

PURDUE
UNIVERSITY

Subsurface Utility Engineering

**A Feasibility Study and Guideline for
Naval Facilities Engineering Command**

by

Jason H. Lockhart

DISTRIBUTION STATEMENT A

Approved for Public Release
Distribution Unlimited

August 2004

20040907 003

**CONSTRUCTION
ENGINEERING &
MANAGEMENT**
PURDUE ■ UNIVERSITY

**Purdue University
Division of Construction
Engineering and Management
School of Civil Engineering
West Lafayette, Indiana 47907-2051**

BEST AVAILABLE COPY

Subsurface Utility Engineering
A Feasibility Study and Guideline for
Naval Facilities Engineering Command

An Independent Research Study

Presented to

The Faculty of

The School of Civil Engineering

Purdue University

by

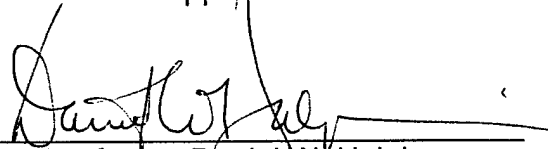
Jason H. Lockhart

In Partial Fulfillment of the Requirements for the Degree of

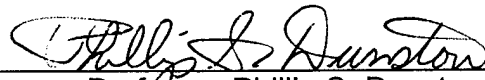
Master of Science in Civil Engineering

August 2004

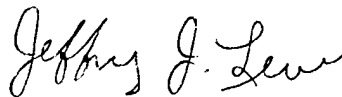
Approved:



Professor Daniel W. Halpin
Chair, Advisory Committee



Professor Phillip S. Dunston
Member, Advisory Committee



Professor Jeffrey J. Lew
Member, Advisory Committee

Acknowledgments

First of all, I would like to thank the United States Navy for giving me the opportunity to pursue my master's degree at Purdue University. The time here has provided a valuable educational experience as well as many friendships and professional relationships. During the last year, it has also been a pleasure to attend classes and work with the other three Civil Engineer Corps Officers: LCDR Richard Anderson III, LT Patrick Jors and LTJG Aaron Turke.

This research paper could not have been accomplished without the input from the many professionals that are listed in the personal contacts section. A special thanks to those who were eager to assist and who went out of their way to provide information:

- Jerry Dummer; Utility Engineer at Naval Facilities Engineering Service Center
- James Anspach; Principal of So-Deep, Inc.
- Jim Allen; TBE Group, Inc.
- Michelle Jackson; Project Manager at NAVFAC Engineering Field Activity Southeast
- Mark Kraynak; Client Liaison Program Director at NAVFAC Headquarters
- C. Paul Scott; National Utilities Liaison for TBE Group, Inc.

Last, but not least, I would like to thank my family, especially my wife, for their encouragement and support that they have given me during this time. The hours that had been set aside for studying and researching, I now plan to spend with my wife and our soon to be born child.

Abstract

There is a general consensus among engineers and facility managers of military installations that the utility records and as-built drawings are of poor quality and/or inaccurate. The goal of verifying the location of all underground utilities before commencement of a construction project is usually unachievable. During the early stages of a construction project, an unknown subsurface utility is often discovered which results in a contract modification and an increased price of the project. Subsurface Utility Engineering (SUE) is an engineering discipline used to designate and verify the location of underground utilities and other obstructions. SUE is not a new technology although it has made significant advances in recent years, including the development and adoption of ASCE Standard Guideline 38-02. Ground Penetrating Radar (GPR), metal detectors and other designating devices are used in conjunction with vacuum excavators to verify the horizontal and vertical position of the utility.

Naval Facilities Engineering Command (NAVFAC) is the organization within the United States Navy which designs, constructs and maintains the facilities, and administers the construction contracts for the Navy and Marine Corps activities around the world. There are numerous subsurface utilities throughout the NAVFAC area of responsibility (AOR) that are not accurately located. This causes concern because there are many monetary and safety risks that arise because the locations of these utilities are unknown. SUE services have proven to be beneficial to some of the state departments of transportation and municipalities. This raises the question of whether or not the Department of the Navy (DON) and NAVFAC should contract or request in the specifications to have this service performed on major installations where unknown

subsurface utilities have caused the most substantial delays and increased the cost of construction projects.

This paper will discuss the most current methods being used throughout the industry and introduce NAVFAC personnel to the SUE process. A determination will be made of whether or not NAVFAC would benefit by incorporating SUE into more projects, especially where subsurface utilities may create a conflict.

Table of Contents

1	Introduction	1
1.1	Problem Statement	2
1.1.1	Accidents	3
1.1.2	Security Issues	4
1.2	Research Objectives	5
1.3	Organization.....	5
2	Methodology.....	7
2.1	Original Plan	7
2.1.1	Problem Encountered	8
2.2	Revised Plan.....	8
2.3	Outcome of Revised Plan	9
3	Subsurface Utilities on Military Installations	10
3.1	Inadequate Records.....	10
3.2	Previous Use of SUE on Navy Installations	11
3.3	Utility Data Management.....	13
3.3.1	Hardcopy Drawings	13
3.3.2	CADD Files	14
3.3.3	GIS Mapping.....	14
3.3.4	Accuracy	14
3.4	Utility Privatization.....	15
3.5	One-Call Utility Locating Service.....	16
3.6	Utility Design Process	18
4	Overview of SUE	20
4.1	Description of SUE.....	20
4.2	History of SUE (FHWA, 2004).....	22
4.3	Subsurface Utility Engineers.....	24
4.4	Disclaimers	25
4.5	Quality Levels of SUE	26
4.5.1	Quality Levels A-D	27
4.6	Current Limitations of SUE.....	30
4.7	Obstacles to overcome	30
4.8	Standards and Guidelines.....	31
4.9	Location of SUE Firms	32
5	Designating Methods	34
5.1	Electromagnetic Methods.....	34
5.1.1	Radio-frequency Pipe and Cable Locators	34
5.1.1.1	Conductive Mode.....	35
5.1.1.2	Inductive Mode	36
5.1.1.3	Passive Mode	36
5.1.2	Sonde Insertion Method.....	36

5.1.3	Tracing Wire / Metallic Marking Tape.....	37
5.1.4	E-line Locator.....	37
5.1.5	Terrain Conductivity Method.....	38
5.1.6	Electronic Marker System (EMS).....	38
5.1.7	Metal Detector	39
5.2	Ground Penetrating Radar (GPR) / Impulse Radar.....	39
5.3	Magnetic Method	40
5.4	Resistivity Method.....	41
5.5	Infrared Thermography / Thermal Imagery Method	41
5.6	Elastic Wave	41
5.6.1	Acoustic Emission Method.....	41
5.6.2	Seismic Reflection / Refraction Method	42
5.7	Designating Utility Depths.....	42
6	Previous Research.....	43
6.1	Previous Cost Analysis	43
6.2	Benefits of SUE.....	44
6.3	Decision Making Tools.....	45
7	Feasibility Study and Recommendations	47
7.1	Opinions by NAVFAC	47
7.2	Contracting Methods.....	49
7.2.1	Design-Bid-Build Contracts.....	50
7.2.2	Design-Build Contracts	50
7.2.3	Specifications.....	51
7.3	Recommendations for Future Work	52
7.3.1	Construction Modification Coding System	52
7.3.2	Cost Analysis Components.....	56
7.3.2.1	<i>Cost Data</i>	56
7.3.2.2	<i>SUE Survey Costs</i>	57
7.3.2.3	<i>Time Reduction</i>	59
7.3.2.4	<i>Contingency Cost</i>	59
7.3.2.5	<i>Change Order / Modification</i>	60
7.3.3	Case Study Experiments	60
7.4	Cost Justification.....	65
8	Conclusions.....	66
8.1	Summary.....	66
8.2	Closing Remarks.....	68
Appendix A	70
	Example of a FIS Modification Report (Original Coding System)	71
	Revised Coding System	72
	Example of a FIS Modification Report (Revised Coding System).....	73

Appendix B 74
 Locations of U.S. Navy Bases 75
 Locations of Qualified SUE Providers 76
 Locations of U.S. Marine Corps Bases 77

References 78

Bibliography 78

Personal Contacts 79

Figures and Tables

Figures

Figure 1: Utility Accident in Maryland	3
Figure 2: Various Utility Accidents	4
Figure 3: Duties of a Subsurface Utility Engineer	25
Figure 4: Progression of Events for a SUE Project	29
Figure 5: Conductive Mode	35
Figure 6: Sonde Method	37
Figure 7: Terrain Conductivity Method	38
Figure 8: EMS Markers	39
Figure 9: GPR Units	40

Tables

Table 1: Comparison of One-Call System and SUE	17
Table 2: EMS Utility Frequencies	39
Table 3: Summary of Purdue / FHWA Study	44
Table 4: Original Coding System.....	54
Table 5: Revised Coding System	55
Table 6: Cost Analysis (Case 1).....	62
Table 7: Cost Analysis (Case 2).....	64

1 Introduction

Subsurface Utility Engineering (SUE) is an engineering discipline used to designate and locate underground utilities. Information can be gathered such as vertical and horizontal location, type, material, size and condition of the utility infrastructure through the use of this technology. The knowledge of and more importantly the accurate location of otherwise unknown subsurface utilities will lead to a reduction in underground utility damage and minimize the disasters that can result from these preventable accidents.

SUE is described as an engineering process that utilizes advanced data processing and site characterization technologies that lead to the cost-effective collection, depiction, and management of existing utility information (Lew, 2000). All of this is accomplished using technologies such as surveying, surface geophysics, and mapping techniques along with Computer Aided Drafting (CAD) and Geographic Information System (GIS) software to efficiently store and utilize the gathered information. Subsurface utility engineers certify utility information in accordance with a standard classification (Quality Level) which allows for a clearer allocation of risk between the project owner, engineer, utility owner, and contractor. This seems to be much more effective and provide more benefits than disclaiming responsibility for the existing utility information (Lew, 2000).

1.1 Problem Statement

Naval Facilities Engineering Command (NAVFAC) is the organization within the United States Navy which designs, constructs and maintains the facilities for the Navy and Marine Corps activities around the world. NAVFAC is also responsible for awarding and administering most of the construction contracts that are performed on these installations.

There are Navy installations that are more than 200 years old and some are larger than small cities. Just like many older cities and facilities, the underground utility system of a military base is very similar to an intricate spider web. There are utilities such as phone, fiber optic, cable television (CATV), electric, gas, water, sanitary and storm sewer that have been placed in locations throughout the base, often interlaced causing many potential points of conflict. With many of these bases having a long history, the extremely frequent turnover of personnel and the change of ownership which sometimes occurs between different branches of the service, it is easy to see that the potential for unknown subsurface utilities is extremely high. At some bases, the chance of finding utility records for a certain area is often very low and if the records are available, the accuracy is sometimes questionable. This lack of subsurface utility information should be cause for concern because of the numerous safety and security problems that can result. A solution is needed that can provide a safer environment for the excavation contractors and at the same time reduce the financial impact caused by the unforeseen subsurface utilities.

1.1.1 Accidents

There is always the risk that an underground utility will not be located or accurately designated before digging begins and as a result, accidents, sometimes catastrophic, can occur. There are a number of ways to manage this risk, including the use of SUE.

In July 1999, a contractor, operating a dozer, unintentionally cut through a 6-inch steel gas main at Fort Meade Military Base in Maryland. The incident resulted in an explosion and the fire ultimately destroyed the dozer. Fortunately the operator escaped without injury. It was reported that the contractor had not contacted One-Call for a utility locate as required. The flames burned for several hours reaching heights of 100 feet and several power poles were destroyed. Figure 1 shows the fire department attempting to extinguish the dozer which is engulfed in flames.



Figure 1: Utility Accident in Maryland (<http://www.undergroundfocus.com>)

In February 2001, a contractor accidentally cut a power cable at the United States Military Academy at West Point, New York. The Academy was without power for approximately an hour and it was not reported if the utility was marked prior to excavation as is usually required on any project where digging may occur.

These two cases are examples of what can occur when the precise locations of underground utilities are not known. These are only two documented instances that occurred on military installations. There are accidents or near misses, usually less severe, which routinely occur during underground excavation. Action should be taken to minimize these accidents by using the most up to date technology that is available. Figure 2 shows some photographs of other catastrophic accidents.



Figure 2: Various Utility Accidents (<http://www.undergroundfocus.com/photolibrary.php>)

1.1.2 Security Issues

There are some important considerations that need to be addressed regarding underground utilities and their existence on critical facilities such as military bases, nuclear facilities, embassies, airports and so forth. Empty or partially filled conduits as well as abandoned pipes such as storm and sanitary lines often transition from the public side of the facility across to the private side, or critical area. Command and control facilities such as valves, manholes, pedestals, junction boxes and other structures for power and communication systems are often located on both sides of the property line. It is possible for people as well as chemicals, gases and other

contaminants to be transported into the sensitive areas through these utility lines. Security personnel should make it an extremely high priority to know the locations and types of all the utilities, abandoned and active, that are located both inside and outside of the property line (Anspach, 2002).

1.2 *Research Objectives*

The purpose of this paper is to research the most current SUE technologies that are being used in the field and to report the potential uses for military engineers. SUE is used in many civil projects, but only a small number of military installations have been introduced to the Subsurface Utility Engineering process. A sample of these projects will be investigated and the benefits and lessons learned will be reported.

This paper is intended to provide an introduction of SUE while describing some of the technical methods and potential benefits that could be realized, if implemented correctly. This work is also meant to provide an overview of SUE, specifically directed toward NAVFAC personnel and others involved in utility work that is funded by the Federal Government. This paper could potentially be used as a guide for NAVFAC personnel or other military engineers that are considering the use of SUE on construction projects where excavation is included in the scope of work.

1.3 *Organization*

This paper has been divided into eight (8) chapters. The first chapter is the introduction which details the problem statement. The second chapter is the methodology which describes the plan of action that was taken to accomplish this research paper. Chapter 3 describes how subsurface utility data are managed on

military installations. The fourth chapter is a general overview of SUE including the history and definitions. Chapter 5 describes the current methods that are used to designate subsurface utilities. The sixth chapter discusses some significant research that has previously been done. Chapter 7 discusses the information that was gathered during the research phase that will be used to determine if SUE can be beneficial to NAVFAC. Recommendations for future work are also made in chapter 7. The eighth and final chapter summarizes the entire paper.

