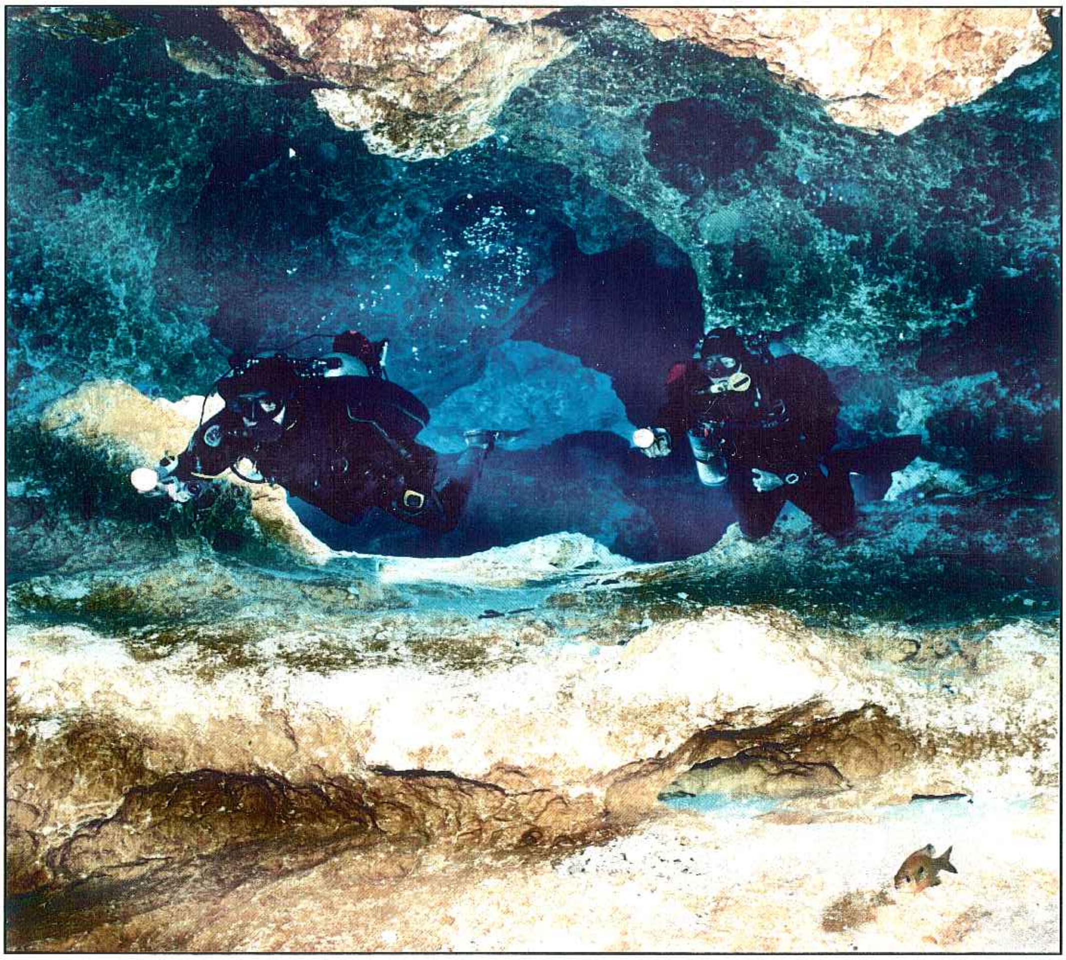
National Association for Cave Diving

Safety, Education, Conservation
Service & Exploration



Cavern / Cave Diver Workbook

First Edition- 2005, 2006

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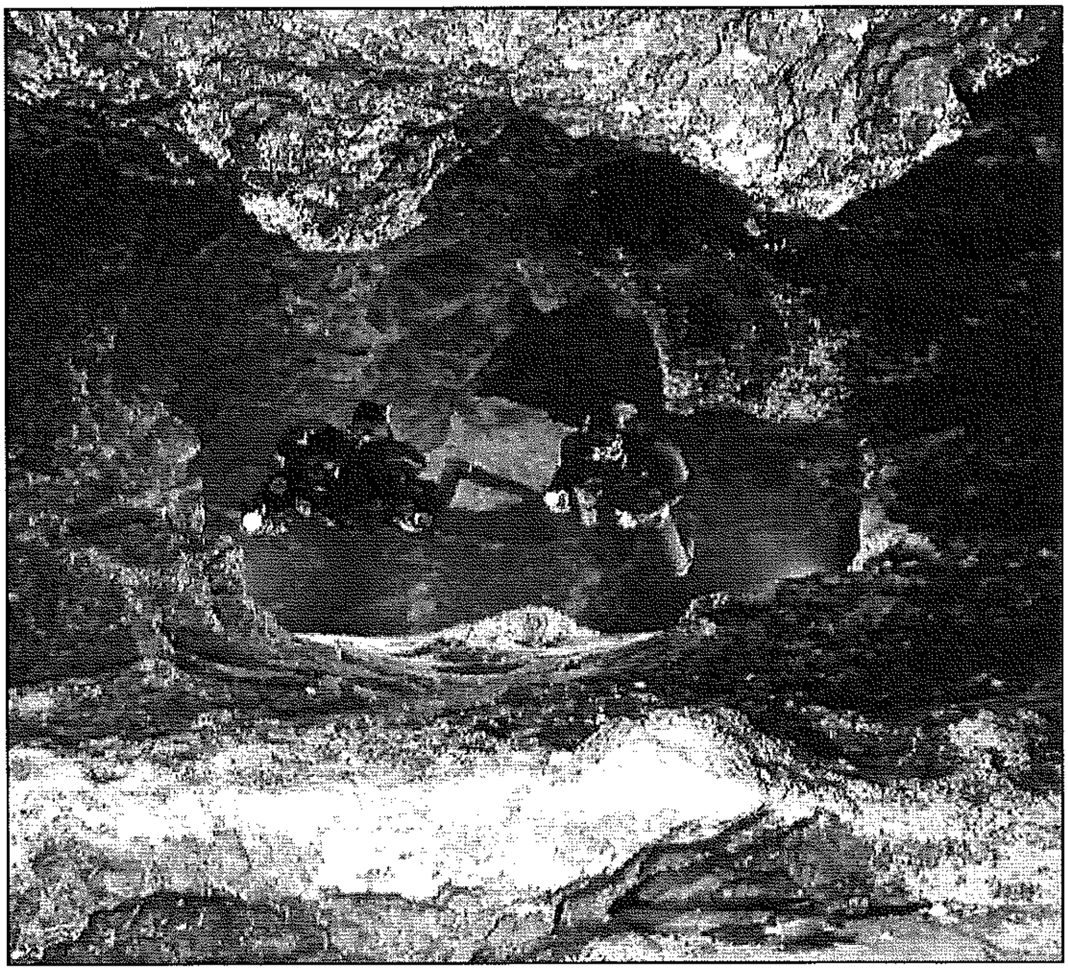

Cavern / Cave Diver Student Workbook

First Edition- 2005, 2006

Safety, Education, Conservation
Service & Exploration

Published in the United States of America
by the National Association for Cave Diving (NACD)

P. 0. Box 14492
Gainesville, Florida 32604
1-888-565-NACD (6223)
www.safecavediving.com

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Revised, April, 2006

Larry Green, International Training Director

The material contained in this workbook is designed to be used by the student cavern/ cave diver as educational material. Students are encouraged to take notes and incorporate additional information in this workbook as received from their instructor.

This workbook is a training aid intended to be used only as part of a sanctioned NACD cavern or cave diving course. Using this workbook without the supervision and training of a certified instructor will not adequately prepare a person to survive in an overhead aquatic environment.

Cavern and cave diving are inherently dangerous activities that can result in injury and death. No amount of preparation and training can fully eliminate the risks inherent in cavern and cave diving. Even strict adherence to the principles and guidelines set forth in this workbook cannot assure the safety of a participant.

Cavern and cave diving are strenuous activities. It is recommended that a person should consult with a physician before taking a cavern or cave diving course. A current list of NACD-certified instructors is available at www.safecavediving.com (under "Instructors") or in the most recent NACD Journal publication.

ACKNOWLEDGEMENTS

Special appreciation is extended to the following members of the NACD for donating time, knowledge and materials for the production of this workbook.

This workbook was compiled for the NACD as an aid in the education of cavern and cave students.

The authors listed below have contributed to the Cavern and Cave Diver Workbook:

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Cavern/Cave Diver Workbook– Contributors

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Cavern/Cave Diver Workbook– Foreword

The National Association for Cave Diving is an educational association whose primary emphasis is cave diving safety. Personal and team safety should always be a basic operational premise for each dive. The concept of personal safety requires the diver to be introspective, to have a realistic understanding of their own abilities, and be able to access their mental and physical state on any given day.

Cavern & Cave Diving is certainly not a new activity. Over the last five decades, this type of diving has become an increasingly popular facet of sport diving. Unfortunately, cavern and cave diver literature has not kept pace with this growing popularity. This book, **"NACD Cavern/Cave Diver Student Workbook"**, provides specific technical information to help educate divers and enhance their decision- making abilities.

Awareness and introspection are essential to a diver's safety. A diver with a high level of awareness can often recognize the early signs and symptoms of potential problems. After recognizing a potential problem, the properly trained cavern or cave diver will take steps to correct them or at least prevent them from escalating. Another goal of the NACD is conservation of our cavern and cave systems. With that in mind, this book is also an attempt to foster a sense of awareness for the need to preserve our overhead aquatic environment.

Diving in underwater caverns and caves is a unique experience that requires specialized equipment and techniques. No other type of diving activity is as dependent on proper technique, equipment and teamwork.

Taking a cavern or cave diving course from an experienced cavern/cave diving instructor can instill in you systematic procedures for dealing with the different scenarios in the overhead environment. In just a few days of training, you can learn the basics that will provide you with the groundwork for a lifetime of learning a sport, a skill, what some even call an "Art". This is an important step toward becoming not just a cavern/cave diver but someone who can safely enjoy this experience.

Education and training should continue beyond simply taking training courses. In order to fully develop one's potential, divers must engage in additional self-study. They must work on skill development and refinement that is only gained through experience. Most importantly, cavern/cave divers need to subject themselves to critical self-evaluations of their performance with the idea to continuously improve their skills. Training and experience provide the foundation for proper performance and an appropriate conditioned response to the situations that you will encounter. Learning to cavern/cave dive is a journey in personal evolution. It is the key that opens the door to the educational process that will develop safety and self-reliance as it expands your horizons.

I want to thank all the volunteers who donated their time to produce this workbook.

Safe Diving,
Larry Green
NACD Training Director

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INTRODUCTION TO THE CAVERN AND CAVE DIVING COURSES

Welcome to the NACD's (National Association for Cave Diving, Inc.) course for Cavern and Cave Diving!!!

This text is divided into four sections: **Cavern Diver**, **Intro to Cave Diver**, **Apprentice Cave Diver** and **Full Cave Diver** and is designed to provide the student with a single reference source for each level of overhead training.

What is cavern and cave diving?

Any time the diver is at a point in the underground, underwater environment which prevents direct and immediate ascent to the surface- our unlimited air supply- he is within a cave environment. In one sense, when the student departs the open water environment for the rock overhead, he is cave diving. You will discover that a cavern is the daylight zone of the cave. Because of the inability of the diver to freely access the safety of the surface, special techniques, skills and procedures apply. This series of courses is designed to provide the student with necessary information to safely dive in the cavern and cave environments.

Just as important as diver safety is the care and conservation of the unique environment you are about to discover. Our enthusiasm to explore the cavern and cave overhead must be tempered by a respect for the cave, its formations and the life found within our cave systems. By undertaking this course of training, you accept a high obligation to protect and conserve our caves for future generations. Damage to this environment- intentional or unintentional- will not be tolerated in any form. The course of training which you now seek requires a high skill and awareness level- one your instructor will demand from you.

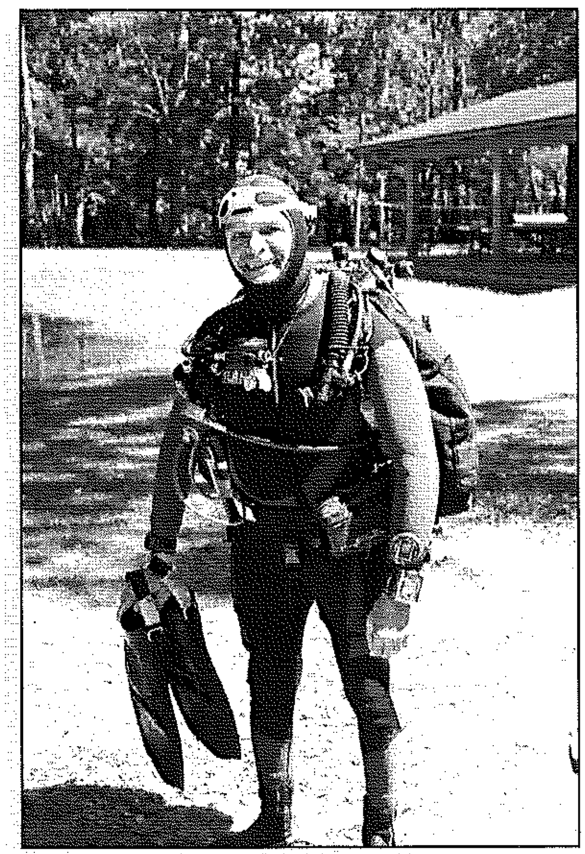
What can you expect from this NACD course?

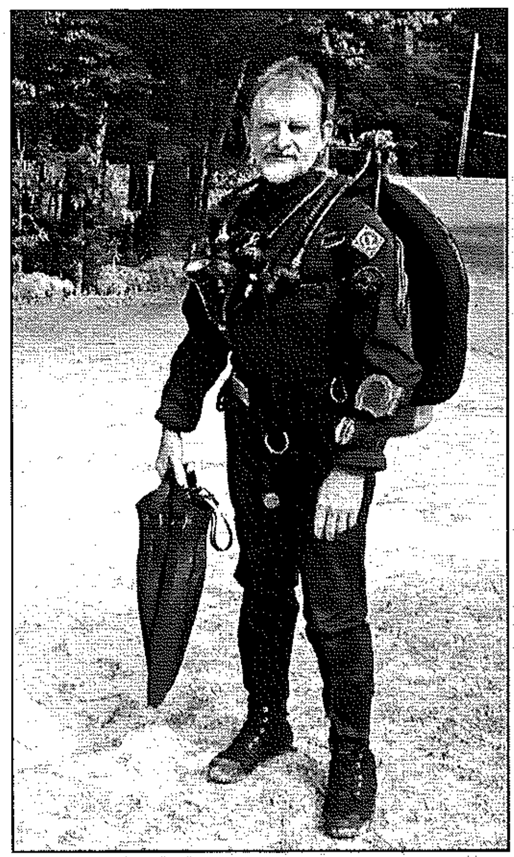
Cave training, beginning at the Cavern level, is the most rigorous, demanding and exacting of any form of recreational SCUBA training. The course of instruction offered is a training- not certification- program for which certain criteria must be met before a completion card is issued. Such criteria include those specifically stated in the Standards for the enrolled course of instruction as well as the Instructor's subjective determination of the student's overall capability, technique, attitude, comfort level and awareness. The course of instruction offered is not a certification program- payment of fees and attendance of training are only partial requirements for completion to the training level sought by the student. Basic buoyancy control skills and awareness levels are assumed- if you don't have the basics well under control, you are not prepared for this course of instruction.

The NACD's goal is to provide you a variety of techniques and skills so that you have the opportunity to demonstrate an acceptable level of proficiency within the overhead environment. The NACD does not subscribe to the "only one way" theory in terms of gear configuration. While certain points of configuration are not subject to variation- the long hose primary regulator attached to the right post- streamlining and efficiency is the primary issue. The positioning of your SPG and other gear configuration concerns will not be dictated to you so long as the overall objective is achieved and you have a sound and rational basis for selecting a particular gear configuration.

Education is the basis of this program. Experience and judgment are developed over time. It is our goal to provide you with the basic understanding and skills necessary to permit you to safely become the very best cavern or cave diver you can be. Keep your eyes and your mind open to the suggestions of others and never stop learning.

Welcome to the exciting world of underwater caverns and caves!





DEDICATED TO SAFE CAVE DIVING

The NACD was established in 1968 for the purpose of achieving safer cave diving through proper training and the development of maturity in judgment which minimizes taking unnecessary risks. It is the pioneer in cave diving training, education, exploration and research with the following goals:

- ◊ To establish and maintain current guidelines in the form of physical and psychological standards along with equipment and techniques necessary for safe cave diving.
- ◊ To encourage education and dissemination of safe cave diving information throughout the facilities of the organization and to provide a program of education and advanced training essential for safe cave diving.
- ◊ To achieve closer cooperation and understanding among members of the cave and recreational diving communities (and the general public) so they may work together toward the common goal of increasing safety in cavern and cave diving.
- ◊ To explore underwater caves and to encourage education and dissemination of information to government, private industry and the general public.

To accomplish these goals the NACD is organized to provide the following services:

Training and Education-The NACD establishes and maintains standards for safe cavern and cave diving.

Seminars and Workshops-The NACD is active in organizing and planning seminars and workshops, often in cooperation with organizations concerning equipment, techniques, safety, education, training, conservation and exploration.

Information Services-The NACD publishes and disseminates information regarding cavern and cave diving in the form of newsletters, journals, pamphlets, seminar proceedings, training manuals, cave maps, textbooks and safety reports.

Membership and Record Maintenance-The association maintains the records of certified cavern and cave divers and instructors as well as individual members of the organization.

Conservation-The NACD supports the preservation of the cave habitat and its unique flora and fauna through education, periodic clean-ups at popular dive sites and safety sign campaigns.

Exploration and Research-The NACD is active in conducting studies of accident prevention, management of cave diving sites and stress in cave diving and promotes scientific endeavors relative to archaeology, cave ecology, geology, hydrology and ground water pollution.

THE NACD PHILOSOPHY: QUALITY TRAINING, SAFE TECHNIQUES AND RESPECT FOR THE SUBAQUATIC CAVE ENVIRONMENT

The goal of the NACD is not to encourage participation in cavern or cave diving. The responsibility of the organization is to aid interested divers in becoming safe cavern or cave divers and to discourage those who may not meet minimum standards. The NACD philosophy of safe cave diving is based on a system of checks and balances to insure that NACD standards are maintained in each course.

1. **A Strong Diving Partner Philosophy.** The NACD strongly advocates diving with a partner as the best approach to safe cave diving. This system is one which unites two or more individuals into an effective dive team. A partner is a member of a team who, in case of emergency, provides both emergency equipment and an emergency gas supply. The divers must recognize individual strengths and weaknesses, create an attitude of mutual trust and honesty and avoid personality differences to maximize team safety.

2. **Pre-Dive Planning and Post-Dive Critiques.** A safe cave dive is totally dependent upon sensible dive planning based on common sense and good judgment. A dive plan does not set objectives; rather it delineates maximum guidelines for each dive. Preparation and planning for a cave dive must take into consideration the equipment, training, experience and abilities of each team member. Constructive critiques after the dives are equally important in order to allow cave divers to mature as a team.

3. **Development of Physical and Mental Capabilities.** During a cave diving course, students are trained to avoid stressful situations and anticipate potentially hazardous conditions. Physical abilities of the diver are initially developed in confined and open water exercises. Students lacking the necessary skills and coordination are discouraged at this level. The cave diving student must learn to develop a safe diving philosophy and continually think through the proper application of common sense, good judgment, techniques, skills and experience.

4. **Appreciation of The Cave Environment.** The NACD promotes a basic understanding of this unique environment with its flora and fauna so that it can be fully enjoyed. Such respect helps establish the foundation for conservation efforts.

NACD MEMBERSHIP

- **Voting membership** in the NACD is open to all individuals who have been successfully certified through a recognized complete cave diving course and who have paid the annual membership fee of $30.

- **Instructor membership** requires successful completion of an NACD Instructor Training/Evaluation Course, the payment of the instructor's annual membership fee of $40 and maintaining current status requirements.

- **Associate membership** is open to the public and all certified cavern divers regardless of certifying agency. This offers all membership benefits except voting privileges. Associate membership allows one to stay informed of developments in cavern and cave diving as well as scheduled courses. (This category provides direct input and support for the cave diving community.) Dues are $30 annually. To encourage savings in monies and to maintain loyal support, the NACD offers ten-year memberships at $225 and lifetime memberships at $450. All members receive a discount on single copy orders of NACD publications, reduced admission fees to NACD events, seminars and workshops and an annual subscription to the NACD quarterly journal.

- **NACD ANNUAL SEMINAR** The purpose of the NACD Annual Seminar has been to promote SAFE CAVE DIVING THROUGH EDUCATION AND TRAINING. These seminars are conducted for the purpose of making cave diving a safer and more enjoyable activity for the diver and to bring a better understanding of cave diving to the recreational diving community, property owners and the general public. With presentations and slide/video shows on a variety of topics including ecology, geology, hydrology, equipment, training and exploration, a universal interest is assured. Held each year in the "heart" of North Florida spring country, the **NACD ANNUAL SEMINAR** is sponsored by the cave community. For specific information, contact the NACD national address.

- **NACD PUBLICATIONS** The NACD maintains a complete library of publications for the cave diver and general public consisting of training texts, newsletters, safety reports, journals, research bulletins, pamphlets and specialized subjects related to the cave environment. **For a complete listing of all NACD publications and price list, write to the following address or visit the web site:**

NACD
P.O. Box 14492
Gainesville, FL 32604
ATTN: Publications Chairman
www.safecavediving.com

NACD LIBRARY

The NACD maintains a list of available cave diving related books, publications, reports and newsletters accessible through the Bureau of Geology, State of Florida Department of Natural Resources. See the NACD Journal for current address.

NACD WAKULLA SAFETY AWARD

The NACD established the Wakulla safety award in recognition of safe cave dives accomplished. This award is named in honor of the first use of compressed air and diving equipment in an underwater cave in the United States in 1935 along with being one of the world's most spectacular cave systems explored. The award is given upon suitable documentation and authentication at the following levels:

⇒ **Bronze Wakulla Safety Award:** 100 or more hours of bottom time in the cave zone or 100 or more cave dives

⇒ **Silver Wakulla Safety Award:** 500 hours or more of bottom time in the cave zone or 500 or more cave dives.

⇒ **Gold Wakulla Safety Award:** 1,000 hours or more of bottom time in the cave zone or 1000 or more cave dives.

A qualified cave dive is any dive on scuba in the subaquatic cave zone, which lasts 20 minutes or more and is separated from another dive by a surface interval of 10 minutes or more. The "hours" requirement is established as all time spent in the cave zone on scuba. An instructor on training dives will accumulate numbers of dives more quickly than an explorer. The explorer, however, will accumulate hours of bottom time more quickly.

The Wakulla Safety Award represents all cave diving formats in providing recognition for safe cave diving accomplished. All **certified full** cave divers worldwide are eligible for this award. To be a recipient, a diver must provide evidence of the stipulated number of dives/hours by submission of photo copies of logged dives **after full cave training is completed** which has been verified by a NACD Instructor. There is no fee for the award and it is provided as an incentive to safe cave diving. Inquiries and applications should be addressed to:

Wakulla Award Administrator
NACD
Box 14492
Gainesville, Florida 32604
(Details also at www.safecavediving.com)

"A NEED FOR BETTER UNDERSTANDING" WORKSHOPS

These workshops are presented by the NACD for the benefit of all scuba diving leaders and scuba divers who are interested in learning more about diving in the cave environment. This permits them to better inform the constantly growing recreational diving community of the need for specialized training before attempting to dive in caves and caverns.

The purpose of this workshop is to expose the participants to the special nature and requirements of diving the "overhead environment," whether in a "cavern" or cave zone. The vast majority of victims with fatal cave-related diving accidents were divers who had NO TRAINING in the special skills required for cavern or cave diving.

One of the main points to be made in the reduction of tragic accidents is informing scuba leaders of the NEED FOR SPECIALIZED TRAINING and discussing the best approach to take with sport divers and diving students regarding cavern and cave diving.

NACD INTERNATIONAL BRANCH

The purpose of this branch organization is to need to serve ALL cave divers from around the world. As cave diving grows in interest and popularity, cave sites will be discovered and developed in many countries on many continents. The International Branch appoints representatives from established cave diving areas to better communicate and expedite dissemination of information, publication, training, exploration projects and science/research tools.

The primary goals for the NACD training program are:

1. Establish and maintain standards for the training of SCUBA divers in cavern and cave diving.
2. Establish and maintain quality standards for the training/evaluation and certification of instructor members.
3. Promotion and encouragement of education and awareness of the general public in the safety and training aspects unique to cavern and cave diving.
4. Supervise and control the professional activities of instructor members while they are engaged in cavern and cave diving instruction.
5. Introduce training programs for instructor members and inform them of current practices.
6. Provide and circulate course curriculum guidelines, materials and publications for cavern and cave training.
7. Coordinate with other professional organizations' programs and activities of cavern and cave diving safety and education.

NACD CAVE CONSERVATION POLICY

A primary purpose of the NACD is TO CONSERVE and TO PROTECT the cave habitat and its varied flora and fauna through education and to development in the cavern/cave student a strong respect for this unique and delicate environment. In consideration of the ever-increasing number of cave divers utilizing the underwater cave environment, it has become of prime importance that conservation of this environment be strongly emphasized at all levels of training. It is the responsibility of all NACD instructors to educate each cavern/cave student of the unique formations found within our cave systems and to develop a high level of awareness in each student of the fragility of the cave habitat. Students must be made aware of the need for proper buoyancy control, trim position, propulsion technique and awareness levels necessary to preserve this limited resource for the enjoyment of future generations. Damage resulting from unintentional contact through the use of poor technique or reduced awareness cannot be condoned by NACD instructors and must be strongly discouraged through the education process at all levels of training. Damage resulting from intentional contact, including contact resulting from the diver's failure to obtain appropriate training, shall not be tolerated in any form. If an NACD certified diver wishes to undertake an advanced activity, that diver agrees with and understands the need for training in that activity. Such advanced activities may include alternate gear configuration (for example, sidemount configuration), operation of a DPV within the cave system and diving to depths beyond 130 fsw. By engaging in such activities without proper training, the diver acknowledges that he is exposing the cave environment to intentional and unnecessary damage. Removal of "souvenirs" of any form from the cave habitat is condemned by the NACD. The diver is encouraged to remove diver debris from the cave systems, but to leave all naturally occurring formations- intact or damaged- within the cave. Each cavern/cave diver must assume a high degree of personal responsibility for protection of the cave environment. It is the duty of each diver to take personal responsibility for eliminating damage to the cave systems and educating others of the need for conservation and protection of these systems. I, as a student in an NACD cavern or cave program, have read this policy and agree to its terms.

______________________________ ______________

STUDENT SIGNATURE DATE

Conserve & Protect!

CAVERN DIVER COURSE

LIMITATIONS OF CAVERN DIVING

As with any other activity, there are clear and distinct limitations to cavern diving. It is of prime importance that the Cavern Diver be well aware of the limitations imposed at this level of training and strictly adhere to those limits at all times. There is sometimes the temptation to go just a "little bit" further than allowed- the cave environment often seems gentle and inviting. Those divers who exceed their limitations of training fall within the highest frequency category of cave diver death and are inviting disaster to themselves and others by that "little bit".

CAVE DIVING IS DECEPTIVELY SIMPLE!!!!!

It may not be until an emergency arises that the need to observe your limits of training becomes apparent- by then it may be too late. If you wish to travel to a point beyond your present level of training, take the time for the training readily available. Family and friends will appreciate your exercise of sound judgment.

CAVERN DIVER LIMITATIONS

1. ***Daylight zone.*** The Cavern Diver must always stay within the daylight zone of the cave system. While it is not necessary to have view of the physical opening to the cavern, clear view of ambient light radiating through that opening must be plainly visible. The Cavern Diver should maintain a high degree of awareness that clear view of ambient light remains throughout the dive. Divers entering or exiting the cave system may negatively impact visibility to the extent that ambient light is no longer available for the Cavern Diver. Swimmers and open water divers may affect open water basin conditions by disturbing particulate in the basin which results in a reduction or absence of ambient light. The Cavern Diver must remain aware during the entire course of the dive and be prepared to exit the cavern zone in the event his primary light source (daylight) is threatened. If the diver must question whether he should continue the dive, it is time to exit and dive another time or place. Local, temporary environmental conditions may make a normally safe cavern dive unsafe. Tannic intrusion from an adjoining river, algae bloom or reduced basin visibility due to flooding may obscure daylight to the extent that there is no longer a daylight zone within the cavern zone. Since Cavern Divers require the sun as their primary light source, there can be no cavern dive made at night- as darkness approaches all dives within the overhead become cave dives.

2. ***Gas supply.*** Cavern divers are limited to one-third (1/3) penetration gas of a single diving cylinder or, when permitted, one-sixth (1/6) of double cylinders. Doubles may be used by Cavern Divers only under the direct supervision of an instructor. Additionally, the Cavern Diver must begin the dive with at least an air supply of either 2000 psi or 58 cubic feet, whichever is greater.

3. ***Penetration distance.*** At this level of training, the diver is limited to two hundred (200) feet of linear penetration **from the surface**- i.e. back to the unlimited air supply of the surface. If, for instance, the navigable portion of the cavern begins at a depth of sixty (60) feet, the Cavern Diver would be permitted to travel into the overhead a distance of one hundred and forty (140) feet. Depth to the navigable entry of the cavern must be subtracted from the maximum linear penetration distance.

4. ***Minimum visibility.*** The Cavern Diver must begin the dive with a minimum visibility of thirty (30) feet. This distance is determined by the ability of the diver to clearly recognize and acknowledge a lighted hand signal. While it is not required that thirty (30) feet of visibility remain constant throughout the course of the dive, the Cavern Diver should "thumb" the dive any time clear view of ambient light from the opening is threatened.

5. ***Maximum depth.*** No dive at this level should exceed one hundred (100) feet in depth. The depth limitation is intended to minimize the possibility of symptoms of nitrogen narcosis in this new environment. Since all dives must be within No Decompression Limits, dive time beyond this depth would be minimal.

6. ***No decompression diving***. The Cavern Diver must remain within the No Decompression Limits of the dive computer or tables he has selected for the dive.

7. ***No restrictions.*** A restriction may be either **major** or **minor**. A major restriction is one which requires manipulation of the diver's body and/or equipment in order to pass through the area. A minor restriction occurs in those areas of the cave which are too small to allow two divers to pass through at the same time and that requires single file formation. "Side-by-side" means any dive team profile which permits team members ready and immediate access to a buddy's air supply- one diver traveling above the other fits well within this definition. The purpose of this limitation is to prevent the newly trained Cavern Diver from entering points in the overhead which restrict ready access to the reserve gas available from a team member in the event of an emergency.

8. ***Safety stops.*** A recommended three minute safety stop should be observed on all dives.

9. ***Continuous guideline.*** The Cavern Diver must maintain a continuous guideline to open water. Does the overhead diver require a guideline to enter the cavern? The answer is "NO", but a guideline may certainly be required to exit the cavern. Guidelines are not placed for ideal circumstances but for the worst-case scenario- zero or substantially reduced visibility within the cavern and the open water basin. Because there are many different factors which may affect visibility on any given dive, the continuous guideline must be placed to assure the Cavern Diver's safe exit from the system. It is imperative that the initial or **primary tie-off** be made in **open water**. Placing this tie-off under any portion of the overhead will not assure the dive team's safe return to the surface in the event of an emergency. It should be followed by a **secondary tie-off** in the cavern zone.

10. ***Use of required and properly configured equipment.*** This subject will be fully discussed in the equipment section of this text. No matter the level of overhead training, if the diver is not properly configured for a cavern or cave dive, he is diving as an open water diver and should never enter the overhead environment.

Jackson Blue Cavern - Florida

ACCIDENT ANALYSIS

No other form of recreational diving reviews and critiques itself to the extent of technical recreational divers. Cave divers are considered the most technical of this group and, as such, are the most critical of all aspects of their discipline. Accident Analysis is the process by which cavern and cave divers learn from and avoid the mistakes of others.

Accident Analysis is the process of conducting a detailed examination of the elements leading up to an event which occurs without apparent cause, is unexpected or unintentional and often results in diver fatality.

Statistics show that since 1960 over 560 divers have perished in underwater caves throughout North America. Many of these divers were not cavern or cave trained- they were open water divers and open water scuba instructors. This illustrates that the cave environment holds no bias to those who choose to enter the overhead environment. The training you receive will help assure the safety and enjoyment of cavern and cave diving and is the result of our self-critique and observation of guidelines established through Accident Analysis. It takes very little skill to enter the overhead environment- our training is designed to permit the diver to safely exit the cave.

A single accident can impact the entire cave diving community. A study of these accidents has had a major influence on the training and development of our sport. By compiling a list of safety procedures and studying those which were violated resulting in cave diving fatalities, the pioneering cave diver Sheck Exley discovered a commonality of factors contributing to cave fatalities. Sheck Exley founded the basis of what is considered the building blocks of all cave diving educational systems. Time has proven that this approach is an effective tool to preventing further fatalities in the overhead environment. Analysis of documented accidents has established five contributing factors to diver fatalities. These are listed in order of their frequency of occurrence.

Guidelines of Accident Analysis

(For the Untrained)

1) Training- Lack of training or exceeding current limitations of training is the primary contributing factor to cave diving fatalities.

2) Continuous Guideline- Failure to run a continuous guideline to the open water allowing for a direct ascent to the surface is the second most common cause of cavern and cave diving fatalities.

3) Rule of Thirds- Failure to reserve at least two thirds (2/3) of the starting gas supply for the exit and ascent to the surface (Rule of Thirds) is the third most common cause of cavern and cave diving fatalities. This rule should be adjusted to a more conservative gas management plan under a variety of circumstances.

4) Depth- Exceeding maximum depth limits for the diver's current level of training and as determined by the breathing medium used (for example, Nitrox) is the fourth most common direct cause of cave diving fatalities. Cavern dives are limited to a maximum depth of one hundred (100) feet and no recreational cave dive shall exceed one hundred thirty (130) feet. Responsible divers must always be aware of any depth related risks.

5) Equipment- Failure to have required working and properly configured/maintained equipment for the diver's level of training is the final cause of cavern and cave diver fatality. As a result of this guideline, some dive sites maintain access restrictions prohibiting untrained overhead divers from using lights. This has proven a most effective manner of preventing unnecessary emergencies.

Further Thoughts

Unescorted, untrained open water divers may dive relatively safely if they avoid entering the cavern or cave, remain in the area of direct ascent to the surface and do not carry dive lights. It is the responsibility of every cavern and cave diver to be alert to the presence of an untrained diver within the overhead environment and advise that diver of the risks associated with diving this unique and potentially fatal environment. As a trained cavern or cave diver, you are responsible in demonstrating a positive and safe attitude.

Guidelines of Accident Analysis

(For the Trained)

Previously it could be said "no trained cave diver has ever perished in a cave". This is no longer true and new guidelines of Accident Analysis have been formulated for the TRAINED cavern and cave diver. Through analysis of cavern and cave diving accidents, it has been determined that one or more of the following three (3) primary causes contribute to fatalities among the trained cavern or cave diver.

1) Depth—Failure to observe the depth limitations of training.

2) Guideline—Failure to maintain a continuous guideline from open water and throughout the cave system. Complacency in observing guideline protocol may result in diver fatality.

3) Gas—Always reserve 2/3 of your gas for exit– never violate the Rule of Thirds. Cheating or "stretching" gas puts the diver and entire team in peril. At the Cavern Diver level it is essential that divers refine gas matching protocol by taking into account dissimilar cylinder volumes and breathing rates. Refer to page 76 for details on dissimilar cylinder volume calculations.

Additional Points

- Dive with a properly trained and equipped diving partner and maintain dive team continuity throughout the dive.
- Increase the complexity of your dives slowly as your experience increases.
- Increase your knowledge of a cave system slowly and methodically as your experience and familiarity with that system increases.
- When diving with team members of differing levels of training, always dive to the level of the least experienced team member. If you are the least experienced diver in the team, it is your responsibility to insist upon remaining within your level of training and comfort.

CONSERVATION

The cave environment in which you dive is one of great beauty and adventure. It is also a very delicate system highly susceptible to damage. Features within a cave may include:

- ***Geothite*** is a mineral deposit composed mainly of iron and manganese oxides that may form with the aid of bacteria. The formation of goethite is centuries-long and typically presents itself as a black or rust-colored coating over the underlying rock.
- ***Phreatic formations*** are those formed as the result of the erosive action of water over rock. A window is an example of such a formation.
- ***Sediment formations*** include stratified clay banks and floors and expanses of smooth or rippled mud and sand floors. Sediment formations are particularly susceptible to negative impact as the result of diver and equipment contact with the floor.
- ***Bacterial colonies*** consist of huge numbers of individual bacterial cells held together very loosely. These colonies can be easily dispersed and killed by a careless fin kick.
- ***Delicate formations*** exist in the form of thin rock ledges, wall protrusions and other delicate erosional features and remains. These formations are easily broken and do not heal. Once broken, they are gone forever with the only evidence of their existence being rock litter on the floor of the cave.
- ***Speleothems*** are the result of secondary mineral deposits within a vadose cave. Examples include stalactites, stalagmites, soda straws and flow stones.

Along with the ever-increasing number of cavern and cave divers, there has occurred an increase in the frequency and nature of negative diver impact to the overhead environment. Every overhead diver assumes a high degree of personal responsibility in preserving the beauty of this unique environment for future generations. The cavern and cave diver must develop and maintain a complete awareness of his surroundings and impact on those surroundings. A few simple guidelines should be observed:

- Do not collect from the cave environment. It makes no difference that the item collected is damaged and on the floor- it should be left in place.

- Leave no debris behind. If you see other's debris, remove it during your exit.

- Avoid all contact except that which may be appropriate for the system in which you are diving. The pull and glide propulsion technique requires contact and is appropriate in a high flow "hardened" limestone environment- it is absolutely inappropriate in a low flow "soft" cave system. Tank scars in cave ceilings and handprints on the floor are damage which will exist for geologic time. They are the diver's permanent signature within the cave system and are the sign of an unskilled, unaware and uncaring diver.

- At more advanced levels of cave diving, in the event contact is required due to restricted passage size, minimize contact to the extent possible.

- Match your level of training and experience to the system you choose to dive. Diving a cave system or area of a cave beyond your current level will result in unnecessary damage to the cave and poses a threat to diver safety.

- Do not dive equipment for which you are not trained and qualified. At higher levels of cave diving, specialized training programs are available for the use of DPVs and additional equipment. The untrained, unskilled use of advanced equipment and techniques will result in extensive and unnecessary damage to our cave environment. Such damage is the equivalent of intentional damage and cannot be tolerated by the cave diving community.

Respect for and care of our overhead environment begins at the Cavern level and continues throughout all of your overhead dives. We choose to enter this unique and fragile environment and, by doing so, owe a commitment to ourselves, our fellow cavern and cave divers and future generations of overhead divers to protect and conserve this environment. Do your part to protect your caverns and caves and do not tolerate damage by others.

Conserve &

Protect!

LANDOWNER RELATIONS

The development of positive landowner relations is imperative to gaining and maintaining access to our favorite caverns and caves. While much of the work in this area is performed by the various cave training agencies, it is important that each individual cavern or cave diver recognize their responsibility in maintaining workable landowner relations. A few simple guidelines should be observed:

◊ Adhere to all posted rules and regulations while cavern or cave diving.
◊ Behave in a professional manner while at ANY dive site since individual divers serve as examples of the entire cave diving community.
◊ Do your part in maintaining the site– if you see trash in the area, pick it up and dispose of it.
◊ Do your part in developing a good relationship with others– both open water divers and non-divers - sharing the site with you.

Land ownership and the resulting access typically falls into one of the following categories:

◊ **Private ownership**- Private ownership consists of either commercial sites for which diver requirements are established and access fees must be paid or privately owned land which require landowner permission to access and dive the site.

◊ **Publicly owned land**- A number of cave sites are owned or controlled by County, State or Federal governmental authorities. These sites tend to be more strictly controlled with strict adherence to site rules required of all divers. Those cavern and cave sites located within a portion of a navigable waterway are also governmentally owned or controlled.

◊ **Simple trespass sites-** While the landowner of these type of sites has never given express access permission, it has never been denied.

◊ **Agency owned sites**- Some sites are owned by cave training agencies and specific diver requirements must be met in order to dive such sites. The NACD, through its Sustaining Contributor Program, is actively seeking the purchase of cave sites for use by its membership.

◊ **Special access sites-** There exist several cave systems accessible only through special permit for scientific or other research purposes.

◊ Respectfully police unqualified and untrained divers through education of the overhead environment, accident analysis and local rules governing the untrained.

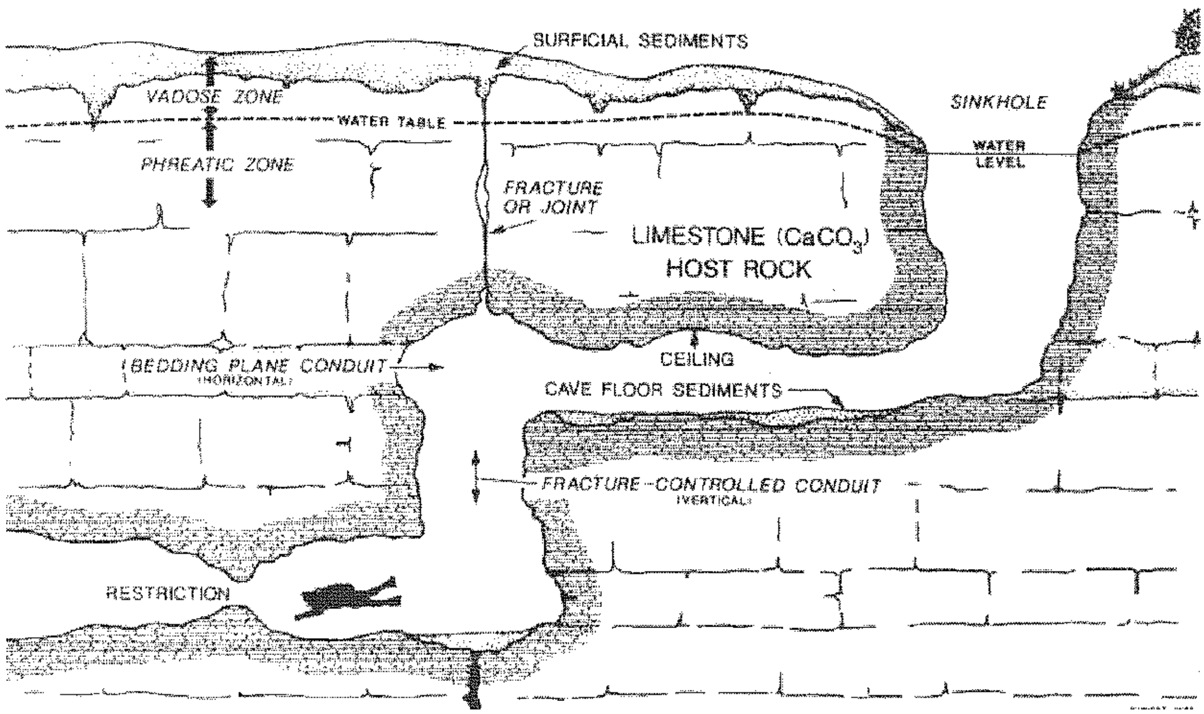
CAVE TYPES, ENTRANCES AND FORMATIONS

A basic understanding of cave type and formation of the cave environment helps the overhead diver minimize negative impact to this unique resource, increases safety and enhances the overall enjoyment of the dive.

