Cave Restoration By Pat Jablonsky and John Roth

Cave restoration in North America has an advantage over restoration of surface features in that prehistoric human impacts on caves processes, except impacts on rock shelters, has been minimal, especially if major cave passages are far from all entrances. There are exceptions, of course, especially in the Southeast, but cave development processes for the most part have evolved without human impacts. Consequently, there has been no need to sort out which human actions are "natural" and which ones are not. Nearly all human impact on a cave is foreign and should be mitigated or eliminated if possible.

Compared to surface environments, most caves are low energy/food environments. Caves usually have little detectible wind, light, freeze-thaw cycles, organics, etc. Thus, fragile minerals and life forms with low metabolisms can thrive underground. Foot traffic, lighting systems, lint and associated debris, graffiti, airflow changes, etc., have high energy/food impacts on the cave. Air currents and visitors bring in lint, skin flakes, dust, mud, spores and seeds, all of which encourage plant growth. Lint and exotic plants under certain conditions can dissolve carbonate cave formations through bacterial processes, the release of carbon dioxide during photosynthesis, or condensation from carbon dioxide-rich air. Other human-caused impacts include movement of cave material, vandalism, changes in water and life-form movement, chemical poisoning from coins, and the introduction of exotic species. To help maintain a natural environment, foreign materials should be routinely removed.

Direct and indirect effects of all restoration techniques must be carefully monitored to ensure protection of the cave environment. A cave restoration log should be maintained to document the details of restoration activities and the results of restoration impact monitoring. Individuals or groups involved in cave restoration work should remove all evidence of their activities (e.g., footprints, mud on handrails, tools, etc.) from work areas.

Cave restoration by volunteer individuals and groups should be actively encouraged. In National Parks, for example, the use of volunteers is through the Volunteers in the Park program (VIP). Restoration objectives involving volunteers can be spelled out in the VIP program or other documents. In any case, recording objectives and accomplishments is important. Restoration by volunteers serves the double function of reversing degradation and increasing protection of resources through public education.

Washing should be done by using cave water or untreated water from nearby wells. The resulting water, if possible, should be contained, and removed from the cave. If the waste water used for cleaning cannot be taken out of the cave, then it should be filtered before allowing it to re-enter the cave-water system. Stiff nylon brushes should be used for a final manicuring but sometimes steel brushes are needed even though they may produce minor scratches. Such scratches seem to vanish within a few years if there is active formation growth. Variable pressure cleaning systems using very small amounts of water, such as the "Hotsy" cleaning machine, will clean accumulated debris from most formations and walls without any abrasive contact. Wet-dry vacuum cleaners can be used in association with the cleaning machine to catch the water and debris. A significant concern with vacuum pickup machines is that the exhaust may just redeposit small material in the cave. If the material picked up is wet, the risk is substantially reduced. If dry material is vacuumed up, machines with very effective filters should be considered. Such machines are available and are most often used in such hazardous material fields as asbestos removal or hazardous chemicals. These same vacuum cleaners can also be utilized for routine trail maintenance and are available in large wheel mounted and smaller back-pack versions.

Plant growth made possible by artificial light systems can dissolve cave formations, discolor cave walls, and add organics to communities adapted to food-poor conditions. Even detergent-rich lint from clothing helps fertilize these plants. Formations and other cave surfaces can be discolored by smoke (torches, candles, and carbide lamps), lint, skin oils and flakes, exotic plants, and dust generated along cave trails and from outside. Both blue-green algae (cyanobacteria) and a mixture of fungi, dust, and lint can also blacken cave walls. Surface soil changes from forest fires, cuttings, altered plant growth and patterns, and acid rain may alter organic acids or minerals that color cave formations. However, only color changes caused by alien plants, fungi, or microbes can be readily treated.

Presently, there is no better treatment for the control of exotic plants than household bleach (5.25% sodium hypochlorite), although light filters and arranging the light differently can reduce algal growth. Bleach leaves no physical residue although it will increase the pH of cave water. At least several years of testing with different spraying regimes is needed to find the least amount of bleach needed to control exotics. The growth rate of the exotic plants is largely dependent on temperature, moisture, airflow, and the effectiveness of the previous spraying. Spraying regimes range from once a year to once every few weeks, sometimes being done more often in the summer when algal growth rates tend to be higher in many caves. However, a complete spraying of exotic plants should be done every few years to reduce spore dispersal. This is especially important in caves with low airflow. Bright flashlight or portable floodlight examination of all dark cave surfaces is needed to locate at least 90% of the algae. All spraying and eradication work should be conducted by at least two persons for the sake of safety. Cave personnel or volunteers spraying bleach in the cave should wear goggles, rubber gloves, hard hats, headlamps, and some type of respirator. This safety equipment is especially necessary when spraying directly overhead. Filling the spray containers, or cleaning of equipment will be done on the surface. All spray equipment, containers, protective clothing, etc., should be removed from the cave at the end of each spraying session. Any spillage in the cave or excessive run-off of the bleach must be cleaned up immediately. Any container of bleach taken into the cave must be in a non-breakable container. A portable eye/skin wash station should be full and ready for use at all times. All equipment must be thoroughly flushed with clear water at the end of each shift. Special attention must be given to the sprayer and the sprayer orifice. When working with bleach, limit exposure to it and try to always spray from upwind. The actual spraying time should not to exceed two hours for any one worker or volunteer. If fumes pose a problem to other personnel or cave visitors, then delay your work to after visitor hours to allow for overnight ventilation. In caves where airflow is variable or there is little air moving through the cave, the project should be postponed until the air flow increases. The maximum amount of bleach used in a cave during any one period should be one gallon or less to keep the pH balance in the cave within normal range. At least 24 hours between spray periods must be provided. Only safe, efficient methods of application should be used. Mist spraying should be adequate unless the sprayer can get no closer than four feet. Successive application trips on a tour route should be in opposite directions in order to see and treat surfaces from different perspectives. After completing all spraying with satisfactory results, the treated area should be cleaned of visible residual organic material one day after the spraying. Techniques described above for removing general debris should be used as a guide for cleanup.

