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PREFIRE WATER SUPPLY PLANNING

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by

Jon E. Bartelson

Donald E. Contois

Patrick J. Bakaj

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Approved:

Professor Robert W. Fitzgerald

Abstract

Water supply is an important part of the local community resources for fire fighting. The time to establish a water supply for fire fighting and the maximum delivery quantity and pressure are important decisions that a community must make. These decisions are influenced by economics, planning, the exposure and attack needs, national standards and local regulations. This project describes these factors and evaluates an office park in Auburn, Massachusetts.

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Chapter

1 Introduction

The need to control fire has existed since man first discovered it and began using it as a tool. Being the dangerous beast that it is, fire has the tendency to get out of control when it is not used properly. Hence, the need for a suppression plan and medium. Water is that medium and its supply analysis enhances that plan that saves life and property.

Some history is necessary to fully understand how fire suppression techniques have developed over the centuries. As time passes by, new forms of fire fighting are learned and passed down.

The art of fire suppression as it stands today is an important guide to how water is applied to a fire once it is supplied. The economics of fire suppression must be considered as well. These tie directly into water supply analysis.

Any professional analysis must be completed with a case study, which backs up and gives the overall discussion strength.

1.1 Technique

For fire to occur, three factors must be present: fuel, oxygen, and a source of ignition. Throughout history fire has been both a friend and an enemy of man. Man has used fire throughout the ages as a tool. It serves many purposes, whether it be cooking and cleaning or warmth and smithing. When used properly, fire is a necessary addition to everyday life. However, fire also has been a threat to life and property ever since man first learned to kindle a flame. When used improperly, fire can become a devastating beast that destroys everything in its path.

One of the first examples of established fire fighting comes shortly after the birth of Christ. The early Roman Empire provided some of the first organized community fire protection brigades. Although mechanical pumps (like the one invented by Ctesibus) were rare, the Romans concentrated on organized manpower to form the core of their fire defense. Slave labor was abundant in the Roman Empire at this time. In order to provide an early warning of fire, suitable male slaves were located at strategic points around the cities. Unfortunately, records show that many slaves were unreliable, and in AD 6, one quarter of the entire center of Rome was destroyed in one devastating conflagration.[1]

This catastrophe brought about major improvements in Roman fire protection, with the formulation of a corps of fire fighters known as vigiles, whose members were not slaves, but enjoyed high social status. The vigiles lived in a collective dormitory with its own private bath (much like the firehouses of today). The vigiles were formed into three basic groups whose functions were:

1. As providers of water to the fire via organized double-line bucket-chains; one line passed water to the blazer, the other returned the buckets for refilling.
2. As crews who actually operated the fire pump.
3. Vigiles whose primary task was to pull down those parts of walls and roofs that were burning, to provide a firebreak and thus to restrict the rapid

[1] Wallington, Images of Fire, p. 13

spread of the fire through starving it of read material upon which to feed. These latter crews were armed with ladders and long hooks to provide the necessary reach. They must have been extremely courageous to carry out their critical work close to and underneath dangerous fire situations with little personal protection.

The Romans went on to establish various corps of vigiles throughout the empire through the teaching of fire fighting skills and experience gained in Rome. Unfortunately, the vigile tradition of fire fighting followed the same downward slope as that of the empire did in the early centuries AD.[2]

The Second Great Fire of London in 1666 finally provided the motivation to move forward from the fire fighting provisions that were set forth by the vigiles a century-and-a-half before. The fire burned uncontrolled for four days and four nights before many unaffected buildings were demolished in its path to form a massive firebreak. An area of about 1 mile long and ½ mile wide was left a charred and smoldering ruin; 13,000 homes, 84 churches, 44 livery halls and many other public buildings were destroyed. Over 100,000 people were left homeless by the conflagration, but amazingly only 6 people lost their lives. The cost of this second great fire was estimated at £10 million.[3]

As a result of the Second Great Fire of London, "Insurance Offices" were erected where parties could insure themselves against fire damage. The first was set up in 1680, and many others followed. However, fire damage was still a widespread problem, and some of the insurance offices assembled their own fire brigades. These brigades were

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[2] Ibid., p.14

compiled of men recruited from the many watermen who plied on the Thames. They were employed on a part-time basis and followed their ordinary work until called out to an outbreak of fire by messenger.[4]

Nevertheless, the early days of organized insurance company fire brigades were not without difficulty and conflict. It was evident upon arriving at a working fire if a building were insured against fire damage and by which company. At first, firemen employed by a specific insurance office would deal only with a fire in a property insured with their company. If another company in fact insured the insured building, other corporate fire brigades would literally stand by and watch the fire take hold. Worse still, during the time up to the early 1700s, rival firemen would actively engage in harassing and obstructing their competitors, and many fights broke out against the backdrop of a burning property.[5]

Outside of London and the large cities, fire fighting remained the legal duty of the parish authorities that were obliged to provide a large and a small engine, together with lengths of leather hose. The custodians of the engines were paid rewards according to their order of arrival at a fire.[6]

Changes in the fire fighting community happened slowly over the years. New equipment became more readily available to suppress fires in increasingly efficient manners. Also, larger urban fire departments were turning in favor of paid firefighters;

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[3] Ibid., p.16
[4] Ibid., p.18
[5] Ibid., p.19
[6] Ibid., p. 20

New York created a paid fire department in 1865, Philadelphia organized one in 1871.[7]

The fire departments of today have come a long way from the practices of the past. Safety is more an issue for today's fire fighters than it ever has. However, as technology becomes better over time, fire fighting will become increasingly safe.

1.2 Apparatus

One of the first recorded attempts at automating fire suppression apparatus goes back to the second century BC, when an Alexandrian named Ctesibus invented a hand pump that could throw a jet of water onto a fire. This is a far cry from a local fire department, but it probably was well suited for a small fire. [8]

Around the time of the Second Great Fire of London, fire-fighting equipment was beginning to be developed. By the end of the seventeenth century, manually operated pumps were quite commonplace. Some of these were horse drawn. Leather hose was now available, which meant that a jet of water could be taken close to, or even into a burning building, instead of relying on the earlier nozzle fixed to the top of a manual pump. Hand-held fire squirts (see Figure 1), like large syringes, were also more readily available although restricted by the need for frequent refills. [9]

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[7] Corbett, Water Supply Evaluation for Firefighting, p. 6
[8] Wallington., p. 13
[9] Ibid., p. 18

Figure 1

The predecessors of modern fire apparatus can be traced back as far as the seventeenth century. During this period, many attempts were made to improve upon the capability of the water squirt. The next logical step was to mount the squirts on wheeled frames and provide a better bucket-fed water supply from which a continuous fire fighting jet could be propelled.[10]

Fire "engines" appeared in some developing American cities during the late 1600s and early 1700s. Boston received its first pumper in 1654, Philadelphia in 1719, and New

York in 1731. However, these early engines still required the use of buckets to supply them with water. A suction apparatus that allows for automatic supply of water to the engine was not introduced to the United States until approximately 1815.[11]

Between 1820 and 1850, increasingly powerful hand pumped engines were introduced into the fire suppression scene. In 1842, New York's Empire Engine Company #42 was built. It could supply several hundreds of gallons of water per minute and required many men to pump it. It was referred to as the “mankiller”.[12]

Through the 1850s and 1860s, a transition was made from the traditional hand pumper to more powerful steam fire engines. These new “steamers” (capable of pumping 300-1300 gallons per minute (g.p.m.)) required only a small amount of manpower to operate. Hand pumpers were virtually eliminated in the major cities around this time, abandoned in favor of the more efficient steam pumpers. However, the hand pumpers continued to be used in rural areas until the turn of the century.[13]

Along with more efficient fire engines came more efficient ways of delivering the water supply to the fire. Major developments in host technology debuted in the same time period. The move was made from the cumbersome and maintenance-intensive leather hose to seamless linen-jacketed rubber hose, which was in use in America until the 1950s.[14]

In the 1880s, the “chemical” fire engine appeared on the fire suppression scene. It produced a pressurized stream of water created by a reaction of sodium bicarbonate,

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[10] Ibid., p. 74
[11] Corbett, p. 3
[12] Ibid., p. 6
[13] Ibid., p. 7

sulfuric acid, and water. This method was most commonly used to extinguish small fires, since the engines contained only a few hundred gallons of water. These engines were most popular in small cities where no immediate water supply was present.[15]

By the beginning of the twentieth century, the internal combustion engine was being applied to road vehicles other than cars. Fire engines began to incorporate the gasoline-powered engine in favor of horse-drawn apparatus, which eventually were retired. The gas-powered engine provided a large speed increase that allowed for a higher fire fighting efficiency. With the advent of gas-powered engines also came enclosed cabs to allow the firefighter to dress for the fire while the apparatus was in motion with little or no personal injury.

During the first 20 years of the 20th century, the

Motorized fire apparatus became increasingly popular. Motor drives for steamers and motorized chemical wagons and hose wagons appeared. The first automobile fire engine came into service in 1903 and eventually became the norm for fire suppression apparatus.

By 1930, the chemical engines, steamers, and hose wagons had been replaced by gasoline powered fire engines. As time went on, the gasoline (and later diesel) pumpers grew in size (pumpage, water tank size, and hose carrying capacity).[16]

1.3 Water Supply

During the American Colonial Period, water used at the scene of a fire was gathered from sources such as wells, rivers, and lakes. Water was taken from these

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[14] Ibid., p. 7
[15] Ibid., p. 7
[16] Ibid., p. 9

supplies with buckets and applied directly to the fire by hand. This technique, deemed the "bucket brigade", was the only means of supplying water to an inferno for over a millennium.[17]

A bucket brigade's range and effectiveness were limited because of the exterior nature of its plan of attack. A bucket brigade could not enter into a burning building to extinguish the fire. All suppression efforts had to be executed from the outside. With these conditions hindering the suppression of fires, the use of hoselines as a water application instrument developed. Early hoselines were made of leather and were sewn together. These lines allowed firemen to penetrate into a building, thus reducing the loss of life and property.

The first hose company to be introduced in the U.S. was the Philadelphia Hose Company in 1803. Hose was used in a small way at working fires, since it had to be carried to the scene in rolls in order to be utilized. Only a very small amount of hose was carried on the engine, thus the need for the hose company in addition to the engine company. Hose was not carried on the engine until the introduction of motorized apparatus in the 20th century.[18]

As American cities began to grow, it became apparent that water needed to be brought to the populace. It was equally apparent that bringing water from it sources via the use of buckets, and in turn supplying the hand pumpers was not practical. A permanent piped water supply became necessary to solve the problem.[19]

Beginning with New York City in 1799, municipal water departments began

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[17] Ibid., p. 2
[18] Ibid., p. 3
[19] Ibid., p. 4

laying down pipe infrastructures to support the supply of water throughout the city. The presence of a piped water supply greatly aided the hand pumpers that were greatly increasing in size.

The first recorded fire "plug" was implemented in New York City in 1807. Early fire plugs were probably nothing more than holes drilled in the wooden water mains with stakes (or plugs) that could be removed at the time of a fire. With the hole unplugged, water could flow from the opening forming a small pond. This small pond resembled those that formed at the water supply end of a bucket brigade. From these makeshift fireplugs, true fire hydrants soon followed in 1817.

Synthetic materials were introduced to the water supply scene in the late 1950s. The production of polyester-jacketed hose eliminated the problem of mildew that was common in cotton-jacketed hose. Polyester also increased the allowable water pressure on a hose.

The 2½" hose line (for pumper supply and handline use) was the mainstay of the fire suppression service for many years. This hose size began to decrease in popularity through the years, as 1¾" handlines and 3, 4, and 5" supply lines were developed. Today, the large diameter supply lines are composed of such materials as Hypalon, a synthetic material developed to resist mildew and abrasion.

1.4 City Conflagrations

During the period between 1870 and 1910, several widespread fires struck some of America's larger cities. Fires raged through Chicago in 1871, Boston in 1872, Baltimore in 1904, and San Francisco in 1906. All of these fires caused the current fire fighting techniques of the time to change. The need for fixed water supplies in busy downtown areas was finally realized.

The impact of these fires led to the development of a high-pressure water system in Philadelphia, New York, San Francisco, and Baltimore. The high-pressure systems were capable of supplying several thousand gallons of water at high pressures (20,000 g.p.m. at 250 p.s.i in the San Francisco system).

A specific example of improvement as a result of one of these massive fires was implemented in Baltimore. In the aftermath of the great fire, an attempt was made to convert the different fire companies in the city to a common hose thread size for use on all fire hydrants. At the time, not all fire companies could use the installed city fire hydrants due to a differing hose thread size. The same problem exists today between cities, since not all cities conform to a national hose thread size.[20]

1.5 Fire Suppression

Fire suppression is the wording generally used to describe the extinguishing of any type of structural fire. One of the most important tasks in fire suppression is the location and establishment of a working water supply. A water supply must be selected that is either close to or brought to the scene of a fire. A water supply must also have enough water to extinguish the fire in an expedient manner.

Fire suppression presents a strain on community resources in the form of damage control, fire department support and size, and general fire suppression call expenses. Depending on the department (be it a full time, call, or volunteer department), the

[20] Ibid., p. 8

requirements of the supporting community will vary.

The fire suppression process begins with the detection or notification of a working fire. This can be accomplished via a phone call to the fire department, or via a fire alarm. After notification has occurred, the fire department responds according to its size and capacity. Once the fire department arrives at the scene of a working fire, they must attack the fire in an efficient and methodical manner.

Water supply is an integral part of the fire suppression processes, since it is essential to extinguish fires. Water can be supplied via fire engines, fire hydrants, or by drafting from a nearby fixed body of water. Water can be transferred from its source to its destination via host, pipes, and/or building equipment such as sprinklers and standpipes.

1.6 Economics

The economics of fire suppression is a science all of its own. An analysis of fire suppression economics must include all aspects of the suppression process, such as department costs, environmental and property damage, water supply and community economy.

Damage caused by a fire includes more than the destruction of a structure. In addition, there are damages to the contents of a structure and whatever lives inside it.

Water supply is also a cost to be included when analyzing fire suppression economics. Water supply will be variable cost depending on sources and their locations. All fire departments must distinguish between public (community) water supplies and private (non community-held) water supplies. There are different costs associated with each. There will be a significant difference in water supply cost between a small town and a large city. Cities need to deal with the existence and maintenance of water mains. The placement of water supply piping can be a make-or-break decision as far as economic analysis goes. Smaller towns have a different set of problems than larger cities. They may be strapped for water during the summer months when water might not be readily available, for instance. They might have staffing problems, since some towns are completely volunteer.

CHAPTER

2

FIRE SUPPRESSION

2.1 Introduction

Fire suppression is a general term, which includes all aspects of fire fighting. Since there are so many different types of fire ground conditions and operations, this paper will focus on interior fire fighting. Interior fire fighting is a subset of structural fire fighting, in which the fire is attacked from within the structure. Interior fire fighting consists of many essential tasks that must be completed in a timely and efficient manner. Some of the major tasks include:

* Establishing a water supply
* Fire attack
* Ventilation
- Rescue
- Salvage and Overhaul

The tasks with * next to them are the most important aspects of interior fire fighting and will be discussed in greater detail later in the chapter. Rescue is important, but it is not encountered at all structure fires, and will not be included as part of this study. If there is any doubt about whether or not a person is trapped inside, rescue is completed along with, if not before, some of the other essential tasks. Salvage and overhaul are usually performed after the fire is under control. Salvage is done in order to protect personal belongings, which have not yet been damaged by the fire, smoke or water. Firefighters will cover or remove belongings in order to protect them. Overhaul is completed in order to ensure the fire has been extinguished and there are not any hot areas, which could rekindle. Firefighters pull down walls and ceilings to check if fire or hot spots are hidden behind them.

Another aspect of interior fire fighting involves the needs and resources of a community. Each community has different numbers of residential, businesses and commercial zones. Cities and large towns will have more residents, business and commercial zones than rural towns. Therefore a city or large town will have more money and a larger need for fire fighting resources. They will usually have either a full time department or a full time department with support from a call department. A rural town will not have as much money and will not have the need for even a partially full time department, so they will have either a call department or a volunteer department. The only difference between a call department and a volunteer department is the fact that call firefighters get paid for their services, but the volunteer firefighters do not.

A full time fire department is fully manned twenty-four hours a day seven days a week. Full time departments are usually located in cities, where they have enough of a tax base to support full fire coverage around the clock. Also cities have more people, cars and buildings, which warrant a full time fire department. A full time department will have firefighters, who have more training, more experience and better equipment than most other fire departments. A full time firefighter is on the job forty plus hours a week. The resources, which the firefighters have, are also very valuable. They will have the best equipment, most hydrants, and the fastest response time. Response time obviously is important, because the longer it takes for the trucks to get on scene the more intense the fire will be. Hydrants are also important, because it eases the job of establishing a water supply. The full time department will be the fastest and best-prepared department for most interior fire attack situations.