GENERAL TYPES OF UNDERWATER CAVES

- **Sea Caves**- Sea caves are found in the coastal marine environment. They are of rock composition subject to physical erosion by wave and current action. These caves normally are not extensive and may be hazardous due to the wave action, surf and tides influencing them. Sea caves are, however, usually abundant with marine life.

- **Coral Caves**- Coral caves are usually found in tropical saltwater marine environments and are composed of limestone tests or skeletons that have been compacted and cemented with calcium carbonate into formidable rock. They are usually small and short and are created by mechanical erosion by wave and current action.



- **Lava Tubes-** Lava tubes are found throughout the world in locations where geological occurrences of extrusive igneous rock are observed. They have been explored in Hawaii, the Northwestern United States and the Canary Islands. Lava tubes are formed during the cooling and degassing phase of lava flows associated with volcanic activity. These caves are hazardous due to the dark rock, tides and silt and exhibit mazes, pits, multiple levels and wet zones very analogous to the features found in solution caves.

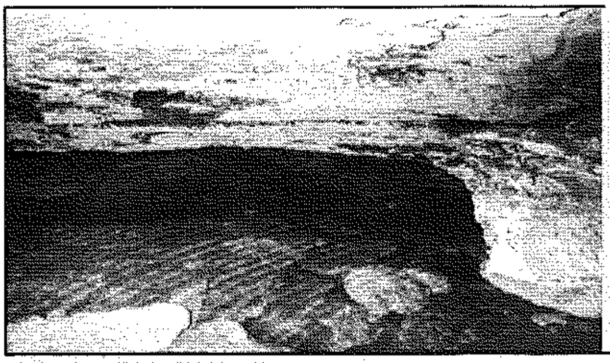
- **Solution Caves-** This type of cave is the longest, most complex and most extensive type of cave. Solution caves (also referred to as dissolution caves) are formed by the dissolution of "cement" bonding the original rock together or layers of sediment between rock planes. They are predominantly composed of limestone (calcium carbonate or CaCO3) or dolomite (calcium magnesium or CaMg) and form some of the most spectacular caverns and caves in the world.

PHYSICAL FEATURES AND ENTRANCES OF SOLUTION CAVES

Solution caves have varied physical features. The entrances consist of springs, siphons, reversing springs, sinks, blue holes and cenotes.

- **Springs-** are caves with water flowing out of the outlet or opening. A spring normally has a head pool, surface boil and a spring run connecting to a surface water feature (river). They vary in current velocity, volume, size, passage configuration and water chemistry.

- **Siphons-** are caves with water flowing into the cave entrance. Siphons may occur with their own head pools, runs and river connections. When diving siphons a diver must use extreme caution and careful gas planning as the Rule of Thirds does not apply and exit will be more difficult than entering due to water inflow.



- **Reversing springs-** are springs that reverse flow through the same outlet. This can be seasonally effected and occurs when a river rises and pushes water back into the spring opening creating a siphon. Reversing springs can also occur near coastal areas where groundwater caves are influenced by tides.

- **Sinks-** are usually associated with collapsed ground and many times provide access into extensive cavern and cave passages. Sinks may be "in-line" through which upstream and downstream water flows, "off-set" through which water flows from one side of sink instead of directly through the bottom or "closed" which has no connecting cave passage.

- **Blueholes-** exist in the Bahamas and Caribbean Sea. Blueholes usually appear as round openings in the shallow sea floor around an island or submerged bank and exchange water with the sea at some deeper and distant opening. Some are no more than tiny openings while others can be 300 feet across. These caves can be rich in life due to the constantly changing tides, can be quite deep and connected to other openings. Blue holes were created when the global sea level was approximately 300 feet lower than current day levels.

- **Cenotes-** is Spanish for "well". It is the name given in Mexico to the cave openings that grant access to the extensive underwater caverns and cave passages found there.

- **Sumps-** are submerged portions of dry caves.

Conserve &

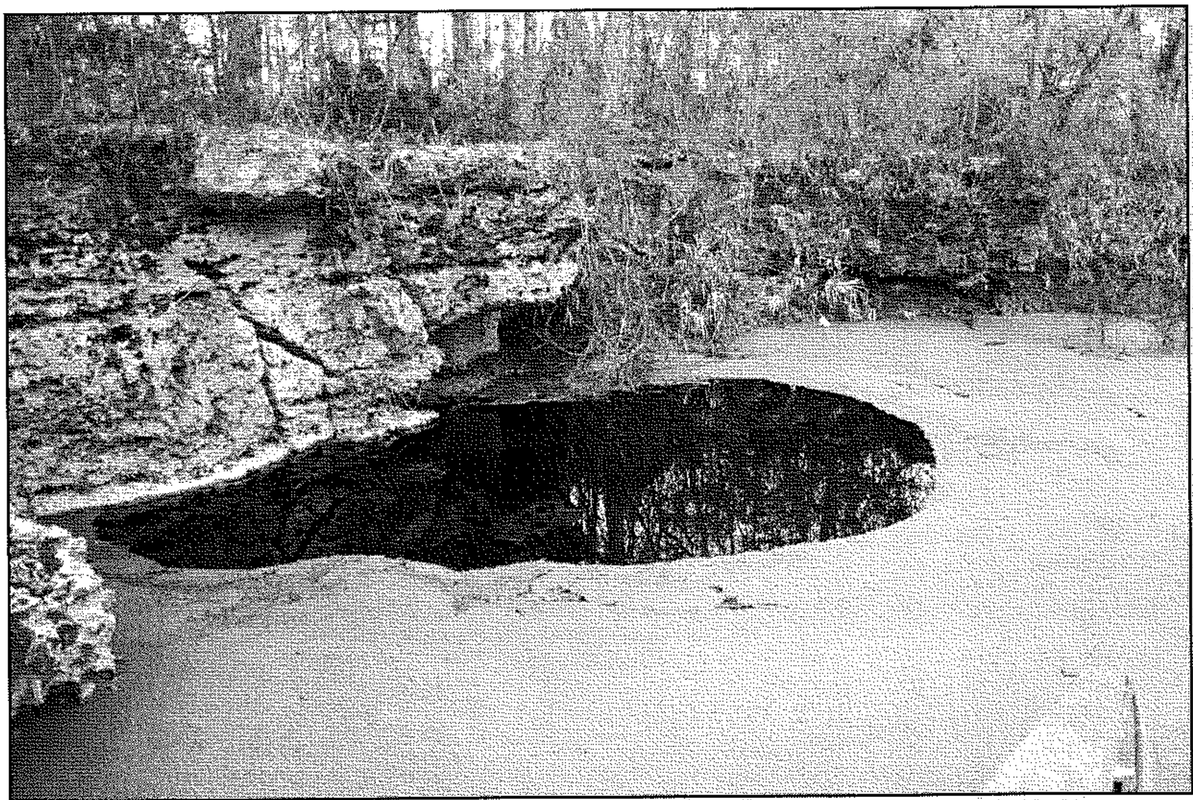
Protect!

GEOLOGY AND FORMATION OF A SOLUTION CAVE

- Sedimentary rock is the host rock with individual grains held together by calcium carbonate cement. The rock has a high permeability capacity for transmitting water. Limestone is an excellent example.
- Carbonic acid and calcium hydrocarbonate are the two basic components necessary and present in fresh groundwater flow involved in the dissolution of the host rock.

STRUCTURAL SETTING

- The portion of the cave environment that is below the present water table is referred to as the **phreatic** zone.
- The portion of the cave environment that is above the present water table is referred to as the **vadose** zone.
- Stalactites, stalagmites and columns are geological evidence of vadose cave formation. Chemical reactions and physical water movement are necessary for cave development.



BUOYANCY, TRIM AND PROPULSION TECHNIQUES

Open water divers often comment on the cave diver "look". How does the cave diver appear to hover effortlessly and maneuver through the water with finesse and style? Student cave divers should ask not how, but why? How are these skills and techniques developed and why do we employ specific techniques in the overhead environment? Practicing and refining buoyancy control, trim, propulsion techniques and awareness are essential for diver safety, cave conservation and personal enjoyment of the cavern or cave environment.

A. **Buoyancy Control-** A diver's buoyancy is determined by several factors including individual body characteristics, diving equipment choices and the water density in which they are immersed in (salt or fresh water). Your goal as a cavern or cave diver is to have complete buoyancy control throughout the entire dive. The cavern or cave dive begins the moment you enter the water and ends as you exit the water.

1. Factors affecting buoyancy control
    a. Lack of proper buoyancy control training
    b. Breathing technique and control
    c. Lack of diving experience
    d. Poor fitting or positioning of equipment
    e. Correct weight selection or overweighting

2. Equipment Selection:
    a. BCD - There are several types of buoyancy control devices (BCDs) used in cave diving. Cavern and Intro students may utilize traditional open water single cylinder BCDs. Most single cylinder BCDs on the market can be modified and adjusted to assist the diver obtain acceptable control. Your NACD instructor will help you make these modifications and adjustments.

    However, the most widely used system is the simple backplate, wing and harness design. This type of system has several advantages including reduced drag, distributed buoyancy and freedom of movement. The traditional BCD does not provide the degree of freedom of movement as cave gear and usually does not possess the lift capacity to handle double cylinders.

    Since gear selection can be confusing, we highly recommend you seek assistance from your NACD instructor or dive retailers who are knowledgeable in cave diving and cave gear selection.

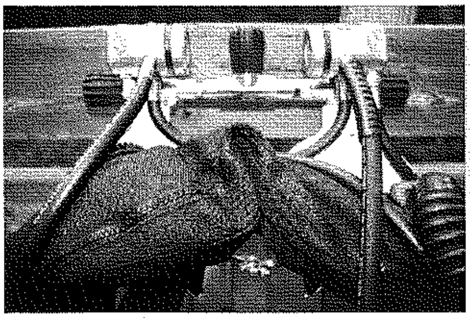
The first step to good buoyancy control is proper gear selection and fit.

b. Weight systems- One reason advanced technique divers prefer double steel cylinders is to eliminate the need for weight belts. The distributed effect of the cylinder weight creates a balanced weight system. Overweighting is the greatest problem with most divers' buoyancy control. Single cylinder users can use trim weights and drop weights to achieve better buoyancy control.

First determine the least amount of weight required to easily submerge by exhaling. Next try moving the weight off the weight belt– perhaps by placing an ankle weight around the neck of an aluminum cylinder. Traditional weight belts tend to force your body out of trim.

Drop weights are used to overcome the buoyancy of exposure suits in shallow water. They are easily removed at depth and attached to a guideline. This assists the diver maintain better control at depth without adding air to the BCD or drysuit and results in less drag. Breathing gas from the cylinder results in the cylinder becoming more positively buoyant– a drop weight can help compensate for cylinder buoyancy at the end of a dive.

Backplate selection can also affect buoyancy. Some divers choose stainless steel plates to help overcome the additional buoyancy of drysuits or aluminum cylinders. Divers requiring less weight may choose an aluminum back plate.



3. Why is buoyancy control important to the cavern or cave diver?

   a. Reduces fatigue and makes the dive more enjoyable with less exertion
   b. Extends bottom time through reduced gas use
   c. Prevents damage to the fragile cavern and cave environment
   d. Prevents damage to life support equipment
   e. In the cave environment poor buoyancy control may lead to more complex problems such as loss of visibility or physical injury

4. Practice buoyancy control techniques before class.

   a. Buoyancy check surface, fifteen feet and at depth
   b. Gear check
   c. Weight distribution and positioning
   d. Streamlining
   e. Fine tune neutral buoyancy in the horizontal position
   f. Hover in mid-water without touching the bottom and perform a task- activate a backup light or deploy a reel
   g. Always check the buoyancy characteristics of new equipment in open water prior to diving it the overhead environment

B. **Horizontal trim position**

Neutral buoyancy alone is not acceptable for the overhead environment. The cavern or cave diver must have the ability to obtain and maintain the proper horizontal body position- commonly referred to as "Trim". With proper trim, the diver's swimming effort and breathing gas consumption decreases as awareness of the environment and safety of the dive increases. The cavern or cave diver's goal is to maintain horizontal trim position throughout the entire course of the dive. This includes all pre-dive safety checks and the diver's ascent to the surface at the end of the dive.

Remember, a cavern or cave dive begins immediately upon the diver entering the water and ends only when the diver exits the water.

a. Factors influencing trim

1. Avoid overweighting and use drop weights
2. Positioning trim weights to enhance balance
3. BCD and cylinder adjustments
    a. Single tank divers may adjust position of tank band
    b. Most wings today offer a choice of positions to help balance the diver
    c. Seek advice from experienced cave divers
4. Steel cylinders generally have better trim characteristics than aluminum. However, small amounts of trim weighting may be added to an aluminum cylinder to adjust the diver's trim. Also, steel backplates may help improve trim characteristics of both single and double aluminum cylinders

b. Proper trim control

1. Reduces diver drag, lessens exertion
2. Prevents unwanted contact with guidelines and the cavern or cave
3. Reduces silting caused by downward thrust of fins or contact with the floor

c. Anticipate buoyancy changes and make continuous adjustments by adding or dumping small amounts of gas from BCD

1. Exposure suit buoyancy changes with depth
    a. Wet Suits
    b. Dry Suits
2. System topography and geologic effects
    a. Haloclines
    b. High Flow
    c. Depth changes within the system

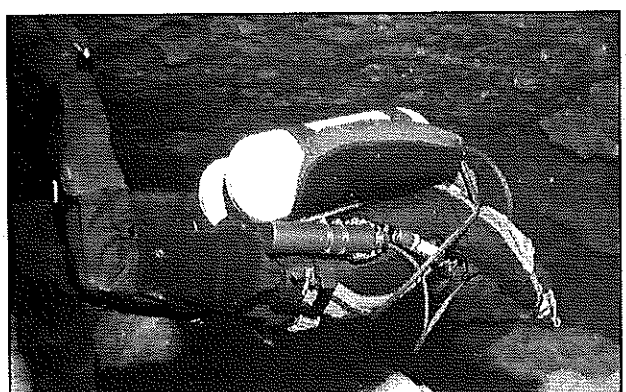
C. Propulsion Techniques- An experienced cave diver may easily alter propulsion technique dependent on changing conditions during the dive. A primary purpose of the Cavern Diver course is to learn and practice the techniques described below with the assistance of your NACD instructor.

1. Proper propulsion technique

   a. The horizontal trim position previously discussed is the preferred anti-silting body position so that thrust from the fins is directed away from silt on the floor of the cave/cavern
   b. Reduces silting, percolation and impact on caves
   c. Maximizes efficiency
   d. Decreases diver fatigue resulting in reduced stress during an emergency
   e. Employs combinations of propulsion techniques based on environmental conditions

2. Forms of propulsion

   a. Will be practiced and reviewed in detail during dive training sessions
   b. Propulsion technique used will vary from cave to cave and even within the same cave
   c. Modified frog
   d. Pull and glide
   e. Modified flutter kick
   f. Shuffle kick
   g. Helicopter turn



D. Equipment Streamlining

1. Reasons for streamlining

   a. Reduces drag resulting in less fatigue and more efficient propulsion
   b. Increases overall comfort while moving through the water
   c. Improves kick efficiency allowing better movement through the water
   d. Protects gear and fragile cave environment by keeping equipment from contacting the environment
   e. Increases safety and helps insure effective placement of gear

2. Suggestions

   a. Maintain a horizontal position throughout the dive presenting smallest surface area (less drag) to the flow
   b. Avoid overweighting
   c. Keep gear neatly attached and tucked closely to the body- avoid loose hoses and dangling items of gear
   d. Use minimal air for BCD and drysuit inflation

EQUIPMENT

Just as specialized techniques are required to safely and effectively dive the cavern or cave environment, so is specialized and properly configured equipment. While the Cavern student may elect to proceed through Cavern training in basic open water equipment modified to meet the demands of the environment, this section will provide a full review of the specialized equipment required at more advanced levels of overhead training. It is strongly suggested that the Cavern student consult with their NACD instructor prior to a substantial equipment purchase– some gear is more suitable to the cavern or cave environment and your instructor will provide valuable information for gear selection.

The Cavern course may be conducted using double cylinders and other cave gear– the Cavern student should first discuss the desire to do so with his NACD instructor.

Equipment alone will not make for a safe and effective cavern or cave diver. The diver's gear must be properly configured and used in conjunction with the dive techniques discussed in the previous section. Reliance on the diver's gear should never replace a constant and continuing development of technique and awareness.

The NACD does not subscribe to the concept of a single gear configuration for all divers. While required gear is not subject to variation, your NACD instructor will not dictate the type and brand of equipment. The desired objective is for the equipment configuration to be streamlined and efficient so as to provide the greatest degree of safety and comfort in the cavern or cave environment.

Observation of other's equipment and discussion with other overhead divers will provide valuable insight to the beginning overhead diver. Don't hesitate to rely on the experience of others and, with guidance, develop the most suitable gear configuration for this very demanding environment.

Your NACD instructor will assist you with initial gear configuration as a part of the Cavern Diver course.

Cylinders

1. The cylinders currently available to cave divers are manufactured of either aluminum or steel. Steel cylinders are best suited for cave divers because of the advantages of buoyancy characteristics and gas volume.

2. Among the most common tanks for cave diving are 95 or 104 cubic foot steel banded together with stainless steel bands. A single cylinder may be used for both Cavern and Intro to Cave levels with double tanks of suitable volume required at the Apprentice and Cave levels of training.

Cylinder Valves

Valves may be either yoke or DIN with DIN preferred due to the fact that the regulator screws into the valve rather than requiring pressure to seat and seal the valve. DIN valves create a more direct connection and are substantially less likely to be "dislodged" during a dive which would result in the uncontrolled loss of breathing gas.

Masks

1. Select a low volume mask for cavern and cave diving
2. A spare mask is recommended
3. Snorkels are not required for cavern or cave diving

Fins

1. Power fins utilizing tape or spring heels to prevent entanglement in the guideline
2. Some fins allow the heel strap to be turned over, creating a clean entanglement-free strap

Lights

1. Primary lights
   a. Illumination sufficient for the dives being undertaken
   b. Burn time 1.5 times greater than the estimated dive time
   c. Note: For cavern, the primary light is considered to be natural sunlight
2. Back up lights
   a. A minimum of two must be carried
   b. Check batteries often
   c. Check operation before each dive
   d. All back up lights shall have a collective burn time equal to or greater than the dive time
   e. Disposable batteries are preferred over rechargeable

Regulators

1. Two independent regulators must be used
   a. Each regulator must be equipped with a second stage
   b. One regulator must have an SPG attached
   c. One regulator must have a 7 foot long hose to facilitate air sharing (recommended, not required at the Cavern Diver level)
   d. Exposure suit selection will determine whether a second inflation hose is needed

BCD

1. Buoyancy compensator/harness/power inflator system
   a. Back mounted wings with harness and backplate
   b. Must provide enough lift for diver and dives being planned

Weights

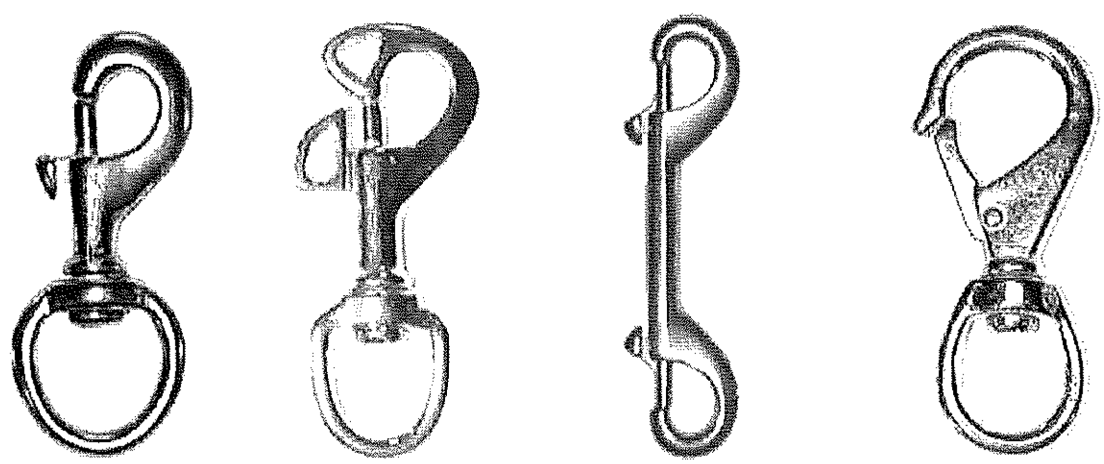
1. For the Cavern Diver, weighting should be minimal
2. For the Cave Diver, additional weighting should not be necessary
3. Weight (if required) should be distributed efficiently
4. Drop weights may be used to compensate for exposure suit buoyancy and air consumption during the dive

Exposure Protection

1. Dive a wetsuit appropriate for the water temperature and environment
2. Drysuits are commonly used by cave divers—proper use of a drysuit takes additional training and practice

Clips, snaps, and D-rings

1. Clips are usually of brass or stainless steel (more durable for salt water)
    a. Bolt clips
    b. Snap clips
    c. Butterfly clips
    d. Double ended clips
2. D-rings are in fixed or non fixed configurations with some being angled
    a. Certain clips and rings are better suited for particular applications



Bolt Clip **Butterfly** **Double Ended** **Snap Clip**

Guideline Reels

1. Primary reel
    a. Provides a continuous guideline from open water along a cavern course or to a permanent main line
    b. 350' - 450' of guideline length
    c. Open and closed face designs
    d. One primary per team is required
2. Safety reel
    a. 100'- 150' of guideline
    b. One safety reel per diver is required with a backup safety reel recommended
3. Gap/jump reel or finger spool
    a. 50' - 75' of guideline
    b. Apprentice or Full Cave only

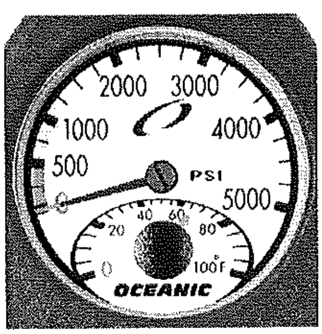
Knife

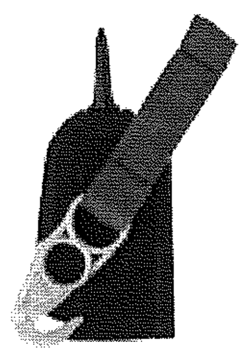
1. Must be compact, easily accessible and sharp
2. In some circumstances, a backup knife is recommended

Instrumentation

1. Timing device and depth gauge
2. Dive computer
3. Submersible pressure gauge

For the cavern and cave diver, "less is better" is the governing concept. Develop the habit of taking with you only those items of gear absolutely necessary to the execution and safety of the dive planned.






REELS AND GUIDELINES

Cavern and Cave Reels

Cave reels (and spools) take three forms, each designed for a separate and distinct function. While the ultimate function of a reel and spool is the same, the decision to use one over the other is one of personal choice based on the individual diver's comfort and familiarity. Each has both mechanical advantages and disadvantages which must be carefully evaluated by the diver.

Spools are generally recognized as "jam-proof", are more compact thus more easily configured in a streamlined package and are very quickly deployed. Disadvantages include the fact that spools cannot be easily locked down in the event the double ended clip is lost during deployment, are subject to becoming unclipped and lost if not securely stowed and are difficult to rewind over longer distances.

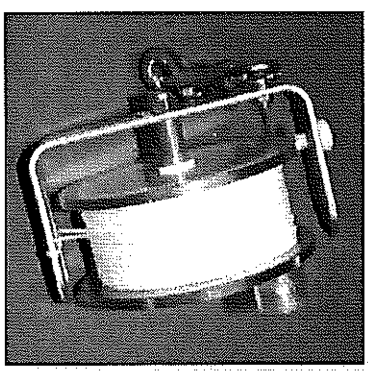
Reels, while bulkier and more likely to jam, are unlikely to become unclipped during a dive and are much simpler to reel in over long distances. It is less likely that loss of other mechanical parts will occur with reels.

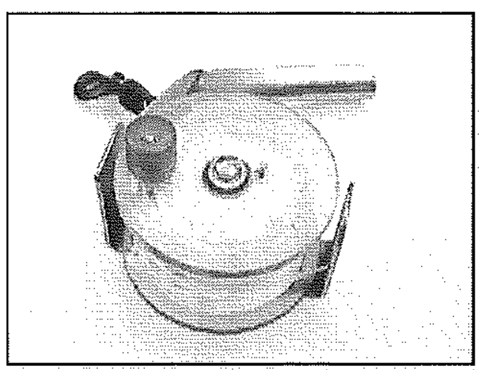
For the purposes of this discussion, the term "reel" shall mean both reels and spools.

Reels are characterized by their function.

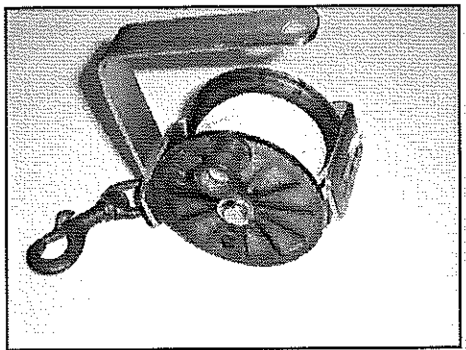
◊ ***Primary Reel*** **-** provides the diver with a continuous guideline from open water either along a cavern course or to the main line and will store 350-400 feet of #24 braided nylon line on the reel. Each dive team is required to have one primary reel. Additional primary reels, in most instances, create unnecessary drag and present the increased likelihood of entanglement without providing a reasonable benefit to the team.

Examples of Primary Reels

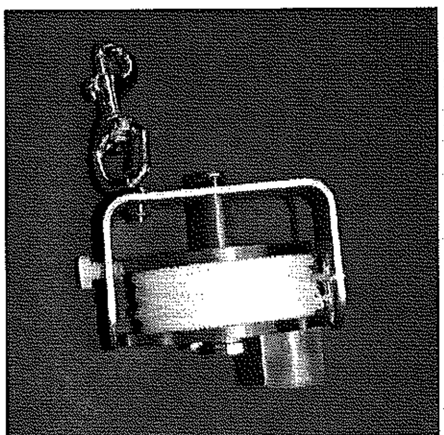




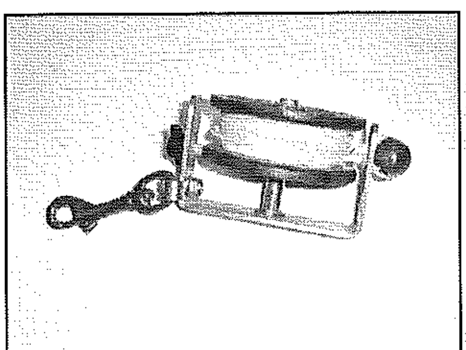
◊ ***Safety Reel*** - should be carried at all times throughout the dive. This reel is a smaller version of the primary reel with approximately 100-150 feet of #24 braided nylon line. The safety reel should remain attached to the diver's gear unless deployed for one of its intended emergency purposes. The NACD very strongly recommends that each diver have a backup safety reel. A useful aid for judging distances with the safety reel is to place knots on the line at your personal double-arm length increments.



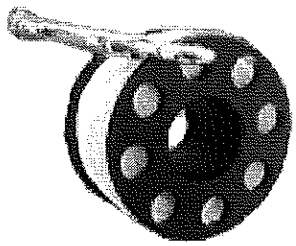
◊ ***Gap or Jump Reel*** - Physically the same with the difference being the intended use.



◊ **A *gap reel*** is used to join the ends of two permanent main lines.



◊ A ***jump reel*** connects one point along a continuous guideline to another guideline, either at the end of the second line or at some point along that continuous line. The gap/jump reel holds 50-75 feet of #24 braided nylon line. The dive team should carry a sufficient number of gap/jump reels to maintain a continuous guideline along the intended route of travel.



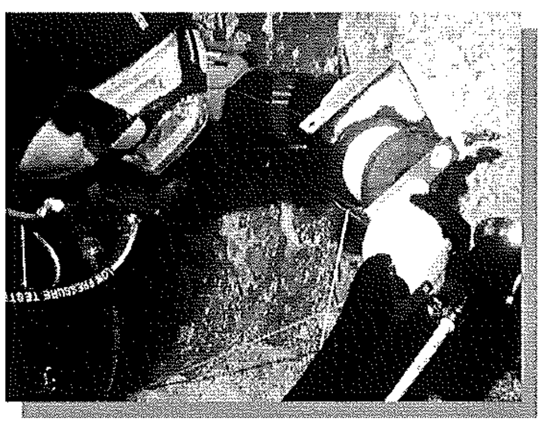
Finger Spool

It is important that each reel, including line, be visually inspected for worn or damaged parts and line before each dive and that any damage be promptly repaired.

With an ever-increasing number of cave divers, it is essential that the rules of line protocol be properly observed. These rules take into account courtesy and safety considerations and are as follows:

1. Do not disturb other lines in the cave.
2. Lay your line to avoid interference with other entering or exiting teams.
3. Do not use another team's tie-off, placement or wrap point.
4. Avoid high tie-offs.
5. Pass your body over existing lines, your guideline under those lines.
6. Do not use another team's guideline without their prior permission and coordination. You should avoid making guideline navigation more complex by having to coordinate use of reels with other teams simply to avoid running another line.

If you encounter other teams in the system while entering, yield to exiting teams.



GUIDELINES

Nylon line is the accepted standard material for cave guidelines. While twisted nylon line provides greater tensile strength, braided line is most commonly used because it is more abrasion resistant. Polypropylene line, although very durable, is used only for limited special applications since it floats. Polypropylene is sometimes used as novice line or as a tow line in very high flow systems.

Guidelines may be generally classified as either temporary or permanent and main or secondary. The primary purpose of guidelines of all character is to provide directional reference to the surface for the diver traveling along them.

- ***Temporary guidelines*** - are those installed by a particular team of divers for a particular dive or series of dives and then removed upon completion of the dive(s). Temporary guidelines include those that run from open water along a cavern course or to the main line and those installed to bridge gaps and jumps.

- ***Permanent guidelines-*** include the following:

- ***Main (or "gold") lines-*** are kermantle line which consists of a nylon monofilament inner core with a gold-colored braided nylon outer sheath one-eighth inch in diameter. First used in the late 1980s, this material is much stronger and more durable than line placed elsewhere in a cave due to the higher level of traffic and (generally) lower level of experience of divers using this line. The main line of a cave is placed to mark the designated main passage of particular cave systems with each cave typically having a single main passage.

- ***Secondary lines-*** are commonly #24 braided nylon line of the type found on the primary, safety and jump reels used by cave divers. Secondary lines are located along routes in the cave other than the main passage. While not always the case, secondary lines tend to mark smaller, possibly siltier passages than do main lines and a higher level of experience and comfort is necessary to safely navigate these passages.

◊ ***Exploratory/Survey line-*** is composed of braided #18 nylon line knotted every ten feet to provide distance reference while exploring, surveying and mapping an area. Since the line is set in a manner to expedite the survey, it may not provide the best aid to navigation as line traps and high silt areas are likely to be encountered.

COMMUNICATION

One aspect of cavern and cave diving that many cave divers enjoy is that of the peace and tranquility of the cave environment. Communication without the ease of verbal exchange is another obstacle which cave divers must overcome.

The ability to communicate can be compounded by cave configuration, team member's distance of separation, visibility and differences in lighting systems. With these concerns in mind, the standards for equipment requirements and the development of various communication techniques has made it simpler for members of a cave diving team to effectively communicate under varying conditions within the cavern or cave diving environment. Not unlike other overhead skills, communication must be practiced and become an integral part of any dive plan.

Effective communication is the conveyance or transmission of information resulting in a clear understanding. Communication is only successful if the message transmitted is understood by the intended receiver. Cave divers have a common language used underwater which can be just as effective as surface communication- so effective that divers of different languages may understand and safely conduct a cave dive in a team formation.

It is important in a three person team that communication is passed backward and forward to all members of the dive team- this is the responsibility of the middle team member.

1. Light Communication

If dive team members each have compatible light sources, light signals are a very effective form of communication. The lead diver can continually be aware of the other dive team members by taking note of their lights. Divers with weaker light sources may wish to lead the dive team (leading in and leading out) thus placing the divers with stronger light sources in the rear with more noticeable illumination and reducing the chances of dive team separation.

"Demand Response" Light Signals:

- OK- Slow circular motion of the light against the cave wall just off the path to the dive team's route of travel. **This signal ALWAYS requires a response.**

- ATTENTION- Slow continuous back and forth or up and down motion. This action requires the lead diver to give attention to the signaling diver. The "Attention" is followed by an additional hand signal. Most commonly, this signal does not indicate an emergency situation but rather the need to gain another diver's attention. **This signal ALWAYS requires a response.**

- EMERGENCY- Rapid continuous movement of the light in a back and forth or up and down motion. This action implies that there is an out of gas emergency requiring the immediate attention of the dive team. **This signal ALWAYS requires a response.**

2. Hand Signals

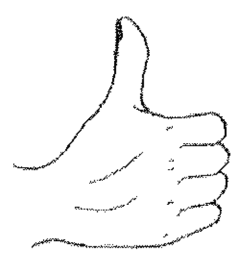
Hand signals may be used in conjunction with light signals - it is important to make certain that, in an attempt to communicate with your dive team, you do not blind them. The cave environment is dark and a diver's eyes will have adjusted to the reduced light conditions. Hand signals may vary from one geographical location to another, so it is important that we provide you with a common understanding of the most widely used hand signals. If your dive team is performing an unusual task you may develop your own hand signal for that task, making certain all members of the dive team understand fully what the new hand signal means. An example of this would be a hand signal to have you perform a required skill during your cave dive training. Hand signals are often used in conjunction with one another for more effective communication.

"Demand Response" Hand Signals

These three hand signals require a response to indicate acknowledgement and acceptance of the signal:

OK? / OK!

HOLD



EXIT

- **<u>EXIT</u>-** This signal is used for any number of reasons but its one meaning is clear to all cave divers- the dive is over and it is time to return to the surface.

  Any diver may call any dive at any time for any reason, no questions and no recriminations! This is the Golden Rule of Cave Diving and must be incorporated in all dive plans.

  The only response of all dive team members is to turn and exit the cavern or cave system.

  This signal ALWAYS requires a response.

- **<u>OK</u>-** A standard hand signal throughout the diving community. The "OK" signal is both a question and a answer.

  This signal ALWAYS requires a response. The response may either be a light OK signal, a lighted OK hand signal or a lighted exit hand signal.

- **<u>HOLD</u>-** Similar to the *STOP* signal but requires the team members to take position near or in contact with the guideline.

  This signal ALWAYS requires a response. The appropriate response is to acknowledge the command with a lighted HOLD hand signal and then hold as directed.

Other common hand signals include:

- LINE– used to reference a guideline
- ENTANGLED– an indication the diver or team member is entangled in the line
- TIE OFF/WRAP– an instruction indicating a line placement point
- REEL– most generally a direction to a team member to reel out of the cavern or cave
- UP (off floor)- a direction to a diver to mover higher and away from the floor

- CUT- A signal indicating the need to cut line such as the hopelessly entangled diver. This signal may also be an indication to team members that a cut or damaged line has been encountered.

  Note: All attempts must be made to correct any problem with a guideline before cutting that line becomes the only option. Be sure all divers are on the exit side of the line before cutting.

- BUBBLES/LEAK- an indication that a diver has a leak at some point in life support equipment

- STOP– a direction to a team member to temporarily halt forward progress

- BACKUP LIGHT ON– an indication to a team member that a backup light is on

- SOMETHING'S WRONG– an indication to a team member of a problem

- STUCK– an indication that a diver is stuck and is unable to free himself

- SILT– an indication of a silty area or that a diver is silting the area

- WRITE IT DOWN– a diver requires more information than can be communicated by hand or light signals

- SWAP – The signal given when there is a requirement for the dive team to change team order

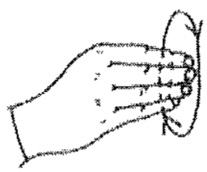
Other hand signals your instructor may discuss with you are:

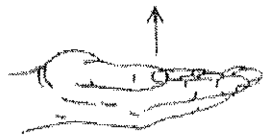
- Slow down
- Direction to exit
- Direction of flow
- Direction of travel
- Cramp
- Cold
- Go over
- Go under
- Turn around
- Back Up

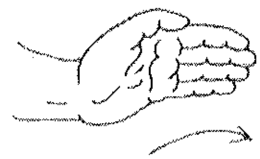

Guideline

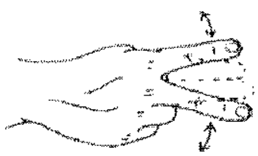

Entangled

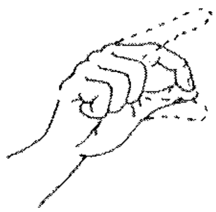

Tie off/wrap


Reel up

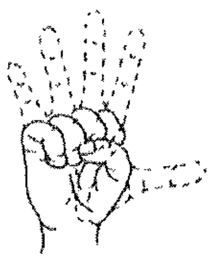

Up (off floor)


Go around


Cut


Bubbles/leak

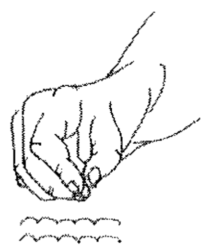

Stop


Light on (backup)


Something's wrong


Stuck


Silt/silty


Write it down


Swap places

There are many standard hand signals taught to divers in their basic open water class which are still very much applicable within the cave diving community. It is important that all divers within the dive team have a common language by which they can communicate and that all dive team members are fully conversant with the hand signals being used.

3. Slate or WetNotes

Slates and WetNotes may be an important tool to the cave diver. Dive plan information can be pre-recorded on the slate and more demanding communications from one diver to another can be written out for better clarity. It is advisable that, if you choose this method of communication, keep your messages short, to the point and understandable.

4. Touch Contact

Touch Contact enables the cave diver to communicate without the use of lights in zero or substantially reduced visibility conditions. For this reason, communication must be simple and straightforward so as to reduce the possibility of miscommunication and compounding of stress.

This form of communication requires that one diver be in physical contact with another diver and with the guideline. Cave divers must have the ability to identify by touch line markers, reels and other equipment in full zero visibility conditions.

The dive team forms in single profile with the team lead diver *"OK'ing"* the guideline and protecting his head from impacting the overhead with the other hand. The following team members also *"OK"s* the guideline and reaches forward to physically contact the diver in front of them. Movement of the dive team in this formation must be done at a controlled pace. Continuous touch contact may not always be necessary. A "push and go" technique may help to facilitate a more efficient exit.

The signals used for this form of communication are as follows:

- FORWARD– a following diver firmly pushes the lead diver forward
- STOP- a following diver gives multiple firm squeezes to the lead diver or breaks contact with the lead diver
- BACKUP- a following diver gives the lead diver a firm pull back

NOTE: A lead diver in a team indicates a directional signal by execution of the action- moving forward, stopping or moving back.

- CROSS OVER LINE- The lead diver removes the following diver's hand from his arm/leg and places that diver's free hand on the guideline. The lead diver signals CROSS OVER by giving the following diver's guideline hand two sharp bumps. Once each diver has crossed over the guideline, touch contact is re-established and the team continues its exit using touch contact signals.
- EMERGENCY (out of gas)- Any diver experiencing a loss of gas should locate and secure a donor's regulator. At no point during this process should any team member relinquish control of the guideline. Once all team members have secured an air supply and have re-established touch contact, the team continues its exit using touch contact signals.
- ENTANGLEMENT- The entangled diver will stop and communicate a "stop" to his team member. Using the hand signal for "line", the entangled diver will signal his team member by rotating his fingers in his team member's "ok" on the line. At that point, the entangled diver should hold his position while the assisting diver attempts to free the entanglement. Once the line is free from the entangled diver, the team members will re-establish touch contact and exit the system using touch contact signals.

Communication in any form must be thoroughly discussed and practiced among team members. There should be no confusion as to the meaning of a signal during the course of a cavern or cave dive.

PRE-DIVE PLANNING

"Plan your dive and dive your plan". How true a statement this is and how often divers take it for granted. The dive planning process starts the moment the decision to dive is made.

Unlike a typical open water dive in benign conditions such as on a shallow warm water reef with flat seas, a dive into the overhead environment should be treated more as a ***mission***, with a specific goal and assignment of duties to each member of the team. The pre-dive planning usually includes a **briefing** to cover key elements of the dive:

- **Dive objective:** Be sure that everyone is in agreement with the general goal of the dive, whether it be to tour a cavern zone, penetrate on the mainline of a cave or to do a complex series of jumps and gaps. Make sure that the dive objective fits within the training and comfort level of all team members.
- **Review overhead environment:** Go over with the use of diagrams or a cave map the planned route, designating tasks to each individual during each phase of the dive.
- **Designate the team size and order:** Select who will run the reel, who is second and who will be third. Note that the largest manageable number for a safe cavern dive is no more than four divers and for a cave dive no more than three. If you have more than three divers consider breaking up into smaller groups, as long as you have at least two per team. Each diver should know what is expected of them at each point of the dive (run the reel, provide light to the reel, do the second jump, etc.). The order of the team should remain the same throughout the dive ("first in, last out"), unless an emergency or drill changes the order.
- **"Fin to face" check:** Since you are relying on your team members in case of an emergency take the time while still above water to see if they are squared away — do they have sufficient backup lights and have they been tested? Is their rig properly configured and the valves opened? Does the primary light fire up and operate prior to descent? This buddy check can occur the moment you pull up to the dive site and begin to assemble your gear. Also perform a "bubble check" for your buddy by looking at their valves, regulators and hoses underwater.
- **Safety ("S") drill:** After you enter the water and before entering the overhead, do an air-share drill as both the donor and recipient. Try to keep your buoyancy, trim and balance stable in the middle of the water column so you can perform the regulator swaps cleanly and efficiently. The "S" drill will not only get you mentally prepared for an air share event should it happen, but it also will catch any improper hose routing or gear issues that may inhibit the ability to deploy your regulators.

- **"Gas math":** Right before starting the dive, calculate the volume of usable gas for the team. Be sure to use the lowest volume for all team members. More information on how to calculate your useable volume is available on page 76.

Usually your instructor will guide you through these steps of pre-dive planning until it becomes second nature. As your training progresses expect more and more of the responsibility of the dive planning to be transferred to the team in a class setting.

In diving, all won't always go as planned. When a problem arises, the diver's training and practice will determine how well he responds to the problem. Poorly practiced skills will be of little value when the time comes to use them. With this in mind, the NACD established the purpose of achieving safer cave diving through proper training and the development of diver maturity and judgment to minimize taking unnecessary risks.