2 Methodology

The initial focus of this paper was to determine if SUE had been used on past NAVFAC construction projects and if SUE would have been beneficial on previous NAVFAC projects in which it was not used. An intended feasibility study along with a cost-benefit analysis was to be performed on the projects that were found. The quantifiable cost data were to be gathered from the field offices and then analyzed.

The first step in learning about SUE and its use in the Navy was to contact some of the utility experts at the Naval Facilities Engineering Service Center (NFESC) in Port Hueneme, California. Early discussions with NFESC indicated there had been no use of SUE on NAVFAC construction projects. Contact was also made with NAVFAC Headquarters in Washington, D.C., which provided no leads to projects or field offices that were using SUE. This information caused the research to focus on NAVFAC projects, which had been affected by unknown subsurface utilities, to determine if there would have been a benefit by using SUE technology.

2.1 *Original Plan*

The original plan for analysis was to locate NAVFAC construction projects that had recently been completed, which had not incorporated SUE during any portion of the project. A search was to be performed in order to locate all change orders or modifications that had been issued because of unforeseen utility conflicts. The financial impact that had been experienced was to be calculated using the actual quantifiable cost data that were extracted from the file archives. Once a dollar figure had been

calculated, the original design documents that had been distributed during the bidding process were to be gathered and sent to a subsurface engineer who was unfamiliar with the project. The subsurface utility engineer would be requested to provide an estimate, detailing the cost it would have taken to perform SUE services in the vicinity of the project, based on the original design documents and the engineer's expert recommendations.

2.1.1 Problem Encountered

The original plan for analysis was not able to be accomplished during the time allotment for this project. It was found to be very difficult to gather the specific project cost data as well as track down the change orders or modifications. The difficulties that were encountered were primarily caused by the modification coding system that is used by the contracting specialists when entering the information into one of the financial tracking software programs. A recommendation to improve this system, toward a greater ability in capturing cost data, will be discussed in chapter 7.

2.2 Revised Plan

The focus of the research shifted from finding NAVFAC construction projects that could benefit from SUE, to finding any military construction projects that had realized a benefit from SUE. Following the initial discussions with NFESC and NAVFAC Headquarters, it was thought that SUE was not being used on NAVFAC projects. Therefore, contact was made with a number of SUE firms to inquire about their prior work on government projects including Air Force and Army construction projects. There were eventually some projects found that had been completed in Florida. Some of the

projects had been administered by NAVFAC, some by the Army Corps of Engineers. The projects that were found in Florida were discovered through discussions with a SUE firm that has an office in northern Florida. These projects were uncovered during the late stages of the research and therefore were not able to be thoroughly analyzed.

Contact was made with some of the NAVFAC personnel that were involved with the above mentioned projects. The professional opinions and lessons learned were asked of each person contacted to provide some insight into how SUE has impacted various NAVFAC construction projects.

2.3 Outcome of Revised Plan

Due to the time constraints of this research, the intended cost-benefit analysis could not be performed. There were some other inhibiting factors that prevented the original plan from materializing such as the modification coding system and the lack of knowledge pertaining to SUE by many instrumental NAVFAC components. A recommendation will be made to suggest changes in the modification tracking methods. Recommendations will also be made to conduct two case studies on NAVFAC construction projects. Gathering the data for these case studies may be the largest obstacle.

3 Subsurface Utilities on Military Installations

Military bases are very similar to small cities with respect to the underground utility system. There is often an abundance of utility pipes, conduits, tanks and many other structures located throughout the base. Naval Facilities Engineering Command is responsible for some very old and very large installations. Four very prominent stateside bases are detailed below:

- Washington Naval Yard – Established in 1799; U.S. Navy's oldest shore establishment; 121 acres
- Naval Training Center Great Lakes – Established 1911; 1628 acres
- Norfolk Naval Station – Established in 1917; world's largest Naval Station; 4300 acres
- San Diego Naval Station – Established in 1919; 977 acres

San Diego, Norfolk and Great Lakes are three of the most active installations and for that reason there are millions of dollars in construction being performed at each base, every year. Underground construction is often a large portion of the work being performed due to the age of the facilities and the continued need to upgrade many of the utility systems.

3.1 *Inadequate Records*

Many military bases are forced to deal with the problems caused by the lack of accurate records or the information which details the erroneous location of some subsurface utilities. The existing records are often incomplete, incorrect or otherwise inadequate. Four common reasons that this problem exists are:

- Existing records are not “as-built” drawings: The construction is performed according to the design drawings. If a field change is made and it is not documented on the drawings, it will cause a discrepancy
- Records are lost or misplaced: There is a very high turnover rate on military installations which makes archiving and filing of documents a logistical problem
- Obsolete utilities are removed from the ground, but never removed from the drawings
- Reference points are often removed such as building corners, property pins, curb lines, and other structures

There are very few projects today in which the responsibility for utility locating is not passed all the way down to the construction contractor. In most cases, the government takes responsibility for unknown utilities because the current policy is that the contractor should not be held accountable for a line that was not documented. However, if the contractor hits a line that was shown on a drawing or approximately designated through the One-Call service, they are usually responsible for the damage. There is usually a note in the construction specifications or on the design documents that places the responsibility on the contractor to locate all the utilities prior to excavation. This causes the contractor to submit an escalated bid to cover the uncertainty of the utilities. The use of SUE would reduce the uncertainty associated with the excavation portion of construction and ultimately reduce the bottom line price for the projects.

3.2 Previous Use of SUE on Navy Installations

Navy involvement with SUE technologies began in the early 1980's. The General Services Administration (GSA) purchased a number of Ground Penetrating Radar (GPR) devices and distributed them to various military installations. Some of the

GPR units were incorrectly used to designate underground utilities because the operators did not understand the concepts behind the technology and therefore found the devices ineffective. Some of the GPR units were used to locate airfield voids and other underground anomalies, but very little information was gathered regarding the location of subsurface utilities.

During the research portion of this paper, an interesting story was uncovered that pertains to NAVFAC and the use of Subsurface Utility Engineering. During the time that Dan Quayle was Vice President of the United States (January 1989 – January 1993) there was a construction project that was performed on the grounds of the Naval Observatory which has been the official home of the Vice President since 1974. The construction project consisted of the installation of a new electrical cable and a swimming pool. Some of the NAVFAC Civil Engineer Corps officers who were either stationed at the Naval Observatory or at other locations in the Chesapeake Bay area knew of this new technology called Subsurface Utility Engineering and contacted one of the providers to perform a subsurface utility survey. This service was essential due to the unknown site conditions at the Naval Observatory and the importance of preventing any type of utility outage, such as power or communication, to this vital facility.

More recently, a very successful project was performed at Mayport Naval Station, Florida. The project was a \$6 million upgrade and renovation of an aircraft carrier wharf to accommodate nuclear as well as conventionally powered aircraft carriers. An electrical and general construction company was awarded the design-build project on September 13, 2001. The aircraft carrier, USS John F. Kennedy, was going on

deployment within a month or two and with the naval cruise schedules kept as classified information; no exact return date or project completion date was available. During the design phase, the prime contractor subcontracted with a SUE firm which provided them with accurate locations of the existing utilities in the wharf area. The prime contractor agreed that the use of SUE was instrumental in completing the project in the very narrow and uncertain window of construction. This project led to the contractor being selected by NAVFAC as the 2002 Construction Contractor of the Year for Southern Division.

3.3 *Utility Data Management*

Each naval base is operated by a different group of individuals and each group has a different mission which they are striving to accomplish. There has been a very strong push for uniformity throughout NAVFAC, all the way down to the individual field offices, but currently there are still bases which are not as technically advanced as some of the other bases when it comes to their utility systems and the management of those systems. There are three common methods of utility data management that are often used throughout NAVFAC. The primary method is either: hardcopy drawings, Computer Aided Drafting & Design (CADD) files or Geographical Information System (GIS).

3.3.1 Hardcopy Drawings

For many years, hardcopy drawings had been the most common way for engineers and surveyors to document everything that is located above ground as well as below ground. The hardcopy drawings are usually on sheets of mylar or on paper.

They are sometimes drawn by hand or printed by a digital plotter. Most military installations have a public works department or a civil engineering office that maintains all of these record drawings.

3.3.2 CADD Files

Some of the bases have taken all of their paper drawings and converted them to CADD files. Since the late 1980's, this has been the most common format for engineers and surveyors to document their work. This format allows the user to keep a working copy of the utility system with useful features such as color mapping and layering.

3.3.3 GIS Mapping

The most advanced bases have been converted to a GIS format which is similar to a CADD format in some aspects, but has the capabilities to perform data analysis. Information can be input into the program describing the utility systems and then useful analysis and reports can be generated to assist in the overall management of the base. Provided the information for the utility systems (depth, size, material, flow, pressure, etc.) is correctly input into the database portion of the GIS software; information queries can be performed and extremely useful information can be extracted from the system.

3.3.4 Accuracy

Regardless of the format in which the utility information is managed, the records and drawings are only as good as the field information that is available. If the information that is documented in the field surveys is erroneous, the accuracy regarding the actual location of the utilities will not be any more correct when it is transferred to one of the data management methods listed above. This needs to be heavily

emphasized with respect to the digital methods (CADD and GIS). The information is not always correct just because it is on a computer. The information is only as good as it was before it was transferred into the computer.

3.4 *Utility Privatization*

In December 1997, the Deputy Secretary of Defense issued a memorandum instructing the Military Departments (Army, Air Force, Navy and Marine Corps) to develop a plan to privatize all of the utility (electric, water, waste water and natural gas) systems, unless it was not financially beneficial to do so. Also, if the ownership transfer of the utility created a security concern, the lines would not be transferred.

Utility privatization is the process in which utility ownership is transferred from the user to the local contractors or utility companies. The goal of utility privatization is to reduce the operation and maintenance costs as well as to improve the long term reliability of the systems.

This presents a problem with the maintaining of accurate utility records because it becomes more difficult to obtain an updated set of drawings after a contractor comes onto the base and alters their utility. Once the utility company takes ownership, they follow their own procedures for documenting and record keeping. Obtaining a courtesy copy of the revised utilities after construction becomes very difficult for the military base.

Once the utility systems have been turned over to the utility companies for operation and maintenance, there may be some additional benefits that result from the implementation of SUE. One benefit that could be realized by the military is that since

the utilities are used by the base and maintained by the utility companies, they share an interest in the accurate location of each component of the utility systems. This could lead to an agreed cost sharing when SUE is performed. Both entities would benefit from the product that is provided by a SUE firm and therefore should share in the cost of the surveys.

3.5 *One-Call Utility Locating Service*

The most common method of utility locating or designating that is performed on military bases is the same method that is used on civilian construction projects. The contractor who is working on the military installation is required to call the One-Call center before they perform any excavation.

The One-Call system is an effective damage prevention tool which is regulated by all fifty states and the District of Columbia. However, it is not an accepted method for gathering design level information. One-Call services recorded over 19 million excavation notices in the United States in 2000. One-Call centers provide one telephone number for notification of excavation, tunneling, demolition, or other similar work. One-Call must be notified at least 48 hours before excavation is to begin and information such as location of excavation, start date and time of excavation including a description of the excavation activity must be provided. The center then notifies the participating members that digging or construction will occur in a given location. The contracted locator service then travels to the excavation site and marks the approximate location of any underground facilities in the area. The accepted tolerance for these markings is two feet on either side of the utility (FHWA, 2002). The accuracy of the

locating that is done before the start of excavation depends on the existing records that are available and the locator's familiarity of the area. The organization structure and governmental involvement of the One-Call centers varies from state to state, as do the penalties for failing to use the One-Call service (Spalj, 2004). Table 1 compares the One-call system to the methods used in SUE.

Table 1: Comparison of One-Call System and SUE (FHWA, 2003)

Descriptions	One-Call System	SUE
Use	Excavation Activity Based	Typically Project Based
Applied Stage	During Construction	During Design
Obligation	By State Law	No Obligation
Range of Service	2-D (Horizontal Location)	2-D/3-D (including depth)
Deliverables	Marking on the Surface	Transferring the obtained data into the project plans
Accuracy / Quality	Relatively Low	Relatively High
Work Solicitation Practice	Bidding - lowest bidder	Typically Negotiated
Major Contract Method	Unit Price	Cost-plus-fee and Unit Price
Major Benefits	Avoidance of pipeline hits	Higher accuracy, avoidance of pipeline hits, construction cost savings, etc.
Major Disadvantages	Relatively low accuracy, not useful for construction cost saving tool	Higher cost of use

The One-Call system has some downfalls that have affected many construction projects, both civilian and military.

- Time constraints: 48 hours is not enough time to accurately locate all the utilities in certain areas.
- One-Call can only dispatch locators to mark the utilities which are part of their network.
- The One-Call locators rely on the utility records of the utility owners. If the records are not accurate or up to date, the locators will likely be unable to mark all lines.

The civilian construction force has taken action to minimize the impact caused by traditional utility locating methods by implementing the use of Subsurface Utility Engineering which increases the accuracy of a utility's whereabouts and also minimizes the dependency on the One-Call locators.

3.6 *Utility Design Process*

When a construction project is initiated on a military installation, the design phase begins with the public works department, civil engineering office or facilities department gathering all of the existing as-built drawings that are available. These data are interpreted and compiled onto a set of new drawings, usually by the design engineer. Next, a utility locate is usually done by a One-Call provider or representatives from each utility company. At the same time, a field survey is usually done by the engineers to verify the above ground features. All of this information is compared to the drawings and then additions or corrections are made to the final design drawings. Very rarely is there any type of utility verification done by excavation during the design phase.

Once the design is considered complete, the designer will provide the utility maps to the contractor for building. At this point, the contractor takes responsibility for the utilities shown on the drawings, in the location(s) shown on the drawings. However, if the utilities are actually in a different location or if there is an unknown subsurface utility, the contractor is not usually responsible for it. If the utility is damaged or if it is encountered and needs to be relocated, the contractor usually requests compensation for the additional work that is required to resolve the situation.

The biggest problem with the process described above is that there are current methods, such as SUE, that are being used to take a more proactive approach to construction site design. The implementation of these methods often minimizes the number of unforeseen conditions that are encountered once construction begins. Reducing the number of conflicts with subsurface utilities can lead to an overall savings to the owner and to the customer, which ultimately in the case of military construction, is the taxpayer.

4 Overview of SUE

The number one cause of subsurface utility damage is excavation that occurs during construction activities. More than 40 percent of pipeline ruptures and leaks are caused by an external force and more than half of all cable service outages are caused by excavation damage. This is a major problem considering that there are more than 20 million miles of underground utilities in the United States (Spalj, 2004).

