*M. yumanensis*) and long eared myotis bats (*M. evotis*). The other six species are the big brown bat (*Myotis fuscus*), the California myotis (*M. californicus*), Western small-footed bat (*M. ciliolabrum*), silver-haired bat (*Lasionycteris noctivagans*), the little brown myotis (*M. lucifugus*), and the fringed myotis (*M. thysanodes*). Because studies of the bat populations at Oregon Caves started so early and have continued, Oregon Caves has longevity records for three species and is the best studied bat population in the Pacific Northwest.

Trapping using harp nets (less damaging to bats than mist nets) in 2002 shows the long-eared myotis as the most abundant (55%), followed by the Yuma (17%) and long-legged myotis (12%). Ratios and total counts (about 700) in 2002 were similar to past years. Although the Exit Tunnel has less use, all 8 species and more males (80% of total) were found there as opposed to the more heavily used 110 Exit which had only 6 of the species and 74% males. Males probably spend more time in the cave than females, presumably to increase their chances of breeding (Cross & Shoen. 1989; Cross 1976, 1988; Cross &

Waldien 2002-3).

The Townsend's big-eared bat may be a glacial relict as they may have moved into near-freezing caves during the last glaciations (Humphrey and Kunz 1976). They prefer caves with near freezing conditions, apparently because this slows down their metabolism so they don't have to expend too much energy reserves. This preference may be why they were not as common in the caves during the warm winters of 2002 and 2003 compared to previous years, a possible impact from global warming. More bats come into the cave during very cold periods, perhaps because at that time their usual inside-tree-bark roosts don't provide enough insulation.

Most bats in Oregon Caves use the cave as a late-night roost and come to the cave after foraging or roosting in other places. This pattern is accentuated in late-summer and early-fall, ostensibly when breeding occurs. On June 12 of 2002 the peak of activity occurred during the first hour, presumably because the bats were day roosting in the cave on that day.

Until 1998 the Oregon Caves were open year around. This had a negative impact on the bats, because once hibernating, bats are very susceptible to disturbance. When bats hibernate, their body temperature drops to around the same temperature as the ambient (surrounding) air. Just the presence of researchers' body heat in small caves raises the temperature enough to wake them. If woken too often, bats can burn off too many calories, thus losing body heat and dying.

New bat friendly gates were installed in the winter of 2002-3 at the main entrance and the 110 Exit. At the 110 exit in fall, 80% of the bats present are males, waiting for the females to come in and mate. Females only come in once, but the males hang around and wait for the next easy catch.

Most tree roosting Oregon bats roost under bark or inside the tree, though two species, the silver haired bat and the hoary bat roost directly in foliage. Some of these tree roosters like caves though, and come in to hibernate. Most bats in the region don't use caves but instead use large trees that have been dead for a few years so that the bark is partly detached. So, because of logging of old growth trees, disturbance of nest sites, and pesticides, most bats in the region have been declining.

3.5.3 Rare Habitats

Three subterranean elements contain rare habitats: 1) caves, 2) groundwater near the top of the zone of water saturation, especially springs, and 3) soils and talus above groundwater in all units.

First, although there is one large and at least six small caves in ORCA, these nonetheless constitute a small map view portion if cave areas are projected vertically to the earth's surface (and an even smaller portion across the ecoregion). Within Monument caves, rare substrates or distinctive habitats include packrat middens, bat guano, twilight zones, ice deposits, streams, and dark zones deep in caves. Packrat middens have many *Neotoma* ectoparasites and commensals restricted to such habitats, especially certain beetles, fleas, and true bugs (Clark & Sankey 1999). Packrat middens, like the ice deposits and deep cave zones (Poulson. 1992), are also reservoirs for determining the effects of climate change on biota (Betancourt et al. 1990). Bat guano may host guanophiles, including rare and/or regionally endemic beetles, mites, millipedes, and/or moths (Franklin 1978; Poulson 1972) as well as more widespread fungi, flies, and bacteria (Fletcher 1984). Twilight zones are refugia for water-loving taxa in areas now dominated by hot, dry summers (Crawford 1989, 1994). It is unknown whether cave ice deposits form a distinct habitat (such as for grylloblattids and certain flies and spiders) or whether they simply contribute to the refugia nature of some twilight zones. Twilight zone species made disjunct (populations of the same taxa outside their normal geographic range) by climate change include certain crickets, harvestmen, and grylloblattids. Underground streams in ORCA have very low macroinvertebrate diversity, mostly microbes, epifaunal caddisflies, and endemic water mites likely from overlying hyporheic zones. Dark zones also contain low macroinvertebrate diversity but at ORCA have a high bacterial diversity and narrow-endemic rate of troglobites and troglophiles, especially millipedes, springtails, beetles, pseudoscorpions, and spiders.

Secondly, the underground interstitial habitat with the highest diversity is likely to be the area around the top of the zone of saturation as this area is diverse in microbes (Chapelle, F.H. 1993; Gounot 1994) and is utilized by both terrestrial interstitial fauna and aquatic stygobionts that depend on a predictable and usually slow rise and fall of groundwater levels. Terrestrial animals killed by rising water levels are eaten by aquatic stygobionts (usually crustaceans and archannelid worms) while the reverse happens when water levels fall (Gibert et al. 1994). The rarest of this habitat type is likely to be found in peridotite/ serpentine due to the rarity of these rocks near Earth's surface and because serpentine mobility and montmorillonite clays likely seal up most fracture zones. Low amounts of organics from overlying soils may reduce biodiversity in these and granitic areas, compared to areas under different soils, but likely indirectly contribute to higher endemism. However, fewer regression/transgression cycles in the bioregion, compared to the Eastern US, and greater connectivity, compared to terrestrial species in caves, has resulted in few species, especially endemics. Widespread species include groundwater worms and crustaceans like bathynellids, copepods, and amphipods (Notenboom 1991).

Thirdly, rare aquatic infaunal habitats include the hyporheic with the most varied grain sizes. Active hydrothermal sites near Oregon Caves likely contain rare or even Cascades-endemic bacteria and archaea but probably have fewer endemics than longer lasting hydrothermal areas such as the Oregon-Yellowstone hotspot or sites over plate subduction in New Zealand. The extent of macroinvertebrates is largely unknown. Due to fewer mineral energy sources, microbial diversity and endemism is likely to be lower in the relict hydrothermal zones in ORCA. Hyporheic fauna in ORCA appear to be all or mostly widespread species, mainly stoneflies, mayflies, midges, diatoms, worms, and fewer beetles, rotifers, dobsonflies, alderflies, and copepods (McElravy &. Resh. 1991). The highest hyporheic biodiversities are likely in low-elevation streams with the greatest diversity of particle size and ecotones between the hyporheic and "true groundwater" and between upwelling and downwelling zones (Dahm & Valett. 1996; Fraser & Williams 1996), most of which is not present in the Monument. Hyporheic water mites have a biodiversity, relic, and endemic hotspot in the bioregion (Cook 1974).

Fourthly, ORCA soils have regional endemics, such as two beetle families and a bristletail genus only from the Western US, and a millipede family known only from ORCA. Species adapted to Western cold and droughts are moving east as climates globally have become drier and colder in the last ten million years. Rapid evolution of fungi completely underground is an adaptation to increased drought. This and the high host diversity of conifers and "saprophytes" results in more subsurface fungi species than nearly anywhere else, likely more than 50 at Oregon Caves National Monument. Some are likely to be regionally endemic and in rare habitats if they are associated with endemic trees such as Sadler's oak.

However, many or most of these taxa are either relics or have speciated due to low migration rates, not because they are in rare soil habitats. Sandy soils from granitics form a distinctive habitat for California harvester ants, ant lions, and sand wasps but are not rare. Well developed soil profiles, good aggregate structure, and/or moderate organics that support proturans, diplurans and symphylans in the lowest soil layers are rare to nonexistent in the Monument. There are rare and disjunct bryophytes (Norris, et al. 2004) and several regionally endemic plants on calcite-derived soils in the bioregion but it is unlikely that Monument soils have a distinctive habitat for fauna or fungi.

However, rare soil habitats include serpentine/ peridotite soils. Narrow endemic megascolid worms, springtails, and *Calcina* harvestmen (Ubick et al. 1989) are known from serpentine and/or granitic soils south of ORCA. Talus is a rare habitat but mostly contains terrestrial species that seasonally or diurnally use the talus, as trogloxenes use caves, for shelter or other purposes. One exception is the Del Norte salamander, a regionally endemic vertebrate. It stays within talus most of its life. Lastly, burrows are common except perhaps for aplodontia burrows with their unique fleas and possibly other taxa.

3.5.3 Species of Special Concern

Definitions: 1 = critically imperiled because of extreme rarity or because it is somehow especially vulnerable to extinction or extirpation, typically with 5 or fewer occurrences

2 = Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction (extirpation), typically with 6-20 occurrences

4 = Not rare & apparently secure, but with cause for long-term concern, usually >100 occurrences.

Critical – Species for which listing as T. or E. is pending; or those for which listing as threatened or endangered may be appropriate if immediate conservation actions aren't taken

Uncertain – Animals in this category are species for which status is unclear

Vulnerable – Species for which listing as threatened or endangered isn't believed to be imminent & can be avoided with continued or expanded use of adequate protective measures & monitoring.

Species of Concern – Formerly C2 Candidate Species. These generally are species that are either declining or are inherently rare but for which there is not sufficient data to determine whether they should be petitioned for listing.

S1 – Oregon Department of Agriculture rank – Only 1-5 known occurrences in state – Critically imperiled in Oregon

S2 -- Oregon Department of Agriculture (DOA) rank – Imperiled in Oregon
G3 – Oregon DOA rank – Rare, threatened or uncommon throughout its range
G4 – Oregon DOA rank - Not rare, apparently secure throughout its range

State or Federal Listed Species Recorded in the Monument's Subsurface since 1950

	Federal Status	Past OR Nat. Heritage	2004 OR Natural Heritage
Silver-haired bat (Lasionycteris noctivagans)	Species of Concern	Uncertain	S4 – Not rare in Oregon
Western small-footed myotis (*Myotis ciliolabrum)*	Species of Concern	Uncertain	S4 – Not rare in Oregon
Long-eared myotis (*Myotis evotis*)	Species of Concern	Uncertain	S4 – Not rare in Oregon
Fringed myotis (*Myotis thysanodes*)	Species of Concern	Vulnerable	S2 – Imperiled in Oregon
Yuma myotis (*Myotis yumanensis*)	Species of Concern	Uncertain	S4 – Not rare in Oregon

Long-legged myotis (*Myotis volans*)	Species of Concern	Uncertain	S4 - Not rare in Oregon
Pacific western big-eared bat (*Corynorhinus townsendii t.)*	Species of Concern	Critical	S2 – Imperiled in OR G4 – Globally not rare

Populations of most or all of the bat species at the Monument may be fairly stable. Although a 1995 study showed a 50% decline in bats from the 1980s, a study in 2002 concluded that this may have largely the result of bats now using the 110 Exit where they were not sampled in 1995. Observations of bats in the Monument and a weekly collection of bat guano from bat houses adjacent to the Monument indicates that the most surface activity occurs during warm or hot summer nights at elevations below that of the Monument.

3.5.4 Fossils

Near the top part of the cave is a series of rooms that terminate in some dome pits blocked off at the top. These may have been alpine-like vertical pits that were filled in with glacial sediment. Before that happened, jaguars, black bears, grizzlies and bats entered the cave nearby. Other bones, paw prints, and claw marks suggests that this was an active denning site for some time. One bone, likely those of a grizzly, was radiocarbon dated at over 50,000 years old, the oldest known grizzly in North America. A jaguar bone has been dated at 38,600 years old (Seymour 2003). Two radiocarbon dates near present entrances indicate that these entrances most likely formed within the last ten thousand years.

A paleontologic study by Dr. Mead from 1999 to 2001 (Mead 1999; Mead et al. 2000) identified at least one other important fossil sites in the cave. The possible bones of the mountain cottontail (*Sylvilagus nuttallii*) indicate that the vegetation and/or the climate 1,945 to 1,535 years before the present (based on charcoal radiocarbon dating) may have been different as this species does not occur at the Monument but just to the east.

3.5.5 Microbes

Although probably neither more common nor more diverse than microbes found on the surface, microbial deposits in Oregon Caves tend to be more visible than those on the surface. Such deposits include moonmilk, manganese/iron patinas, hydrothermal pyrite, bacterial/algal fossils in wallrock, and lichen-like actinomycetes. Archaea may have been present during the formation of hydrothermal pyrite found in the Exit Tunnel. While most organics ultimately come from "eating" sunlight, cave microbes utilize other energy by oxidizing iron, manganese, sulfur, sulfate, and hydrogen sulfide. In this way, bacteria can "eat" the iron and manganese, leaving black stains on the rock at Oregon Caves (Potter & Rossman 1979).

The park inventoried some of the microbial deposits of minerals in Oregon Caves. Dust and evaporation near cave entrances concentrate the acids eaten by actinomycete bacteria. A powder called moonmilk then forms because there isn't enough acid left to keep calcite in solution. Other cave deposits include rust from sulphide-eating archaea, desert varnish from manganese- and iron- "eating" bacteria, lichen-looking spots from other actinomycetes, and microbes within other cave animals. Together they illustrate that microbes surpass all other lifeforms in regard to biodiversity, ecosystem functions, invention of all major metabolic pathways, geologic age, biomass, and practically everything else that is important ecologically or evolution wise. Microbes produce most of the acids that dissolve out caves in the first place. They also create fulvic acids that cause cave calcite to glow under a blacklight. Higher temperatures and rainfall increases the fulvic acid and so past climates can be determined back to half a million years ago.

Microbes are almost as important on the surface but are more obvious and so can best be interpreted in plant and soil-free caves. It is likely that most of the world's biomass is underground, as are nearly all archaea and bacteria. Most culturable (those that grow on agar or other growth medium) bacteria sampled in Oregon Caves in 2000 have only been identified down to genera. As DNA fingerprinting indicates that the ratio of culturable to unculturable bacteria and archae may be 1 to 12,000, there are likely more species of microbes in Oregon Caves than all the other cave critters combined.

3.6 CULTURAL RESOURCES

3.6.1 Overview

Although, it is likely that the cave was known to Native Americans, the main cave was found by a dog and a hunter (Elijah Davidson) in 1874. Major development of the cave trail began around the turn of the century (Burch & Burch 1884). This included construction of two tunnels, deepening of the trail to allow walking rather than a fair amount of crawling, and the first lighting system in the 1930s. The trail was paved in the 1950s. With the possible exception of the tunnels and marble steps, both mostly constructed around the time of the Civilian Conservation Corp, there is little historic integrity to the trail system as so much has been added or taken away since the turn of the century. Still, objects such as the marble steps in the Caves need to be further evaluated by subject matter experts to determine how significant historically such objects are and if they qualify for national historic status. A cultural landscape report documents how the aboveground National Historic District is an integral part of the history of development and exploration of the Caves.

3.6.2 Archeology

A general inventory of most rooms in the cave from 1993 to 1996 and an archeological survey started in the summer of 2003 after some surface assessments (Kritzer 2000) found no archeological remains aside from historic development of the cave trails. The nearest area of known carbonate cave use by Native Americans is in the Sierras. The known use there seems to have been the removal of calcite by the use of hammerstones. Unless artifacts are found in Monument caves, it is unlikely at this time to differentiate such possible usage from vandalism of the last century. Oregon Caves has few walls suitable for Native American pictographs or petroglyphs and no such rock art has been found.