The second best department will be the full time department with a call department support. The full/call department will have some full time firefighters, but will not be covered around the clock nor will it have enough manpower to handle a large incident like a structure fire. In order to get the help, the call firefighters are notified and respond from wherever they maybe. Obviously this increases the response time because it takes time for the call firefighters to get on scene. Most full/call fire departments will be found in larger towns where a fast response time is necessary, although a completely full time department is not necessary due to a small number of fire calls. These departments also normally have very good equipment and plenty of hydrants. They will have a similar response time to that of a full time department, but they will not have the manpower to complete all of the tasks necessary to extinguish the fire in a timely manner.

The final type of department is the call or volunteer department. As mentioned before they are the same organization, except the call firefighters are paid per call. The call department does not have any full time firefighters, which means the response time will be much longer than that of the previous two organizations. This time elongation is due to the fact that the firefighters must drive from their location to the fire station then drive to the scene. This type of department will be found mainly in small rural towns, where the call volume is low. Call departments normally do not have the best equipment available and they also have the most difficulty establishing a water supply. Since this department is usually found in small towns, the hydrant coverage will not be as thorough as it would be in a city or large community. The lack of hydrants means the firefighters must find other sources of water supply, which usually takes a lot longer to set up. A small town does not have the need for another type department, because it would be a waste of money.

2.2 Losses and Resources

As described in the introduction, the fire coverage in a community is directly related to the community's potential losses and its resources. One of the biggest influences on a community's fire coverage is industry and business. The more industry and business a community has, the larger the fire coverage that is needed. This relation is mostly due to the fact that business is very important to a community's economics. Business brings in a large amount of money into a community, but it also causes more traffic and people to be in the community. Therefore, many communities will have a full time department or at least a full time with call support department, in order to ensure proper fire coverage. Also, businesses may supply money either by choice or by agreement with the community to the town for additional fire equipment that the community would not normally be able to buy, in order for the business to build in that community. For example, some businesses may partially pay for trucks or even things like traffic control devices. Businesses also might have hydrants installed near the building, or the town may mandate hydrant installation, since there are businesses in a certain area, which require hydrants to be nearby. The town is more likely to have hydrants installed because business brings in a mass of people, and hydrants are needed to ensure faster fire suppression and increased life safety.

Other areas of a community that affect fire coverage are municipal buildings. Places like schools, community offices, and other buildings all have important documents and/or expensive equipment, and the loss of these buildings would be devastating to a community. For example, fire stations have many fire trucks which cost anywhere between a quarter of a million dollars to a million dollars per truck. In order to ensure that the firefighters have the best possible chance to protect these valuable items, hydrants will most likely be in located these areas.

The final factors, determining the fire department resources in a community, are the number of people and the density of buildings in an area. Heavily populated areas will require more fire coverage than the more rural areas because more lives and property will be at risk. Therefore, thickly populated parts of a community often will have the most fire resources located near them. They may have hydrants, because there will be many people and buildings located in this location. Since many lives and property could possibly be endangered all at once, time is a factor. The less time it takes to establish a water supply, the better chance the firefighters have to save both lives and property. There also might be a fire station or stations nearby to ensure a fast response time. The less time it takes for the fire apparatus to arrive on scene, will give the firefighters a better chance to save more people and property. Also, the more heavily populated areas are where big businesses and municipal buildings will be located.

The rural parts of a community may not have hydrants or fire stations nearby for several reasons. The main reason for a lack of fire hydrants would be the lack of piped water into the community. Many rural areas do not have water distribution systems, so it is impossible to have hydrants. Since the buildings are located so far apart, having a fire station or a hydrant in this area would not be as beneficial as having them in a heavily populated area, where fire loss is a greater issue. Although losing a house is unfortunate, it is not as great of a loss to a community as losing businesses, municipal buildings, or multiple houses.

2.3 Fire Suppression Systems

The first part of fire suppression is detection and notification. Obviously, if a fire is not reported, the fire department will not respond. There are two ways a fire is detected and reported. The first is human detection and a phone call directly to the community's fire department dispatch. This form of detection may take some time because for a person to find a fire they either have to hear it, see it or smell it. In a building that has a large population, a fire may be discovered rather quickly. A smoke detector will be tripped or the person may smell or see smoke. The main problem with human detection is in an unoccupied building. Usually by the time a person notices there is a fire in this type of building, the fire has already spread throughout a significant part of the building. The firefighters are at a disadvantage to save the building. In most buildings now there is a second form of detection and notification, an automatic fire alarm system.

The fire alarm system is most beneficial in an unoccupied building or in a large building. Heat or smoke trips a detector, which in turn notifies the alarm company's dispatch service. The operator then notifies the town's fire department dispatcher. This form of detection is significantly faster in an unoccupied building than human detection, because the fire will be detected much sooner and will not be as large at detection. The firefighters will, therefore, have a better chance to save the building. Also, in large buildings the fire may start in a room that is not occupied. Therefore the fire alarm system will often detect the fire before a person would. The fire alarm system gives information about the general location of the fire by the use of an annunciator panel. This information is very helpful in large buildings, because it can assist the firefighters in finding the fire.

After the fire is detected and the fire department is notified, the fire department responds to the incident. There are many different responses, which are all dependent on the fire department. For example, some full time fire departments may respond to a building fire with as many as four engines, two ladders, and a rescue truck. Other responses include two engines and one ladder, or two engines, one ladder and a rescue truck. The full time department will have the fastest response time because all the needed manpower is normally already at the fire station. The response of a full time department, which has call support, varies greatly between department since each department will have different amounts of full time firefighters. Obviously as many trucks as possible will respond. Usually the response will be at least one engine and one ladder truck. The initial response time is often the same as the full time department. However if more manpower and resources are needed, the response time will be delayed for the extra equipment and firefighters. The final type of department will be the completely call or volunteer department. The response of this type of department varies between departments due to the difference in apparatus. A call or volunteer department usually responds initially with one engine, then a ladder, and then with more engines and rescue trucks. As mentioned before, the call or volunteer department will have the slowest response time because they must first go to the fire station and then to the scene of the incident.

The next few parts of fire suppression are in no particular order, because the order they are performed vary greatly depending upon the fire department and the incident. Since each fire department has different standard operating procedures (SOP's), general guidelines describing how the fire department handles incidents, the different tasks might be done in different orders. Also different incidents require certain actions to be taken to insure that no firefighter is injured. For example, if a back draft is possible the first task that must be completed is ventilation. By ventilating the structure, all of the hot gasses are released and oxygen is introduced into the fire. If a door were just opened, an explosion would occur and fire personnel or citizens could be injured. In most situations though the most common way to fight a structure is for the first engine to a go directly to the scene and start fire attack. The next task done is usually establishing a water supply by the second due in engine, and then finally the ladder company completes ventilation. Obviously all of these tasks are not done in order. They overlap greatly and even sometimes are done at the same time.

Fire attack is done in many ways. This report describes the tasks associated with interior fire attack. The biggest difference during fire attack is the number of lines and the size of each line. A line is a term used in the fire service, which is short for hose line. The number of lines and the size of the lines depend greatly on the size of the fire. Most fires are fought using either an inch and a half or an inch and three quarter hose line. For larger fires a two and half inch line is used because more water is needed to extinguish the fire. The reason, a two and a half inch hose is not always used, is due to the weight of the hose. A hose line of that size is very hard to handle and maneuver.

Most fires are fought using at least two lines. One is for the attack and the other is a backup line incase a problem may arise. If the fire is large then more lines are used as necessary. The firefighters on the engine company perform the fire attack. They stretch the needed number of lines into the building to the fire. A nozzle is attached to the end of the line to control the output of water.

The fire fighters extinguish the fire using one of two attack methods. The firefighters either use a direct attack or an indirect attack. A direct attack is when the firefighter on the nozzle directs the stream of water directly at the base of the fire. This method of attack creates a large amount of smoke and heat to build up at the ceiling, and requires more time and water to extinguish the fire. The preferred way to fight fire is using the indirect attack. This attack is completed by directing the stream of water at the ceiling above the fire. This cools the hot gasses at the ceiling and takes less water to extinguish the fire. The only problem with this method of attack is it causes a large amount of steam to be formed. If there is a victim in the building, indirect attack must not be used to ensure that the abundant amount of steam created will not burn the victim and possibly injure him or her even more. In this situation a direct attack would be used because it creates significantly less steam.

Also, some forms of building equipment may ease fire attack. The most common is a sprinkler system. Sprinkler systems ease fire attack in two ways. The sprinkler may extinguish the fire completely, but more commonly it controls the fire. If the fire is controlled by the sprinkler system, then all the firefighters have to do is use one line to extinguish a small fire that is not spreading. The other building equipment, intended to ease fire attack, is a standpipe. A standpipe is a pipe that runs up the side of a building, which has an input connection on the outside of the building and output connections on each of the upper floors of the building. The engine connects to the input connection on the outside of the building and pumps water up the standpipe. The firefighters carry an uncharged, empty, hose line into the building and connect it to the standpipe output connections in the building. Fire attack is eased because an empty hose line is easier to maneuver and carry than a hose line that is full of water and very heavy. Also less hose is used to get to the fire, because the firefighters only have to stretch the hose line up one flight of stairs rather than every flight of stairs.

Since most fire attacks are prolonged and require a great deal of water, a water supply must be established. Most engines only carry a minimal amount of water, at most 1000 gallons of water, and cannot supply enough water for a prolonged fire attack. In order to keep a constant water flow of water on the fire, the engine must be supplied water. This supply of water can be completed in a few ways. The most common is for either that engine or another engine to connect to a nearby water supply source. The source is then used to create a constant source of water to the engine. The engine then pumps that water to the attack lines and a constant source of water on the fire is established. The major problem is if there is not a nearby source of water. Water supply will be examined further in the next few sections of this chapter.

The final task of fire suppression is ventilation. Ventilation is used to dissipate the hot gasses and smoke to the outside of the building. Since the heat and smoke are vented to the outside, the firefighters will be able to see easier and they will not get as tired as quickly. Being able to see eases fire attack because the firefighters can avoid the obstacles in front of them and also can find the fire much faster. Also by venting out some of the heat and hot gasses the firefighters will not tire due to heat exhaustion as fast, and the room will not flashover. A flashover is when all the contents of a room reach their ignition point and ignite momentarily. Flashover has caused many deaths and injuries to firefighters.

Ventilation can be completed in two distinct ways. The most common is by using natural ventilation. Natural ventilation is accomplished by cutting a hole in the roof and/or by opening windows. The hot gasses and smoke are then exhausted out of the holes. The other form is positive pressure ventilation (PPV). PPV is attained by closing all possible exit passages, and setting up a fan in front of an open door. The fan is turned on and envelops the whole doorway. Since the air that is being blown in has no where to go, the building becomes pressurized. After the building has been pressurized, windows and doors are opened systematically. This allows for the building to remain pressurized, while the smoke and hot gasses are forced out of the building by the pressure. Everything must be performed systematically, in order to keep the building pressurized. If too many doors and windows get opened at once, the building will lose the pressure built up inside and PPV is no longer effective. PPV is not used as often as natural ventilation, because it is a fairly new concept.

2.4 General Water Supply Systems

Establishing a water supply is essential to fire suppression. As mentioned earlier, an engine only carries a minimal amount of water, which is only enough water for an initial attack. It does not allow for a prolonged attack, therefore, a water supply must be established.

There are two main forms of water supply sources. There are a pressurized source, and sources from which the engine must draft. A pressurized source is a hydrant. The hydrant is connected to an underground pipeline that is always pressurized. The firefighters connect a hose to the ports on the hydrant, then they open the valve and water flows out of the hydrant and through the hose.

The other water supply source is a source used for drafting. An engine drafts water by sucking the water from a large water source like a pool, lake etc. The engine that is drafting is then used in one of two ways. The engine may have to be a supply truck, or it might be used to fill up the tankers in a tanker shuttle. If the engine is required to be a supply truck, it will either supply the attack lines with water, or it may act as like hydrant and supply another engine with water.

2.5 Delivery of Supply

The most common form of water supply is a hydrant. The way the hydrant delivers water is very simple. The engine first must drop off a firefighter and the equipment needed to connect the hose to the hydrant. The firefighter then wraps the hose around the hydrant, and then the engine pulls away laying the hose out behind it. After the engine arrives at its destination, the firefighters connect the supply line into either the engine that laid in or into another engine. While the firefighters are connecting the supply line into the appropriate engine, the firefighter at the hydrant is removing the caps from the hydrant and connecting the necessary valves and the hose or hoses to the hydrant. After everything is connected, the hydrant is opened. Since the hydrant is pressurized, the water flows into the engine. The engine then relays the water to another engine, if the hydrant does not have enough pressure to reach the attack engine, or it directly supplies the attack lines. Once the engine, that is being used to attack the fire, receives the necessary water, the water supply system has been established. An example of a hydrant set up using one engine fore attack (E-2) and one engine as a relay truck (E-1) is shown in figure one.

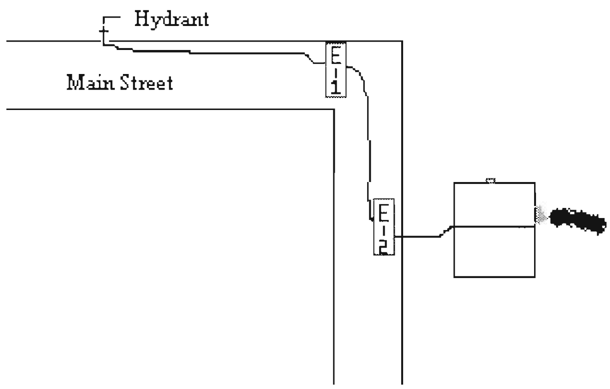


Figure 1: Hydrant set up

Although most hydrants are able to supply enough water for the majority of fire department operations, there are still problems associated with hydrants. The most common is distribution. Many fire departments do not know where the hydrants are located or if there is even a hydrant in the area. It is time consuming to try to find a hydrant, and establishing a much-needed water supply is delayed. Also, many departments may assume there is a hydrant in the area so they may try to find one when there might not be one in the area. This search causes an even longer delay in setting up another form of water supply. The other common problem with hydrants is most profound in the cold. Some hydrants do no function, because of many possible reasons. Some just do not get used enough, but usually they just freeze shut. Unfortunately the only time this problem is realized is after the hose has been all laid out and connected.

Usually another engine will connect to another hydrant, because trying to move all of the hose would take too long.

The only other problem, which does not arise nearly as often, is pipe size. Most fire departments do not know the pipe sizes, and therefore just assume that the pipes are big enough to supply adequate water. Unfortunately sometimes this is not the case, and another hydrant must be used as well. Although connecting to another hydrant is slightly more time consuming, it really is not that much of a delay. Usually, one hydrant can supply enough water for a few attack lines. Multiple hydrants are usually only used at big fires, where time may not be of concern anymore.

The second form of water supply delivery is drafting. As described in the above section, drafting is done by an engine pumping water from a large water source. The most basic form of drafting is when a water source is located near the fire. An engine can then just draft the water and pump it directly to the engine that is being used for the fire attack. Essentially the engine, that is drafting, has become a hydrant. Although this arrangement is not complicated to set up, it is more time consuming than just using a hydrant.

The most time consuming water supply to establish is a tanker shuttle. A tanker shuttle is used if there is not a water source near the fire. A tanker shuttle requires multiple tanker trucks and multiple engines. In order to establish a tanker shuttle an engine must draft from a water source, and fill a tanker truck. The tanker truck then goes to the fire scene and dumps its contents into a dump tank, which is a little pool. While one tanker is dumping the water at the scene, another tanker is being filled. Another engine drafts the water from the tank, and pumps the water to the attack engine. Once the water arrives at the attack piece of apparatus, the water supply has been established.

Figure two shows an example of a tanker shuttle using two tankers, where the E-x are engines and the T-x are tankers.

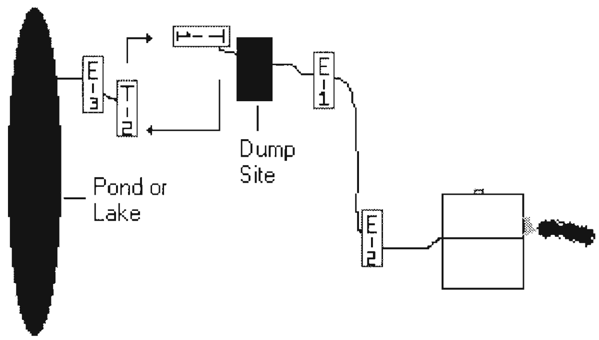


Figure 2: Tanker Shuttle

The problems with a tanker shuttle are the time it takes to set up, and it is very difficult to coordinate. The more distance between the site that the tanker is filled to he dumpsite, the more tankers that are needed in order to keep the tank full. Obviously, the more tankers the harder it is to coordinate, and most departments do not have more than one tanker. Therefore it is time consuming just to get the needed number of tankers on the scene because they must come from other communities.

2.6 Community Resources

As shown in prior sections, the community resources depend greatly on the type of community. In a rural community, the fire resources will not be as significant as in an urban area. A rural area may not have hydrants, and therefore the fire department will have to draft from a local water source or set up a tanker shuttle. The reason for the lack of hydrants is due to the fact that the houses are spread out over a large area, there are no businesses, and there are not any municipal buildings. Also, there may not be any running water because the houses are too spread out, so that piped water would not be an efficient water source. Unlike rural areas, the urban areas will have hydrants, because the houses will be closely packed together. Also, there will be more businesses and municipal buildings, because there will be more people in this area of the community. Since there will definitely be piped water in this area, hydrants can be installed. Also most of the municipal buildings and equipment, like fire, police, and highway department buildings and equipment, will be located in this area of the community. The loss of any of these building or equipment would be a very large economical loss to the community.