Sometimes serious and unexpected in nature, emergencies require our immediate and urgent attention. Some divers suggest that the only true emergency is an out-of-gas scenario and everything else is just an inconvenience. To a degree this is true- subject to the individual diver's psychological make up, training and skill proficiency and environmental and equipment awareness.

A. HAZARDS OF THE CAVERN AND CAVE ENVIRONMENT

The underwater cave environment presents various hazards that make diving within it particularly dangerous. These unique dangers must be understood and accounted for prior to any underwater cavern or cave adventure. The hazards presented here have resulted in the development of specific equipment and techniques to greatly increase safety and comfort for the trained cavern and cave diver. Without such specialized equipment and techniques, cavern and cave diving is extremely hazardous. To the well-prepared cavern or cave diver, the environmental hazards present a technical challenge that can also be a source of extreme satisfaction.

General hazards of all cavern and cave environments are:

1. Water – we are air breathing creatures
2. Ceiling – no direct access to the surface removing the ability to directly ascend to the surface
3. Limited space – limits the diver's ability to maneuver to assist another team member or turn to exit the cave system

4. Darkness– potential for loss of visual contact to guideline and loss of directional reference

5. Combination of all the above factors- cumulative anxiety and stress induces a narrowing of perception which may result in panic

⇒ No two caverns or caves are alike. With this in mind it is necessary to consider hazards encountered in cavern and cave diving specific to the environment and which may vary from system to system.

A. **Visibility**- may be lost if proper buoyancy and trim are not maintained or if the diver fails to develop awareness of the passage in which he is moving. Bottom composition will vary from passage to passage and system to system. Chemicals in the water may affect clarity and will play a role in determining visibility. Visibility may be affected by:

1. Sediments- classified by particle size and composition. The cave floor is comprised of sand, mud, clay, rock or organic growth.

   a. Sand- very easily disturbed and yet settles very quickly
   b. Mung- organic growth found primarily in marine caves which is very easily disturbed with moderate settling
   c. Mud- may be of organic or inorganic composition, easily disturbed and slow to settle. Absorbs light and renders dive lights ineffective
   d. Clay- smallest particulate, very slow to settle and causes the most hazardous conditions of cavern and cave diving

2. Sediment agitation- It is important that once you have exited a silted cave to advise other divers and inspect your equipment as silt may stick to it and you. Silt in itself is not a problem unless it becomes disturbed through:

   a. Poor buoyancy and trim control
   b. Incorrect propulsion techniques
   c. Equipment dragging on the bottom
   d. Percolation of diver's exhaust bubbles

3. Chemicals in the water, such as:

a. Tannic and carbonic acid- is the result of organic decay and runoff causing a dark tea like color in the water reducing penetration of light

b. Hydrogen sulfide– results from decaying organic matter usually of animal form with a very disagreeable rotten egg smell causing a layered discoloration and cloudiness in the water

c. Halocline- causes a distortion of vision by the mixing of various layers of water having differing degrees of salinity and density (saltwater and freshwater)

B. Flow- presents a distinct hazard to the cave diver in that the diver will be required to anticipate changes in buoyancy and desired direction of travel. Upstream flow will assist the diver on exiting the cave while a downstream or siphon flow is considered dangerous to cavern and unprepared cave divers.

1. High flow- offers resistance to the diver when penetrating the cavern or cave and will assist on exiting the system. Flow may increase substantially at points where passage configuration narrows. Usually having less sediments, those that are present travel with the diver downstream.

2. Low or no flow- offers little resistance to the diver when penetrating the cavern or cave. The diver should expect siltier passageways and percolation is more common. Diver technique and awareness is of utmost importance in these kind of systems.

3. Reversing flow– may occur with either a high or low flow system. A reversing flow occurs as the result of temporary environmental conditions– during periods of localized flooding– and is a temporary condition.

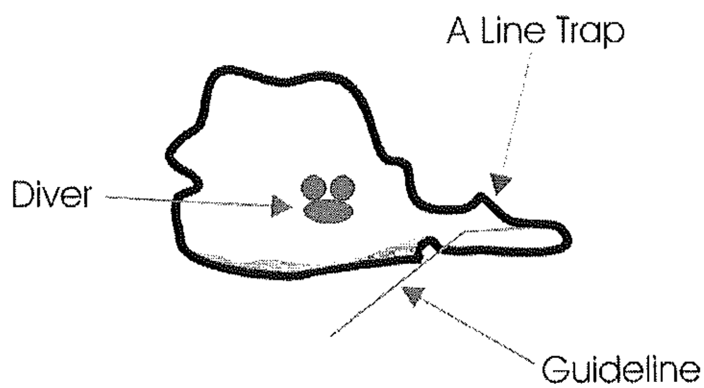
C. Restrictions- are not permitted at the Cavern Diver training level. Restrictions are classified as minor or major. Any restriction forces a dive team into a single file formation and increases risk by creating exit delays, possible silting and makes emergency management more difficult.

1. ***Minor Restrictions*** are areas too small to allow two divers to pass through at the same time, forcing the divers to swim in single file profile.

2. ***Major Restrictions*** require the dive team to manipulate the diver's body position and/or equipment in order to pass through the area.

D. **Passage Configuration**– may also play a role in creating problems for the unprepared cavern or cave diver. The passage must be large enough for the dive team to turn the dive in a safe and effective manner. The Cavern Diver must maintain a sufficient degree of awareness of the existence of the daylight zone and the manner in which passage configuration affects that zone.

E. **Line Traps**- Failure to maintain an **effective** continuous guideline to open water is the second leading cause of cavern and cave diver fatality. All dive team members have the responsibility of insuring the guideline provides effective access to the surface in the worst case scenario. Lines should not be placed so they are trapped under rock formations or in crevasses and unable to be located by a diver in zero or substantially reduced visibility. Dive team members should select and place guidelines in easily accessible locations along the floor or passage walls in a manner which will permit the team to maintain continuous contact with the guideline on exit from the system. Line awareness is the responsibility of all team members throughout the dive.



F. **Air Pockets on Ceilings**- Generally it is not advisable to breathe air or gas from a small pocket of trapped gas. Most often these pockets of gas are caused by trapped exhaust from divers, organic gases or a low water table within the cave passage (sump). These gases may contain carbon dioxide or hydrogen sulfide and may not contain sufficient oxygen to sustain life.

B. PSYCHOLOGY AND STRESS MANAGEMENT

Divers choose to pursue cavern and cave diving for a variety of reasons. Positive motivations include the desire to explore this unique environment, basic improvement of skills and knowledge and development of the technical expertise demanded by the environment. Negative motivations include peer pressure, thrill seeking, over-confidence and lack of respect for this potentially hazardous environment. Whatever the reason, the cavern or cave student will experience some degree of stress during the course of their training. The manner in which the diver copes with that stress will mean the difference in successful completion of training or a temporary, possibly permanent, cessation of training. Each person is motivated in a different way. Some perform better under stressful situations, others learn to cope with stress, while others simply cannot deal with the heightened stress imposed by this type of training.

To better understand the required responses required to survive a cave diving emergency, let us look at the psychology and stress factors that every cavern or cave diver may face at one time or another in their diving career. These factors will help prepare the diver to evaluate a dive as it progresses. Dive team members must remain aware of the team's objectives and should never assume that team member's motivations and expectations are the same. Communication is the key to dive team planning.

A. Psychology- is the mental characteristics or attitude of a person or group governing a situation or activity and having the ability to control its outcome. We look at psychology in terms of positive and negative motivators:

1. Positive Motivation

   a. Discovery and enjoyment of a new and unique environment few are willing or able to venture into
   b. Exploration
   c. Development of technical interests
   d. Development and improvement of dive skills

2. Negative Motivators

   a. Thrill seekers
   b. Risk takers- those who are drawn to the activity because of the perceived risks and a desire to "beat" those risks
   c. Peer pressure
   d. Ego threat- "he did it, so can I"

B. **Stress**- is the demand on an individual's physical and mental resources when confronted with a perceived or real psychological or physiological threat. Stress may turn a small problem into a life-threatening emergency and may result from a combination of factors. Forms and sources of stress include:

1. Psychological (mental) stress, either imagined or real:

    a. Time pressure- no decompression limits/time requirements
    b. Directional requirements- vertigo, lack of directional reference
    c. Ego threat
    d. Self doubt

2. Physical threat:

    a. Exertion- heavy workload
    b. Cold- improper environmental protection
    c. Equipment- out of adjustment, unfamiliarity
    d. Buoyancy and trim- insufficient lift, balance of load, breathing pattern
    e. Flow- strong, changing, poor buoyancy control
    f. Loss of visibility- disorientation, loss of directional reference
    g. Gas supply limits- inadequate gas supply, exertion
    h. Physical injury and limitations- cramps, strength

3. Task Loading – the accumulation of a variety of stressors and can be the result of both psychological and physiological factors. Example—running the primary reel while holding a light swimming against flow wearing insufficient environmental protection in cold water and feeling uncomfortable in the environment.

4. Panic– The panic cycle– stress, near-panic, panic- begins to form when the mind fails to properly process information and perceptual narrowing occurs allowing the diver to focus on only one thought. A *fight or flight syndrome* takes control with a feeling of terror overcoming the diver. The ultimate failure to cope with the situation results in panic– an unreasoned, unthinking response to the source of stress. It is unlikely the cavern or cave diver will survive panic.

C. **Recognizing Stress**- The ability of the diver to recognize and deal with stress within themselves and others can be the difference in how quickly it is controlled or avoided. Many signs of stress may appear before the dive begins. It may be in the form of family issues, new or ill-fitting equipment, new team members, medical conditions and many other factors. Recognizing stress is the first step in controlling it. Remember, any diver can call any dive at any time, no questions or recriminations. The Golden Rule of Cave Diving applies as much before the dive begins as during the dive.

1. Personal stress and signs and symptoms:

   a. Uncomfortable- physically or emotionally, for whatever reason
   b. Fatigue- late nights, long trips
   c. Illness, equalization problems, headache
   d. Loss of concentration- failure to follow normal patterns of behavior
   e. Frustration
   f. Obsessive, non-characteristic behavior

2. Team member stress:

   a. Perceptual narrowing, fixation
   b. Failure to respond, verbal or signal
   c. Clumsy and unnatural behavior
   d. Fidgety, jumpy, unaware, distant
   e. Frustration, anger
   f. Withdrawn
   g. Wide-eyed look
   h. Heavy breathing, exertion, physical limits and conditioning
   i. Muscle tension and stiffening
   j. Excessive attention to gauges
   k. Poor buoyancy control
   l. Rapid jerky movement
   m. Excessive nervous talk

D. **Reacting to Stress**– The diver's reaction to stress will often determine control of it and the final outcome. Cavern and cave divers must understand that quitting is not an option. The ability to control stress may be expressed in just four simple words:

STOP, BREATHE, THINK AND ACT

1. ***Stop*** - all action so that the immediate problem may be effectively dealt with.

2. ***Breathe*** - think first of current gas supply available and insure a relaxed breathing pattern. Take three (3) deep, slow breaths to relax and control the respiratory system and then re-establish a normal deep, slow breathing pattern. This will allow the diver to relax and logically think through the problem. You have more time than you initially think and not all problems as so bad that they require much thought to correct. With time, training and experience you come to understand how to work the problem through to a successful outcome.

3. ***Think & Breathe*** - there is no true emergency other than insufficient gas supply. If you can breathe you can safely end the dive. Once breathing is in check, the problem is capable of resolution. The Rule of Thirds was designed to anticipate problems encountered by the cavern or cave diver.

4. ***Act*** - complete the action required to solve the problem or reduce the stress to a tolerable limit. Act- don't react.

E. Managing stress– Eliminating, reducing and coping with stress are the steps in keeping what could be a possible emergency under control. The cavern or cave diver must identify and either eliminate or reduce possible sources of stress. This is the role of proper training, equipment configuration and maintenance and emergency preparation. Since not all sources of stress can be eliminated or reduced the cavern or cave diver must learn to cope with some sources of stress. In so doing the cavern or cave diver must:

1. Accept that a certain level of stress will always exist and it must be anticipated
2. Understand that some levels of stress are good in keeping the diver aware
3. Practice and refine skills so that they are first nature in response, particularly emergency skills. Unpracticed survival skills will be of little benefit to the diver
4. Discuss the dive, tasks to be performed and the team positioning and abilities — plan your dive to the lowest level of training within the team
5. Recognize safety and conservation before fun; and
6. ***Remember that anyone can call the dive at any time and for any reason and without criticism***

F. Perception of Risk – The cavern or cave diver's attitude, ability and awareness allows the diver to recognize his or her personal comfort zone and that of team members. It allows them to avoid and anticipate potential problems and make adjustments to permit a higher level of safety throughout the course of the dive. Cavern and cave diving are controlled risk activities. While it is not possible to eliminate all risks, every effort must be made to reduce or minimize them.

1. Proper attitude- the cavern or cave diver must respect the environment in which they dive. They must come to recognize and understand their physical and psychological limits. Attitude should be one of constantly exercising mature judgment and the application of common sense. Accept constructive criticism from dive team members.

2. Ability- the cavern or cave diver must refine all skills, seek additional training when appropriate and observe and imitate individuals with highly developed skills. Practice, practice, practice and then practice more.

3. Awareness- is one of the most valuable skills a cavern or cave diver can develop. Awareness allows for anticipation of changing environmental conditions, the team and its members, equipment and the ability to make corrective adjustments as necessary.

C. PROBLEM SOLVING AND EMERGENCY PROCEDURES

This section presents the types of problems that may occur in the cave diving environment. In the process of resolving a problem the diver must insure he or she maintains a clear thinking analysis of the problem and total awareness of the environment. *The diver must avoid or minimize contact with the floor or ceiling as this could further compound any hazardous situation.* Remember your level of training and do not plan dives beyond this level. Seek out opportunities to advance your cave diving education. Practice all the developmental skills and review them regularly. Set agreed upon limits with dive team members. In short *"PLAN YOUR DIVE AND DIVE YOUR PLAN".*

The diver may encounter multiple problems– deal with one problem at a time and do so in order of priority. For example, a burst disc failure must be dealt with before a simple line entanglement.

1. **Loss of Visibility:**

   a. Immediately establish contact with the guideline and "*OK*" the guideline
   b. Turn to orient yourself to the direction of exit
   c. Establish touch contact
   d. Utilize touch contact communication until clear of the silt or percolation or back to open water

2. **Primary Light Failure**- This is a minor problem but one that still requires the dive to be turned.

   a. Establish contact or reference to guideline, remember you should be in team contact and able to use their lighting
   b. Activate and deploy a backup light
   c. Communicate failure to team members and adjust team positioning with "injured" diver in the lead position
   d. Exit pulling reels if appropriate

3. **Loss of Vision** - Mask failure or flooding

   a. Secure guideline, maintain directional sense and gain attention of team members
   b. Put on spare mask (if equipped) or clear mask as required
   c. Stow faulty mask
   d. Exit

4. **Entanglement** – always pass over guidelines keeping them in sight if at all possible. Secure and streamline your equipment.

   a. Once you realize you are entangled, *STOP ALL MOVEMENT*. Twisting and pulling may make it worse
   b. Signal team member of entanglement
   c. Attempt to free and untangle yourself first before a team member assists you
   d. If line must be cut:
      (1) Move all team members to exit side of entangled diver
      (2) Maintain continuous guideline by securing entangled line on both sides of the entangled diver using a gap reel or safety reel and line arrows as needed

It is recommended each diver have a backup safety reel to keep safety line free from any further entanglement of diver by wrapping or placing connecting line around a rock and away from the diver

(3) Make cuts to original line as close to entangled diver as possible, but within the tieoff points of the gap or safety line splice

(4) Untangle the diver and move diver to exit side of line

(5) Attempt to repair by retying and securing original line, splicing or adding a new section (leaving gap reel in place is an acceptable temporary solution)

(6) Notify EVERYBODY of cut or repaired line

5. **Cut, Broken or Removed Exit Line**– A line may be cut or break from normal wear and tear or have been removed in error.

a. Once a line break is found, stop and determine that you are still on the original planned route and correct guideline

b. Have a team member hold position of known end of guide line. This will provide a lighted reference or beacon to last position should other problems occur

c. Secure a second line to the known line using a jump or safety reel and line arrows as required

d. Locate cut or broken line using appropriate search techniques running safety reel as you search. Note flow and cave configuration prior to and during search

e. Once the line is located, secure the search reel to the cut line using line arrows or tie points as required

f. Attempt to re-tie old line ends together- you may need to leave temporary splice in place or add a new section of line. If this is conducted as a re-establishment of exiting line you can go back later to retrieve reel using standard penetration techniques

g. Notify EVEYBODY of cut or repaired line. It is good practice to mark line at point of cut or break using non-directional marker or other suitable marker

6. Lost Diver- *Your personal safety is your priority!!!*

a. A diver who has lost directional reference to the exit should stop, locate the line and use directional references such as line arrows, flow, prominent cave features, bubbles and silting to determine direction to the exit.

b. A diver who has "lost" his buddy, but is on the guideline should:

1. Stop forward motion and orient to the exit
2. Perform a shielded light search for the missing team member or his light. The searching diver should not turn his light off as it may not re-activate
3. Perform a light search for the missing diver- look for the diver and signs of the diver- bubbles or silt trail. Be sure to look up and down as well as side to side
4. Re-evaluate gas reserve — The proper gas management calculation will provide a reserve to use during a search. A recommended one third of the reserve could be used for the search
5. Use line arrows to anchor a safety reel and begin an effective search pattern
6. Since your team member may have exited the cave already, do not overstay your search time
7. Exit the cave, confirm on the surface the absence of your team member and report the diver as missing if required

c. A diver who has lost sight of the exit or guideline should:

1. Stop and establish a fixed position making note of current and prominent cave features
2. Rise over any silt if possible while shielding light to locate the source of any ambient light
3. If the diver cannot locate a light source or is in zero or substantially reduced visibility, secure safety reel and begin an organized search for lost line and exit
4. Search until line or exit is found

8. **Gas Supply Emergencies**. The dive planning process must include planning for gas limitations suitable for the safe exit of all dive team members taking into account problems which may arise during the dive. The Rule of Thirds is a safe benchmark from which to begin dive planning. This Rule, however, may be adjusted depending on the presence of factors which require a more conservative approach. Instances of reducing useable gas supply to less than thirds include new system, new gear, new team member, low or no flow system, dissimilar cylinder volume Among team members, dissimilar breathing rates among team members and any other exceptional circumstance.

a. Equipment Systems

(1) Single outlet valve, single cylinder systems provide no redundant regulator or isolation capability. Although these cylinders are permitted at the Cavern Diver training level, they are not suitable for Intro to Cave and beyond. It is recommended that the Cavern Diver consider the use of dual outlet valves ("H" or "Y" valve) and redundant regulator systems.

(2) Double cylinders with redundant regulators and a dual outlet manifold with isolator is the preferred configuration. Some configurations employ the use of double tanks without a manifold- sidemount configuration and double independent tanks.

(3) DIN valves are preferred to yoke valves since DIN valves are more secure if an impact occurs with the cavern or cave system. Such impact to a yoke valve may dislodge the regulator first stage resulting in rapid and uncontrolled loss of gas.

b. Types of Gas Emergencies

(1) Gas emergencies are characterized as:

i. **Critical** – next breath is threatened

ii. **Immediate** – total loss of gas supply will occur within minutes

iii. **Delayed** – total loss more than a minute away, diver has time to react

(2) Examples of problems:

- i. Failure to observe pressure gauge
- ii. Rupture of supply line hoses
- iii. O-ring failure
- iv. Regulator failure including free flow
- v. Valve failure, blown burst disc or valve roll-off
- vi. Manifold or valve knob damage
- vii. Incorrect starting pressure
- viii. Incorrect or insufficient gas for planned dive
- ix. Excessive breathing rate or high work load and stress
- x. Failure to gas match and calculate turn pressures
- xi. Failure to fully open tank valves
- xii. Excessive depth

c. Management of problems- It is imperative to quickly identify the problem and correct it as required. If a catastrophic failure occurs, the diver should continue to breath all remaining gas available to him with his team member ready to provide gas when needed. Depending on the nature of the gas emergency, the diver must be prepared to make the decision whether to switch to an alternate air source, isolate the failure or begin air-sharing with a team member. In any case the dive will be terminated and the team will exit the system.

d. Gas management procedure

- i. Signal team members, request assistance and begin gas-sharing if required
- ii. Begin self-management of the problem until a team member arrives and then hold to permit the team member to identify and correct the problem
- iii. Re-establish reference to cave exit and guideline
- iv. In the event gas-sharing is required, initiate the procedure with the out-of-gas diver taking the lead position. The donor should control pace and other team members must

remain available to assist either the donor or out-of-gas diver. Communication by touch contact is not required except in zero or substantially reduced visibility

v. The out-of gas diver must stow his long hose and the team must maintain proper trim, propulsion technique, buoyancy control and awareness in order to prevent compounding the problem

vi. Do not delay exit by removal of reels

9. **Guideline Awareness-** is critical in any emergency. If the emergency results in the diver silting out the passage, the guideline becomes a critical survival tool in safely exiting the cave system. Proper deployment and awareness will facilitate a safer, more efficient exit. The appropriate time for confirmation of reels, placements and wraps may cause a delay in exit. Divers must avoid pulling on the guideline as this may result in removal of placements and wraps creating yet additional risks and delays. Unless required as a result of poor visibility, contact with the guideline is not required- it is more efficient to swim out. Should the need to contact the guideline arise, an *"OK"* of the line is all that is required and touch contact among all team members provides the means of communication.

10. **Excessive Depth**- Diving deeper than one's present level of training is one of the most common violations of limitations that trained cave divers make. Too many divers rely solely on the technology of today's dive computers without understanding the risks associated with deep dives and the effects on the human body. These potential risks only increase when divers use nonstandard gas mixtures and exceed no-decompression limits. It is easy within the cave environment to exceed these limits. Cave divers follow the configuration of the cave system while task loading distracts the diver from monitoring time, depth and gas supply. For all of these reasons, the cavern or cave diver must maintain awareness of depth, time and gas supply at all times.

Considerations regarding depth:

a. Dives made to 100 feet or deeper causes divers to experience a narcotic impairment affecting their ability to clearly think and reason (nitrogen narcosis)
b. The deeper the depth, the faster the air supply is used
c. No-decompression limits are greatly reduced as depth increases
d. At greater depths there is an increased risk of decompression sickness
e. Sufficient gas supply to meet decompression requirements may not exist
f. The risk of oxygen toxicity increases, particularly for nitrox divers

Summary

The opportunity to explore our world of underwater caverns and caves is one available to only a few. The cave environment is a beautiful, exciting and challenging environment which demands a great deal of those who choose to enter it. The cave diving community is made up of a diverse group of people bonded by a common interest. If, as a result of our training and preparation, we are able to educate other divers as to the risks of this environment and we are be able to prevent even one tragic accident, we have done our job.

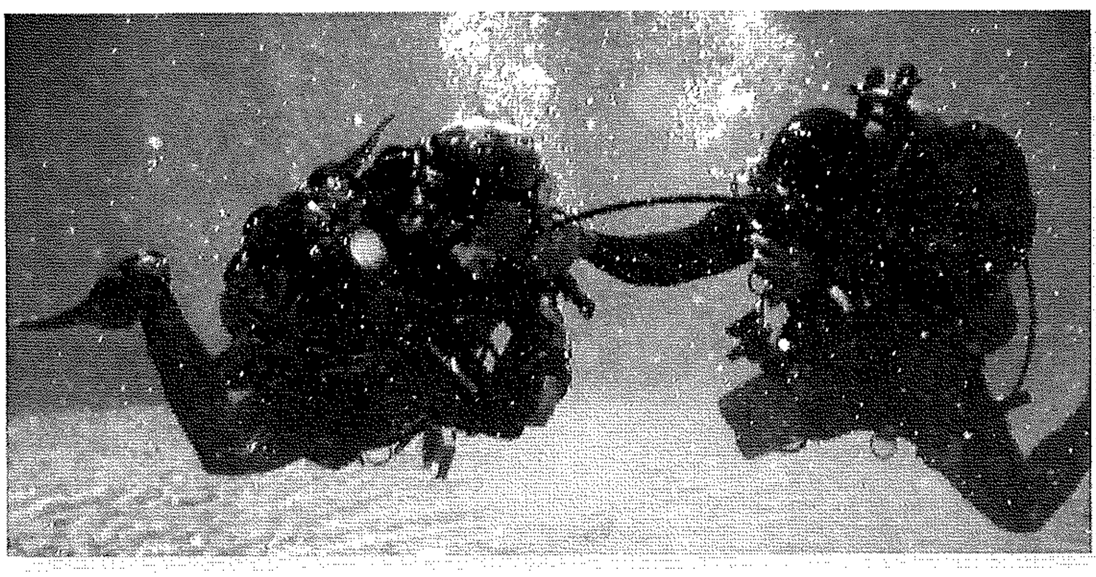
This course is designed to insure you are properly trained and give you the knowledge to permit you to dive within your limits of training and experience. If you wish to "go a little further", seek the training required to do so and be adequately prepared to face new challenges ahead.

The good diver is always training and training divers are always learning.

Safety should always be the first consideration, conservation the next primary consideration followed by all the personal reasons that individual divers have for entering this environment.

Practice, Practice, Practice... and then practice more.

INTRODUCTION TO CAVE DIVER COURSE



INTRODUCTION TO CAVE DIVER LIMITATIONS

The following limitations apply to the Intro to Cave Diver:

Main line penetration only (no gaps, jumps, circuits or traverses). The Intro diver is limited to navigation along the main line- the only time an Intro Diver should use any line other than the main line is when placing the primary reel from open water to the main line so as to maintain a continuous guideline to open water. Since the main line is most often placed in larger, less silty sections of cave passage, it travels along a safer course than other passages within the system. The Intro Diver is presented with the opportunity to practice and refine the skills and techniques with which he has been provided- penetration distance into the cave system should be of no concern.

Gas supply. Intro divers are limited to one-third (1/3) penetration gas of a single diving cylinder or, when permitted, one-sixth (1/6) of double cylinders.

Additionally, the Intro Diver must begin the dive with at least an air supply of either 2000 psi or 58 cubic feet, whichever is greater.

Minimum visibility. The Intro Diver must begin the dive with a minimum visibility of thirty (30) feet. This distance is determined by the ability of the diver to clearly recognize and acknowledge a lighted hand signal. While it is not required that thirty (30) feet of visibility remain constant throughout the course of the dive, the Intro Diver should remain mindful of both the Rule of Thirds and the Golden Rule of Cave Diving in determining the point at which a dive should be terminated.

Maximum depth. No dive at this level should exceed one hundred (100) feet in depth. The depth limitation is intended to minimize the possibility of onset of symptoms of nitrogen narcosis in this new environment. Since all dives must be within No Decompression Limits, dive time beyond this depth would be minimal.

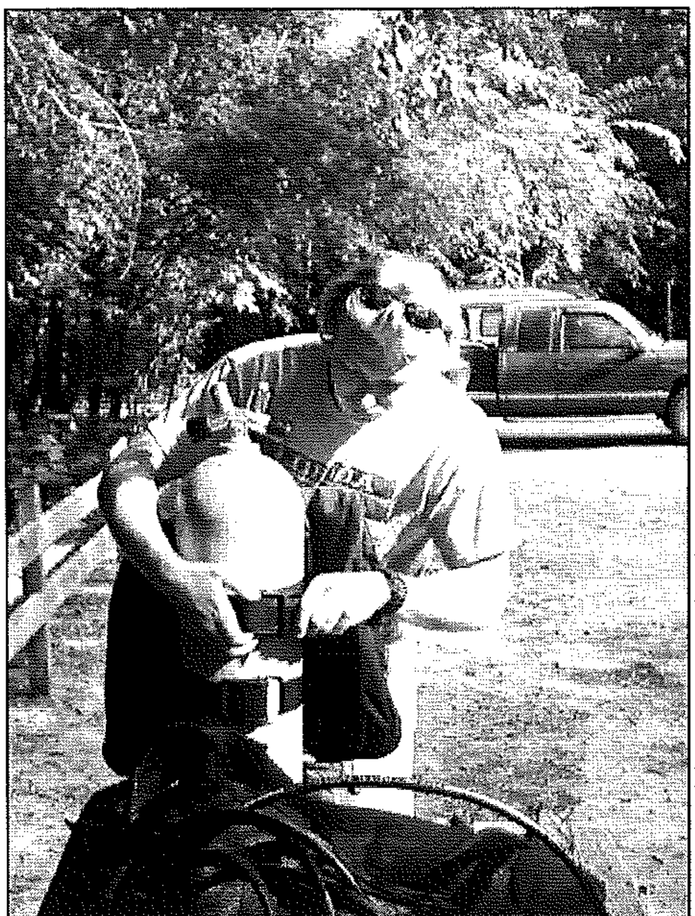
No decompression diving. The Intro Diver must remain within the No Decompression Limits of the dive computer or tables he has selected for the dive.

Minor restrictions permitted. Minor restrictions- those areas of the cave which are too small to allow two divers to pass through at the same time and require a single file formation- are permitted at the Intro Diver level. Under no circumstance should the Intro Diver attempt entering any area comprising a *major* restriction- one which requires the diver to manipulate his body and/or equipment. Furthermore, there is no circumstance which justifies removal of life support equipment in the overhead environment.

Safety stops. A recommended three minute safety stop should be observed on all dives.

Continuous guideline. The Intro Diver must maintain a continuous guideline to open water. Does the overhead diver require a guideline to enter the cave? The answer is "NO", but a guideline may certainly be required to exit the cave. Guidelines are not placed for ideal circumstances but for the worst-case scenario- zero or substantially reduced visibility within the cave, cavern and the open water basin. Because there are many different factors which may affect visibility on any given dive, the continuous guideline must be placed to help assure the Intro Diver's safe exit from the system to open water. It is imperative that the initial or **primary tie-off** be made in **open water** with direct access to the surface. Placing this tie-off under any portion of the overhead will not assure the dive team's safe return to the surface in the event of an emergency. It should be followed by a **secondary tie-off** in the cavern zone.

Use of required and properly configured equipment. This subject will be fully discussed in the equipment section of this text. No matter the level of overhead training, if the diver is not properly configured for a cavern or cave dive, he is diving as an open water diver and should never enter the overhead environment.



Guidelines of Accident Analysis

(For the Trained)

Previously it could be said "no trained cave diver has ever perished in a cave". This is no longer true and new guidelines of Accident Analysis have been formulated for the TRAINED cavern and cave diver. Through analysis of cavern and cave diving accidents, it has been determined that one or more of the following three (3) primary causes contribute to fatalities among the trained cavern or cave diver.

1) Depth- Failure to observe the depth limitations of training.

2) Guideline- Failure to maintain a continuous guideline from open water and throughout the cave system. Complacency in observing guideline protocol may result in diver fatality.

3) Gas- Always reserve a *minimum* of 2/3rds of your gas for exit– never violate the Rule of Thirds. Cheating or "stretching" gas puts the diver and entire team in peril. At all levels of overhead training it is essential that divers refine gas matching protocol by taking into account dissimilar cylinder volumes and breathing rates (see page 76).

Additional Points

- Dive with a properly trained and equipped diving partner and maintain dive team continuity throughout the dive.
- Increase the complexity of your dives slowly as your experience increases.
- Increase your knowledge of a cave system slowly and methodically as your experience and familiarity with that system increases.

When diving with team members of differing levels of training, always dive to the level of the least experienced team member. If you are the least experienced diver in the team, it is your responsibility to insist upon remaining within your level of training and comfort.

EQUIPMENT

At the Intro to Cave Diver level of training, it is recommended that students obtain and utilize their own equipment. Borrowed or rented equipment only serves to increase task loading and may reduce the student's ability to successfully complete this course.

⇒ Mask and fins (instructor can give guidance as to how to "snag proof" these items)

⇒ Diving cylinders of the appropriate size for the dives undertaken

⇒ Dual outlet valve or manifold

⇒ Exposure suit designed for the temperatures and durations expected

⇒ Buoyancy compensator- wings

⇒ One first stage regulator equipped with a 7 foot hose

⇒ One first stage regulator equipped with a shortened length hose

⇒ One primary battery powered dive light

⇒ Two backup or redundant battery powered dive lights

⇒ Safety reel

⇒ Three directional markers (line arrows) and one non-directional marker

⇒ Knife or line cutting tool

⇒ Submersible pressure gauge

⇒ Timer/watch and submersible dive tables or dive computer

⇒ Slate/wetnotes and pencil

⇒ One primary cave diving reel PER TEAM

DISSIMILAR CYLINDER VOLUMES (US)

In today's dive community there is a wide diversity of cylinder sizes for divers to choose from. At the Intro to Cave Diver level it becomes increasingly important for the dive team members to match volumes of dissimilar cylinders, as they now venture beyond the natural light zone. All team members are required to utilize the same volume of gas for the penetration of the dive. The team member who uses the allotted volume of gas first will call the dive, the other team members will acknowledge and all will start their exit.

Gas volume matching allows for an increased gas reserve for the team. The team will establish the team's usable gas volume for penetration from the smallest volume carried by a team member. If all members are honest and abide by using the same volume, this should allow for enough gas in the smallest cylinders to share gas with the heaviest breather for a safe exit. Divers need to plan all dives in a conservative manner, for the unlikely event that an emergency arises. The gas we carry for a dive is a limiting factor, so we must plan carefully.

The term "baseline" refers to a unit of pressure which correlates to a unit of volume. Using the baseline, the volume of gas contained within a cylinder can be determined from its pressure. Considerations for determining baseline include:

1. Baseline is calculated by using the DOT/CTC pressure and volume rating.
2. Low pressure steel cylinders which are stamped 2400 will use a 10% overfill of pressure (2640) to achieve its rated volume.
3. Aluminum and high pressure steel cylinders do not use the 10% overfill rule for calculations.
4. Baseline is determined by dividing the rated volume (cubic feet) of the cylinder by its rated pressure.

To determine the baseline of an aluminum 80 cubic foot cylinder: 80 cubic foot divided by 3000 psig = 0.026 X 100 psig = 2.6 cubic feet for each 100 psig, therefore the baseline of a single Al 80 is 2.6.

To determine the baseline of the low pressure steel 104 cubic foot cylinder: 104 cubic foot divided by 2640 psig = 0.039 X 100 psig = 3.9 cubic feet for each 100 psig, therefore the baseline of a single steel 104 is 3.9.

For double cylinders, simply multiply the single baseline calculated above by 2. Double aluminum 80 cylinders will have a baseline of 5.2 cubic feet for each 100 psig. Double low pressure steel 104 cylinders will have a baseline of 7.8 cubic feet for each 100 psig.

Having determined baseline, the divers will next match volumes within the dissimilar cylinders of a dive team. Let's look at some examples on the next page.

Example: Diver A, using a LP 104 cf cylinder, filled to 2400 psig.
Diver B, using a LP 85 cf cylinder, filled to 2600 psig.

Using either the baseline calculation or the chart on the next page, Diver A's baseline is 3.9 and Diver B's baseline is 3.2. Diver B's cylinder has a smaller baseline and with less gas, showed by the math below, this will make him the determining factor for usable gas for the dive team.

Diver A: 3.9 X 24 = 93.6 cf Diver B: 3.2 X 26 = 83.2 cf
Diver A has a total of 93.6 cubic foot and diver B has a total of 83.2 cubic foot.

NOTE: When calculating thirds of pressure, if the pressure is not evenly divisible by 3 drop to the next lower number that is evenly divisible by 3.

Diver B, having the least gas, will calculate one third of his starting gas pressure. Next, convert that to volume, which establishes the team's usable gas supply for the dive.

Diver B's pressure is 2600 psig, not equality divisible by 3; the next lower number which will be is 2400 psig; 2400 psig divided by 3 will equal 800 psig for his usable gas for the dive.

To convert 800 psig in the LP 85s to volume: 3.2 X 8 = 25.6 cubic foot
To convert 25.6 cubic foot for Diver A's 104: 25.6 / 3.9 X 100 = 656 psig

Diver A's usable pressure will be no more than 650 psig, which establishes a turn pressure of 1750 psig. Diver B's usable pressure will be no more than 800 psig, which establishes a turn pressure of 1800 psig.

By adjusting individual's usable gas to match as equal volume, we have increased the gas reserves in case of an emergency. This will also limit the diver with the highest gas consumption rate from using more than one third the volume of the smallest cylinder on the team. We should understand that our planned volume usage is a constant, but our consumption rates may be variable. The team member that uses his allotted usable gas first will call the dive, and do not let it be a problem for you to be the first to call a dive.

Foremost, be honest with yourself and your teammates, be objective, and plan your dives conservatively. To use one third of your gas supply is the maximum usage for a dive, not a minimum. Be conservative when you are diving a new site, with new buddies, new equipment, poor visibility, cold temperatures, into a siphoning passage, etc. Take the time to develop your skills and experience in a conservatively progressive manner. Strong skills and good experience will not come to anyone quickly.

Volume (Actual) Cu.ft.	DOT/CTC Pressure Rating (psig)	Psi / Cu.ft Single Cylinder	Baseline Cuft/100 Psi Single-Double Cylinder
50 (48.5) AL	3000	61.8	1.6-3.2
63 (61.1) AL	3000	49.1	2.0-4.0
65 Gen	3500	53.8	1.9-3.7
66 AA	2640	40.0	2.5-5.0
72 (71.2) AA	2475	34.8	2.9-5.8
80 (77.6) AL	3000	38.6	2.6-5.2
80 Gen	3500	43.8	2.3-4.6
80 (79.3) E	3442	43.4	2.3-4.6
85 AA	2640	31.0	3.2-6.4
95 AA	2640	27.8	3.6-7.2
98 AA	2640	26.9	3.7-7.4
100 (97.0) AL	3300	34.0	2.9-5.9
100 Gen	3500	35.0	2.8-5.7
100 (99.2) E	3442	34.7	2.9-5.8
104 AA	2640	25.4	3.9-7.8
112 AA	2640	23.6	4.2-8.5
120 (119.0) E	3442	28.9	3.4-6.9
120 Gen	3500	29.2	3.4-6.8
125 AA	2640	21.1	4.7-9.5
131 AA	2640	20.2	4.9-9.9

Popular tank sizes and their baselines

DISSIMILAR CYLINDER VOLUMES (Metric)

In today's dive community there is a wide diversity of cylinder sizes for divers to choose from. At the Intro to Cave Diver level it becomes increasingly important for the dive team members to match volumes of dissimilar cylinders, as they now venture beyond the natural light zone. All team members are required to utilize the same volume of gas for the penetration of the dive. The team member who uses the allotted volume of gas first will call the dive, the other team members will acknowledge and all will start their exit.

Gas volume matching allows for an increased gas reserve for the team. The team will establish the team's usable gas volume for penetration from the smallest volume carried by a team member. If all members are honest and abide by using the same volume, this should allow for enough gas in the smallest cylinders to share gas with the heaviest breather for a safe exit. Divers need to plan all dives in a conservative manner, for the unlikely event that an emergency arises. The gas we carry for a dive is a limiting factor, so we must plan carefully.

The term "baseline" refers to a unit of pressure which correlates to a unit of volume. Using the baseline, the volume of gas contained within a cylinder can be determined from its pressure. Considerations for determining baseline include:

1. Baseline is calculated by using the CE pressure and volume rating.
2. Baseline is determined by dividing the rated volume (liter) of the cylinder by its rated pressure.

To determine the liter/volume of a 7 liter cylinder: 7 times its filling pressure = 7 liter x 200 bar = 1400 liter free gas.

For double cylinders, simply multiply the single liter volume by 2. Double 12 liter: 2 x 12 liters x 200 bar = 2 x 12 x 200 = 4800 liter free gas.

There is no difference in calculating for steel or aluminum tanks in the metric system.

Having determined baseline, the divers will next match volumes within the dissimilar cylinders of a dive team. Let's look at some examples on the next page.

Example: Diver A, using a double 12 l tanks, filled to 210 bar. 1/3 is 70 bar.
Diver B, using a double 10 l tanks, filled to 240 bar. 1/3 is 80 bar.

Using either the baseline calculation or the chart on the next page, Diver A's baseline is 5040 liter and Diver B's baseline is 4800 liter. Diver B's cylinder has a smaller baseline with less gas, showed by the math below, this will make him the determining factor for usable gas for the dive team.

Diver A: 2x12x210= 5040 liter Diver B: 2X10x240= 4800 liter
Diver A has a total of 5040 liter and diver B has a total of 4800 liter.

NOTE: When calculating thirds of pressure, if the pressure is not evenly divisible by 3 drop to the next lower number that is evenly divisible by 3.

Diver B, having the least gas, will calculate one third of his starting gas pressure. Next, convert that to volume, which establishes the team's usable gas supply for the dive.

Diver B's volume is 4800 liter, divisible by 3; will be is 1600 liter; .

To convert 1600 liter for Diver A's double 12 liter 1600 liter / 24 liters (double 12 liter tanks) = 66 bar.

Diver A's usable pressure will be no more than 66 bar, which establishes a turn pressure of 144 bar. Diver B's usable pressure will be no more than 80 bar, which establishes a turn pressure of 160 bar.

By adjusting individual's usable gas to match as equal volume, we have increased the gas reserves in case of an emergency. This will also limit the diver with the highest gas consumption rate from using more than one third the volume of the smallest cylinder on the team. We should understand that our planned volume usage is a constant, but our consumption rates may be variable. The team member that uses his allotted usable gas first will call the dive, and do not let it be a problem for you to be the first to call a dive.

Foremost, be honest with yourself and your teammates, be objective, and plan your dives conservatively. To use one third of your gas supply is the maximum usage for a dive, not a minimum. Be conservative when you are diving a new site, with new buddies, new equipment, poor visibility, cold temperatures, into a siphoning passage, etc. Take the time to develop your skills and experience in a conservatively progressive manner. Strong skills and good experience will not come to anyone quickly.

Volume (Actual) Liter	CE Norm Pressure Rating (bar)	Free Volume filled to 200 bar Single Tank	Free volume filled to 200 bar Double Tanks
3	200/300	600 L	1200 L
5	200/300	1000 L	2000 L
6	200/300	1200 L	2400 L
7	200/300	1400 L	2800 L
8	200/300	1600 L	3200 L
80 (77.6) AL (11.1 L)	200	2220 L	4440 L
10	200/300	2000 L	4000 L
12	200/300	2400 L	4800 L
15	200/300	3000 L	6000 L
16	200/300	3200 L	6400 L
20	200/300	4000 L	8000 L

Useful conversion table for divers:

1 cubic foot	28.32 liters
104 cubic feet	2945 liters
1 liter	0.0353 cubic feet
2000 liter	70.6 cubic feet
1 bar	14.504 PSI
200 bar	2900 PSI
1 PSI	0.0689 bar
2400 PSI	165.5 bar

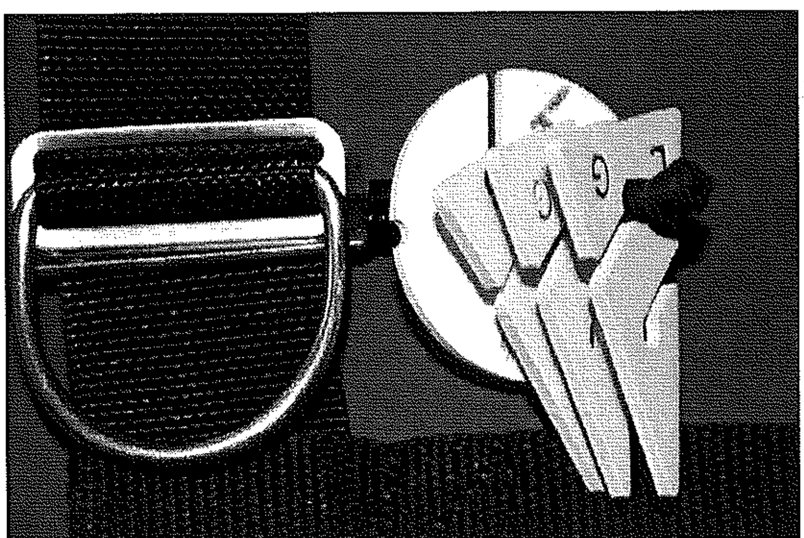
GUIDELINE MARKERS

For a detailed discussion of cave reels and guidelines, please refer to the Cavern Diver Course section of your NACD Student Workbook.