3.6.3 Historical

The Cave was extensively vandalized around the turn of the century. Cave formations, hereafter referred to as "formations", include speleothems that result from deposition, bedrock and fill features, and speleogens that result from solution. At least 1,000 formations, especially delicate small-diameter stalactites, were broken near the 731 meter (2,400 feet) paved trail and there has been no detectable growth on most of the broken stalactites within the last hundred years. However, most of the Cave away from the main tour route is in a more pristine condition except for sediment compaction, where tubular stalactites come or came close to the floor of the Cave, the possible loss of transportable speleothems such as cave pearls, where mud has been tracked around on routes, and where small delicate calcite crystals occur or did occur in small pools or other concavities on the floor of the Cave.

3.6.4 Visitor Use and Experience

Visitation at Oregon Caves National Monument has been relatively stable over the past decade, with an average of about 90,000 visitors per year. This is a modest decline from the 1980s and an almost 100%

decline from the late 1970s. Peak visitation occurs in July and August. A visitor survey conducted in the summer of 1995 indicated that 94% of peak season visitors took the tour of the cave as part of their visit to the Monument.

The same study indicated that 87% of respondents reported some degree of crowding on their cave tour, with most feeling moderately crowded. Ninety-eight percent of respondents felt that tour group size should be limited (Rolloff et al. 1996). The reduction of tour sizes from 17+ to 16 (including the tour guide), longer times between tours, and longer cave tours starting in 2001 seems to have appreciably affected this perception as a 2002 survey (Hoger, Littlejohn & Hollenhorst 2003) reported only 35% of visitors feeling at least somewhat crowded. 78% of respondents said that tour group size should be limited. Most visitor groups (83%) felt the maximum number of people on a tour should be 15 or under.

A visitor use survey in 2003 (Hoger, Littlejohn & Hollenhorst) showed few major changes in visitor use patterns. Twenty-eight percent of visitor groups were groups of two; 42% were groups of three or four. Most visitor groups (74%) were family groups. Forty-six percent of visitors were aged 36-60 years and 29% were aged 15 or younger. International visitors, comprising 6% of the total visitation, were from Canada (42%), Germany (18%), and 8 other countries. United States visitors were from California (38%), Oregon (34%), Washington (10%) and 32 other states.

Eighty percent of visitors reported that this was their first visit to Oregon Caves NM. Mostgroups (60%) spent three or four hours at the monument. Forty-five percent of visitors spent one day in the Illinois Valley area.

Prior to this visit, visitors most often obtained information about the Monument through friends, relatives, or word of mouth (36%), maps/brochures (31%), and the Oregon Caves NM website (30%). Most visitors (60%) were aware prior to visiting that Oregon Caves National Monument is a unit of the National Park System. When asked what management option they would prefer if the current tour size had to be reduced in order to protect the cave resources, charging higher prices for longer tours was cited by 40% of visitor groups. “Other” options listed by respondents were having a short and a long tour with separate prices, reservation only tours, and tours of different parts of the cave.

When asked their primary reason for visiting Southwest Oregon, 36% were traveling through Southwest Oregon and 20% of visitors said Oregon Caves was their primary destination.

On their visit, the most common activities were taking a cave tour (96%), visiting the Chateau (56%) and hiking (33%).

Seventy-eight percent of groups were taking their first Oregon Caves cave tour. When asked about the current cave tour fee, 91% of visitor groups felt the fee was “about right.” Forty percent of visitor groups would use a reservation system for cave tour tickets if it were available, but 36% would not.

The most used services by the 318 respondents included the restrooms (95%) and park directional road signs (85%). The most important service was the restrooms (84% of 295 respondents) and the best quality service was the Illinois Valley Visitor Center (76% of 67 respondents).

Most visitor groups (96%) rated the overall quality of visitor services at the Monument as "very good" or "good." No visitor groups rated the overall quality of visitor services as "very poor." In comparing Monument cave tours to previous experiences, 49% of visitors rated them as more informative (49%), interesting (45%), or enjoyable (50%) versus the 4%, 5%, and 4% of visitors who rated them as less informative, interesting, or enjoyable, respectively.

Based on the recommendations in the General Management Plan, cave tours changed from being concession-guided to being ranger-guided in the spring of 2001. There appears to have been increased satisfaction with cave tours from both analysis of visitor comments and when visitor use studies from 1995 (Rolloff, Johnson & Shelby 1996) and 2003 ((Hoger, Littlejohn & Hollenhorst 2003) are compared. Visitors in 1995 rated cave tours as "good" (50%) and "very good" (25.2%) whereas visitors in 2003 rated ranger programs as good (27%) and very good (69%).

HUMAN IMPACTS

Airflow: Constructing tunnels is one of the greatest human impacts on the Caves because it changed water and airflow critical to both cave-adapted species and to both speleothem and speleogen growth,. Single doors placed at the Clay Pockets and in the Connecting Tunnel stopped ice expansions damage to flowstone. Hydrothermographs and temporary second doors indicated that a second door for each area would not appreciably restore airflow further than it has been restored by the single doors. However, this should be revisited to see if second doors are warranted.

Waterflow: Any impervious structure or human-created surface (such as pavement) can have an impact on the subsurface because it prevents water entering in certain areas while concentrating it in others. In terms of caves, however, the only structure overlying known cave is a small portion of a small cabin directly overlying a small part of a small passage in the Caves. Of greater area impact is the use of drain fields. They are unlikely to greatly affect ratios of subsurface/ surface fruiting fungi as all such fruiting bodies are either on the surface or just a few inches down in duff.

Fire Suppression: This is more fully covered in the EA on the Monument's Fire Plan. It may be the first or second most important human-caused impact on the Monument's subsurface in part because it influences nearly all the Monument both on the surface and underground. The main effect most likely is less water available in the subsurface due to increased evapo-transpiration. Increased interception of precipitation by increased foliage coverage is likely a minor impact.

Carbon Dioxide: Some caves in Europe with poorer air circulation and more visitors have created large corrosion dome in the ceiling from acid dew caused by condensation of water in contact with the higher carbon dioxide from breathing. However, the amount of carbon dioxide put into the Caves by human breathing probably does not significantly the cave because its many entrances flush out the carbon dioxide quickly and no detectable increase in carbon dioxide has been detected except within a foot or two of someone breathing out.

The affect of the greater than 25% increase in atmospheric carbon dioxide caused largely by human impacts in the last two hundred years is having largely unknown impacts on the Caves. This impact likely is slowing down precipitation of calcite formations because with less of a concentration gradient of carbon dioxide between the outside and inside of the Caves, there is less efficient flushing of carbon dioxide from the Caves. Increased carbon dioxide and temperatures and the resulting increase in organics (unless counteracted by increased summer drought) predicted for the region by recent climate models of global warming may cause solution of formations because if incoming water is too acidic from increased organics or by absorbing carbon dioxide in air gaps in water flow, it may still be under-saturated with respect to calcite by the time it enters the Caves. Since the beginning of the 20th century, annual precipitation has increased on average by 10% in the Pacific Northwest (Scientific Consensus 2004) and about 1 inch in the local area (Motte 2003a). In the last fifty years, temperatures have increased about one degree in the local area (Motte 2003) and is projected by increase in the Pacific Northwest from .9 to 4.70

F. by 2020 (Scientific Consensus 2004).

Energy: Forest productivity worldwide ranges from 200-500 grams/square meter/ year. Measurements of dissolved organics in cave water in various parts of this cave indicates the amount of surface organics to underground organics ratio is 100 to 1 or 2 (Aley 1999 personal communication). The main stream in the Caves has very little organic carbon (Salinas 2003) although more was measured from dripping water (National Park Service 1989). There are organics from lint, human hair and skin flakes within one meter of the main trails. This apparently reduces the number of cave-adapted species near the trails, perhaps because less cave-adapted species can best use that energy and out-compete cave arthropods and slow growing actinomycetes. Compared to most surface environments, most caves have little food or other types of energy. Caves usually lack much wind, light, ice, or organics. Thus, fragile crystals, jaguar bones, and species with low metabolism can persist underground. Foot traffic, lights, lint, and tunnels are high energy/food impacts on caves. Visitors bring in skin flakes, dust, spores, and detergent-rich lint; all this helps grow non-native plants.

Global Warming: The deeper rock within the cave has a relict temperature several thousand years old, while global warming has increased the temperature of the larger rooms because there is not enough rock near enough to cool air entering the cave. The temperature of the lowest part of the cave has also increased since 1916 (41 F.) because it is so close to the surface and therefore lacks insulating rock thickness of deeper parts of the cave. Understanding past climates in Oregon Caves helps managers predict what future changes may occur (Clark 2002).

The mean temperature of the outside during the last twenty years is 47.5 F. while average cave air and water temperature (which is the mean of the outside temperatures at some point in time) now is 42.5 F. This cannot be solely from global warming as the mean increase in the Puget Sound area was 1.5^0 C. in the last century and 1^0 C. in the Pacific Northwest and local areas in the last fifty years, (Mote 2003a-b). That means the River Styx is now a cold spring - meaning a spring with temperatures appreciably below mean annual atmospheric temperature. Streams will increasingly have decreased flows in lat summer and higher flows in winter ((Scientific Consensus 2004). This increases the possibility of debris flows, one of which in 1964 almost destroyed what is now a National Historic Landmark. Warming also may increase the metabolism of cave insects so much that they starve. Drier summers are likely to increase tree vulnerability to insects, disease, and fire.

Like the effects of increased evapo-transpiration from fire suppression, drier summers also creates air pockets in rock, allowing for increased acid through absorption of carbon dioxide before water enters the cave. Increased waterflow in winter also will likely increase solution rates. Add increased atmospheric carbon dioxide (30% more in last 100 years) and the effects of fire suppression and this could increase solution in the upper part of the cave and deposit more calcite in the lower part. Areas of active moonmilk formation have decreased in the last 15 years and this may be related to warmer average temperatures in winter.

Lint: Over a pound is deposited in Oregon Caves every year. Differences in lint accumulation result from the rate of lint decomposition, wind patterns, distance from the trail, and body movements. More lint falls on stairs as people descend them. Over 90% of the lint likely falls within the first 4’ on either side of the trail. The lint here shows less than 5 percent wool or cotton fibers (normal clothing ratio of organic to synthetic fibers is 1/1), suggesting that natural fibers decay rapidly in the cave. Increased nutrients can result from disturbance of mud (increased surface area of nutrients for microbes), and deposition of organic particles from visitors (hair, skin flakes, lint).

Based on lint collected in Carlsbad Caverns (Yett, Bill & P. Jablonsky, 1995) and Oregon Caves, the amount of particles from the annual expected number of visitors (400) would be about 2.1 grams. Having visitors shake their clothing and brush their hair before entering the cave would further mitigate this minor effect. Some caves in semi-arid areas are likely to be more affected by increased organics from visitors because more lint appears to be shed in dry caves compared to wet ones. The difference between natural inputs and human-caused inputs is greater in drier caves than in caves such as in the Monument, with its 50 to 45 or so inches of rain per year. Dissolved organics measured in Oregon Caves in the early 1990s indicate substantial natural input of organics near the paved trail. Organic-rich mud and silt that has accumulated alongside the trail in the last six years has been removed during cave restoration; new buildups will be studied to determine where the material is coming from.

Microbes: Studies of pool bacteria indicate that those nearest the trail are not adversely affected by human impacts such as lint. This may be because the amount of natural input of organics in Oregon Caves pools is high relative to the amount of human impact, unlike many other western caves. Contrast this with cave slime bacteria, which look like small dots of white lichens on ceilings above the largest tree roots in the Cave. The only bacteria found so far in Oregon Caves cave slime is probable *Azotobacter*. Other cave slimes in other caves have yielded *Actinomycetes* bacteria, the same genus often found in moonmilk. Oregon Caves cave slime likely depends on small amounts of organics and are very slow growing compared to pool bacteria. They apparently are affected by being near the trail, perhaps being out-competed by other bacteria that can best use the extra organics near the trail. An ongoing study of the DNA biodiversity in cave sediments is not so much affected by cavers causing sediment compaction as by the amount of organics and water.

A bacterial study in 2000 identified seven genera of bacteria commonly found in subsurface habitats as well as human-associated bacteria found on some of the railings in the cave. A 2002 to 2004 study has found some differences in microbial diversity between human-compacted sediments and non-compacted sediments. Twenty species of microfungi, most of which are commonly found in surface soils, have been identified from the cave in one study and 49 additional species were found in the Cave in a second study. One species found on lint probably was brought in by visitors. DNA work has so far not found any archaea or fungi in cave sediments. Five species were found in moonmilk and seven species were found in woodrat (*Neotoma*) feces.

Paleontology: Other areas of the cave including the caving route have been sampled for bone material. Old newspaper and more recent anecdotal accounts indicate that some bones have been moved around in the cave and some have been taken from the Cave without curatorial documentation.

CHAPTER 4 – IMPACTS OF ALTERNATIVES

This section presents the environmental consequences that could be caused by implementation of the alternatives and allows a comparison between alternatives based on standardized impact topics.

Methodology

Relevant studies, articles, input and site visit reports from affected agencies (NPS and USFS) were consulted to predict magnitude, scale, duration, cumulative effects, taxa-specific, and other likely effects of potential impacts to park resources and to update the methodologies, especially those involved in cave restoration, education, inventory, and monitoring in the subsurface management plan. The most important references are cited in this document's bibliography while others are listed by discipline (cave management, archaeology, geology, paleontology, climatology, bats, insects, etc.) and by locale (states) in bibliographies on Canadian and US caves maintained by the Park. Annotative lists of all known and some likely to occur species in the Caves and from other caves north of Mexico are also available from the Park.

Impact Intensity

For this analysis, intensity or severity of the impact is defined as follows:

Negligible – The impact to the resource is barely perceptible, not measurable and confined to a small area. Negligible impacts would not result in impairment of that particular Park resource.

Minor – Impact to the resource is perceptible and measurable, but is localized. Minor impacts would not result in impairment of that particular Park resource.

Moderate – Impact is clearly detectable and could have appreciable effect on the resource.

Major – Impact would have a substantial, highly noticeable influence on the resource on a regional scale.

Duration

The duration of the impacts in this analysis is defined as follows:

Short term – Impacts that last one year or less.

Long term – Impacts that last longer than one year. With the exception of some impacts from research studies and from actions or non-actions subsequently found likely to cause impairment, all impacts identified in this document are likely to be long term.

Cumulative Effects

The Council on Environmental Quality (CEQ) regulations, which implement the National Environmental Policy Act, requires assessment of cumulative impacts in the decision-making process for federal projects. Cumulative impacts are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions (40 CFR 1508.7)." Cumulative impacts are presented at the end of each alternative discussion.

Impairment of Park Resources or Values

In addition to determining the environmental consequences of the preferred and other alternatives, NPS *Management Policies* and Director's Order 12, *Conservation Planning, Environmental Impact Analysis and Decision-Making*, require analysis of potential effects to determine if actions would impair park resources.