Subsurface Utility Engineering is a detailed process which will be described in this chapter. When it is used correctly, it can lead to the prevention of utility damage or relocation. This chapter will provide an introduction for individuals that are not very familiar with SUE.

4.1 *Description of SUE*

SUE is described as an engineering process that utilizes advanced data processing and site characterization technologies that lead to the cost-effective collection, depiction, and management of existing utility information (Lew, 2000). Subsurface Utility Engineering consists of three separate activities:

Designating: The process of using existing records, above-ground features, personal recollection and technical methods to determine the approximate horizontal position and confirm the existence of an underground utility.

Locating: The process of exposing the utility by use of an excavating method to verify the horizontal position and determine the vertical location as well as the utility type, material, and size.

Data Management: Documenting information, obtained by designating and locating, into a computer-based data management system (GIS / CAD).

With respect to SUE, the terms “designating” and “locating” were developed by James Anspach, a former Penn State geophysicist, and Jeff Oakley, a Penn State physics graduate. By definition, a utility is considered to be located after it has been exposed. A utility of which the existence and approximate location has been determined is considered to be designated. There are many different methods that have been used to designate an underground utility. These methods will be discussed in chapter 5.

Locating is usually performed using a technique called vacuum excavation. Vacuum excavators come in both a compressed air and a high-pressure water model which describes the method used to loosen the soil before the vacuum hose extracts the recyclable material. Vacuum excavation has become very popular because it is cost-efficient to the contractor and also non-destructive to the neighboring structures. After the vacuum is used to excavate a test hole or pot hole, the utility is inspected and surveyed to determine the exact location. The utility is surveyed to an accuracy of 0.5-foot for horizontal and 0.05-foot for vertical (Sterling, 2000). Once the utility data has been recorded, the excavated material can be recycled and used to backfill the void. This method is also more convenient because of the small hole that is made and considered safer for the public because there is not a large excavation to avoid.

Data management is the portion of the process where the information that has been gathered is compiled into a digital format. The digital format is usually in a Computer Aided Drafting & Design (CADD) file or a Geographic Information System (GIS) file. These are the two most common forms of digital media for surveyed

information. The final product consists of a comprehensive map and automated digital diagram of a construction site with detailed information for all the utilities in the area (Spalj, 2004).

4.2 History of SUE (FHWA, 2004)

The first person to come up with the idea of Subsurface Utility Engineering is said to be Henry "Garon" Stutzman. In the 1970's, he was working as a relocation engineer in the Washington, D. C. area. Stutzman was bothered by the traditional methods that were being used to maintain and manage underground utilities because he knew that the taxpayers and ratepayers were not receiving the level of service they should. He felt so strongly about the potential use of an air-vacuum system to safely excavate and locate the underground utilities that he partnered with another gentleman, W. R. Owens. Together they started their own company that today specializes in SUE.

Some government agencies were quick to learn of the new technology and to conduct trial projects. The first governmental body in the U.S. to enter into a SUE service contract was the County of Fairfax, Virginia in 1982. The Virginia Department of Transportation (VDOT) entered into a first time trial project in 1983. The project selected was a large road reconstruction in Crystal City, Virginia. Virginia DOT stated that there was a savings of over \$1 million due to the utility designating and locating services that had been performed. In 1985, Virginia entered into the first statewide SUE contract in the country. They now have the most comprehensive use of SUE mapping in the country. Every project done by VDOT uses the two highest levels of SUE (Quality

Level B and Quality Level A) mapping. In recent years, other states such as North Carolina, Ohio and Texas have begun to implement SUE into their DOT projects.

Throughout the 1980's, these services of designating, locating and providing accurate maps of the underground utilities had not been given a specific name which accurately described the work that was being done. In 1989, at the First National Highway and Utility Conference in Cleveland, Ohio, the term Subsurface Utility Engineering or SUE was first used to describe the methods and services that had previously been and were currently being performed. Also in 1989, for the first time, SUE was recognized in a court of competent jurisdiction as being a professional service. It was realized that the information that was being provided through these services affected the public well-being and for that reason should be classified as a professional service.

Since the late 1980's, the FHWA Office of Program Administration has been encouraging the use of SUE in the preliminary phases of design for Federal highway projects. FHWA believes that the proper use of this cost-effective professional engineering service will eliminate many of the utility problems encountered on highway projects, including:

- Project delay caused by preliminary utility relocation
- Project delay caused by redesign due to unexpected utility conflicts
- Delays to contractors when a utility is damaged causing work stoppage
- Contractor claims for delay

- Death, injury, property damage, and release of product into the environment when a utility is damaged

These problems can be avoided when a knowledgeable qualified SUE provider performs the service. Unfortunately, some providers do not understand the process and therefore are not giving their customers the level of quality they should receive.

4.3 *Subsurface Utility Engineers*

SUE was not considered an engineering science when it was first being performed. It was thought that anyone could operate the equipment and perform the service. It was later determined that a substantial amount of interpretation was required to provide an accurate survey of the subsurface infrastructure. An understanding of civil engineering, electro-magnetism, soil properties, geophysics, and other technical disciplines are needed to correctly perform subsurface investigation.

In the mid 1980's, it was determined that the seal of a registered professional engineer (PE) should be placed on the final documents because of the technical information that was included. This event led to the initiative to classify SUE as a professional service rather than a contractor service (FHWA, 2004). The professional subsurface utility engineers are now taking responsibility for accuracy and completeness of the utility data that they provide on the design documents and most of them also have specialized liability insurance to support their services (Anspach, 1992).

The Subsurface Utility Engineers are responsible for a number of essential duties to successfully perform the service. Some of the most important duties are shown in Figure 3.

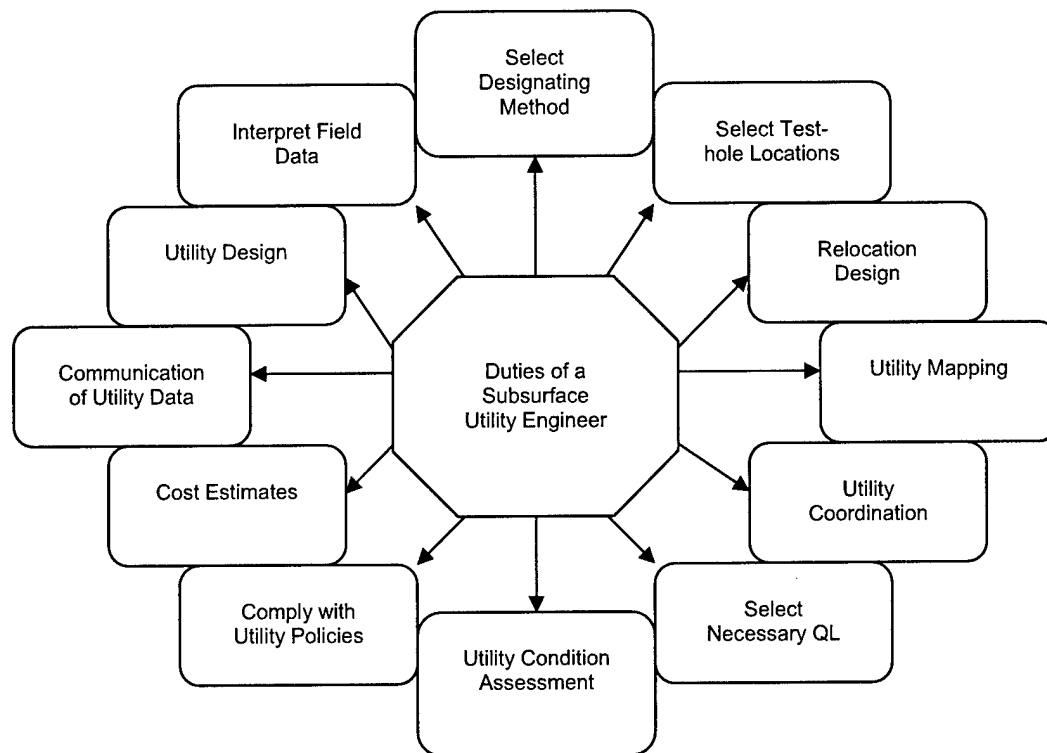


Figure 3: Duties of a Subsurface Utility Engineer

4.4 Disclaimers

Engineers inherently accept a certain amount of liability for the accuracy of their designs and plans. The data that are used to produce the design are not always from a source which is independent from the engineer. In the case of utilities, most engineers realize that information gathered from potentially incomplete records and a nationwide locating service (One-Call) may not be reliable. Therefore, the engineers will place a disclaimer on the documents to alleviate some of the responsibility and liability which

may, in some courts, protect them from litigation. A typical disclaimer will read as follows:

Utilities depicted on these plans are from utility owners' records. The actual locations of the utilities may be different. Utilities may exist that are not shown on these plans. It is the responsibility of the contractor at the time of construction to identify, verify, and safely expose the utilities on this project (Anspach, 1995).

These disclaimers are indicators to contractors that there are some potential unknown conditions on a construction project and may cause the contractors to increase their bid price to cover the extra time and effort that may be needed to perform their job if an unforeseen condition is encountered. When a SUE provider performs a survey, they usually take the responsibility for the area that was surveyed. This eliminates the need for disclaimers which leads to lower bid prices from the contractors.

4.5 *Quality Levels of SUE*

Subsurface Utility Engineering is performed at four (4) different quality levels depending on the necessary data. Stutzman and Anspach defined the four quality levels of SUE information with input from Bob Stevens, a former nuclear power officer for the United States Navy (FHWA, 2003). SUE, performed at the different levels of quality, is used by the designers, engineers, contractors and project managers to take a proactive approach to prevent the disruption and damage to underground utilities. The four quality levels represent different combinations of traditional records research, site surveys, geophysical imaging techniques and locating techniques. Quality Level A (QL

A) provides the highest degree of accuracy and Quality Level D (QL D) provides the most basic level of information. The level of accuracy used to survey a utility is determined by the importance of the utility and the potential conflicts that it may cause. The cost of the service with respect to the project budget is usually a factor in determining the level of quality required. The appropriate levels of quality for a certain area should be determined with input from the architect, engineer, owner, contractor and all other parties involved with the excavation.

4.5.1 Quality Levels A-D

There are four (4) quality levels (QL) that are performed, depending on the importance of the survey. As a project requires more accuracy and detail and the Quality Level moves toward QL A, it should be understood that the lower levels must also be incorporated into the final package. For example, if QL B is required in a certain area, QL C and QL D must also be done in order to meet all the requirements of QL B. Also, as the Quality Level goes up from QL D to QL A, the cost increases.

QL D – Existing Records: This level uses existing utility records or personal recollection to determine the existence and the congestion of the subsurface utilities. It should be used during route selection and project planning phases.

QL C – Surface Survey: This level is used to determine existence and approximate location of the utility using surveying instruments and above-ground features along with engineering judgment and professional expertise.

QL B – Designating: This level is used to determine the approximate horizontal position using surface geophysical methods. The results from the geophysical methods are reproducible at any point of the survey. It should not be used for design basis vertical information, or where a horizontal tolerance of zero is expected. Two-dimensional horizontal

mapping can be produced and a preliminary to advanced design can be established using this data.

QL A – Locating: This level is used when exact horizontal and vertical location is required. This information is obtained by exposing the utility at a specific point. Excavation equipment such as air or water jets, vacuum extractors and hand tools are used to prevent damage to the utilities. Additional information such as utility size, type, material and condition is also gathered. Three-dimensional horizontal and vertical mapping shall be produced after this level of survey is performed.

The level of quality must be determined by the project owner; however it is extremely beneficial to discuss this portion of the specification with an in-house engineer or a consultant to make the final decision. If the owner is unsure of the necessary level of quality, it is wiser to choose a higher level as opposed to a lower level because the owner will ultimately have to pay for additional investigation or for the repair of an unforeseen utility which becomes damaged.

Figure 4 depicts the different Quality Levels, how they correspond with the different stages of a construction project and the SUE functions that are usually performed on a typical project.

Most construction projects already require a level of utility investigation equal to QL C based on the specification documents. There is usually a paragraph in the specifications that requires the prime contractor or a specialized subcontractor to perform a utility investigation. There is usually some type of electromagnetic receiver that is used to designate the existing utilities and this is often performed by the One-Call utility locating service.

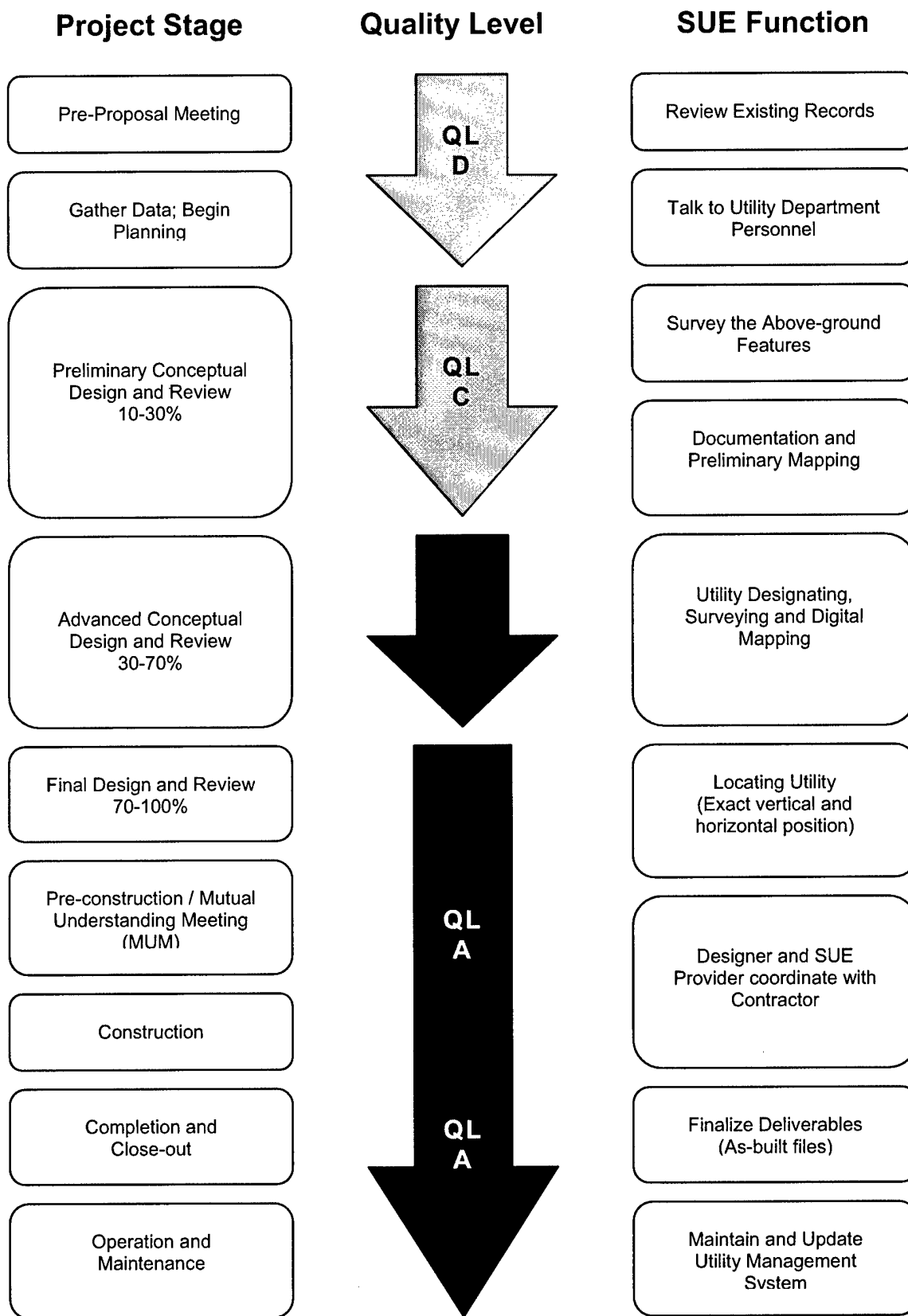


Figure 4: Progression of Events for a SUE Project

4.6 *Current Limitations of SUE*

There is not one single method that can be used to designate every single utility. Each designating method has a special use to find a particular type of utility or performs best in a particular area. A wide variety of geophysical imaging technologies and differing application conditions make it difficult to select the appropriate imaging method. The existing site conditions, utility size and composition must be considered when selecting an imaging method. SUE is not an x-ray which will identify and locate all the utilities in a specific area.