In addition to the permanent lines within our cave systems, another aid to navigation for cave divers is line markers — either ***directional markers*** or ***non-directional markers***.

1. Directional markers are permanent or personal line arrows which, when properly installed, point the direction to the nearest navigable exit. Directional markers allow for both visual and tactile reference to the exit. Permanent line arrows are installed on permanent lines within the cave, are often marked by distance, in feet, from the exit and are not to be tampered with in any manner. Permanent line arrows may also indicate the presence of a "popular" side passage or a point equidistant between two navigable cave openings. Personal line arrows, which should be clearly and uniquely marked by the individual diver, are used by individual divers for a variety of purposes including marking maximum distance of penetration, securing jump lines where there is no permanent line arrow at the point of jump and indicating a diver's direction of travel in emergency situations.

2. Non-directional markers include round plastic discs- "cookies"- and clothespins and are generally used for the same purposes as personal line arrows. An advantage to these markers is the elimination of confusion which may result from an incorrectly placed line arrow. Since they do not indicate direction, non-directional markers are easily recognized as temporary and should not be relied upon by any diver other than the one placing it and his team members. As with personal arrows, each marker should be distinctly marked and individualized for easy recognition.



Emergency Procedures

1. **Loss of Visibility:**

    a. Immediately establish contact with the guideline and "*OK*" the guideline
    b. Turn to orient yourself to the direction of exit
    c. Establish touch contact
    d. Utilize touch contact communication until clear of the silt or percolation or back to open water

2. **Primary Light Failure**- This is a minor problem that still requires the dive to be turned.

    a. Establish contact or reference to guideline, remember you should be in team contact and be able to use their lighting;
    b. Activate and deploy a backup light;
    c. Communicate failure to team members and adjust team positioning with "injured" diver in the lead position; and
    d. Exit pulling reels if appropriate

3. **Loss of Vision** - Mask failure or flooding

    a. Secure guideline, maintain directional sense and gain attention of team members
    b. Put on spare mask (if equipped) or clear mask as required
    c. Stow faulty mask
    d. Exit

4. **Entanglement** – always pass over guidelines keeping them in sight if at all possible. Secure and streamline your equipment.

    a. Once you realize you are entangled, *STOP ALL MOVEMENT* — twisting and pulling may make it worse
    b. Signal team member of entanglement
    c. Attempt to free and untangle yourself first. If not easily accomplished, allow buddy to assist
    d. If line must be cut:
        (1) Move all team members to exit side of entangled diver
        (2) Maintain continuous guideline by securing entangled line on both sides of the entangled diver using a gap reel or safety reel and line arrows as needed

It is recommended each diver have a backup safety reel. To keep safety line free from any further entanglement of wrap or place the connecting line around a rock and away from the diver.

(3) Make cuts to original line as close to entangled diver as possible, but within the tieoff points of the gap or safety line splice

(4) Untangle the diver and move diver to exit side of line

(5) Attempt to repair by retying and securing original line, splicing or adding a new section (leaving gap reel in place is an acceptable temporary solution)

(6) Notify EVERYBODY of cut or repaired line

5. **Cut, Broken or Removed Exit Line**– A line may be cut or broken, break from normal wear and tear or have been removed in error.

a. Once a line break is found, stop and determine that you are still on the original planned route and correct guideline Check your gas supply to see how much "repair time" you have

b. Have a team member hold position of known end of guide line. This will provide a lighted reference or beacon to last position should other problems occur

c. Secure a second line to the known line using a safety reel and line arrows as required

d. Locate cut or broken line using appropriate search techniques and running a safety reel as you search. Note flow and cave configuration prior to and during search

e. Once located line is located, secure the safety reel to the cut line using line arrows or tie points as required

f. Attempt to re-tie old line ends together- you may need to leave temporary splice in place or add a new section of line. If this is conducted as a re-establishment of exiting line you can go back later to retrieve reel using standard penetration techniques

g. Notify the appropriate authorities of cut or repaired line. It is good practice to mark the line at point of cut or break using line arrows

6. Lost Diver- *Your personal safety is your priority!!!*

a. A diver who has lost directional reference to the exit should stop, locate the line and use directional references such as line arrows, flow, prominent cave features, bubbles and silting to determine direction to the exit.

b. A diver who has "lost" his buddy, but is on the guideline should:

1. Stop forward motion and orient to the exit; mark location and direction of exit on line
2. Perform a shielded light search for the missing team member or his light. The searching diver should not turn his light off as it may not re-activate
3. Perform a light search for the missing diver- look for the diver and signs of the diver- bubbles or silt trail. Be sure to look up and down as well as side to side
4. Re-evaluate gas reserve — The proper gas management calculation will provide a reserve to use during a search. A recommended one third of the reserve could be used for the search
5. Use a directional marker on the guideline to anchor a safety reel and begin an effective searching pattern
6. Since your team member may have exited the cave already, do not overstay your search time
7. Exit the cave, confirm on the surface the absence of your team member and report the diver as missing if required

c. A diver who has lost sight of the exit or guideline should:

1. Stop and establish a fixed position making note of current and prominent cave features
2. Rise over any silt if possible while shielding light to locate the source of any ambient light
3. If the diver cannot locate a light source or is in zero or substantially reduced visibility, secure a tie-off with safety reel and begin an organized search for lost line and exit
4. Search until line or exit is found

7. Gas Supply Emergencies. The dive planning process must include planning for gas limitations suitable for the safe exit of all dive team members taking into account problems which may arise during the dive. The Rule of Thirds is a safe benchmark from which to begin dive planning. This Rule, however, may be adjusted depending on the presence of factors which require a more conservative approach. Instances of reducing gas supply to less than thirds include new system, new gear, new team member, low or no flow system, dissimilar cylinder volume among team members, dissimilar breathing rates among team members and any other exceptional circumstance.

a. Equipment Systems

(1) Single outlet valve, single cylinder systems provide no redundant regulator or isolation capability. Although these cylinders are permitted at the Cavern Diver training level, they are not suitable for Intro to Cave and beyond. It is recommended that the Cavern Diver consider the use of dual outlet valves ("H" or "Y" valve) and redundant regulator systems.

(2) Double cylinders with redundant regulators and a dual outlet manifold with isolator is the preferred configuration. Some configurations employ the use of double tanks without a manifold- sidemount configuration and double independent tanks.

(3) DIN valves are preferred to yoke valves since DIN valves are more secure if an impact occurs. Such impact to a yolk valve may dislodge the regulator first stage resulting in rapid and uncontrolled loss of gas.

b. Gas emergencies are characterized as:

1. **Critical** – next breath is threatened
2. **Immediate** – total loss of gas supply will occur within minutes
3. **Delayed** – total loss more than a minute away, diver has time to react

c. Examples of problems:

1. Failure to observe pressure gauge
2. Rupture of supply line hoses
3. O-ring failure
4. Regulator failure including free flow
5. Valve failure, blown burst disc or valve roll-off
6. Manifold damage or valve knob break
7. Incorrect starting pressure
8. Incorrect or insufficient gas for planned dive
9. Excessive breathing rate or high work load and stress
10. Failure to gas match and calculate turn pressures
11. Failure to fully open tank valves
12. Excessive depth

d. Management of problems. It is imperative to quickly identify the problem and correct it as required. If a catastrophic failure occurs, the diver could continue to breathe all remaining gas available to him with his team member ready to provide gas when needed. Depending on the nature of the gas emergency, the diver must be prepared to make the decision whether to switch to an alternate air source, isolate the failure or begin air-sharing with a team member. In any case the dive will be terminated and the team will exit the system.

e. Gas management procedure

1. Signal team members, request assistance and begin gas-sharing if required
2. Begin self-management of the problem until a team member arrives and then hold to permit the team member to identify and correct the problem
3. Re-establish reference to cave exit and guideline
4. In the event gas-sharing is required, initiate the procedure with the out-of-gas diver taking the lead position. The recipient should control pace and other team members must

remain available to assist either the donor or out-of-gas diver. Communication by touch contact is not required except in zero or substantially reduced visibility

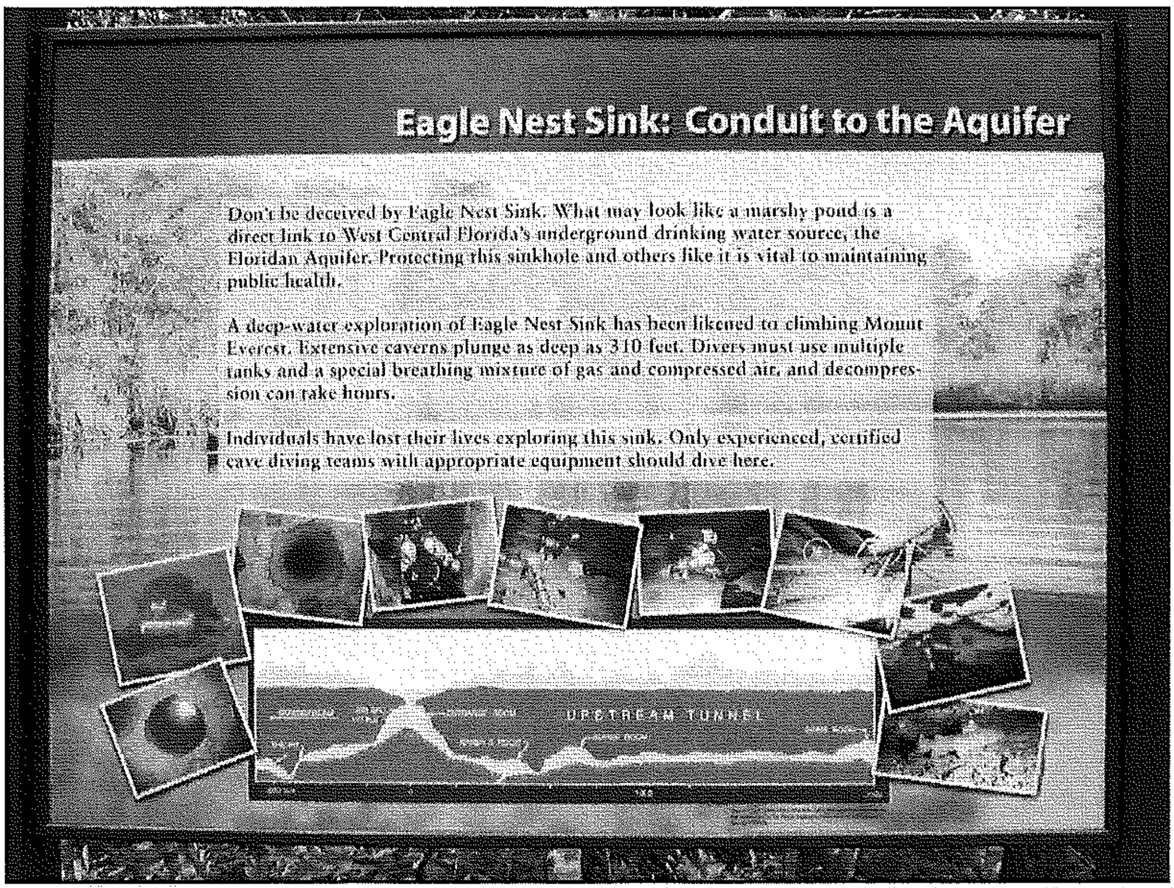
5. The out-of gas diver must stow his second stage regulator and the team must maintain proper trim, propulsion technique, buoyancy control and awareness in order to prevent compounding the problem
6. Do not delay exit by removal of reels

8. Guideline Awareness- is critical in any emergency. If the emergency results in a diver silting out the passage, the guideline becomes a critical survival tool in safely exiting the cave system. Proper deployment and awareness will facilitate a safer, more efficient exit. The appropriate time for confirmation of reels, placements and wraps may cause a delay in exit. Divers must avoid pulling on the guideline as this may result in removal of placements and wraps creating yet additional risks and delays. Unless required as a result of poor visibility, contact with the guideline is not required- it is more efficient to swim out. Should the need to contact the guideline arise, an *"OK"* of the line is all that is required and touch contact among all team members provides a means for communication.

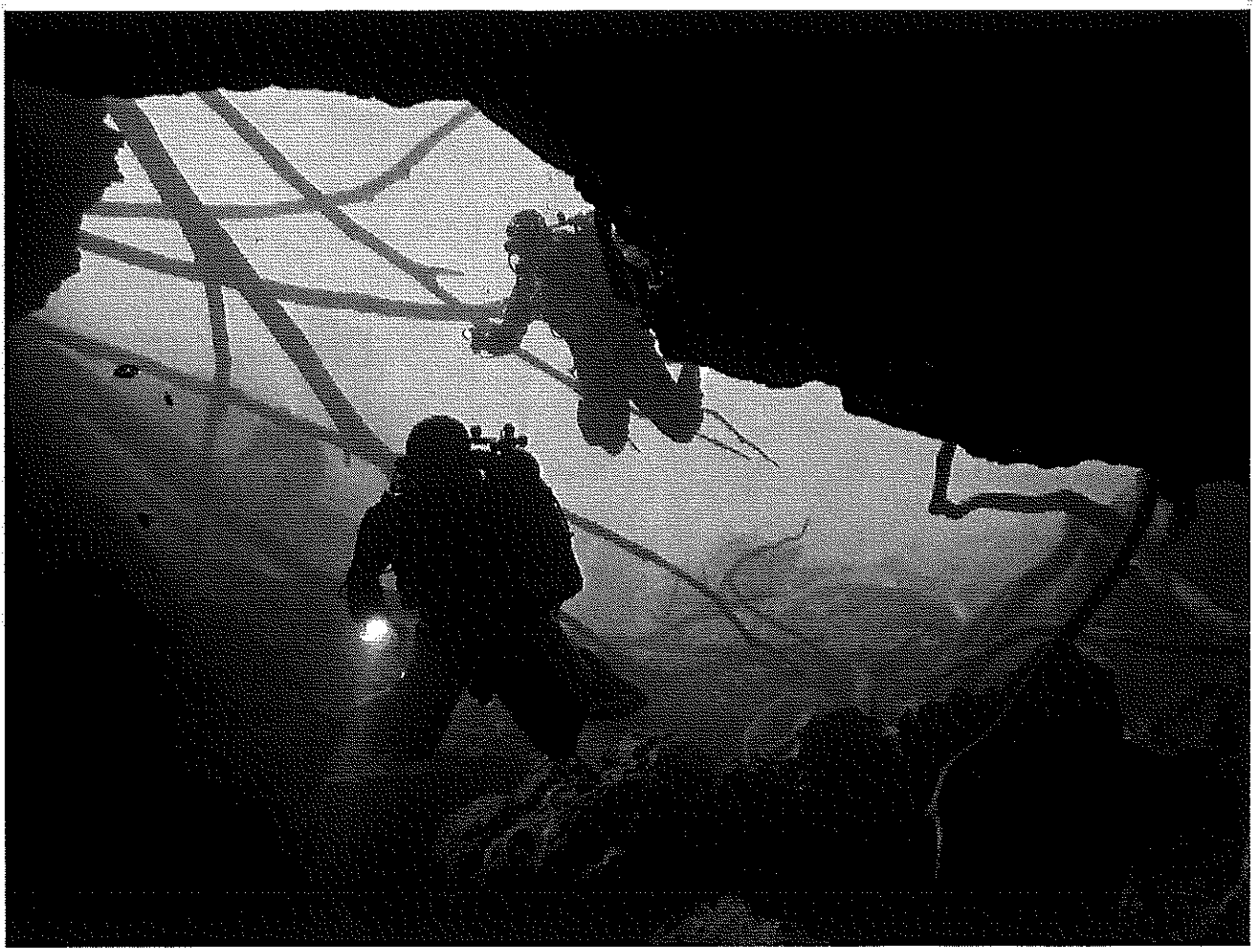
9. **Excessive Depth**- Diving deeper than one's present level of training is one of the most common violation of limitations divers make. Too many divers rely solely on the technology of today's dive computers without understanding the risks associated with deep dives and the effects on the human body. These potential risks only increase when divers use nonstandard gas mixtures and exceed no-decompression limits. It is easy within the cave environment to exceed these limits. Cave divers follow the configuration of the cave system while task loading distracts the diver from monitoring time, depth and gas supply. For all these reasons, the cavern or cave diver must maintain awareness of depth, time and gas supply at all times.

Considerations regarding depth

a. Dives made to 100 feet or deeper causes divers to experience a narcotic impairment affecting their ability to clearly think and reason (nitrogen narcosis)
b. The deeper the depth, the faster the air supply is used
c. No-decompression limits are greatly reduced as depth increases
d. At greater depths there is an increased risk of decompression sickness
e. Sufficient gas supply to meet decompression requirements may not exist
f. The risk of oxygen toxicity increases, particularly for nitrox divers



APPRENTICE CAVE DIVER COURSE



APPRENTICE CAVE DIVER LIMITATIONS

Upon successful completion of Apprentice Cave Diver training, the diver shall be permitted the use of double cylinders for cave penetration utilizing the Rule of Thirds within the following limitations:

Gas Supply. Double tanks, with a minimum volume of one hundred and forty-two (142) cubic feet of gas, are required at the Apprentice Cave Diver level. The Apprentice Diver may use up to one-third (1/3) of available gas for cave penetration- keep in mind that there are many circumstances which justify reducing usable gas and that the Rule of Thirds is a guideline established for maximum usable penetration gas.

The Apprentice Cave Diver must begin each dive with a minimum volume of at least 116 cubic feet or 2,000 PSI, whichever represents the larger volume.

Minimum visibility. The Apprentice Cave Diver must begin the dive with minimum visibility of twenty (20) feet. This distance is determined by the ability of the diver to clearly recognize and acknowledge a lighted hand signal.

Maximum depth. No dive at this level should exceed one hundred and thirty (130) feet in depth. The depth limitation is intended to recognize the Apprentice Cave Diver's need for a greater range within the cave system while still minimizing the possibility of onset of symptoms of nitrogen narcosis in the overhead environment.

Limited decompression only. This is the first level at which the diver may begin to lengthen the dive by exceeding No Decompression Limits.

"Limited decompression" means the use of a decompression gas on a single stop. The use of multiple decompression gases and multiple stops is beyond the limits of training of the Apprentice Cave Diver. The diver is encouraged to obtain this experience through Nitrox, Advanced Nitrox and Decompression Procedures courses.

The use of stage cylinders to extend the diver's range is not permitted for the Apprentice Diver - the use of a single decompression cylinder is acceptable.

Limiting partial pressure of oxygen. The diver's PPO_2 should not exceed 1.4 ATA for the working portion of the dive and 1.6 ATA for decompression.

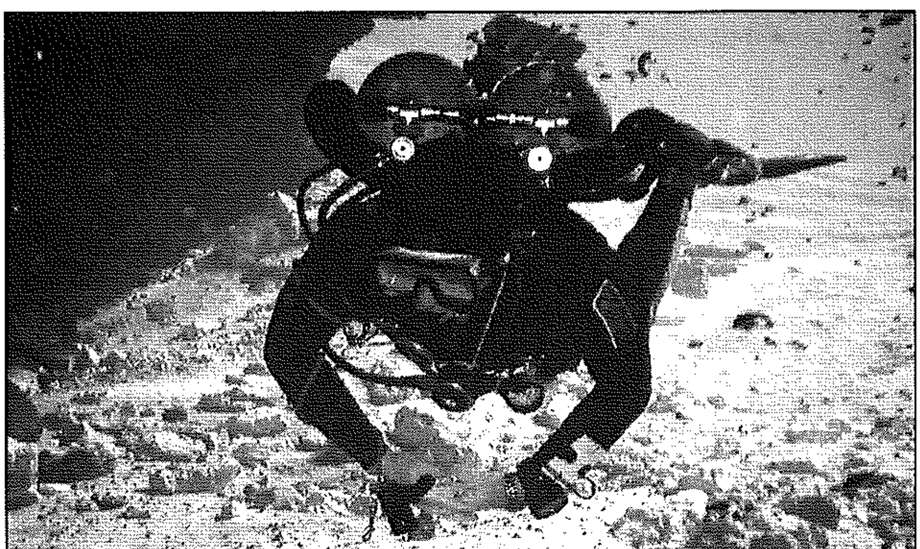
No DPV use. Use of a DPV requires specialized skills and techniques that are presented only after the diver has completed a minimum number of dives beyond Full Cave Diver. For both diver safety and conservation of the overhead environment, there is no appropriate use of a DPV by the diver in the overhead environment at this training level.

Simple jumps and gaps permitted. The Apprentice Cave Diver should develop the skills, techniques and awareness required to begin the Full Cave Diver course in large, lower silt passages of the cave system. Multiple jumps and gaps along multiple lines should be avoided at this level. No circuits or traverses are permitted unless the diver is under the direct supervision of a Full Cave instructor.

Continuous guideline. As with previous levels of training, the Apprentice Cave Diver must maintain a continuous guideline from open water and throughout the cave system. This includes the placement of a primary reel from open water to the main line and installation of temporary lines by the team along all jumps and gaps within the cave system.

Use of required and properly configured equipment. This subject was fully discussed in the equipment section of this text. No matter the level of overhead training, if the diver is not properly configured for a cavern or cave dive, he is diving as an open water diver and should never enter the overhead environment.

NOTE: **Apprentice Cave Diver is a training level only and, upon successful completion, shall result in the issuance of a time-limited temporary card. Such temporary card shall expire of its own force and effect one (1) year from the date of issuance. Upon expiration, the diver will be certified to the Intro Diver level and will be required to repeat the Apprentice Cave Diver program in order to subsequently dive at this level.**



Guidelines of Accident Analysis

(For the Trained)

Previously it could be said "no trained cave diver has ever perished in a cave". This is no longer true and new guidelines of Accident Analysis have been formulated for the TRAINED cavern and cave diver. Through analysis of cavern and cave diving accidents, it has been determined that one or more of the following three (3) primary causes contribute to fatalities among the trained cavern or cave diver.

1) Depth- Failure to observe the depth limitations of training.

2) Guideline- Failure to maintain a continuous guideline from open water and throughout the cave system. Complacency in observing guideline protocol may result in diver fatality.

3) Gas- Always reserve a minimum 2/3rds of your gas for exit– never violate the Rule of Thirds. Cheating or "stretching" gas puts the diver and entire team in peril. At all levels of overhead training it is essential that divers refine gas matching protocol by taking into account dissimilar cylinder volumes and breathing rates.

Additional Points

- Dive with a properly trained and equipped diving partner and maintain dive team continuity throughout the dive.
- Increase the complexity of your dives slowly as your experience increases.
- Increase your knowledge of a cave system slowly and methodically as your experience and familiarity with that system increases.

When diving with team members of differing levels of training, always dive to the level of the least experienced team member. If you are the least experienced diver in the team, it is your responsibility to insist upon remaining within your level of training and comfort.

APPRENTICE CAVE DIVER - EQUIPMENT

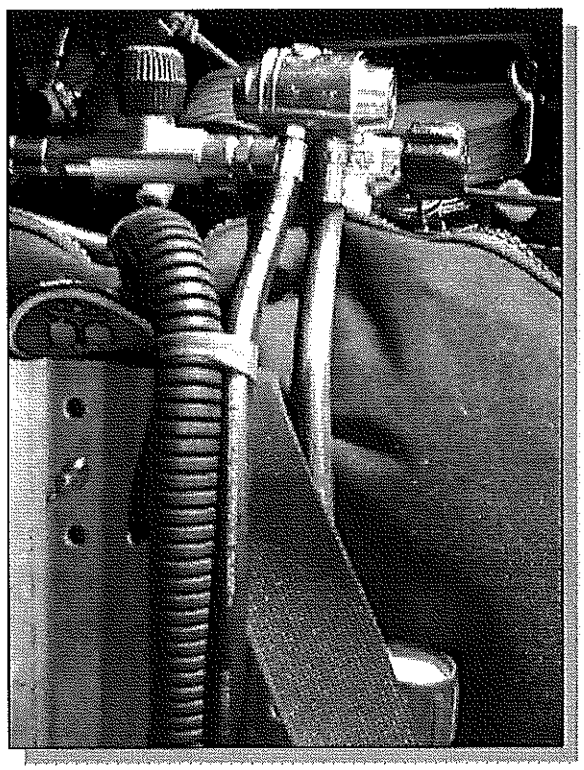
It is recommended that students obtain and utilize their own equipment at all levels of cavern/cave training. Borrowed or rented equipment only serves to increase task loading and can reduce the student's ability to complete these courses.

All equipment required in the Introduction to Cave Diving course, with the *addition* of:

⇒ Twin diving cylinders with dual-valve manifold of the appropriate size for the dives undertaken.

⇒ Jump/gap reels required for planned dives.

⇒ It is recommended that each diver provide an in-water decompression cylinder properly identified on all dives. The cylinder should be clearly marked, equipped with a proper regulator and contain 1.5 times the gas expected to be utilized.



COMPLEX NAVIGATION- A BEGINNING

Having reviewed tools for navigation, it is appropriate to now examine different types of navigation employed by cave divers. At earlier stages of training, cave divers are limited to linear penetration- i.e.- dives limited solely to the main line. As the diver gains experience and obtains additional training, complex navigation techniques become available to them to expand exploration of the cave. These complex techniques include ***gaps***, ***jumps***, ***circuits*** and ***traverses***.

A ***gap*** occurs when an intentional break in the main line is encountered, usually to prevent the exposure of cave lines to non-trained divers in open water. A ***jump*** occurs typically to join a lined cave passage that is not connected to the main line. Popular jumps are often marked by the placement of double line arrows, both pointing the same direction to the exit.

The procedure for bridging a gap is as follows:

1) As the dive team approaches the gap, each team member should check gas supply and make the decision to commit to departure from the original line. There is little point in placing a reel only to call the dive during the process of laying the reel or shortly thereafter.

2) The team leader ties into the end of the original line and begins across the gap while all other team members hold position on the original line, except where required for the team to remain in sight of the leader.

3) The team leader ties into the permanent line on the other side of the gap. Remaining team members may proceed across the gap and continue the dive so as to remain within sight of the team leader.

The procedure for completing a jump is as follows:

1) As with a gap, prior to deploying the jump reel each team member should check gas supply and make the decision to commit to departure from the present route of travel.

2) Many popular jumps are marked with double line arrows pointing the direction to the nearest exit. If double line arrows are in place and no other jump reels are already set, the team leader could place his tie-in between the two line arrows or directly to either arrow. In the event a jump line is already set, the team leader should place his tie-in on another arrow so as not to interfere with any existing lines in place.

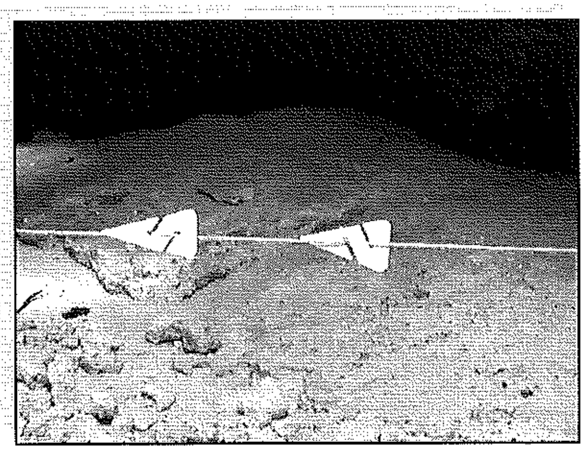
3) If double line arrows are not located at the point of jump or several lines are encountered, the team leader should place his personal line arrow on the line pointing back in the direction of the team's exit.

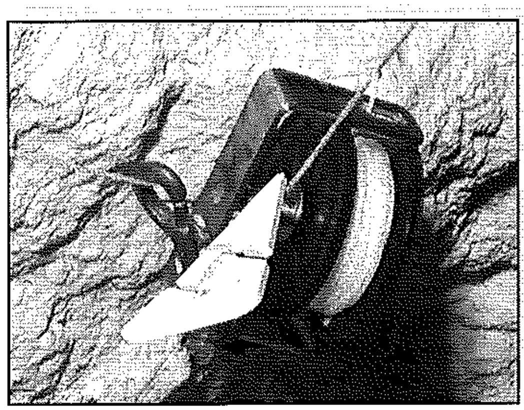
4) Before deploying his jump reel, the team leader should place a directional marker on the exit side of the line arrow(s). It is important that the team leader receives acknowledgement from other team members of the placement of the directional marker.

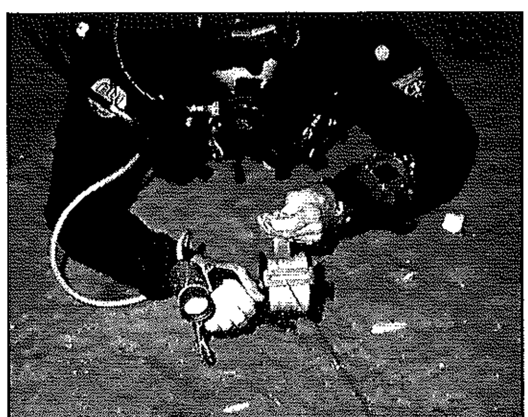
5) The team leader will tie into the original line or in a slot of his personal line arrow and begin across the jump while all other team members hold position on the original line.

6) Only after the team leader has completed his tie-in to the jump line and a continuous guideline to the surface has been established may remaining team members proceed across the jump and continue the dive.

Since jumps and gaps are integral elements of a successful traverse or circuit, divers must be proficient with jump and gap procedures before moving on to more complex navigation.







DECOMPRESSION CONSIDERATIONS

1) WHAT IS DECOMPRESSION DIVING?

It is important to understand that every dive is a decompression dive in that all divers are subject to limits of depth and time. These limits are based on pressure and the amount of nitrogen that pressure causes our bodies to absorb. Decompression diving occurs when the diver elects to exceed No Decompression Limits and is required to regulate ascent by making predetermined "decompression stops".

2) WHY DECOMPRESSION DIVE?

As a cave diver, the opportunity for decompression diving will present itself– either as the result of poor planning or the need for further exploration of the cave environment. Since the surface is not readily accessible, the diver may find that the penetration distance resulting from an improved RMV rate, following the Rule of Thirds and depth may put him in a required decompression profile. To avoid "accidental" decompression, the diver must carefully plan and carry out the dive according to that plan.

At some point the Cave Diver may wish to explore greater distances and times than are possible by remaining within No Decompression Limits. To do so, an understanding the of the basic principles of decompression diving and the associative risks are important.

THIS SECTION IS NOT A SUBSTITUTE FOR FORMAL DECOMPRESSION DIVING TRAINING. IT IS STRONGLY SUGGESTED THAT YOU SEEK FURTHER TRAINING TO OBTAIN A WORKING UNDERSTANDING OF THE PRACTICES AND GUIDELINES REQUIRED FOR DECOMPRESSION DIVING BY A CERTIFIED INSTRUCTOR IN DECOMPRESSION DIVING PROCEDURES.

3) **GASES**

The most common gas mixture available on the planet is air. Air is comprised of the following:

N_2 (nitrogen) - 79%
O_2 (oxygen) - 20.9%
CO_2 (carbon dioxide) - < 1%
Ar (argon) - <1 %r
Other gases - < 1%

A. Nitrogen is the most abundant gas in the air we breathe. It is considered an inert gas but its effects on divers make it the most problematic gas we deal with.

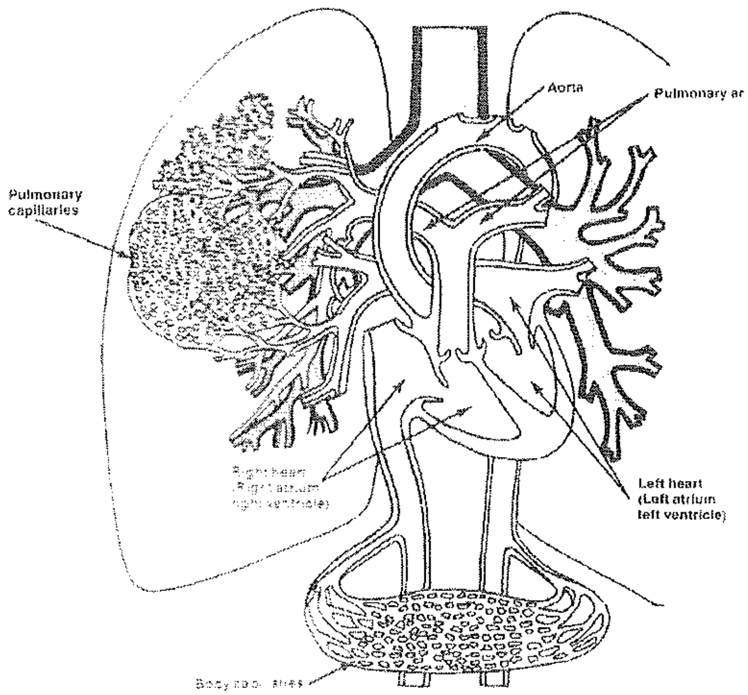
B. While it is not used in the respiratory process, nitrogen has the unique ability to sedate the central nervous system when breathed under pressure, a condition known as *nitrogen narcosis.* In addition to its narcotic effect, nitrogen causes increased breathing resistance when used for extremely deep dives. Since nitrogen is not used in the respiratory process, it absorbs into liquid and tissues and makes the diver susceptible to DCS.

C. Oxygen is the second most common gas in the atmosphere and is the gas our bodies metabolize into energy. We do not use the full amount of oxygen available- in fact we only use some of what we breathe in. Oxygen in high concentrations can have an undesirable effect on a diver in the form of *Oxygen Toxicity*.

D. Carbon dioxide is another gas with which divers need be concerned. Excessive levels of carbon dioxide may result in unconsciousness (hypercapnia), hyperventilation (hypocapnia) or shallow water blackout. Carbon dioxide build up can contribute to DCS, oxygen toxicity and nitrogen narcosis as well. This gas "tells" the body when to breathe.

E. Argon is a gas that is incapable of supporting life. Argon is used as an insulating gas for drysuit divers due to its greater molecular weight and thermal retention capability.

4) PHYSIOLOGY



In the cardiovascular system, oxygen-rich blood from the lungs enters the left heart and is pumped into the aorta. The blood flows through the aorta, branching into smaller arteries until reaching the body capillaries, where the tissue receives the blood oxygen in exchange for carbon dioxide. Oxygen-poor blood returns to the right heart via the veins and is pumped to the lungs for gas exchange. Then the cycle repeats to support life. It is here that nitrogen is also carried and distributed throughout the body. Without the metabolic function acting on nitrogen, the nitrogen will continue to accumulate within the body's tissues (*Henry's Law).*

Henry concluded that the amount of gas that will dissolve into a liquid at a given temperature is almost directly proportional to the partial pressure of that gas. There are at least two factors that will affect gas solubility in liquids – pressure and temperature. As a diver descends more nitrogen is absorbed and as the diver ascends nitrogen must come out of suspension. This effect creates a potential problem for divers in the form of decompression sickness.

As the diver ascends, ambient pressure on his body decreases. Because the diver has absorbed nitrogen throughout the dive, he will eventually reach a depth where his body's tissue pressure is greater than the ambient pressure and his supersaturated tissues are holding more dissolved nitrogen than the ambient pressure will permit them to hold. The dissolved nitrogen must now come out of solution.

It is important to note that not all nitrogen bubbles cause DCS. *Silent bubbles* are small bubbles that are released from the body through normal respiration. Silent bubbles can reform into a larger bubble resulting in onset of DCS. Not all tissues will absorb or release nitrogen at the same rate. Different tissues have different *half times* — some are fast and others are slow.

Modern dive tables and dive computers are a means of controlling this critical ratio and calculating the levels of nitrogen in a diver's body- they are designed to control the size of these bubbles rather than their elimination. Failure to use tables and computers correctly, or not at all, places the diver at great risk. However, given current DCS theory, no table or computer can provide 100% protection from this form of diver malady. The diver must plan dives conservatively.

5) TREATMENT

Bubbles can form in any part of the body. DCS is an illness that is characterized by many symptoms varying in degree of severity. Nitrogen absorption and collection in the joints can produce such severe discomfort it will cause a diver to bend over in pain, hence its nickname *"the bends"*. This type of bubble formation in the joints and skin is designated *Type I DCS and constitutes approximately 75% of all cases*. If the same bubbles were to form in the spinal column or brain, paralysis could result. This type of DCS is designated *Type II*.

A. First Aid Treatment. Treatment for the bends is relatively straightforward. It starts at the dive site with the assisting divers having basic first aid knowledge. Assisting divers must:

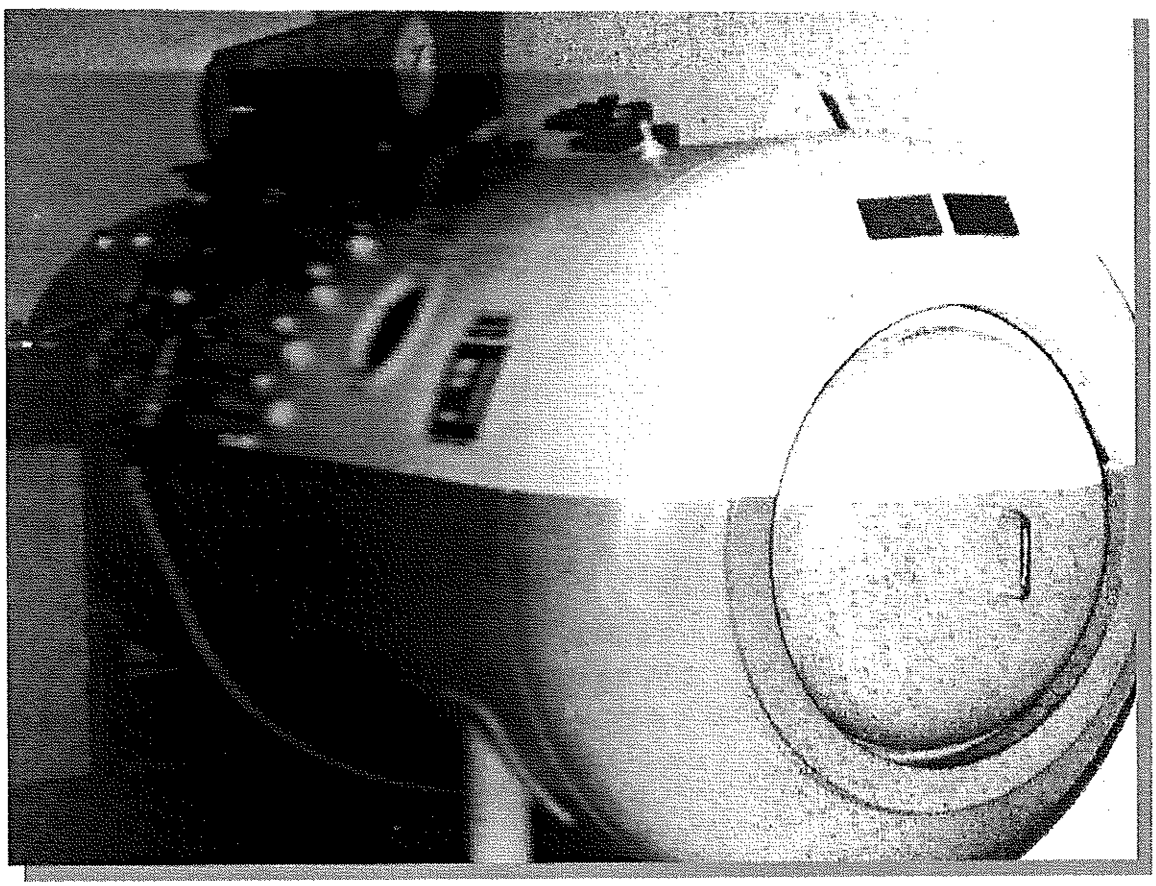
1. Recognize the signs and symptoms of DCS
2. Relay the information and call for help
   (DAN Emergency Hotline: (919) 684-8111)
3. Respond using appropriate emergency protocols
4. Administer oxygen and transport the victim to a recompression chamber, if medically prescribed

CPR and rescue breathing techniques are skills all divers should possess– if the diver is not breathing, nothing else takes a higher priority. Administering oxygen will help the diver to recover more quickly by flushing out residual nitrogen faster from the body.

B. Advanced Treatment – Medical facilities with recompression chambers are located throughout North America and the Caribbean. At such facilities, doctors and technicians assess the victim to determine the type of treatment which should be used. There is no medication that will reduce the symptoms of DCS. The only appropriate treatment is a return to pressure in a controlled environment — a recompression chamber.

Treatment starts with pressure increased within a recompression chamber subjecting the victim to a depth equal to approximately 2.8 atmospheres or sixty feet (60 ft) of seawater, depending on the treatment table prescribed by a hyperbaric physician.

This reduces the size of the nitrogen bubbles within the tissues permitting them to offgas at an acceptable rate and is usually combined with alternating breathing pure oxygen at depth and "air breaks". It is not uncommon for the treatment to be repeated if the symptoms do not resolve after one chamber treatment. In some cases if the symptoms fully resolve, the diver may return to normal diving activities.



Typical Recompression Chamber used for Treatment of DCS

6) CONTRIBUTING FACTORS

As mentioned earlier, DCS may be the result of many different factors. Scientists are studying this form of diver illness and new discoveries are regularly made. Divers usually associate DCS with rapid ascents, extended time at depth, heavy workloads and dehydration, but there are many other known causes. Type I and Type II forms of DCS can develop at the same time, placing divers in a life-threatening situation. Some researchers consider Type I simply to be an undeveloped form of Type II.

To better understand the contributing factors, it is necessary to recognize the signs and symptoms most commonly associated with DCS:

A. Numbness- Loss of skin sensation to touch, DCS affecting the muscle and skin tissue
B. Paralysis- more severe form of DCS usually relating to Cerebral DCS
C. Vertigo and dizziness- reduced sense of balance and loss of coordination
D. Tingling- A "pins and needles" feeling. Noticed as one of the first symptoms, usually in the hands or feet and legs and back of neck
E. Weakness and fatigue- Blood flow lacking oxygen causes a depletion in body energy levels
F. Altered mental state- headaches, nausea, anger, drowsiness, a desire to sleep and confusion
G. Dexterity- Coordination of otherwise simple movements is reduced
H. Blurred vision and discoloration- Disrupted blood flow to the brain
I. Rashes- Blotches appear on the skin, usually associated with tingling

More severe symptoms will begin to show as impaired lung capacity or immediate unconsciousness. Bubble formation impeding the flow of blood to the lungs may cause difficulties in breathing also known as *'the chokes"*. This may begin as simple difficulty breathing and worsen to a faster breathing rate finally resulting in a circulatory collapse. This condition is potentially life threatening if recompression treatment is delayed.