The fundamental purpose of the National Park System, established by the Organic Act and reaffirmed by the General Authorities Act, begins with a mandate to conserve park resources and values. NPS managers must always seek ways to avoid or minimize, to the greatest degree practicable, adverse impacts on park resources and values. However, the laws do give managers the discretion to allow impacts to park resources and values when necessary and appropriate to fulfill the purpose of a park, as long as the impact does not constitute impairment of the affected resource or values. Impairment is an impact that, in the professional judgment of the responsible manager, would harm the integrity of park resources or values, including opportunities that otherwise would be present for the enjoyment of those resources or values. An impact to any park resource or value may constitute impairment. However, an impact would more likely constitute impairment to the extent it affects a resource or value whose conservation is:

- Necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park unit;
- Key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park; or
- Identified as a goal in the park's General Management Plan or other relevant NPS planning documents.
- Necessary because the resource or value is nationally or globally significant

Impairment may not result from NPS management activities, visitor activities, or activities undertaken by concessionaires, contractors and others operating in the park. Based on the best and most comprehensive information currently available, none of the alternatives proposed in this document are likely to cause impairment of park resources. A determination of impairment is made for each natural and cultural resource impact topic analyzed in this document.

Assessment of Environmental Impacts of Alternatives

Impacts of Alternative A – No Action (minimal subsurface management)
This would likely result in moderate impacts that would include increased touching of formations from visitors, increased vandalism, and increased impact from algae and bacteria growing around lights.

Air Quality: The average person's exhalations release about four percent carbon dioxide in about 800 cubic centimeters. The number of people under all alternatives would remain relatively consistent with historic levels of about 60,000 annually. There would be no or negligible change in air quality under the no action alternative. However, the lower part of the cave may be impaired due to changes in airflow from an artificially enlarged 110 Exit. Also, impacts may include a doubling of carbon dioxide or a heating effect of up to 3^0C. (Baker & Genty 1998). However, given the values of past atmospheric measurements, the high airflow, and relatively constant or declining visitation of the Caves, neither effect is likely to be so extreme in the Caves.

Cave Formations: Two broken cave formation surveys and comparison with a historic graffiti database indicates that few new graffiti sites become established and up to a few cave formations broken every five years. Both types of vandalism seem to occur in areas where the tour guide and most members of the group are not visible, as at some right angle turns of a cave passage. All previously broken formations would not be digitally photographed and marking surveys done to determine that no formations have been broken. Therefore, new breakage would not be detected and so no further protective measures would be implemented.

Cultural Values: The cave is listed as a historic classified structure due largely to the presence of historic signatures in the cave, and the marble steps and pathways which were largely established by the 1930s. Lack of removal of grit from the trail curbs every two years would increase the wear rate of marble steps and this will increase the likelihood of visitor and staff injuries. Medical evacuations from the cave are likely to impact cave resources. Without good training, the amount of vandalism overlain over historic signature might slightly increase. Under this alternative further removal of objects with no cultural integrity or eligibility for historic listing would not occur.

Education: There would be a reduction in the training of park interpreters especially in regards to subsurface management, conservation, and science. This would most likely result in a slight reduction in compliance from park visitors and a reduction in the appreciation and subsequent advocacy for protection of park resources.

Mineralogy: There would likely be less replacement and/or increased control (shutting off) of hot lights that might alter calcite to aragonite or increase deposition of cave popcorn.

Safety – There would be no actions such as scouring steps to increase traction or having certain emergency equipment in the Caves. The promotion of safe caving practices would be lessened due to less effective training.

Sediments: Not removing compacted dirt trails would not offset additional compaction impacts of dirt trails by the public or park staff. Understanding of where human-caused sediments are occurring in the Caves would be reduced and therefore it would be even less likely that adverse impacts on such sediments would be mitigated or prevented. Without that understanding, it is slightly more likely that cave restoration might inadvertently remove undisturbed sediments.

Special Status Species: Few bats along the route has been observed to respond to loud noises although it seems reasonable to assume that talking, lights, and/or a combination of body movement and lights has disturbed some bats adjacent to the paved trail. In Arizona, maternity colonies of a bat species not present in Oregon Caves increased the number of takeoffs and landings, and generally increased activity levels when there was talking during cave tours. Light intensity also increased bat vocalizations (Mann et al. 2002).

With less well-trained staff, tour participants would more likely talk, shine flashlights, and use flash photography, all of which impact at least one species of bat in the Caves. The timing of public tours is designed to have tours impact less than 10% of the winter high bat populations (average count of 40) visible from the trail. In other words, the cave is closed to tours at times when bat populations are most likely to be along the trail, from early December to late March. However, under this alternative, there likely would be some additional disturbance as there would be fewer studies to determine how best to conduct tours with minimal impacts on bats and when would be the best dates for both starting and ending tours.
For example, under this alternative lights would not likely be moved or reduced in intensity in order to reduce disturbances on bats.

Water: The previous asphalt trail and galvanized handrails (removed from 1993-1997) may have affected water quality. However, a test for long chain hydrocarbons in 1991 and on in 2003 (Salinas) indicated that little if any of the more toxic, but less soluble, aromatic hydrocarbons remain in the Caves. One test in 1993 indicated high levels of zinc in cave water, perhaps from the galvanized railings, but subsequent tests have shown very low levels of zinc. Some small pools of water immediately adjacent to the paved trail do show higher total dissolved ionic concentrations than the rest of the cave's water, but this affect does not appear to extend further into the cave or to the cave's main stream. Future changes could not be evaluated under this no-action alternative.

Wildlife: Past trapping of macro-invertebrates along gradients perpendicular to the paved trail suggests that the effects of trampling and other human impacts extends to less than 10% of cave populations. However, the only way to determine this conclusively and scientifically (at the 95% confidence interval) would be to conduct an intensive mark and release program. Such a program could adversely affect invertebrate populations (Dr. Jerry Lewis, personal communication). Also, there are no prevalent and abundant cave-adapted animals that could be effectively marked with current technologies.

In the early 1970s, the amount of human visitation in the Caves was more than double current yearly estimates. Energy use from electric lights along the tour route, and resultant algae growth, was higher than it is today. Algal growth for that period has been estimated at four times the average coverage compared to present day levels. This is primarily because tours are no longer given during the winter and a new lighting system installed in 1996 illuminates much less of the Caves than did the old system. No control of algae and bacteria would dramatically increase growth and impacts on cave formations and cave life.

Given the proportionately large number of known endemics in Oregon Caves, it is unlikely that major impacts from visitors would have extirpated or caused the extinction of few if any species. Consequently, it is unlikely that current visitation patterns under all alternatives (except possibly the no-action alternative) pose that risk. Biological studies indicate that most species take longer than 10,000 years to evolve so the endemics within Oregon Caves likely survived the freezing of at least the upper part of the Cave and extensive flooding prior to 10,000 years ago (Turgeon 2001). If they could survive such impacts, then they would be likely to continue to survive current, less severe human impacts predicted under all alternatives, with the possible exception of continued fire suppression or global warming. Most studies of what is causing the ongoing global mass extinction point to loss of habitat as the main culprit.

The lost-habitat causes of human-caused extinction in US cave species are changes in water level, closure of cave entrances, aquatic pollution, and decreases in bat guano as food for cave species (Roth, 1999; Elliott 2000). No such effects would occur from the proposed actions or non-actions.

Long-Term Impacts: Skin oils blacken formations and grit on hands wears down or polishes cave formations. Minimally trained tour guides likely would lead to increases of these impacts and such impacts would not be addressed by cave management in this alternative.

The impact of global climate is a long-term impact. Since impacts seem to be occurring now in terms of desiccation and higher cave temperature and it is unclear what some of these impacts are, minimal subsurface management could result in impairment from both ignorance and non-action.

The amount of moonmilk formation may continue to decrease but with this alternative, the cause of this decline would not be discovered.

Indirect Effects: Under this alternative, whether prescribed burns are reversing fire-suppression impacts in the Caves could not be evaluated.

Cumulative Impacts: For alternative A, there might be a slight increase in organics due to electric lights or particles shed from clothing, skin, and shoes if yearly visitation increases. Since the cave is wet most of the year, it is likely that most of the organics are oxidized from year to year. Without mitigation actions, there might be a major buildup of organic-rich mud along the trail. Coupled with global warming effects on the cave, no control of algae and bacteria would result in a buildup at least comparable to the 1970s and early 1980s when many formations were green along the tour route.

Conclusion: Alternative A (no action). Under the present ranger-guided tours, tour schedule, and visitation levels of about 61,000 visits to the cave per year, the extent of human impacts on and adjacent to cave trails affects park resources or values via noise, bats, increased organics, accidents, and vandalism. Human impacts on the rest of the subsurface are largely from the effects of fire suppression and anthropogenic changes in the amount of snow pack. Based on the present state of knowledge of Monument processes, the extent, duration, and intensity of human-caused impacts, and comparisons with other subsurface areas, impairment of Monument resources is unlikely to be happening now or in the next twenty years. However, with little monitoring in this no-action alternative, it would be more difficult to determine whether or not major impacts are occurring, compared to the other alternatives.

This alternative is not the environmentally preferred alternative because cave restoration would not be available to assure "aesthetically and culturally pleasing surroundings." Without understanding the cave's geo-ecologic processes, the Monument also would be unable to "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences" because certain uses such as caving tours could not be evaluated effectively and therefore would not be allowed. Alternatives B and E probably provide the widest range of beneficial uses while adopting Alternatives A or E would likely reduce the Park Service's ability to detect undesirable and unintended consequences of human actions, including management actions.

Impacts of Alternative B (preferred) – (Increase the Emphasis on Subsurface Management but Balance the Emphasis on Subsurface Research and Non-Research Actions*)*

Although this is the preferred alternative, the reduced emphasis on surface management under this alternative could result in reduced understanding of cave processes because of the many connections between the surface and the Caves and the present limited understanding of which surface processes are most important in affecting cave processes. Emphasis would be given to understanding the impacts of management actions, such as cave entrance cross-sectional restoration, cave gates, emergency toilets, replacement of lights, and the allowing of paved trail and off-the-paved-trail tours such that only those actions with the greatest potential for restoration of natural processes and with minimal negative impacts themselves are carried out.

Air Quality: The changes in carbon dioxide and heat levels represented by differences in tours, research and mitigation in the Caves would be negligible or immeasurable within the Caves. Even if a change was measurable, the higher concentrations are not high enough to change community structure, as may have happened in some caves with at least a ten-fold increase in carbon dioxide (Howarth 1993). Studies in other caves indicate that, with moderate airflow, carbon dioxide from up to 1,000 people in a cave does not measurably change carbon dioxide concentrations.

The electrical lights in the cave consume about 15,000 watts per day during the regular schedule of tours in the summer months. Body heat from humans could be considered as a very minor factor. However, changes in body heat effects from humans under the proposed action would be virtually immeasurable due to the very small increase in numbers of people in the cave under this alternative. Further, installation of compact fluorescents along the paved trail route has already reduced heat output and has reduced impacts during replacement of bulbs.

Exhalation likely increases the average humidity in the upper parts of the cave during the summer because relative humidity sometimes falls below 100%. However, any additions are more than likely to be offset by increased dryness in the cave due to decreased surface water infiltration resulting from vegetation increases caused by decades of fire suppression.

Particulates from skin, clothing or shoes could increase atmospheric condensation (“cave fog”), but this has only rarely been observed in Oregon Caves and it is not likely to be from people, as it normally occurs near entrances with natural aerial particulates or areas in the cave where cave air masses are mixing, as in Miller’s Chapel and the start of the Ghost Room.

Radon has been measured along the paved tour and proposed caving tour per current NPS protocols. Based on past radon, carbon dioxide, and airflow measurements, it is unlikely that high amounts of radon will be detected anywhere on any sizeable section of the cave where human would be exposed to its effects for any significant amounts of time. However, with less recordkeeping under this no-action alternative and likely alteration to NPS radon limits in the future, the projected number of tour-guide hours per guide could some day exceed current NPS maximum working level limits.

Cave Formations: Features that could be damaged by deliberate vandalism include coarsely crystalline calcite clusters at the end of the Sand Room, quartz palettes near the start of the Sand Room, clay vermiculations, and small diameter tubular stalactites. The likelihood of both deliberate and accidental damage to cave formations would be decreased by having the park staff better trained.

Cultural Values: Despite an archaeological survey of the entire Monument in 2003 and more limited surveys in the 1960s (Davis 1963), and 2000, there is no evidence of Native American use or artifacts in the cave. Comparisons with the location of cave use in the Sierra Nevada indicate that it is unlikely that Native Americans would have ventured far into the cave to leave impacts that would be presently detectable. There are no historic artifacts or built features along the proposed caving route.

Education - As recommended by the GMP and in accord with comments received on scoping during management plan revisions, the park has increased the tour length from 60 to 75 minutes to 90 to 95 minutes in part in order to allow for sufficient stops in the cave for detailed interpretation and the reduce the perception of crowding.

Mineralogy: There would likely be more replacement and/or increased control (shutting off) of hot lights that might alter calcite to aragonite or increase deposition of cave popcorn.

Paleontology: The cave has been intermittently sampled for macrofossils and microfossils and bone fragments by Dr. James Mead of Northern Arizona University and by Dr. Richard Toomey of Kartchner Caverns. It is likely that some bone underlies most of the trails in the cave. Some bones could be further impacted by visitors being led by less trained park staff.

Safety – This alternative strikes a balance among safety concerns or actions (such as scouring steps or having certain emergency equipment in the Caves), the efforts to understand how best to promote safe caving practices, and effective and conservation training in cave rescues. However, efforts to study a less impacting alternative to scouring what may be culturally significant steps would be reduced.

Sediment Compaction or Translocation: Any further increases in compaction from the controlled use of dirt trails in the Caves would be mitigated by the use of flags and flagging to guide caving participants within a two-foot wide trail and by the continued removal of compacted trails during cave restoration. Compaction and release of organics might reduce aerobic microbial activity and increase anaerobic activity (methanogens, hydrogen users, nitrifying bacteria), but it does not seem likely that any further compaction would greatly affect cave biology. Determination of human *E. coli* microbes or DNA would not be determined as often under this alternative so there can be less assurance that cave trails are not contaminated with human wastes. Changes in DNA along the trail would not be studied every five years, or the proper time interval determined by a microbiologist, so a determination could not be made that off-paved trail tours are not causing significant impacts.

Under this alternative better studies of where lint and other human-caused sediments in the Caves would allow for more efficient collection and removal of such sediments from the Caves.

Human wastes have caused impacts in other caves and in this cave along the main paved route. Under this alternative, rangers would be less likely closely supervise the tours and provide adequate emergency containers to insure that no urine, feces or vomit is left in the cave. This alternative also would allow for the installation of several emergency toilets in the cave that visitors can use without safety or privacy concerns. The toilet would be taped such that their use would be obvious and human wastes would be taken out of the Caves within 24 hours.

Special Status Species: With better trained staff, tour participants would be less likely to talk, shine flashlights, and use flash photography, all of which could impact bats. Under this alternative, there likely would also be reduced disturbance as there would be more studies to determine when would be the best yearly dates for both starting and ending tours.

Water Quality & Quantity: Without adequate training of guides, visitors may be more likely to drop flashlights off the tour route. Since there were be no recovery of these items under the no-action alternative, heavy metals could leak into cave water. Under this no action alternative, the extent of groundwater contamination would not be studied and ways to reduce this contamination would be less likely undertaken.