CHAPTER 3

ECONOMICS OF FIRE SUPPRESSION

As with any economic analysis, the economics of fire suppression is not an exact science. Many cost factors are dependent upon a specific situation or sequence of events. In order to analyze the economics of fire suppression, one must have knowledge of the components of fire suppression. The components of fire suppression are the water supply, the physical suppression systems, and the interaction of the two, all which were discussed in previous chapters. The damages caused by the fire also will be discussed in this section. After that, an economic analysis can continue with the costs of water supply systems, suppression systems, and the cost of the damages.

3.1 DAMAGES

Fire is an everyday phenomenon that many people do not notice. A internal combustion engine which powers most of the cars on the road today is a controlled explosion of gas and air, which is, essentially, fire. The burning of other fossil fuels provides power to homes. Although fire can be helpful and productive, it can also be very destructive in all of its forms.

Damages caused by fire do not end with what the fire can cause directly to the structure. In any fire, there are the damages to the property and the items inside the building. Smoke and heat also cause vast amounts of damage. Smoke in a fire is composed of ash and heat. When it is exposed to a surface, it will not only burn the surface, it will also leave ash and soot. In the case of a commercial business, there are other damages, which have a vast effect. If a business is close to another building, there is the possibility of starting a fire in the exposed adjacent building. This fire exposure can create damages with that building as well.

When a fire damages a building, it causes damage to replaceable and non-replaceable items. For example, if a fire starts in a warehouse, the insurance would cover the damages caused to the goods stored in the building. If a fire were to ignite in a professor's office, there are other damages to consider. The insurance would cover the replaceable items like the computer and the desk and the textbooks. The insurance, however, would not cover the cost of the time and information in research and papers.

3.2 Water Supply

In order to simplify the analysis of water supply costs, the examination will be broken down into public and private water supply. The distinction between public and private is not black and white. Therefore, there will be an overlap of some topics. For simplification, public water supply is the water supply of the community and is publicly available, and private water supply is that which is on private property. A few factors must be taken in account about the land before construction is possible.

Public water supply is the domestic water that is used for the community fire suppression. It is used by the fire departments as a source of water to fight fires. Public water supply is based on a grid-like system. Large diameter pipes supply smaller diameter distribution lines, which in turn supply small supply pipes to houses and fire hydrants (see Figure 3.1). When there is a fire, fire fighters use available hydrants when attacking a fire. Before this is possible, hydrants must be in place for the fire fighters to use. The placement of hydrants and mains is only one of the decisions associated with public water supply.

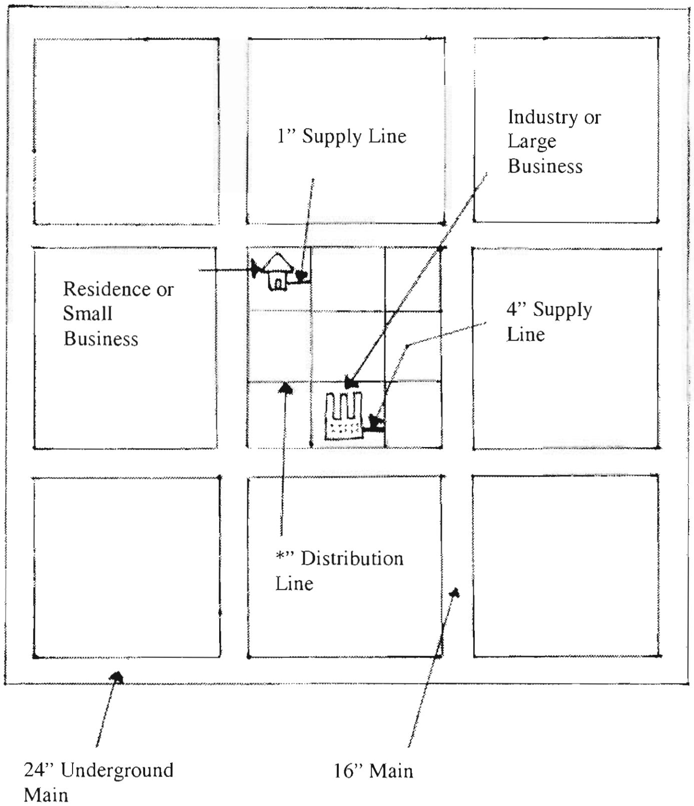


Figure 3.1: Water Distribution Grid

Very few new large water mains are installed in established cities; there are usually enough in place already to supply any building. Although, many new mains are installed in new construction such as a sub-division where there are no existing water mains. There are a few choices that the builders have when installing the water supply. A new main can be installed, an extension can be made to the new area, or combinations of the two are possible choices.

Installing new mains involves excavation and the placement of large bore steel pipes. A task made feasible by large machinery and cranes. Much time is needed to place and test an entirely new large main. This supply may be ample enough to supply the hydrants, sprinklers, and domestic needs of the development. Although it is costly and time consuming, the choice is viable if the area being supplied is very large and requires its own water supply. In addition, in the case of a large development, the entire supply might be needed, which includes a supply, a pump and complete system of mains. Costs of underground mains will be discussed later.

If the area is small, an extension from the existing mains is possible to supply the area. There is less construction involved and extending an existing main and it is much more cost effective. There is a problem if the demand on the supply is too great. With a small pipe, less water is available. This can lead to a loss in pressure, and in the case of automatic sprinklers, an insufficient water supply pressure and continuous flow is necessary for proper operation.

An effective solution to both problems can be found in the combination of the two previous choices. By extending the main into the new area, the supply is adequate, but the pressure is still an issue. A possible solution to this problem is to loop the supply from another part of the water system (see figure 3.2). This will solve the problem of the decreased water supply and the decreased pressure due to the high demand.

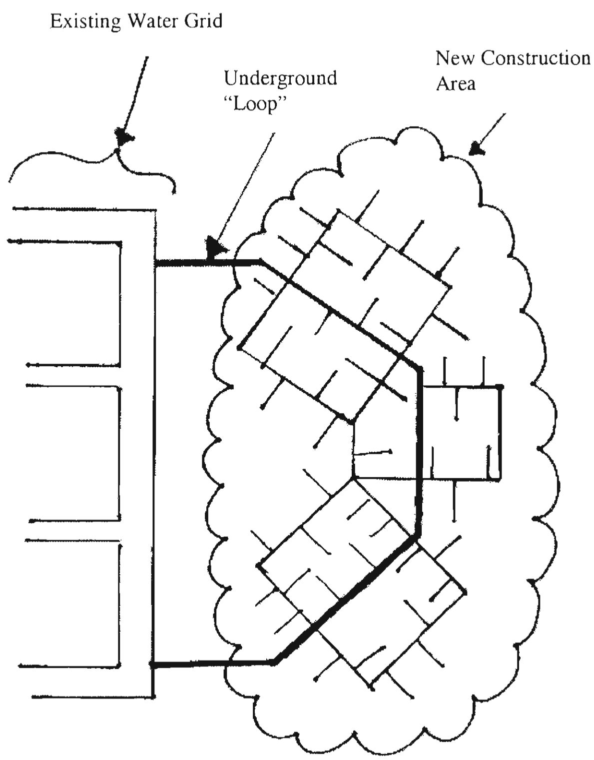


Figure 3.2: "Looped" Main Alternative

The cost of water supply is not only determined by the choice of physical supply, but also by the placement of the piping. Placing the piping above ground may be inexpensive because there would be no need for excavation. However, this is not possible where there are any commercial or residential buildings and in northern climates, where the temperature drops below freezing, bursting pipes would be a problem. The residents would not allow such an eyesore to remain on their property. Water supply piping should not be buried very deeply in the unfortunate chance that there is a break in the pipe. Then another large excavation would be needed to reach, remove, and then replace the damaged section. Compromise and bury the piping relatively shallowly in the ground. It is out of sight, and relatively simple to repair. This leads to complications of other utilities such as underground electric, telecommunications, gas, and sewers getting in the way. This is especially true in large cities such as New York, Boston, or Worcester. Beneath the streets of New York is a maze of not only water supply pipes, but also electric, cable, telephone, sewer, steam, and subway tunnels. In contrast to an inner city site, a new construction site usually is not supplied with any utilities. This creates a simple situation for installing piping; there are no conflicts with other utilities because all of them are installed at the same time. Other complications may arise.

Topographical and geotechnical issues may occur in some situations. If a new sub-division is to be built in an area where there are elevation changes, piping water up to the buildings may prove to be a problem. The greater the change in elevation the greater the demand on the pump to move the water through the pipe. A larger elevation change requires a larger pump to push the water to the desired location. Large elevation changes cause problems with required pressures for hydrants and automatic sprinklers. This affects the cost of supplying the area. Yet another related issue is the geotechnical composition of the earth into which the piping is being installed. In simpler terms, the make-up of the earth, be it rocks, soil, sand, or mud, where the main is being placed can adversely or positively affect the cost. Although much can be inferred about a site by a few strategically placed core samples, no test is perfect. A core sample is a vertical sample of the different layers of soil and rock at a construction site. In some unfortunate cases, core samples do not detect a large crop of rock, or ledge, that cannot be removed easily. This may be detected only when the construction crew begins excavating the site. Large rocks, or ledge, must be blasted and at a cost to the project. Skill and luck on the part of the crew installing the main is important in the economics of water supply piping.

Placement is important in matter in water supply position. Who or what decides the placement of the piping and related components. This seemingly impossible task is left to the Town Water District, the Town Planner, and whoever is performing the placement. The Town Planner and Town Water district are notified and have to approve new construction before it can begin. In a perfect world, the Water District would keep an exact record of all of the underground water mains and related hydrant locations. However, this is not always the case, and often is not. Problems can arise because of this. One contractor may think that a main is in one location, when in reality it is several feet away. Water supply cost increases when events like this occur. Barring any problems, what is the knowledge base upon which decisions are made? The Town Planner, the Town Water District, and the construction firm should have experience with water supply construction. If any of these organizations does not have sufficient experience within the are that they work, their performance could prove expensive at the completion of the project. A planner who is knowledgeable about his/her town and geotechnical composition will serve the economic outcome of the project better. Experience invaluable in town projects.

During or after the construction and installation of the underground water mains, fire hydrants are placed. In a similar manner to the underground mains, hydrants must be placed in the correct locations. Once a hydrant is placed, it will be a great task to move, and in most cases is not moved. The Fire Department Water Supply Officer is in charge of deciding the locations of hydrants in developments. As in any office of importance, this officer should have ample experience in the needs and required locations of hydrants. An adequate number of hydrants is necessary if the fire department must fight a fire in the are of new construction. Though more hydrants will increase the cost of the project, a higher project cost is much better than the cost of replacing a house that has burned down because of inadequate fire flow.. There have been cases where an inadequate water supply has caused losses. That will be discussed later in the chapter. Hydrants are the primary source of water for fire department suppression.

Hydrants are required to have a minimal pressure depending upon the size of the hydrant and the supply. This is crucial to fire department suppression. They are color coded so the fire department can determine the method that they are going to connect to they hydrants. If a hydrant does not have enough pressure to properly supply the trucks, the fire fighters will not be able to suppress the fire as efficiently. This will cause unneeded damage to the already damaged, burning structure.

Hydrants are available in numerous configurations. Some hydrants one, two, or three connections, and others, different sizes. In most cases, cost will be higher for a taller hydrant or a hydrant with more connections. This example will use a two-connection hydrant for the cost analysis installed where the depth of the main is two feet. The valve within this hydrant is four and a half inches. The cost without excavation and back-fill is $930.00. The cost includes installation and materials cost. A two-connection hydrant for a depth of two and a half feet is $955.00. The cost of installation is proportional to the depth of the supply main, the size of the hydrant, and the inclusion of excavation and back-fill required for completion of the task.

Before a main is installed, not only must the future location be known, but also the size of the new main must also be known. What determines the size of the main to be installed? The main criterion in determining the size of a future main is the load that will be put on it. This is analogous to the design of a steel beam; the load that it will support is needed before the size of the beam is determined. If a main is going to support one small residential home, then the size of the pipe need not be more than an inch or two to supply the dishwasher and shower at the same time. Contrary to that is the load of a high-rise hotel that will house many people who are possibly all taking showers at the same time. That is a very high water demand. Other factors such as time of day and year must also be accounted. People use more water in the summer than any other season for good reason. Depending upon the load a size is selected accordingly. Certain size pipes will only allow a specific amount of water to be pumped through per unit of time.

Similar to the costs of the fire hydrants the costs of water supply piping are increased as the pipe diameter increases. Water supply pipes come in a variety of materials such as, cement lined ductile iron, cast iron, polyethylene, and polyvinyl chloride (PVC). Each type and size has its own associated cost. Consonant with the hydrant examples, the piping examples do not include the cost of excavation and back-fill, it is an extra cost. When iron is in contact with moisture, by simple chemistry, it reacts and forms an oxide, iron oxide, more commonly known as rust. When a pipe ages and the rust increases, the metal weakens and eventually, breaks. When a main breaks, the water must be shut off, the area excavated, and the pipe replaced.

To prevent such corrosion and weakening, the body installing the main can apply a corrosion resistant coating to the main. The coating adds to the total thickness of the pipe, but it increases the life span of the underground main. The "wrap and coat" coating, according to the R.S. Means Building Construction Cost Data index, is $1.42 for each linear foot of pipe four inches in diameter. The cost of the coating increases as the diameter of the pipe increases. For example to coat one linear foot of eight inch pipe is $2.30, and for 24 inch pipe, $6.50 for each linear foot. Another coating similar to and ingredient in the surface of most roads, a bituminous coating is on a per-diameter-inch and per-linear-foot basis. One coat costs $0.25 per diameter inch per linear foot, and three coats costs $0.40 per diameter inch per linear foot. Yet, another type of coating, a tar epoxy that has a base similar to the bituminous coating, is $0.17 for one coat, and $0.31 for three coats. Three coats provide more protection than one, but also cost more.

The most important part of public water supply is the system of underground water mains that carry the water. As common sense would dictate, the larger the pipe, the more expensive it is. This is true with water mains. One of the most common types of piping used for water mains is cement lined ductile iron. The sizes of pipe range from four inches in diameter to as large as 24 inches in diameter. According to the R.S. Means Building Construction Cost Data index, one should estimate the cost to install an 18 foot length of four inch pipe at $13.70 per linear foot of pipe. The cost steadily increases with the increase is diameter of the pipe. The same type of pipe at an identical length but at a larger diameter of 12 inches is $35.50 per linear foot. The 24-inch pipe is $84.50 per linear foot.

A similar type of water supply pipe is cast iron pipe. Made of the same material as ductile iron, it is cast instead of extruded. Cast iron is not available in as many diameter sizes as ductile iron or some of the next pipe types. It is only available in four, six, eight, ten, and 12-inch diameters. The four-inch size costs $11.96 per linear foot. The price increases as the diameter increases, the eight-inch size is $19.30 per linear foot, and the largest size, 12 inches is $33.93 per linear foot.

Another type of water supply pipe is PVC pipe, a polymer. This pipe is seldom used for the large underground mains that are used to supply the smaller distribution pipes. Typically, this pipe is used for the distribution lines. Unlike ductile iron or cast iron, there is no need for corrosion resistance as the polymer composition does not corrode. The cost of the PVC pipe is for each linear foot of installed pipe. PVC pipe is available in diameters from one and a half inches to eight inches. As before, the cost increases as the diameter increases. One and a half inch PVC pipe installed is $3.26 per linear foot. Where eight-inch PVC pipe is $12.25 per linear foot.

Similar to the PVC pipe, Polyethylene pipe is also polymer based in its construction. It is available in two types, 160 psi (pounds per square inch) polyethylene and 100 psi polyethylene. The number is the amount of pressure that the pipe can sustain without bursting. The 160 psi pipe is slightly more expensive than the 100 psi pipe because it can sustain a higher pressure. The four-inch diameter costs $6.86 and $6.05 for the 160 psi pipe and the 100 psi pipe respectively. As expected, the 12-inch diameter cost is $26.20 and $19.40 for the 160 psi and the 100 psi pipe respectively. The cost includes cost of equipment and labor of installing the pipe, not excavating, or back filling.