Anyone experiencing any ill effects from the fumes or personal contact with the bleach should notify their supervisor immediately. Before any spraying or use of bleach in the cave begins, adequate warning signs should be in place advising the public of its use.

Incandescent lights over 80 watts should not be used in caves because they can produce noticeable temperature changes, alter or damage nearby minerals, and cause drying circles on flowstone. Compact fluorescent or E-bulbs (radio controlled) are preferred because most give off very little heat and use less than 80 watts of energy. Incandescents convert about 10% of their energy into light while compact fluorescents covert about 40% of their energy into light. Compact fluorescents last approximately 2 1/2 to three years for eight-hour-a-day use while E-bulbs may last up to 14 years. This lowers costs and reduces foot-traffic impact. Flexible plastic layers, similar to those used in stage sets, can hide wire where shadows or in-place cave features cannot be used. Concrete "snakes" are unsightly, but are better than naked cables. The concrete should be poured on thick plastic and then the plastic removed so as to facilitate removal of the "snake" at some later date without damaging the underlying cave surface. An effort should be make to route cables to avoid such aesthetic problems.

The major impacts to cave pools are evaporation from human-cause air flow changes and coins or organic matter tossed into the pools by visitors. Most coins contain copper, one of the most deadly elements to aquatic life. Removal can be done by using a long-handled spoon or, better, a pick-up tool at least 6-8 feet long. Removal should be prompt as even a few coins dramatically increases additional tossing. Airborne organics and human food deposited in the water can greatly reduce dissolved oxygen content. This condition can react with iron to produce a black sulphate mass that can release sulfur dioxide into the cave air. Annual or even daily changes in cave air temperatures usually are enough to cause convective overturn and oxidation of the organics. In some rare cases, stirring the water with paddles may be needed. The black residue can be removed with electric pumps. Preventing most food from entering the cave in the first place is preferred.

Lint is generated, primarily from the constant rubbing and abrasive movement of clothing worn by visitors. This constant rubbing and abrasive movement generates large cumulative quantities of lint along the trail system. The walking action generates a slight current along the trail and these currents then carry the lint and associated debris up and away from the trail. These currents send the lint onto cave formations and surrounding walls especially on rough surfaced, constricted passages or at the downwind end of a constricted passage. Light to moderate amounts of lint are not easily detected with the naked eye, but under a long-wave ultraviolet light, the deposits show-up quite readily. Lint serves as the basis for alien communities that can include spiders, mites, ants, and other exotic invertebrates. When wet, it can increase the numbers of naturally occurring and exotic bacteria and fungus. Except in very dry conditions, at least 80% of all lint from visitors clothing falls within two feet of the center of the trail. By installing curbs along the trial you can inhibit movement of lint and confine a major portion of it on the trail where, with a regular maintenance program, you can collect a good percentage of any lint accumulations. A rough trail surface, grates, or other surfaces that tend to clean the bottom of shoes just before entering a cave can help prevent the spread of foreign matter into the cave.

Care should be taken to make sure that features other than exotic algae or lint are not removed. Some black blue-green algae does occur near lights but such algae away from lights may be native to the cave and should not be sprayed. Lint and algae globs can resemble poorly-formed vermiculations, also called clay worms. These vermiculations usually are rounded, unconnected, dark clumps with a high water content and greasy feel. The naturally-formed clay worms usually have more complex forms, are mostly clay, and have a nearby source of clay. They appear to be caused by the electrostatic attraction of clay particles when a film of water dries out and there are no longer enough water molecules to keep the clay particles apart. The globs also can resemble "cave slime," which are rounded, light-colored films of actinomycetes. Native to caves, these bacteria resemble very thin lichens and feed on incoming organics. They grow very slowly and as a result usually are not found on cave walls undergoing lint deposition, travertine deposition or atmospheric corrosion. The lint may foster bacterial growth that competes with the cave slime.

Local additions or removal of material may change air flow patterns within that area, especially if the passages are small. Increasing the size of entrances increases upward airflow in winter and downward airflow in summer. This can increase air pollutants, which will darken upward-facing cave surface further from entrances. Enlarged cave entrances increase safety hazards due to increased frost wedging.

There should be no outgassing of construction materials. Greater airflow can cause erosion of formations by freezing, dehydration, or dissolving of formations due to an increased carbon dioxide level. Cave species adapted to high humidity may be forced to retreat to small crevices in the cave or die off.