Wildlife: Invertebrates could be stepped on accidentally. One such instance was reported in which a visitor on the paved pathway stepped on a Pacific Giant salamander. The incidence rate for this type occurrence on the basic cave tour has been extremely low, even with well over 50,000 persons taking this tour per year. More small invertebrates may have been stepped on and not observed. Studies of caves in Mt. St. Helens National Monument in Washington and the Organ Cave system in West Virginia indicate that the effects of trampling on invertebrates is only measurable where visitation is high, such as Washington's Ape Cave (Senger and Crawford 1988; Carlson, 1991; Jim Nieland, personal communication, 2001). A no-action alternative would not affect this appreciably.

In all of the proposed alternatives, some cave invertebrates move away from the lights and vibrations of the paved trail. Although this is a measurable impact, the percentage of the cave affected is likely to be too small to adversely affect populations as a whole.

Under this alternative, two controls of non-native cave species would be used, hydrogen peroxide (Faimon et al. 2003) and sodium hypochlorite bleach. The amount of treated cave surfaces and the speed of re-colonization would be measured. Probably a mix of the two types of controls would be chosen that had the least concentrated impact on cave resources and the most effect on the non-natives. When used by itself and if bleach enters the River Styx it can cause changes in pH (McCrea 1987).

Under this alternative, cave gates would be replaced with less impacting materials and would only be replaced if there was no major impact on animal migrations such as bats. Before and after studies of bat activity would be undertaken so that new gates put in to protect cave resources from human activity will not have a major impact on bat activity.

Visitor Use: Visitor groups in 2002 were asked, "On a future visit to Oregon Caves NM, what subjects would you and your group like to learn more about?" The most popular subjects included cave animals (70%), geology (58%), and fossils (52%) (Hoger et al. 2003). Completion of inventories under this alternative would increase the amount of information on these subject areas.

Under this alternative and with subsequent required approval, park management would have the option of charging on a trail-length basis higher prices for long tours and a lower price (both compared to the current standard rate) for shorter tours to the 110 Exit. This would be continued in subsequent years if it could be shown that such fee arrangements reduced impacts on the Caves, did not turn away a sizeable section of the visiting public from seeing a part of the Caves, and increased choices for the public.

Long-Term Impacts: Skin oils blacken formations and grit on hands wears down or polishes cave formations. Well trained tour guides should decrease these impacts.

The impact of global climate is a long-term impact. Since impacts seem to be occurring now in terms of desiccation and higher cave temperature and it is unclear what some of these impacts are, it would be most prudent to balance research with other management actions such as installing air restrictors.

Indirect Effects: Under this alternative, a synergy between a balance of studies and management actions would indirectly, through research, increase the effectiveness of management actions in reducing the possibility of major human-caused impacts.

Cumulative Impacts: Particle buildup and increased organics on the caving route would likely be insignificant and not measurable. Human inputs of carbon dioxide (exhalation), body heat, and heat from lights are unlikely to be cumulative due to natural airflow in the cave and the tiny incremental increases of temperature and carbon dioxide from those objects. Trail sediment compaction would likely be slightly cumulative at diminishing returns but the effect is likely to be minor (that is, very localized although possibly measurable). Changes on wildlife populations would likely not be cumulative. Given the slow renewal of cave formations under the current cave climate, damage to cave formations or fossils could be cumulative but of minor or negligible effect as it is not expected that the damage, if any, would be measurable.

Mitigation: As detailed in the Monument's most recent general management plan, tour size should be reduced to 15 people (including the tour guide). Although this would likely result in increased time for visitors waiting to go on a tour, there is public support for this action. A survey (Hoger et al. 2003) asked "On a future visit, would you and your group be willing to tolerate a slightly longer wait for the cave tour in order to provide better protection of the cave?" Most visitor groups (70%) were willing to wait a little longer, 14% were not willing and 17% were "not sure."

More lasting and less impacting video documentation and marking of broken formations would be undertaken under this alternative.

Conclusion (Alternative B): Under the present ranger-guided tours, tour schedule, and visitation levels, of about 61,000 visits to the cave per year the extent of human impacts on and adjacent to cave trails affects park resources or values via noise, bats, increased organics, accidents, and vandalism. A maximum increase of about one percent from caving tours is very unlikely to substantially increase impacts to Monument resources and certainly will not be greater than mitigation offsets under this alternative, such as dirt trail removal to reduce overall sediment compaction in the cave. Human impacts on the rest of the subsurface are largely from the effects of fire suppression and anthropogenic changes in the amount of snow pack. Based on the present state of knowledge of Monument processes, the extent, duration, and intensity of human-caused impacts, and comparisons with other subsurface areas, impairment of Monument resources is unlikely to be happening now or in the next twenty years.

Due to the greater emphasis on subsurface management, a more equal balance among research, mitigation, prevention compared to the other alternatives, and an understanding the impacts that these and others are having on the Caves, alternative B provides the highest level of protection among the alternatives listed in this document. In other words, management actions and feedback that evaluates such actions are both needed and need to be balanced on a case-by-case basis in order to reach resource management goals and objectives.

This alternative is the environmentally preferred alternative in part because cave restoration would insure "aesthetically and culturally pleasing surroundings." With an understanding the cave's geo-ecologic processes, the Monument also would be able to allow low impact uses so as to "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences". Alternatives B and E probably provide the widest range of beneficial uses while adopting Alternatives A or E would likely reduce the Park Service's ability to detect undesirable and unintended consequences of human actions, including management actions. Alternative B would also "preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity, and variety of individual choice." Alternative B and E may provide the greatest variety of individual choice but Alternative B does the best preservation overall because it strikes a more even balance among mitigation, restoration, and prevention and understanding the impacts that these human actions and others are having on the subsurface.

Impacts of Alternative C - Decrease Emphasis on Subsurface Management**.**

Air Quality – The impact would be similar to Alternative B except for negligible changes in carbon dioxide and temperature. However, the ability to document changes in the Caves from such impacts as global warming would be reduced.

<u>Cave Formations</u> – There would be fewer studies and mitigation of human impacts.

<u>Cultural Values</u> – There would be fewer studies and mitigation of human impacts. Since no archeological sites are known in the cave, unless some of the historical features along the paved route are considered archeological because they are underground, impacts on archeological resources would likely be negligible.

<u>Education</u> – In this alternative, detailed, and accurate interpretation would be lessened because of less training or auditing by cave management staff of tour guides.

<u>Mineralogy</u> - There would likely be less replacement and/or increased control (shutting off) of hot lights that might alter calcite to aragonite or increase deposition of cave popcorn.

<u>Paleontology</u> – The rate of inventorying and (if needed) added protection (gates, air restrictors, flagging, motion detectors, etc.) of sites inventoried would decrease.

<u>Safety</u> – There would be fewer actions such as training in by individuals from OSHA, National Cave Rescue Commission and regional caving groups, scouring steps to increase traction, or having the right emergency equipment in the Caves. This is likely to result in more frequent and extended rescues from the Caves and this would likely increase human impacts on the Caves.

<u>Sediments</u> – The effect is likely to be minor (very localized although possibly measurable). Removal of exiting compacted dirt trails that more than offset additional compaction impacts of dirt trails by the public or park staff would be reduced. Understanding of where human-caused sediments are occurring in the Caves would be reduced and therefore it is less likely that such sediments would be restored or mitigated. Without that understanding, it is slightly more likely that cave restoration might inadvertently remove undisturbed sediments.

<u>Special Status Species</u>: With less well-trained staff, tour participants would more likely talk, shine flashlights, and use flash photography, all of which has been shown to impact at least some one bat species (Mann et al. 2002). Under this alternative, there likely would be some additional disturbance as there would be fewer studies to determine when would be the best dates each year for both starting and ending public tours.

<u>Water Quality & Quantity</u> –The impact of additional lint on water quality would be negligible as most lint or other material from visitors appears to be deposited within the first 1,000 feet of entering the cave. This was based on how much sediment was cleaned on the edges of the trail in 2001-2002.

Under this preferred alternative, the extent of groundwater contamination would be studied and ways to reduce this contamination would be undertaken.

<u>Long-Term Impacts</u>: Skin oils blacken formations and grit on hands wears down or polishes cave formations. Minimally trained tour guides likely would lead to increases of these impacts and such impacts would not be addressed by cave management in this alternative.

The impact of global climate is a long-term impact. Since impacts seem to be occurring now in terms of desiccation and higher cave temperature and it is unclear what some of these impacts are, minimal subsurface management could result in impairment from both ignorance and non-action.

Due to increased uptake of water by plants, fire suppression likely has reduced habitat for water-loving species in Oregon Caves. The smaller a habitat, the more likely an animal will be extirpated from that habitat by events such as severe flooding, freezing, or decades-long drought. This alternative would not be able to address these concerns because there will be a lower probability that past data on infiltration rates and water quality entering the cave would be compared to future studies done after prescribed burn and in parts of the cave directly below both planned prescribed burns and controls.

Cumulative Impacts: Particle buildup and increased organics on the caving route would likely be insignificant and not measurable although this alternative would make it less likely that attempts would be made to measure changes. Human inputs of carbon dioxide (exhalation), body heat, and heat from lights are unlikely to be cumulative due to natural airflow in the cave and the tiny incremental increases of temperature and carbon dioxide from those objects. Trail sediment compaction would likely be slightly cumulative at diminishing returns but the effect would likely be minor (that is, very localized although possibly measurable). Changes to wildlife populations would likely not be cumulative. Given the slow renewal of cave formations under the current cave climate, damage to cave formations could be cumulative but of minor or negligible effect as it is not expected that the impacts, if any, would be measurable.

Indirect Effects: Under this alternative, lack of management actions likely would lead to an increase probability of major human-caused impacts. Without knowing the effectiveness of prescribed fires in reducing the possibility of major human-caused impacts in the Caves, there would be less incentive in doing more prescribed burns.

Mitigation: Greater efforts would be made to complete studies and initiate other management actions with the use of volunteer, Geocorp, Student Conservation Association, and student staff. However without some of the initial studies it would be difficult to prioritize actions and research so as to utilize such help efficiently.

Conclusion (Alternative C): Under the maximum proposed visitation levels of about 61,000 visits to the cave per year and assuming substantial acreage of prescribed fires is initiated within the next ten years, most human impacts on the Caves are not likely to cause impairment, that is, major and irreversible human-caused impacts of any known park resource or value in terms of sediment movement, carbon dioxide, relative humidity, aerial particulate, airflow, and temperature changes, increased organics, trampling, potential accidents, vandalism, cave restoration, research, and volume percentage of habitats. Under this alternative there would be less mitigation of human impacts and less monitoring of those efforts to see if park actions are effective in reducing the likelihood of major human-caused impacts.

This alternative is not the environmentally preferred alternative in part because there would be little or no cave restoration to insure “aesthetically and culturally pleasing surroundings.” Without an understanding the cave’s geo-ecologic processes, the Monument also would not be able to allow low impact uses so as to “attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences”. Alternatives B and E probably provide the widest range of beneficial uses while adopting Alternatives A or E would likely reduce the Park Service’s ability to detect undesirable and unintended consequences of human actions, including management actions.

Impacts of Alternative D – Increase Emphasis on Baseline and Monitoring Studies.

General: Under expected visitation levels of about 61,000 visits to the cave per year, the extent of human impacts on and adjacent to the dirt and rock trail would not be likely to cause impairment, that is, major and irreversible human-caused impacts of any known park resource or value in terms of sediment movement, carbon dioxide, relative humidity, aerial particulate, airflow, and temperature changes, increased organics, trampling, potential accidents, vandalism, cave restoration, research, and volume percentage of habitat changes.

The following list details the state of the major data sets and their major subsets. Those marked with a * are currently completed. Under this alternative, completion of major data sets and their subsets associated with the subsurface would be accelerated at the cost of reduced mitigation and prevention actions.

Air, Weather and Climate
- High Elevations
- *Low Elevations
- Cave Climate
- Paleoclimate
- Particulates
- *Radon

Fire
- Effects on Cave
- *Surface History

*Geology
- Air – See Air
- Bedrock
  - *Cave
  - *Surface
- Sediment
  - Cave
  - *Soils
- Water – See Water

GIS
- *Cave Map and Inventory Data
- *Fire
- Surface Features

Human Impacts
- Cave
  - *Broken Speleothems
  - Effects on Biodiversity
  - Fire Suppression – See Fire
  - Climate Change
  - Visitor Impact Mapping

Surface
Climate Change
Fire Suppression – See Fire
*Animal Feeding

Surface Invertebrate Species
*Stream

Nocturnal
*Moths
Beetles

Vegetation

Subsurface Invertebrates and Microbes
*Cave
Soil
Groundwater
Microbes
Archaea
*Bacteria
*Fungi

Vertebrates
*Mammals
Herps
Fish
*Birds

*Vegetation and Macrofungi
*Species
*Distribution

Water
Quality
*Cave
Surface
Wetlands

Quantity
*Cave
Surface
Wetland Distribution

Administrative History

Cultural Landscapes
Cave
Development

    Exploration
        Historic Signatures

  *Historic District
  Trails

Ethnohistory
  Concession
  Native American

Historic Resource Study

Historic Structures Reports
  *Chateau
   Chalet
   Guide Dormitory
   Information/ Comfort Station

Air Quality – There would be better documentation of changes in air quality due to global warming and the global increase in atmospheric carbon dioxide but no additional mitigations would be done, such as installing low-energy lights, emergency toilets, airlocks, or airflow reducers.

Given the impacts of global warming and without studies to determine ways to reduce light heat outputs by going to low heat lights and/or by finding ways to reduce the amount of time lights are on in the cave (either left on inadvertently or for visitor safety), elevated temperatures may be elevated from one to a few degrees from prehistoric levels. As contrasted with the other alternatives, this alternative would devote more time to finding ways to reduce the amount of lights on, as recommended in a letter received during scoping for the revision of the cave management plan (Coffman 2003). One possibility would be to have an additional control on lights, such as having a map of the cave with lit diodes showing which lights are on and having the means of turning those sectional lights off if they are inadvertently left on overnight or when tours are separated by more than 15 minutes.

Within a 25 year period, understanding of how changes in global temperatures and levels of carbon dioxide are affecting the cave would be increased in this alternative although there would be less a likelihood of mitigating such impacts such as through prescribed fires or further modifications of cave airflow with air restrictors.

Biology – A better understanding of where different species lived in the cave and what their habits were might be gained but this would be offset by possible impacts on populations and by the inability to find taxonomists willing and able to do the proper identifications.

Cave Formations – Negligible or minor affects under alternative D. The possibility of damage to park resources might be slightly reduced because there would be less cave restoration but that would be more than offset by reduced manicuring (last stage of rubble removal) and reduced cleaning of formations with hydrogen peroxide or sodium hypochlorite. Without studies to determine ways to reduce light heat outputs by going to low heat lights and/or by finding ways to reduce the amount of time lights are on in the cave (either left on inadvertently or for visitor safety), elevated temperatures may impact formations. The once complete rimstone sequence in the Rimstone Room would likely not be restored.

Under this alternative, photo-monitoring would be increased, as recommended in a letter received during scoping for the revision of the cave management plan (Coffman 2003). However, if significant impacts are detected, those impacts would less likely to be mitigated or prevented in the future.

Cultural Values – There would be a negligible affect under alternative D except that the historic signature list would likely be more complete sooner rather than later. Non-historic signatures would be less likely to be removed because it would be harder to determine if they were historic or not.