One limitation that is difficult to overcome is the use of GPR on military installations where flight operations are performed. During the 1980's when the military was using the GPR units to locate airfield voids it was discovered that the waves emitted by the units had an effect on the radar systems in the control towers and also in the aircrafts. This can make it very difficult to use the GPR units on bases where the flight operations are essential.

4.7 *Obstacles to overcome*

There are some obstacles that must be overcome in order for SUE to be implemented into more construction projects. Some of the obstacles are caused by lack of knowledge by all parties involved, especially the owner; negative first experience with the technology; and resistance from construction contractors and engineers because of the reduction in change order work.

Project owners provide little incentive to their design engineers to do a better job at identifying and avoiding existing utilities. Tradition implies that it is acceptable to have change orders and delays caused by unforeseen subsurface utilities. The technologies of SUE must be communicated to the project owners so that they will understand the benefits and demand that it be used on all projects which require excavation.

One other reason that SUE is not being used is because a bad first experience may have been had with early SUE methods. The provider may have performed the service incorrectly or may have overused the techniques which led to a high cost for which the benefits may not have been realized.

Another obstacle is the resistance from contractors and engineers because they could potentially lose money from a reduction in the number of change orders issued for unforeseen conditions. Contractors make money from the additional work and the engineers make money for the additional design that is required when an unknown subsurface utility is encountered. This is not implying that contractors have a strategy of profiting from unknown subsurface conditions; however it is believed that contractors and engineers usually receive a higher percentage of profit on change order work when compared to the project's original bid.

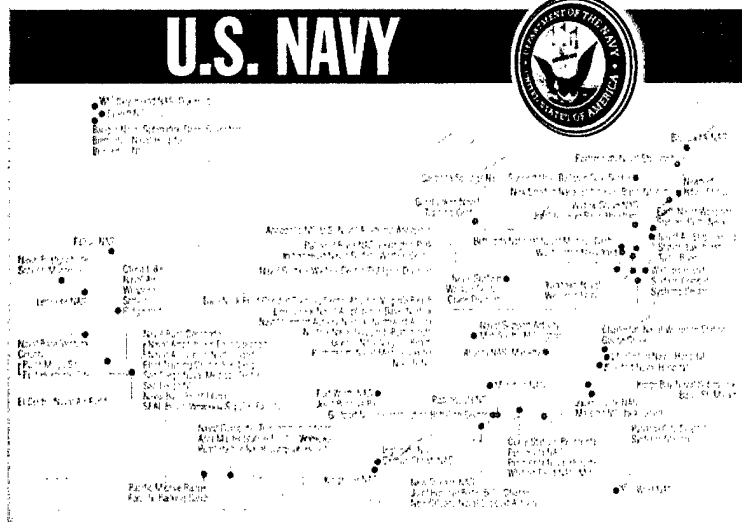
4.8 *Standards and Guidelines*

In 2002, the American Society of Civil Engineers (ASCE) released a national standard that provides specific guidance for Subsurface Utility Engineering. The document is titled, "C/I ASCE 38-02: Standard Guidelines for the Collection and

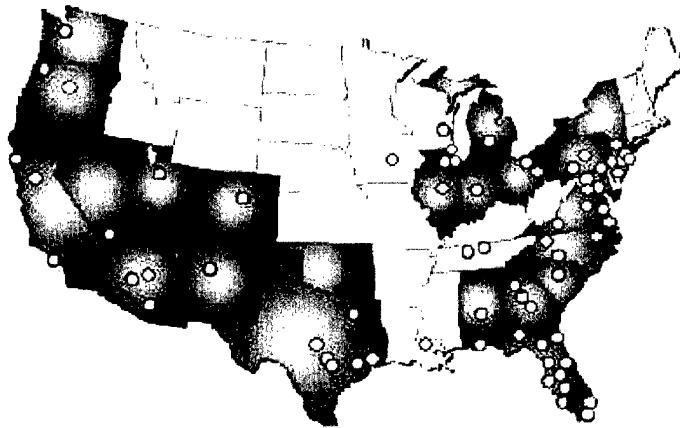
Depiction of Existing Subsurface Utility Data.” It provides a framework for the engineer and project owner to develop an unambiguous scope of work that clearly defines roles and responsibilities for the investigation of these utilities (Ryan, 2002). The guidance defines all of the commonly used terms associated with SUE, details the individual tasks and responsibilities that should be assigned to the engineer and the project owner, and lists the utility characteristics that should be obtained by the engineer for each Quality Level. The ASCE 38-02 also discusses the methods and technology used to gather utility information and explains how the information can be conveyed to the information user. This standard should be used as a reference or incorporated into the design specifications for all excavation work.

4.9 *Location of SUE Firms*

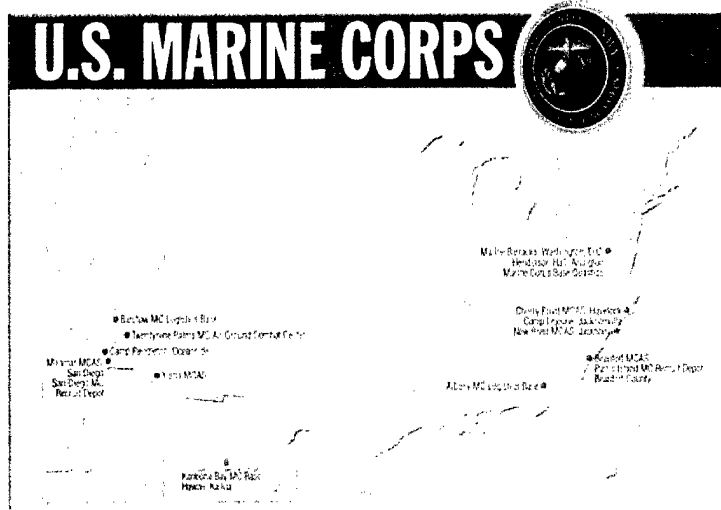
SUE began in the eastern United States in the early 1980's. Many of the first contractors established businesses in this area and many of the first projects were performed in the Virginia area. The maps on the following page depict the locations of the: Navy bases, Marine Corps bases and some of the most qualified SUE contractors within the United States. The maps have been enlarged to make them more readable and placed in appendix B. The maps are meant to show how the locations of the SUE contractors and the NAVFAC installations correspond. There is a SUE contractor in nearly every state where there is a Navy base and in every state that there is a Marine Corps base. The darker shaded area represents the states where SUE firms have established a presence. The lighter shaded states have yet to be thoroughly introduced to the methods of SUE.



Locations of U.S. Navy Bases



Locations of Qualified SUE Providers



Locations of U.S. Marine Corps Bases

5 Designating Methods

Designating is to be done before the utility is physically located. It is essential that a SUE provider be equipped with different instruments to perform different designating methods. No single technology is currently able to designate all types of utilities at any depth and in all the differing soil conditions. Six technologies – electromagnetism, ground penetrating radar, magnetism, resistivity, infrared thermography / thermal imagery, and elastic wave – will be discussed here. For a more detailed explanation of these methods and some less frequently used methods, reference: Anspach, 1995; Lew, 2000; and Jeong, 2001.

5.1 *Electromagnetic Methods*

Many of the designating methods are based on electromagnetic theory, which is the sensing of an object by detecting the differing electrical properties of the object with respect to the surrounding materials. If the object is made of a highly conductive material such as steel, iron, copper or aluminum it will carry an electrical or electromagnetic current. Some of the designating methods use a transmitter to introduce electromagnetic energy into the conductive object and then a receiver is used to detect the object.

5.1.1 Radio-frequency Pipe and Cable Locators

Radio-frequency (RF) pipe and cable locators are the most commonly used devices for designating utilities. The method is relatively inexpensive, yet highly effective on metallic utilities and utilities in which a transmitter or conductor can be

inserted. A transmitter is used which emits an electromagnetic wave and a receiver is used to detect any changes in the wave. The frequencies used range from 50 Hz to 480 Hz. This method works well for metallic utilities or non-metallic utilities that have a metallic tape or tracing wire installed directly above the line. There are three techniques or modes that are available to utilize the pipe and cable locators which will be described in paragraphs 5.1.1.1 – 5.1.1.3. They are: conductive, inductive, and passive.

5.1.1.1 Conductive Mode

This method is performed by physically connecting a transmitter to the line and then tracing the utility with a receiver. The transmitter can be connected to an exposed portion of the line or to other access points such as a manhole, valve, service meter, hydrant or sprinkler. A handheld receiver is then used to trace the signal and designate the utility (FHWA, 2003). Figure 5 illustrates how the transmitter and receiver are used to establish a signal.

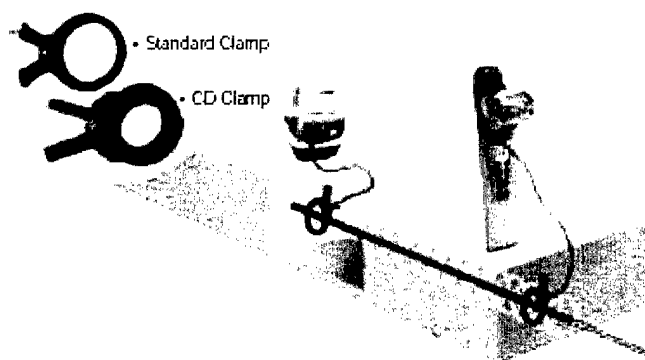


Figure 5: Conductive Mode (<http://www.linetools.com/RD/RD4000.pdf>)

5.1.1.2 Inductive Mode

This method is used when there is not a physical access point to the utility. A transmitter is placed on the ground above the approximate location of the utility and an electromagnetic frequency is emitted. A handheld receiver is then used to trace the utility by detecting the signal which is coming from the utility.

5.1.1.3 Passive Mode

No transmitter is required for this method. The receiver can detect very low frequency radio waves emitting from buried cables. Buried power cables and utilities that are near a power station or above-ground cables carry some frequency currents that can be detected by this method. This technique is usually used to detect unrecorded lines rather than tracing a known utility (FHWA, 2003).

5.1.2 Sonde Insertion Method

A sonde is a small radio transmitter which is often used to designate non-metallic utilities that have an access point where the transmitter can be inserted into the line. An electromagnetic receiver is used to trace the horizontal location of the sonde when it is in the line. Some of the transmitters used for this method can determine an approximate depth to the sonde. Since the sonde sits on the bottom of the pipe the depth of the utility can be roughly estimated. This method is often used to designate non-metallic non-pressurized utilities such as sanitary and storm sewer as well as drain lines.

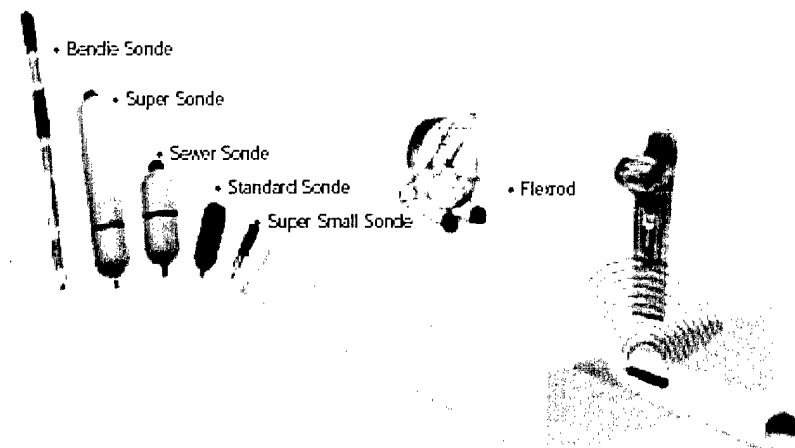


Figure 6: Sonde Method (<http://www.linetools.com/RD/RD4000.pdf>)

5.1.3 Tracing Wire / Metallic Marking Tape

Tracing wires and marking tapes are commonly installed above non-metallic utilities in order to be able to designate them at a later date. If the wires or tapes are installed correctly they can be traced using both conductive and inductive methods.

To eliminate the problems with the installation of the marking tapes and wire, there have been some new polyethylene (PE) pipes that have been impregnated with strontium ferrite particles. Approximately 12-24% by weight is added to the traditional PE mixture to extrude these semi-metallic detectable utility pipes.

5.1.4 E-line Locator

This method consists of performing a live tap on a pipe and inserting a flexible locator line into the pipe. A live tap is the process of puncturing a hole into a utility that is in service. This process is more difficult on pressurized utilities, but can be done using a specialized coupling and drill. The locator wire is then inserted into the utility

and directed in the direction of alignment. The locator wire is approximately 300 feet long, providing 600 feet of designating from each mechanical tap. This method has been used extensively to designate plastic gas pipe.