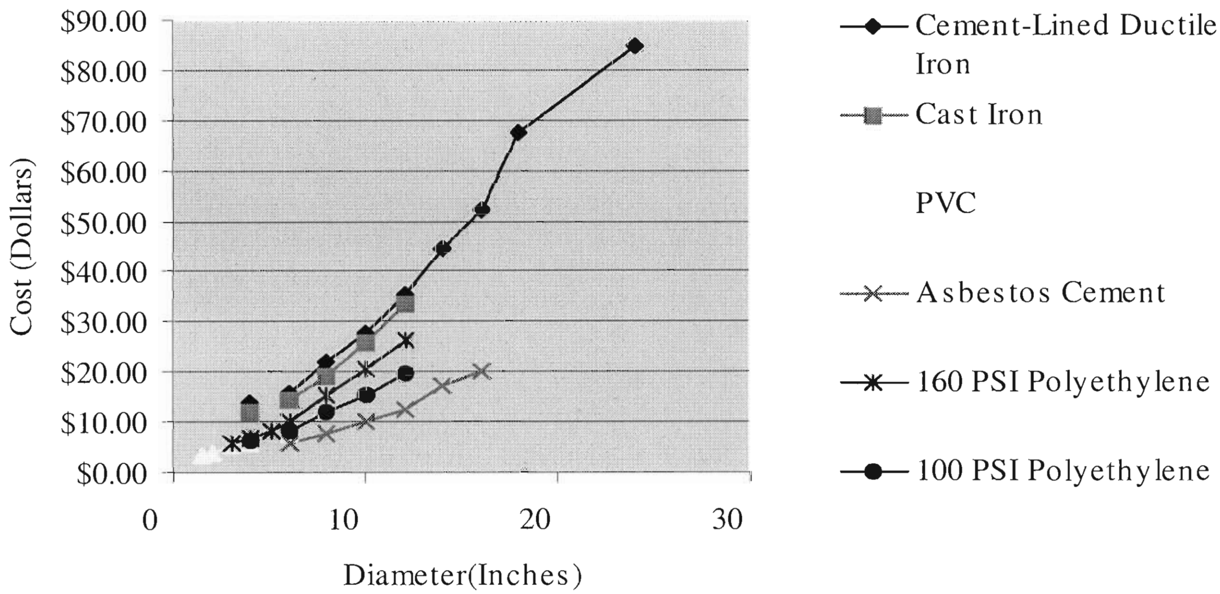
Asbestos cement pipe also is sometimes used for water pipe. Although there is asbestos in the pipe, there is no danger to people who use the supply. Similar to the other pipe cost example the cost of excavation and back fill is not included. These pipes are used as the main underground pipes that supply the smaller distribution lines. The size availability of asbestos cement pipe is in larger sizes such as six-inch diameter up to 16 inches in diameter. As with the other pipe types, the cost is greater with the larger diameter. For example the six-inch pipe is $5.87 per linear foot, and the ten-inch is $10.29. The largest size is the 16-inch diameter pipe with a cost of $20.12 per linear foot.

The following two figures show the comparison of the diameter of each pipe type with the related cost.

Diameter (inches)	Cement-Lined Ductile Iron	Cast Iron	PVC	Asbestos Cement	160 PSI Polyethylene	100 PSI Polyethylene
1 1/2			$3.26			
2			$3.95			
3			$5.25		$5.85	

4	$13.70	$11.96	$5.70		$6.86	$6.05
5					$8.29	
6	$15.70	$14.23	$7.75	$5.87	$9.82	$8.03
8	$22.00	$19.03	$12.25	$7.59	$15.12	$12.06
10	$28.00	$25.69		$10.29	$20.40	$15.51
12	$35.50	$33.39		$12.42	$26.20	$19.40
14	$44.50			$17.35		
16	$52.00			$20.12		
18	$67.50					
24	$84.50					

Underground Main Cost



The water that is used in domestic water supply mains originates at a natural water source. In it's natural state, most water is not clean enough by government standards to be consumed by humans. That being the case the water must be cleaned and pressurized to supply the entire water grid. At a water treatment plant, the water is filtered and bacteria and sediment are removed. In some communities, the water has chemicals added to it. Sometime chlorine is added to prevent bacteria and other biological organism from growing in the water. In other towns, fluoride is added for the health of people's teeth. After treatment, the water is not at a high enough pressure to supply the entire town. A pumping station is needed to boost the pressure of the water.

The treatment facility and the pumping station are both community buildings. Consequently, the cost of them is covered by the town and the state taxes. No one person in the community owns the facilities. Like most homes in the United States, the cost of these buildings is paid for over time. Even after the buildings are acquired and they are no longer being paid for, there are still costs associated with them. Workers are required to run and maintain the facilities. Unfortunately, workers will not work for nothing, they must be paid. Their cost is also taken care of by the tax dollars from every person in the community. The water that is pressurized at the pumping stations is then fed through the underground mains to the hydrants and houses in the community.

In the unfortunate situation that a hydrant is not accessible to a fire truck or there is no public water supply at all in the community, there are other means of supply. As stated in previous chapters, water can be brought in by a truck or it can be taken directly from a static water supply such as a lake or river. Although it may not seem relevant to the economics of water supply, it is. If no water can be supplied or if there is a slow supply, more damage than is necessary will be caused to the structure. There is also the greater chance of not only having a firesafety issue, but a lifesafety issue as well. In addition, water that is brought in by truck requires and extra truck for the fire department to pay for and ultimately the community to pay for, but in some communities is the only possible choice.

Private water supply is not so much the actual water as it is the piping and equipment on private property. The community is responsible for providing the eight or ten-inch underground water main, in the street. The private owner incurs the cost of tapping the main and providing the water for his or her residence. There are three different applications for private water supply. Residential water supply is for domestic water and, if the house is equipped, for automatic sprinklers. Commercial and industrial water supplies are usually a greater demand than residential, but have the same uses. Private hydrants are also supplied by the private water supply.

The term given to water supply piping that supplies only automatic sprinkler, standpipes, and hydrants on private property is the private fire service main. Traditionally an underground pipe is considered a private fire service main when it crosses the property line. Residential automatic sprinkler systems, though not required, are becoming more popular. They may be supplied by piping that is not necessarily ductile iron pipe or cast iron pipe but PVC pipe. The required size required for commercial or industrial applications is much larger than the three-quarter-inch pipe needed for residential sprinklers. Though residential automatic sprinklers may be supplied by as small as a three quarter inch PVC pipe, the only data available for a cost analysis was of the one and a half inch PVC pipe. As stated earlier, one and a half-inch PVC pipe installed without excavation or backfill and compaction per linear foot is $3.26. In many communities in the United States, houses may not be built any closer than 40 feet from the property line. Therefore, to install the pipe for the automatic sprinklers, the owner of the house would have to estimate a cost of $130 just to install the pipe.

Unlike the entire demand on the underground mains in the community, the individual residence needs much less. A residence is usually supplied by a one or two inch pipe. The demand for the residence at one time may be someone taking a shower, running the dishwasher, the washing machine, and watering the garden. This may seem as though a great deal was happening at once, but it really is not. When the demand for a house is calculated it must be when the load is the highest. If it is not, then when the load becomes higher than the supply, there is a shortage and a loss of pressure. In a worst case scenario, a house equipped with sprinklers would have a fire when the pressure is low and more damage than should occur will.

Water supply is the most important component in the suppression of fires. Though costly at times, the benefit is immeasurable. As the saying goes, an ounce of prevention is worth a pound of cure. This is certainly true in fire suppression. Adequate water supply is the best defense against a fire. As will be seen later, a hindered water supply can cause great problems.

3.3 Fire Suppression

In a similar manner to the economic analysis of water supply, the economic analysis of fire suppression will be split into the public costs and the private costs. Unlike water supply, the costs of fire suppression are easily discernible as public and private. Public costs include fire department costs and the cost of automatic-fire-suppression systems in public and state buildings. Private fire suppression costs include alarm systems, sprinklers, automatic detection systems, and extinguishers.

The equipment that the fire department uses on their fire fighting trucks is also a cost to them. There are two main types of trucks used by fire departments, and they each have different gear. Equipment is primarily the same for the engines, pumpers, as it is for the ladder trucks. Depending on the department hoses on an engine might include 1 ½", 1 ¾", 2 ½", 3", 4", 5", or 6." Because the engines are used to supply the attack lines, they must also carry hose appliances such as adapters, reducers, and nozzles. An integral part of the fire fighting equipment is the Self-Contained Breathing Apparatus (SCBA). There are several of these on the engines. Fire fighters need hand tools to open the hydrants and to gain entrance to buildings. Some such tools include axes, both pick-headed and flat-headed, haligan bars, hooks, lights, door rams, and spanner wrenches. Engines also carry extension ladders, roof ladders, salvage covers, and buckets. Some equipment that may not be on every fire departments engine includes generators, the pneumatic Jaws of Life, and large fans.

Very similar to the engine's equipment compliment is the equipment stored on the ladder truck. Not all ladder trucks carry hose since it is primarily carried by the engine. Most ladder trucks have the same hand tools, ladders, and salvage equipment as the engines. Also included in the ladder truck's arsenal is the power saw.

Just like everyone's cars need routine maintenance, the trucks in the fire department need maintenance as well. This includes oil changes, which for diesel engines, is more costly than gasoline engines. Analogous to cars, part of the trucks wear out and need to be replaced like the tires, the alternators, the batteries, the air filters, the windshield washer fluid, brake fluid, power steering fluid, and many other items. All of these need to be replaced periodically at a cost to the fire department. Expenses to the fire department are covered by the community.

Other costs that the fire department incurs over time are the upkeep of the fire fighters gear. Anything that gets extensive use will wear just like with the fire trucks. The Self-Contained-Breathing-Apparatus that the fire fighters use when trying to suppress a fire have parts that need to be replaced and upgraded over time: as well as needing to be refilled after each use. Boots, jackets, and gloves all receive wear and have to be replaced eventually. All of these are costs that the fire department has to cover. Although, again the community covers the cost of the fire department.

The other side of fire suppression is private fire suppression. Private fire suppression costs include alarm systems, automatic suppression systems, and fire extinguishers. These are all associated with fire suppression without or before fire department involvement. They are the first line of fire defense; installed to contain the fire until the fire department can arrive and put the fire out. These systems are also in place to alert the fire department of a fire.

Alarm systems serve a dual purpose. They alert the occupants of the building that there is an emergency and that they should get out of the building, but the alarm system should also alert the fire department of the fire or emergency. When the fire department reaches the building, they need to know the location of the fire so that they can attack the fire effectively. Alarm components called annunciator panels provide this service. Each region of the building is called a zone, certain annunciator panels are able to monitor more zones than others. Coincidentally they are also more costly. For example, an eight-zone annunciator panel has a cost of $395.00 and a 16-zone panel costs $665.00. They are part of the equipment in the fire control room of most large-scale buildings. The fire control room is where all of the fire control equipment is stored. Also stored in this room is the fire alarm control panel. This panel interprets signals from the smoke detectors, heat detectors, and pull stations and turns on the horns and strobes, and alerts the fire department of an emergency. Working in a similar manner to the annunciator panels, they are available in different numbers of zone coverages. A four-zone control panel costs $1,175.00, and a 12-zone control panel costs $2,250.00.

The components of the alarm system that the occupants would have the most contact with would be those that alert them to an emergency and those that allow them to report any emergency. This includes horns, strobe lights, smoke detectors, electromagnetic door holders, and manual pull stations.

Alarm horns audibly alert occupants of the emergency and are required where there is an alarm system. They are especially need in buildings housing people with impaired vision. A combination device that includes a strobe and a horn is $175.00 per unit. However, the horn is also available by itself at $95.00 per unit.

Smoke detectors are available in two different types. One is used in open spaces such as rooms and corridors. The other is used inside air ducts to detect smoke flow through them. The open room type cost $142.00, and the duct type smoke detector is $390.00. There are also heat detectors, which do just that, detect a change in the temperature of the room, they are available at a cost of $83.00.

Fire tends to spread very quickly if it encounters an open door. Not only is the heat, smoke and flame allowed to exit through the door, but the open door also lets in oxygen, which fuels the fire. Electromagnetic door holders hold doors open for normal access during regular non-emergency hours. When an emergency arises, the door holders disengage and let the doors close, not allowing smoke, flame or oxygen through. Electromagnetic door holders cost $178.00 each. However, the same door holders are available with integrated door closers, which close the door after the electromagnetic holder disengages. These are available at a cost of $590.00 each.

Each manual pull station is a chance for someone that notices the fire to alert others of the danger. They should be placed at each exit at an accessible level. Therefore, the more exits that a building has, the more pull station it will need. To install one pull station, the cost is $114.00. Although it may seem costly, the benefit of having the alarm system is great. In fact, high-rise buildings and most non-residential buildings are required to have alarm systems.

Many fires are allowed to grow out of control because the fire department is never alerted that there is a fire. If the building is occupied, there is a chance that one of the occupants might notice the fire and either pull a pull station, or call 9-1-1. However, if it is not occupied, for instance it is night-time, then the fire department may be notified after a smoke detector goes off.

That is if the smoke detector is connected to a central fire alarm at the fire department. In some situations, smoke detectors are only for notifying the occupants of the building. If this is the case, then the only other way that the fire department would be notified is if there is an automatic sprinkler system. Automatic sprinkler systems are designed to have an alarm sound when a sprinkler head goes off. The water flow is detected and then the alarm is sounded. The most effective form of fire protection is the automatic sprinkler. There are many components to automatic sprinkler systems.

Automatic sprinkler systems are the same as having a fire fighter with a fire extinguisher on hand at all times. Sprinklers are ready to work 24 hours a day. There are two types of automatic sprinkler systems, each have specific components and there are components that are need for both systems. The two types of systems are dry and wet systems. The difference is that one has water in it at all times, wet, and the other is dry until one of the sprinklers goes off.

Automatic sprinkler system costs can be calculated in two methods. The first method involves the square footage of the building in which sprinklers are going to be installed. The costs are per square foot of floor area. An exposed wet sprinkler system for a building that is 5,000 square feet will cost $1.79 per square foot. For buildings that are 5,000 to 15,000 square feet the cost will be $1.52 per square foot. Finally, for buildings over 15,000 square feet, the cost will be $1.34 per square foot. Sprinkler systems can also be concealed, for example hidden in the ceiling. The cost of these systems is higher than for an exposed system. The costs are $2.00, $1.61, and $1.52 for buildings of 5,000 square feet, 5,000 to 15,000 square feet, and over 15,000 square feet respectively.

The other method for calculating the cost of a sprinkler system is by individual component. As was stated before, there are many automatic sprinkler components. Such components include, check valves, pressure switches, flow alarms, gate valves, retard pressure switches, retard chambers, sprinkler heads, wall hydrants, supervisory switches, inspector's test connection, fire pumps, and dry pipe components. Each item is available in different sizes depending on the amount of sprinkler heads to be installed and the available flow and pressure. Also Sprinkler heads do not all go off at the same temperature. There are different sprinkler heads for different hazard conditions. Residential sprinkler heads are designed to activate very quickly. Due to the large number of components, the costs per component are tabulated below. Prices include material and installation labor.

Component	Cost	Component	Cost
Upright Sprinkler Heads		**Check Valves (Continued)**	
Brass Pendant155 - 200 degree	$20.10	8" Double check detector assembly	$4,827.00
Brass Pendant 286 degree	$20.40	**Dry System Components**	
Brass Pendant 360 degree	$20.80	3" Dry Pipe Valve	$749.80
Brass Pendant 400 - 500 degree	$29.50	4" Dry Pipe Valve	$903.00
Chrome Pendant 155 - 200 degrees	$20.75	6" Dry Pipe Valve	$1,205.00
Chrome Pendant 286 degrees	$20.95	Dry Vale Trim and Guages	$304.40
Dry Pendant Head	$57.50	**Wall Hydrants**	
Zone Valves		Single Outlet - 2.5" X 2.5"	$322.80
2" OS&Y Gate Valve	$222.70	Two-Way Outlet - 2.5" X 2.5" X 4"	$486.00
3" OS&Y Gate Valve	$263.80	3-Way Outlet - 2.5" X 2.5" X 3.33" X 4"	$807.00
4" OS&Y Gate Valve	$344.80	Fire Department Connection	$486.00
6" OS&Y Gate Valve	$518.00	Pumper Connection	$875.00
8" OS&Y Gate Valve	$945.00	Roof Manifold with valves	$612.00
4" Alarm Valve	$448.00	**Misc. Sprinkler Components**	
6" Alarm Valve	$570.00	Air Mantenance Device	$170.70
8" Alarm Valve	$784.00	Low Air Supervisory Unit	$473.30
Alarm Valve Trim only	$240.50	Low Air Pressure Switch	$170.80
4" Alarm valve package	$1,678.00	Pressure Switch	$217.20
6" Alarm valve package	$1,840.00	.5" Ball Drip at check valve	$23.86
8" Alarm valve package	$2,383.00	Water Powered Gong	$252.10
Retard Pressure Switch	$252.70	Cabinet with 6 spare heads and wrench	$76.60
Check Valves		Inspector's Test Connection	$96.20
3" Swing Check Valve	$223.80	**Fire Pumps**	
4" Swing Check Valve	$244.80	500 GPM Diesel 50 Psi	$50,000.00

6" Swing Check Valve	$408.00	750 GPM Diesel 50 Psi	$53,500.00
3" Wafer Check Valve	$203.80	1000 GPM Diesel 100 Psi	$57,000.00
4" Wafer Check Valve	$224.80	2000 GPM Diesel 100 Psi	$62,500.00
6" Wafer Check Valve	$333.00	3500 GPM Diesel 100 Psi	$108,000.00
8" Wafer Check Valve	$420.00	250 GPM Electric 55 Psi	$13,300.00
10" Wafer Check Valve	$699.00	500 GPM Electric 50 Psi	$16,100.00
3" Double check detector assembly	$1,356.00	750 GPM Electric 50 Psi	$22,600.00
4" Double check detector assembly	$1,800.00	750 GPM Electric 100 Psi	$20,600.00
6" Double check detector assembly	$2,705.00		

Another small component of private fire suppression is fire extinguishers. Fire extinguishers are effective in controlling small fires. A common place to find fire extinguishers is in people's kitchens for the occasional unsupervised pan or roast. In past years extinguishers were available in three types at different sizes. The types being carbon dioxide, dry chemical, and Halon. Halon has now been discontinued as an extinguishing agent, and is therefore no longer available. Carbon dioxide extinguishers are available in three sizes, five, ten, and 15 pound. The five-pound size is the least expensive at $196.10, and the 15-pound is the most expensive at $371.10. The dry chemical extinguishers are not as costly as their carbon dioxide relatives, but also leave a powder that needs to be cleaned up after the fire is out. The dry chemical extinguishers are not as costly. A five-pound dry chemical extinguisher costs $73.80. It is also available in a ten and a 20-pound size at $104.20 and $159.10 respectively.