Education – Although more information on cave processes would be gained by the emphasis on research in this alternative, detailed, and accurate interpretation would be lessened because of less training or auditing by cave management staff of tour guides. Compared to alternatives A and C, there would be more literature searches and more updating of existing bibliographies and it would be more likely that such plans as a library acquisition plan would be developed and implemented.

Mineralogy – Elevated temperatures from lights that could alter mineral composition or increase cave popcorn deposition would still persist under this alternative (see above comments on air quality). There would, though, be a better catalogue of what minerals exist in the cave. One study would involve radiometric dating of quartz pebbles based on the amount of certain beryllium and aluminum isotopes. This would help trace the time that such pebbles entered the cave.

Paleontology – Negligible or minor changes under alternative D. The park would know more about the different species represented at each fossil or sub-fossil site but would not be able to protect those sites better.

Safety - There would be fewer actions such as training in safe cave practices, scouring steps, or having the right emergency equipment in the Caves. Understanding the impact of such actions or non-actions involving safety might be increased. Under this alternative and as recommended in a letter received during scoping for the revision of the cave management plan (Halliday 2003), there would be no cave rescue training prior to the completion of all studies of possible impacts of cave rescue training. This might slightly decrease the impact of training but it would also increase the possibility of damage done to the cave during a cave rescue by staff unfamiliar with how to extricate an individual from a particular cave route or how to avoid damage to the cave during such rescues.

Sediments – There would be very minor trail compaction and clay translocation under alternative D. There would be some sediment moved by people in the caves that would not be restored.

Special Status Species: With less well-trained staff, tour participants would more likely talk, shine flashlights, and use flash photography, all of which would impact bats. Under this alternative, there likely would be some additional disturbance to bats as there would be fewer studies to determine when would be the best dates for both starting and ending tours.

Water Quality & Quantity: – There would be a negligible or minor affect in alternative D compared to alternative B. The park would learn more about longitudinal changes in park water quality but would not be able to mitigate such changes if they are found to be anthropogenic. Testing for some of the less likely pollutants such as endocrine disrupters and prescription drugs would not occur.

Without adequate training of guides, visitors may be more likely to drop flashlights off the tour route. Since there were be a less likely recovery of these items under this alternative, heavy metals could leak into cave water. Under this no action alternative, the extent of groundwater contamination from a sewage drain field would be studied but ways to reduce this contamination would be less likely undertaken.

Wildlife: There would be a better understanding of populations as to their lifestyles, distributions, and effects from trampling, increased organics or noise but this would be offset by the impacts on cave populations from sampling. Because there is no current way to easily identify or mark most cave invertebrates, which is essential in population studies in order to distinguish among species, captures, and recaptures, the only way to identify and count populations so that it is scientifically valid is to kill the individuals that are captured.

Long-term Impacts: The impact of global climate is a long-term impact. Since impacts seem to be occurring now in terms of desiccation and higher cave temperature and it is unclear what some of these impacts are, minimal subsurface management could result in major human-caused impacts from both ignorance and non-action.

Cumulative Impacts: Particle buildup and increased organics would likely be insignificant and not measurable. Human inputs of carbon dioxide (exhalation), body heat, and heat from lights is unlikely to be cumulative due to natural airflow in the cave and the tiny incremental increases of temperature and carbon dioxide from those objects. Trail sediment compaction would likely be slightly cumulative at diminishing returns but the effect would likely be minor (very localized although possibly measurable). Changes to wildlife populations would likely not be cumulative. Given the slow renewal of cave formations under the current cave climate, damage to cave formations or fossils could be cumulative and this might be measurable under this alternative of increased studies.

Mitigation: Greater efforts would be made to complete management actions (other than studies) with the use of volunteer, Geocorp, Student Conservation Association, and student staff.

Conclusions of Alternative D: Under this alternative of increased studies, the extent of human impacts on and adjacent to all trails would be better measured, evaluated and contrasted in terms of sediment movement, carbon dioxide, relative humidity, aerial particulates, airflow, and temperature changes, increased organics, trampling, potential accidents, vandalism, and volume percentage of habitat changes. There would be less mitigation or prevention if such impacts are discovered or better quantified although some additional funding might be approved due to better justifications based on past research. This alternative accords with recommendations received from the public (Coffman 2003) of the need for resumption of studies at the Caves and it supports the emphasis in the enabling legislation on the “unusual scientific interest and importance” of the Caves. Under this alternative, the maximum increase in visitation to the cave would be about 610 people, an increase of one percent compared to the approximately 61,000 who visited the main cave in fiscal year 2004.

Based on the present state of knowledge of Monument processes, the extent, duration, and intensity of human-caused impacts, and comparisons with other subsurface areas, impairment of Monument resources is unlikely to be happening now or in the next twenty years. This alternative is not the environmentally preferred alternative in part because there would be little or no cave restoration to insure “aesthetically and culturally pleasing surroundings.” Although the increase in research and monitoring under this alternative might enable an earlier prediction of possible future impairment, the relative lack of mitigation and restoration may not be able to prevent or avoid such possible impacts. However, with a much better understanding of the cave’s geo-ecologic processes that likely would result under this alternative, the Monument would be able to allow low impact uses so as to “attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences”. Alternatives B and E probably provide the widest range of beneficial uses while adopting Alternatives A or E would likely reduce the Park Service’s ability to detect undesirable and unintended consequences of human actions, including management actions.

Impacts of Alternative E – Decrease Emphasis Placed on Baseline and Monitoring Studies; Major Actions Would Include Subsurface Restoration, Mitigation and Prevention of Human Impacts.

Potential environmental impacts would be similar to Alternative A except that there would be more cave restoration. There would be less literature review and consultation so ongoing cave restoration might not use appropriate and/or less impacting technologies and methodologies. Opportunities for public appreciation of caving and cave conservation would be fewer compared to Alternative B. Visitors likely would end up with a more limited understanding of the geology and human history of the caves compared to Alternative B.

Air Quality – Under this alternative, there would be negligible or minor changes in carbon dioxide, oxygen, temperature, temperature; stratification, ionic concentrations, dust levels, etc. Under this alternative, there would be less understanding of how global climate change is affecting the quality (temperature, relative humidity, particulates) of air in the Caves.

Cave Formations – Likely negligible or minor affect under alternative D but this would be much harder to evaluate. The possibility of damage to park resources might be slightly increased due to inadvertent effects from cave restoration. There would be more cleaning of formations using hydrogen peroxide or sodium hypochlorite but there would be fewer studies to evaluate the effects of such a recently recommended material for cave restoration. Under this alternative greater efforts would be made to continue to reduce the size of cave tours (as recommended by a letter answering scoping requests for input (Coffman 2003)) and this is likely to slightly decrease impacts on cave formations from touching.

Cultural Values – Negligible effect under alternative D although lower cave tour sizes might decrease marring of the historic signatures in the Caves.

Education – Less information on cave processes would be gained by the emphasis on management actions other than research in this alternative. Therefore, detailed, and accurate interpretation would also be lessened because of less training or auditing by cave management staff of tour guides. Compared to alternatives B (preferred) and D, there would be fewer literature searches and less updating of existing bibliographies and it would be less likely that such plans as a library acquisition plan would be developed and implemented.

Mineralogy: Negligible under all alternatives except possibly A. Understanding of the type, scale and duration of effects from hot lights would be reduced.

Paleontology - Negligible or minor changes under alternative D. More mitigation measures to prevent resource impacts would be offset by the inability to adequately evaluate the effectiveness of such impacts.

Safety – There would be more actions such as training in safe cave practices, scouring steps, or having the right emergency equipment in the Caves. Understanding the impact of such actions or non-actions involving safety might be decreased or stay the same.

Sediments – Minor trail compaction and clay translocation under alternative E. Compared to Alternative A, there might be some additional compaction of sediment in that part of the cave that would be traversed by cave restoration but this would be more than offset by removal of areas of compaction during cave restoration. Under this alternative of increase mitigation, there would be more sediment traps such as tarps under stairs and cement basins beside the trail and these would be cleaned out more frequently. As recommended in a letter received during scoping for the revision of the cave management plan (Coffman 2003), lint restoration largely staffed by volunteers would clean out more lint from the Caves at a more frequent interval than what has occurred in the past.

Understanding of where human-caused sediments are occurring in the Caves would be reduced compared to Alternative D. Without that understanding, it is slightly more likely that cave restoration might inadvertently remove undisturbed sediments.

Special Status Species: With better trained staff, tour participants would more likely not talk in high frequencies, shine flashlights, or use flash photography, all of which would lessen impacts on bats. Under this alternative, however, there likely would be some additional disturbance as there would be fewer studies to determine when would be the best dates in terms of reducing disturbance for both starting and ending tours.

Water Quality and Quantity – Due to increased cave restoration under this alternative, the amount of lint, human organics or mud brought in by visitors and which enters the Cave's water flow would decrease. Without adequate training of guides, visitors may be more likely to drop flashlights off the tour route. Since there were be no recovery of these items under the no-action alternative, heavy metals could leak into cave water. Under this alternative, the extent of groundwater contamination from a Monument sewage system would not be studied.

Wildlife – There would be minor or negligible changes in populations from slightly greater trampling or noise from cave restoration under alternative D. Under this alternative greater efforts would be made to continue to reduce the size of cave tours and this is likely to slightly decrease impacts on bats from noise. Due to increased cave restoration under this alternative, the amount of lint, human organics or mud brought in by visitors and affects cave populations would decrease.

Long-term Impacts: The impact of global climate change is a long-term impact. Since impacts seem to be occurring now in terms of desiccation and higher cave temperature and it is unclear what some of these impacts are, minimal subsurface management could result in major human-caused impacts from both ignorance and non-action.

Cumulative Impacts: Particle buildup and increased organics would likely be insignificant and not measurable compared to current conditions although this would be harder to measure under this alternative of reduced studies. Human inputs of carbon dioxide (exhalation), body heat, and heat from lights are unlikely to be cumulative due to natural airflow in the cave and the tiny incremental increases of temperature and carbon dioxide from those objects. Changes to wildlife populations are not likely to be cumulative although this alternative might be able to better determine that possibility. Given the slow renewal of cave formations under the current cave climate, damage to cave formations would be cumulative but of minor (if any) increased effect compared to current impacts. Such impacts might be better quantified in this alternative.

Mitigation: Greater efforts would be made to complete studies and initiate other management actions with the use of volunteer, Geocorp, Student Conservation Association, and student staff. Greater reliance would be made on studies relevant to resource management and interpretation from other caves and to species known from the Caves. However, some inventory, monitoring and other research would be necessary to ensure that Monument conditions are similar enough with such areas that some relevant conclusions can be drawn from these outside studies.

Conclusion: Under expected visitation levels of about 61,000 visits to the cave per year, the extent of human impacts on and adjacent to the dirt and rock trail would not be likely to cause impairment, that is, major and irreversible human-caused impacts of any known park resource or value in terms of sediment movement, carbon dioxide, relative humidity, aerial particulate, airflow, and temperature changes, increased organics, trampling, potential accidents, vandalism, cave restoration, research, and volume percentage of habitat changes.

This alternative is not the environmentally preferred alternative in part because, without an understanding the cave's geo-ecologic processes and monitoring of present and past uses, the Monument would not be able to allow low impact uses so as to "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences". However, increased cave restoration would help insure "aesthetically and culturally pleasing surroundings." Alternatives B and E probably provide the widest range of beneficial uses while adopting Alternatives A or E would likely reduce the Park Service's ability to detect undesirable and unintended consequences of human actions, including management actions.

Comparative Impact Summary Table

Impact Topic	**Alternative A No Action**	**Alt. B (preferred) More Cave Mgt.; Caving Tours; Cave entrance restoration**	**Alternative C Less Cave Management**	**Alternative D More Cave Research**	**Alternative E Less Cave Research**
Air	Minor: rare 1-3^0F rise	Minor: rare 1-2^0F rise	Minor: rare 1-2^0F rise	Minor: : rare 1^0F rise	Minor: : rare 1-2^0F rise
Cave formations	Minor: 1-8 marred/ year	Negligible: 1-3 marred/ year	Minor: 1-8 marred/ year	Minor: 1-8 marred/ year	Negligible: 1-3 marred/ year
Cultural	Minor/ Negligible	Minor/ Negligible	Minor/ Negligible	Minor/ Negligible	Minor/ Negligible
Cumulative Impacts	Minor	Negligible	Minor	Minor	Negligible
Education	Negative Moderate	Positive Moderate	Negligible/Minor	Negative Minor	Negative Minor
Fossils	Minor/ Negligible	Minor/ Negligible	Minor/ Negligible	Minor/Moderate	Minor/ Negligible
Minerals	Minor/ Negligible	Negligible	Negligible/Minor	Minor/Moderate	Minor/Moderate?
Safety	Minor/moderate	Minor	Minor	Minor	Negligible
Sediment	Minor	Negligible	Minor	Minor	Negligible?
Special Status Species	3-10 disturbed	3-10 disturbed	3-8 disturbed	3-15 disturbed	3-8? Disturbed
Water	Negligible	Negligible	Negligible	Negligible	Negligible
Wildlife	Minor: few tramplings	Minor: few tramplings	Minor: few tramplings	Minor: few tramplings	Minor: few tramplings?

Based on the best and most comprehensive information currently available, none of the alternatives proposed in this document is likely to cause impairment of park resources.