5.1.5 Terrain Conductivity Method

This method is very similar to the Inductive Mode of the pipe and cable locating method only the transmitter and receiver are incorporated into the same instrument. This technique is moderately inexpensive and is most useful in areas of minimal utility congestion or areas of high ambient conductivity. It is often used for underground drum and tank detection. Figure 7 shows the one-man crew carrying the designating device.

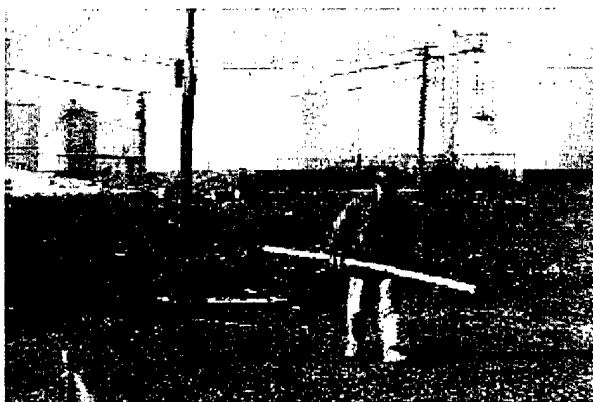


Figure 7: Terrain Conductivity Method

5.1.6 Electronic Marker System (EMS)

In the electronic marker system (EMS), the marker consists of a passive resonant circuit that reflects a signal back to the locator. The markers are buried near specific features such as valves, bends, and other fittings. The markers are made to react to a specific frequency. A different frequency is used to mark a specific utility as shown in Table 2. The markers come in disks, balls, or pegs as shown in Figure 8



Figure 8: EMS Markers (Locator Equipment, 2004)

Table 2: EMS Utility Frequencies (Locator Equipment, 2004)

Type of Utility	Frequency
Electric Power	169.8 kHz
Water	145.7 kHz
Sanitary	121.6 kHz
Telephone	101.4 kHz
Gas	83.0 kHz
CATV	77.0 kHz

5.1.7 Metal Detector

Metal detectors emit an Alternating Current (AC) magnetic field into the ground. The search coil inside the detector will sense any changes in the magnetic field and produce an output signal, usually audio. This method is usually used to detect shallow metallic objects.

5.2 Ground Penetrating Radar (GPR) / Impulse Radar

The use of ground penetrating radar (GPR) or impulse radar is moderately inexpensive, yet it requires a great deal of interpretation, field experience and a high degree of training. GPR is a technology that was originally developed by the military

and has been in use for over 30 years. It is useless in areas of high ambient conductivity or when looking for small utility targets. The equipment measures the reflection of microwave pulses which are beamed into the ground. It is one of the most commonly used method along with pipe and cable locators and similarly metallic and non-metallic utilities can be designated with this method. The frequency range that is used is from 10 MHz to 1000 MHz. The higher the frequency, the more detailed the images. The use of a lower frequency allows for utilities to be found at greater depths. Another benefit of using this method is the detection of other underground obstructions such as large boulders. There are many different types of GPR units as shown in Figure 9.

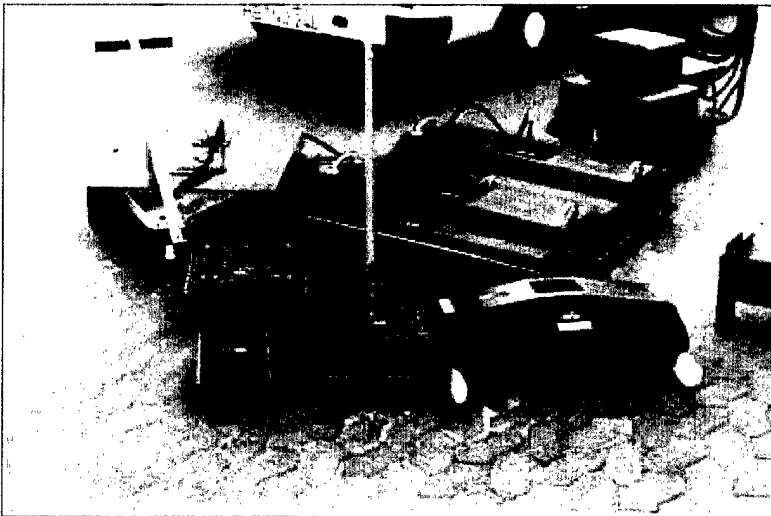


Figure 9: GPR Units (<http://www.impulsegeophysics.com/radar.html>)

5.3 Magnetic Method

The magnetic method is relatively inexpensive and highly effective for utilities which emit a strong magnetic field at the surface of the ground. This method measures the intensity of the earth's magnetic field. Deviations in the magnetic field are caused by ferrous (steel or iron) objects which emit their own magnetic field.

5.4 Resistivity Method

The resistivity method is performed by placing receiving electrodes into the ground which record different resistivity signals produced by transmitting electrodes. This method is useful in areas which have a highly conductive soil which may cause GPR and electromagnetic methods to fail. It works well for finding the existence of a utility, but does not work well for tracing the utility's path.

5.5 Infrared Thermography / Thermal Imagery Method

The thermal images produced using this method require some specialized interpretation and are moderately expensive. This method uses an infrared sensor which can detect differences in thermal energy. Very useful to detect utilities such as chilled water, sewer and steam lines. However it is very sensitive to temperature variations caused by weather.

5.6 Elastic Wave

A Pressure wave is introduced at an access point and the receiver picks up the resulting wave signal. The pressure wave may be either a sound wave as in the acoustic emission method or an impact wave as in the reflection/refraction method. These techniques are often used to detect plastic or concrete pipes.

5.6.1 Acoustic Emission Method

This method is often used to trace non-metallic water lines. A sound wave is applied to a line causing a seismic disturbance in the soil. Sensors, such as geophones or accelerometers, detect where the vibrating sound waves are the greatest.

5.6.2 Seismic Reflection / Refraction Method

This method is commonly used in areas where new utilities are being proposed or where the existing soil profile is required. One benefit is that its use can provide a profile of geological features such as top of bedrock or water table depth. It is expensive and requires a great deal of interpretation. A seismic wave is created using an explosion or a hammer striking a metal plate on the surface of the ground. Geophones that have been planted in the ground detect both the refracted and the reflected waves.

5.7 Designating Utility Depths

The approximate depth of a utility line can be obtained by using one or a combination of three designating devices: high performance electromagnetic locators, sondes and GPR. The electromagnetic locators can be used to determine the depth of metallic utilities. The locators will give a reading to the center of the pipe because that is the center of the electromagnetic field which surrounds the pipe. The sonde can be used to determine the depth of any pipe in which the device can be inserted. It is important to remember, the depth that is displayed on the signal receiver is going to be to the bottom of the pipe since that is where the sonde is usually located. The GPR units can measure to the top of most utilities, if the soil conditions are optimal. The use of these three methods will give a good approximation of the utility depth, however, the best way to accurately locate the utility is to excavate down to the line and record the depth.

6 Previous Research

During the literature review of this research there were many informative documents that were read in order to gain a strong understanding of SUE. One of the most educational studies that had been conducted was a report that was done by Purdue University for the Federal Highway Administration which resulted in many significant contributions to the advancement of SUE. The Purdue study developed a list of benefits and performed a cost-benefit analysis on a number of highway construction projects. Also, a computer program was written by a Purdue graduate student which was meant to be used as an educational tool to describe the SUE process and the different designating techniques.

6.1 *Previous Cost Analysis*

The cost-benefit analysis of SUE services has been performed on a number of construction projects. In the majority of these construction projects, there have been financial benefits that were realized because of the use of SUE.

In 2000, a group of faculty and graduate students from Purdue University surveyed four state departments of transportation and asked questions regarding the use of SUE. The four states that were surveyed were North Carolina, Ohio, Texas and Virginia. Data were received relating to 71 construction projects which had a total construction cost of over \$1 billion. Some of the data that were submitted in the survey questionnaire were not actual costs. Some of the information had been estimated and reportedly had been done with a high degree of certainty. Only the monetary values

associated with the benefits listed in section 6.2 were included in the analysis. It should be noted that even though the qualitative values were not used in the analysis, they are significant and should be considered additional benefits.

Some of the most significant statistics that resulted from the Purdue study pertain to the amount spent on SUE and the financial return yielded by the use of SUE. The amount of funds spent on SUE services (Quality Level B or A) was an average of less than 0.5%, for the total amount of construction. Only 3 of the 71 projects had a negative Return on Investment (ROI) while the remaining projects realized a benefit of at least \$1 for every \$1 spent on SUE services. The average savings realized was \$4.62 for every \$1 spent on SUE services. As mentioned before, the qualitative benefits were not assigned a dollar value and incorporated into this analysis. Therefore, the actual cost savings could actually have been much higher. Table 3 provides an overview of the cost savings found in the Purdue study.

Table 3: Summary of Purdue / FHWA Study (Lew, 2000)

State	Projects	Construction Cost (million)	SUE Savings per \$1 spent
North Carolina	21	\$205	\$6.63
Ohio	14	\$284	\$5.21
Texas	27	\$606	\$4.27
Virginia	9	\$42	\$4.12
	71	\$1,138	Avg. = \$4.62

6.2 Benefits of SUE

In the study conducted by Purdue University for the FHWA, there were 21 potential benefits that were identified. Some of these benefits are easily quantified while others are more qualitative or speculative (Lew, 2000).

- Reduction in unforeseen utility conflicts and relocations
- Reduction in delays due to utility relocations
- Reduction in claims and change orders
- Reduction in project design costs
- Reduction in travel delays to the motoring public
- Reduction in delays due to damaged utilities
- Reduction in costs caused by conflict redesign
- Reduction in cost to utility companies to make repairs
- Reduction in Right-of-Way acquisition cost
- Reduction of contingency fees
- Lower project bids
- Improvement in contractor productivity and quality
- Minimization of utility customers' loss of service
- Minimization of disturbance to existing pavements
- Minimization of traffic disruption
- Elimination of survey duplication
- Facilitation of electronic mapping accuracy
- Introduction of the concept of a comprehensive SUE process
- Minimization of the chance of environmental damage
- Improved relationship with utility companies
- Induced savings in risk management and insurance

The benefits can be summarized as fewer claims and delays, lower costs and increased safety.

6.3 Decision Making Tools

In 2001, a graduate student at Purdue University developed a computer program and web site in conjunction with the Federal Highway Administration and the Joint Transportation Research Program. The name of the program is IMAGTECH and the purpose of the program is to be used as a tool to better understand SUE and the most common methods that are available for designating underground utilities. The program will assist the user in making a decision on which designating method is most suitable in a particular situation. The tool can be downloaded from the following webpage:

<http://www.new-technologies.org/ECT/Other/imagtech>

There has been a disclaimer placed on this program which must be mentioned in this paper.

“Neither the Construction Industry Institute nor Purdue University in any way endorses this technology or represents that the information presented can be relied upon without further investigation.”

This tool, along with this paper, should be very useful for any individual that is considering the use of SUE on a military construction project.

7 Feasibility Study and Recommendations

The intended purpose of this work was to locate military construction projects that had either used SUE technologies, or should have used SUE technologies to improve the utility design process. Underground utility projects that had been administered by NAVFAC were not discovered until the late stages of the research process and for that reason could not be thoroughly analyzed.

There was a plethora of information that was researched and gathered during the development of this paper. The purpose of this chapter is to discuss the information that was gathered that may be useful to NAVFAC personnel and persuade them to implement SUE into more construction projects where subsurface utilities may be uncovered. Recommendations will also be made to improve the data management of construction projects and to conduct some case studies to assist NAVFAC in determining if SUE is beneficial.

7.1 *Opinions by NAVFAC*

During the research portion of this paper, contact was made with many NAVFAC personnel. Two of the most helpful individuals that were interviewed, regarding their experience with SUE, were located near Jacksonville, Florida. During the interviews, questions were asked regarding the use of SUE on the Navy construction projects and also, the subjects were asked their professional opinions of SUE.

The water utilities director of the Public Works Center in Jacksonville was interviewed on June 3, 2004. When asked how many projects he had been involved with or seen in the past, he said that he had seen SUE used on 3 projects in the previous two years. The projects had consisted of design work and were awarded to an A/E firm for approximately \$100,000 each. The A/E firm had subcontracted with a SUE provider to perform a survey and the cost of the SUE portion was between \$20,000 and \$50,000 for each project. His professional opinion was that SUE should be used on almost every project where underground excavation is to be performed.

A Navy project manager from Engineering Field Activity Southeast was interviewed on June 7, 2004. Her previous experience with SUE included 8 to 10 projects in the past 3 years. When asked why more projects within NAVFAC do not use SUE, she responded that some people feel that SUE is an expensive and time consuming service that does not provide enough of a benefit. She thought that another reason that more NAVFAC offices were not using the service was that many of the other bases may not have enough qualified contractors in the area to perform the surveys. The professional opinion of the project manager was that, "SUE has always been a benefit to the projects and to the Navy, in the long run." She believed that one of the main reasons that SUE was being used in the Jacksonville area was because the Public Works Center had specifically asked for the service and because there are a few very qualified providers in the area. During the time that the project manager has been involved with SUE contracts, she could not think of any projects which had a negative impact caused by the implementation of SUE. One of the major benefits that had been seen in the Jacksonville SUE projects was that the product provided by the service was

used to help determine the most feasible method of construction that should be used (i.e. directional bore versus open cut excavation).

The projects that have been done in Florida were performed by some highly qualified contractors who have extensive experience in SUE technologies. The SUE contractors in the area have been one of the most influential factors in the use of SUE on the Navy projects. According to the interviewees, the SUE firms had apparently contacted the general contractors who were bidding on the government contracts and sold their methods and services to them.

7.2 Contracting Methods

The contracts that are awarded by NAVFAC are usually fixed price contracts. Some of the fixed price contracts are negotiated and some of them are competitively bid. In recent years, NAVFAC and their customers have favored the Best Value award method in which the contract is awarded to the bidder which proposes to provide the best product or service, for the best price. The selected contractor is not always the lowest bidder in Best Value awards.