In order to make the extinguishers readily available to those who would need to use them, they should be placed in fire extinguisher cabinets. Depending on the size of the extinguisher, a specific sized cabinet is needed. They come in two sizes with either a full glass or a break glass door. The break glass door is the more expensive of the two in each size. For example the nine inch by 24-inch by five-inch with the full glass door is $129.40. The same size with the break glass door is $144.30. To make the cabinet entirely out of stainless steel, it is an extra cost of $160 to the owner.

3.4 Damage

The cost of damages does not only include the obvious physical damages, there are others. The other costs include the cost of insurance, the cost of lost income, and the mental damage that cannot be replaced with money. These costs are virtually the same for the private owner and the community. They will be discussed together.

After a fire, the owner must submit a claim to his or her insurance agent. Next, the cost of the damages is assessed, the deductible is deducted, and the insurance pays the owner the difference. In most cases, this is not as much as the owner would like. That is not the only cost related to insurance. The cost to the owner is two-fold. The owner must pay not only the deductible, but also the premium. Premiums are the cost of the insurance that the owner pays in order to have the insurance coverage. Depending upon the amount of coverage, the premium is higher or lower. The higher the premium, the larger the cost to the owner, but the smaller the deductible and that means that the insurance company pays more of the damages. Conversely, the lower the deductible, the more the owner must pay in the even of a fire. Similarly, the cost of insurance for firefighters is the same as for a homeowner. However, since a fire fighter has a hazardous job, the cost that a firefighter pays for insurance coverage is higher. Another cost that is related to public water supply and fire suppression is the cost of insurance for the fire department.

When there is a fire at a business, the business not only suffers the cost of the damages, but also the lost time. Time, to a business, is money. When a business cannot sell its services or goods, it loses money. The point of a business is to make money. Some insurance companies cover businesses for losses of this type. A related cost is the potential for damage to neighboring businesses. Whether this cost will be covered by the insurance company of the business of origin or by the neighboring business is dependent upon the insurance company.

Fire creates tremendous damage, but not only to physical objects. There is no way to calculate the costs of lost family heirlooms or memories frozen in photographs. Like the example given in the introduction of a fire in a professor's office. The desk and computer are easily replaced. The time and energy spent in research and writing are not replaceable by money. There is no formula for calculating losses of this type.

3.5 Case Studies

As stated before, if a plentiful water supply is not available to fire fighters more damage than expected may result. The following are case studies of just such an event. Through actions to suppress the fire or luck, water supply was hampered which caused problems with the manual suppression of each fire.

In some fire fighting operations, for safety reasons, the power is cut to the area in which the fire originated. This action is exactly what caused a water supply problem in a small Vermont town in the winter of 1991. A 150-year-old building was the scene of a fire of unknown origin. As fire fighters rushed to the fire, other volunteer fire fighters evacuated the building. As a safety precaution, the power to that are was cut off. Coincidentally, the main power line ran in front of fire building. Unfortunately, the public water supply is driven by electric pumps. By shutting off the power, the pumps were shut off as well. Fire fighters then needed an alternate supply of water. A near-by river provided a drafting point. However, Vermont winters are not known for their warm temperatures, it was –22° out and there was 18 inches of ice on the river. After chopping through the ice with axes, the fire fighters laid 1,500 feet of four-inch hose to supply the pumper trucks. To augment the drafted supply, a ski resort half a mile away also supplied the trucks through its snow making system. Collectively, 16,000 feet of four-inch hose and 10,500 feet of three-inch and one-and-a-half-inch hose were used to suppress the fire.

Remoteness of hydrants also poses a problem to manual suppression tactics. As reported in the January/February 1991 issue of the NFPA Journal, a postal facility that was under construction was damaged by a propane fire. The building was not completed at the time of the fire. A temporary wall was thought to be the cause of the fire. High winds toppled the wall; it in turn struck a propane supply line spraying fuel into the air. A near-by propane heater then ignited the airborne fuel. The fire was suppressed relatively quickly, however, the intense heat produced by the fire caused a second fire to start. The roof was fashioned out of a rubber membrane under which insulation was installed. Beneath the insulation was a metal deck. The heat was transferred through the metal roof decking and into the insulation and rubber membrane. In theory, an easy fire to suppress, however, the nearest fire hydrant was more than 2,000 feet away from the postal facility. An estimated $350,000 in damages were sustained.

In rare cases, the water supply that is provided is not adequate simply because the fire is too large. A movie studio in California was the site of fire that was presumed to be arson. According to the May/June 1991 issue of the NFPA Journal, in November of 1990, a fire was reported by 9-1-1 because the movie studio complex was not equipped with any automatic detection or suppression devices. The complex consisted of 420 acres of false front structures of city buildings; none had fire protection systems installed in them. When the fire department arrived, three structures were fully involved. High winds aided in the growth and spread of the fire to near-by structures. Due to the size of the fire, drafting operations and supplemental water pressure from the water department were required. Automatic sprinklers would have limited the size of the fire nullifying the need for drafting and external water pressure increase. The estimated resulting damages of the fire were $25,000,000.

3.6 CONCLUSION

The amount of potential costs in fire suppression water supply is great. Although sometimes unclear, the costs of water supply are divided between the private owner and the community. Each must pay for some of the necessary protection against fires. The community provides the necessary underground water mains to supply hydrants and automatic sprinkler systems. The private owner then provides the automatic sprinkler systems and sometime the hydrants, which the fire department would use in the even of a fire. Consonant with water supply costs, fire suppression costs are also divided between the private owner and the community. The community provides the fire department to combat fires manually. The owner provides the automatic suppression and fire extinguishers to prevent fire in the first place.

Chapter

4

Water Supply Standards

In the midst of discussion of water supply provisions for a given fire prevention plan, NFPA standards must be taken into consideration. NFPA standard 1231, *Water Supplies for Suburban and Rural Fire Fighting*, provides the guidelines for water supply existence and use by a fire department.

4.1 Water Supply Classification and Use

The water supplies for fire fighting purposes can be supplied from natural bodies of water and constructed sources of water. Natural bodies of water are defined as bodies of water contained by earth only and include ponds, lakes, rivers, streams, bays, creeks, springs, artesian wells, and irrigation canals. Constructed sources of water include aboveground tanks, elevated gravity tanks, livestock watering tanks, cisterns, swimming pools, wells, quarries, mines, reservoirs, aqueducts, mobile water supplies, and hydrants served by a water system.[1]

The surface at the water access point must be able to support heavy vehicles at all times of the year. Such water gathering points must be visible and usable in all weather conditions, be it heavy snow, brush conditions, or mudslides.[2]

Some water supply systems require the use of a dry hydrant. A dry hydrant is a permanent piping system, normally a drafting source that provides access to a water

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[1] NFPA Standard 1231, *Water Supplies for Suburban and Rural Fire Fighting*, 1993, Chapter 6, Section 1.0
[2] Ibid., Chapter 6, Section 1-1

source other than a municipal-type water system (such as a lake or pond).[3] If a dry hydrant is located close to vehicular traffic, suitable barriers shall be constructed to protect fire fighters, equipment, and the dry hydrant.[4]

4.2 Water Supply Transfer

The transfer of water from a water source to the scene of the fire can be done by a number of different methods. These methods include mobile water supply shuttles, pumper relays using large diameter (normally 3½ inch (89 mm) or greater) hose, portable piping, irrigation piping and ditching, helicopters, railroad tank cars, etc.[5]

4.3 Minimum Water Supply

When a fire department approaches a working fire, minimum water supply must be calculated in order to properly handle the fire. "The fire department having jurisdiction shall compute the minimum water supply, in gallons (liters), needed for the structure under its authority."[6] In general, suburban areas (where structures are generally greater than 50 feet apart) need a minimum of 2000 gallons (7570 liters) of water. Urban areas (where structures are generally less than 50 feet apart (considered an exposure risk, since the fire may spread)) need a minimum of 3000 gallons (11,355 liters) of water. However, for any structure protected by an automatic sprinkler system that fully meets the requirements of NFPA standards, the fire department may waive any requirement for minimum water supply. Table 4-1 provides a quick method for determining the water

[3] Ibid., Chapter 1, Section 4
[4] Ibid., Chapter 6, Section 1-2
[5] Ibid., Chapter 6, Section 2
[6] Ibid., Chapter 5, Section 1-1

requirements suggested by this standard for structures without exposures. For structures with exposures, multiply the water requirements developed by 1.5.

Precalculated Minimum Water Supplies by Occupancy Hazard and Construction Classification (no exposures)

Occupancy Hazard Classification	3				4			
Construction Classification	0.5	0.75	1.0	1.5	0.5	0.75	1.0	1.5
Cubic Feet	Gallons				Gallons			
8,000		2,000	2,667	4,000			2,000	3,000
12,000	2,000	3,000	4,000	6,000		2,250	3,000	4,500
16,000	2,667	4,000	5,333	8,000	2,000	3,000	4,000	6,000
20,000	3,333	5,000	6,667	10,000	2,500	3,750	5,000	7,500
24,000	4,000	6,000	8,000	12,000	3,000	4,500	6,000	9,000
28,000	4,667	7,000	9,333	14,000	3,500	5,250	7,000	10,500
32,000	5,333	8,000	10,667	16,000	4,000	6,000	8,000	12,000
36,000	6,000	9,000	12,000	18,000	4,500	6,750	9,000	13,500
40,000	6,667	10,000	13,333	20,000	5,000	7,500	10,000	15,000
44,000	7,333	11,000	14,667	22,000	5,500	8,250	11,000	16,500
48,000	8,000	12,000	16,000	24,000	6,000	9,000	12,000	18,000
52,000	8,667	13,000	17,333	26,000	6,500	9,750	13,000	19,500
56,000	9,333	14,000	18,667	28,000	7,000	10,500	14,000	21,000
60,000	10,000	15,000	20,000	30,000	7,500	11,250	15,000	22,500
64,000	10,667	16,000	21,333	32,000	8,000	12,000	16,000	24,000
68,000	11,333	17,000	22,667	34,000	8,500	12,750	17,000	25,500
72,000	12,000	18,000	24,000	36,000	9,000	13,500	18,000	27,000
76,000	12,667	19,000	25,333	38,000	9,500	14,250	19,000	28,500
80,000	13,333	20,000	26,667	40,000	10,000	15,000	20,000	30,000
84,000	14,000	21,000	28,000	42,000	10,500	15,750	21,000	31,500
88,000	14,667	22,000	29,333	44,000	11,000	16,500	22,000	33,000
92,000	15,333	23,000	30,667	46,000	11,500	17,250	23,000	34,500
96,000	16,000	24,000	32,000	48,000	12,000	18,000	24,000	36,000
100,000	16,667	25,000	33,333	50,000	12,500	18,750	25,000	37,500
104,000	17,333	26,000	34,667	52,000	13,000	19,500	26,000	39,000
108,000	18,000	27,000	36,000	54,000	13,500	20,250	27,000	40,500
112,000	18,667	28,000	37,333	56,000	14,000	21,000	28,000	42,000
116,000	19,333	29,000	38,667	58,000	14,500	21,750	29,000	43,500
120,000	20,000	30,000	40,000	60,000	15,000	22,500	30,000	45,000
124,000	20,667	31,000	41,333	62,000	15,500	23,250	31,000	46,500
128,000	21,333	32,000	42,667	64,000	16,000	24,000	32,000	48,000
132,000	22,000	33,000	44,000	66,000	16,500	24,750	33,000	49,500
136,000	22,667	34,000	45,333	68,000	17,000	25,500	34,000	51,000
140,000	23,333	35,000	46,667	70,000	17,500	26,250	35,000	52,500
144,000	24,000	36,000	48,000	72,000	18,000	27,000	36,000	54,000
148,000	24,667	37,000	49,333	74,000	18,500	27,750	37,000	55,500
152,000	25,333	38,000	50,667	76,000	19,000	28,500	38,000	57,000
156,000	26,000	39,000	52,000	78,000	19,500	29,250	39,000	58,500
160,000	26,667	40,000	53,333	80,000	20,000	30,000	40,000	60,000

Occupancy Hazard Classification	5				6				7			
Construction Classification	0.5	0.75	1.0	1.5	0.5	0.75	1.0	1.5	0.5	0.75	1.0	1.5
Cubic Feet	Gallons				Gallons				Gallons			
8,000				2,400				2,000				
12,000			2,400	3,600			2,000	3,000				2,571
16,000		2,400	3,200	4,800		2,000	2,667	4,000			2,286	3,429
20,000	2,000	3,000	4,000	6,000		2,500	3,333	5,000		2,143	2,857	4,286
24,000	2,400	3,600	4,800	7,200	2,000	3,000	4,000	6,000		2,571	3,429	5,143
28,000	2,800	4,200	5,600	8,400	2,333	3,500	4,667	7,000	2,000	3,000	4,000	6,000
32,000	3,200	4,800	6,400	9,600	2,667	4,000	5,333	8,000	2,286	3,429	4,571	6,857
36,000	3,600	5,400	7,200	10,800	3,000	4,500	6,000	9,000	2,572	3,857	5,143	7,714
40,000	4,000	6,000	8,000	12,000	3,333	5,000	6,667	10,000	2,857	4,286	5,714	8,571
44,000	4,400	6,600	8,800	13,200	3,667	5,500	7,333	11,000	3,143	4,714	6,286	9,429
48,000	4,800	7,200	9,600	14,400	4,000	6,000	8,000	12,000	3,429	5,143	6,857	10,286
52,000	5,200	7,800	10,400	15,600	4,333	6,500	8,667	13,000	3,715	5,571	7,429	11,143
56,000	5,600	8,400	11,200	16,800	4,667	7,000	9,333	14,000	4,000	6,000	8,000	12,000
60,000	6,000	9,000	12,000	18,000	5,000	7,500	10,000	15,000	4,286	6,429	8,571	12,857
64,000	6,400	9,600	12,800	19,200	5,333	8,000	10,667	16,000	4,572	6,857	9,143	13,714
68,000	6,800	10,200	13,600	20,400	5,667	8,500	11,333	17,000	4,857	7,286	9,714	14,571
72,000	7,200	10,800	14,400	21,600	6,000	9,000	12,000	18,000	5,143	7,714	10,286	15,429
76,000	7,600	11,400	15,200	22,800	6,333	9,500	12,667	19,000	5,429	8,143	10,857	16,286
80,000	8,000	12,000	16,000	24,000	6,667	10,000	13,333	20,000	5,715	8,571	11,429	17,143
84,000	8,400	12,600	16,800	25,200	7,000	10,500	14,000	21,000	6,000	9,000	12,000	18,000
88,000	8,800	13,200	17,600	26,400	7,333	11,000	14,667	22,000	6,286	9,429	12,571	18,857
92,000	9,200	13,800	18,400	27,600	7,667	11,500	15,333	23,000	6,572	9,857	13,143	19,714
96,000	9,600	14,400	19,200	28,800	8,000	12,000	16,000	24,000	6,857	10,286	13,714	20,571
100,000	10,000	15,000	20,000	30,000	8,333	12,500	16,667	25,000	7,143	10,714	14,286	21,429
104,000	10,400	15,600	20,800	31,200	8,667	13,000	17,333	26,000	7,429	11,143	14,857	22,286
108,000	10,800	16,200	21,600	32,400	9,000	13,500	18,000	27,000	7,715	11,571	15,429	23,143
112,000	11,200	16,800	22,400	33,600	9,333	14,000	18,667	28,000	8,000	12,000	16,000	24,000
116,000	11,600	17,400	23,200	34,800	9,667	14,500	19,333	29,000	8,286	12,429	16,571	24,857
120,000	12,000	18,000	24,000	36,000	10,000	15,000	20,000	30,000	8,572	12,857	17,143	25,714
124,000	12,400	18,600	24,800	37,200	10,333	15,500	20,667	31,000	8,857	13,286	17,714	26,571
128,000	12,800	19,200	25,600	38,400	10,667	16,000	21,333	32,000	9,143	13,714	18,286	27,429
132,000	13,200	19,800	26,400	39,600	11,000	16,500	22,000	33,000	9,429	14,143	18,857	28,286
136,000	13,600	20,400	27,200	40,800	11,333	17,000	22,667	34,000	9,715	14,571	19,429	29,143
140,000	14,000	21,000	28,000	42,000	11,667	17,500	23,333	35,000	10,000	15,000	20,000	30,000
144,000	14,400	21,600	28,800	43,200	12,000	18,000	24,000	36,000	10,286	15,429	20,571	30,857
148,000	14,800	22,200	29,600	44,400	12,333	18,500	24,667	37,000	10,572	15,857	21,143	31,714
152,000	15,200	22,800	30,400	45,600	12,667	19,000	25,333	38,000	10,857	16,286	21,714	32,571
156,000	15,600	23,400	31,200	46,800	13,000	19,500	26,000	39,000	11,143	16,714	22,286	33,429
160,000	16,000	24,000	32,000	48,000	13,333	20,000	26,667	40,000	11,429	17,143	22,857	34,286

Note: For structures with exposures, multiply results by 1.5 for water supply requirements.