MITIGATION MATRIX for PROPOSED ACTIONS (Alternative B)

Potential Impacts	Mitigation Measures	Responsible Party and Critical Milestones
Sediment: Undisturbed sediments may be disturbed during cave restoration. Some material would stick to boots off the paved trails. Further compaction on the trail could occur which could alter nutrient and oxygen availability for bacteria or change water flow.	Follow procedures for distinguishing human-disturbed sediments from other sediments. Visitors and park staff will clean shoes before getting back on the paved trail. Removal and reducing compaction of other trails. Complete impact mapping	Natural Resources Specialist Physical Science Technician - Installs cleaning station by 5/1/06 Physical Science Technician Physical Science Technician – 7/1/06
Water Quality: Human debris likely increases ionic content of pools near trails. A dropped battery, human waste, or chemical control of non-native species by cave lights could degrade water quality.	All batteries would be accounted for at the end of each trip. Containers will be provided to contain human wastes. Recover dropped flashlights and other debris on paved trail. Treat human waste sites with 65% household bleach.	Install emergency toilets in cave by 7/1/05 Physical Science Technician Physical Science Technician
Fossils: Buried bones could be stepped on or trace fossils such as claw marks and tracks could be damaged.	A paleontologist will monitor possible impacts after a hundred or so visitors travel over the proposed caving route. The flagged trail and guidance from the park guides to stay on the trail and not grind one's heels into the sediment will prevent any traffic over possible trace fossils or significant damage to bones. No route will pass by claw marks or tracks.	Dr. Richard Toomey - Completes Fossil Survey of major routes by 6/1/06
Geology: Small pieces of wallrock might be knocked off ceilings by being hit by heads. Cave Formations could be damaged.	Visitors will be monitored and cautioned by park guides to watch where their heads are in relation to the ceiling, where their hands are in relation to fragile formations and not to flail legs, etc. Fragile areas will be flagged with precautionary red tape. Photomonitoring baselines and broken speleothem inventories will help detect damage to cave formations.	Natural Resources Specialist – Certifies guides prior to tours Physical Science Technician- Flagging completed by 6/1/04 Natural Resources Specialist – Inputs data into Investigator's Report by 5/1/06

Wildlife: The amount of lights may disturb both bats and invertebrates and cause algal or bacterial growth. Bats could be affected by partial closure of 110 Exit Effects of human-caused organics and trampling could affect populations	Install tarps to catch lint Develop cement catchment basins to capture human caused organics Monitoring of bats via light intensifying devices will be compared to baseline data to determine if populations are affected by temporary partial closure of 110 Exit Have visitors on paved trails walk in the middle of the trail where there are fewer invertebrates Visitors are cautioned to reduce sounds and lights if invertebrates are encountered. Red lights and no talking will be mandatory for viewing bats. Photographing of passive pitfall traps, macro-visual identification and comparison with past trap data	Natural Resources Specialist – Analyzes wildlife counts on most routes by 5/1/06 Physical Science Technician –all tarps and catchment basins installed by 4/1/07 Chief of Interpretation – Trains guides prior to tours Chief of Interpretation – Trains guides prior to tours Physical Science Technician – Anabat survey done by 7/15/04 Physical Science Technician – Bio-study begins 10/1/05 and ends 10/1/07
Safety: Traversing over pits or slick rock could pose hazards, especially for those individuals not used to such action. An injury to a visitor is likely to cause damage to the cave during a rescue. Radon might increase the probability of developing lung cancer, especially to those who smoke nicotine.	Park guides and/or visitors will be instructed by park guides on how to cave safely via use of Job Hazard Analysis sheets and other orientation materials. All visitors will be guided as to how to traverse a narrow pit safely. Helmets and long pants will be mandatory for caving trips. Because of the amount of time that park guides and visitors are allowed in the cave is limited; no limits involving Working Levels of radon will be exceeded. Smokers will be advised that taking the cave tours could increase their risk from radon.	Natural Resources Specialist – Certifies guides prior to tours Park rangers supervising caving tours. Landauer, Inc. – Reports Avg. Radon Conc. Pci/l For whole year by 7/29/05

Air Quality: Visitors deposit lint and skin cells, increase humidity from sweat, increase temperatures from human bodies, and increase carbon dioxide from breathing. Global warming may dry out cave	Remove human-caused organics from trails at least once a year. Modify 110 Exit closer to original size	Physical Science Technician – Sampling of atmospheric particulates and carbon dioxide by 7/1/07; cave restoration of entire trail each year
Cultural Resources: Historic marble steps are being worn down by grit on trails	Remove grit from trails at least once a year. Survey all parts of former trail to make sure they are not eligible for historic listing.	Physical Science Technician Steve Mark, NPS Historian – by 6/1/07

CONSULTATION AND COORDINATION

Scoping

Scoping for subsurface management alternatives was initially addressed through both the mailing of a draft cave management plan to about 20 cave managers (both government and non-government organizations (NGOs) in 1990. Few comments were received. A geologist from the Seattle Support Office of the NPS mentioned concerns about how past or planned flourescein dye tracing experiments might interfere with future tracings. The draft was also sent to several hundred subject matter experts in 1993 and portions of the General Management Plan and Environmental Impact Statement (GMP/EIS) process (public and internal) in 1996.

Several initial scoping meetings for the GMP were held in 1996 with the public, interest groups, and stakeholders and 88 letters were received during the scoping period. A total of 111 people attended public workshops in 1998, and 980 written comments were received on the draft GMP/EIS. Some comments (1998 GMP: 5, 150) supported the intent to close the Caves to the public in order to protect bat populations. Other comments stated that other cave preservation was important and should be primary over guided tours. Total numbers of people in caves should be kept to a minimum to protect bat populations and to protect the cave. But there were also some concerns about winter cave closure and the impact on area tourism particularly if the Caves were closed prior to the Christmas holidays. One commentator recommended caving tours for the public.

The Roseburg office of the US Fish and Wildlife Office commented that if seasonal cave closures are implemented, the Service encourages a statistically designed monitoring scheme to help assess whether or not closures were effective in reducing disturbance to bats and other biota at critical times of the year. This has been largely done through studies by bat researchers in 2001 and 2002 and by weekly monitoring of animals by the trail.

A comment by a caver advocated greater protection for the karst upstream of the cave (GMP: 121). Another NSS member implied that, since the Cave's biological and paleontological resources are of greater importance than what was originally thought, more attention should be focused on these resources in regards to management recommendations, scientific research needs, staffing needs, and resource protection issues (1998 GMP: 138).

A comment by a park visitor stated that there should be a limit to the amount of visitors to the Caves and restoration projects could occur during closures. (1998 GMP: 105). Restoration mostly occurs during the winter but some volunteer groups can only do restoration during other seasons of the year. Minor disruption to tours and some spreading of mud before it can be cleaned off the paved trail does occur at non-winter times but this is believed to be more than offset by the value of visitors learning about cave restoration first hand and by the restoration itself.

An internal scoping session was conducted on site with Geologic Resources Division employees Ron Kerbo (National Cave Management Coordinator), John Roth (Natural Resources Specialist), Roger Brandt (Chief of Interpretation), and Greg McDonald (National Paleontological Coordinator) in August 2001. This session focused on proposed caving tours but the resulting recommendations had much greater scope in regards to the management of Monument caves.

In Early December of 2001, a letter was sent in early May to most cavers in Oregon, Washington, and California and to those agencies and individuals on the park's NEPA list. In this letter the Park's Superintendent asked for input in the process of implementing the selected alternative of the GMP. Of the fifteen topics addressed in the letter, the first one was “Development and implementation of a revised resource management plan that will include a cave management plan, a cave restoration plan, and a cave inventory and monitoring plan.” Comments received from the public are detailed in the environmental assessment on public tours at the Monument. One comment relevant to cave management was apparent support for cleaning cave formations near the trail in the Ghost Room to get them to look white as claimed by the first known explorer in the Ghost Room.

A copy of the draft cave management plan, along with ten other files, was sent to several hundred subject matter experts in 2002. No substantive comments were received.

An internal scoping meeting was held on April 28, 2003. It was attended by John Roth (Natural Resources Specialist), Roger Brandt (Chief of Interpretation), Craig Ackerman (Superintendent), John Cavin (Facility Manager), and Kelly Donley (Administrative Officer). Written comments on the identified topics have been incorporated into this document.

The internal scoping session for the cave management plan resulted in the following list of issues or impact topics to be addressed in this document:

1. Access policies include administrative closures, use of other Monument caves, what can be brought into or taken out of the cave, and use by and/or certification of park maintenance, park rangers, volunteers, and management staff, and researchers, explorers, curriculum based education groups, service animals, and the public while traveling on and/or off the paved trail in the Monument’s main cave.

2. The appropriate security level and location of gates, locks, and security monitoring devices should be determined.

3. Safety concerns that will be addressed should include updating protocols and interpretive messages, and/or emergency operating procedures involving radon, cave travel, cave rescues, slick surfaces, spiders, rock fall, bumped heads, and where to place medical supplies and cardiac resuscitation devices.

4. Site-specific relationships and memorandums of agreement with the Cave Research Foundation, the National Speleological Society, the National Cave Rescue Commission, and other relevant groups should be developed.

5. Data management should include determining what cave objects should be catalogued into the park’s museum collections and what type of and layers of GIS and other methods of data storage, retrieval, and analysis should be used to obtain maximum benefit from present and future data sets.

6. What types of activities in the cave should be prohibited or allowed and how to encourage or discourage such activities in the cave should be determined based on the best available information on potential or actual impacts and should be modified if substantial new information becomes available. Examples include 1) sediment removal in order to continue exploration and assess outside impacts on the cave, 2) construction of lint traps and installation of light timers, both to constrain human-caused organics in the cave, 3) cosmetic infilling of holes drilled in the cave, 4) removal of human-placed wood which cave-adapted animals are dependent on, and 5) leaving lights on in the cave.

These topics and an invitation to attend two scoping meetings were included in a letter sent in early May to most cavers in Oregon, Washington, and California and to those agencies and individuals on the park’s

NEPA list. Five responses were received as a result of these letters. Most of the replies detailed the need to conduct further studies within Monument Caves.

One comment from a member of a regional chapter of the National Speleological Society (NSS) was the need to include interpretation/education in the cave management plan. The EA and the revised plan follow that recommendation. Other specific but more detailed substantive comments are addressed in the appropriate sections in the Impacts of Alternatives and Alternatives Considered but Rejected.

Scoping meetings were held in the nearby town of Cave Junction on May 29 and the nearest city (Grant's Pass) on May 30th of 2003. Four individuals attended the first meeting and no participants attended the second meeting. One commentator suggested advertising the Cave's planning process on cave management in such caving periodicals such as the NSS News.

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GLOSSARY Note: words outlined in bold are defined elsewhere in the glossary.

accreted **terrane** – a very large mass of rock at least several kilometers across which has been **tectonically** emplaced by **faulting** or **crustal** plate movement onto a large rock mass such as a continent.

accretionary wedge – Highly distorted sediments and rocks squeezed up against buoyant rock (usually a continent) by **subduction** but which are not **subducted** because the material is too lightweight to be dragged down completely.

acid dew – Also called condensation-corrosion. - Warm, moist air rising in a cave from the **geothermal** or other temperature gradients condenses on colder surfaces &, by absorbing CO2, dissolves ceilings, walls, & cave formations. Common in large vertical caves, hydrothermal caves, caves with sulfuric acid, near entrances, where warm & cold air masses mix (fogs) & where warm surface streams enter caves.

adaption – adjustment of organisms to their environment that involves development of new or better functioning structures or other improvements.

aerosol sinter - a hardened crust or coating of calcareous dust.

allogenic or allochthonous stream or drainage - Surface drainage coming off of non-karst, as in the case of Oregon Caves.

alluvial corrosion - Where greater intensity of solution is caused by water moving through sediments rich in CO2, thus increasing the ability of the water to dissolve carbonates, as in the case between the Rimstone Room and the Ghost Room and in the Wedding Cake Room.

alluvium **-** Any sediment deposited by stream, ocean, or river. Pebbles are usually rounded, unlike angular colluvium

alpine karst **-** Formed in areas of high altitude & relief. Similar to arctic karst but may have more kotlic sinks, etc. from greater snowfall.

apron **-** A smooth bulging mass of flowstone covering sloping projections from walls of caves (as in Paradise Lost) or limestone cliffs.

aspect **-** direction toward which a slope faces.

backflooding or back-flooding **-** Temporarily rising water level in a cave caused by downstream passage being too small to pass an abnormally high discharge. Creates bevels, clastic deposits, dead end passages, genetic flow, & possibly rills.

Baldacchino **canopy -** One formed when downward growing flowstone meets a water surface.

basalt – a dark-colored fine-grained extruded volcanic rock, rich in iron and magnesium, that is chiefly composed of the minerals plagioclase and pyroxene.

bedding plane – in sedimentary or stratified rocks, the division planes which separate the individual layers, beds, or strata. Cracks within them are normally created by the release of pressure when adjacent rocks are eroded.

bedrock – Primary in-situ rock as opposed to secondary deposits like speleothems, talus, etc

bell canopy – a variety of canopy which is shaped like a bell or mushroom and which forms where flowstone builds up laterally as well as vertically.

bevel – Horizontal **channel** indentation more than 3" high in walls. Develop where **vadose** standing water with an open air surface absorbs carbon dioxide and therefor corrodes faster than water further below.

bladed **popcorn** – Cave popcorn that has arranged in the same orientation and which appear as dull blades.

boxwork – minerals which originally formed as blades or plates along cleavage or fracture planes and then the intervening material dissolved leaving the intersecting blades or plates as a network projecting from the floor, wall, or ceiling.

braided stream - One with interlacing networks of channels separated by branch islands or bars. Often the result of a stream with a high sediment load. Oregon Caves most resembles three-dimensional braided surface streams and tend to form under conditions of high hydraulic head, short cave evolution times and short expanses of soluble rocks, conditions often present in temperate mountains**.**

breakdown - 1. Angular cave **detritus** > 10 cm. wide fallen into a cave room. <u>Incl</u>. block (ceiling, wall), chip, chockstone, congelifract, loose, rafted, room, and slab (ceiling, wall).

breakthrough - The great increase in erosional rates from the change from laminar to turbulent flow. Breakthrough time is how long it takes for a conduit to enlarge enough to begin turbulent flow. 10,000 to several million yrs. depending largely on length, hydraulic gradient, & initial width of cracks. It probably was fast in Oregon Caves, from 10,000 to several hundred thousand years.

breccia - a sedimentary rock formed of angular fragments of older rock and cemented together by minerals or by a fine-grained matrix. A meta-breccia is one that is metamorphosed.

calcareous - Containing calcium carbonate (CaCO3).

calcite – calcium carbonate, $CaCO_3$. Major mineral component of limestone and marble.

canopy – 1. The heights in a forest with the most leaves. A multi-storied canopy has different elevations where leaves are concentrated. 2. a subtype of flowstone where material projects laterally away from a cave wall or other speleothem. The overhanging flowstone could have formed on sediment now removed (some fill may be imbedded underneath), by meeting a water or ice surface (baldacchino canopy).

carbon dioxide - CO2, a gas usually from double to fivefold (500 to 1,500 ppm) in caves compared to the surface. Concentrations can also increase during a fire although the production of carbon monoxide during some fires is much more of a hazard.

carbonate - 1. Mineral with the anionic structure of CO3-2. <u>Incl</u>. calcite**.**

carrying capacity - Limit of human activities beyond which the system irreversibly changes.

categorical exclusion (CE**)** - an action with no measurable environmental impact which is described in one of the categorical exclusion lists in section 3.3 or 3.4 and for which no exceptional circumstances (section 3.5) exist. NPS also uses the acronym “CX” to denote a categorical exclusion.

cave – 1. a natural subterranean cavity, fissure, or tube which is person-sized or larger and which extends past the twilight zone.

cave bacon – a variety of thin, translucent drapery with parallel color banding generally caused by organics.

cave breathing **-** Periodic microscale & mesoscale wind changes that most often occur in constricted passages. Some occur from surface atmospherics, from waterfalls in a cave, or possibly from wind blowing across entrances or from gravity acoustic waves (55-70sec.) of auroral type originating in the ionosphere or by the jet stream (6-30 minutes) (Lewis, 1981).

cave crust – See crust

cave ghost **- Speleogen** caused by aqueous or condensation corrosion of speleothem. Usually opaque, chalky if by condensation corrosion (Watson’s Grotto), more translucent (just before Ghost Room) if by renewed aggression from dripping or flowing water.

cave popcorn – a nodular variety of subaerial **coralloid**.

cement **-** Precipitated material that holds adjacent grains together. Cement changes a sediment into a rock during lithification.

channel, (solution) **-** 1. Incised **karren** slots > 50 cm. wide. Narrower ones are **rills** or microrills. <u>Incl</u>. **anastomoses,** canyon, ceiling, chute, **meander, & notch (bevel)**.

chert – Hard, very dense or compact **sedimentary** silicate of quartz crystals < 30 microns wide.

chimney **-** 1. A narrow, rounded, vertical or sub-vertical shaft or small **dome pit** in the roof of a cave, generally smaller than an aven or dome pit & traversible by chimneying. A blind chimney does not reach the surface. 2. descriptions of fairly steep slopes each with a different aspect which causes fire to rapidly move upslope.

clastic **-** Pertaining to a rock or sediment mostly made up of clasts (rock fragments) that have been moved some distance for their place of origin.