In the civilian construction arena, SUE services are typically obtained through negotiated contracts. There are some projects that have been performed under a competitively bid contract, but this is usually avoided because it can cause the service to fall below the necessary quality level. The state DOT projects have seen success by awarding an open-ended or a not to exceed (NTE) contract through an Architect-Engineering (A/E) firm or directly with a SUE firm. The owner can receive a consistent level of underground utility information and consultation from a SUE firm and can

eliminate the repetitive selection process of securing the services by using one of these contracting methods. The FHWA study revealed that the most frequently used contracting method for SUE services has been a cost-plus-fee contract (FHWA, 2003).

Subsurface Utility Engineering is now considered a professional service and should be considered similar to the design services provided by an A/E firm. The Navy is capable of contracting with A/E firms through a multi-year negotiated open-ended contract which would be similar to most of the state DOT contracts. NAVFAC administers both Design-Build and Design-Bid-Build contracts. Contracting methods to procure SUE services for both types of the construction contracts are discussed below.

7.2.1 Design-Bid-Build Contracts

In the case of a Design-Bid-Build construction project, the owner will have a company employed engineer design the project, or contract with an independent A/E firm to develop the design. In this situation, SUE services would either be procured by the owner prior to the company engineer doing the design or the services would be subcontracted by the A/E firm which has been contracted to do the design. In the situation where the A/E performs the design, the A/E should be familiar with the subcontractor's SUE work in order to provide a more consistent product to the owner.

7.2.2 Design-Build Contracts

In Design-Build construction, the owner will contract with a construction company which will partner with an A/E firm who will develop the design documents. The SUE services will be procured by the A/E firm, by direction of the construction specifications, and then the information will be incorporated into the early stages of design.

Federal Government contracts for architectural and engineering services are procured under the Brooks Act which is an amendment to the Federal Property and Administrative Services Act of 1949. This act allows for the contract to be awarded to the A/E firm which has proposed the best value as opposed to awarding to the lowest bidder. This allows the government to acquire quality design services.

The Federal Highway Administration (FHWA) has developed some sample construction documents which are available for use when preparing for the procurement of SUE services. The sample documents include: a request for letters of interest, Request for Proposal (RFP), and a portion of a contract agreement or construction specifications which pertains to SUE. The documents can be obtained from the FHWA website, <http://www.fhwa.dot.gov/programadmin/document.htm>.

7.2.3 Specifications

On the Aircraft Carrier Wharf Improvement project mentioned earlier in section 3.2, the NAVFAC construction specifications had a section that required the use of SUE services. A portion of the specification is below:

“Scan the construction site with electromagnetic or sonic equipment, and mark the surface of the ground where existing underground utilities are discovered. Verify the elevations of existing piping, utilities, and any type of underground obstruction...”

This particular project was awarded to a construction contractor who was required to obtain SUE services through a specialized contractor. NAVFAC specified that utility designating and locating activities were required and the information was then used to develop the design documents. No other projects were discovered in which NAVAFAC specified SUE services.

7.3 *Recommendations for Future Work*

There are two recommendations that are being made that could be used to benefit NAVFAC. The first recommendation is to revise the construction modification coding system that is used by the contracting specialists within NAVFAC. This data management system is used to track all of the costs associated with the construction projects. The second recommendation is for NAVFAC to conduct 2 case studies using underground utility projects, which are funded by the Federal Government. The methods for conducting the case studies will be detailed. A simple cost analysis method will be suggested for each case.

7.3.1 Construction Modification Coding System

During this research project, it was very difficult to locate specific cost data from previous NAVFAC construction projects. One of the most inhibiting factors was the Facilities Information System (FIS) database and the methods that are used to code and describe the contract modifications for a particular contract. It is recommended that a more detailed method to describe contract modifications should be developed so that specific information can be extracted from the database.

During the data gathering portion of this research project, an attempt was made to acquire specific cost data pertaining to NAVFAC construction projects. The projects that were targeted were those which included subsurface utility and excavation work. The contracting office at Engineering Field Activity (EFA) Midwest was contacted and an inquiry was made regarding specific cost data for projects within their area of responsibility (AOR).

The first step was accomplished by performing a query of the database to find cost information for each of the projects. The search was intended to locate contracts for which construction modification had been issued because unforeseen subsurface utilities had been encountered. An example of the report that was generated by the FIS is shown in appendix A. It was very difficult to extract information from the FIS database that could be used for a cost analysis. One of the inhibitors was the coding system that is used to describe the modification. The modification description consists of two parts: the Reason Codes and the written description. The Reason Code is a four letter code that is used to classify the type of modification. The written description is a text cell within the software program that allows for a description to be entered. The description can be as detailed as necessary; however, when the report is generated it only displays 20 characters.

There are only a few Reason Codes which are commonly used. The generic Reason Codes such as Unforeseen Conditions (UNFO) and Customer Requested (CREQ) make it very difficult to gather historical data for analysis. The description line is beneficial for determining the details of the modification, if the description is detailed

and complete. In most modifications, 20 characters are not enough to accurately describe the specific details. Table 4 shows a portion of the original modification report. The highlighted portion of the table shows the coding system which consists of the Reason Code and the description text cell. This is a description of an actual modification that was issued by EFA Midwest. Most of the details in the example modification report have been changed, except for the descriptions.

Table 4: Original Coding System

N68888-00-C-0000					
BEQ	BEQ, BLDG 6		GREAT LAKES, IL		SMITH & SON
P00004	UNFO	VARIOUS UNFORESEEN CO	2/12/2003		
		OBLIGATED			2/18/2003

An improved coding system is suggested and an example of the different description method is shown in appendix A. The new coding system is more efficient because it takes the original four character Reason Code which was used to describe the type of modification and replaces it with a five character code which can describe four different attributes of the modification. The 20 character description cell should remain at 20 characters and should be sufficient since some of the major attributes will be detailed in the revised Reason Code.

The revised coding system includes a Reason Code which can describe four different portions of the modification. The revised Reason Code will consist of five characters instead of four. The reason for the modification has been reduced from a four letter alpha code to a two digit number. This can be seen in the suggested codes in appendix A. The example of an unforeseen condition which was coded as UNFO is

now coded as 01. The third character in the revised code describes the action that should be taken to execute the modification such as remove (R) or design (D). The fourth character describes the material, if applicable, and the fifth character describes the object that is being modified. The suggested coding system can be altered and added to as needed. Only a portion of the possible codes have been suggested. A complete coding system can be developed by incorporating all the potential descriptions that are currently used in the FIS modification tracking system. Table 5 shows a portion of the revised modification report. The highlighted portion of the report details the revised coding system which can be compared to Table 4. On the page following the suggested coding system, in appendix A, a revised modification report using the suggested coding method is shown.

Table 5: Revised Coding System

N68888-00-C-0000					
BEQ	BEQ, BLDG 6		GREAT LAKES, IL		SMITH & SON
P00004	08RCU	UNKNOWN PIPE	2/12/2003		
	08D-E	DESIGN MANHOLE			
		OBLIGATED			2/18/2003

The new coding system would make it easier to gather historical cost data that could be used in many different ways. One use would be to determine the cost incurred by the government due to certain contract modifications. If the cost data could be extracted from the system it could help the government to develop an annual budget for SUE work. Previous case studies have shown that there is a positive return on investment for SUE work. Therefore, if the SUE budget for current year was based on the previous years cost of unforeseen subsurface utility modifications, eventually the

average annual cost of the modifications would be reduced. At the end of every fiscal year, the government could also use the cost data from each base to determine which installations are most affected by unknown subsurface utilities. The information could then be used to decide which bases should have funds allocated to them in order to contract SUE services which would provide the base with a better understanding of their underground utility infrastructure.

Perhaps some type of coding system, similar to the suggested system, should be implemented into the next computer software package that NAVFAC decides they are going to use to manage the construction projects.

7.3.2 Cost Analysis Components

In both of the case studies that will be discussed, the costs must be tracked very closely and clearly documented in order to perform a useful cost analysis. Paragraph 7.3.2.1 will discuss some of the costs that should be tracked in order to perform a through cost analysis. Paragraph 7.3.2.2 will discuss the different costs associated with the performance of a SUE survey. Paragraph 7.3.2.3 will discuss how the use of SUE can lead to a time reduction in the project schedule. This time reduction may ultimately lead to a financial benefit as well as early completion. Paragraphs 7.3.2.4 and 7.3.2.5 will discuss the financial disadvantages that may be incurred when SUE is not used on a construction project.

7.3.2.1 Cost Data

In previous studies and cost analysis reports that have been done regarding SUE, the quantitative and estimated numbers have usually been used. It would be very

useful to everyone who is deciding whether or not to use SUE, to have a cost analysis that has been performed using exact and actual cost data from a number of similar projects. The cost data that should be tracked in order to perform a useful cost analysis are shown below:

- Change order cost paid to contractor(s)
 - Repair of utility
 - Relocation of utility
 - Redesign fees
- Financial impact caused by time extensions granted to contractor(s)
- Damages suffered by customer/owner/client
 - Time
 - Monetary damages
- Damages suffered by contractor
 - Injury to employees
 - Loss of future potential work caused by delay

This list does not include all of the costs that may be incurred when an unknown utility is discovered during a construction project. Each project is unique and would need to be evaluated independently.

The most reliable cost data are the quantifiable data as opposed to qualitative. Quantifiable cost data can either be exact or estimated. Qualitative cost data are not able to be estimated due to lack of information; however they may be very significant to the cost analysis.

7.3.2.2 SUE Survey Costs

There are many different costs associated with a SUE survey. The major cost components of performing a SUE survey are outlined below:

- Mobilization
- Designating Services
 - Direct Cost
 - Hourly Rates
- Locating Services (Test Holes)
 - Direct Cost
 - Hourly Rates
- Surveying Services
 - Direct Cost
 - Hourly Rates
- Maintenance of Traffic (MOT)
 - Direct Cost
 - Hourly Rates
- Demobilization

The designating methods such as the pipe and cable tracers are usually priced on a per linear foot basis. The linear foot cost is dependant on many different factors such as the type of utility that is being designated or whether or not a survey is necessary. The designating methods that require the use of a specialized piece of equipment such as the Ground Penetrating Radar (GPR) are usually priced as a fee per day.

The locating service which incorporates the use of an air or water vacuum to excavate the test holes is priced per test hole. The number of test holes is usually determined by the congestion of utilities in a particular area as well as the soil and pavement conditions above the targeted utility.

The designating and locating prices will vary because each project is different. Some of the SUE projects will require the engineers and technicians to travel to the job site. If travel is necessary the SUE firm will request compensation. If the project is near traffic, the crew will have to spend time and effort to maintain the traffic. Another major

cost factor is the signature and seal of a registered professional. Some projects require this type of certification, while others do not.

The individual costs for SUE work are not usually detailed in a bid. Since SUE is a professional service that is performed to produce a map or a report, the projects are usually proposed in a lump sum bid. The map or the report is the deliverable. Therefore, the payments are made based on the status of the deliverable.

7.3.2.3 *Time Reduction*

The use of SUE usually leads to a reduction in overall construction time. Time is reduced because the contractor is able to work more efficiently because they are confident in the survey that has been provided by the subsurface engineer. There is also the case where there is no time reduction; however the project is delivered on time because there were no construction delays caused by unforeseen conditions. A construction delay can cause the entire project to be delayed which can result in extra expenses for the contractor and the owner of the project.

7.3.2.4 *Contingency Cost*

When a contractor is given a project that has a number of unknown factors, the contractor is usually going to take steps to physically protect themselves which will ultimately lead to protecting themselves financially. A contingency amount is often added to the price of the contract to minimize the financial risk associated with having inadequate project information. When there is a potential for unknown underground utilities, the increased bid price is determined by estimating the amount of time and effort that will be required to slowly hand excavate around the utilities. If additional

safety precautions are required due to the risks, it will also cause the bid price to increase.

7.3.2.5 *Change Order / Modification*

When an unknown utility is encountered by the contractor the event usually results in a change order or modification to the contract. The contractor is usually compensated for time lost and for the cost to either relocate the existing line or to reroute the new utility. Not only does the contractor receive compensation for the cost of the extra work; the contractor usually adds all of the typical fees and mark-up percentages such as overhead and profit. The project owner is usually responsible for paying these extra expenses because of the differing or unforeseen conditions. In this situation, the project owner would receive the most benefit from the implementation of SUE because there would be less chance of encountering an unknown utility if a SUE survey was performed during design.

7.3.3 Case Study Experiments

The second recommendation for future work is to perform a pair of case study experiments on NAVFAC construction projects to determine if SUE is a beneficial service. During the research portion of this paper, no such study was discovered. All of the SUE cost-benefit analysis studies that were discovered had consisted of cost data that were acquired after the project had been completed. At least a portion of the cost savings that were reported consisted of estimate values, as opposed to being composed entirely of actual quantitative numbers. The most conducive project for this type of study would be one that consists of subsurface utility replacement or the

installation of new utilities in an area that is highly congested with existing subsurface utilities.

Case 1:

For the first case, the construction project should be divided into two portions of equal size and complexity. This will allow a comparison to be performed between the two mini-projects, under the same management. The same group of contractors should be hired to perform the utility work on both mini-projects. The construction price for each mini project would be estimated and bid, based on the existing record drawings. The only difference between the two portions of the project would be the method used to designate and/or locate the utilities during the design phase. On one portion of the project (mini-project 1), the existing record drawings would be used to develop the design along with help from the One-Call crews. The One-Call service would be called at the beginning of the project to give the designers a general idea of where the subsurface utilities are located. This would provide additional information beyond what the existing record drawings depict. On the other portion of the project (mini-project 2), the same information would be used for the design except for the information provided by the One-Call crews. Instead of contacting One-Call, a SUE contractor would be hired to perform a survey, at the level of quality that the designer and the utility engineer recommend.

The cost of each portion of the project will be tracked very closely, especially if there are any change order or modification requests. Once both mini-projects are

complete a comparison can be made between the two. A simple cost analysis could be done using a format such as the one shown in Table 6.