SI units: 1 gal = 3.785 L; 1 cu ft = 0.0283 m³.

Table 4-1

Occupancy Hazard Classification	3				4				5				6				7			
Construction Classification	**0.5**	**0.75**	**1.0**	**1.5**	**0.5**	**0.75**	**1.0**	**1.5**	**0.5**	**0.75**	**1.0**	**1.5**	**0.5**	**0.75**	**1.0**	**1.5**	**0.5**	**0.75**	**1.0**	**1.5**
Cubic Feet	**Gallons**				**Gallons**				**Gallons**				**Gallons**				**Gallons**			
175,000	29,167	43,750	58,333	87,500	21,875	32,813	43,750	65,625	17,500	26,250	35,000	52,500	14,583	21,875	29,167	43,750	12,500	18,750	25,000	37,500
200,000	33,333	50,000	66,667	100,000	25,000	37,500	50,000	75,000	20,000	30,000	40,000	60,000	16,667	25,000	33,333	50,000	14,286	21,429	28,571	42,857
225,000	37,500	56,250	75,000	112,500	28,125	42,188	56,250	84,375	22,500	33,750	45,000	67,500	18,750	28,125	37,500	56,250	16,071	24,107	32,143	48,214
250,000	41,667	62,500	83,333	125,000	31,250	46,875	62,500	93,750	25,000	37,500	50,000	75,000	20,833	31,250	41,667	62,500	17,857	26,786	35,714	53,571
275,000	45,833	68,750	91,667	137,500	34,375	51,563	68,750	103,125	27,500	41,250	55,000	82,500	22,917	34,375	45,833	68,750	19,643	29,464	39,286	58,929
300,000	50,000	75,000	100,000	150,000	37,500	56,250	75,000	112,500	30,000	45,000	60,000	90,000	25,000	37,500	50,000	75,000	21,429	32,143	42,857	64,286
325,000	54,167	81,250	108,333	162,500	40,625	60,938	81,250	121,875	32,500	48,750	65,000	97,500	27,083	40,625	54,167	81,250	23,214	34,821	46,429	69,643
350,000	58,333	87,500	116,667	175,000	43,750	65,625	87,500	131,250	35,000	52,500	70,000	105,000	29,167	43,750	58,333	87,500	25,000	37,500	50,000	75,000
375,000	62,500	93,750	125,000	187,500	46,875	70,313	93,750	140,625	37,500	56,250	75,000	112,500	31,250	46,875	62,500	93,750	26,786	40,179	53,571	80,357
400,000	66,667	100,000	133,333	200,000	50,000	75,000	100,000	150,000	40,000	60,000	80,000	120,000	33,333	50,000	66,667	100,000	28,571	42,857	57,143	85,714
425,000	70,833	106,250	141,667	212,500	53,125	79,688	106,250	159,375	42,500	63,750	85,000	127,500	35,417	53,125	70,833	106,250	30,357	45,536	60,714	91,071
450,000	75,000	112,500	150,000	225,000	56,250	84,376	112,500	168,750	45,000	67,500	90,000	135,000	37,500	56,250	75,000	112,500	32,143	48,214	64,286	96,429
475,000	79,167	118,750	158,333	237,500	59,375	89,063	118,750	178,125	47,500	71,250	95,000	142,500	39,583	59,375	79,167	118,750	33,929	50,893	67,857	101,786
500,000	83,333	125,000	166,667	250,000	62,500	93,751	125,000	187,500	50,000	75,000	100,000	150,000	41,667	62,500	83,333	125,000	35,714	53,571	71,429	107,143
525,000	87,500	131,250	175,000	262,500	65,625	98,438	131,250	196,875	52,500	78,750	105,000	157,500	43,750	65,625	87,500	131,250	37,500	56,250	75,000	112,500
550,000	91,667	137,500	183,333	275,000	68,750	103,126	137,500	206,250	55,000	82,500	110,000	165,000	45,833	68,750	91,667	137,500	39,286	58,929	78,571	117,857
575,000	95,833	143,750	191,667	287,500	71,875	107,813	143,750	215,625	57,500	86,250	115,000	172,500	47,917	71,875	95,833	143,750	41,071	61,607	82,143	123,214
600,000	100,000	150,000	200,000	300,000	75,000	112,501	150,000	225,000	60,000	90,000	120,000	180,000	50,000	75,000	100,000	150,000	42,857	64,286	85,714	128,571
625,000	104,167	156,250	208,333	312,500	78,125	117,188	156,250	234,375	62,500	93,750	125,000	187,500	52,083	78,125	104,167	156,250	44,643	66,964	89,286	133,929
650,000	108,333	162,500	216,667	325,000	81,250	121,876	162,500	243,750	65,000	97,500	130,000	195,000	54,167	81,250	108,333	162,500	46,429	69,643	92,857	139,286
675,000	112,500	168,750	225,000	337,500	84,375	126,563	168,750	253,125	67,500	101,250	135,000	202,500	56,250	84,375	112,500	168,750	48,214	72,321	96,429	144,643
700,000	116,667	175,000	233,333	350,000	87,500	131,251	175,000	262,500	70,000	105,000	140,000	210,000	58,333	87,500	116,667	175,000	50,000	75,000	100,000	150,000
725,000	120,833	181,250	241,667	362,500	90,625	135,938	181,250	271,875	72,500	108,750	145,000	217,500	60,417	90,625	120,833	181,250	51,786	77,679	103,571	155,357
750,000	125,000	187,500	250,000	375,000	93,750	140,626	187,500	281,250	75,000	112,500	150,000	225,000	62,500	93,750	125,000	187,500	53,571	80,357	107,143	160,714
775,000	129,167	193,750	258,333	387,500	96,875	145,313	193,750	290,625	77,500	116,250	155,000	232,500	64,583	96,875	129,167	193,750	55,357	83,036	110,714	166,071
800,000	133,333	200,000	266,667	400,000	100,000	150,001	200,000	300,000	80,000	120,000	160,000	240,000	66,667	100,000	133,333	200,000	57,143	85,714	114,286	171,429
825,000	137,500	206,250	275,000	412,500	103,125	154,688	206,250	309,375	82,500	123,750	165,000	247,500	68,750	103,125	137,500	206,250	58,929	88,393	117,857	176,786
850,000	141,667	212,500	283,333	425,000	106,250	159,376	212,500	318,750	85,000	127,500	170,000	255,000	70,833	106,250	141,667	212,500	60,714	91,071	121,429	182,143
875,000	145,833	218,750	291,667	437,500	109,375	164,064	218,750	328,125	87,500	131,250	175,000	262,500	72,917	109,375	145,833	218,750	62,500	93,750	125,000	187,500
900,000	150,000	225,000	300,000	450,000	112,500	168,751	225,000	337,500	90,000	135,000	180,000	270,000	75,000	112,500	150,000	225,000	64,286	96,429	128,571	192,857
925,000	154,167	231,250	308,333	462,500	115,265	173,439	231,250	346,875	92,500	138,750	185,000	277,500	77,083	115,625	154,167	231,250	66,071	99,107	132,143	198,214
950,000	158,333	237,500	316,667	475,000	118,750	178,126	237,500	356,250	95,000	142,500	190,000	285,000	79,167	118,750	158,333	237,500	67,857	101,786	135,714	203,571
975,000	162,500	243,750	325,000	487,500	121,875	182,814	243,750	365,625	97,500	146,250	195,000	292,500	81,250	121,875	162,500	243,750	69,643	104,464	139,286	208,929
1,000,000	166,667	250,000	333,333	500,000	125,000	187,501	250,000	375,000	100,000	150,000	200,000	300,000	83,333	125,000	166,667	250,000	71,429	107,143	142,857	214,286

Note: For structures with exposures, multiply results by 1.5 for water supply requirements.

SI units: 1 gal = 3.785 L; 1 cu ft = 0.0283 m^3.

Table 4-2

The following information is necessary to fully compute the minimum water supplies for a structure, and should be collected during a building survey:[7]

(a) Area of all floors, including attics, basements, and crawl spaces.

(b) Height between floors or crawl spaces and in the attics from floor to ridgepole.

(c) Construction materials used in each building, including walls, floors, roofs, ceilings, interior partitions, stairs, etc.

(d) Occupancy (occupancies) of buildings.

(e) Occupancy (occupancies) of yard areas.

(f) Exposures to buildings and yard storage and distances between them.

[7] Ibid., Appendix A, Section 2-1.1

(g) Fire protection systems – automatic and manual protection systems, hydrants, yard mains, and other protection facilities.

(h) On-premises water supplies, including natural and constructed sources of water.

4.4 Water Supply Accessibility

Water supplies for fire fighting purposes must be accessible to fire fighting equipment. The fire department shall determine, as part of its property survey, the maximum safe load limits of roadways, laneways, and bridges, and determine accessibility during various climatic conditions. Any means of access shall be constructed in accordance with NFPA 1141, *Standard for Fire Protection in Planned Building Groups*. An appropriate sign must be erected at each water point identifying the site for fire department emergency use.[8]

4.5 Water Supply Officers

Many progressive rural fire departments depend on a water supply officer (WSO). The work of a properly trained and equipped WSO makes it possible for the officer supervising the actual fire attack to plan it on the basis of reliable water supply information, to coordinate the attack with the available water supplies, and to help prevent the confusion inherent in fighting a major fire when the chief officer at the scene must divert too much personal attention from the attack to the logistics of backing it up.[9]

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[8] Ibid., Chapter 6, Section 4 and Section 5
[9] Ibid., Appendix B, Section 1-2.0

The WSO is designated to provide sufficient water at the fire site, to plan availability of additional water resources, and to determine water requirements at the various locations over the district. The WSO should maintain and even carry a complete set of files, which should include cards showing water points and lists of automatic and mutual aid mobile water supply apparatus available. Modern technology in optics and computers makes it feasible for even a relatively low-budget department to reduce this data to microfiche or photographic slides, or even to small laptop or hand-held computing devices, which can be maintained in the fire alarm communication center and taken to the scene of every fire. The WSO is, basically, the individual who implements the water supply prefire planning.[10]

As the WSO visits neighboring fire departments, a list of all apparatus, equipment, and personnel available to the officer's department should be developed. At this time, arrangements can be developed where certain apparatus and personnel will respond under an automatic aid agreement (first alarm response) or a mutual aid agreement (called as needed), depending on the needs of the department. These needs will be dictated by the nature of the structure(s) involved.[11]

"At the fire scene, the WSO becomes the rural equivalent of the water department representative who responds to major municipal fires. The WSO's duty to maintain continuous fire streams in rural areas is frequently a very complicated task involving setting up several water hauling facilities, assembling water-carrying equipment of automatic and mutual aid departments, calculating estimated arrival times of mobile

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[10] Ibid., Appendix B, Section 1-2.1
[11] Ibid., Appendix B, Section 1-2.1

water supply apparatus, and having a thorough knowledge of available water supplies throughout a wide area of fire department jurisdiction."[12]

4.6 Natural Water Sources

Streams. Streams, including rivers, bays, creeks, and irrigation canals, can represent a continuously flowing source of substantial capacity. Where considering water from flowing streams as potential water sources, the fire department should consider the following factors:[13]

(a) Flowing capacity

(b) Climatic characteristics. Flooding, drought and freezing are some of the characteristics that must be evaluated.

(c) Accesibility

Ponds. Ponds can include lakes or farm ponds used for watering livestock, irrigation, fish culture, recreation, or other purposes while serving a secondary function for fire protection. Most of the factors relative to streams are pertinent to ponds, with the following items to be considered:[14]

(a) Minimum annual level should be adequate to meet water supply needs of the fire problem the pond serves.

(b) Freezing of a stationary water supply, contrasted with the flowing stream, presents a greater problem.

(c) Silt and debris can accumulate in a pond or lake, reducing its actual capacity.

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[12] Ibid., Appendix B, Section 1-2.2
[13] Ibid., Appendix B, Section 3-1

(d) Accessibility should always be a prime consideration.

Other natural sources might include springs and artesian wells.[15]

4.7 Developed Sources of Water

The developed sources of water supplies adapted for fire fighting are limited only to the innovative nature of the fire department. They range from cisterns, swimming pools, quarries, mines, automatic sprinkler system supplies, stationary tanks, driven wells, and dry hydrants, to situations where fire fighters have drafter water out of the basement of a burning building into which it was pumped only minutes before to fight the fire.[16]

Cisterns. Cisterns should have a minimum usable volume as determined by the fire department, using minimum water supply computation methods described above. There is no real limit to the maximum capacity. A cistern should be accessible to the fire apparatus or other pumping device but should be located far enough from the hazard that personnel and equipment are not endangered.[17]

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[14] Ibid., Appendix B, Section 3-2
[15] Ibid., Appendix B, Section 3-3
[16] Ibid., Appendix B, Section 4-1
[17] Ibid., Appendix B, Section 4-2

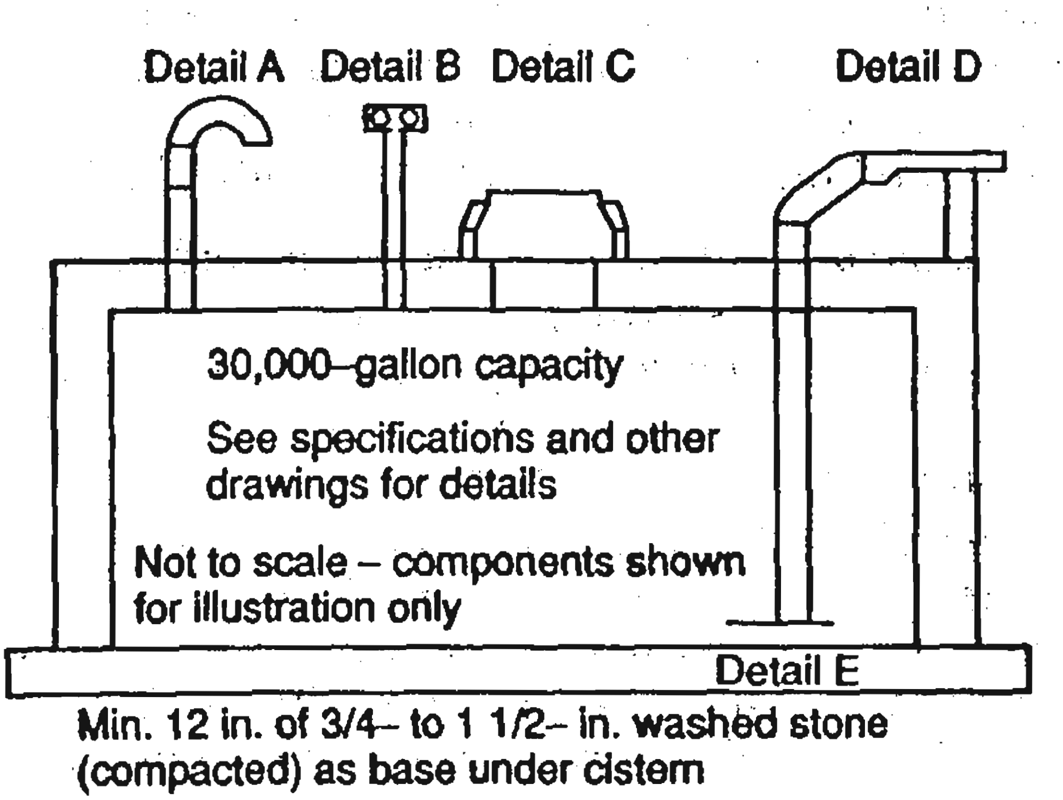

Figure 4-1 -- Cistern

Swimming Pools. Swimming pools are an increasingly common source of water for fire protection. Even in some areas with normally adequate hydrant water supplies, they have been a factor in providing protection; such as in cases in which water demands have exceeded availability because of wildfire disasters, etc.

They provide an advantage in that they are sources of clean water, but have major drawbacks due to the weight of fire department vehicles and poor accessibility for large apparatus. There are some areas of the country in which swimming pool distribution is better than hydrant distribution.[18]

Livestock Watering Ponds and Tanks. Many farms have livestock water tanks and similar facilities located adjacent to the barnyard, accessible to the fire department for emergency use.