clay **- Sediment** composed of particles of any composition (often a crystalline fragment of a clay mineral) < 1/256 mm or .00016 inches. Particles above this size generally do not form colloids. Clay smears & doesn't feel gritty in hand or on teeth.

closure **-** Legal restriction, but not necessarily elimination of specified activities such as smoking, camping, or entry that might cause fires in a given area.

colluvium **-** Any mixed **sediment** of soil material, cave **fill** &/or rock fragments deposited by rainwash, sheetwash, or creep

concretion **-** Concentric-layered rounded rock that is chemically precipitated in **sedimentary** bedrock. Often flattened in the same orientation as adjacent bedding planes due to faster water flow in that direction and subsequent faster precipitation and growth.

conduit **-** 1. Tubular voids >10mm in diameter or 100mm -10m. Smaller voids are sub-conduits. Sometimes the term only refers to karst conduits or is restricted to water-filled voids. 2. A subterranean stream course filled or once filled completely with water & under water pressure. Usually circular or elliptical in cross-section with the longest dimension parallel to bedding, as is often the case in Oregon Caves.

congelifract **-** Talus split off by frost action. A type of **felsenmeer**.

conglomerate **- Sedimentary** rock of rounded, waterworn fragments of rock or pebbles, cemented by another mineral. Cemented cave **fill** cannot be pulled apart with fingers.

contact **-** The junction of two different geologic **formations** or units, as in **bedding planes,** and the meeting of igneous and sedimentary rocks, or layered sediments. Most contacts in or adjacent to carbonate deposits are often preferentially penetrated by groundwater.

contact spring **-** Gravity spring where water flows to the land surface from permeable strata over less permeable or impermeable strata that prevent or retard downward moving water, as appears to be the case with the River Styx.

coralloid – a **speleothem** type which is nodular, globular, botryoidal, or coral-like in shape and which forms from thin films of water. Cave **popcorn** is a rounded, microcrystalline coralloid that forms above the water saturated zone. Subaqueous coralloids form underwater but are not common in Oregon Caves.

corrosion **-** Erosion where rocks & soil are removed or worn away by natural chemical processes.

corrosion **bevel -** Corrosion notch or **bevel** extending several meters into the rock. Creates a flat roof regardless of geologic structure. Assoc. with the **foot caves** of karst **towers** abutting alluvial floodplains or, as in Oregon Caves, at the base of cliffs.

corrosion notch **-** 1. Any substantial indentation in cave walls or cliffs. Incl. waterline notches, corrosion bevels, vadose wall notch, paragenetic wall notch. 1. **Bevel** in cave walls tapering off very steeply below a past or present waterline.

crust – the outermost shell of the earth above the mantle.

crust, (cave) **- Flowstone** (mostly) or other speleothem usually < a few cm. thick. In general, rougher, flakier, and more brittle, porous and granular than a **coating**.

crystal **-** A substance with a regularly repeating atomic pattern often expressed by plane faces, as in minerals. Recrystallization into larger crystals is common in wet speleothems.

cultural resources **-** Aspects of a cultural system that arevalued by or significantly representative of a culture or that contain significant information about a culture. A cultural resource may be a tangible entity or a cultural practice. Tangible cultural resources are categorized as districts, sites, buildings, structures, and objects for the National Register of Historic Places, and as archeological resources, cultural landscapes, structures, museum objects, and ethnographic resources for NPS management purposes.

detritus **-** Sediment of loose rock/minerals eroded off by mechanical means.

diffuse flow - Slow circulation of groundwater in **karst** aquifers where all, or almost all, openings in the **karstified** rock intercommunicate, are full of water in the saturation zone and are not big or permeable enough to allow conduit flow. Being replaced by term "slow flow." Probably occurs in Oregon Caves only in very narrow vertical and bedding plane cracks.

dike - A tabular intrusion structure that cuts across the bedding or foliation of the surrounding bedrock. Dikes with positive relief from differential solution are **petromorphs**.

directional popcorn - Points in direction of airflow.

disjunct – Populations of the same species or other taxa level which are separated by geographical areas in which the taxa does not occur.

dog(-)tooth spar - Sharp-tipped scalenohedral **calcite** crystals. Forms in Oregon Caves cave **velvet** in high humidity.

dome pit – in a cave, a rounded vertical passage or high chamber, characterized by vertical solution grooves on its walls and usually by showering water.

drapery – Often called cave drapery. Curtainlike, linear **flowstone** from water droplets running down walls or ceilings. Often wavy or folded. May have a web-like attachment to **stalactites**.

dripstone - **Speleothems** deposited by dripping water. They usually result from **mineral** deposition due to loss of carbon dioxide or water (evaporation) but they include frozen deposits like ice but not volcanic frozen deposits like lavacicles.

efflorescence - A whitish fluffy or crystalline **crust** on rock or soil where surface or wicked water is evaporated & solutions crystallized.

El Nino - As a weather cycle characterized by unusually warm ocean temperatures in the Equatorial Pacific, compared to La Nina, is characterized by unusually cold ocean temperatures in the Equatorial Pacific.

epiphreatic - Adj. for water moving through intermittently or seasonally saturated or floodwater zones above the phreatic zone.

erosion – the group of processes whereby earthy or rock material is loosened or dissolved and removed from any part of the earth's surface. It includes the processes of weathering, solution, corrosion, and transportation.

erratic speleothem - 1. Syn: eccentric. 2. Where forces of crystal growth, airflow, or capillarity dominate over gravity-driven vertical growth.

etchpits - Small, usually circular, holes one mm. to several cm. wide. **Pitting** commonly assoc. with atmospheric corrosion if on bedrock & with splashing corrosion if on flowstone. Incl. **drop dent** & **solution pit**.

exfoliation - **Erosion** of broken or peeled-off scales, lamellae, as concentric sheets from bare rock surfaces. Exfoliation **detritus** from frost action forms **felsenmeer**.

facetten - Inclined walls with a slope of about 45 degrees. Standing **phreatic** water features formed by slowly moving cells of density-driven currents. A 1-3 mm layer of relatively denser water forms above rock surfaces and flows downward at about .5 cm./s to create flow cells.

fault – a break in the earth's crust along which movement has taken place. Can both increase or decrease conduit enlargement depending on width, fault gouge concentrations, sulfide emplacement, etc. (Kastning 1977; Palmer 1988), Conjugate joints or faults are two sets formed as a result of the same stress, especially shear pairs.

fault breccia - A **tectonic** breccia of angular fragments from the crushing, shattering, or shearing of rocks during **faulting**, from friction between the walls of the fault, or from distributive ruptures assoc. with a major fault.

fault gouge - Materials generally composed of clay sized particles along a **fault**. Usually the result of movement along fault surfaces but may result from hydrothermal alteration because faults enhance movement of such fluids.

felsenmeer - **Detritus** rubble produced by frost shattering.

fill, cave - 1. Syn.: cave clastic sediment. 2. Unconsolidated, transported deposits flooring or filling a cave passage. **Breakdown** may become cemented as **breccia**, gravel as **conglomerate**.

flowstone – **Speleothem** or non-cave chemical sedimentary deposit formed by flowing or seeping water as hard coatings or cascades.

flowstone welt - Apparently from junction of different waterflows, commonly where stalagmites & stalactites join into columns.

foot caves – Those that form at the base of cliffs because of concentrations of acidic soils and vegetation there.

formation – 1. stratigraphically, the primary unit in lithostratigraphy consisting of a succession of strata useful for mapping or description generally possessing distinctive lithologic features. 2. speleographically, secondary deposits in a cave forming stalactites, stalagmites, etc., best prefixed with cave so as to avoid confusion.

General Management Plan - Also referred to as the GMP, it is the document that has gone through the NEPA document as an EIS and which outlines management actions for a National Park Service area for a 20 year period.

geothermal gradient - The rate of increase of temperature in the Earth with depth. High gradient areas are more likely to have caves of **hydrothermal** or lava tube origin.
gour - Includes **rimstone** dam & **microgour**. Syn.: rimstone pools.

gradient - The change in **hydraulic head** over a given distance with groundwater flow usually occurring in the direction of decreasing hydraulic head.

graphite – **Mineral** of native carbon, black to steel-gray, very soft. Its weakness probably helped cause faulting along bedding planes.

granite – a coarse-grained intruded rock that has a high percentage of **quartz** and potassium **feldspar**.

granitic – rocks that have similar compositions to granite, such as monzonite

grylloblattid – Members of an order of insects that likely is related to crickets and grasshoppers.

half(-)**tube -** 1. Trace of a **ceiling channel** or **tube**. Most form during incipient speleogenesis.

helictite – a spleothem type which is twisted and worm-like, and which grows via a small capillary canal at its center.

herb – A non-woody vascular plant

humic substance **-** Certain organics, usually acids such as fulvic and humic, derived from soil. Provide most color for speleothems. May be transported into speleothems as ligands binding calcium ions

hydraulic gradient – the difference in the free standing water level between one place and another. 1. The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head. 2. The slope of the water table or potentiometric surface in an aquifer.

hydrothermal water **-** Subsurface water at least 4-6o C. hotter than mean annual temperature on the surface.

hyporheic – That area of sediment under running water such as in streams and rivers.

igneous – Rock that was once molten.

imbricated **-** Angle of flat pebbles, a **sediment** structure, like shingles on a roof, point downstream.

inception horizon **-** That part of a bedrock sequence that passively or actively favors the localized inception of dissolutional activity. It is a geologic unit most susceptible to **speleogenesis**, especially to the earliest cave-forming processes. It is critical to the origin of many if not most nontectonic caves.

incised **flowstone -** Micro**karren** composed of dendritic meander **karren** or micro**rills** from flowing water re-solution.

infiltration - Discharge yield or downward entry of water through **sediment** or permeable rock.

initiation **-** The phase of speleogenesis that includes the initiation phase (which includes inception phase of laminar flow) & up to or the start of turbulent flow in the gestation phase.

inventory: The systematic documentation of cave resources, usually linked to a coordinate system via survey stations. Managers have historically used two different kinds of inventories: an inventory of caves and an inventory of the contents of caves.

invasion vadose **- Vadose** cave or cave passages created by new streams invading rock already drained during previous cave development. Incl. vertical shafts.

island arc – curved chain of islands, generally convex toward the open ocean, margined by a deep submarine trench and enclosing a deep sea basin.

joint – Generally more or less vertical or transverse to bedding, .parallel sets of **apertures**, cracks, fractures, or partings in bedrock with no sign of offset on either side of crack. Preeminent structural control on cave formation. Rectangular (often from tensional (pull-apart)forces) & 60/120 degrees (often from compressional or shearing forces) systems are most common.

K-selection – Refers to species that tend to have specialized habitats, long individual lifespans, few offspring, and prolonged parental care, as in many if not most subterranean species.

karren - 1. Karstic solution grooves from a few mm. to about 10 or a few meters in width and which are separated by ridges. Larger features of this form are **karst**. 2. All small bedrock **corrosion** features in soluble rocks.

karst – a type of topography that is formed on limestone, gypsum, and other rocks by dissolution, and that is characterized by sinkholes, caves, and underground drainage such as caves and spring resurgences. Surface karst is exokarst & subsurface is endokarst.

keyhole or keyhole passage - A small **passage** or opening in a cave; in cross section, rounded at the top, constricted in the middle & rectangular or flared out below. Usually the result of initial solution of water filled **conduits** at the rounded top and subsequent erosion of a slot by streams with an air surface.

La Nina - La Niña is a weather cycle characterized by unusually cold ocean temperatures in the Equatorial Pacific, compared to El Nino, which is characterized by unusually warm ocean temperatures in the Equatorial Pacific. During a La Niña year, winter temperatures are cooler than normal in the Northwest.

limestone – a sedimentary rock composed primarily of calcite.

lizard skin **popcorn** or **flowstone** - Bumpy (coralloidal) flowstone in which bumps are elongated in the direction of splashing, dripping or airflow that produces atmospheric corrosion and/or moonmilk or popcorn deposition. May be the horizontal (flow-wise) equivalent of splattermites. Known from only two areas in the Cave.

loess – Non-stratified silt, clay, and dust, originating as glacial sediment, but re-deposited by wind. Uniform, porous, slightly solidified, often highly calcareous aeolian dust (mainly silt) from desert basins or glaciofluvial sediments from newly glaciated areas. Grains usually are angular and so fit together enough so that vertical cliffs may develop, as in the case near the first Paradise Lost platform, although this is not strictly loess as it is loess redeposited by water.

long term - Impacts that last longer than one year.

losing stream - A stream or reach of a stream in which water flows from the stream bed into the ground. In karst terranes, losing streams may slowly sink into fractures (the case at Oregon Caves) or quickly disappear down a bedrock ponor.

luminescence - Emission of light by a substance that received a different wavelength energy externally. Dripstone & flowstone often give a bluish to greenish white light if excited by strobe lamps & UV. Calcite incl. calcium salts of fulvic acid (bright blue-green). Most from calcium salts of fulvic (lighter, brighter) & humic (darker, weaker, longer wavelengths) acids and lesser amounts of low-molecular weight organic esthers.

manganese oxides - Ore minerals that can't be identified ID in field; **FMO** if charcoal-black, clay size, & has no odor. Often have some **iron oxides, calcite, quartz** and, less commonly, the mineral romanchite.

mantle – The layer of the earth below the crust, usually starts around 8-15 miles under oceans and 20 to 45 under continents.

marble – a metamorphic rock, mainly of calcium carbonate, that was derived from limestone. Usually coarser grained than limestone and of lower porosity, averaging less than 1%

maze cave - A complex pattern of repeatedly connected passages. Usually has or had less directed waterflow than branchwork or single-conduit caves.

meander - 1. Overdeveloped or self-exaggerated bend in a stream course or other channel either on the surface or underground, caused by more erosion on the outside than on the inside of a bend through natural wash of the flow. Commonly originate in caves as half-tubes along bedding-planes during protocave development (Smart 1977).

meander niche - A crescent-shaped **alcove** on the wall of a cave; formed by stream erosion, as after the first River Styx bridge. Syn.: conical wall niche.

meandering runnel - Wavy or winding rain rill. Solutioning may or may not be from dripping water.

memo to file - A memo to the planning record or statutory compliance file that NPS offices may complete when (a) NEPA has already been completed in site specific detail for a proposal, usually as part of a document of larger scope, or (b) a time interval has passed since the NEPA document was approved, but information in that document is still accurate.

metamorphism – alteration of rocks in the earth's crust due to heat and pressure (the rock does not truly melt, if it did we would call it igneous).

microgours - Parallel &/or convoluted **flowstone** or **sediment** ridges less than 1/2" high. Usually on steep slopes.

microkarren - **Karren** from 1mm to 3mm. across & up to several cm. deep, usually with parallel runnels, or, less often, convergent or randomly intersecting **runnels**. Most common in areas of slow solution, as in deserts and periglacial areas. Probably due to overflow and concensation corrosion.

mid-ocean ridge – great median arch or swell of the sea bottom extending the length of an ocean basin and roughly paralleling the continental margins; one in the Atlantic is several hundred miles wide, very irregular topographically, and rises at some places to form islands.

mineral soil - Soil layers below the predominantly organic horizons; soil with little combustible material.

mixed corrosion - Solution of carbonates from the mixing of two **saturated** waters that differ in CO_2 partial pressure, as in domes, joint intersections, etc.

moderate – Impact is clearly detectable and could have appreciable effect on the resource.

moonmilk – a speleothem type consisting of white, finely crystalline clay which feels like powder when dry and cream cheese when moist. From Swiss dialect moonmilch, elf's or gnome's milk, as antibiotic activity was ascribed to magical little people. May result in Oregon Caves from **organic** activity such as from bacterium actinomycetes, and less often or likely, fungi or algae.

mylonite - Compact, chertlike with streaking/banding from fault micro**breccia**tion.

negligible – The impact to the resource is barely perceptible, not measurable and confined to a small area. Negligible impacts would not result in major human-caused impacts of that particular Park resource.'

neoteny – Refers to species with delayed sexual maturity, such as in humans.

nodule - A small, irregularly rounded knot, mass, or lump of a mineral or mineral aggregate, normally having a warty or knobby surface and no internal structure, and usually exhibiting a contrasting composition from the enclosing sediment or rock matrix in which it is embedded. Most nodules appear to be secondary structures in sedimentary rocks; they are primarily the result of postdepositional replacement of the rock and are commonly elongated parallel to the bedding and show distortion of surrounding sedimentary layers, as is the case in Oregon Caves.

normal fault - Where the hanging wall appears to have moved downward relative to the footwall. Usually from extensional tectonics & therefore more likely to develop into caves than can reverse faults.

notch, solution - Curved **bevel** incuts from decimeters in cross-section & meters in length. Usually occur where humic soils abut very steep or vertical carbonates, especially limestone. May enlarge into foot caves.

off-trail - Sections of the cave that are beyond developed portions of a cave. These areas may have preferred routes of travel marked with flagging tape or some other marker to reduce impact to the cave features.

ophiolite – A regular sequence of rocks formed during the formation of ocean crust, usually either in mid-ocean ridges or in back-arc basins. The deepest to shallowest rocks range from **peridotites** (depleted **mantle**), to **serpentine**, to sheeted **dikes**, to pillow **basalts**, to chert, to (in some cases) limestone.

organic - Material presently or once part of life forms and viruses or compounds normally produced by life forms but not necessarily derived from them (as in organics in meteorites).