To restore naturally occurring airflow, airlock systems in tunnels should be considered and should be made of non-oxidizing materials. PVC plastic with stainless steel fittings and pressure-operated shut mechanisms work well. Plastic is a good insulator and therefore retards heat transfer between a cave and the surface, or between different parts of a cave, that normally would be separated. However, plastic changes temperature more slowly in response to airflow changes than does metal and therefore allows for unnatural condensation and possible corrosion. Plastics other than PVC may be needed for entrances subjected to very low temperatures. Cement used to surround the door should be of a type that contains little calcium hydroxide, which is more soluble than calcite and can increase speleothem growth. Clear lexan can be used as air restrictors on the sides of artificially deepened trails to restore the original cross-section of the passage. Placement should occur so as to avoid condensation that may cause calcite solution.

Graffiti vandalism is sometimes difficult to distinguish from historical graffiti (more than 50 years old). As with coin tossing, graffiti not promptly removed or obscured will induce further graffiti. Graffiti can usually be removed by stiff nylon brushes and vinegar, but steel brushes and a 5% solution of hydrochloric acid (muriatic acid) may be needed if the graffiti proves too stubborn for nylon brushes and vinegar or where mud splattered during blasting has hardened on cave walls. The acid can be used with a CO2 powered pressure washer such as those used to remove paint. Remember to trap and collect all run-off if using these cleaning techniques.

A vandalism inventory should include a count of broken formations, regrowth measurements, classifications of and a photo and video documentation of a cave's formations and graffiti. The inventory will insure that only graffiti vandalism is promptly removed, not historical graffiti. A broken formation count should be conducted every two years after the initial one is completed. Only after two to three surveys will a fairly accurate baseline be established. Surveys should be done with headlamps since having the cave lights on will most likely result in only partial coverage. A minimum size of broken formations should be chosen, below which the breakage is not counted. Grouping of small, broken formations, such as popcorn, should be done. The diameter of the groups to be counted will vary from cave to cave but usually averages a few inches.

Formations can be repaired during the driest time of the year by a combination of fast-drying glue in the center of a broken area and slow-drying glues surrounding that area. Structural epoxies used in historic preservation can be adapted for speleothem repair by using crushed calcite as a base. The size of the calcite particles should be reduced until the mixture approximates the texture of the formation. Epoxies used in structural bonding also work. If heat is needed for proper setting of the epoxy, care should be taken not to burn and oxidize the epoxy. For stalactites and draperies, especially those with very small attachment areas, holes can be drilled for the attachment of expansion bolts, steel pins or screws. Because calcite cleaves easily, very small holes should be drilled and progressively enlarged with larger drill bits.

Some trails that have been artificially deepened require retaining walls to prevent loose cave fill from falling onto the trail. If a naturally occurring water flow is inhibited because of the retaining wall then puncturing this wall may help restore water flow and still hold back sediments. Drill holes, steps cut into flowstone, and other manmade modifications can be repaired by using terrazzo or a 5/1 ratio of cave mud to cement. Terrazzo is mostly crushed, bleached calcite and, therefore, closely resembles limestone cave formations. Altering its color to match adjacent cave features, is easier to do than altering the color of most types of cements.

Oxidation of skin oils and flakes can blacken formations after they have been touched only a few hundred times. Given protection, some blackened formations will return to their original colors in about fifty years. Abrasion and polishing occurs especially if rock fragments harder than limestone are present, such as minute grains of chert inadvertently rubbed on formations by visitor's hands. As in most cases, prevention through education, use of handrails and physical barriers deal with the problem best.

Railings of anodized aluminum is better than galvanized iron but is very susceptible to corrosion from water and salt from human skin. Using railings as intended or unintended electrical grounds may accelerate corrosion and produce aluminum gels. Type 317L, a low-carbon, high-chromium stainless steel with molybdenum, may be a good choice for most humid caves. Whatever metal is used, periodic rinsing with cave water to remove salt is still needed, especially in areas with high salt deposits, such as the start of steep stairways.

Organics (exotic plants, lint, skin flakes and oils, asphalt, temporary wooden walkways, slash burning on the surface, etc.) can cause cave animals adapted to a low-energy food environment to be out-competed by surface-adapted animals.

Removal of organic debris, such as wooden boards, older than 50 years, but not of historic value, should be gradual, as abrupt removal may disrupt cave communities. However, some biologists argue that such debris should be left in place.

Artificial fill in commercialized caves results from the dumping of trail material, tunnel debris, or the construction of artificial walls, pads, trails, dams or gates which change natural conditions in the cave. This debris or materials may be removed and natural features restored through a series of mitigating steps. Discussion will include recognizing ?in situ? cave sediment versus human-caused debris and defining goals to restore prehistoric airflow, waterflow, formation growth and dissolution rates, and biotic communities. The tools and techniques used to remove debris will be discussed.

History of and reasons for conducting artificial fill removal projects
Although, artificial fill has existed ever since caves began to be developed for visitors, it wasn?t until the late1970?s that the need to restore natural conditions and remove harmful materials in developed caves was recognized. Early on, a general rule was formulated that said, ?Remove all unnecessary unnatural materials from the cave but leave natural materials in the cave? (Irving, 1989).