Table 6: Cost Analysis (Case 1)

	Mini Project 1	Mini Project 2
Construction Bid Price (based on record drawings)	\$\$\$\$\$	\$\$\$\$\$
One-Call Service	\$\$\$\$\$	---
SUE Service	---	\$\$\$\$\$
Survey	---	\$\$\$\$\$
Map / Digital File	---	\$\$\$\$\$
Design Cost	\$\$\$\$\$	\$\$\$\$\$
Total Investment	\$\$\$\$\$	\$\$\$\$\$
Construction Modification(s)	(\$\$\$\$\$)	(\$\$\$\$\$)
* Related to Subsurface Utilities		
Cost Impact of Time Delay	(\$\$\$\$\$)	(\$\$\$\$\$)
Damages suffered by customer/owner/client	(\$\$\$\$\$)	(\$\$\$\$\$)
Damages suffered by contractor	(\$\$\$\$\$)	(\$\$\$\$\$)
Unforeseen Cost Impact	(\$\$\$\$\$)	(\$\$\$\$\$)
Total Investment	\$\$\$\$\$	\$\$\$\$\$
Unforeseen Cost Impact	(\$\$\$\$\$)	(\$\$\$\$\$)
Remaining Investment +/-	\$\$\$\$\$	\$\$\$\$\$

The top portion of the table calculates the total investment for each mini-project. The middle portion calculates the unforeseen negative financial impacts that occur during the construction of each mini-project. The bottom portion makes an overall financial comparison between the two mini-projects. Theoretically, the project with the greatest remaining investment, points to the better method for developing the design of a subsurface utility construction project. Care should be taken to ensure that other

uncontrolled significant differences between the two mini-projects are not factored into this comparison.

Case 2:

The second case will be the analysis of a single project. A project should be chosen that has not used any SUE information during the design. Costs should be diligently tracked for the entire project. After the project is complete, the amount of additional cost that was incurred due to unforeseen subsurface utility conditions should be determined. The next step is to have a SUE contractor provide a retroactive cost estimate for a SUE survey of the project. The estimate should be based on the original design documents. This step could also be performed at the beginning of the project as long as the contractor that is to perform the work and the designer are not exposed to any of the subsurface information that results from the subsurface engineering consultation.

At the end of the case study it should be possible to compare the estimated cost of the SUE services to the actual cost incurred due to the unknown utilities that were discovered, if any. Table 7 shows a simple method for a cost analysis

Table 7: Cost Analysis (Case 2)

Estimated SUE Services (based on original design documents)	\$\$\$\$\$
Survey	\$\$\$\$\$
Map / Digital File	\$\$\$\$\$
Total Investment - SUE	\$\$\$\$\$
Construction Modification(s) * Related to Subsurface Utilities	(\$\$\$\$\$)
Cost Impact of Time Delay	(\$\$\$\$\$)
Damages suffered by customer/owner/client	(\$\$\$\$\$)
Damages suffered by contractor	(\$\$\$\$\$)
Unforeseen Cost Impact	(\$\$\$\$\$)
Return on Investment	
ROI = $\frac{\text{Unforeseen Cost Impact}}{\text{Total Investment - SUE}}$	$= -1 \times \frac{($$$$$)}{$$$$$}$

The top portion of the table calculates the estimated cost of the SUE services. This will be an anecdotal number but should be relatively close to the actual cost that would have been charged to perform the SUE services if it had been done before construction. The middle portion calculates the unforeseen financial impact caused by unknown subsurface utilities which may be encountered during construction. Theoretically, this dollar amount could have been avoided, if a thorough SUE survey had been conducted. Therefore, a return on investment (ROI) calculation can be performed as shown in the bottom portion of Table 7. If the number is greater than or equal to 1, it would have been beneficial to use SUE. If the ratio is less than 1, it would not have been beneficial for the individual project. However, as discussed later in section 7.4, there is also a future benefit that is often realized after a SUE survey is performed.

7.4 Cost Justification

The money that is spent on SUE must be viewed as an investment as opposed to a one time expenditure on a single project. Once a SUE survey is performed in an area, the information that is provided can be useful on numerous jobs that are performed in the approximate area. If the data management is performed correctly and continuously updated when new work is done, the SUE survey should never have to be repeated. It is theoretically a one time cost, which will potentially yield infinite benefits.

8 Conclusions

The purpose of this paper was to research the current technologies of Subsurface Utility Engineering and determine if it should be used on NAVFAC construction projects. The information that has been presented in this paper suggests that SUE is an extremely useful engineering discipline, when used correctly. Based on the information within, this work is meant to encourage NAVFAC to avoid unnecessary utility damage and relocations by expanding the use of Subsurface Utility Engineering to all of their field offices throughout the world.

8.1 Summary

Naval Facilities Engineering Command is responsible for some very old and some very large military bases. Many of these installations have inadequate subsurface utility records which cause problems for all the parties involved with the on-base excavation work. SUE technologies and methods are improving at a rapid pace and are currently very effective for locating underground utilities and other potential conflict areas that may arise during the excavation process. This engineering discipline is being used on a routine basis for civilian construction, but has yet to become the standard operating procedure (SOP) for the military. SUE has been used on some military construction projects and the results have been positive. The use of SUE on more NAVFAC construction projects should seriously be considered.

There have been many benefits that have been realized through the use of SUE. Three of the most important benefits that were discussed in this paper were the

improved safety conditions, the reduction of physical as well as financial damage caused by unforeseen subsurface utilities, and a more clear understanding of the utility infrastructure for all necessary base personnel, specifically the security department. SUE has been shown to improve the safety conditions and reduce the injury and death rates on excavation projects. This should interest an organization such as NAVFAC that preaches "Safety First" and strives for zero accidents. SUE has also been shown to minimize the damage caused to vital utilities and the other property surrounding the utilities. Minimizing this damage can lead to cost savings and the release of contingency funds that can be spent on other projects. The threat of terrorist attacks is a never ending concern for critical facilities such as military bases. Subsurface utility engineers can provide a set of deliverables that detail the entire underground infrastructure for a particular area. This information is necessary for the security personnel to prevent vulnerable points of access into the critical facilities.

During the development of this project, there were a small number of Navy construction projects that were discovered and investigated. The SUE projects that were found to have been done with the Navy were in the northern Florida area (Jacksonville, Mayport, and Pensacola). There were no Navy funded projects found that had a negative outcome due to the use of SUE. Once the Navy contracting offices had seen the benefits of the service, they began to use SUE more frequently. Engineering Field Activity Southeast has used the SUE services on a number of projects and in some cases even requested them in the specifications.

It is difficult to accurately measure the impact that SUE has on a construction project because no two jobs are the same. If SUE is correctly used during a project, it is impossible to predict the results of the project if SUE had not been used and vice versa. There have been cases where SUE services did not result in a benefit to the project. However, this is often due to some misapplication or misunderstanding of the correct SUE procedures as opposed to the actual SUE services. Even in the worst scenario, SUE services are going to provide new information pertaining to the utility systems which can often be used on future projects, regardless of whether or not there was a financial benefit on the intended project. SUE services should be considered an investment that may provide infinite future benefits as opposed to a one-time expenditure that will only provide an immediate benefit. The SUE services may be considered a sunk cost (approximately 0.5 - 1.0 percent of the total construction cost) for the intended project, but will ultimately benefit a future project that is performed in approximately the same area.

8.2 *Closing Remarks*

Recommendations have been made to improve the data entry methods for construction modifications and to perform two separate case studies. The improvement to the data entry methods will allow for more thorough cost analysis to be performed, based on actual cost information. It is believed that by performing a detailed cost analysis as well as the case studies that have been recommended, the results will support the author's opinion that SUE is and can be extremely beneficial to NAVFAC. The complete implementation of SUE will provide a financial benefit as well as a more manageable subsurface utility system for each individual base.

The technology is available to eliminate activities such as utility relocation and repair of damage due to negligence or faulty information. Therefore, public dollars provided by the taxpayers should not be used to pay for these unnecessary costs in instances where SUE was not used, or where the methods were not performed correctly. This paper should persuade other Federal Government employees and military members to push for the implementation SUE, in order to improve the construction and management of the installations and facilities that are funded by the American taxpayers.

Appendix A

Example of a FIS Modification Report (Original Coding System)

CONTRACT MODIFICATION REPORT										PAGE: 1	
REPORT NUMBER: SUBMITTED BY:		DIVISION PROJECT				AS OF: 23-Feb-04 TIME: 6:26:27					
CONTRACT NUMBER CNT ACO CDE	CNT DESCRIPTION	CNT ATY LOCATION	CONTRACTOR NAME	CNT SPECIALIST	CNT OBL AMT	CNT CWE					
DO	DO DESCRIPTION	DO ATY LOCATION	DO ACO CDE	DO SPECIALIST	DO ISS DTE	DO ISS AMT					
MOD REASON	MOD DESCRIPTION	PR RCPT	RFP ISSU	NEG DTE	MOD START	COM OSG					
	MOD STATUS	GVT EST	FND RSVD	NEG APV	MOD END	MOD EXU AMT					
			CTR PROP	CTR SIGNED	GVT SIGNED						
N68888-00-C-0000	BEQ, BLDG 6	GREAT LAKES, IL	SMITH & SON	JOHNSON	68,758,245.35	68,758,245.35					
P00001	UNFO VARIOUS CHANGES OBLIGATED	10/14/2002	10/29/2002		10/29/2002	0.00					
P00002	CREQ VARIOUS CUST REQ OBLIGATED	11/24/2002	11/30/2002		11/30/2002	0.00					
P00003	UNFO ASBESTOS REMOVAL OBLIGATED	01/03/2003	01/14/2003		01/15/2003	0.00					
P00004	UNFO VARIOUS UNFORESEEN CO OBLIGATED	02/12/2003	02/18/2003		02/19/2003	0.00					
TOTAL NUMBER OF MODS:						4					
TOTAL NUMBER OF CONTRACTS:						1					

Note: This is a fictional report.

Revised Coding System

Reason			Action		Material		Item	Description (20 characters)
01	ADMIN	Administrative	A	Award	A	Asbestos	A	XXXX XXXX XXXX XXXX
02	CREQ	Customer Request	B		B		B	XXXX XXXX XXXX XXXX
03	CRIT	Critical	C	Change	C	Concrete	C	XXXX XXXX XXXX XXXX
04	OTPT	Option	D	Design	D	Contaminated (dirty)	D	Soil (dirt) XXXX XXXX XXXX XXXX
05	PLAN	Planned	E	Extension	E		E	Equipment XXXX XXXX XXXX XXXX
06	SCPE	Scope	F	Furnish & Install	F		F	Furniture XXXX XXXX XXXX XXXX
07	TIME	Time	G		G		G	XXXX XXXX XXXX XXXX
08	UNFO	Unforeseen Condition	H		H		H	XXXX XXXX XXXX XXXX
09			I		I		I	XXXX XXXX XXXX XXXX
10			J		J		J	XXXX XXXX XXXX XXXX
11			K		K		K	XXXX XXXX XXXX XXXX
12			L		L		L	XXXX XXXX XXXX XXXX
13			M	Relocate (move)	M		M	XXXX XXXX XXXX XXXX
14			N	De-obligate (negate)	N		N	XXXX XXXX XXXX XXXX
15			O		O		O	Option XXXX XXXX XXXX XXXX
16			P	Purchase	P		P	XXXX XXXX XXXX XXXX
17			Q		Q		Q	XXXX XXXX XXXX XXXX
18			R	Remove	R		R	Roof XXXX XXXX XXXX XXXX
19			S		S	Steel	S	Siding XXXX XXXX XXXX XXXX
20			T		T	Transite	T	XXXX XXXX XXXX XXXX
21			U		U		U	Utilities XXXX XXXX XXXX XXXX
22			V		V		V	XXXX XXXX XXXX XXXX
23			W		W		W	XXXX XXXX XXXX XXXX
24			X	Fix	X		X	XXXX XXXX XXXX XXXX
25			Y		Y		Y	XXXX XXXX XXXX XXXX
26			Z		Z		Z	XXXX XXXX XXXX XXXX
-								XXXX XXXX XXXX XXXX
99			-	Blank	-	Blank	-	Blank XXXX XXXX XXXX XXXX

The first table in this appendix A is an example of a construction modification report from FIS. The Reason Codes and descriptions are from actual reports.

The table on this page is the suggested coding system that could be used to improve the coding method.

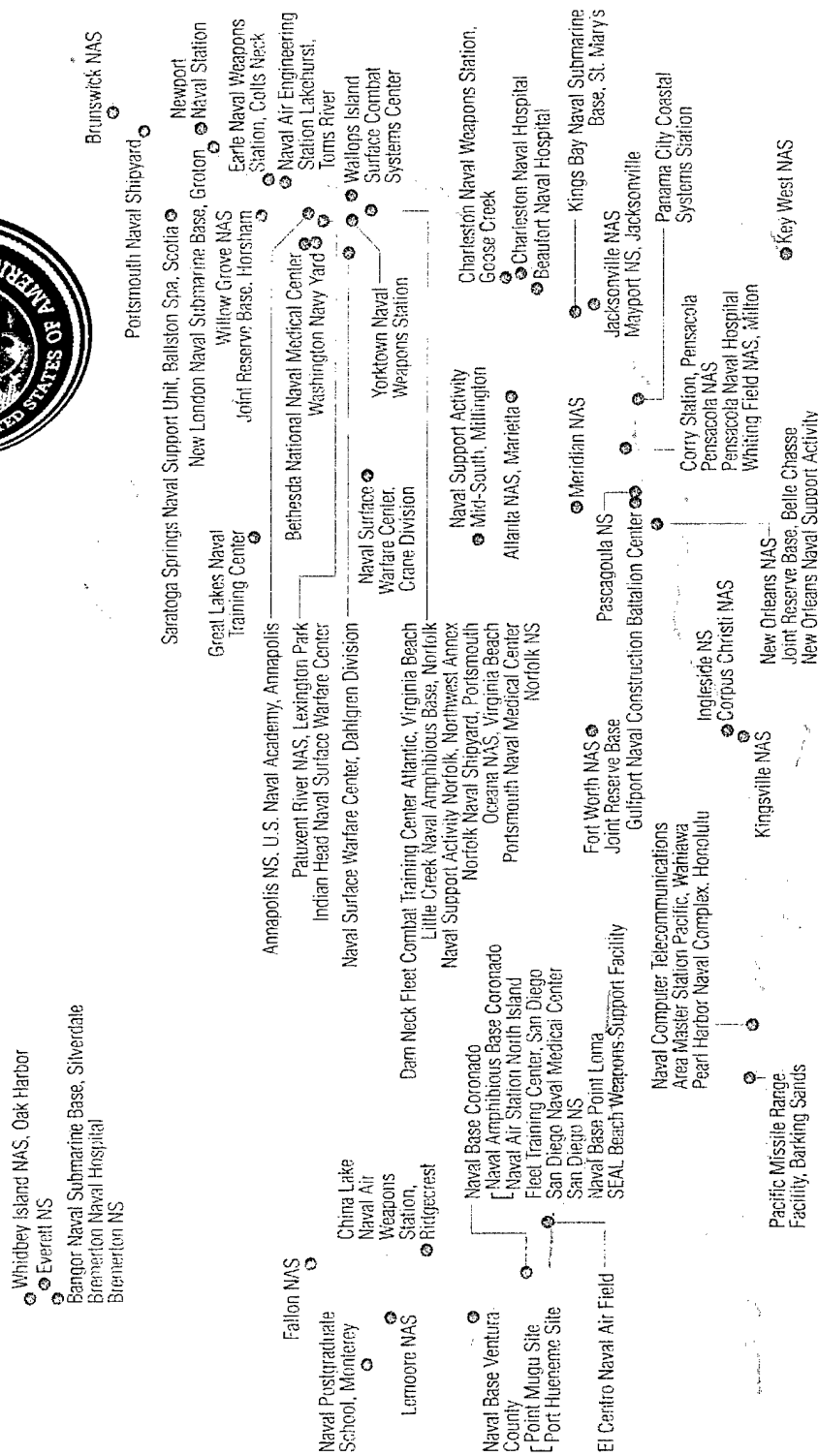
The table on the following page is a modification report that has been modified with the suggested coding system. The highlighted portions of each modification report should be compared to see the difference.