Sprinkler Systems. In some rural areas, the only large water supply might be storage provided for use of a sprinklered building. Extreme care should be exercised in the use of water supplies provided for sprinkler protection. A certain amount of water should be retained in these systems for minimum sprinkler protection. A careful study and preplan should be make to determine such use.[19]

4.8 Dry Fire Hydrants

As the installation of rural dry fire hydrants using constructed or natural water sources increases, an understanding of the planning, permitting, design criteria, and construction processes becomes evident. A strategically placed rural dry fire hydrant system, with all-weather road access, significantly reduces water point set-up time and turnaround time to the fireground, improves the life safety of the fire fighter, and can reduce insurance costs.[20] Some factors to consider in determining the need and locations for a dry fire hydrant system are:[21]

(a) Current and future population and building trends.

(b) Property values protected.

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[18] Ibid., Appendix B, Section 4-8
[19] Ibid., Appendix B, Section 4-10
[20] Ibid., Appendix B, Section 5-1
[21] Ibid., Appendix B, Section 5-2

(c) Potential for loss.

(d) Fire history of the area protected.

(e) Current water supply systems.

(f) Potential water supply sources – constructed or natural.

(g) Cost of project.

(h) Other factors of local concern.

Figure 4-2 – Dry Hydrant

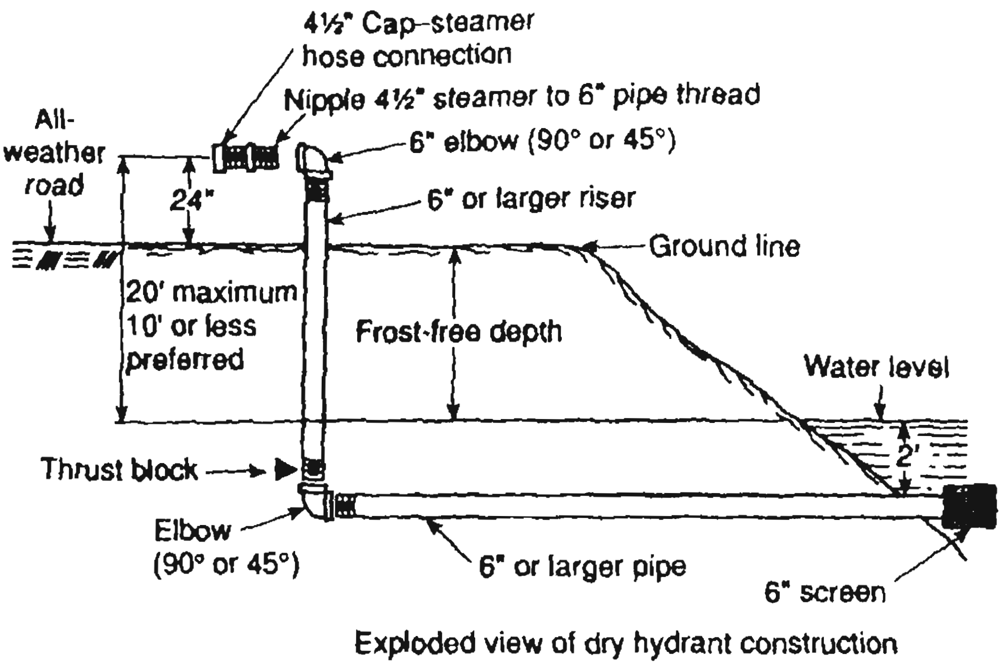


Figure 4-3 – Dry Hydrant

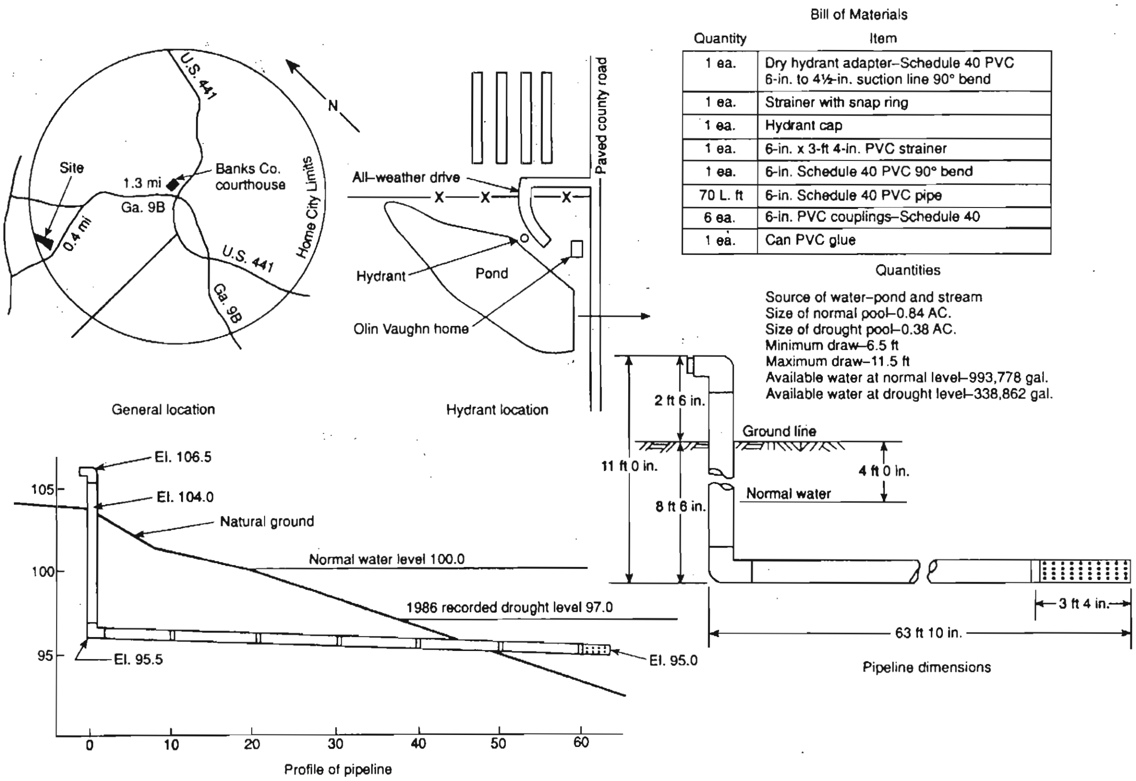


Figure 4-4 – Sample Dry Hydrant Location Diagram

4.9 Preplanning Water Supply

In any given fire department, the officiating water supply officer must complete a water supply preplanning strategy. Structures within the district of responsibility of the fire department must be surveyed in accordance with NFPA 1231. The water requirement should be calculated, and the type and amount of equipment that should respond on first alarm should be designated. The response of fire apparatus, in conjunction with capacity of mobile water supply apparatus, travel distance to haul water, and the volume of the water supply, can then be arranged so that a constant flow to equal the water flow requirements is obtained.

The procedure should be verified under training conditions prior to a fire emergency. This training exercise should include the spotting of equipment to protect the fire property and the exposures, exploration of the water sources, designation of fire lanes or routes, and review and modification of the operations to meet unusual conditions.[22]

[22] Ibid., Appendix B, Section 8-1

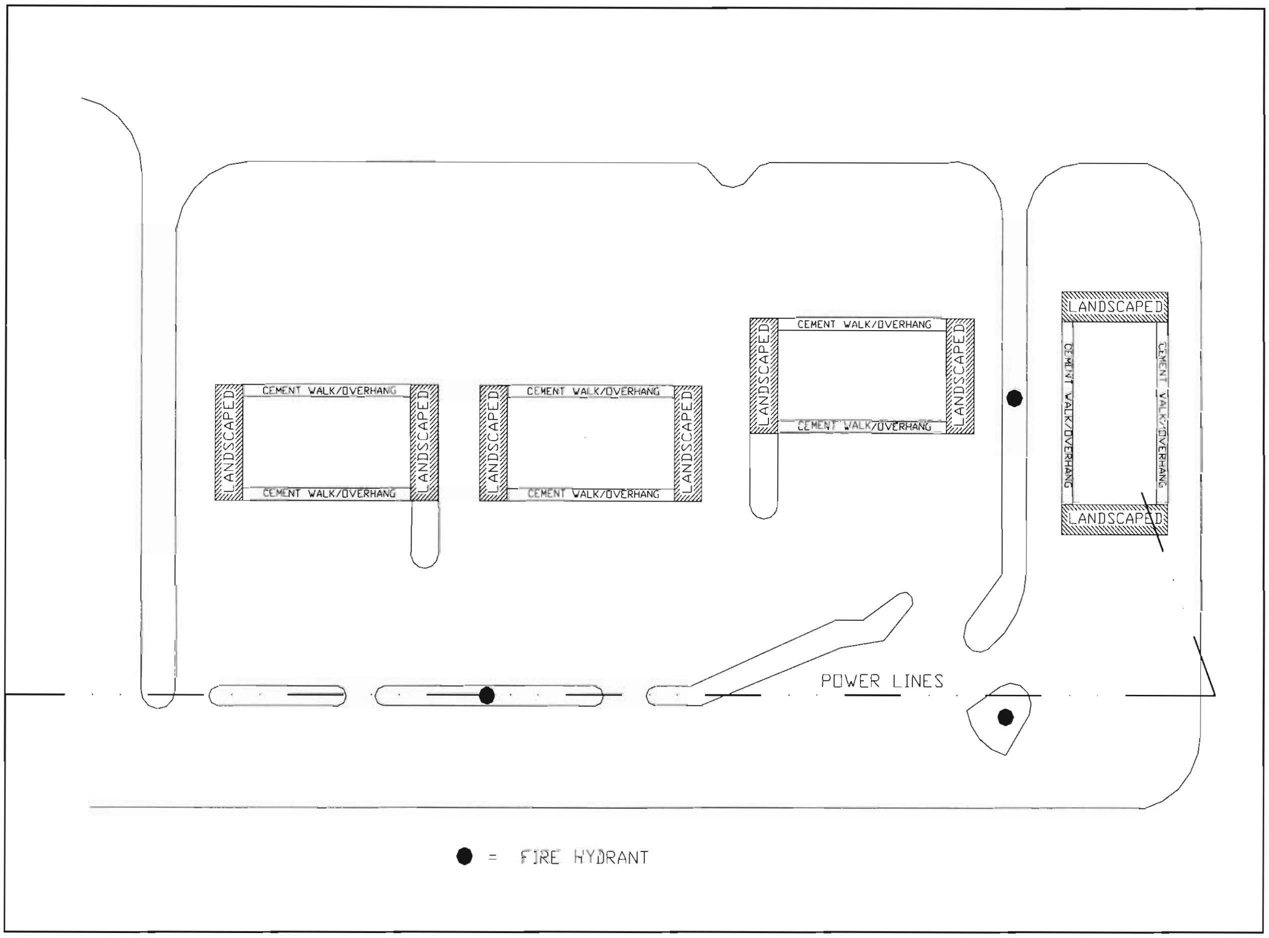
CHAPTER

5.1

CASE STUDY – AUBURN OFFICE PARK

The Auburn Office Park is located off Route 12 in Auburn, Massachusetts near the Interstate 290 exit from the Massachusetts Turnpike (I-90). The area is relatively flat but with a slight incline towards the back of the buildings. The office park consists of four buildings, all of which are the same size. There are a number of hydrants located on the site. Each of these topics will be discussed in the following chapter.

The office park is situated ver closely to the Mass. Pike. The Turnpike Authority and tollbooths are located across the main driveway. Also located nearby is a Park and Ride parking lot for commuters. The main driveway, Midstate Drive, is located off Golding Drive, before the entrance to a CVS Pharmacy. The office park begins on the left. There is a slight elevation change between the front of the buildings and the back of the buildings. Between each of the buildings is an asphalt ramp that leads to parking on the upper level. There are little to no obstructions in the area to fire trucks. There is ample access to the rear of the buildings. The first and second buildings on the left when driving into the office park are on the same line, their front facades are in line. The third building is set back about 30 feet from the first two. The fourth building is set perpendicular to the first three, and the face nearest the drive is about in line with the first two buildings. The fourth building is isolated slightly by a median between it and the third building. There is a power line that runs in along the left side of the drive and continues roughly straight across the park and then connects to the fourth building.



The buildings appear to be identical in size and construction. They are each approximately 150 feet long by 75 feet wide. On the front and the back are cement walks or stoops that are 10 feet wide and span the entire length of the building. On each of the ends are garden areas that have grass and trees growing. Also in these areas are the garbage dumpsters. Each of the gardens is about 25 feet wide and spans from the cement walk in the front to the cement walk in the back or about 100 feet. The buildings are two stories with brick exteriors. They are most probably wood construction. The office park is home to many companies in each building. The first building houses Automatic Data Processing, Life Alert, The Radiation Oncology Association, Mass Metro Mortgage, Manpower, Central Credit Union Fund, and the CCUF Brokerage Services Inc., offices. State Police C.P.A.C., Total Communications, Inc., and the American Cancer Society are in the second building. The third building is home to Noram

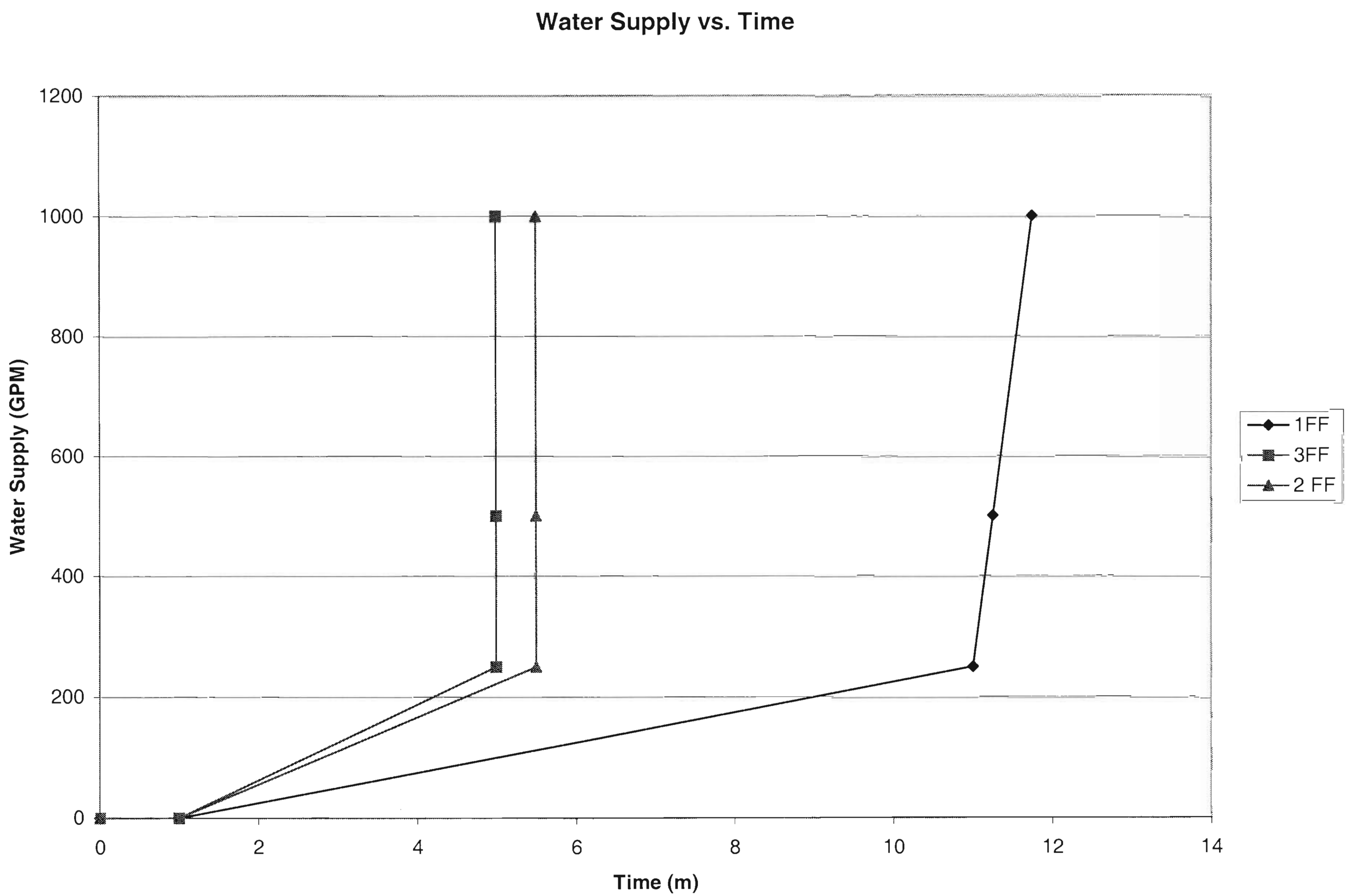
Energy Management Inc., PC-Plus Technologies Inc., Qestec Inc., Rivard Electronics Center, Host Marriott, RGIS Inventory Specialists, Polytec PI, Inc., and DJ USA. Whether the buildings were equipped with automatic sprinklers was not determined.