The goal of artificial fill removal projects can be the restoration of any combination of the following natural conditions: airflow, water flow, excavated pits, formation growth rates, biotic communities, or visual scenes. These projects may also be used to remove harmful materials or conditions from the cave environment.

Artificial fill, trails, walls, drillholes or solid gates can disrupt the volume and speed of air flowing in or out of a cave. Where possible, the original volume and configuration of an area (pre dumping) should be restored. Where barrow pits were dug to obtain trail construction debris, they can be refilled with artificial fill, as long as that fill is natural to the cave, is similar to the fill that was excavated, and their locations are carefully documented. The presence of fill, excavated pits, or the altering of cave entrances can lead to unnatural drying out of passages or even freeze/thawing deeper into caves than is natural. It can also change temperatures enough that bats abandon certain roosts. Likewise, bats may be attracted by temperature changes where there are no historical or paleontologic record of their presence. In such cases, the value of restoring natural conditions must be carefully weighed with such things as the species present, its vulnerability, and the availability of suitable alternate roosting sites.

Natural hydrologic flow paths can be disrupted by the presence of artificial fill, trails or dams. These obstructions can entirely change biotic communities within a cave, especially if formally dry passages are flooded. These blockages may change the nature and amounts of secondary speleothem deposition as well as organic energy flows in a cave

The growth rates of formations can be unnaturally disrupted when pre-existing formations are covered with artificial fill. This may lead to the cementation of the fill, which adds difficulty to the fill removal process.

By reexposing a natural substrate that was covered with artificial fill, biotic communities may be restored when original living surfaces or food sources are re-exposed. Decompaction of even natural fill can increase habitat for microbes, egg laying crickets and egg predators

Sometimes, the reason to restore a room or passage are largely aesthetic. These restoration projects may enhance part of a tour route, adding interesting visual scenes where none existed since the initial impact.

Construction materials slated for removal may include galvanized steel, epoxy covered trail chips, or aluminum railings, among other materials. Various impacts can occur from fill materials harmful to the cave or to people. Galvanized steel may be leaching zinc into cave waters and impacting cave biota (Jameson, 1995). Likewise, aluminum handrails may be leaching aluminum into the cave in the presence of undersaturated or acidic waters. A major target of fill removal are toxic materials such as batteries, asphalt (carcinogenic aromatic hydrocarbons) or old transformers with PCB contaminated oil. Toxic materials safety sheets should be consulted when contemplating moving toxic materials.

Types of Artificial Fill

Artificial fill is differentiated from natural fill as, ?material added to or internally disturbed by human activity in a cave?. The goal during any artificial fill removal project must be to not disturb any natural or ?in situ? fill. One way to prevent this from happening is to have at least two experienced people evaluate each potential fill area. If all the people involved cannot agree that the material was moved by people, then the site is left until the nature of cave fill is better known. Such knowledge may occur during a fill project.

Artificial fill usually results from one of three activities: blasting of tunnels, trail or utility line projects or construction projects. The original goals of any these projects were often to facilitate the visiting public, by either simplifying or aiding access or artificially enhancing visual scenes. Occasionally, these projects were conducted to shorten routes for returning guides or create level areas for electrical equipment.

Blasting debris may result from entrance enlargement, tunnel construction, trail leveling, widening or deepening, ceiling expansion, or platform construction. Gravel-sized to very large angular blocks of rock often was dumped in the nearest convenient spot, so that laborers wouldn?t have to haul it all the way out of the cave. In some cases, tiny chips of rock reveal that rocks have been rolled down planks into a convenient hole. These type of activities usually generate the largest volumes of artificial fill and may partially fill existing passages, greatly reducing their volumes and aesthetic appeal.

Trail and utility line projects will produce small to large volumes of debris, including silt, sand, clay, gravel or flowstone. This material is often stuffed into every available pit or alcove along a trail. When flowstone or formations are found in this type of debris, the material should stay in the cave and not be dumped outside, where it would encourage collecting. This material may be stored in a dead-end side passage (so it doesn?t effect natural airflow movement), and certainly away from visitors sight and reach. Broken formations should never be used as ?touching stones?, since this type of encouragement may lead to additional touching when visitors wonder how the other formations feel that look different from the ones they touched. Touching stones may also encourage collecting and vandalism.

Construction projects in developed caves can cause the same type of problems as artificial fill. Sometimes, non-native gravels were used in trail construction, causing potential leaching or deposition problems. Such structures as rock walls, cement pads, artificial dams, asphalt trails, soil cements or gates are often found in developed caves. Due to soluble calcium hydroxide in cement, it is easily dissolved and quickly redeposited as ?soda straws or flowstone? below the trail. These formations grow at an accelerated pace compared to normal calcium carbonate formations. For this reason, an attempt should be made to keep cement trails in the lowest part of a passage or in areas that undersaturated water doesn?t drip or run onto them. If possible, trails should not be built below actively dripping formations, thus encouraging formations to develop on the trail. High tensile strength cement can be used that has low amounts of calcium hydroxide and will last longer. Artificial dams can reduce habitat for some species while create new habitat for others, both of which disturb caveecosystems. An improperly built gate can reduce air flow, impede natural biota, and change air temperatures and relative humidity.