The diver may have blood in their sputum indicating a lung overexpansion injury. Treatment is the same as DCS, but this symptom may also be a result of the breakdown and blockage of the gas exchange within the diver's lung caused by expanding bubbles tearing the alveoli pockets. Another very dangerous form of barotrauma is *Arterial Gas Embolism* which is a major blockage of blood flow to the brain.

Factors predisposing divers to decompression sickness are varied. While one diver may experience symptoms, another may go symptom-free even after doing the same dive. Researchers formulating dive tables for computer and hard copy formats base their models on a small segment of the diving population. Factors that predispose a diver to DCS are generally not known from one individual to the next and therefore cannot be taken into account with any certainty. For this reason no dive table or computer can assure the diver of absolute safety. It is in the interest of the diver to plan their dives as conservatively as possible and accept the risks associated with more advanced forms of diving.

The following are a list of factors believed to contribute to the onset of DCS:

A. Denial. More of an ego concern or a sense of feeling weak among peers, divers deny that they are feeling any symptoms of DCS. Treatment is not provided and the condition worsens.
B. Fat tissue. Fat is a slow tissue capable of holding high amounts of nitrogen. Divers who have a higher percentage of body fat may be at greater risk.
C. Age. As we get older, the circulatory and respiratory systems work less efficiently, interfering with the exchange of gases.
D. Dehydration. Dive tables and computer algorithms are formulated on the basis of normal metabolic circulation. Dehydration reduces the quantity of blood available for transport of nitrogen through gas exchange. Consumption of diuretic substances like coffee, alcoholic drinks and even the dry filtered air breathed by scuba divers combined with profuse perspiration tend to predispose the diver to DCS.
E. Illness and injury. Any condition that is known to affect normal circulation and potentially affect nitrogen elimination from the body may contribute to the onset of DCS. Aside from problems with equalizing, diving with a cold impairs the body's ability to offgas nitrogen. The body will favor an injured area and increase blood flow to that area resulting in a concentration of nitrogen.
F. Cold. Cold water or environmental conditions and insufficient environmental protection changes normal circulation as the body takes measures to reduce heat loss.
G. Exertion. The diver should consider the activity of diving to be their exercise for the day. This is especially true for divers conducting dives that call for planned decompression ascents. Heavy exertion causes the body to accelerate nitrogen absorption loading body tissue and reduce nitrogen offgassing half times. As the diver's body returns to normal circulation, there is an accelerated elimination of nitrogen.

H. Carbon dioxide. Elevated carbon dioxide levels impairs the body from a correct gas exchange process. This usually is a result of improper breathing techniques, skip breathing, breath holding and heavy breathing from exertion.

I. Altitude and flying after diving. Although dive computers may have the ability to preset or sense atmospheric pressure, dive tables are established at sea level. The reduced atmospheric pressure of altitude increases the pressure gradient between ambient pressure and body tissues and may result in large bubble formation. It is best to wait 24 hours before flying after diving. Use of special tables and procedures are required for diving at altitudes greater than 1,000 feet above sea level.

7) DECOMPRESSION SICKNESS – TYPES

Signs and symptoms of DCS may manifest up to 48 hours following a dive. Physiologists have grouped DCS into Type I and Type II classifications. Typically Type I is skin and pain-only manifestations. Type II presents more significant and possibly life-threatening symptoms.

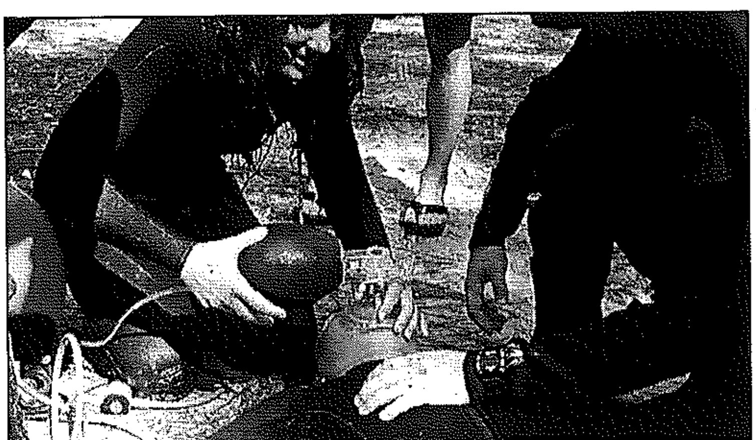
A. Subcutaneous DCS. Bubbles forming in skin capillaries characterized by red rash patches, usually on the shoulders and upper chest.

B. Joint and limb involvement. Bubbles collecting at joints, knees, knuckles, ankles and neck. This accounts for approximately 75% of all DCS cases.

C. Neurological DCS. The most serious form of DCS affecting the central nervous system causing failure in muscle movement and life support functions such as breathing and heart function.

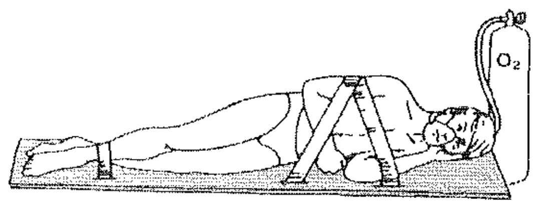
D. Pulmonary DCS. Fortunately this form of DCS is very rare. It manifests in the lung capillaries causing the most immediate threat to life.

E. Other. Less common forms of DCS may range from dizziness to heart attack.



8) FIVE MINUTES THAT MAY SAVE A LIFE

The occurrence of DCS is not common considering the number of divers active in the sport. The treatment for DCS starts at the dive site. A diver suspected of having DCS should be given oxygen and placed on the left side with their head supported. In addition to the benefits of keeping the diver's airway open, research has shown that it is the left lung which is smaller in size and more susceptible to barotrauma injuries. A non-breathing diver with an undetectable pulse diver should be level on a firm, flat surface and provided rescue breathing and CPR. Training in *Automated External Defibrillation (AED)* has shown to greatly enhance the survival rate of a victim and divers should seek this type of training. The *Trendelenburg position* which elevates the feet above the victim's head should not be used for a diver suspected of suffering from DCS- increased blood flow to the brain creates further complications in DCS victims.



9) FIVE MINUTE NEUROLOGICAL EXAM

NOTE: SHOULD THE SUPPLY OF OXYGEN BECOME DEPLETED AND AN ENRICHED AIR SOURCE IS AVAILABLE, IT IS SUGGESTED THAT A BREATHING DIVER CONTINUE TO BREATH THE ENRICHED AIR SOURCE UNTIL MEDICAL ASSISTANCE ARRIVES.

The *FIVE MINUTE NEUROLOGICAL EXAM* is an efficient manner to check for signs of DCS in a diver. Be prepared at any time to administer oxygen and CPR/AED procedures if it becomes obvious that the diver is in trouble. Signs and symptoms of DCS may appear as little as ten minutes following a dive or up to 48 hours later. If a diver appears symptom free after 24 to 48 hours following the dive, there is little likelihood of DCS. However, be aware of the denial factor and seek medical advice.

Orientation. Ask the diver his name and birthdate and other questions that should be easily recalled. These questions may reveal confusion.

Eyes. Have the diver keep his head still and hold your hand about 10-15 inches away from his face. Move your fingers in a side to side, up and down motion, noting the tracking ability of the diver's eyes. The eyes should track smoothly and pupils should be of equal size and respond to light.

Forehead. Have the diver close his eyes and observe balance. Have the diver gently touch his face and make note of any numbness. Note whether the diver has even movement of his mouth and eyebrows.

Face. Keeping the eyes closed, ask the diver to whistle and note any unusual differences in the lips (drooping). Have the diver smile, clench his teeth and note if there is equal tension on the jaw muscles. Determine if the diver slurs his speech.

Gag Reflex. Can the diver swallow with normal movement of the "Adam's Apple"?

Tongue. Can the diver stick his tongue out and move it without abnormal movement?

Strength. Place your hands on the diver's shoulders and ask if he can shrug them up while applying a downward force. Repeat a similar test of the diver's arm and wrist strength. Push and pull the diver's arm against resistance. Can he raise and lower his arms against resistance? Ask the diver to squeeze your finger with each hand. Test for skin sensitivity and sensation by touching the diver's arm. Similar exercises can be conducted for the diver's legs by having the diver lie down and raise and lower his legs.

Balance and Dexterity. Have the diver walk a straight line heel-to-toe. With his eyes closed, have the diver touch his nose or cross his arms. Have the diver tie a knot or some other task requiring use of their hands to check manual dexterity.

If in doubt of any of the diver's abilities or a change in normal behavior, administer first aid for DCS and transport the diver to a recompression chamber for treatment.

10) CONCLUSION

Decompression diving is likely as the Cave Diver gains experience and advances in his training. If the diver is not trained and prepared for this type of diving, the consequences may be life-threatening. It is suggested that divers at this level of training receive training in *Decompression Diving Procedures, First Aid, Oxygen Administration, CPR and Rescue Diver* through a recognized agency and instructor before undertaking advanced decompression diving. Always plan the dive using available current technology.

PLAN THE DIVE AND DIVE THE PLAN

FULL CAVE DIVER COURSE

FULL CAVE DIVER LIMITATIONS

Gas Supply. Double tanks, with a minimum volume of one hundred and forty-two (142) cubic feet of gas, are required at the Full Cave Diver level. The Full Cave Diver may use up to one-third (1/3) of available gas for cave penetration- keep in mind that there are many circumstances which justify reducing usable gas and that the Rule of Thirds is a guideline established for maximum usable penetration gas.

The Full Cave Diver must begin each dive with at least a minimum volume of 116 cubic feet or 2,000 PSI, whichever represents the larger volume.

Minimum visibility. The Full Cave Diver must begin the dive with a minimum visibility of twenty (20) feet. This distance is determined by the ability of the diver to clearly recognize and acknowledge a lighted hand signal.

Maximum depth. No dive at this level should exceed one hundred and thirty (130) feet in depth.

Limiting partial pressure of oxygen. The diver's recommended PPO2 should not exceed 1.4 ATA for the working portion of the dive and 1.6 ATA for decompression. An overview of these limits will be presented the Full Cave Diver- further mixed gas training should be undertaken by the diver. The diver is encouraged to obtain this experience through Nitrox, Advanced Nitrox and Decompression Procedures courses.

No DPV use. Use of a DPV requires specialized skills and techniques that are presented only after the diver has completed a minimum number of dives beyond Full Cave Diver. For both diver safety and conservation of the overhead environment, there is no appropriate use of a DPV by the diver at this training level.

Continuous guideline. As with previous levels of training, the Full Cave Diver must maintain a continuous guideline from open water and throughout the cave system. This includes the placement of a primary reel from open water to the main line and installation of temporary lines by the team along all jumps, gaps, circuits and traverses within the cave system.

Use of required and properly configured equipment. This subject was fully discussed in the equipment section of this text. No matter the level of overhead training, if the diver is not properly configured for a cavern or cave dive, he is diving as an open water diver and should never enter the overhead environment.

Guidelines of Accident Analysis

(For the Trained)

Previously it could be said "no trained cave diver has ever perished in a cave". This is no longer true and new guidelines of Accident Analysis have been formulated for the TRAINED cavern and cave diver. Through analysis of cavern and cave diving accidents, it has been determined that one or more of the following three (3) primary causes contribute to fatalities among the trained cavern or cave diver.

1) Depth- Failure to observe the depth limitations of training.

2) Guideline- Failure to maintain a continuous guideline from open water and throughout the cave system. Complacency in observing guideline protocol may result in diver fatality.

3) Gas- Always reserve *a minimum* 2/3rds of your gas for exit– never violate the Rule of Thirds. Cheating or "stretching" gas puts the diver and entire team in peril. At all levels of overhead training it is essential that divers refine gas matching protocol by taking into account dissimilar cylinder volumes and breathing rates.

Additional Points

- Dive with a properly trained and equipped diving partner and maintain dive team continuity throughout the dive.
- Increase the complexity of your dives slowly as your experience increases.
- Increase your knowledge of a cave system slowly and methodically as your experience and familiarity with that system increases.

When diving with team members of differing levels of training, always dive to the level of the least experienced team member. If you are the least experienced diver in the team, it is your responsibility to insist upon remaining within your level of training and comfort.

EQUIPMENT

It is recommended that students obtain and utilize their own equipment at this level of training. Borrowed or rented equipment only serves to increase task loading and may reduce the student's ability to complete this course.

All equipment required in the Introduction to Cave Diving course in addition to:

⇒ Twin diving cylinders with dual-valve manifold of the appropriate size for the dives undertaken.

⇒ Jump/gap reels required for planned dives.

⇒ It is recommended that each diver provide an in-water decompression cylinder properly identified on all dives. The cylinder should be clearly marked, equipped with a proper regulator and contain 1.5 times the gas expected to be utilized.

COMPLEX NAVIGATION

Terminology and Procedures

Complex navigation requires the use of techniques and protocols for maintaining a continuous guideline from open water. Since jumps and gaps are integral elements of a successful traverse or circuit, divers must be proficient with jump and gap procedures before moving on to more complex navigation.

It is strongly advised that different teams **avoid** using the same reels during a cave dive, especially for jumps, gaps, traverses and circuits. Let's review jumps and gaps before describing more complex navigation.

Jump

A jump connects the line from the guideline of one passage to a separate guideline of another passage using a jump reel. When a jump creates a "T" from the mid section of a guideline, directional information for the team's exit must be installed.

Gap

A gap is the connecting of one line (at the end of one passage) to the line in the continuing passage that is typically across an open water sink. You connect these two lines using a gap reel.

"T's"

In Florida "T's" have been avoided in the most popular parts of the cave, with hopes to minimize divers confusion with intersections. In Mexico "T's" are more popularly used, with one reason being the complexity of their systems. Divers are strongly encouraged to consult local guides/instructors for information regarding safe navigation of these systems.

Outline of procedures for simple and complex traverses:

- ◊ Gather all information available about the dive you are planning.
- ◊ Select the proper equipment and qualified team mates.
- ◊ The team plans out all details of the dive with contingences for all conceivable "what ifs".
- ◊ Each team member understands his position and responsibilities for the dive.
- ◊ Emphasis should always be on safety and to take no short cuts that may compromise your team's safety. The team should always be conservative in planning gas needs and usages.
- ◊ Failure to maintain a continuous guideline from open water is in violation of NACD policy, and a large contributing factor in accidents in the accident analysis data.

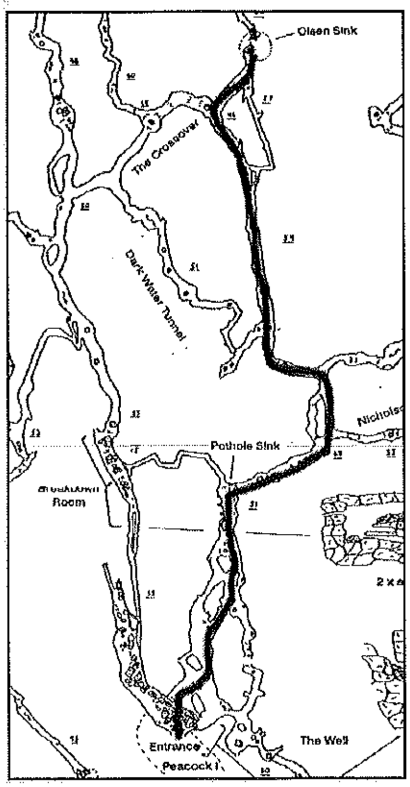
A ***traverse*** occurs when divers enter one location and exit another and may be simple or complex. A ***simple traverse*** describes a single passageway between two entry points with one continuous permanent guideline along the route of travel that can be completed in one dive. A ***complex traverse*** describes multiple passageways between entry points with multiple permanent guidelines along the route of travel.

Simple Traverse

Here is an example of the steps during a simple traverse:

The team leader will establish a primary tie off in open water at a point that will allow a direct ascent to the surface. The team leader will reference the team and continue into the cavern, establish a secondary tie off just inside the cavern. After the secondary tie off is complete, the leader references the team, the team validates secondary tie off and the team continues to the beginning of the permanent guideline in the cave. The team leader will tie the primary reel line to the permanent guideline, all team members should reference the primary reel before continuing into the cave.

The team will enter into a cave passage from a spring and travel along a single passage on one continuous guideline until it ends at a sink. The team will tie a line from a reel onto the end of the permanent guideline, and reel out into open-water, do a safety stop and surface. This dive should be completed within the rule of thirds gas management, and a continuous guideline to open water maintained. If the traverse can't be accomplished using the thirds air management rules, or along a single passage, more complex procedures will need to be used.



Sample simple traverse in the Peacock Springs cave system.

The path indicated by the thick black line is from the entrance to Peacock I at the bottom of the map all the way to Olsen Sink at the top right. Note that depending on the mainline configuration within Peacock this is either a simple traverse (mainline is continuous from Peacock I through Olsen) or two simple traverses connected with a gap at Pothole Sink. Be sure to validate any current mainline configurations with either your instructor or other experts for each cave. Also note that the dive is an upstream dive. A primary reel should be used at Peacock I to connect to the mainline, possibly a gap needed over Pothole and definitely use a reel when surfacing at Olsen. This dive can typically be accomplished within the 1/3rd rule.

Complex Traverse

A traverse becomes **complex** when the dive involves **multiple** passageways and / or multiple dives to complete. The following is an example of a typical complex traverse dive:

The team should plan the first dive into the spring entrance. The team leader will establish a primary tie off in open water at a point that will allow an ascent to the surface. The team leader will reference the team and continue into the cavern, establishing a secondary tie off just inside the cavern. After the secondary tie off is complete, the leader references the team, the team validates secondary tie off and continues to the beginning of the permanent guideline in the cave. The team leader will tie the primary reel line to the permanent guideline and all team members should reference the primary reel before continuing into the cave (typically done with a light "OK" by all on the tie-in). The team will travel along their planned route until a team member has used his usable gas supply and calls the dive, or the dive is called for another reason. The team will note the bottom time and each member will note their personal gas usage. One member of the team (designated in advance) will place a non-directional reference marker on the guideline at this point, (this marker will have the recognizable name or initials of one of the team members) all members of the team will validate it (OK with lights), and the team will start their exit back to their original entrance. The team will validate all reels installed for this dive during their exit, and leave them in place. (The team is making sure the reels are secure, not interfering with cave passage for other divers, and that the line is tight). Each team member should validate time and the amount of gas used to return to open water from the most distant point of their dive. This is vital information needed for the second dive of this traverse.

A second dive can now be planned from the destination site of the first dive, which is typically the siphon passage of the sink. The team will have to adjust gas management plans for diving into a siphon. From information gathered from the first dive the team has good information on swim and gas consumption rates for more accurate dive planning.

The team will follow the same protocol as they did on the previous dive as they enter into the siphon side of the sink. The team establishes a continuous line from open water to the permanent guideline of the cave. The team will travel a planned route to locate the marker that was installed on the previous dive. ***If the team locates the team's marker, and all team members validate the marker, their gas supply, and bottom time, and all team members agree, the marker can be removed and the team can complete the traverse to the spring***. When the team located the marker on the second dive, by doing so, the team validated that they had at least two thirds (or more) of their gas supply remaining, and by doing so, the team knew that they had a continuous guideline to open water.

Simple Circuit

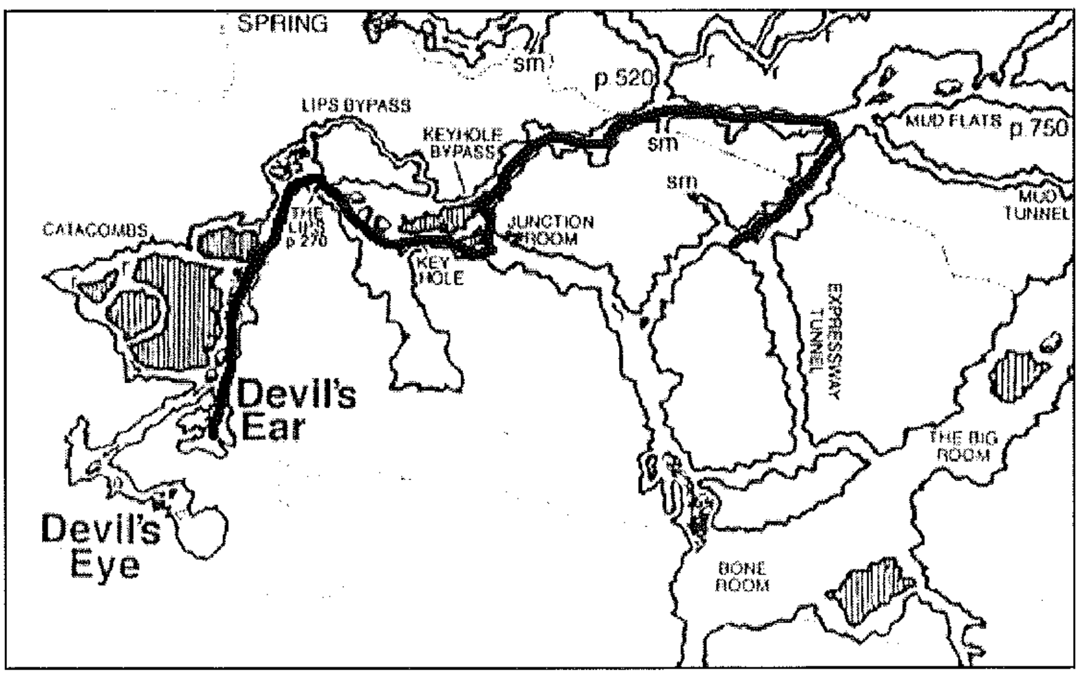
A ***circuit*** dive is when the entrance and exit site is the same, with a portion of the dive requiring one way travel. A ***simple circuit*** is when the dive can be completed in one dive using the rules of thirds. Another dive will be required in ***reverse*** order to pull reels left from the previous dive.

Any additional dives, passageways and reels will create more complexity in the dive planning.

Complex Circuit

A ***complex circuit*** is when it takes two or more dives to complete a circuit. Complex circuits may require additional reels, dives or gas to complete.

A circuit is best explained with a cave map. A popular complex circuit is the Ginnie Springs expressway circuit, which can typically be accomplished with two dives. A third dive may be necessary to retrieve the jump reels left in the cave from the second dive.



Dive 1: Primary to mainline from Devil's ear; take first jump to right after Hill 400 jump on left; jump to expressway; reach thirds; mark and exit, leaving the reels in place for dive 2. This dive requires 3 reels (one primary, two jump) for the team.

Expressway Complex Circuit

Dive 1:

The team starts up the permanent guideline until they arrive at the third set of double markers. The reel person installs the first jump reel (with proper directional information for exit) and secures it to the line in the expressway tunnel. After the reel person secures the jump reel to the shortcut line to the expressway, he will OK the team members and they will follow the jump line over. Each team member will verify the jump reel is in place and secure, back-reference the junction, and then the team proceeds down the shortcut tunnel in the order they previously decided upon. Usually the team can reach the second jump from the shortcut to the expressway tunnel. They take that jump (using the same protocol mentioned for the first jump) and head **right** on this line, following the direction of the double markers, towards the bone tunnel. They travel that line until a team member has used his usable gas supply for the dive, and the dive is called (the dive may also be called prior, for a number of other reasons). At the time the dive is called the team will note the bottom time, and each member will note their personal gas usage. One member of the team (designated in advance) will place a non-directional reference marker on the guideline at this point, (this marker will have the recognizable name or initials of one of the team members) all members of the team will validate it, and the team will start their exit back to their original entrance. Each team member will validate all reels installed for this dive during their exit, and **leave them in place**. (The team is making sure the line is tight, reels are secure, and not interfering with cave passage for other divers). Each team member will validate time and the amount of gas used to return to the exit from the most distant point of their dive. This is vital information needed for the second dive of this circuit.

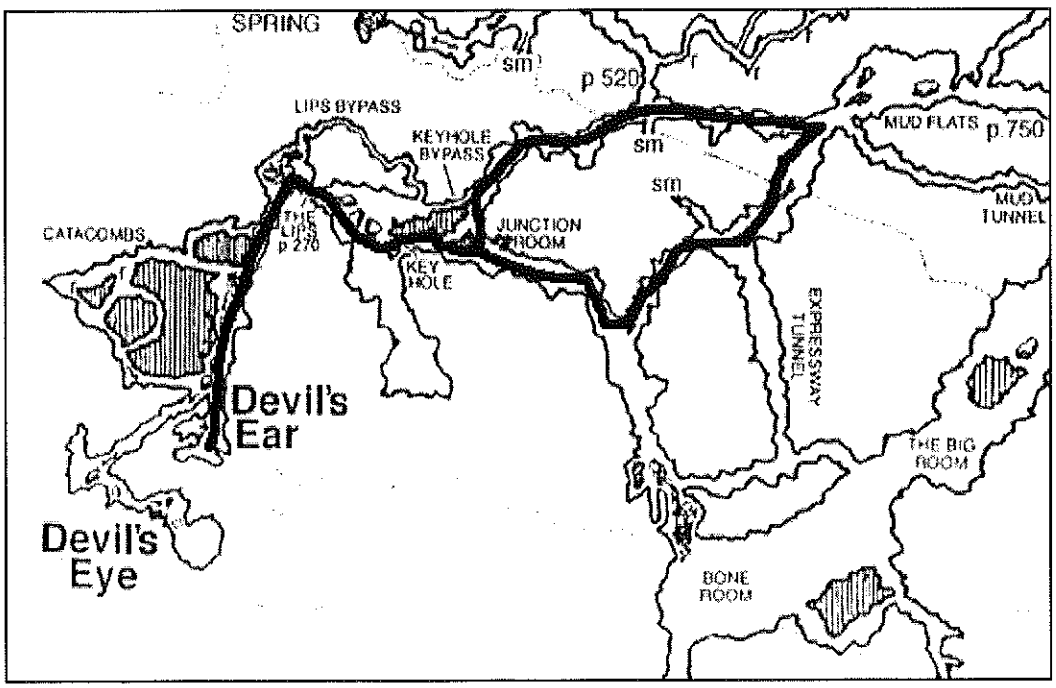
2nd Dive:

From information gathered from the first dive, the team has good information on swim and gas consumption rates for more accurate dive planning. Be sure to, of course, top off your tanks prior to the dive to ensure you have the same volume as you did for the first dive.

The team will follow the same protocol as they did on the previous dive as they enter the cave. The team will travel a planned route to locate the non-directional marker that was installed on the previous dive and complete the circuit coming from the **other side** of the circuit. This time the team takes the jump at the first set of double markers onto the bone tunnel line; the reel person makes the jump and OK's the team members after the line is securely installed. The team proceeds to the new passageway; each team member will verify the jump reel is in place and secure, back-reference the junction, and then the team proceeds down the bone tunnel in the order they previously decided upon.

Expressway Complex Circuit — continued

When the team arrives at the location of the next jump (the first set of double markers in the bone tunnel), the reel person ties into the guideline that the team has been following (leaving directional information on that line), and connects the jump reel to the line of the next passage. After the reel person secures the jump reel to the other line, he will OK the team members and they will follow the jump line over to the line of the next passage. Each team member will verify the jump reel is in place and secure, back-reference the junction, and then the team proceeds down that passageway in the order they previously decided upon. As the team travels along this line, they will find the non-directional marker installed on the previous dive. At this point, all team members validate the marker, their gas supply, and bottom time, and all team members will agree whether or not to complete the circuit. If onward is chosen the marker can be removed and the team can continue on this line and complete the circuit. When the team locates the marker on the second dive they validate that they have at least two thirds of their gas supply remaining, and by doing so, the team knows that they had a continuous guideline to open water ahead of them so they can continue the circuit and pull out the jump reels that were installed on the previous dive. It will be the reel person's responsibility to make sure that all team members are always on the exit side of the reels as the reels are being removed. A continuous guideline to open water was always maintained in either direction, and conservative gas management rules were followed.



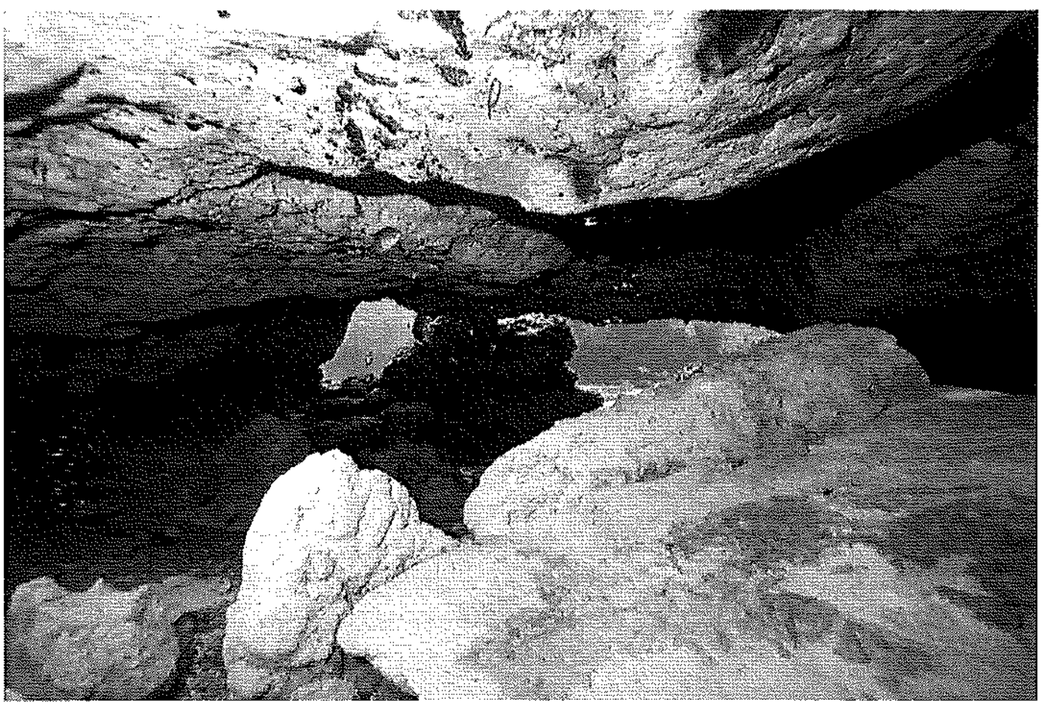
Dive 2: Completing the circuit: mainline to bone tunnel; bone tunnel to expressway until marker reached; continue on other side of circuit, pulling dive # 1 reels. Need 3 reels (primary and two jumps) for this dive.

Controversial Topics

Often divers will choose to execute a ***blind traverse*, *blind circuit*, *visual jump*, *visual gap*, *"trust me" dive or solo dive*.** While the description of these techniques appear below you should talk with your instructor about these controversial topics to fully understand the risks and implications of each. These techniques will **not be taught** as a part of any NACD course but you may come across these techniques in your diving. These practices have lead to diver fatalities.

◊ Blind traverse or circuit- A diver who follows a one-way route of travel without verification of distance, time and gas volume requirements in order to complete a traverse or circuit has performed a blind traverse or blind circuit. This practice should be discouraged as it may result in a violation of the Rule of Thirds. Additionally, the diver will travel passage unfamiliar to him and there exists the likelihood of diminished ability to effectively prevent or handle emergencies. There is no substitute for the time and effort required to properly establish a traverse or circuit.

◊ Visual gap or jump- occurs when a diver elects not to set a line connecting two lines, but simply relies on visual reference to complete a gap or jump. The evaluation process in electing to perform a visual gap or jump is very much the same as proceeding into the cave without setting a primary guideline from open water to the main line. In either event, there is a failure to maintain a continuous guideline back to the diver's unlimited air supply and this decision should be made only after very careful consideration of a number of factors.



◊ Trust me dives- in which a diver leads another diver to an area unknown to the second diver with the second diver trusting the first diver for navigation, line awareness, etc. A diver should never relinquish personal responsibility for the management of the tenets of accident analysis (guideline, gas, depth). The team leader's years of cave dive experience, familiarity with the system, apparent physical health and the personal relationship between the two divers are all factors to be considered before undertaking such a dive. Additionally, it is imperative that all customary practices be strictly adhered to and that a definite and comprehensive dive plan, with appropriate contingency and emergency considerations, is followed.

◊ Solo diving- The NACD does not condone or disapprove of solo diving and believes that individuals have the right to make decisions to dive within their limitations in the manner they choose so long as other divers and the environment is not damaged. The NACD believes there are many ways to dive safely and in the freedom of each diver to make decisions regarding his own well-being.

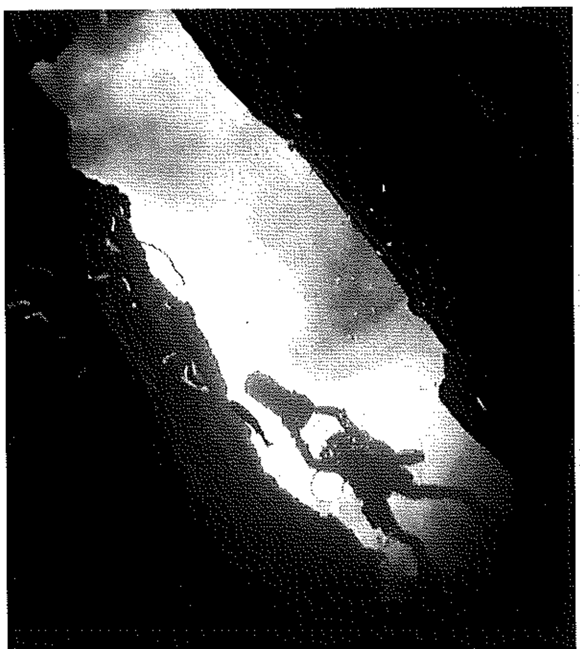
Expressway Complex Circuit—comments

◊ **Cleanup dive** — in the Ginnie expressway example the circuit was completed in just two dives. To preserve a continuous guideline to open water, however, the two reels that were deployed on the second dive (mainline to bone tunnel to expressway) **had to be left in place**, in case your team decided to bail on completing the circuit. A third dive is required to pull these reels. Some teams may have enough gas to safely retrieve these two reels at the end of dive # 2 when they reach the junction room during the exit.

◊ **Proper use of maps and pre-dive planning**—planning a cave dive should always involve some time with a map, especially for complex traverses and circuits. All members of the team should know exactly what is expected of them at each point in the dive. This includes small details such as who is supposed to run the reels. Some teams prefer the first diver to do all of the "reel work", including running the primary, laying the jump lines and retrieving them all on exit. This keeps the dive order the same throughout the dive. Others prefer to "hand off" the task in a round-robin fashion, to spread the load across the entire time (e.g., diver # 1 does the primary, diver # 2 puts in the first jump, etc.). Typically the diver who places a reel would also be the one to retrieve that same reel on exit. This can be an enjoyable way to share the load and it also makes all team members keep proficient with their reel skills and heightens awareness, since during the dive you go from "on deck" to "at bat". Making sure that the dive order is preserved is more challenging, though, as you may decide to just reform the original dive order after each reel deployment or, as you get more comfortable, always place the person who is going to place the next reel in the front, in a "leap frog" fashion. Either way, it is **vital** that **all** team members know exactly their tasks, team order (whether static or dynamic) and required equipment for the dive.

◊ **Strong dive awareness and team coordination** — even the best cave maps are no substitute for actually being in the passageways. Cave passages can look different on the way in than they look on the way out, which can occasionally cause consternation if you aren't paying attention. If you add in the extra duties of creating circuits the requirement for coordination and correctness grows stronger. The Ginnie expressway circuit is full of excellent examples where alertness and keeping an inner eye on the cave map is crucial. At the end of our dive # 1 the team jumped from the expressway line to the line leading to the bone tunnel. Your final jump will actually create a temporary "T" in the line, where if you remember the map incorrectly, you could inadvertently turn left and head towards the big room (consult the map), whereas if you choose to turn right you will head (correctly) towards the bone tunnel. Students in cave classes have occasionally made this mental error and started heading the wrong way before being caught by another student or the instructor. In fact, some of the most interesting and lasting "cave lessons" can occur at these points where the team learns how to solve "underwater arguments" at key critical junctions.

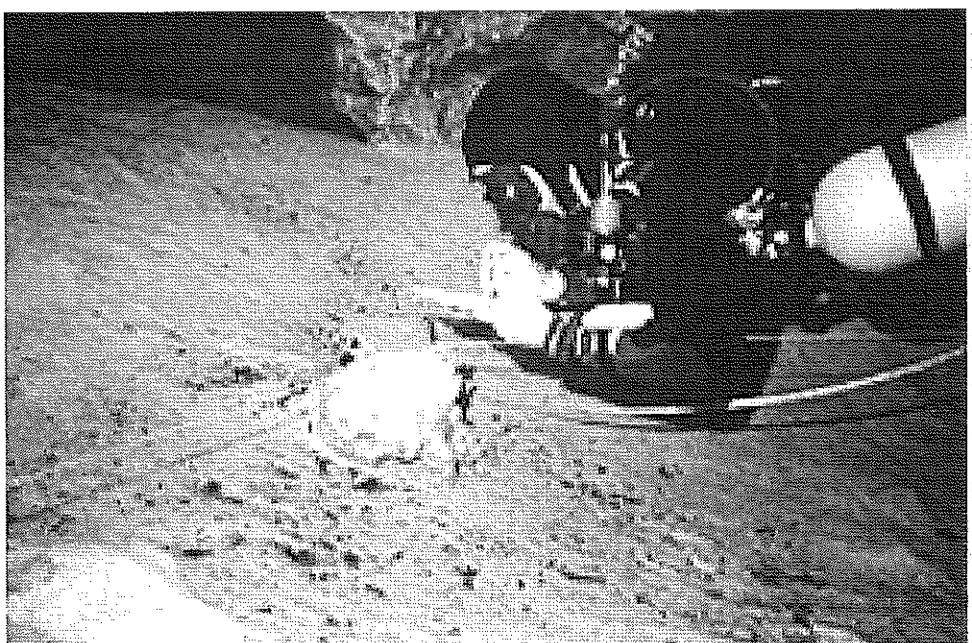
CAVE DIVER SPECIALTIES
GAS MANAGEMENT
ADVANCED DIVE PLANNING
CAVE MAPS
Training Tips reprints
NACD Safety Brochure



Specialty Cave Diver - Survey & Cartography

The NACD Survey and Cartography Course is designed to provide the experienced Full Cave Diver the ability to increase their education, knowledge, and skills regarding the process of surveying underwater caves. The course includes, but is not limited to topics such as — understanding maps and their purposes, the survey process, safety while surveying, post diving data recording, errors and how to avoid them, drawing line plots, and the cartography process.

Documentation of underwater caves is one of the very strengths of the cave diving community's value to local and regional government, and this must be perpetuated. Data collected from underwater caves, can and does assist decisions makers in reaching intelligent choices regarding groundwater concerns. Additionally, the methods of surveying underwater caves are a devotion to be passed on.



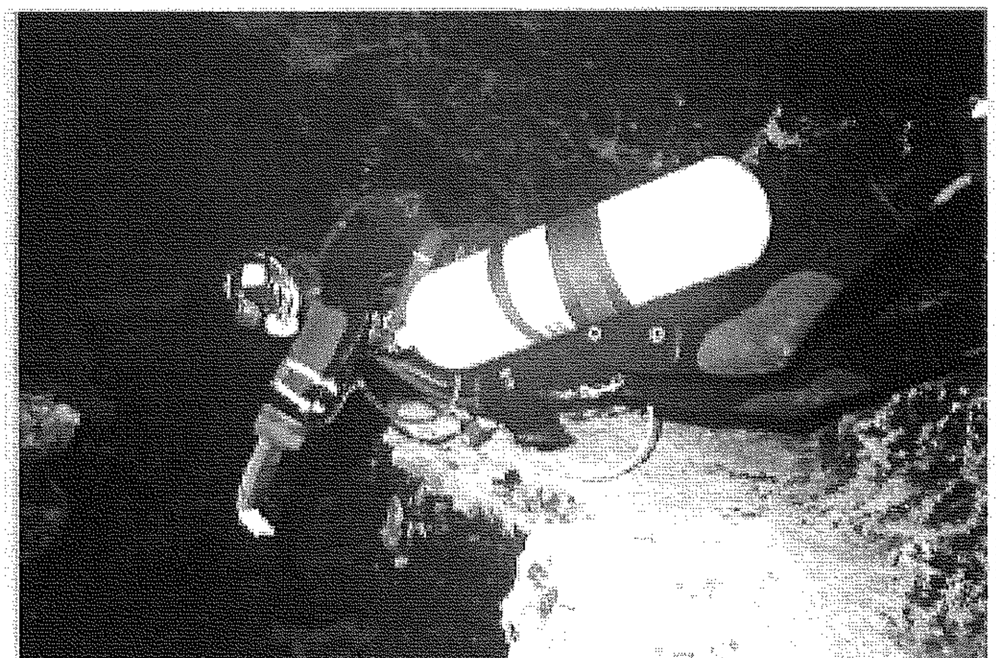
Specialty Cave Diver - Stage Diving

The NACD stage diving course is designed to provide the experienced Full Cave Diver, the ability to increase their education, knowledge, and skills in the use of additional cylinders to extend cave penetration and bottom time. Course topics include, but are not limited to, configuring equipment to handle stage cylinders, how to properly deploy stages and minimizing cave impact, dive planning with multiple gas sources and how stage cylinders affect emergency procedures.