ORCA – Acronym for Oregon Caves National Monument

palette, (cave) - 1. A more or less flat protruding sheet of crystalline carbonate **petromorph** , usually a vein, that is spared during solution of the rock on each side of it.

paragenesis - **Phreatic** enlargement upward due to sediment armoring of floor (Lauritzen & Lauritzen 1995).

paraphreatic - Adj. for a cave passage with an air surface under relatively low flow but which becomes completely water filled under high flow and/or when the downstream drainage is temporarily impeded.

partings - **Bedding** plane **apertures** between beds. Perhaps the third most important zone of weakness for cave enlargement in general but the most important one in Oregon Caves.

patina - A colored film or thin outer layer **crust** produced on the surface of a rock or other material by weathering after long exposure.

PDO - The "Pacific Decadal Oscillation" (PDO) is a long-lived El Niño-like pattern of Pacific climate variability. While the two climate oscillations have similar spatial climate fingerprints, they have very different behavior in time. Fisheries scientist Steven Hare coined the term "Pacific Decadal Oscillation" (PDO) in 1996 while researching connections between Alaska salmon production cycles and Pacific climate (his dissertation topic with advisor Robert Francis). Two main characteristics distinguish PDO from El Niño/Southern Oscillation (ENSO): first, 20th century PDO "events" persisted for 20-to-30 years, while typical ENSO events persisted for 6 to 18 months; second, the climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, while secondary signatures exist in the tropics - the opposite is true for ENSO. Several independent studies find evidence for just two full PDO cycles in the past century: "cool" PDO regimes prevailed from 1890-1924 and again from 1947-1976, while "warm" PDO regimes dominated from 1925-1946 and from 1977 through (at least) the mid-1990's (Bond & Harrison 2000).

pendulous flowstone – Often with a droopy look, likely the result of clays, moonmilk, etc.

pendant, (rock) - Vertical (90 to 45 degrees) **petromorph** often surrounded by anastomoses and projecting from a ceiling. Vertical section is >3 times longer than thickest dimension.

peridotite – Rock thought to be the main part of the mantle.

permafrost - Ground that is perennially below the freezing point of water.

petromorph - 1. A **speleogen** jutting out from bedrock because of differential solution.

phosphorescence - **Luminescence** in which the stimulated substance emits light after the external stimulus ends. Cave carbonate often displays green (sometimes blue) phosphorescence unless much iron, clays or organics occur.

phreatic – the major subsurface zone of water saturation.

phreatic loop - Where water dissolves passages around a blockage , common in dipping limestone with widely spaced bedding-related fissures, as is the case at Oregon Caves.

piracy, subterranean (stream) - Capture of a surface stream perched on soluble rocks & its diversion underground to an adjacent entrenched stream.

pitting - Rounded **cavities** up to ten cm. across. Often from splashing water on flowstone & atmospheric corrosion (deeper, more vertical pits) or other solution on bedrock.

pluton – a large mass of intruded molten rock below the earth's surface which eventually cools and crystallizes.

pocket - 1. **Cavity**, less common on floor, or walls of a cave, shaped like a round-bottomed kettle, unrelated to pitting, joints, bedding, or potholes. Either length or width is less than six inches.

pothole - 1. Small, rounded cavity in floor flowstone or bedrock irrespective of origin.

powder, cave - A cave **fill speleothem** with crystals 10-50 microns. Over 100 minerals worldwide. Often caused by dehydration, less often by redox reactions & strong acid aggression. Differs from moonmilk in mode of formation & lack of plasticity.

pressure, hydrostatic - The pressure exerted by the weight of water at any given point in a body of water at rest.

pressure solution – solution occurring preferentially at the contact surfaces of grains (crystals) where the external pressure exceeds the hydraulic pressure of the interstitial fluid. It results in enlargement of the contact surfaces and thereby reduces pore space and tightly welds the rock.

pyrite - Pale-bronze or brass-yellow **sulfide**, FeS_2, often in the form of cubes. Assocaited with organics in carbonates or thin noncarbonate beds such as shales or coal. Oxidation with or without bacterial mediation releases sulfuric acid.

quartz - A **silicate**, $Si0_2$, the most common mineral after feldspar & commonly forms sandstones.

relict - 1. A type of species belonging to ancient groups whose fortunes have waned through geological time.

reverse fault - Hanging wall appears to have moved upward relative to the footwall. Usually from compressional tectonics & therefore less likely to form open conduits for cave development than normal faults.

rhythmites - Varve-like **sediment structure**. Common in caves in glaciated areas. Represents deposition from pondings beneath or along the flanks of glaciers. Whether each couplet is a annual (true **varve**) is unknown. The ones in Oregon Caves probably represent slight variations in slackwater deposition, with larger grain layers depositing first.

rill - Small **karren** grooves up to 50 cm. wide on surface exposures of limestone and less commonly in caves. Most common in arid & semi-arid areas. Can form in vertical shafts, from bedding or joint inflow after flooding, from point source or sheetflow, from enlarging of joints or glacial striations, & from condensation-corrosion above cave floods.

rillenkarren - Downslope parallel Hortonian **rill**s about 1-4 (2-3) cm. (avg. 2cm) wide, no space between & with sharp intergroove crests or ridges no more than 1 cm. high & cut by subaerial solution. Meanders are greater at the lower angles. Planar solution surfaces (ausgleichflache) develop further downslope where runoff depth prevents raindrop erosion.

rimstone dams – a speloethem type consisting of a barrier of material which obstructs a cave stream or pool.

rockshelter or rock shelter - Grotto, large embayment, or relict or corrasion cave (Def.#1) in which all traversible parts is reached by sunlight, esp. a shallow cave or other traversible cavity under an overhanging rock ledge. A concavity in rock that may not have extensive passageways but has a large enough cavity or rock overhang to provide shelter for humans. Rock shelters are generally wider than they are long and usually do not extend into total darkness.

rootsicles – roots of trees or plants which become calicified when they grow down into a cave passage.

scallops – a mosaic of small shallow intersecting hollows formed on the surface of soluble rock by turbulent dissolution. They are steeper on the upstream side, and smaller sizes are formed by faster-flowing water.

scarp, solution **- Karst** cliff at least ten meters long & two meters high formed by more active solution of lower area or by corrosional undercutting of the base of the cliff, as is likely the case at the Exit Tunnel. Larger than **solution notch**.

sedimentary **-** Rocks, such as most cave **bedrock**, speleothems, or cemented sediments, formed at normal temperatures at earth's surface.

serpentine – A mineral group the erodes into soils toxic to or too dry to most plant life.

shelfstone, (cave) **-** A horizontally projecting speleothem ledge attached to the edge of a past or present pool. Top of shelfstone may be highest water level while bottom may be the lowest water level.

short term - Impacts that last one year or less.

show cave **-** Commercial cave with human-made alterations such as stairs, lights, paved walkways, etc., for public access & usually for guided tours.

silicate **-** Rock, **mineral**, or **sediment** with SiO4 atomic units. Incl. feldspar, quartz, & chert.

sill – A layer crosscutting earlier features and usually igneous.

sink(hole) - 1, American term for a circular, 2' wide to larger size **karst** depression. Grades into shafts if > six feet deep & sides are more or less vertical. Locally higher solution rates caused by water flow convergence result in sinks. The formation of one sink favors the formation of others. Most common along lineaments in temperate areas.

slickenside - Polished & smoothly striated surface from friction along **fault**s.

solifluction - The slow viscous downslope flow of unsorted & saturated surficial sediment especially in areas underlain by frozen ground. Can clog **sinks** & other access to caves & concentrate flow in other access points.

solubility - The total amount of solutes that will remain indefinitely in a solution maintained at a constant temperature and pressure in contact with the solid crystals from which the solutes were derived.

spar - Loosely applied to any transparent or translucent **crystalline** mineral, especially calcite. Microspar, crystals 5-20 microns wide cause cave velvet.

speleogen – A cave shape at least partly dissolved by water solutions. Defined in **FCRPA** as "relief features on the walls, ceiling, & floor of any cave or lava tube which are part of the surrounding bedrock, including but not limited to **anastomoses**, **scallops**, **meander** niches, & rock **pendants** in solution caves.

speleogenesis **-** The process of cave formation and destruction, including all changes between the start and end of an underground drainage system. The initiation phase includes the inception phase of laminar flow & up to or the start of turbulent flow in the gestation phase.

speleothem – a secondary mineral deposit formed in caves by the action of water.

spitzkarren - Pinnacle karren grooves about .5 meters apart, separated by rows of sharp-crested pyramidal, spearlike, or steeplelike peaks (needles). Common on surface but rare in caves. From turbulence of high-gradient passages (subaqueuous) & possibly in cave from mixing of air masses & resulting acud dew (subaerial).

splash patches - Condensation corrosion areas (often elliptical) resulting from the concentration of falling condensation droplets in particular areas. Areas may be fairly smooth or, if falling from great heights or with water still able to dissolve a lot of calcite, may show extensive cusp-shaped pitting.

splitkarren - Karren depressions elongated one cm. to several meters along minor joints, veins, **stylolites**, or micro-fractures. Length to maximum width ratios < 3:1. Features taper sharply with depth & appear to be splitting the rock. Closed splitkarren terminate on the host fissure while open splitkarren can end in more solutionally widened karren such as rills or grikes. May begin as microfissures.

spongework - Irregular network of randomly shaped solution voids from a few cm. to >1 m. wide. Likely phreatic & formed under slow flow and dissolution close to calcite saturation. May result from epiphreatic floodwaters otherwise known for forming maze caves or in the waters of meltwater channels in decaying snowpatches. Larger and more isolated hollows are pockets. The larger spongework is termed boneyard.

stalactite – a cylindrical or conical dripstone deposit of minerals, generally calcite or aragonite, hanging from the roof of a cavern.

stalagmite – columns or ridges of carbonate of lime rising from a limestone cave floor, and formed by water charged with carbonate of lime dripping from the stalactites above.

stylolites – A feature in which solution usually of carbonates results in usually jagged lines of insoluble residues due to differential rates of solution.

subduction – plate collision boundary where one plate is sinking beneath another.

suppression - All the work of extinguishing or containing a fire, beginning with its discovery.

sulfide - Ore mineral linkage of sulfur with metal or semimetal.

symbiosis – The growth together of different species in a close relationship such as mutualism or parasitism.

syncline - Downfold of bedding with a troughlike form & the youngest strata in the center.

talus - Rocky **detritus** of any size or shape (usually coarse & angular) derived from & lying at the base of a cliff or very steep, rocky slope. Also, the outward slopping & accumulated heap or mass of such loose broken rock, considered as a unit, & formed chiefly by gravitational falling, rolling, or sliding.

tectonics – Large scale movement of parts of the earth relative to each other.

terrane – a large group of rocks bounded by fault surfaces that has been displaced from its point of origin and has distinctive rock types and fossils by which it is recognized.

transgression **-** The spread of the sea over level areas due to sea level rise or **tectonic** downwarping.

troglobite – an organism that must live its entire life underground.

troglophile – any organism that completes its life cycle in a cave but that also occurs in certain environments outside the cave.

trogloxene – any organism that regularly or accidentally enters a cave but that must return to the surface to maintain its existence.

tube **-** 1. A generally smooth-surfaced **phreatic** passage of (nearly) elliptic cross section. Range from just human-size to over 15 meters; larger ones rarely are of uniform section. May be straight or winding. Increased solution along bedding planes in horizontally bedded rock tends to result in more flattened elliptical cross sections and in more vertically elongated cross sections in areas of vertical joints, faults, etc.

turbulent flow **-** Flow in which physical (in contrast to only molecular) mixing of a fluid occurs. It begins in a dissolutional subconduit as its diameter increases to the point where differences between flow velocity at the bounding wall (slowed by friction and adhesion) and the maximum velocity of the tube's center are sufficient to cause eddies within the flowing water.

underfit stream **-** Where a stream is presently too small to have created the enclosing valley or cave passage. Often caused by higher Pleistocene flows or where the opening of lower levels in caves causes **piracy**

uplift – elevation of any extensive part of the earth's surface relative to some other parts.

vadose – above the water table, the area where water and air mix.

vascular plant – one in which there are distinctive vessels from conducting fluids. It includes flowering plants, conifers, and ferns but does not include mosses, liverworts or lichens.

vermiculation **-** Thin, irregular, discontinuous **sediment** usually of clay, sometimes of silt, but may be composed of hydrated iron and aluminum oxides, and soot. From flocculation/soil-like aggregation of sediment from drying, liquid films. Most common in Oregon Caves where floodwaters filled the room with water muddy from glacial silt Leopard-skin vermiculations can evolve into intersecting straight lines in densely fractured areas. The more diffuse & slimy & less dendritic ones can form from human-caused lint & algae.

water table – the surface between the zone of saturation and the zone of aeration; the surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere. The contact between the vadose and phreatic zone. Water tables often are complex in carbonate areas, especially where subsurface conduits and subconduits have recently developed; water filled conduits can overlie dry ones. Further increases in permeability can result in a better defined & relatively flat water table.

welt **-** 1. Linear **speleothem** in which water moves through medial cracks under capillary pressure & deposits carbonates, usually calcite. A flat analog of an helictite.

wind, cave. Thermic airflow results from different weights of air columns at different temperatures and operates in caves with two or more entrances at different elevations, as is the case with Oregon Caves.