Recognizing in situ deposits:
Because it is often very difficult to recognize in place, or in-situ deposits, artificial fill removal projects must be proceeded by testing and then work crews should be closely supervised. Test pits should be dug in the suspected fill to determine what has been dumped, what the in-situ material looks like, what tools are going to be needed, and what issues you may face. Even a quick analysis of the types and history of naturally laid material in the cave is helpful in identifying artificial fill and where material has been excavated in a cave. Fossils, frost wedging, popcorn lines, moonmilk deposits, and the orientation of coralloids, cave rims, and atmospheric corrosion sites can be used to determine prehistoric airflows. The presence of epikarst (sculpted bedrock with thin necks), popcorn or straight wallrock color changes can indicate where sediment has been removed although such sediment can be removed naturally as well. A number of criteria can

indicate if the deposits are in-situ, including: layering, compaction, voids, broken surfaces, scratching, calcite deposition, organics and artifacts.

Normally, fine-scale layering of deposits is a sure sign of in-situ deposits. However, it is possible to get some artificial layering created by maintenance workers spreading down alternating layers of sand or gravel to prepare an area for trail construction or for more gross layering caused by the changing nature of material removed and dumped from another site. In such instances, the coarser blasting material may be overlain by finer materials being dumped on top, creating artificial layering. However, if fine laminations, cross bedding or pebble imbrication are present, the material is naturally laid down (figure __). There may even be varying degrees of calcification of materials, creating weakly cemented siltstone.

Compaction is another great tool to use when looking for in-situ materials. Water-lain materials usually will have very little airspace between the grains or rocks. One exception is an area that has been walked over for extended periods of time, compacting the sediment into a hardpan surface. Tests pits, however, will reveal that such compaction is less than six inches deep. Voids, especially those near natural walls, are normally a good indicator that material has been re-excavated and dumped.

Fresh fractures on rocks are another sign of artificial fill. It is common for undisturbed rocks in caves to be covered with a thin veneer of calcite or other layers. Carbonate rock broken during blasting, etc. usually will have a white, sparkly surface with small amounts of calcite dust. However, rocks from blasting debris may be covered with a thin film of blasting mud, now calcified, that masks fresh fractures or scratches.

Scratches are often found on rocks that have been excavated using tools. Thus, scratches, especially randomly oriented ones, are good indicators of artificial fill. Since the calcite dust produced by scratches are easily dissolved, prehistoric scratches often are not visible. Exceptions are bat claw scratches on rock softened and outlined by organic activity.

The easiest restoration is to find artificial fill dumped on flowstone or stalagmites, as it is obvious what is in-situ. Other calcite deposits can also indicate in-situ materials, including: floor coatings, wall coatings on rocks and coralloids such as popcorn. As these surfaces are approached, metal tools should not be used to remove the fill, as they will scratch the soft calcite surfaces. However, sometimes a thin layer of partly cemented fill or blasting mud can only be removed with densely haired metal brushes that may cause some minor scratches. Only clean, unrusted steel and new nylon brushes should be used as rusty or old ones tend to shed steel, rust or nylon in the cave.

The presence of organics may indicate that artificially dumped debris is present. It is not uncommon to find wood in artificial fill. Look for squared ends, saw or axe marks on such pieces. As some biologists believe that removal of rotting wood piles can cause population crashes among native troglobite species, the wood should be checked for fauna and a biologist should be consulted if troglobites are found. Troglobites are those species confined and specifically adapted to the low food levels in caves. Boards should not be removed if they will disintegrate during transport and thus provide a unnatural nutrient windfall (Lewis, 1993).

Pack rat nests can indicate when natural floors have been reached. Sometimes the organics have decomposed from these nests, only leaving bones to indicate their former existence and the presence of in-situ materials below.

The presence of historical or cultural items usually indicates the presence of artificial fill. However, burrowing animals may take items down into in-situ material. These objects may also fall into cracks between rocks or, rarely, be washed in during flooding.

The presence of construction debris is usually a good indication that the fill has been disturbed. Such debris may include; gravel, sand, cement splatter or trash. If the gravel and sand is a rock type not native to the cave and is not in a stream deposit, you can assume it has been dumped at the site. Sharp, angular gravel or boulders with some calcite dust is usually fill from a human-made tunnel. Thick beds of coarse, angular rock fall can occur in carbonate caves but there usually is some rounding of the rock or the predominance of the uncemented breccia is chert or something else harder than calcite. Blocks of breccia sometimes are hard to distinguish from concrete but usually will have some amount of calcified mud as opposed to mud-free cement.

Certain natural processes may produce material that resembles artificial fill. If your project is near an entrance, piles of frost wedged wallrock or thin layers from speleothems may resemble artificial fill. Dessicating speleothems in a dome, humidity changes on gypsum layers or atmospheric corrosion of ceilings may leave piles of debris on the floor that resemble artificial fill.

Special Issues

Special issues include: safety, cultural artifacts and graffiti, broken speleothems, cement-covered speleothems, recemented fill, destabilization, utility lines, and artificial lakes.