Specialty Cave Diver - Sidemount

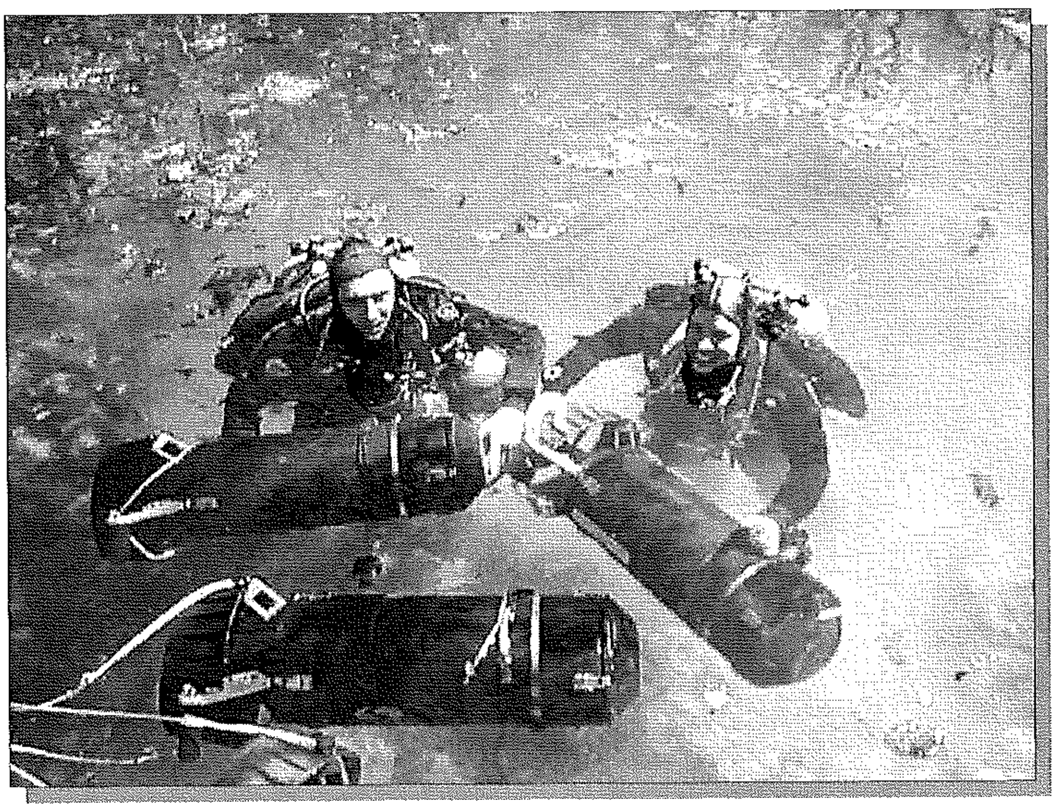
The NACD Sidemount Course is designed to provide the experienced Full Cave Diver the ability to increase their education, knowledge, and skills regarding different gear configurations utilized in the underwater cave environment. The use of side mounted tanks by the cave diver has been steadily gaining popularity in North America, due to a variety of reasons — cylinder transportation benefits when diving more remote caves, breathing supplies that are totally independent of one another — and represents a different 'style' of cave diving.

The sidemount configuration also allows the cave diver to access areas of the cave that were previously inaccessible to the back mounted cave diver. This potentially opens up more underwater cave passage to explore, for the cave diver that has the ability and desire to safely modify their gear configuration, and their mindset for diving in small passages and/or restrictions. Scuba cylinders are connected to the diver's sides by a variety of methods, which include special clips, belts, harnesses, bungees or inner tubes. Furthermore, the ability to quickly unclip and remove a cylinder or cylinders to pass a restriction is a desirable function of this type of configuration.



Specialty Cave Diver - DPV

The NACD DPV (Diver Propulsion Vehicle) Course is designed to provide the experienced Full Cave Diver the ability to learn how to safely use a DPV (aka "scooter") in the overhead environment. Topics include, but are not limited to: types and styles of DPVs, how to properly maintain and use DPVs, appropriate techniques for DPV use in the cave environment, emergency procedures involving the DPV (towing, air share, etc.) and the need for increased cave awareness to minimize DPV impact on the environment.



Gas Management/Dissimilar Breathing Rates (US)

As the safety of open water and the surface is left further behind, the Cave Diver must become more accurate in gas matching with team members.

The purpose of gas matching is to help assure that all team members have a sufficient gas supply to safely exit the cave in emergency circumstances. The ultimate goal of every cave dive is to arrive safely at the surface at the dive's end. It is of prime importance for cave divers to fully and adequately understand both the need and means of reaching a safe gas management plan for each dive. Equally important is each diver actually implementing this plan. The time to consider the need for such a plan is not after an emergency has arisen, but in anticipation and preparation for it.

In order to determine an accurate Respiratory Minute Volume (RMV), the diver should execute a series of dives over a period of time– a single dive will not be an accurate measure of RMV rate. Additionally, the diver should determine RMV rate at rest, under moderate work load and under heavy work load. By doing so the diver should have adequate information to formulate an effective gas management plan in a variety of conditions.

RMV rate is determined as follows:

(Volume ÷ Bottom time) ÷ ATA = RMV rate.

Please note that the result obtained by this method will provide the diver with a gas consumption rate **at surface** which must then be depth adjusted.

An effective manner in which to arrive at a working RMV rate is to swim an area of known average depth over a measured distance and time. The diver should note time and pressure at the beginning and end of the swim. Using the pressure difference and adjusting for depth calculates the diver's Surface Air Consumption (SAC) rate. Convert the SAC rate (units of pressure) to units of volume to determine a working RMV rate. This method may also be used to arrive at both moderate and resting RMV rates.

EXAMPLE:

Diver A, using double LP 95s, enters a passage to an average depth of 95 feet with 2600 psi of gas at 12 minutes into the dive. Maintaining this average depth, Diver A returns to his measuring point with 2200 psi of gas at 22 minutes into the dive. What is Diver A's RMV rate?

Volume = gas expended (in 100s of psi) X baseline of tanks or:

4 X 7.2 = 28.8 cubic feet of gas expended.

Recall that atmospheric pressure is 14.7 pounds of pressure per square inch of surface area and accumulates in water at the rate of one atmosphere for each 33 feet of saltwater (fsw) and every 34 feet of freshwater (ffw). Since cave diving predominantly occurs in freshwater, that will be the unit of measurement used in our calculations. The term "Atmosphere Absolute" (ATA) refers to all pressure exerted on the diver by the water surrounding the diver plus the additional one atmosphere of surface pressure and may be determined as follows:

(Depth ÷ 34) + 1 = ATA.

Using the example above, determine Diver A's RMV rate:

ATA= (95 ÷ 34) + 1 = 3.70 ATA

(Volume ÷ Bottom time) ÷ ATA = RMV rate or

(28.8 ÷ 10) ÷ 3.79 ATA = .759 RMV rate (.76).

Diver A consumes .76 cubic feet of gas per minute at the surface. Using this information, Diver A now has a benchmark to calculate gas consumption.

EXAMPLE:

If Diver A, using double LP 95s filled to 2600 psi, plans a dive to an average depth of 70 ffw, what volume of usable gas is available to him and what is his maximum dive time?

8 x 7.2 = 57.6 cubic feet of usable gas (1/3rd is 800 PSI)

Diver A must adjust his RMV rate to depth:

(70 ÷ 34) + 1 = 3.05 ATA

.76 X 3.05 = 2.32 cubic feet of gas per minute as Diver A's adjusted RMV rate

57.6 usable gas ÷ 2.32 adjusted RMV rate = 24.82 minutes penetration time

It is important that each member of a dive team knows and plans for individual RMV rates– the team should match dissimilar RMV rates in order to establish a safe gas management plan for the dive.

EXAMPLE:

Diver A, using double LP 104s filled to 2600 psi and .76 RMV rate, plans a dive to an average depth of 100 ffw with Diver B, using double 95s filled to 2500 psi and a .65 RMV rate.

First, match dissimilar volumes:

Diver A- 8 X 7.8 = 62.4 cubic feet of usable gas (1/3rd is 800 psi)

Diver B– 8 X 7.2 = 57.6 cubic feet of usable gas (1/3rd is 800 psi)

Diver B's volume controls the team (smaller volume)

Diver A– 57.6 ÷ 7.8 = 7.38 X 100 = 738 (round down to 700) psi of usable gas

Diver B– 800 psi of usable gas (57.6 cubic feet)

Next, match dissimilar RMV rates:

Diver A- .76 X 3.94 (ATA at 100 ffw) = 2.99 cubic feet/minute

Diver B- .65 X 3.94 = 2.56 cubic feet/minute

Remember, usable gas for the dive for both divers is 57.6 cf based on Diver B's lower volume cylinders. To formulate a safe gas management plan, the team need only determine available time at depth:

Diver A– 57.6 ÷ 2.99 RMV rate = 19.3 minutes

Diver B– 57.6 ÷ 2.56 RMV rate = 22.5 minutes

Diver A, because of his higher RMV rate, is the controlling diver. This team is permitted a maximum penetration time of 19 minutes. Of course the actual turn point will occur whenever either diver hits their third, regardless of the time. This is useful, though, for being able to anticipate for both divers expected penetration time.

A diver's RMV rate may vary from day to day as a result of personal psychological and physiological factors. As the diver's trim, propulsion, buoyancy control and awareness levels develop and refine, his RMV rate should lower. Including RMV rate calculations as a part of your dive planning is a method of providing the diver with an indication of improving technique and awareness.

Advanced Dive Planning (US)

Along with RMV rate, the diver should develop an awareness of his personal travel rate. If both RMV and travel rates are known, the diver may safely and accurately plan dives along a specific course or to a known point within the cave system.

Travel rates in low, moderate and high flow systems should be measured over a series of dives and verified periodically.

EXAMPLE:

Diver A, at a normal swim rate, travels a distance of 600 feet in 12 minutes yielding a foot per minute travel rate of 50 feet.

Diver A, using double LP 104s filled to 2600 psi, has a RMV rate of .56 and an average swim rate of 50 feet/minute. What is his maximum point of penetration at an average depth of 90 ffw?

Usable volume- 7.8 X 8 = 62.4 cubic feet (1/3rd is 800 psi)

Adjusted RMV rate- .56 X 3.64 (ATA @ 90 ffw) = 2.03 cubic feet/minute

Maximum time– 62.4 cf ÷ 2.03 cf/min = 30 minutes

Maximum penetration distance– 30 mins X 50 ft/min = 1,500 feet

NOTE: All calculations in the above example employ the use of "maximums". There are many occasions the diver must use a more conservative plan.

EXAMPLE:

Diver A, using double LP 104s filled to 2400 psi, has a RMV rate of .63 and an average swim rate of 65 feet/minute. Does he have sufficient gas to reach a desired destination 1200′ within the cave system at an average depth of 110′?

Usable volume- 7.8 X 8 = 62.4 cubic feet of usable gas (1/3rd is 800 psi)

Adjusted RMV- .63 X 4.23 (ATA @ 110′) = 2.66 cubic feet/minute

Maximum time– 62.4 ÷ 2.66 = 23.5 minutes

Maximum penetration- 65 feet/minute X 23.5 minutes = 1,524 feet

So, this diver can make this distance, assuming the dive progresses as planned.

Gas Management/Dissimilar Breathing Rates (Metric)

As the safety of open water and the surface is left further behind, the Cave Diver must become more accurate in gas matching with team members.

The purpose of gas matching is to help assure that all team members have a sufficient gas supply to safely exit the cave in emergency circumstances. The ultimate goal of every cave dive is to arrive safely at the surface at the dive's end. It is of prime importance for cave divers to fully and adequately understand both the need and means of reaching a safe gas management plan for each dive. Equally important is each diver actually implementing this plan. The time to consider the need for such a plan is not after an emergency has arisen, but in anticipation and preparation for it.

In order to determine an accurate Respiratory Minute Volume (RMV), the diver should execute a series of dives over a period of time – a single dive will not be an accurate measure of RMV rate. Additionally, the diver should determine RMV rate at rest, under moderate work load and under heavy work load. By doing so the diver should have adequate information to formulate an effective gas management plan in a variety of conditions.

RMV rate is determined as follows:

(Volume ÷ Bottom time) ÷ ATA = RMV rate.

Please note that the result obtained by this method will provide the diver with a gas consumption rate **at surface** which must then be depth adjusted.

An effective manner in which to arrive at a working RMV rate is to swim an area of known average depth over a measured distance and time. The diver should note time and pressure at the beginning and end of the swim. Using the pressure difference and adjusting for depth calculates the diver's Surface Air Consumption (SAC) rate. Convert the SAC rate (units of pressure) to units of volume to determine a working RMV rate. This method may also be used to arrive at both moderate and resting RMV rates.

EXAMPLE:

Diver A, using double 10 Liter Tanks , enters a passage to an average depth of 30 meter with 175 bar of gas at 12 minutes into the dive. Maintaining this average depth, Diver A returns to his measuring point with 149 bar of gas at 22 minutes into the dive. What is Diver A's RMV rate?

Volume = gas in bar X baseline of tanks or:

2 X 10 L x 175 start of the dive = 3500 liter gas expended.

Recall that atmospheric pressure is appr. 1 bar of pressure per square cm of surface area and accumulates in water at the rate of 1 bar for each 10 m of saltwater (msw) and every 0.98 m of freshwater (mfw). Cave diving occurs in fresh– and saltwater, saltwater will be the unit of measurement used in our calculations for simplicity. The term "Atmosphere Absolute" (ATA) refers to all pressure exerted on the diver by the water surrounding the diver plus the additional one atmosphere of surface pressure and may be determined as follows. In addition: In Europe it is common to use bar for all the calculations instead of ATA.

(Depth ÷ 10) + 1 = bar.

Using the example above, determine Diver A's RMV rate:

ATA= (30 ÷ 10) + 1 = 4 bar

(Volume ÷ Bottom time) ÷ Ambient Pressure = RMV rate or

(3500 L - 2980 L) ÷ 10 min. divetime) ÷ 4 bar = 13 liter/min

Diver A consumes 13 liter of gas per minute at the surface. Using this information, Diver A now has a benchmark to calculate gas consumption.

EXAMPLE:
If Diver A, using double 10 liter filled to 180 bar, plans a dive to an average depth of 21 m, what volume of usable gas is available to him and what is his maximum dive time?

180 bar x 2x10 l = 3600 l (1/3rd is 60 bar or 1200 liters)

Diver A must adjust his RMV rate to depth:

(21 m / 10) +1 = 3,1 bar

3,1 bar X 13 L SAC = 40.4 liters RMV on 21 meters.

1200 usable gas ÷ 40.4 liters RMV rate = 29.7 minutes penetration time

It is important that each member of a dive team knows and plans for individual RMV rates– the team should match dissimilar RMV rates in order to establish a safe gas management plan for the dive.

EXAMPLE:

Diver A, using double 12 liter filled to 180 bar and 15 liter RMV rate, plans a dive to an average depth of 30 mfw with Diver B, using double 10 liter filled to 150 bar and a 13 liter RMV rate.

First, match dissimilar volumes:

Diver A– 2x12 X 180 = 4320 liter of usable gas (1/3rd is 60 bar or 1440 liter)

Diver B– 2x10 x 150 = 3000 liter of usable gas (1/3rd is 50 bar or 1000 liter)

Diver B's volume controls the team (smaller volume)

Diver A–1000 / size of B tanks = 1000/24 = 42 bar

Diver B– 50 bar of usable gas (1000 liter)

Next, match dissimilar RMV rates:

Diver A– 15 l X 4 bar = 60 liter/minutes

Diver B– 13 l X 4 bar= 52 liter/minutes

Remember, usable gas for the dive for both divers is 1000 liter based on Diver B's lower volume cylinders. To formulate a safe gas management plan, the team need only determine available time at depth:

Diver A– 1000÷ 60 l RMV rate = 16,67 minutes

Diver B– 1000 ÷ 52 l RMV rate = 19,23 minutes

Diver A, because of his higher RMV rate, is the controlling diver. This team is permitted a maximum penetration time of 16 minutes. Of course the actual turn point will occur whenever either diver hits their third, regardless of the time. This is useful, though, for being able to anticipate for both divers expected penetration time.

A diver's RMV rate may vary from day to day as a result of personal psychological and physiological factors. As the diver's trim, propulsion, buoyancy control and awareness levels develop and refine, his RMV rate should lower. Including RMV rate calculations as a part of your dive planning is a method of providing the diver with an indication of improving technique and awareness.

Advanced Dive Planning (Metric)

Along with RMV rate, the diver should develop an awareness of his personal travel rate. If both RMV and travel rates are known, the diver may safely and accurately plan dives along a specific course or to a known point within the cave system.

Travel rates in low, moderate and high flow systems should be measured over a series of dives and verified periodically.

EXAMPLE:

Diver A, at a normal swim rate, travels a distance of 180 meter in 12 minutes yielding a meter per minute travel rate of 15 meter.

Diver A, using double 12 liters filled to 180 bar, has a RMV rate of 13 l and an average swim rate of 15 meter/minute. What is his maximum point of penetration at an average depth of 30 meter?

Usable volume- 12x12 X180 = 4320 liter (1/3rd is 1440 liter or 60 bar)

Adjusted RMV rate– 13 liter x 4 = 52 liter/minutes

Maximum time– 1440 liter / 52 l/m = 27,69 minutes

Maximum penetration distance– 27,69 mins X 15 m/min = 415 meter

NOTE: All calculations in the above example employ the use of "maximums". There are many occasions the diver must use a more conservative plan.

EXAMPLE:

Diver A, using double 12 liters filled to 150 bar, has a RMV rate of 13 l and an average swim rate of 20 m/minute. Does he have sufficient gas to reach a desired destination 360 m within the cave system at an average depth of 33 m?

Usable volume– 2x12x150 = 3600 liter of usable gas (1/3rd is 1200l or 50 bar)

Adjusted RMV– 13 l X 4,3 = 55.9 l/minutes

Maximum time– 1200 / 55,9 = 21,46 minutes

Maximum penetration– 20 m X 21,46 minutes = 429,2 m

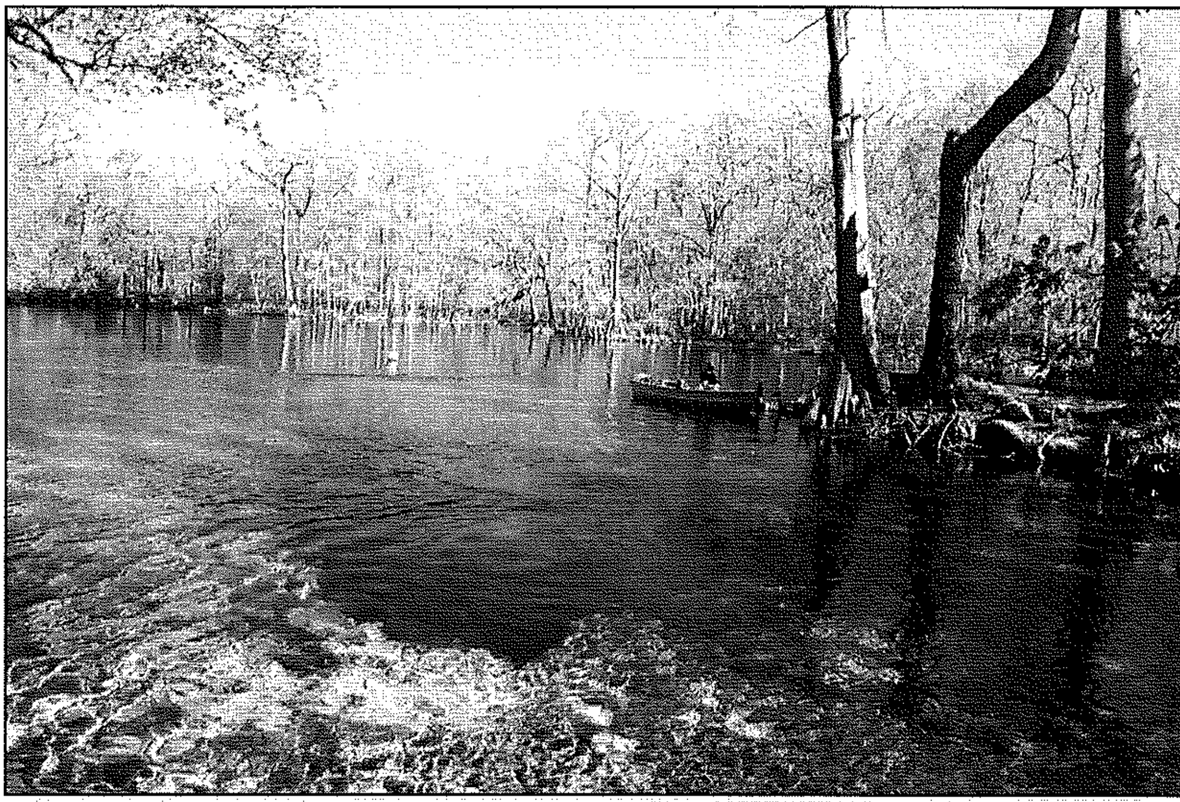
So, this diver can make this distance, assuming the dive progresses as planned.

SUMMARY

The previous examples in this section for illustration purposes only. Each diver must accept individual responsibility for all aspects of the dive plan. Personal and team limitations must be carefully observed. The cave environment presents many challenges which require thorough preparation for every dive.

Complacency kills.

The diver should take nothing for granted and must maintain a high level of skill, preparedness and awareness at all times. Plan all dives in a safe, conservative manner so you will be prepared for any emergencies that may arise.



Underwater Cave Maps

Acknowledgements

The National Association for Cave Diving would like to both acknowledge and thank the following individuals for their support of the NACD. The individuals listed below donated the following underwater cave maps for use in this student manual.

Devils Eye Cave System Map #1 — Anita Berman

Devils Eye Cave System Map #2 — Anita Berman

Crystal Beach Spring Cave System — Michael Garman

Sistema Taj Mahal — Steve Gerrard

Sistema Aktun Koh — Steve Gerrard

Cow Spring/Siphon — James Hurley

Apopka Blue Sink — James Hurley

Malo Okence — Uros Ilic & Igor Vrhovec

Veliko Okence — Uros Ilic & Igor Vrhovec

Nascentes do Formoso e Formosinho — Afonso Pinherio Jr.

Peacock I — Michael Poucher

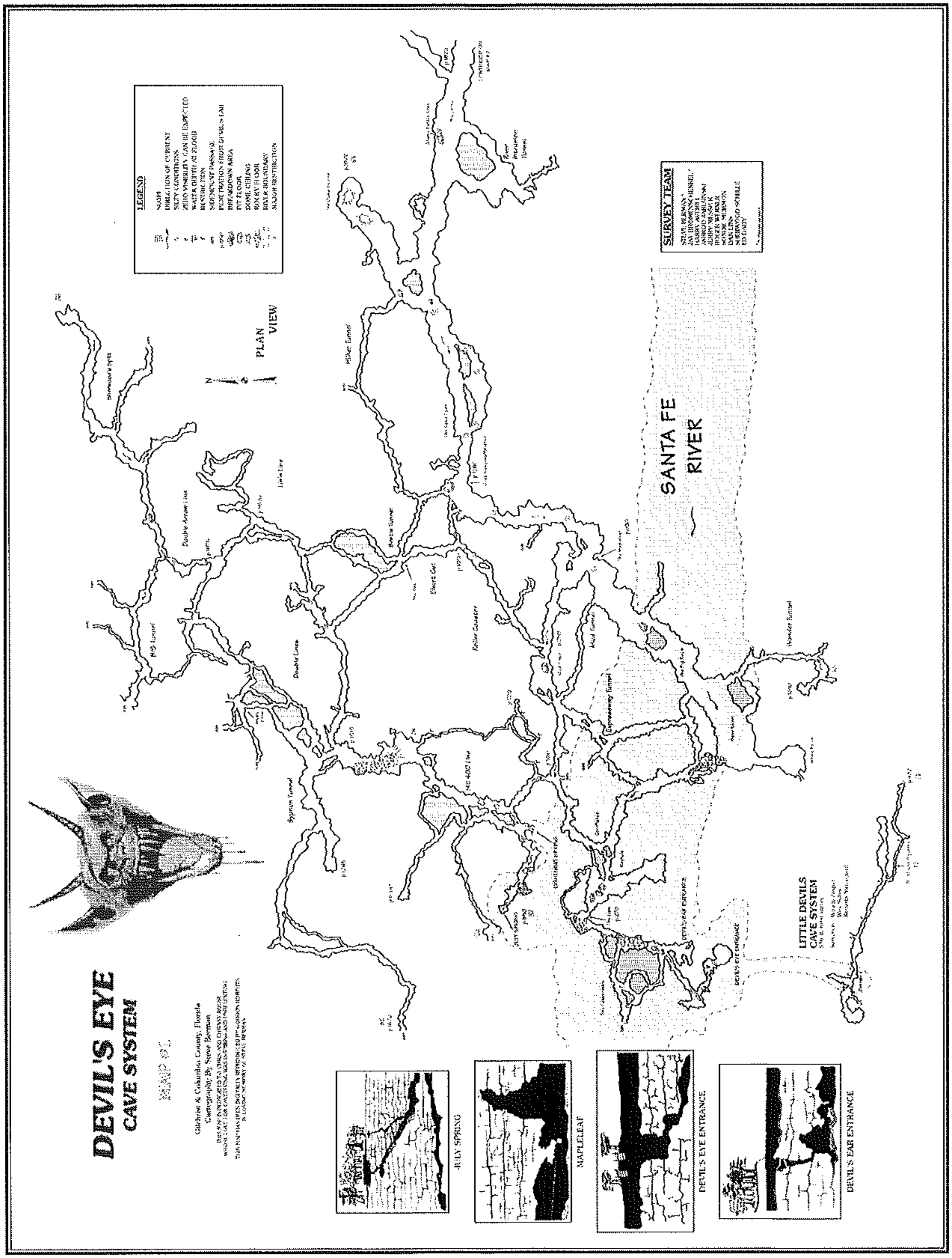
Peacock III Cave/Syphon — Michael Poucher

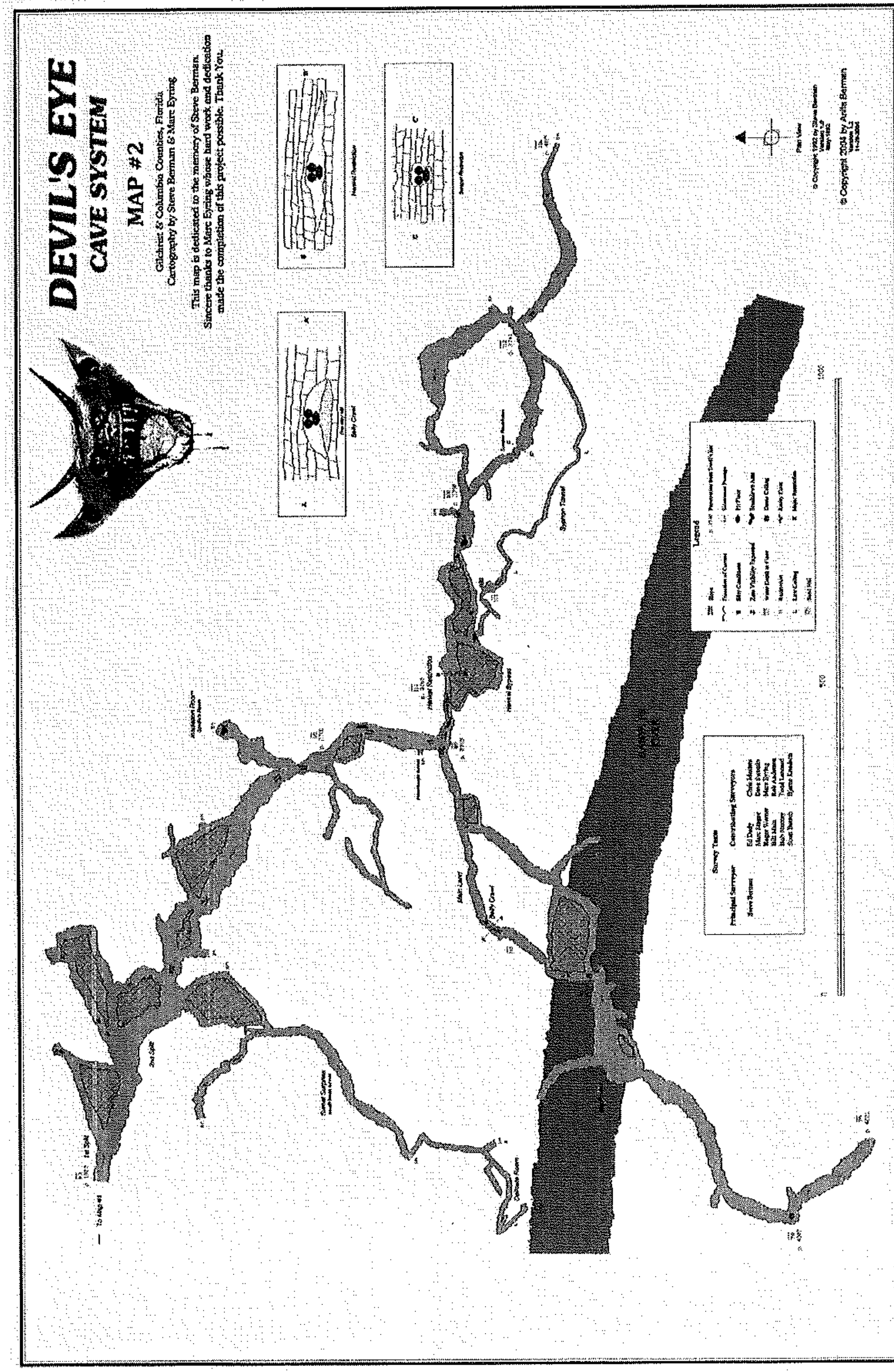
Telford Springs Cave System — Michael Poucher

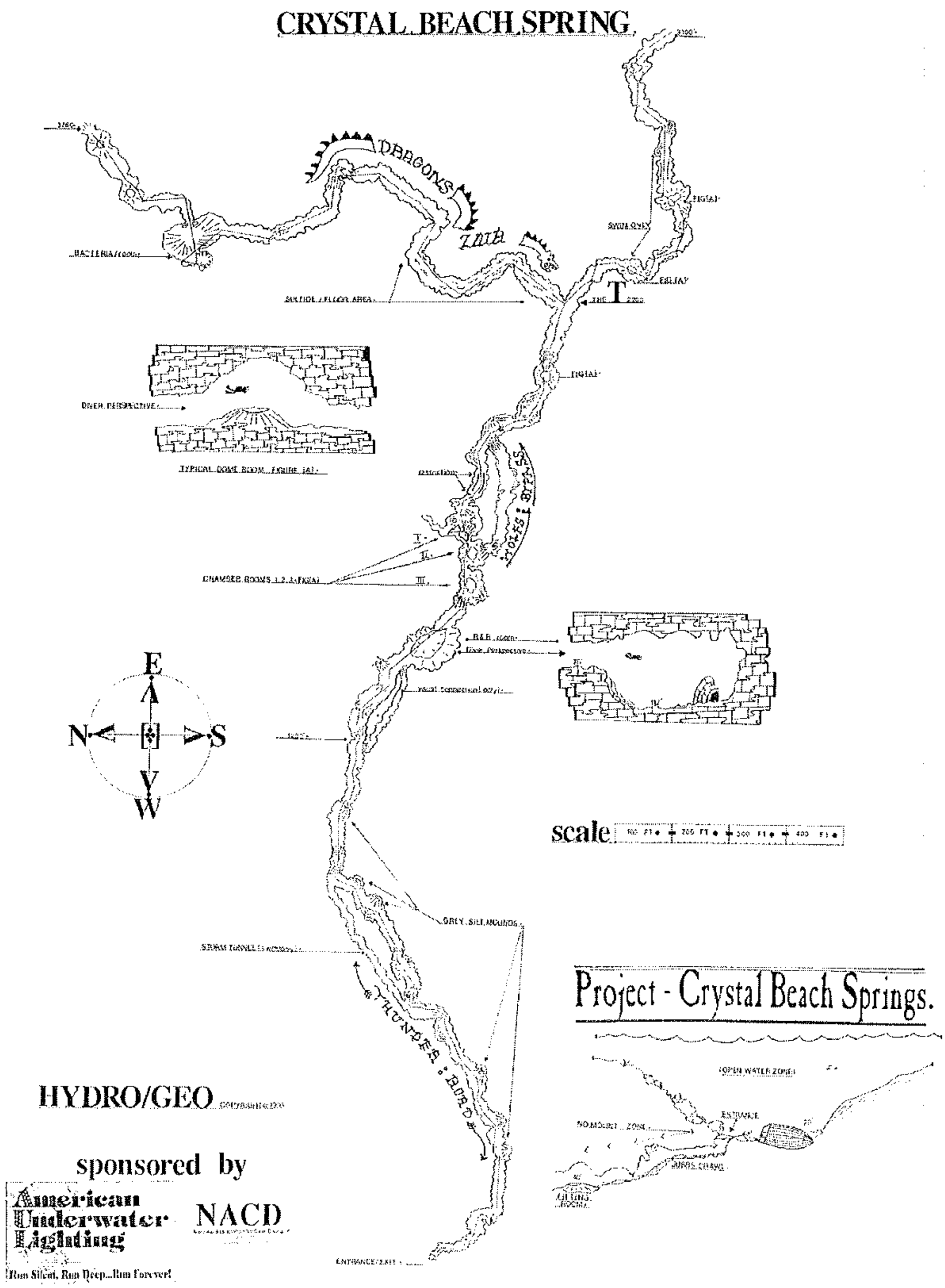
Beacon Woods Cave System — South East Exploration Team

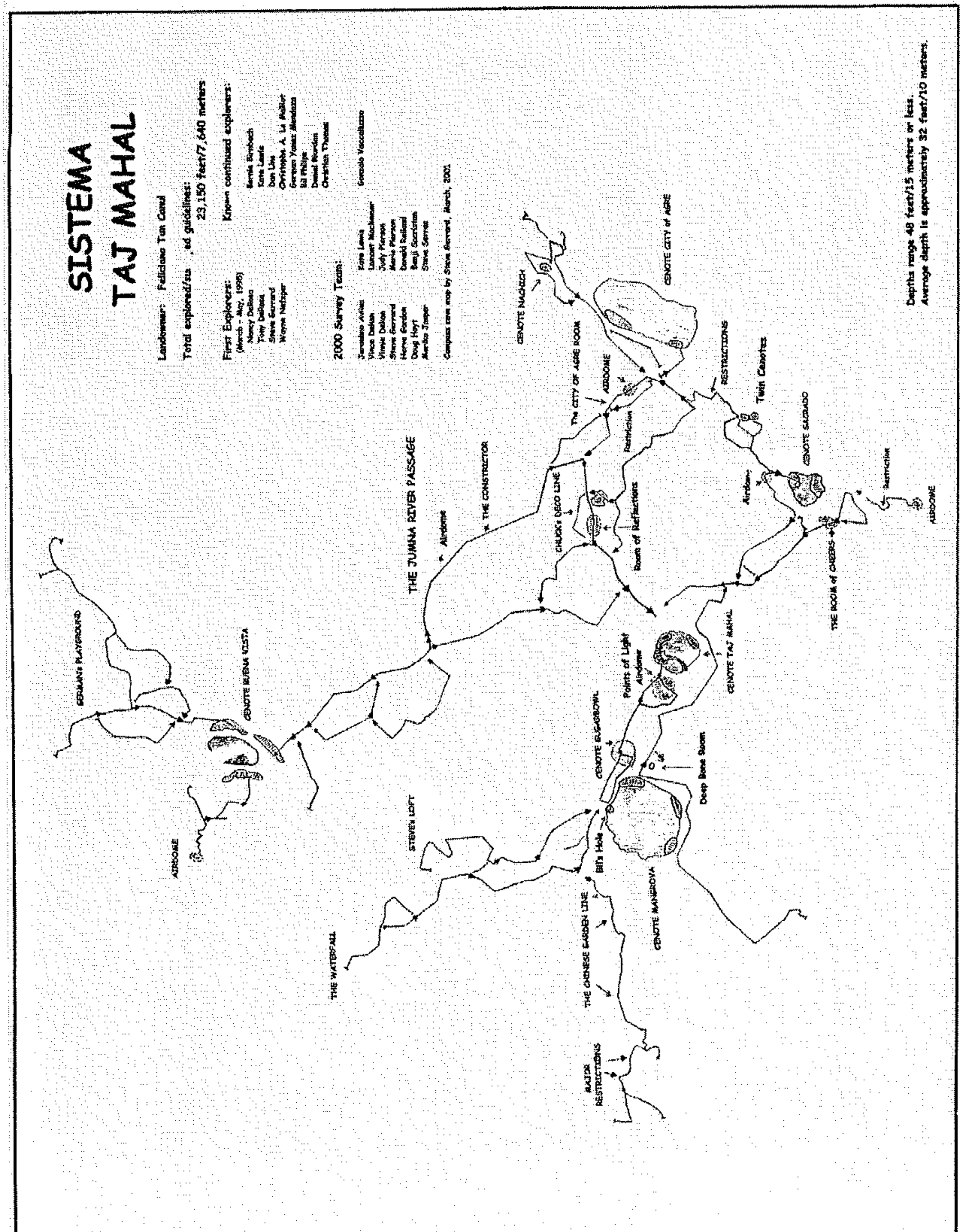
Cenote Xlacah — Coastal Karst Foundation

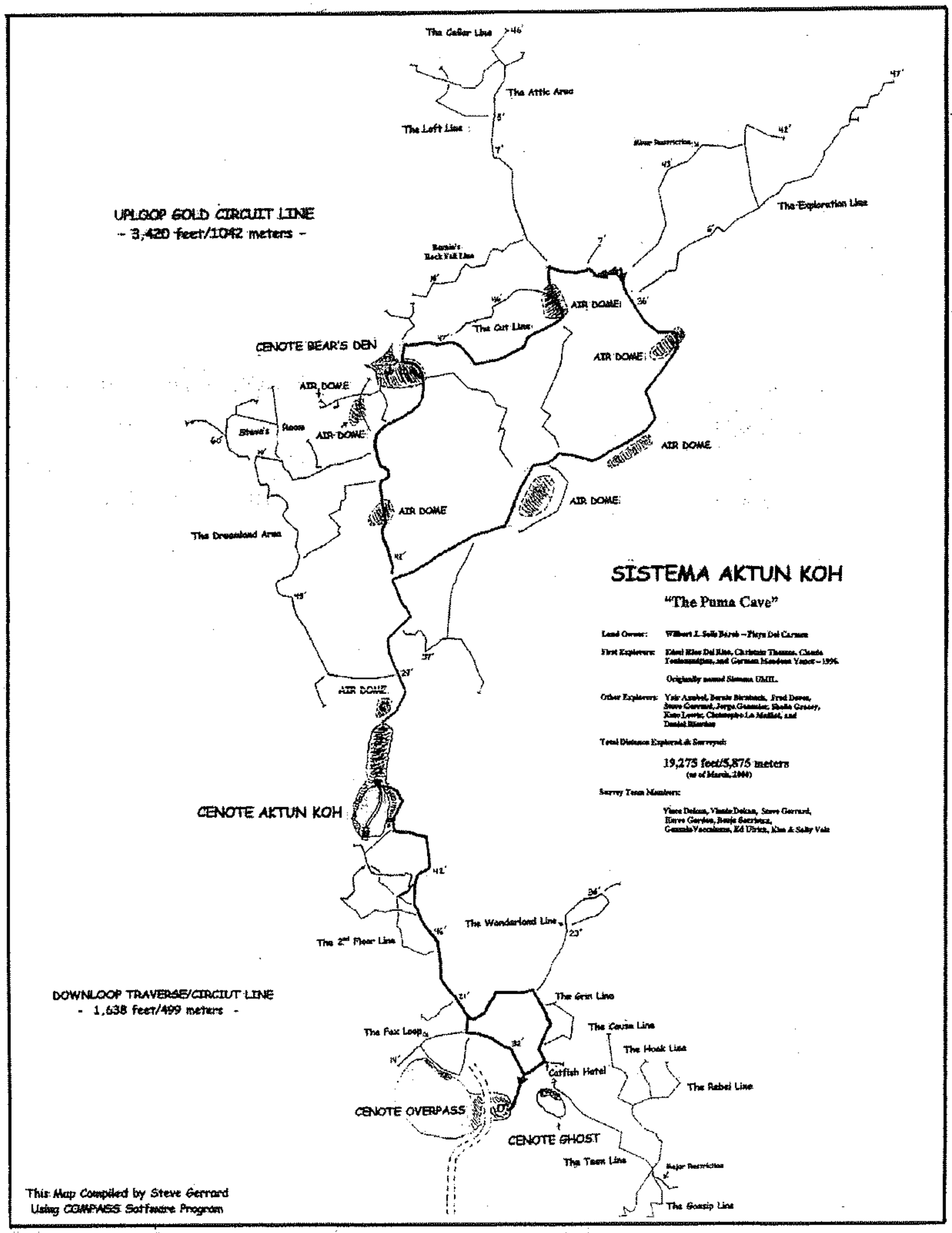
Warning: The following cave maps are provided for illustration purposes only and are considered too small for effective dive planning. Students are encouraged to obtain actual sized maps for planning their dives.