Example of a FIS Modification Report (Revised Coding System)

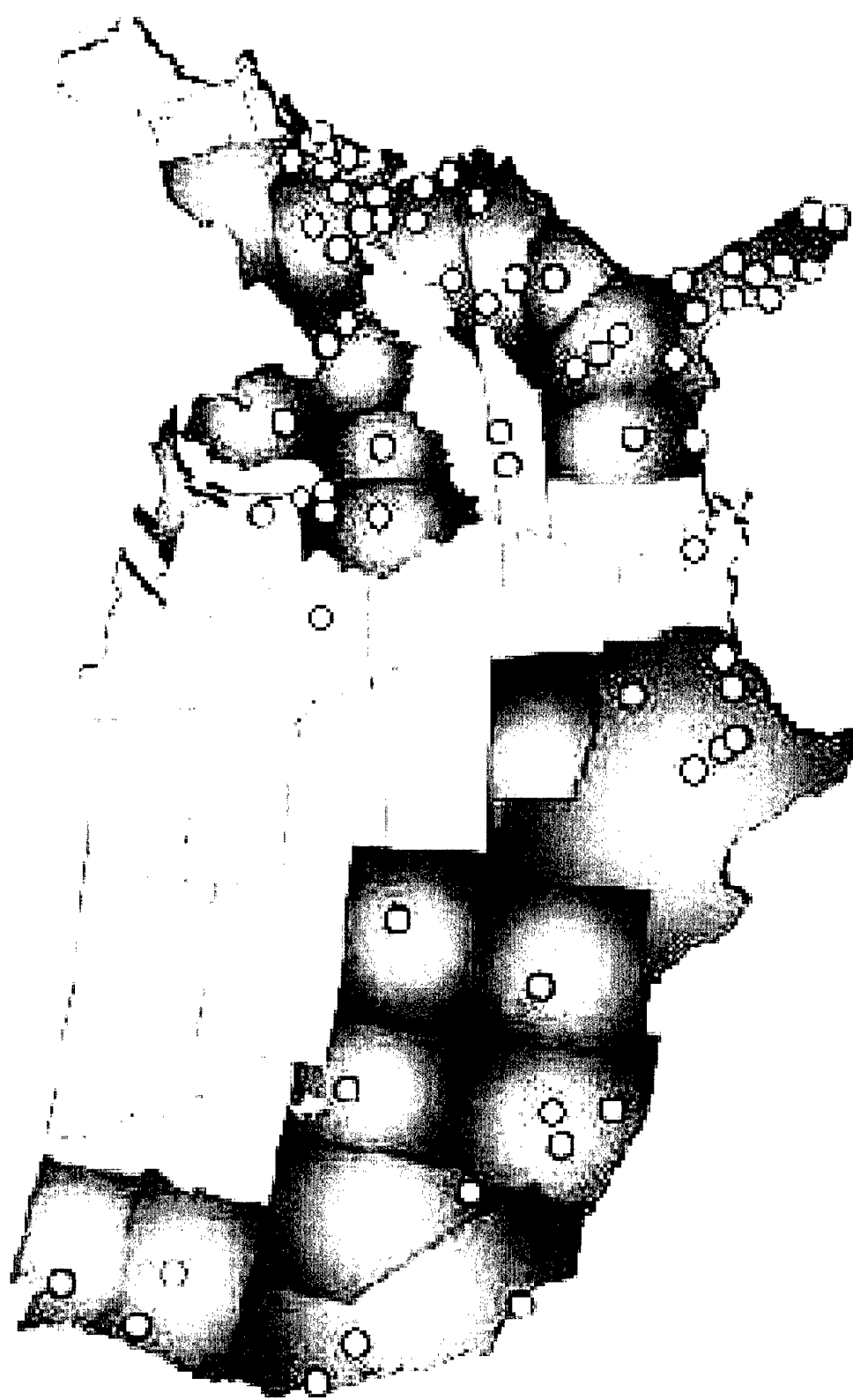
REPORT NUMBER: SUBMITTED BY:		CONTRACT MODIFICATION REPORT										PAGE: 1 AS OF: 23-Feb-04 TIME: 6:26:27	
		DIVISION PROJECT											
CONTRACT NUMBER CNT ACO CDE		CNT DESCRIPTION		CNT ATY LOCATION		CONTRACTOR NAME		CNT SPECIALIST		CNT OBL AMT		CNT CWE	
DO		DO DESCRIPTION		DO ATY LOCATION		DO ACO CDE		DO SPECIALIST		DO ISS DTE		DO ISS AMT	
MOD REASON		MOD DESCRIPTION		PR RCPT		RFP ISSU		CTR PROP		NEG DTE		MOD START	
MOD STATUS				GVT EST		FND RSVD		MOD EFF		NEG APV		MOD END	

Note: This is a fictional report.

Appendix B

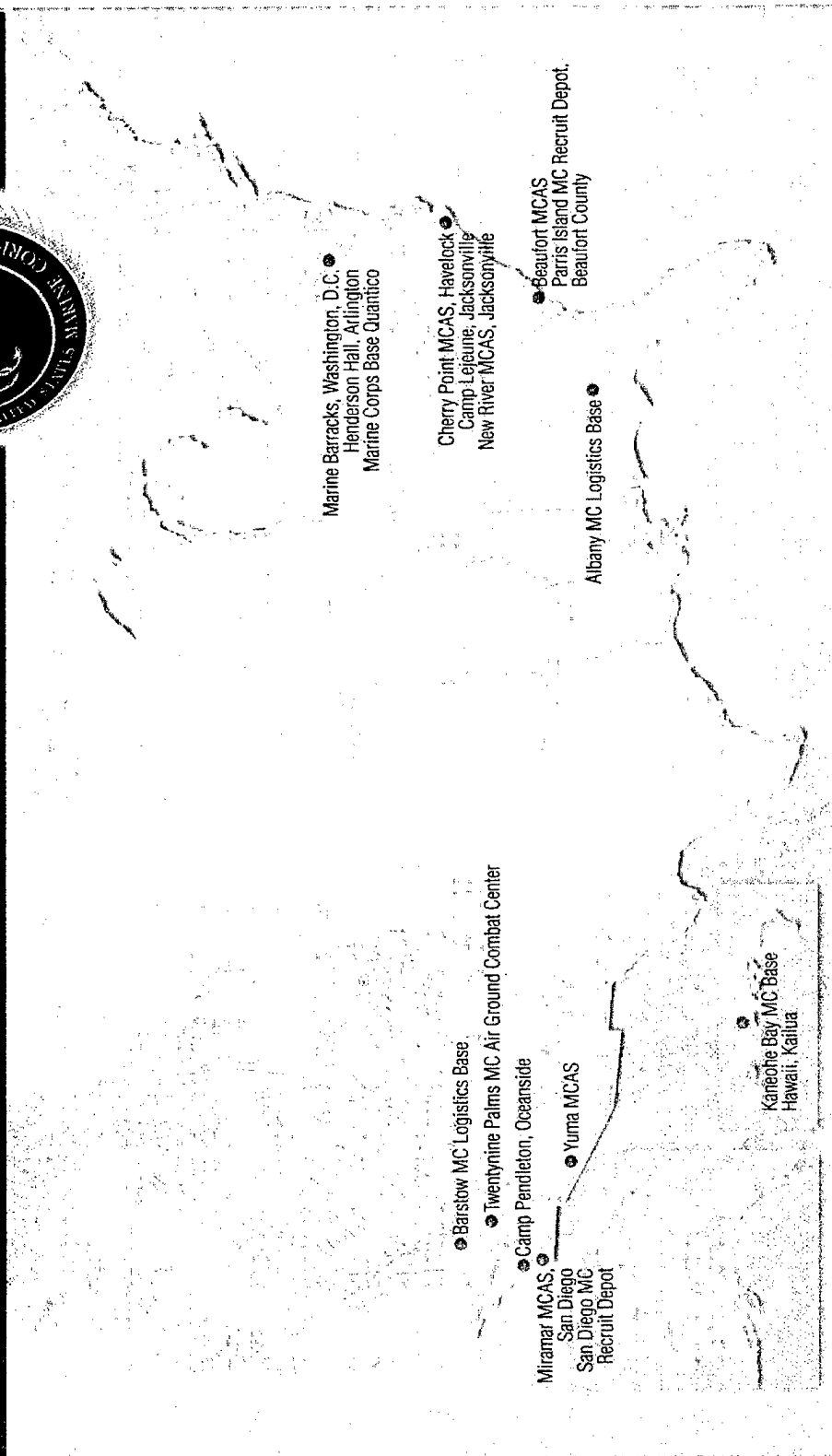


75



Locations of Qualified SUE Providers

U.S. MARINE CORPS



Locations of U.S. Marine Corps Bases

References

Anspach, J. H. (1995). "Subsurface Utility Engineering: Upgrading the Quality of Utility Information." Proceedings of the American Society of Civil Engineers 1995 Conference on Advances in Underground Pipeline Engineering.

Anspach, J. H. (1992). "Subsurface Utility Engineering." Proceedings from the Twenty-Ninth Paving and Transportation Conference, University of New Mexico. 1992.

Federal Highway Administration (FHWA). (2004) "Subsurface Utility Engineering." <http://www.fhwa.dot.gov/programadmin/sueindex.htm> (June 2, 2004).

Federal Highway Administration (FHWA). (2003). "Imaging and Locating Buried Utilities." Joint Transportation Research Program. Publication No. FHWA/IN/JTRP-2003/12. October 2003.

Federal Highway Administration (FHWA). (2002). "Avoiding Utility Relocations." Research Development and Technology. DTFH61-01-C-00024. July 2002.

Lew, J. J. (2000). "Cost Savings on Highway Projects Utilizing Subsurface Utility Engineering." Purdue University / Federal Highway Administration. Publication No. FHWA-IF-00-014. January 2000.

Locator Equipment, LLC (2004). "Locating Products." <http://www.sihope.com/projects/locator/products.htm> (June 5, 2004).

Ryan, P. K. and Anspach, J. H. (2002). "Pipeline Planning Utilizing C/I ASCE 38-02." 2002.

Spalj, G. T. (2004). "Underground Utility Strikes by Contractors." <http://www.pccaweb.org/Magazine/PC0404.html> (June 3, 2004).

Sterling, R. L. (2000). "Utility Locating Technologies: A Summary of Responses to a Statement of Need Distribution by the Federal Laboratory Consortium for Technology Transfer." Federal Laboratory Consortium Special Reports Series No. 9 ISSN 1075-9492C, February 2000.

Bibliography

Aircraft Carrier Wharf Improvements. (2000). "Section 01110: Summary of Work". Naval Station Mayport, Florida.

American Society of Civil Engineers (2002). "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data." C/I ASCE 38-02, Reston, VA.

Anspach, J. H. (2002). "Underground Utility Security Issues at Critical Facilities." 2002.

Department of the Navy (2004). " Department of the Navy – Utility Privatization." <http://energy.navy.mil/privatization/> (June 11, 2004).

GeoSpec, LLC (2004). "Subsurface Utility Engineering." http://www.geospec-llc.com/downloads/SUE_white_paper.PDF (June 2, 2004).

Jeong, H. S. (2001). "A Decision Tool for Subsurface Utility Engineering." Independent Research Study, School of Civil Engineering, Purdue University. December 2001.

Lew, J. J., Lew, J. C., and Harter, J. E. (2000). "Proceedures for the Incorporation of Subsurface Utility Engineering (SUE) in the Design Process".

So-Deep, Inc (2004). "Subsurface Utility Engineering." http://www.so-deep.com/subsurface_utility_engineering.htm (June 2, 2004).

U.S. Department of Transportation, Federal Highway Division, Office of Engineering. "Subsurface Utility Engineering." October 1994.

Personal Contacts

Allen, Jim, TBE Group, Inc., Telephone and electronic communication, May ~ July, 2004.

Anspach, J. H., Principal of So-Deep, Inc., Telephone and electronic communication, January ~ July, 2004.

Bernold, Leonhard, Ph.D. Director of the Center of Construction Technology & Integration at North Carolina State University., Electronic communication, April 2004.

Burns, Fred, Water Utilities Director of Navy Public Works Center Jacksonville, Telephone communication, June 2004.

Dummer, Jerry, Utility Engineer at Naval Facilities Engineering Service Center. Telephone and electronic communication, January ~ June 2004.

Gokhale, Sanjiv, Ph.D. Director of Construction Management at Vanderbilt University. Electronic communication, April 2004.

Jackson, Michelle. Project Manager at NAVFAC Engineering Field Activity Southeast. Telephone communication, June, 2004.

Robert Kight. Project Manager for Reynolds, Smith & Hill of Jacksonville, Florida. Telephone conversation June 1, 2004

Kraynak, Mark. Client Liaison Program Director at NAVFAC Headquarters. Telephone and electronic communication, March ~ June 2004.

Rosencrans, Ron. Editor of Underground Focus Magazine. Electronic communication, May 2004.

Thompson, Mark. Senior Executive VP of MIL-CON Construction Corporation, Telephone and electronic communication, June 2004.

Peterson, Greg. Owner of Peterson Engineering, Telephone communication, June 2004.

Scott, C. Paul. National Utilities Liaison for TBE Group, Inc. Telephone and electronic communication, May ~ June 2004.

Zembillas, Nicholas. Senior Vice President of TBE Group, Inc. Telephone and electronic communication, January ~ June 2004.