It is common to find cultural items mixed in with artificial fill. Their preservation, historical significance and age can determine if they should be collected or thrown out.
Cultural artifacts include, ?any manufactured item that is over 50 years old?, (regardless of the current date). If cultural items are worthy of collection, they are bagged with a completed artifact label. Their location is marked on a map and the depth below the surface is recorded. Each item should be numbered and bagged separately. Their location should be recorded on a large-scale map. It is necessary to collect this type of data at the time of collection, even if the value isn?t immediately obvious, as it can not be recreated at a later date. The presence of datable artifacts may aid in determining when overlying layers of fill was dumped.

It is common to find broken speleothems, pieces of flowstone, or rocks with popcorn or wall coating mixed in with artificial fill. These materials may be hand picked from the artificial fill if they are in large pieces or screened out if in smaller pieces. These materials must stay in the cave for the following two reasons; first, they are natural to the cave and second, if dumped outside they will encourage collecting, both individual and commercial. These materials should be dumped in an area of the cave that is not accessible or visible to visitors, that is near its origin, and one that doesn?t impact natural airflow or clog natural hydrological drains.

Concrete is often found applied directly to flowstone surfaces, as sidewalks, platforms or light shields. It can also be found splattered on speleothem surfaces adjacent to paved trails or covering wire runs between transformers and light fixtures. Restoration should not attempted if speleothems would be damaged to a degree greater than the benefits from restoring the natural surface. Rapid deposition can cover over light scratches resulting from restoration. Concrete may often be removed using hammers, cold chisels and dental picks. It may sometimes be popped off using a light blow to a cold chisel parallel to the contact between smooth flowstone and concrete. This technique can not be used when bumpy surfaces are covered with concrete. Any chiseling must be done at an angle and not perpendicular to the surfaces being cleaned (Schaper, 1995).

If a significant amount of time has elapsed since the artificial fill has been dumped, dripping water may have cemented the fill together. If more than a thin film has accumulated, several questions should be asked and answered: is the artificial fill impeding natural air flow or hydrological drains, is the fill preventing the growth of existing buried formations, or are there biologic considerations?. If the answer is yes to any of these questions, serious consideration should be given to removing the fill. When buried formations are encountered, dripping water may have already cemented the fill to that formation and the resulting conglomeration will have to be carefully removed.

Due to settling of large breakdown blocks, removing artificial fill from around them can destabilize these blocks. Volunteers must be carefully watched, as they may dig underneath or around these types of hazards. If the large block is also artificial fill, it can be broken up before it becomes unstable and hauled away with the rest of the debris. One highly effective, low impact technique that can be used to easily break up large blocks is a hammer drill and plug and feathers. Care should be taken to reduce dust caused by hammer drills. Holes may be drilled and filled by expandable materials such as Dyna-mite to reduce dust although such materials also need to be removed after they have broken up the rock.

Any time that artificial fill is removed from a developed cave, you may encounter buried utility lines, especially electric cables, water lines or phone lines. High voltage cables can be life-threatening. Maintenance employees or original developers should be contacted before work begins. If a electrical cable is known to be buried in a certain area, the power should be turned off before the project begins..All continuous wires should be tested with an electromagnetic device to make certain the wires are not live. The artificial fill from that area should be carefully removed until the cable is encountered. Once found, it should be uncovered using hand tools throughout its entire length. Lines can then be bundled together and lifted or tied out of the way so they are not stepped on or hit with metal tools.

If an artificial lake has been built in a developed cave, the lake can be slowly drained using small tubing or the water used in cleaning dirty areas. Care should be used to not cause unnatural erosion.

Equipment and Tools

Before your artificial fill removal projects starts, there are certain items that should be gathered or constructed, such as:

permits
rocking screens
large-scale maps
Parental Consent Form (if youth are used)

The following checklist can be used to gather everything else that may be needed for your project.

Camera & flash
Wheelbarrows
Five-gallon handled buckets
Powerful portable lights
Extension cords
Square-nose shovels
Round-nose shovels
Short-handled shovels
Army shovels
Garden trowels (metal and plastic)
Push brooms
Gloves
Hand-held squirt bottles
Drinking water bottles
Paint brushes
Toothbrushes
Rags
Handled brushes
Quart-sized zip-lock bags
Artifact labels
Permanent markers

Some artificial fill removal projects may require some specialty equipment, including:

Breaker bars
Impact hammer
Plug & feathers
Powered wheel barrows (for outside use only!)
Hammers and cold chisels
Dental tools

Each worker should have the following personal gear:

Helmet
Leather gloves
Knee pads / elbow pads
Sturdy, padded boots

Change of clothes

Goggles (depending on job)
Ear plugs (depending on job)
Dust masks (depending on job)

Safety Measures

Some pre-planning can greatly increase the safety margin at artificial fill removal projects. When using volunteers that are under aged, you should have their parents sign a Parental Consent Form. You may also want volunteers to sign a liability release form. At the excavation site, each worker must wear gloves, safety helmet, sturdy boots and layered clothes (so layers can be removed if they overheat). There should be at least an one to six supervisor to worker ratio to watch the progress of the excavation to make sure that no excavator is undermining sediment or large rocks, that workers are wearing appropriate safety ware for individual tasks, are not overtiring, that there is sufficient spacing between workers (so they are not swinging equipment and hitting each other or the walls), that the buckets and wheelbarrows are operated by individuals physically capable of handling them, and that nobody is tossing rocks or tools.