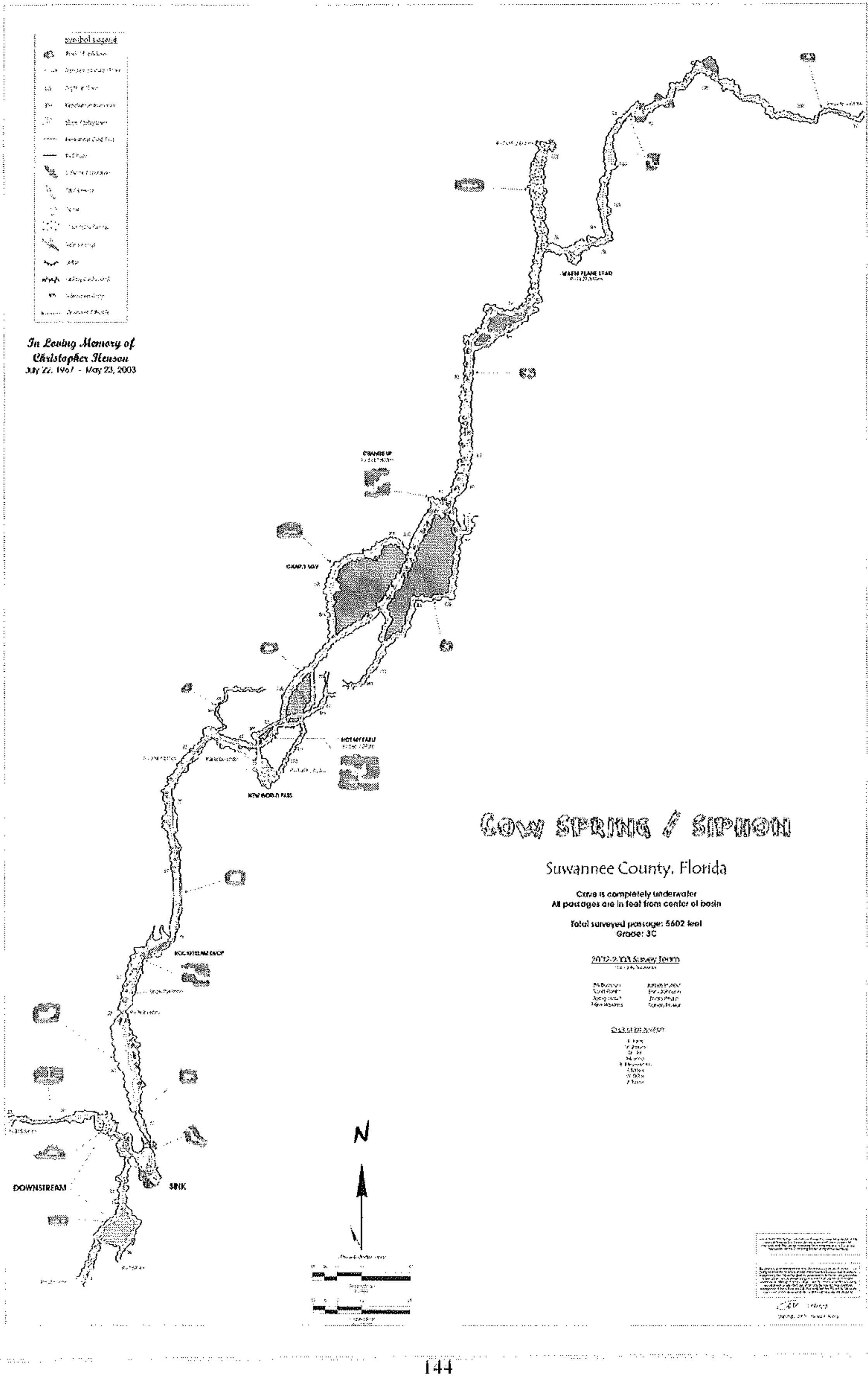

DEVIL'S EYE
CAVE SYSTEM
LEGEND
PLAN VIEW
SURVEY TEAM
SANTA FE
RIVER
LITTLE DEVILS
CAVE SYSTEM
JULY SPRING
MAPLELEAF
DEVIL'S EYE ENTRANCE
DEVIL'S EAR ENTRANCE

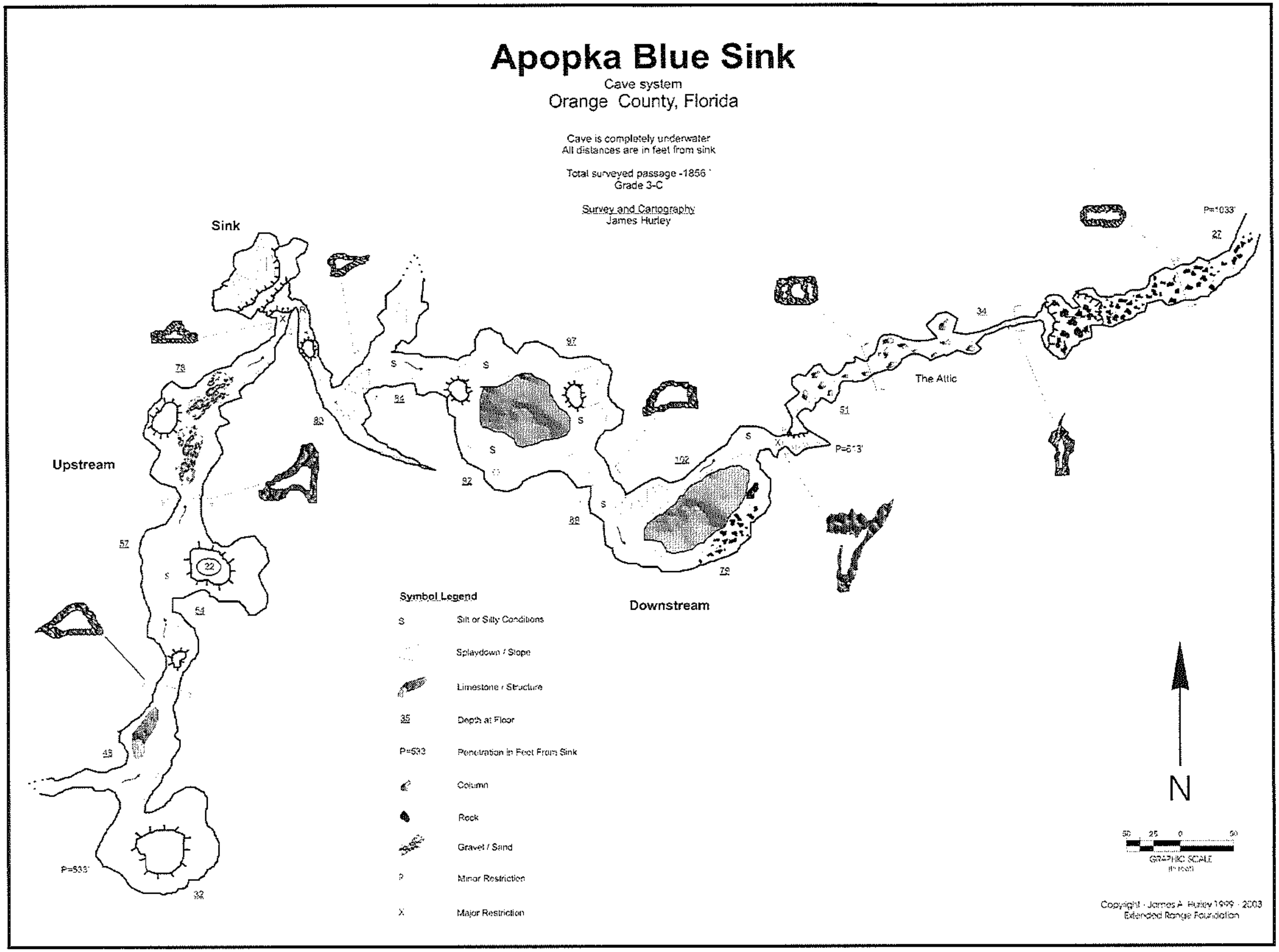

DEVIL'S EYE
CAVE SYSTEM
MAP #2
Gilchrist & Columbia Counties, Florida
Cartography by Steve Berman & Marc Eyring
This map is dedicated to the memory of Steve Berman.
Sincere thanks to Marc Eyring whose hard work and dedication
made the completion of this project possible. Thank You.

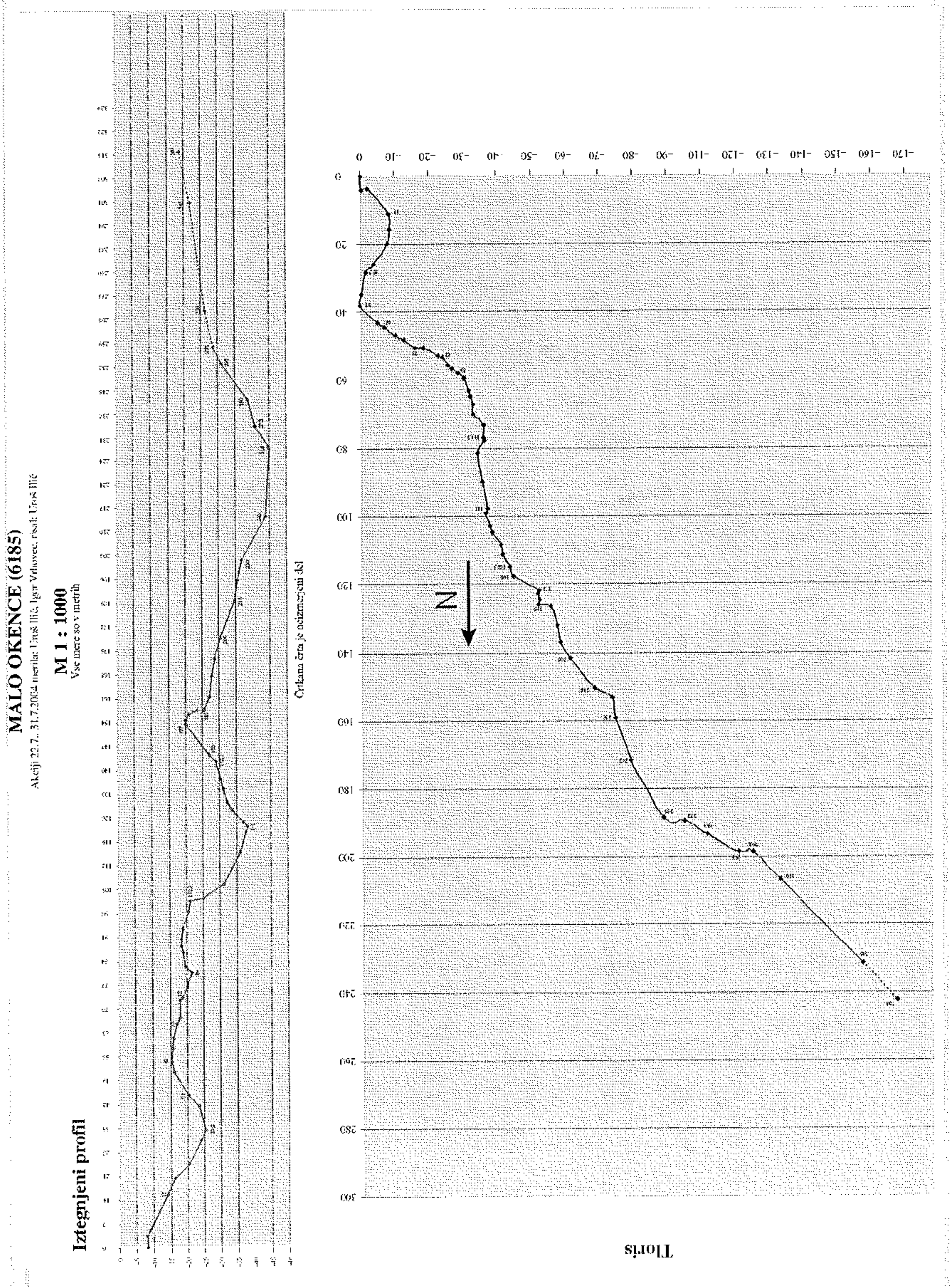

CRYSTAL BEACH SPRING
DRAGONS
TEETH
THE T
TYPICAL DOME ROOM FIGURE (A)
DIVER PERSPECTIVE
CHAMBER ROOMS 1,2,3-FIG(A)
E
N
S
W
scale
GREY SILT MOUNDS
THUNDER ROAD
HYDRO/GEO
sponsored by
American Underwater Lighting
NACD
Run Silent, Run Deep...Run Forever!
ENTRANCE/EXIT
Project - Crystal Beach Springs.
OPEN WATER ZONE
ENTRANCE


SISTEMA
TAJ MAHAL
Landowner: Feliciano Tun Canul
23,150 feet/7,640 meters
First Explorers:
(March - May, 1996)
Nancy DeRosa
Tony DeRosa
Steve Gerrard
Wayne Nelzger
Known continued explorers:
Bernie Birnbach
Kate Lewis
Dan Lins
Christophe A. Le Maillot
German Yanez Mendoza
Bil Philips
Daniel Riordan
Christian Thomas
2000 Survey Team:
Jeronimo Aviles
Vince Dekan
Vinnie Dekan
Steve Gerrard
Herve Gordon
Doug Hoyt
Mariko Jasper
Kate Lewis
Lamont Mackenzer
Judy Pierson
Merle Pierson
Donald Railand
Benji Sacristan
Steve Serres
Gonzalo Vaccalluzzo
Compass cave map by Steve Gerrard, March, 2001
Depths range 48 feet/15 meters or less.
Average depth is approximately 32 feet/10 meters.
GERMAN's PLAYGROUND
AIRDOME
CENOTE BUENA VISTA
THE WATERFALL
STEVE's LOFT
THE JUMNA RIVER PASSAGE
Airdome
THE CONSTRICTOR
CENOTE NACHICH
CHUCK's DECO LINE
The CITY OF AGRE ROOM
AIRDOME
Restriction
Room of Reflections
CENOTE CITY of AGRE
MAJOR RESTRICTIONS
THE CHINESE GARDEN LINE
Bil's Hole
CENOTE SUGARBOWL
Points of Light
Airdome
CENOTE MANEROVA
Deep Bone Room
CENOTE TAJ MAHAL
RESTRICTIONS
Twin Cenotes
Airdome
CENOTE SAGRADO
THE ROOM of CHEERS
Restriction
AIRDOME
N


SISTEMA AKTUN KOH
"The Puma Cave"
Land Owner:
First Explorers:
Other Explorers:
19,275 feet/5,875 meters
Survey Team Members:
UPLOOP GOLD CIRCUIT LINE
- 3,420 feet/1042 meters -
DOWNLOOP TRAVERSE/CIRCUIT LINE
- 1,638 feet/499 meters -
CENOTE BEAR'S DEN
CENOTE AKTUN KOH
CENOTE OVERPASS
CENOTE GHOST
AIR DOME
The Attic Area
The Left Line
The Exploration Line
The Cut Line
Steve's Room
The Dreamland Area
The Wonderland Line
The 2nd Floor Line
The Grin Line
The Hook Line
The Rebel Line
The Fox Loop
Catfish Hotel
The Teen Line
The Gossip Line
This Map Compiled by Steve Gerrard
Using COMPASS Software Program


Symbol Legend
In Loving Memory of
Christopher Henson
July 22, 1967 - May 23, 2003
GRAND SAY
NEW WORLD PASS
DOWNSTREAM
SINK
N
Cow Spring / Siphon
Suwannee County, Florida
Cave is completely underwater
All passages are in feet from center of basin
Total surveyed passage: 5602 feet
Grade: 3C


Apopka Blue Sink
Cave system
Orange County, Florida
Cave is completely underwater
All distances are in feet from sink
Total surveyed passage -1856 '
Grade 3-C
Survey and Cartography
James Hurley
Sink
Upstream
Downstream
The Attic
P=1033'
P=613'
P=533'
Symbol Legend
S Silt or Silty Conditions
Splaydown / Slope
Limestone / Structure
35 Depth at Floor
P=533 Penetration in Feet From Sink
Column
Rock
Gravel / Sand
Minor Restriction
X Major Restriction
N
GRAPHIC SCALE
Copyright - James A. Hurley 1999 - 2003
Extended Range Foundation


MALO OKENCE (6185)
Akciji 22.7.-31.7.2004 merila: Uroš Ilič, Igor Vrhovec, risal: Uroš Ilič
M 1 : 1000
Vse mere so v metrih
Iztegnjeni profil
Črkana črta je neizmerjeni del
N
Tloris

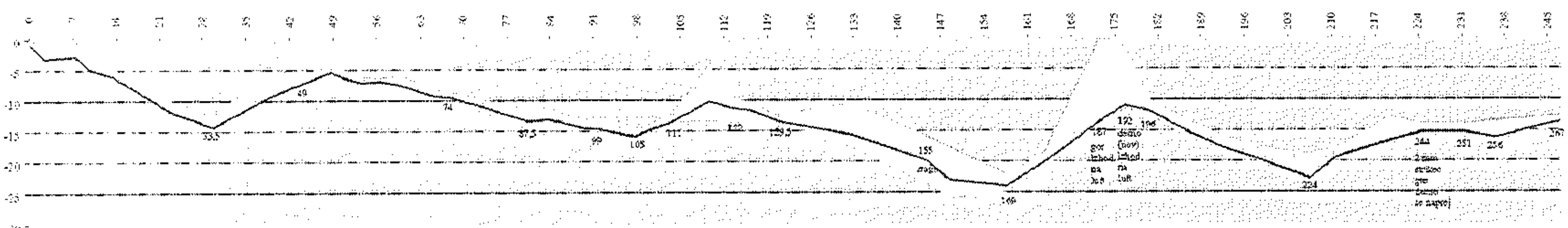
VELIKO OKENCE

Akcija 23.12.2001–9.4.2002: Uroš Ilič, Igor Vrhovec, Simon Oprešnik, Primož Kumše
Merila: Uroš Ilič, Primož Kumše
Risal: Uroš Ilič, 18.7.2002

M 1 : 1000

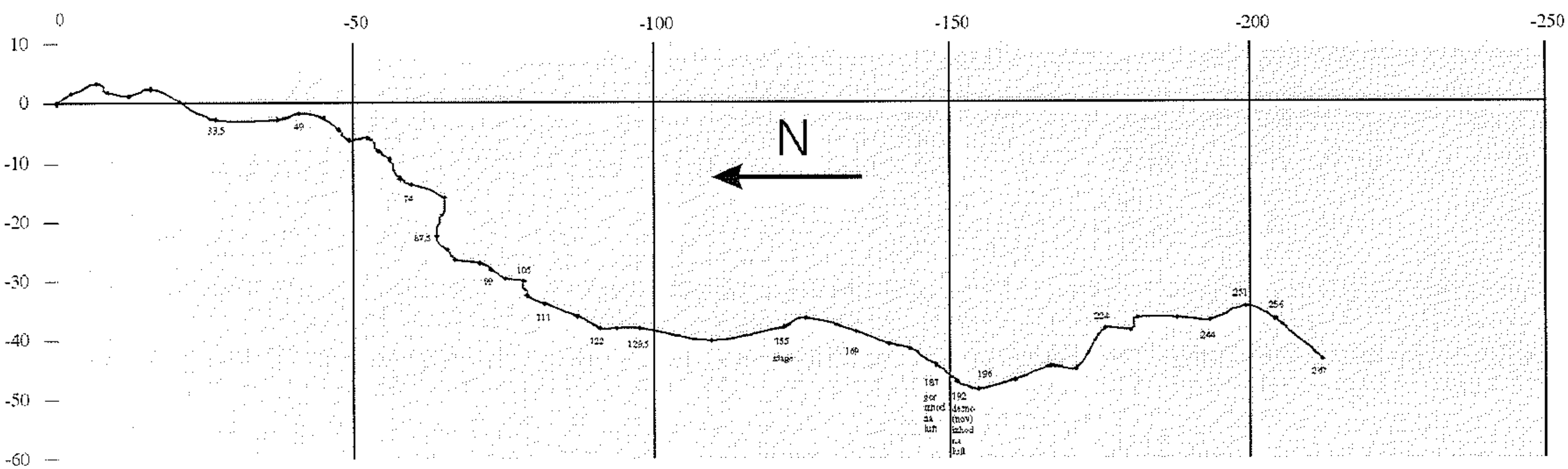
Vse mere so v metrih

Iztegnjeni profil



V rdeči barvi je vrvica, v modri je sifon – od tal do stropa. Modri trikotniki so merilne točke stropa.

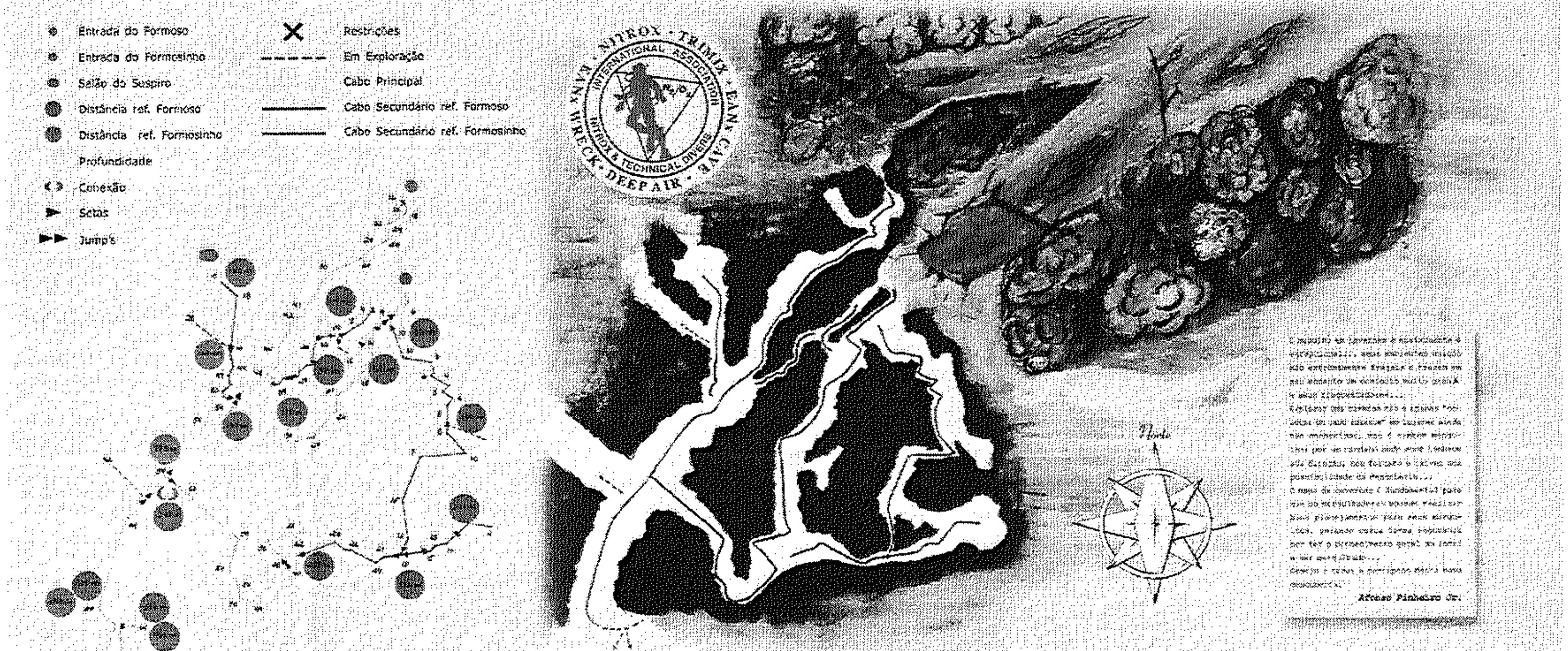
Tloris



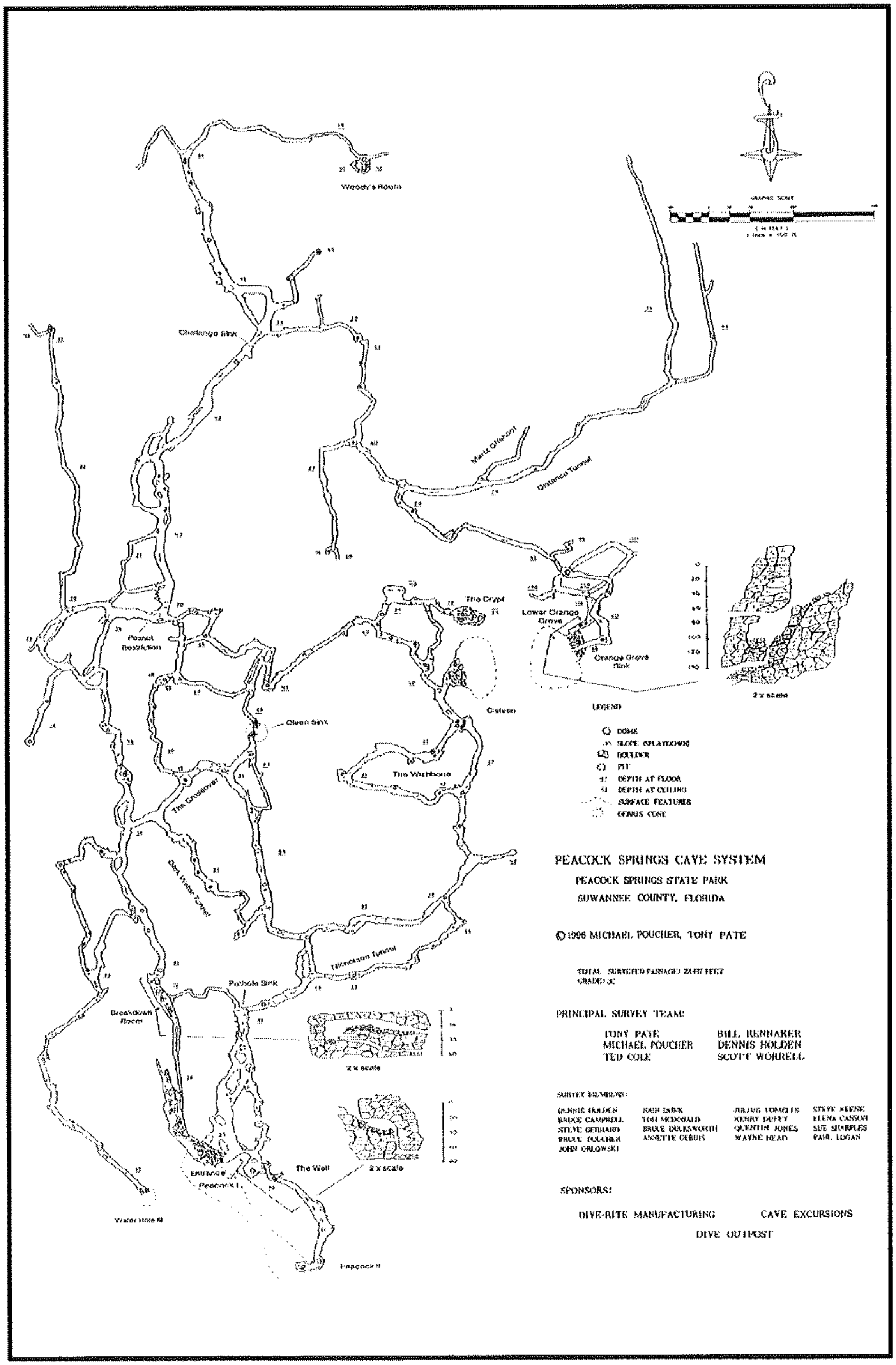
Nascentes do Formoso e Formosinho

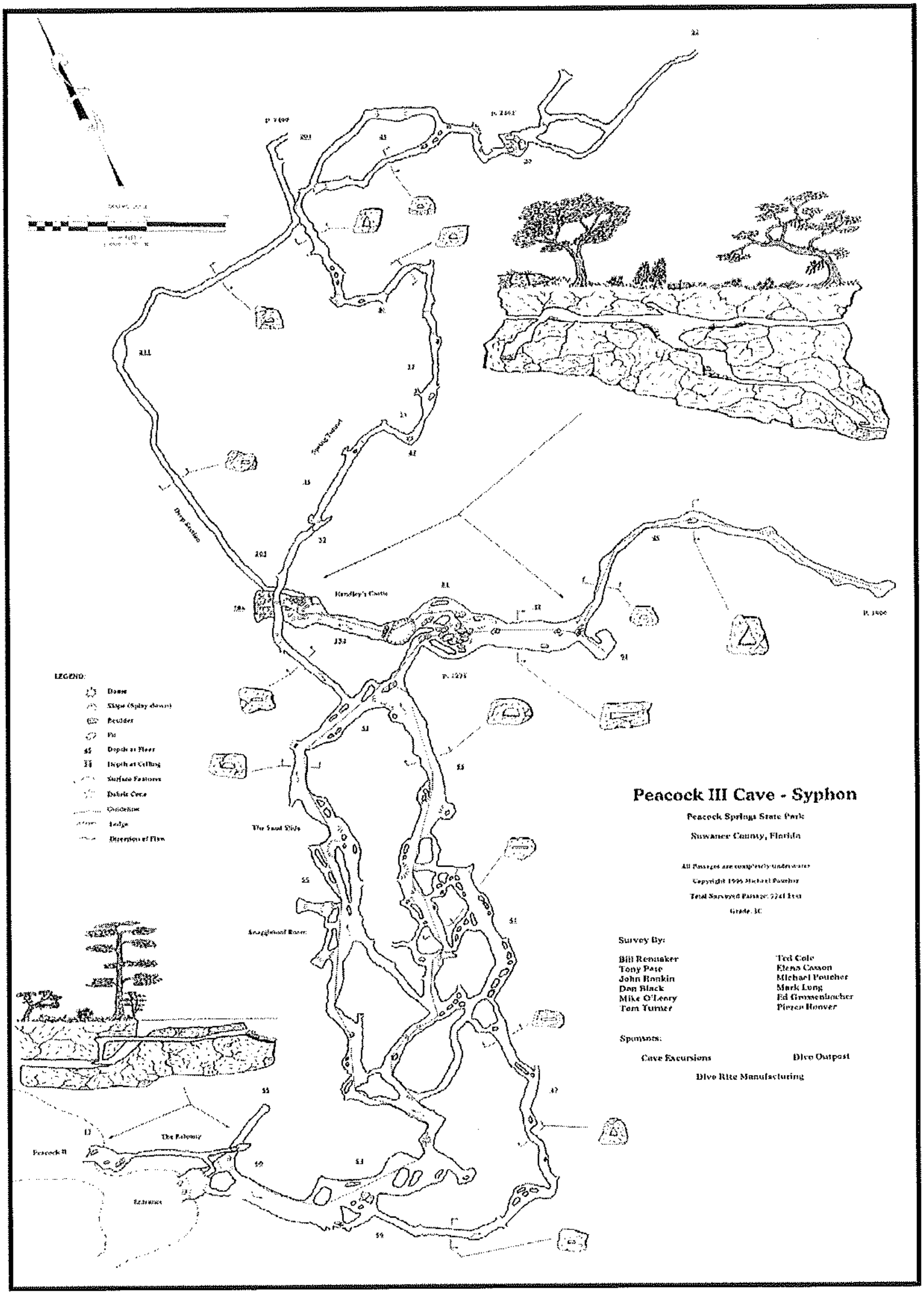
No início do mês de Junho do ano de 1999, os mergulhadores Afonso Pinheiro Jr. e Gilberto Menezes, cartografaram as Nascentes do Formoso e Formosinho.

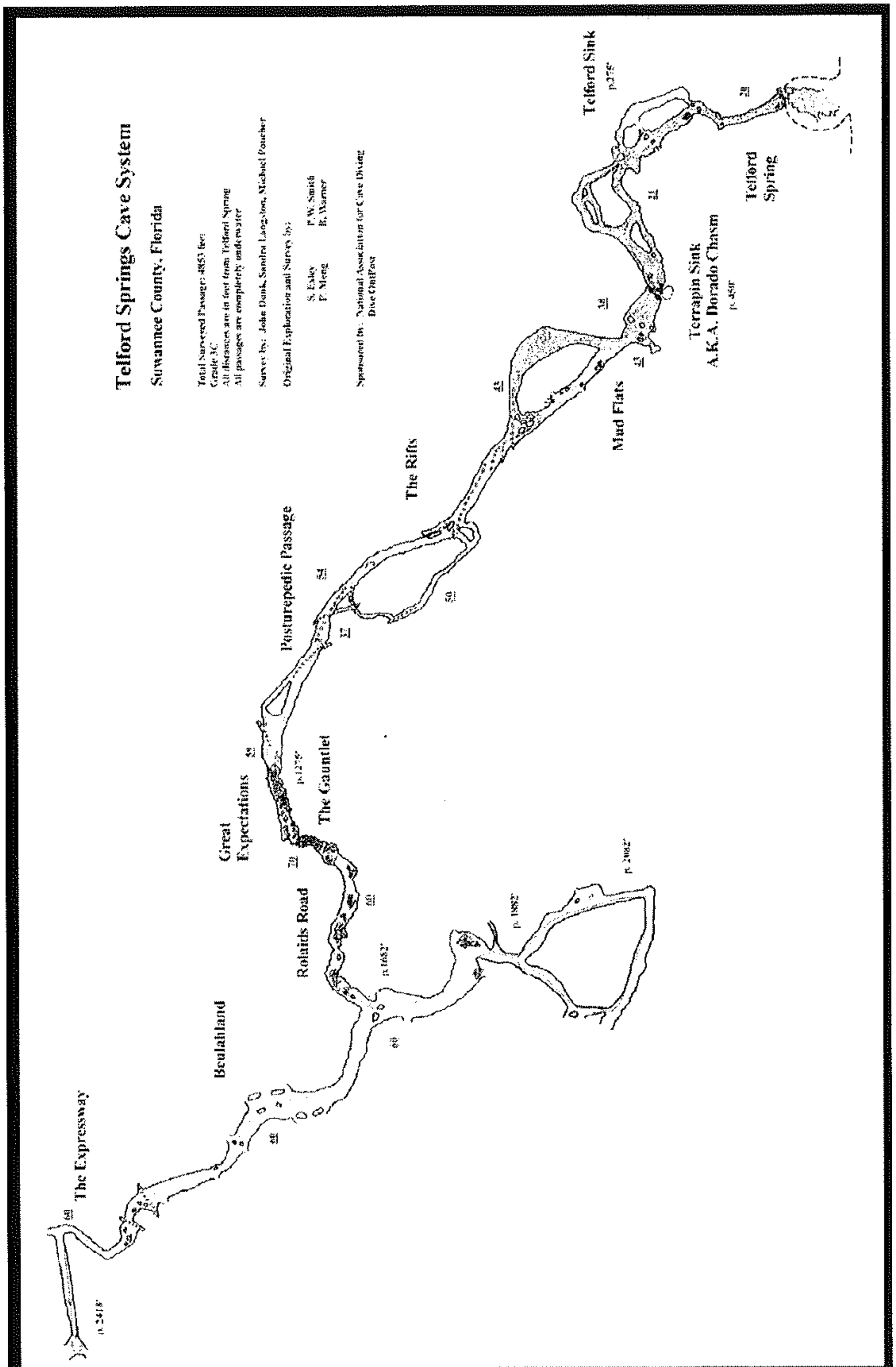
Através desta cartografia foi possível a criação de uma figura artística, demonstrando uma anatomia semelhante a realidade das cavernas e, a elaboração de um mapa técnico, contendo informações complexas quanto a estrutura interna das nascentes...

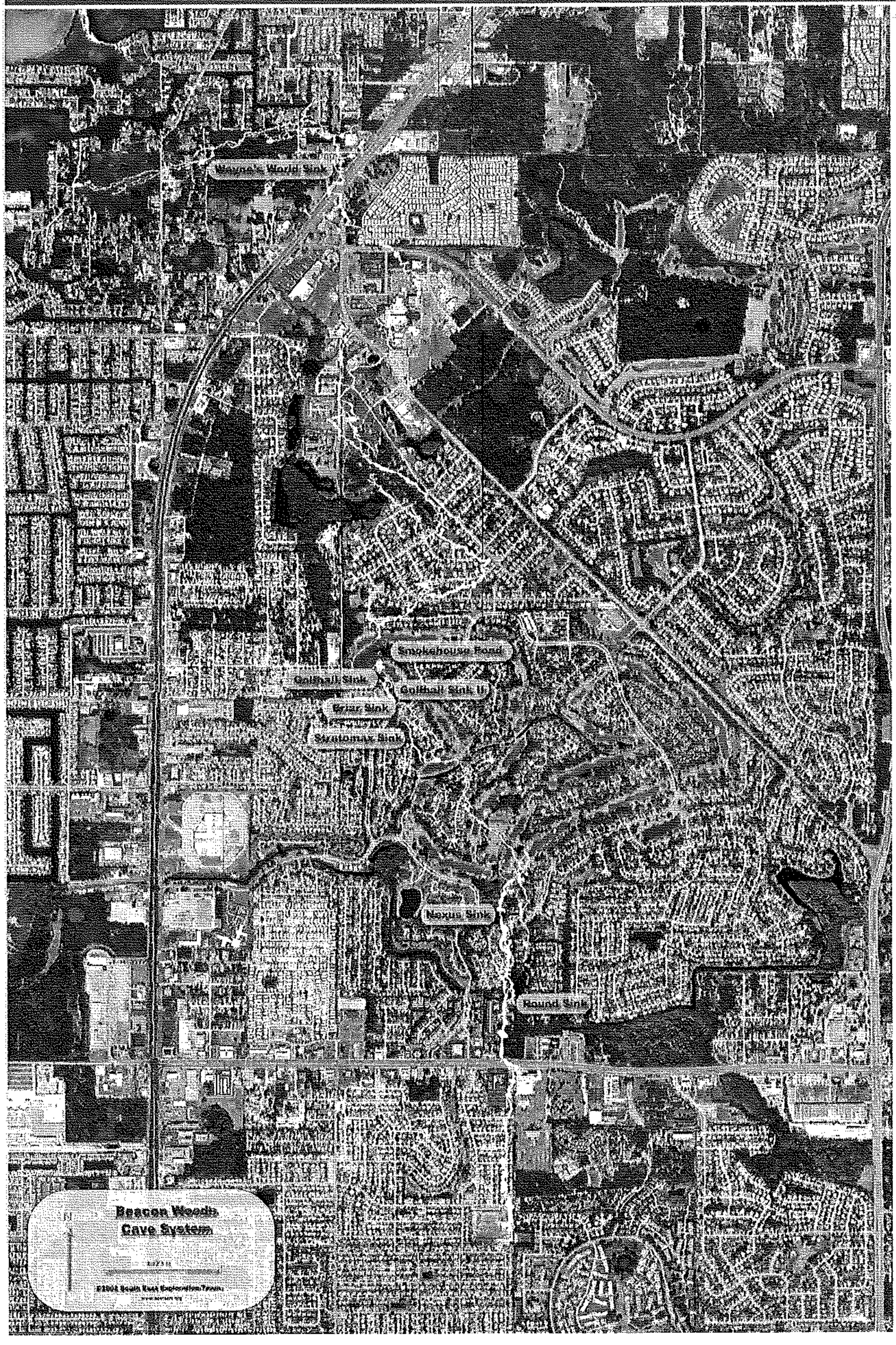


mergulhadores: Afonso Pinheiro Jr. • Gilberto Menezes arte e desenvolvimento: Denise C. Bueno diagramação e arte final: Spyn Design • SP • 3060 9368


Woody's Room
Challenge Sink
Distance Tunnel
Peanut Restriction
The Crypt
Lower Orange Grove
Orange Grove Sink
Olsen Sink
Cistern
The Washboro
The Crossover
Pothole Sink
Breakdown Room
2 x scale
2 x scale
2 x scale
The Well
Entrance Peacock I
Water Hole III
Peacock II
LEGEND
DOME
SLOPE (PLATFORM)
BOULDER
PIT
DEPTH AT FLOOR
DEPTH AT CEILING
SURFACE FEATURES
DEBRIS CONE
PEACOCK SPRINGS CAVE SYSTEM
PEACOCK SPRINGS STATE PARK
SUWANNEE COUNTY, FLORIDA
©1996 MICHAEL POUCHER, TONY PATE
PRINCIPAL SURVEY TEAM:
TONY PATE
MICHAEL POUCHER
TED COLE
BILL RENNAKER
DENNIS HOLDEN
SCOTT WORRELL
BRUCE CAMPBELL
JOHN ORLOWSKI
BRUCE DUCKSWORTH
ANNETTE GEBUIS
KERRY DUFFY
QUENTIN JONES
WAYNE HEAD
ELENA CASSON
SUE SHARPLES
PAUL LOGAN
SPONSORS:
DIVE-RITE MANUFACTURING
CAVE EXCURSIONS
DIVE OUTPOST


Peacock III Cave - Syphon
Peacock Springs State Park
Suwanee County, Florida
Survey By:
Bill Rennaker
Tony Pate
John Rankin
Dan Black
Mike O'Leary
Tom Turner
Ted Cole
Elena Casson
Michael Poucher
Mark Long
Pieter Hoover
Sponsors:
Cave Excursions
Dive Outpost
Dive Rite Manufacturing
LEGEND:
Dome
Boulder
Depth at Floor
Debris Cone
Ledge
Direction of Flow
Peacock II


Telford Springs Cave System
Suwannee County, Florida
Grade 3C
All distances are in feet from Telford Spring
All passages are completely underwater
Original Exploration and Survey by:
S. Exley
P.W. Smith
B. Warner
Sponsored by: National Association for Cave Diving
Telford Sink
Telford Spring
Terrapin Sink
A.K.A. Dorado Chasm
Mud Flats
The Rifts
Posturepedic Passage
The Gauntlet
Great Expectations
Rolaids Road
Beulahland
The Expressway


Wayne's World Sink
Smokehouse Road
Golfball Sink
Golfball Sink II
Briar Sink
Stratomax Sink
Nexus Sink
Round Sink
Beacon Woods
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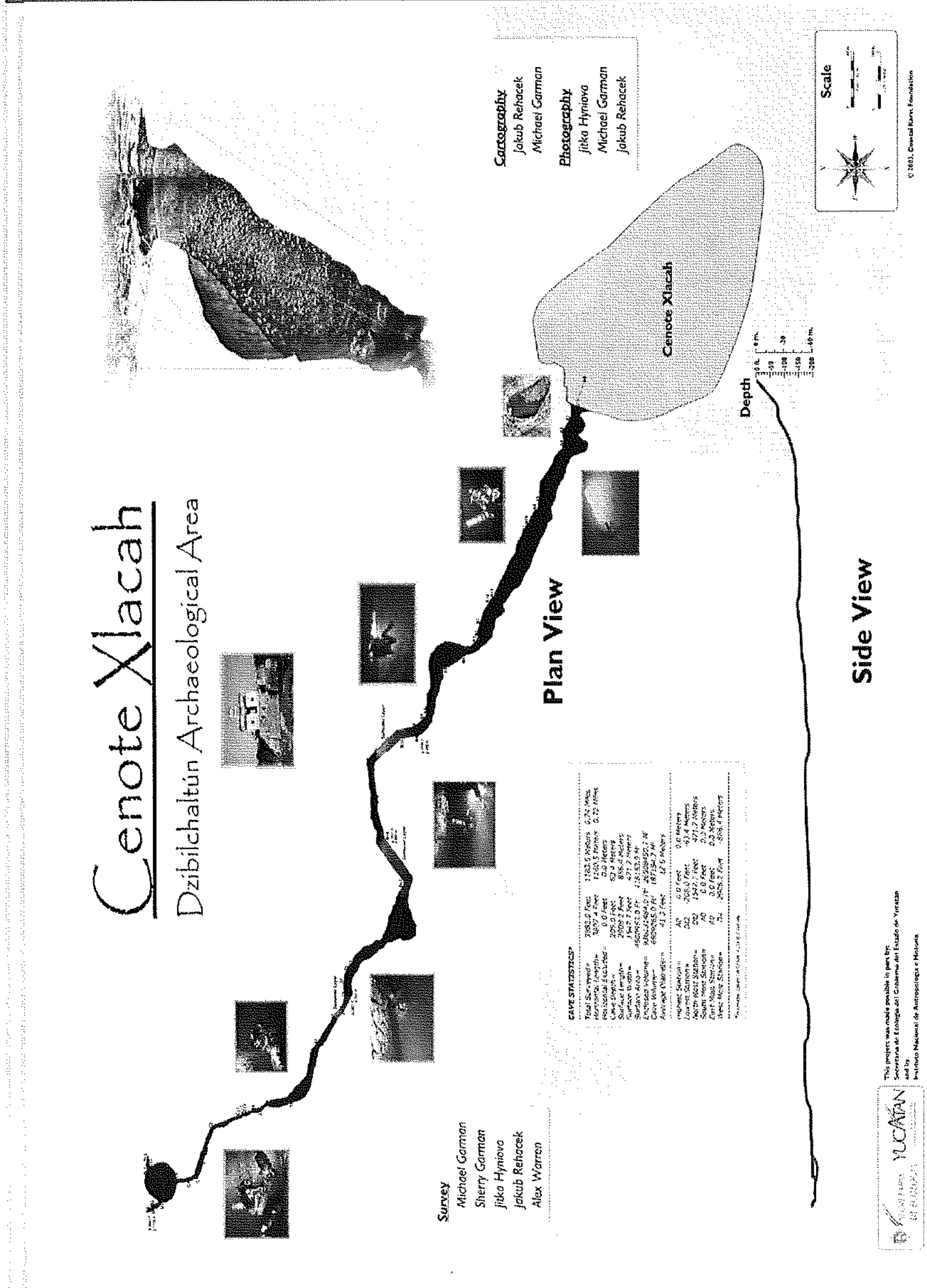
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Sherry Garman
Jitka Hyniova
Jakub Rehacek
Alex Warren
Cartography
Jakub Rehacek
Michael Garman
Photography
Jitka Hyniova
Michael Garman
Jakub Rehacek
Scale
YUCATAN

Training Tips (NACD Journal, Volume 37, 4th Quarter)

Editor's note: The NACD is first and foremost a training and education agency. Many of us learn skills during the formal courses and rarely if ever review, practice or update our knowledge of safety skills. The ***Training Tips*** *column will feature an in-depth article on a particular safety skill or aspect of the overhead environment to help refresh our knowledge. This issue's skill discusses the lost line skill, as taught by the NACD Training Director Larry Green. Please note that the NACD training standards do specify that this skill is required for particular levels of training, but the actual specifics of how the skill is to be performed are left up to the discretion of the instructor. This article is not intended to be the official NACD stance on how this skill is taught but should get you thinking about the skill in more detail.*

Reviewing the Lost Line Skill

By Larry Green, NACD Director of Training

Many of the emergency procedures that are taught in cavern and cave classes originated as a solution to a problem that developed during an actual emergency. The lost line skill is no exception. Despite being in the cave training repertoire for many years there is some evidence in recent tragedies that loss of the line was a contributing factor. To help this discussion, the term "safety reel" will be used to indicate any typical line carrying device, such as a reel or spool. The choice you make as to what type of device you use is yours to make, as long as you are proficient in using it, especially in zero viz or during an emergency.

