

CAD Applications at Wind Cave NP

By Jim Nepstad

Wind Cave NP, located in the Black Hills of western South Dakota, is an intricate, multi-level maze of underground passages of incredible dimension. To date, explorers have mapped over 52 miles of these passages, making Wind Cave the seventh longest cave system in the world. All indications suggest that many more miles of cave await discovery. But Wind Cave is much more than just a collection of passageways hidden beneath the hills.

Contained within this maze is an astonishing variety of resources, ranging from items of historical or cultural interest, to magnificent examples of some of the world's rarest cave formations (or "speleothems," as they are more properly called). Woven into this is a tiny, highly specialized, and extremely fragile ecosystem. Managing so many resources with such a high level of susceptibility to human impact is difficult. Making proper management decisions invariably comes down to knowing precisely what resources are located in each area of the cave. For this reason, cave maps have always been invaluable tools for the cave manager.

Wind Cave has traditionally presented its mappers with nontraditional challenges. Perhaps the most daunting of these is the three dimensional maze nature of the cave itself. The entire known cave is contained below a surface area of less than 500 acres. Thus in many areas, several passages overlap at different elevations in the limestone. It is difficult to portray the three dimensional relationships of these passages on a two dimensional piece of paper. Resources found within the cave have normally been kept off of the map for fear of "cluttering it up," resulting in a map which lacks some of the most critical information concerning the cave. Thus, determining what resources may be found in any particular passage has meant pouring through reams of survey notes, trip reports, and inventory forms – a time consuming process.

In Pursuit of a Better Cave Map

During 1985 and 1986, with the help of a magnetic induction device known as a "cave radio," work was carried out which eventually proved that the existing Master Map for Wind Cave was not accurate. Many rooms and passages on the map were shown several hundred feet from their true positions. Concerned that the map should more accurately portray the relationship between the cave and the overlying surface features and developments, the management at Wind Cave decided that a redrafting of the map was necessary.

The original plan had been to produce a typical ink on mylar drawing of the cave. Since declination changes had to be made in the survey data, and since radio located passages had to be constrained – thereby vastly complicating the problem of closing the hundreds of surveyed loops in the cave simultaneously – it was immediately apparent that a computer would be necessary.

Initially, the idea was to use the computer to reduce the survey data for the cave's 11,700 survey stations. The resulting coordinates could then be stored away and used to help produce the hand drawn map. But after researching the IBM and IBM compatibles software market, it seemed that we could take it one step further – we could also store the drawing itself (including passage outlines) in the computer with the use of computer-aided-design (CAD) software.

An Introduction to CAD

Just as a word processor is used to manipulate words, sentences, and paragraphs, CAD software is designed to manipulate lines, arcs, circles, and the drawings which contain them. Anything which can be drawn by hand can also be drawn using CAD software. The ability to draw objects on individual "layers" (similar to transparent overlays on conventional drawings) is one of several features which make CAD drawings superior to their paper counterparts. For instance, the plans for a house can be contained in just one drawing, with separate layers for each floor, layers for wiring and plumbing, and even a layer for landscaping. These layers can be viewed one at a time or together in any combination. Once created, they can be plotted at any scale or orientation.

It was the above capabilities which initially attracted us to CAD. No longer did we have to worry about the map being unreadable in vertically complex sections of the cave. By placing each survey station on a layer based on its elevation, we could "turn off" layers in complex areas of the cave to zoom in on the area we were interested in. Layers could be created to portray surface topography, surface developments, and vegetation types overlying the cave, providing visual clues to the links between surface and subsurface worlds.

The software we chose for the redrafting of Wind Cave's map was AutoCAD, published by Autodesk, Inc. Primarily, this was because AutoCAD was (and continues to be) the recognized industry standard. Its huge user base ensures that the program will be constantly evolving. The program's "open architecture" provides programmers with an opportunity to develop add-on programs which complement the original. AutoCAD is extremely powerful "out of the box," but this feature extends its power significantly. A wealth of information is also available in the form of books, magazines, and user groups making it easier to learn some of the program's finer points.

Methods

The first step in producing our digitized map of Wind Cave was to enter the survey data into a program which could analyze it. Since there are more than 11,700 stations in the cave, representing roughly 40,000 individual measurements, this was no small task. Approximately 600 hours were spent on this part of the project, the end result being a file which contained a unique set of coordinates for each station.

Once this was accomplished, a program was written to read in the coordinates from this list, placing them in an AutoCAD ".dxf" file, a file which directs AutoCAD to create a drawing on its own. This file instructed AutoCAD to draw a line between each survey station, and to draw a triangular symbol at the exact location of each station, along with the station's name. This provided the skeleton around which the map would be drawn.