The most important aspect of cave restoration is safety training. Many cave restorers are inexperienced cavers and need to be trained in safe and conservation oriented caving/climbing techniques as such skills are needed in reaching many fill sites. Fill removal jobs should be rotated frequently to prevent tedium, muscle strain, or repetitive motion injuries

The most common safety hazard in cave fill removal is to overfill buckets. This can easily result in strained muscles, back injuries, bone bruised heels, and short-lasting buckets. Buckets should be marked inside with a line only 1/3 above the bottom of the bucket and supervisors should be careful not to have fillers exceed that mark. The weight should be geared to the smallest member of the crew and/or that individual in the most awkward position for carrying a bucket. If possible, individuals in assembly line crews should be of similar size. Workers need to be reminded how to bend in order to lift buckets without causing back strain.

The second most common safety hazard is overtiring your workcrew. There is a loss of coordination among tired workers and this can lead to accidents. There should be a workload maximum of three hours in the morning and three hours in the afternoon with plenty of breaks in between and plenty of time to exit the cave at a safe speed. One way to detect tiredness is for supervisors to banter with workers up and down the line.

The third most common safety hazard may be moving rocks that are too large. Blasted rock can be broken up into smaller pieces for removal. Large breakdown pieces of rock that have few if any broken surfaces should be left in the cave in accordance with the normal pattern of breakdown, such as concentrations of breakdown in the middle of large rooms.

There are so many other potential hazards that only the most prominent ones can be listed. A surrounding space needs to be cleared of people whenever overhead tools are used. Picks and sledge hammers with fiberglass or plastic handles should be used as wooden ones are more likely to splinter. Overheating is a potential problem in southern caves due to the high humidity. Filter masks should be used in any case where guano (woorat, mouse, bat, birds, crickets) or amberat (dried woodrat urine) may be disturbed. Spent carbide should be stored safely. Care should be taken near entrances where disease-carrying mites, rattlesnakes or the more venomous spiders (Meta, black widow, brown recluse, hobo spiders) are present. Exposed skin should be checked for ticks or other mites. Supervisors need to monitor workers who might hyperventilate or become anxious due to higher carbon dioxide in some caves. An EMT should accompany each group or be able to respond within twenty minutes. A group needs to leave a cave fill project immediately if any unusual or strong odors are encountered.

Techniques

There are a number of special techniques that have been developed to accomplish the following artificial fill removal tasks: documentation, planning, excavation, transporting materials, tallying fill totals, and locating stalagmites.

It is always crucial to document any artificial fill removal project with before, during and after pictures. When taking the before picture, the camera must be mounted on a recoverable point (that will never be removed during any stage of the project). It is good to document with a digital camera or in black and white, which lasts longer than color films. If a project is completed in stages, it is good to document the extent of each period of excavation on a large scale map (fig. __).

Before any artificial fill removal project begins, the material should be tested to determine the extent of the deposit, the nature of the fill, what is in situ and what is not, the number of excavator/haulers needed, the tools required, the techniques required to remove the debris and access issues.

Artificial fill removal projects must be closely supervised by experienced cave restorers. Expertise in archaeology and paleontology are also very helpful. There are several potential disasters that can occur if workers are not closely watched, including: digging down into in-situ materials, destabilizing large breakdown blocks, damaging or not documenting historic artifacts, or wheelbarrows spilled in the cave by underweight workers. Supervision must be available for each work area, including crews excavating, hauling and screening.

Each artificial fill removal project will require different excavation techniques and tools. some of which, you will have to develop specifically for individual projects. When developing these techniques, the following issues must be kept in mind: the safety of the workers, keeping dust down, flying rock chips, the proximity of formations and the durability of the tools. Workers should be a great number of different types of tools to a specific project as each area is different is requires different tools. If gravel sized material is being removed, the worker can get downhill from the area being excavated, put a five-gallon bucket between their legs, and simply use a garden trowel or an army shovel to pull the fill into the bucket. Whenever the natural floor is approached, which is often marked by a change in color of the fill, the worker must switch to carefully removing the fill using hand tools, or switching to plastic tools if formations are present. If cement walkways are being removed, they can be easily broken up by tunneling underneath them and using a sledge hammer to break them up.

If historical artifacts or broken pieces of calcite are present in the fill, many of them can be hand-picked by careful observation while excavating. If the fill is pea-size or smaller, the remaining fill should be screened so small historical artifacts, fossils and pieces of calcite are not dumped outside the cave, two scenarios that would encourage unwanted collecting. At one National Park Service Cave, where the fill wasn?t screened, pieces of calcite started showing up in local rock shops after the waste pile was discovered by visitors. Large rocking screens with double handles on one or two sides work well (fig. __). These can easily be constructed out of lumber, PVC or fiberglass, bolts and ?? window screen. If fossils are uncovered then non-rocking, very fine screens (.5 millimeters) need to be used

When large groups of volunteers are available, the fastest method of moving large volumes of rubble is assembly lines. By spacing workers arms length apart, five gallon buckets can be passed out of an excavation, down passages to paved cave trails, up or down stairs (fig. __). If a longer distance must be crossed, the group can pass a collection of buckets, stack them up and then move the line forward, repeating the process until the paved trail is encountered. At Timpanogos Cave in Utah, volunteer crews were able to move up to a ton of fill out of an excavation site every 15 minutes using these methods. Once the paved trail is reached, the fill can be dumped into waiting wheelbarrows or several buckets can be stacked on a dolly if you have to move through narrow passages.