The lost line skill is, like many emergency procedures, a skill you hope to never actually use but one that you should definitely know how to execute in the extreme case of having lost the line. The first step in deciding whether or not to actually start the procedure is deciding that an easier method for discovering where the line is won't work. Sometimes losing the line is a very temporary condition and, given good visibility, is merely a matter of using your primary light to look around and find it. In other instances, especially if you are paying closer attention to some feature of the cave or of your dive team, it can be merely a matter of finding your dive team and then finding the line nearby. More than likely a total loss of the line is due to total loss of visibility, which is usually due to temporary silty conditions more so than loss of lights. If you find yourself in such a situation here is a recommended sequence of events to follow:

1. STOP all your movement – don't make things worse. THINK about where the line was when you last saw it. Do you remember where your dive team was? How about the configuration of the cave? Are you in a low, tight passage or a large, wide section? Is there flow and can you use that to help you figure out where the line is? The main point here is to acknowledge that you have transitioned from a normal cave situation to a potentially dangerous one, especially if you don't take the time to get your breathing under control so you can properly analyze the situation. It's also important, especially if you have lost your ability to see, to maintain a clean horizontal position and good buoyancy. If you are in a high flow system merely taking these few minutes may bring in clearer water, making your job easier and reducing your stress.
2. If by now you haven't located the mainline or your dive team through vision then the next step is to solidify your current position by establishing a "home base" – you may not know where you are, but once you start searching you don't want to make it worse by not being able to know where you used to be – or have already searched. Deploy your safety reel and find an attachment point somewhere along the wall, ceiling or even the floor. Some may have been taught that in a smooth passageway you could use a backup light stuck in the mud. While that may help establish a base it is not a good idea to voluntarily give up a piece of perfectly working emergency gear that you may need later. As with all diving decisions, how you establish your home base is a judgment call.

3. Once you have your base established pick a direction where you think the line is at and start a SLOW search pattern. The type of search pattern will vary on your frame of mind and your memory of the cave configuration prior to getting lost. A common sense approach would lessen the amount of reel handling you have to do. I suggest that you have knots tied on your safety line at double arm's length distances so that you can count the knots by feel as you venture off of your home base. The The typical 10 foot knots are OK, but assuredly you are not doing survey work in zero vis during the lost line procedure so a shorter length that is more in touch with a distance "by feel" would be more appropriate. Double arm-length knots allow you to count the knots by feel which gives you a reliable way to judge distances in zero visibility. It is better to take small semi-circular back and forth movements, using the knots to decide your reach on each pass and your free hand in an up and down motion (since usually the line you have lost is positioned horizontally) than to attempt elaborate ceiling to floor loops or extensive "reel in-reel out" stabs in the dark.

4. At some point hopefully you will come across a line. Take the time to establish a connection to this line that will help you and others in navigation. Tension up your reel, lock off your reel, wrap it over the line you just found and clip it back on your "home base" line. Get out a line arrow and put it on the line you just found, pointing the arrow in the direction that you think is the exit. Secure your "home base" line through the line arrow so it's clear by touch which of the three lines at this junction you have created is hopefully the exit direction. Why go through this elaborate of a ritual? Let's think about what this means – another diver (or yourself, if you have to return back this way) who may come across this particular scene in the near or far future cannot mistake a reel attached to a line arrow as anything but the result of a successful lost line procedure. When else do we tie off a reel to the middle of another line with a marker? Jumps typically tie the reel off to the beginning of a jump line and arrows indicating exit are placed on the jump line, not the line being jumped to. Some divers may forego the use of a line arrow and just use the reel as a directional marker; this could be confusing to other divers who may be in the same part of the cave at almost the same time. A diver coming across, by feel, the arrow and the safety reel attached would not confuse which of the lines is the exit – the arrow points the way, hopefully.
Proceed along the direction of travel that you chose, until you come across a verifying line arrow. If it turns out that you selected the wrong direction, then reverse directions. When you reach your arrow and "home base" reel, take the time to reverse the direction of the arrow so it now tells the correct direction. At this point you have a decision to make regarding the rest of your dive team. Essentially you would have to decide whether or not you want to just wait for them and start the lost diver procedure or exit. Making that decision involves invoking the lost diver skill, which would include looking at your current gas and time management; that's a topic for a future article.

Some other points are worth mentioning in relation to this skill. What do you think your dive team would be doing while you are looking and feeling around for the line? Hopefully they have begun a lost diver skill around the same time and as you leave your home base you run into your buddy who has his or her safety reel leading back to the line. Another consideration is the one piece of critical gear that many choose not to make redundant – the safety reel. What if you lose that, especially while fumbling in zero vis to deploy or secure it? Do you have a backup reel? Safety reels are certainly cheap enough and small enough to stow somewhere on you, just in case. Finally, don't forget that one of the goals of training, or more precisely over-training, is to get the emergency procedures ingrained in your brain so that they become automatic. Try practicing with your buddy the next time you do a dive under safe conditions. Go tie double arm-length knots in your current safety line and practice using it on dry land and in the water. Could you or your buddy find the line?

Training Tips (NACD Journal, Volume 38, 1st Quarter)

*Editor's note: **Training Tips** debuted in the last NACD Journal with an article entitled Reviewing the Lost Line Skill by Larry Green. This month the trend continues with a new article related to training and safe cave diving habits. In the spirit of cooperation it is noteworthy to refer readers interested in more training and safety articles to Underwater Speleology, Vol 31, No 6, page 6 (Lost Buddy Drill, by Ralph DiPanfilo, NSS/CDS Instructor # 351). Note, as mentioned last time, that this article is not intended to be an official NACD stance on policy; refer to the Standards and Procedures for those details. The intent of these articles is to help fill in some of the details of skills and procedures that have traditionally only been passed orally from instructor to student.*

Turning under pressure

By Larry Green, NACD Director of Training

From the Cavern level of training and up, student divers in the overhead environment are introduced to the importance of keeping track of their air supply. Recall the classic accident analysis rule, where a direct cause of a fatality in the overhead environment was attributed to improper gas management. Post recovery analysis that discovers empty tanks is an indicator that this rule was probably violated in one way or another. Safe cave diving is all about risk management and the "rule of thirds" was created as a way of lessening the risk of violating the gas management rule. As with many things in cave diving, however, relying merely on the rule of thirds may not be enough. Let's treat the "1/3rd rule" as a guaranteed not to exceed, best-case or **at most** gas rule and discuss factors that might affect that rule. As we all learned at some point in our overhead training, the 1/3rd rule assumes that divers forced to air share on exit have the same air consumption and state of comfort as they had breathing down the initial 1/3rd; this may not always be the case.

Level of training: Cavern and Intro to Cave divers are taught to only dive at most 1/3rd of single tanks and, if permitted by their instructor, can use 1/6th of double tanks only during training. Apprentice and Full Cave students are allowed to dive up to their full thirds. Beyond full cave, with the addition of more gear that extends a dive's distance and time, the standards are less specific, since the number of variables increase dramatically. During training, with a competent and ethical instructor, the students will be taught how to calculate and check their turn pressures throughout the dive day. After any level of training, students should have not only the skills to perform "gas math" under any combination of buddy tank sizes but also the judgment to not dive beyond their gas restrictions. Have you ever cheated thirds, even for just a measly 100 PSI, so you could extend a dive to that next little piece of cave you haven't been to yet? Did you ever let your pride prevent you from turning a dive with a buddy who really does have a better air consumption rate? Did you ever, under Intro restrictions, dive the first dive on doubles using 1/6th and then, without topping off your tanks, just use the 1/3rd rule on the second dive? All of these are examples of lousy risk management – the diver is increasing the potential risk during the dive just to get a few minutes more at depth or distance. Consider if your tolerance to higher risk is equal, less or greater than your buddy's.

Dissimilar tanks and divers: Ask yourself if you can still recall how to "do the math" for dissimilar tank volumes. Can you accurately calculate or "guess in the water" what the turn pressure should be for both divers where one person is diving a low pressure single 104 filled to 3,200 PSI and the other is diving a set of double low pressure 95s filled to 2,700 PSI? Tables and simple ratio equations for calculating dissimilar tank volumes are taught or reinforced at all levels of overhead training and, as your cave diving matures, you should be able to derive turn pressures for any set of tanks. What if you have a three person team? You should use the 1/3rd calculated from the smallest volume buddy's tanks, even if the other two divers have enough 1/3rd to back each other up. This lowers the risk since an actual out of air emergency would not require having to hunt down the buddy that you know has the third to get you out, even if the buddy with the smaller volume has the best air consumption rate.

Team awareness: If you dive often with the same set of divers (as most divers tend to do) you will come to know the air consumption rates of each person. Even early on, given two strangers with similar experience in a well-known cave, you should have a rough idea as to when a dive should be called. Is that buddy goal oriented and attempting to squeak just a bit past where you would expect one or both to call on account of reserve gas? In case of a gas emergency do you know what is connected to which post on your backmounted buddy in case you have to do a valve shutdown on their behalf? If you are diving with a sidemount or rebreather buddy and you are back-mounted did you work out a plan for air sharing in case you lose all your gas?

Environmental conditions: During your training you were advised to back off the 1/6th or 1/3rd, depending on a number of environmental factors – is the cave a siphon? Is it a new system, where you may not be so certain that the time to exit would be equal to the time to hit your turn pressure? Are you diving with a new buddy or with new equipment or is this a "big dive" for you? Do you need extra gas at the end of the dive for any required de-compression? Did you calculate for any extended deco, should symptoms arise?

Specialty situations: Beyond the Full Cave level divers have a dizzying array of equipment and training that they can use to extend bottom time, range or perform different tasks. Slap a stage bottle on a backmounted diver and now you have another gas source that can be used to extend your dive. Do you use the 1/3rd rule on the stage? Could you accept the added risk of ½ plus 200 PSI, as some stage divers do? Where do you drop your stage bot-tle, at the point of hitting it's turn pressure or farther upstream? What about clipping on a DPV? Common sense would say that the 1/3rd rule could get you into trouble, as you must consider worst case scenarios with your and your buddy's gear. One DPV class that I taught I had the students drill on various combinations of loss of one or both DPVs at maximum penetration, loss of lights and loss of air. Air consumption rates calculated from these experiments, even under controlled situations, showed that without careful, detailed and redundant gas planning most of the DPV/light/backgas failures would have resulted in either a single or dual fatality simply because there wasn't enough gas available to, say, swim 3,000 feet out after two scooters failing. Mix in stages and scooters and now the dive team has to figure out the combined issues of managing gas in those two environments. Deep diving, with gases designed to only be used in different depth ranges, further complicates the gas management issues, as does the need to calculate volumes needed for required decompression at the deco stops. How do you account for sidemounting buddies or a buddy on a rebreather? Does the team treat them as solo divers (self-sufficient with respect to gas management) that happen to be along for the ride? In a zero viz situation as a back-mounted diver would you remember to not bother going to the sidemount or rebreather buddy, since more than likely they only have sufficient sidegas or bailout to get them out? How do you factor in the additional tasks in-volved while doing survey or recovery work?

Solo diving: Some people simply bypass the entire argument of having to worry about preserving some portion of their gas for a low (but non-zero) probability event happening to their buddy by diving solo. The NACD, as speci-fied in the S&P, neither condones nor disapproves of solo diving. Unlike all the other forms of speciality diving interwoven above, the NACD does not offer a course in solo diving. Still, people are not all the same and some of you may have actually done solo diving or are considering it. If you do decide to "dive with AL" make sure that you have thought through all of the factors besides worrying about having enough gas should you have a fail-ure in your doubles, stages, sidemount bottles or rebreather. Most folks, however, choose to rely on competent buddies that have exhibited strong awareness of team gas management and the ability in a true pinch to revert to their training and be an asset rather than a liability during a dive.

Summary: This short article is no replacement for formal training or actual experience. It should help raise awareness of how complex an issue gas management can be and how, before your next dive, you may consider more carefully the rule of thirds.

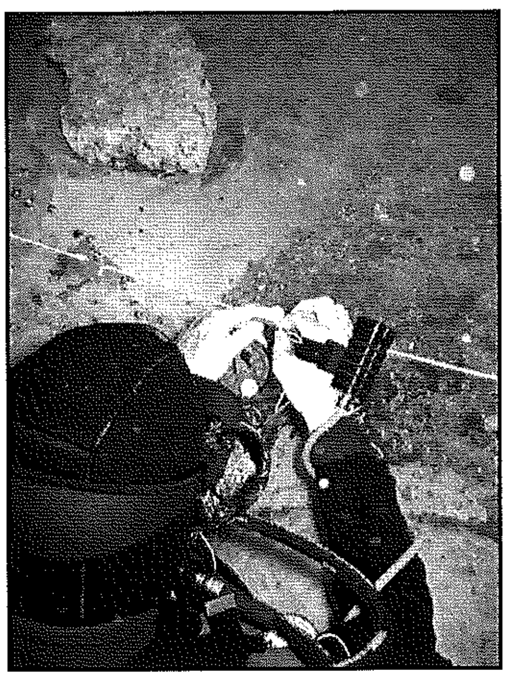
Training Tips (NACD Journal, Volume 38, 3rd Quarter)

Managing Transitions

By Larry Green, NACD Director of Training

Teaching cave diving is a matter of training and conditioning students to respond properly both physically and mentally during a cave dive. Some skills, like the modified frog kick, have a pure physical component and mastery is achieved through demonstration, teaching, critique and practice. The true skill of cave diving, after the physical techniques are mastered, is in achieving mental mastery of the discipline. One of the most critical mental components of a cave dive is how individuals and the team respond to **transitions** during the dive.

A transition is any point of the dive where an event occurs that changes the phase of the dive. Transitions start at the very beginning, from the moment the team leader gives the "descend" thumbs-down hand signal, to the final "surface now" signal at the end of a safety or final deco stop. The most critical cognitive factor is making sure that everybody on the dive team is fully aware of the transition so that they know what to expect next. Usually a simple "OK" that is returned by all team members (recall "OK" is a command signal that commands a response and if one isn't received then things are not OK) is enough to acknowledge that the transition is occurring. Taking the time to stop and signal your buddies after any logical transition point also serves as a nice mental break before beginning the next phase. Other key transition points include the tie-in of the primary into the mainline, tie-off of both ends of jumps, dropping and switching gas mixes, moving from swimming to DPV and back, retrieving reels, starting and stopping survey work, etc. An instructor during a class dive will look for communication breakdown during these transitions and may even perturb the dive enough to make the point that lack of a "full team synchronization" caused a small problem (such as faking a primary light failure) to snowball into a lost buddy drill. Some of the best "lessons learned" during post dive analysis invariably revolve around an assumption about what a buddy thought he or she was supposed to do at these key transition points. Think about the transitions you will perform on your next cave dive. While no accident analysis statistics point definitively to lack of communication during a transition as a cause of a fatality or an injury, our own experiences might indicate otherwise. Have you ever just tied off the primary then continue swimming without signaling or had a buddy do the same? How about a stage switch or retrieval? Next time you "plan your dive and dive your plan" think about making your transitions smooth, clear and distinct elements of your dive. Always remember each member of the team will take responsibility for validating all navigational transitions during their dive. Don't be a follower.



The Ins and Outs of HID lighting: 18/21 W HID lights
(NACD Journal, Volume 39, 1st Quarter)

By Marius Clore, Equipment/Technology Chair

Editor's note: This is an article written about dive light technology and while the information presented here will eventually become dated as technology advances the information will still prove useful for some time to come.

Cave diving is critically dependent on lighting, hence the absolute minimum requirement of one primary light and two backup lights. The primary light must be sufficiently powerful both to signal appropriately and to view the cave, while the backup lights, which must be very reliable, need be only sufficient to follow the guideline out of the cave.

The advent of HID lighting has led to considerable improvements in both the quality of light and burn time over the older halogen lights. HID stands for High Intensity Discharge, and HID bulbs consist of two electrodes a short distance apart in a gas-filled chamber. A high voltage (low current) pulse across the electrodes creates an initial spark that results in the formation of a small plasma arc which produces a very broad band of high intensity light extending from the infrared to the ultraviolet.

In this brief article, I will summarize the basic features of HID lights, and compare HID lights in the 18/21W range from a number of manufacturers, including Salvo, Halcyon, Dive Rite and Sartek (see Table for summary of features and specifications).

In terms of components, an analogy between a HID light and a tank and regulator is useful. Every HID light comprises a battery canister, a battery, a ballast and a light head which are analogous to the tank, air supply, regulator 1st stage and regulator second stage, respectively. It is also worth considering that HID light usage should be considered in the same vein as air usage. Just as one turns a dive on 1/3rds, one should never plan a dive where the total possible duration of the dive is going to exceed half the burn time. Moreover, one should be conservative in this estimate since, in contrast to one's air supply where one has a direct read out of remaining air pressure, it is impossible to know exactly what the total burn time is going to be, since this is obviously dependent on how well the battery has been charged (see below).

Given that HID lights are built from standard components, the variations in design are rather limited, and consequently, the choice of light is to a large extent a personal one based on preferences relating, for example, to the size of the canister, the packaging of the light head and the materials employed.

The canister. The canister should be robust and water tight. Salvo and Halcyon use Delrin, Dive Rite uses PVC and Sartek uses acrylic. Delrin is a more reliable material under extreme conditions, is not susceptible to cracking when dropped, and doesn't become brittle in extreme cold. This may be important when diving in the Arctic, but under the environmental conditions found in Florida and Mexico, there is little to distinguish between the three materials. The dimensions of the canister are governed by the choice of battery pack configuration. The dimensions of the Salvo and Halcyon 9 Ah canisters are identical, while Dive Rites' is wider, and Sartek's is both wider and shorter. Indeed, the dimensions of Dive Rite's wreck canister is the same length as the Salvo and Halcyon's 13 Ah canister and only minimally narrower (3.5" versus 3.75").

The batteries. Modern HID lights are generally powered by nickel metal hydride (NiMH) rechargeable batteries. NiMH batteries provide the same energy (measured in Wh) as lead acetate batteries in a much smaller package (about half the weight and size for equivalent power capacity), they have a relatively long life with no cell memory, and withstand high charge/discharge currents. Generally, the nominal voltage of the pack is 12V and the total energy is given by the capacity in Ah times the nominal voltage. Thus a 9Ah 12V battery pack has a total energy of 108 Wh. If the ballast consumes 24 W (for an output of 18 W dues to losses), the total burn time can be estimated at 4.5 hours. However, the capacity of NiMH batteries is usually 10% lower than the rated capacity, yielding an actual burn time of about 4 hours. A 9 Ah pack can be built from either twenty 4.5 Ah 4/3 Fat A batteries comprising two strings in parallel, each comprising 10 batteries in series which easily fits into a 2.75"x10.5" canister, as in the case of the Salvo and Halcyon lights. Alternatively, a more reliable pack in terms of obtaining a full charge (see below) can be built from a string of ten 12V, 9Ah D batteries in series, but the dimensions of this pack are quite a bit larger and can therefore only fit in either the 13.5 Ah Salvo and Halcyon canisters (3.75 x 10.75").

A critical aspect of any battery is the ability to easily and reliably obtain a full charge. The simplest and most compact charger, in my opinion, is the multi-current Universal Smart Charger (which comes with the Salvo light but can be bought from under $30 from a third party supplier such as batteryspace.com) or equivalent (e.g. sold with the Dive Rite and Sartek lights). These chargers automatically detect the battery pack's voltage and are automatically cut-off by a negative delta V when the battery pack is fully charged. Halcyon employs a more cumbersome, bulky and, in principal, more sophisticated charger which also makes use of a thermistor to cut-off the charger should the battery pack overheat. For a 12V battery pack, however, a thermistor is completely unnecessary and unfortunately can result in the unfortunate circumstance of the charger being shut off before a complete charge is obtained. This, of course, is potentially highly problematic in the context of cave diving if, for example, a situation arose in which the battery pack were only half charged and one went diving on the expectation of a burn time of say 4 hours when the available burn time was actually only 2 hours!

One problem associated with the series/parallel design commonly employed by HID dive light manufacturers is that one string can take all the charge leaving the other string uncharged or only partially charged. This will occur when the impedance of the two strings is no longer close to identical. This will invariably occur with age as the capacity of the individual cells falls off at slightly different rates. One solution would be to charge the two strings separately, but the way the packs are put together doesn't allow this and, moreover, an external connection between the strings would probably introduce an undesirable failure point. Alternatively, one can directly monitor both the voltage and the capacity during the charge by means of a mini-power analyzer (e.g. Watt's Up which can be purchased for around $50) which monitors energy (Wh), charge (Ah), power (W), current (A) and voltage (V). Given the importance of knowing that one's battery pack is fully charged, I personally consider the mini-power analyzer as an absolutely essential piece of gear that should always be used when charging one's battery pack. Another very useful tool is a battery burn tester such as the CBAII West Mountain Radio computerized battery analyzer, which performs a constant current capacity test that can be directly visualized on a PC.

In terms of battery capacity, I would personally advise going with a 13.5 Ah battery pack rather than a 9 Ah one. This isn't an issue if one is only going to do a single 60-90 minute dive per day, but for visitors to cave country who want to do two or more dives a day, the additional 50% burn time afforded by the larger battery pack gives piece of mind. At this time, 13.5 Ah battery packs are offered by both Halcyon and Salvo and are built from 3 strings in parallel, each comprising ten 12V 4.5Ah 4/3 Fat A batteries. These fit into a canister 3.75" x 10.75". Although the diameter of the 13.5 Ah canister is about 30% wider than the 9 Ah canister, the difference in size does not result in any increase in drag and is completely unnoticeable under water.

The canister/battery pack is connected to the ballast by a cable, typically around 40" in length. The connections to the canister and the ballast should be equipped with strain relievers. Robot grade cable which is flexible and resists ware well is desirable. However, if damaged, water will be forced down the robot grade cable and can potentially damage the whole system. To prevent this, Salvo has recently introduced a completely sealed dry lid that prevents water intrusion into the canister should the cord or switch boot be damaged. More reliable cable may be afforded by submarine grade waterblocked cable which has even greater damage tolerance, but is less flexible.

The ballast. The purpose of the ballast is to ensure a constant, high voltage, power supply to the bulb. (The typical voltage required to start a HID light is between 1000 and 2000 V). As the voltage of the battery decreases, so the amps drawn increases. The two main manufacturers of HID bulbs and ballasts are Welch Allyn (US) and Brightstar (Taiwan). The Welch Allyn ballast is about 75% efficient, while Brightstar's ballast is greater than 85% efficient. That is 25% of the input power in the case of the Welch Allyn ballast, and 15% in the case of the Brightstar one is dissipated in the form of heat. What this means in practice is that for 18W of output from the ballast, the input power required by the Brightstar ballast is significantly less than that for the Welch Allyn ballast (about 21W versus 24W). This directly translates into a proportionately longer burn time for the Brightstar compared to the Welch-Allyn ballast/bulb system (i.e., for a 9 Ah battery pack and a HID bulb powered at 18W, 5 hours versus 4 hours, respectively). In addition, because the Brightstar ballast is digital it allows for a hot re-strike at an interval of less than 1 second compared to over 8 seconds for the Welch Allyn ballast. From an ergonomic perspective, there are also differences in the form of the ballast. The Welch Allyn ballast is a rectangular block while the new Brightstar one is cylindrical (see below).

The HID bulb. In considering the HID bulb itself, several factors need to be taken into consideration. The intensity of the beam, both perceived and real, is governed not by the wattage, but by the color temperature (measured in Kelvins), the luminosity (measured in lumens), and the ability of the reflector to redirect and focus the light into a narrow beam.

Technically, the color temperature refers to the temperature to which one would have to heat a theoretical black body source to produce light of the same visual color. Typical color temperatures are 1500 K for candle light, 3400 K for a tungsten lamp, 5500 K for sunny daylight around noon, and 6500-7500 K for an overcast bluish sky. Color temperature is not measured quantitatively but by human perception comparing the light source to a true black body source. Hence the numbers quoted by different HID manufacturers are not strictly comparable. That being said, the the old 21W Brightstar bulb (5500 K) appears white, the new 18W/21W/24W Brightstar bulb appears distinctly bluish at 18W (7000K), as does the 18W Welch-Allyn (6500 K). Moreover, when driven by an 18W ballast the new Brightstar HID bulb is clearly bluer than the 18W Welch-Allyn one. When the same Brightstar bulb is driven by a 21W ballast, the color temperature is virtually identical to that of the Welch-Allyn bulb, but the overtones around the outer edges of the beam are greenish versus reddish in hue. The latter are irrelevant since they cannot be seen under water.

Lumens are a measure of total light output at the source, but it is important to stress that one *cannot* directly compare the lumen ratings from one manufacturer to another. This is because visible light ranges from 400-700 nm, but HID lights produce a lot of invisible light in both the infrared and ultraviolet, and the spectral power distribution of the different HID lights is not the same. Thus, for example, although the 18W Brighstar is rated at 1300 lumens, the light produced does not appear to be quite as intense as a brand new 18W Welch-Allyn which is rated at 1100 lumens (note the intensity of the Welch Allyn bulb tends to decrease with age and usage). However, the exact same Brightstar bulb driven by a 21W ballast, which is rated at 1500 lumens, is essentially identical to the naked eye in intensity (perhaps a little brighter) and color to the 18W Welch-Allyn bulb. Since the Brightstar ballasts are more efficient than the Welch-Allyn one, the burn time of the new 21 W Brightstar system is the same as that of the 18W Welch Allyn.

The reflector. The reflector takes the light generated by the HID and redirects and focuses it into a tight beam. The narrower the beam, the less the scatter, and the further the throw. Thus a floodlight, which is useful for videography, will produce a lot of illumination but only extends over a short distance, whereas a narrow beam, which is essential for signaling, will extend over a much longer distance. It is therefore desirable to have a focusable light. This is easily obtained by a design in which the position of the reflector relative to the bulb can be easily adjusted. The beams produced by the Salvo, Halcyon and Dive Rite lights are all quite comparable. The Salvo and Halcyon reflectors are identical and personally I prefer their design to that employed by Dive Rite. (In addition, the Salvo and Halcyon beams are a little narrower than Dive Rite's). An even more narrowly focused beam can be obtained with the EKPP reflector but this comes at a cost. The diameter of the EKPP reflector is 27% larger (3.25" versus 2.75").

The Goodman handle assembly. Effective use of a HID light in cave diving requires a means to hold the light head assembly while still permitting one to use one's hands for other things (e.g. running a line, pulling oneself along, etc....). This is accomplished by a Goodman Handle. My preference is for a metal (generally aluminum) Goodman handle which brings me onto the feel/ergonomics of the light in one's hands. If one just looked at the Salvo and Halcyon 18W HIDs, the only noticeable difference would be the shape of the ballast. The Brightstar ballast is cylindrical, whereas the Welch Allyn one is a rectangular block. The complete light head used by Dive Rite is also cylindrical but of larger diameter than the Salvo light. Personally, I prefer the way the Salvo cylindrical ballast and light head lies on one's wrist, but this is very much a personal opinion.

HID durability. In considering HID lights, one other important consideration needs to be borne in mind, namely the sturdiness of the bulb to the sort of abuse that is likely to be encountered by a diving light (both in the water and on land). HID bulbs are expensive (upwards $200) and therefore not throw away items. The design of the Welch-Allyn bulb is such that it is very easily broken by shear forces. This is not an issue in the water unless one were to smash one's light with considerable force against a rock, which is probably quite a lot harder to accomplish than one might imagine, given the viscosity of water. However, it is a very significant problem on land. Both the old 21W Brightstar bulb used by Dive Rite and the new 18/21/24W Brightstar bulb used by Salvo are very resilient to sheer. Thus, one can drop a Salvo or Dive Rite light with impunity and the HID bulb will not be damaged in any way, but the Welch-Allyn bulb employed by Halcyon will very likely break. Likewise one can smash the Salvo HID light on a table again and again with no ill-effect. This is absolutely not the case for the Halcyon HID bulb which will break immediately upon such harsh treatment.

Newer developments.
Switchable power HID lights. I didn't test the old Sartek 18W HID. While the design is a little different from that of the Halcyon and Salvo HIDs (the rectangular block-shaped ballast on the Sartek model is mounted at right angles to the light head), the old Sartek 18W HID makes use of the Welch Allyn ballast and bulb, and consequently it's performance is basically the same as that of the Halcyon HID. Sartek, however, are coming out with a new HID light which is switchable between 10W and 21W. The size of the light head and ballast assembly is similar to that of the Halcyon and Salvo lights, although it is made of aluminum instead of Delrin. The ability to switch between two power levels may at first appear to be something of a gimmick. However, power switchability may have some significant advantages. For example, most of the time the power of an 18/21W HID may not be required and one would only switch to higher power when one wanted the beam to project further, for example, for signaling or to see the depths of the cave. In addition, when visibility is reduced by particulate matter (e.g. murky water), dimming the light may actually yield better visibility by reducing the backscatter (equivalent to driving with fog lights or dimmed headlights in fog or snow).

Li-ion battery packs. Li-ion rechargeable batteries offer increased capacity in an even smaller package than NiMH batteries. For example, a 14.4V 9.6Ah Li-ion pack can readily fit into the 9 Ah Salvo and Halcyon canisters, offering close to 50% more burn time, relative to a 12V 9.5Ah NiMH battery pack. (i.e. for the Salvo 21W HID, the burn time is increased from 4 to 6 hours). Salvo has recently introduced a series of 21W HID lights powered by various Li-ion packs of different capacities, using the same Brightstar bulb and ballast employed for their NiMH based lights. Although these Li-ion packs employ a parallel/series design, the use of IC chips ensures that all strings in the pack can be fully and reliably charged. In addition, Li-ion batteries exhibit a much lower self-discharge rate than NiMH batteries (about 5% per month compared to 30% month). The disadvantage of Li-ion batteries, however, is that their capacity decreases over time from the date of manufacture, irrespective of usage, the extent of which depends upon storage conditions: at 100% charge about 20% per year at room temperature but only 4-6% per year at typical refrigerator temperatures; at 40% charge, however, these numbers are significantly reduced to 4 and 2%, respectively. In other words, do not fully charge up a Li-ion battery pack after a dive, but wait until the night before one's next dive, and keep the pack in a refrigerator when not in use.

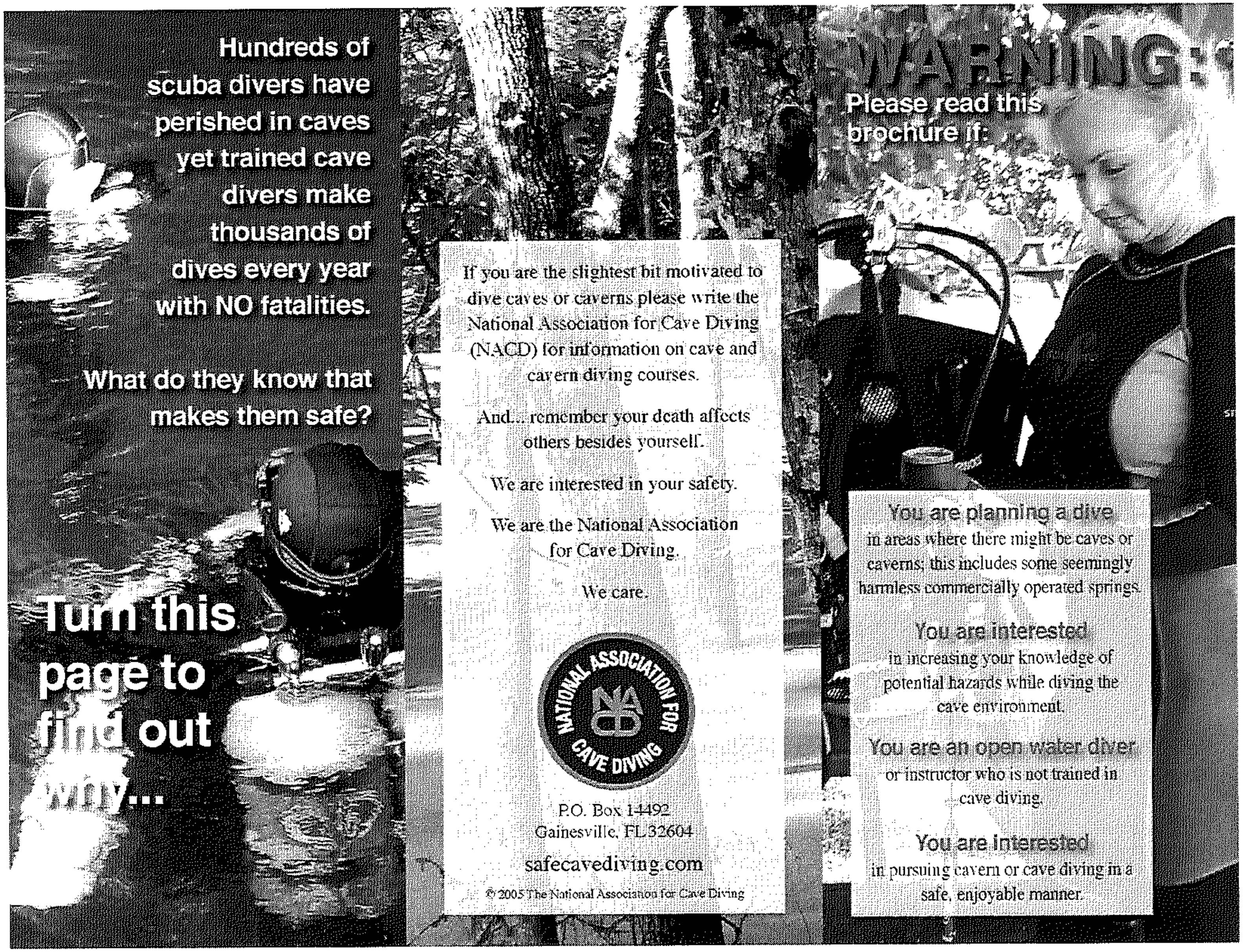
LED primary lights. A more revolutionary development is the use of LED lights. The problem with LEDs is that while they produce a lot of light, the light is difficult to focus and therefore, until recently, of little use in diving. A new company, Solus in Ireland, has succeeded in designing an LED array with high power optics of sufficient intensity to be suitable for a very nice primary wreck diving light. The Solus LED canister light generates light only in the visible range (400-750 nm) with an intensity that is claimed to be comparable to an 18W HID (although direct comparison with the Salvo 21W HID, incorporating the new Brightstar bulb, indicates that it is actually quite a bit less intense). The current Solus light design is not focusable, but the beam is still quite narrow (12 degrees), although nowhere near as narrow as those produced by the Salvo, Halcyon and EKPP reflectors (6-8 degrees). In addition the intensity of the LED light is switchable between two power levels. LED lights are virtually indestructible, extremely reliable since they employ solid state electronics, can be switched on and off instantly, just like a regular LED flash light, and their expected life time is about 30 times greater than that of a HID light (30,000 hours versus 1000 hours), which is probably more than enough for a lifetime of diving. Further refinement of the LED technology to generate narrower (6-8 degrees) and more intense beams clearer represents the wave of the future.

Conclusions. Salvo, Halcyon, Dive Rite and Sartek all make very high quality HID lights and provide outstanding after-sales support should things go wrong. Any one of these HID lights makes an excellent primary light for cave diving. Thus, choice comes down to personal preference and cost. With respect to the HID lights specifically listed in the Table, my own choice, taking into account value for money, performance, durability, quality of design and ergonomics, would be for the Salvo 21W HID. It should be noted, however, that Dive Rite has discontinued its 21W HID and is in the process of finalizing the design for a new 24 HID. Likewise, as noted above, Sartek is coming out with a new HID light that is smaller than their older 18W HID and has the added advantage that the light beam can be switched on the fly from low (10W) to high (21 W) power.

Comparison of 18/21 W HID lights from different manufacturers.

	Salvo	Halcyon	Dive Rite[a]	Sartek[b]
Canister[c]	Delrin	Delrin	PVC	Acrylic
Dimen-	2.75"x	2.75"x	3.5"x	3.75"x
Battery	12V, 9Ah	12V, 9Ah	10.8V,	12V, 9Ah
Burn time	5hr	4hr	3hr	4hr
Bulb and ballast	Brightstar	Welch Allyn	Bright-star	Welch Allyn
Power	18W/21	18W	21W	18W
Lumens[g]	1300/150 0 lm[f]	1150 lm	1100 lm	1150 lm
Color tempera-	7000/650 0 K[f]	6500 K	6000 K	6500 K
Cost	$1200	$1550	$1269	$1365

[a]The 21W Dive Rite HID has been discontinued, and will shortly be replaced by a 24 HID.
[b]The 18W Sartek has been discontinued and will be replaced by a switchable 10W/21W HID.
[c]Only the specifications for the 9Ah canister are given. The 13.5 Ah Salvo and Halcyon canisters are of larger diameter (3.5"), but the height remains the same.
[d]Burn time is directly proportional to the stored energy in Wh given by V x Ah. Thus, the burn time of a 13.5Ah 12V NiMH battery pack will be ca 40% longer than that of a 9Ah 12V NiMH battery pack.
[e]The old 21W Brightstar bulb.
[f]The first number relates to the 18W ballast, and the second to the 21W ballast. The bulb is identical in both cases.
[g]The intensity to the naked high and the rating in lumens are not strictly correlated since the spectral and power distribution of the light factors in to what the eye perceives. This is why, to the naked eye, the intensities of the new 21W Brightstar and 18W Welch Allyn, both of which have the same color temperature rating of 6500 K, are comparable, although their lumen ratings are significantly different.


Hundreds of scuba divers have perished in caves yet trained cave divers make thousands of dives every year with NO fatalities.
What do they know that makes them safe?
Turn this page to find out why...
If you are the slightest bit motivated to dive caves or caverns please write the National Association for Cave Diving (NACD) for information on cave and cavern diving courses.
And... remember your death affects others besides yourself.
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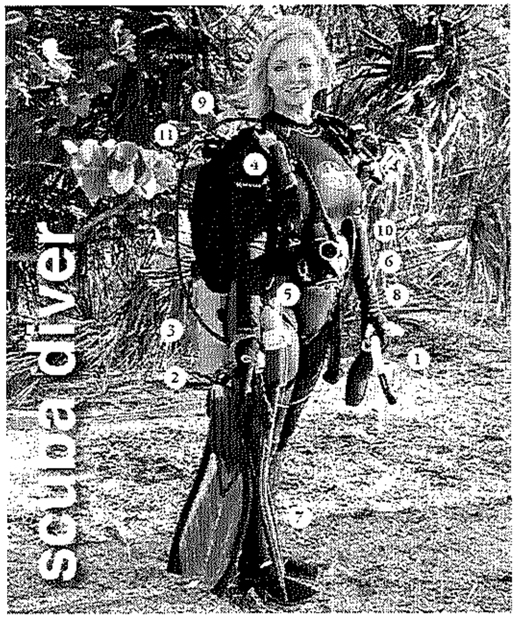
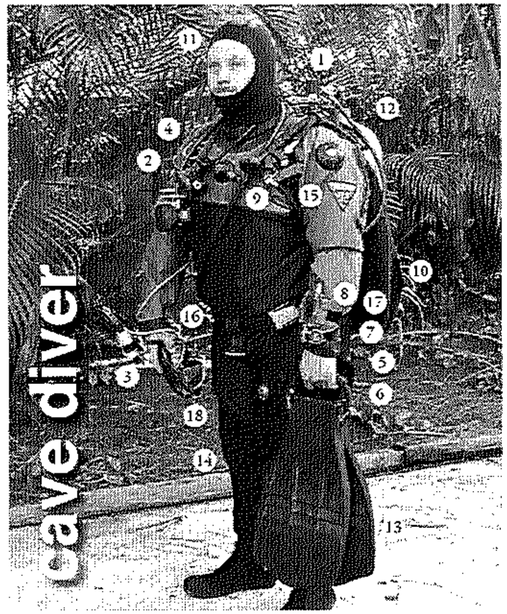
WARNING:
Please read this brochure if:
You are planning a dive
in areas where there might be caves or caverns; this includes some seemingly harmless commercially operated springs.
You are interested
in increasing your knowledge of potential hazards while diving the cave environment.
You are an open water diver
or instructor who is not trained in cave diving.
You are interested
in pursuing cavern or cave diving in a safe, enjoyable manner.



1 Snorkel: useless in caves, could cause line entanglement
2 Reef gloves: limits sense of touch
3 Single tank: although limited work can be done on a single tank, the time to solve problems is greatly reduced
4 One light: the chances of light failing is 86% in 100 dives. If you are in a cave the last thing you may see is the dying glow of the filament when it quits
5 Alternate air source: some are inappropriate for caves
6 Weight belt: forces fins towards cave floor which can cause sudden loss of visibility
7 Large knife: good for skinning fish, bad for caves, causes potential line entanglement
8 Depth gauge and watch: some caves are deep and involve training in decompression procedures, backups should be worn
9 Short hose: cannot share air through tight passageways
10 Sport tables: good for no-decompression diving only
11 Single outlet valve: provides no safety cushion against regulator failure

Scuba diver or instructor certification: safe on the reef but does not qualify you to dive caves. Instructors sometimes compound the problem by taking themselves and students in cave areas



1 Dual orifice manifold: allows for safe management of regulator failures
2 Redundant regulators: provides safety cushion and alternate air source for sharing air, one with long hose
3 Primary light: long burn time and bright illumination
4 Safety/backup lights: minimum of 2
5 Reel & guideline: helps locate exit in low visibility and prevents confusion in complex tunnels
6 Safety reel: navigational aid in emergency
7 Watches or timers
8 Depth gauges
9 S.P.G.: provides for safe air management
10 Buoyancy device: keeps diver neutral and off the cave floor
11 Hood: protects head
12 Twin tanks: more air = more time to sort out problems
13 Power fins: overcome additional drag from cave gear
14 Thermal protection: many caves are cold
15 Backup knife or line cutter
16 Decompression tables, slate or wetnotes
17 Knife: small and razor sharp
18 Spare mask (optional)

Cave certification: trained, comfortable and responsible

Please let us help save your life!

FACT:
No amount of open water experience can prepare your for safe cave diving.

FACT:
No formal training in open water diving including instructor courses can prepare you for safe cave diving.

FACT:
Open water divers have a very BAD safety record in caves.

FACT:
Trained cave divers have an excellent safety record.

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