A feature of this line plot is that it takes advantage of AutoCAD's 3D capabilities. The lines between stations are "three dimensional" in that they may be viewed from any possible angle. This provided us with an opportunity to view the profile of the cave for the first time. Other views are providing us with interesting clues into the cave's development by giving us insight into the structural and stratigraphic relationships of the passages.

Once this line plot has been produced, it is possible to add the passage outlines with the use of a digitizing

tablet. Passage outlines are drawn with pencil or ink around a line plot, then traced over with the digitizing tablet, which sends a stream of coordinates to the host computer to be stored away. Passage outlines are drawn on layers different from those that contain the line plot, enabling us to turn off the line plot for more artistically appealing maps. Layers are also created for passage features and contents, so that traditional cave maps may be plotted if desired.

The Map Becomes a Database

Another important feature supported by AutoCAD and other CAD packages is "attributes." An attribute can be thought of as a tag that can be attached to a part of the drawing. This tag can contain a piece of information concerning that particular part of the drawing. For instance, in a drawing of a house, attributes could be assigned to the door and window symbols. These attributes could contain information concerning the type of door or window needed, its cost, its energy efficiency, and any other information which seems necessary. All of this can be kept invisible if desired.

In the drawing of a cave, attributes could be attached to survey stations. The information which could be stored with each station on a map would include the survey station's name, its X, Y, and Z coordinates, any speleothems present, items of historical and biological interest, information regarding the amount of water present, search and rescue information (rigging instructions, etc.), travel statistics, and any other bits of information which may be acquired in the future. In short, everything known about every survey station in the cave could be included on the map, ready to be accessed at the push of a button.

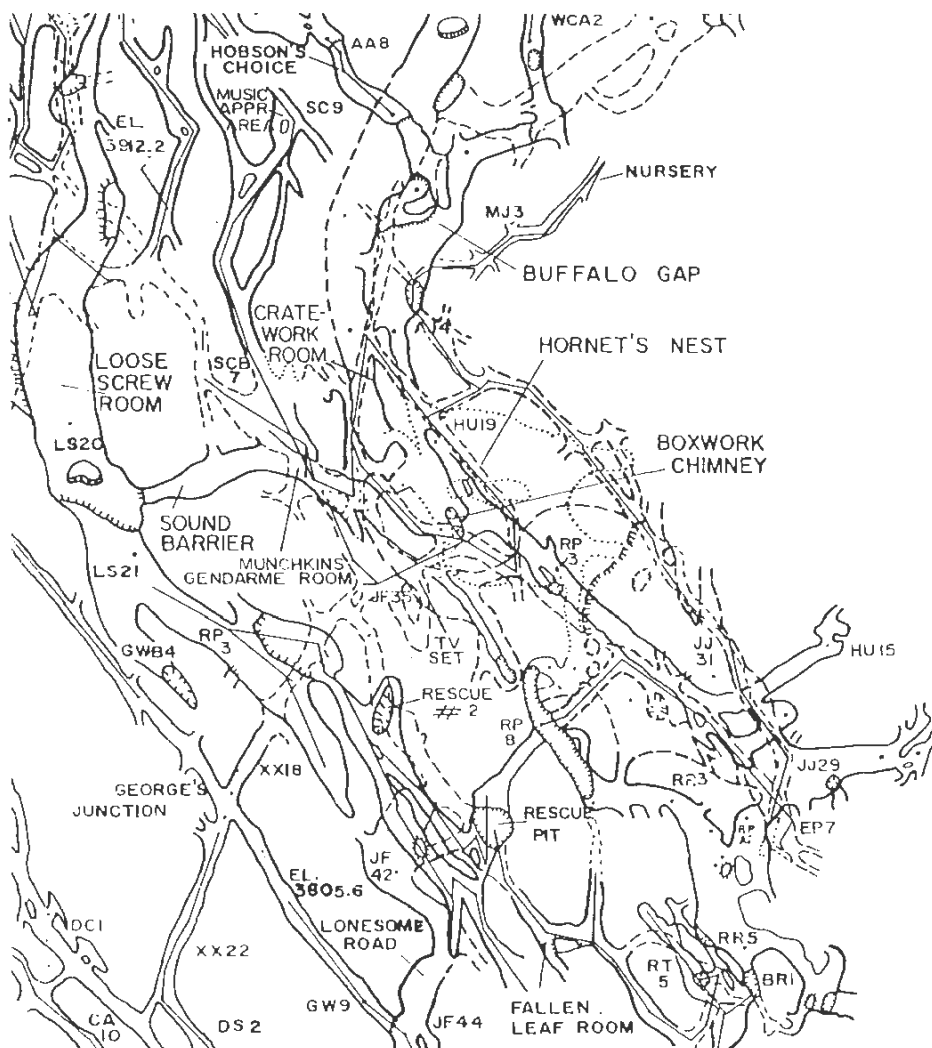
A cave much smaller than Wind Cave would work quite well with the above scenario. But the amount of information inventory trips are bringing in from the field would quite simply cripple the drawing by vastly slowing down the rate at which it generates on the computer screen. It was therefore decided to store inventory information in dBASE III+ files, with each database record corresponding to a survey station in the cave.