It is good for morale to keep track of the amount of fill being removed. If five-gallon buckets are used, several of these can be filled to a predetermined level and then weighed on a common weight scale to arrive at an average weight for that particular type of fill. Individual bucket weights will vary depending on the material being moved and the void space in the buckets. The weights of these buckets may vary between 30-35 pounds. Once the average weight is determined, one person can keep track of the number of buckets dumped into a wheelbarrow or hauled out of the cave using a simple tally sheet (fig. __). At the end of a work session, the number of ticks can be multiplied by the average bucket weight to obtain a good estimate of the amount of fill removed by a group.

It is also important for morale and documentation to keep projects on a doable scale, keeping them small enough so that workers can complete manicuring (final fill removal) of an area and see the results of their effort. Projects chosen should start at peripheries and later projects should be closer to established trails to prevent further impacts on manicured areas.

By checking the ceiling for soda straws and stalactites, the location of stalagmites can be predicted, weather or not the stalactites are currently dripping. Workers at each potential stalagmite location can be cautioned to be on the lookout for that formation. Likewise, flowstone on a wall or uphill from the fill can be used to predict the presence of flowstone surfaces. When excavating, it is always easiest to start on a flowstone or popcorn surface, using plastic tools and working along that surface, removing fill as you progress.

Dirty handrails and trails need to be cleaned during and after a fill removal project. Tools need to be cleaned and sharpened if needed. All restoration material that will rust or decompose should be removed from the cave. All other material stored for an ongoing fill-removal project should be hidden from sight of the developed trail.

Bibliography

Benton, John M. 1995. Marengo Cave Second Annual Restoration weekend. NSS News 53(2): 41-2.

Crisman, B., 1985. Cave restoration at Carlsbad Caverns National Park. NSS News 43(5): 177-80

Crisman, B., 1985. Pioneering cave restoration at Carlsbad Caverns. Inroads 47: 40-3

Horrocks, Rodney D. 1994. ?Artificial Fill Removal Project: Timpanogos Cave System, Timpanogos Cave National Monument?. NSS News, Vol. 53, No. 4, April, pp. 102-107.

Irving, David. 1989. ?Wind Cave Restoration Field Camp?, NSS News, Vol. 47, No. 2, February, pp. 34-36.

Jameson, Roy A. 1995. ?Zinc Leaching from Galvanized Steel in Mystery Cave, Minnesota?. 1995 National Cave Management Symposia Proceedings. Indiana Karst Conservancy. pp. 178-185.

Kohlwey, Kirsten. 1992. ?1991 Timpanogos Cave Restoration Project?, NSS News, Vol. 52, No. 1, January, pp. 12-13.

Lewis, Julian J. 1993. The effects of cave restoration on some aquatic communities. (Abstract).. P. 22 in: 1991 National Cave Management Symposium, October 23-26, 1991, Bowling Green, Kentucky, Guidebook. Liberty Printing: Bowling Green, Kentucky, pp. 346-50.

Meyer, P.J. & J.A. French. 1995. Cathedral Caverns: techniques for restoration and cleaning. NSS News 53(7):186-93.

Meyer, P.J. & J.A. French. 1996. Crossings Cave: testbed for cave restoration. NSS News 54(2-3):54-8.

Rhode, K., R. Kerbo, 1978. Cave restoration: an underview of correcting overviewing. (abstract). In 3rd National Cave Mangement Symposium Proceedings., Big Sky, Montana. Ed. Ron Zuber, James Chester, Stephanie Gilbert & Doug Rhodes. Albuquerque, NM: Adobe Press, pp. 58-9.

Rhodes, Doris. 1976. Cave Restoration: A(n) (Im)Possible Task. NSS News 34(11): 200-2

Rogers, N. 1995. Mammoth Cave restoration field camp. NSS News 53(2):44-5.

Rohde, Kay. 1989. ?Cave Restoration Begins at Wind Cave?, NSS News, Vol. 47, No. 2, February, pp. 32-34.

Schaper, Jo. 1995. ?Techniques and Volunteer Issues in the Restoration of Cathedral Cave. 1995 National Cave Management Symposia Proceedings. Indiana Karst Conservancy. pp. 279-281.

Schmitz, S.A. 1996. Lost Soldiers Cave restoration project. NSS News 54(2-3):59-63.

Tranel, Michael J. 1992. ?Changing to Prevent Change: Building a Science and Resource Management Program?. NSS News, Vol. 52, No. 1, January, pp. 22-25.

Veni, G. 1994. The 3rd Annual Caverns of Sonora Restoration Project. The Texas Caver 39(1):3-4.

Veni, G. 1995. The 4th Annual Caverns of Sonora Restoration Project. The Texas Caver 40(1):3-4.