This required a little more creativity, since programs had to be written to interact between dBASE and AutoCAD. We can now search the dBASE files for any set of conditions, at the same time highlighting the survey stations on the AutoCAD map which satisfy those conditions. Even with the huge database and drawing files which Wind Cave generates, this process takes less than five minutes.

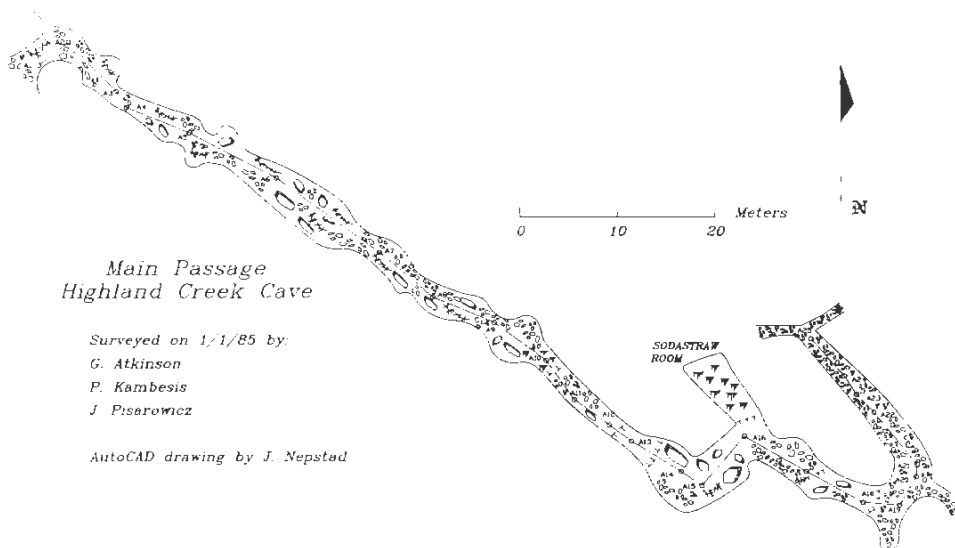
It is this important step that takes the digitized map beyond the realm of the traditional cave map. Traditional maps convey most of their information graphically, with little or no text. This is fine for a general overview of a cave. But what if you want to know where all the wet sections of a cave are? What if you want to see all occurrences of a particular speleothem at a particular elevation range? With a little programming, we have unleashed the real power of the digitized map.

The Map as a Collection of Maps

The programs produced at Wind Cave help us mimic one of the greatest talents of a GIS, the ability to produce new maps based on the outcome of some kind of query. By manipulating the information stored in the dBASE files, it is possible to produce an almost infinite number of maps from the original. Cross referencing data from two or more fields will produce graphical representations of relationships only dreamed of in



A vertically complex section of Wind Cave. Large numbers of areas such as this resulted in a map which was difficult to read.



An example of a digitized cave map showing survey information, passage features, and passage contents, each on a different drawing layer. Layers can be turned on and off to attain the level of detail desired.

the past. What effects are surface developments having on the cave? Do all major aragonite occurrences occupy the same elevation? What fragile areas are experiencing the highest visitation? Maps which will contribute to answering these questions can be produced in very little time. Thus, instead of being limited to one map which attempts to show us everything at once, we have a *collection* of maps, which will show us practically anything we want to know about the cave.

Implications for Management

By allowing such a vast amount of information to interact with the map, digitized cave maps such as the one under construction at Wind Cave will be of tremendous value to cave managers in the future. The decision-making process will not only be quickened, but considerably enhanced.

It should be further noted that applications for AutoCAD at Wind Cave go far beyond the cave itself. Surface maps showing vegetation types, burn areas, cultural sites, and much more can be produced with little effort, enabling managers to learn more about relationships between these factors. The information age is just beginning at Wind Cave NP.

Nepstad is Park Ranger Naturalist at Wind Cave NP.