There are three hydrants located in the office park. The first is located on a median left of the main driveway in front of the first and second buildings. The second is located on a median between the third and fourth buildings. The last hydrant is located on a median on the same line as the second hydrant. The median has a power line pole on it as well. The lack of town owned information on the subject of size and location of underground mains made it impossible to obtain that information about the case study.

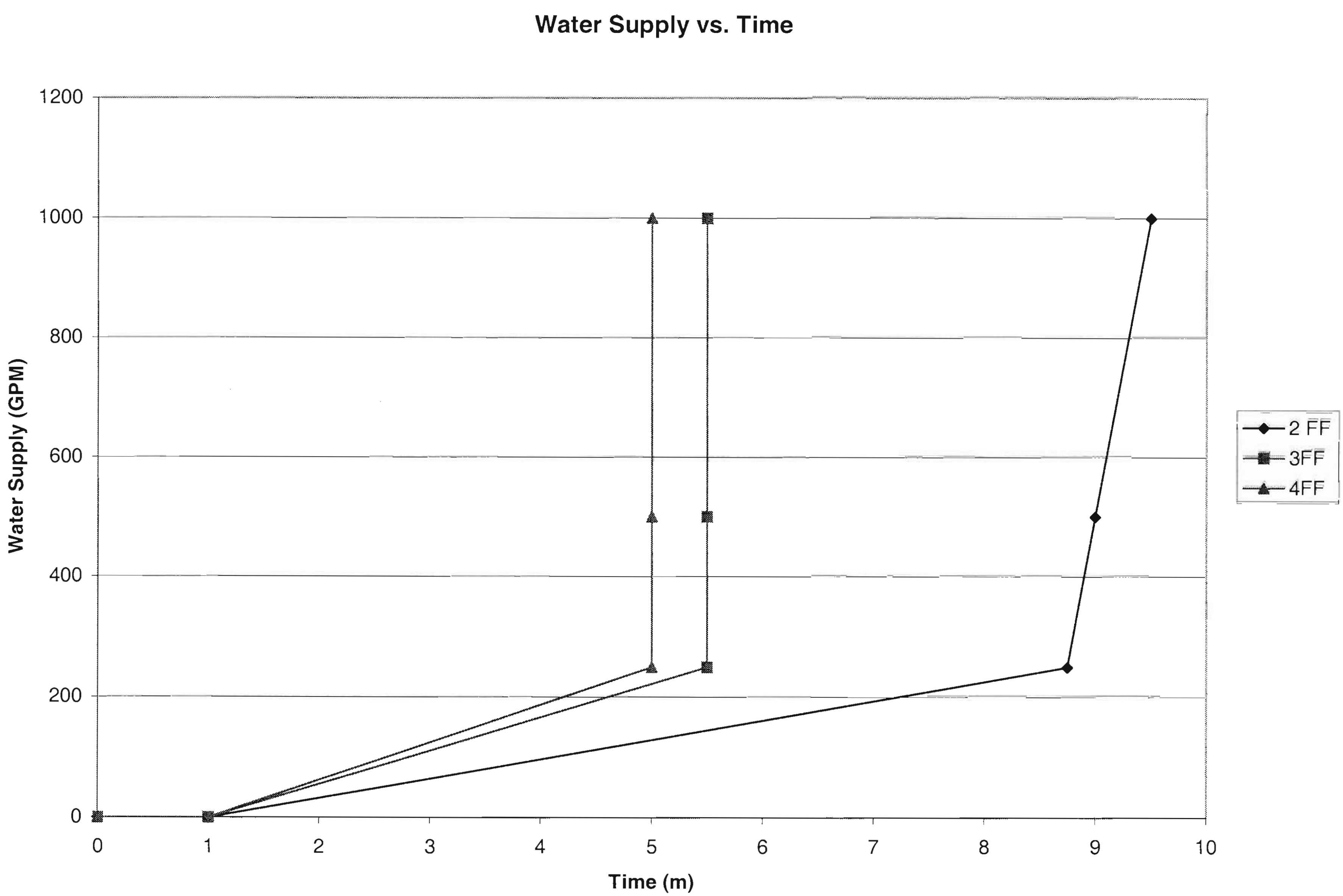
CHAPTER

5.2

WATER VS. TIME CURVES



Water vs. Time Curve for one engine one, two and three firefighters



Water vs. Time Curve for two engines two, three and four firefighters

Appendix

A

Hose Lay Analysis

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*****************
*Reverse Lay, 1E*
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Assumptions
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      1.) One (1) firefighter (FF), one (1) engine.
      2.) Two (2) firefighters (FF), one (1) engine.
      3.) Three (3) firefighters (FF), one (1) engine.
      4.) Firefighters know of a working fire.
      5.) First engine will lay from fire to nearest hydrant.
      6.) Begin scenario once engine stops at scene.
      7.) Standpipes are involved.

Vairables
---------
      1.) Weather
      2.) Roadway conditions
      3.) Experience of firefighters
      4.) Firefighter's knowledge of area and immediate hydrant
          locations.
      5.) d(h), distance to the hydrant and its associated variables:
            x t(ulh) time to hydrant from engine, unladen
            x t(lh) time to hydrant from engine, laden with hose
            x t(lb) time to hydrant from engine, laden with equipment
        6.) d(p), distance to the standpipe and its associated variables:
            x t(ulp) time to standpipe from engine, unladen
            x t(lp) time to standpipe from engine, laden with hose
      7.) l, number of supply lines and its associated variable:
            x t(l) time to connect supply lines to engine

Procedure
---------

Predecessor: Drive time from HQ to arrival at scene.

1. FF disembarks and proceeds to the back of engine    [0.5 minutes]
2. FF gets hydrant bag and other misc. equipment       [0.25 m]
3. FF locates the nearest stationary object (hydrant)  [0.25 m]
4. FF brings hydrant bag to stationary object          [t(lb) m]
5. FF returns to engine                       [t(ulh) m]
6. FF grabs hose from the back of engine          [0.5 m]
7. FF pulls hose until he reaches the stationary object  [t(lh) m]
        x {note: hose size = 2,2.5,3,4,5,6 inches?}
8. FF repeats steps 5-7 for each additional supply line  [multiplier]
9. FF connects supply lines to intake valves on engine [t(l) m]
10. FF walks back to hydrant                      [t(ulh) m]
11. FF takes hydrant wrench and undoes hydrant caps   [0.5 m]
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12. FF quickly surveys hydrant for damage and any debris inside [0.25 m]
13. FF opens hydrant and flushes hydrant [0.5 m]
14. FF shuts off hydrant [0.25 m]
15. FF dresses all hydrant ports with gates, wyes, siameses, caps [0.5 m]
16. FF ataches hoses to the gates, wyes, siameses [1.0 m]
17. FF completely opens the hydrant [0.25 m]
18. FF walks back to engine [t(ulh) m]
19. FF pulls standpipe connection hose off engine [0.5 m]
20. FF connects hose to engine [0.25 m]
21. FF pulls hose to standpipe connection [t(lp) m]
22. FF dresses the standpipe [0.25 m]
23. FF connects hose to standpipe [0.25 m]
22. FF returns to engine [t(ulp) m]
23. Continuous water arrives on fire [total]

2FF,1E

1. FF1 and FF2 disembark and proceed to the back of engine [0.5 m]
2. FF1 and FF2 locate the nearest stationary object [0.25 m]
3. FF1 gets hydrant bag and other misc. equipment [0.25 m]
4. FF1 brings hydrant bag to stationary object [t(lb) m]
5. FF2 grabs hose from back of engine [0.5 m]
6. FF2 pulls hose until he reaches the stationar object [t(lh) m]
   x {note: hose size = 2,2.5,3,4,5,6 inches?}
7. FF2 returns to engine [t(ulh) m]
8. FF2 repeats steps 5-7 for each additional supply line [multiplier]
9. FF1 takes hydrant wrench and undoes hydrant caps [0.5 m]
10. FF1 quickly surveys hydrant for damage and any debris inside [0.25 m]
11. FF1 opens hydrant and flushes hydrant [0.5 m]
12. FF1 shuts off hydrant [0.25 m]
13. FF1 dresses all hydrant ports with gates, wyes, siameses, caps [0.5 m]
14. FF1 ataches hoses to the gates, wyes, siameses [1.0 m]

15. FF2 connects supply lines to intake valves on engine [t(l) m]
16. FF2 pulls standpipe connection hose off engine [0.5 m]
17. FF2 connects hose to engine [0.25 m]
18. FF2 pulls hose to standpipe connection [t(lp) m]
19. FF2 dresses the standpipe [0.25 m]
20. FF2 connects hose to standpipe [0.25 m]
21. FF1 completely opens the hydrant [0.25 m]
22. FF2 returns to engine [t(ulp) m]
23. FF1 returns to engine [t(ulh) m]
24. Continuous water arrives on fire [total]

3FF,1E

1. FF1, FF2, FF3 disembark and proceed to the back of engine [0.5 m]
2. FF1 gets hydrant bag and other misc. equipment [0.25 m]
3. FF1 located and goes to the hydrant [t(ulh) m]
4. FF2 & FF3 grab hose from the back of engine [1.0 m]
5. FF2 & FF3 pull hose until they reach the stationary object [2 * t(lh) m]
   x {note: hose size = 2,2.5,3,4,5,6 inches?}
6. FF2 & FF3 return to engine [t(ulh) m]
7. FF2 & FF3 repeat stps 4-6 for each add'l supply line [multiplier]
8. FF1 takes hydrant wrench and undoes hydrant caps [0.5 m]

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9. FF1 quickly surveys hydrant for damage and any debris inside  [0.25m]
10. FF1 opens hydrant and flushes hydrant                [0.5 m]
11. FF1 shuts off hydrant                                [0.25 m]
12. FF1 dresses all hydrant ports with gates, wyes, siameses, caps [0.5 m]
13. FF1 ataches hoses to the gates, wyes, siameses       [1.0 m]
14. FF2 connects supply lines to intake valves on engine [t(l) m]
15. FF3 pulls standpipe connection hose off engine     [0.5 m]
16. FF3 connects hose to engine                        [0.25 m]
17. FF3 pulls hose to standpipe connection               [t(lp) m]
18. FF3 dresses the standpipe                    [0.25 m]
19. FF3 connects the hose to standpipe                 [0.25 m]
20. FF3 returns to engine                        [t(ulp) m]
21. FF1 completely opens the hydrant                     [0.25 m]
22. FF1 returns to engine                        [t(ulh) m]
23. Continuous water arrives on fire                   [total]
```

4FF,1E

```
1. FF1, FF2, FF3, FF4 disembark and proceed to the back of engine [0.5 m]
2. FF1 gets hydrant bag and other misc. equipment      [0.25 m]
3. FF1 located and goes to the hydrant                 [t(ulh) m]
4. FF2 & FF3 & FF4 grab hose from the back of engine         [1.0 m]
5. FF2 & FF3 & FF4 pull hose until they reach the stationary object
            x {note: hose size = 2,2.5,3,4,5,6 inches?}
6. FF2 & FF3 & FF4 return to engine                      [t(ulh) m]
8. FF1 takes hydrant wrench and undoes hydrant caps      [0.5 m]
9. FF1 quickly surveys hydrant for damage and any debris inside  [0.25m]
10. FF1 opens hydrant and flushes hydrant                [0.5 m]
11. FF1 shuts off hydrant                                [0.25 m]
12. FF1 dresses all hydrant ports with gates, wyes, siameses, caps [0.5 m]
13. FF1 ataches hoses to the gates, wyes, siameses       [1.0 m]
14. FF2 connects supply lines to intake valves on engine [t(l) m]
15. FF3 & FF4 pulls standpipe connection hose off engine     [0.5 m]
16. FF3 & FF4 connects hose to engine                        [0.25 m]
17. FF3 & FF4 pulls hose to standpipe connection               [t(lp) m]
18. FF3 & FF4 dresses the standpipe                    [0.25 m]
19. FF3 & FF4 connects the hose to standpipe                 [0.25 m]
20. FF3 & FF4 returns to engine                        [t(ulp) m]
21. FF1 completely opens the hydrant                     [0.25 m]
22. FF1 returns to engine                        [t(ulh) m]
23. Continuous water arrives on fire                   [total]
```

Successor: Plan of attack methods

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*****************
*Reverse Lay, 2E*
*****************
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Assumptions

      1.) Two (2) firefighters (FF), Two (2) engines.
      2.) Three (3) firefighters (FF), Two (2) engines.
      3.) Four (4) firefighters (FF), Two (2) engines.
      4.) Firefighters know of a working fire.

5.) First engine will lay from fire to nearest hydrant. Second will be supplied by
first engine.
6.) Begin scenario once engines stop at scene.
7.) Standpipes are involved.

Vairables

1.) Weather
2.) Roadway conditions
3.) Experience of firefighters
4.) Firefighter's knowledge of area and immediate hydrant locations.
5.) d(h), distance to the hydrant and its associated variables:
   x t(ulh) time to hydrant from engine, unladen
   x t(lh) time to hydrant from engine, laden with hose
   x t(lb) time to hydrant from engine, laden with equipment
6.) d(p), distance to the standpipe and its associated variables:
   x t(ulp) time to standpipe from engine, unladen
   x t(lp) time to standpipe from engine, laden with hose
7.) l, number of supply lines and its associated variable:
   x t(l) time to connect supply lines to engine
8.) d(ee). Distance between engines and its associated variables:
   x t(ee) time to go from engine to engine, laden with hose
   x t(eeu) time to go from engine to engine, unladen

Procedure

Predecessor: Drive time from HQ to arrival at scene.
1St Engine
1. FF disembarks and proceeds to the back of engine [0.5 minutes]
2. FF gets hydrant bag and other misc. equipment [0.25 m]
3. FF locates the nearest stationary object (hydrant) [0.25 m]
4. FF brings hydrant bag to stationary object [t(lb) m}
5. FF returns to engine [t(ulh) m]
6. FF grabs hose from the back of engine [0.5 m]
7. FF pulls hose until he reaches the stationary object [t(lh) m]
x {note: hose size = 2,2.5,3,4,5,6 inches?}
8. FF repeats steps 5-7 for each additional supply line [multiplier]
9. FF connects supply lines to intake valves on engine [t(l) m]
10. FF walks back to hydrant [t(ulh) m]
11. FF takes hydrant wrench and undoes hydrant caps [0.5 m]
12. FF quickly surveys hydrant for damage and any debris inside [0.25 m]
13. FF opens hydrant and flushes hydrant [0.5 m]
14. FF shuts off hydrant [0.25 m]
15. FF dresses all hydrant ports with gates, wyes, siameses, caps [0.5 m]
16. 16. FF attaches hoses to the gates, wyes, siameses [1.0 m]
17. FF completely opens the hydrant [0.25 m]
18. FF walks back to engine and opens the outlet and inlet valves [t(ulh) m]

2nd Engine
1. FFA disembarks and proceeds to back of 2nd engine [0.5 m]
2. FFA grabs hose from back of 2nd engine [0.5 m]
3. FFA pulls hose until he reaches the 1st engine [t(ee) m]
x {note: hose size = 2,2.5,3,4,5,6 inches?}
4. FFA connects hose to outlet valves on 1st engine [0.25 m]
5. FFA returns to 2nd engine [t(eeu) m]
6. FFA attaches hose to intake valves [0.25 m]
7. FFA proceeds to the back of the engine [0.25 m]
8. FFA pulls standpipe connection hose off engine [0.5 m]
9. FFA connects hose to engine [0.25 m]
10. FFA pulls hose to standpipe connection [t(lp) m]
11. FFA dresses the standpipe [0.25 m]
12. FFA connects hose to standpipe [0.25 m]
13. FFA returns to engine [t(ulp) m]
14. FFA opens outlet and inlet valves [0.5 m]
15. Continuous water arrives on fire [total]

3FF,2E
1st Engine
1. FF1 and FF2 disembark and proceed to the back of engine [0.5 m]
2. FF1 and FF2 locate the nearest stationary object [0.25 m]
3. FF1 gets hydrant bag and other misc. equipment [0.25 m]
4. FF1 brings hydrant bag to stationary object [t(lb) m]
5. FF2 grabs hose from back of engine [0.5 m]
6. FF2 pulls hose until he reaches the stationar object [t(lh) m]
x {note: hose size = 2,2.5,3,4,5,6 inches?}
7. FF2 returns to engine [t(ulh) m]
8. FF2 repeats steps 5-7 for each additional supply line [multiplier]
9. FF1 takes hydrant wrench and undoes hydrant caps [0.5 m]
10. FF1 quickly surveys hydrant for damage and any debris inside [0.25 m]
11. FF1 opens hydrant and flushes hydrant [0.5 m]
12. FF1 shuts off hydrant [0.25 m]
13. FF1 dresses all hydrant ports with gates, wyes, siameses, caps [0.5 m]
14. FF1 ataches hoses to the gates, wyes, siameses [1.0 m]
15. FF2 connects supply lines to intake valves on engine [t(l) m]
16. FF1 completely opens the hydrant [0.25 m]
17. FF2 opens outlet and inlet valves [0.25 m]
18. FF1 returns to 1st engine [t(ulh) m]

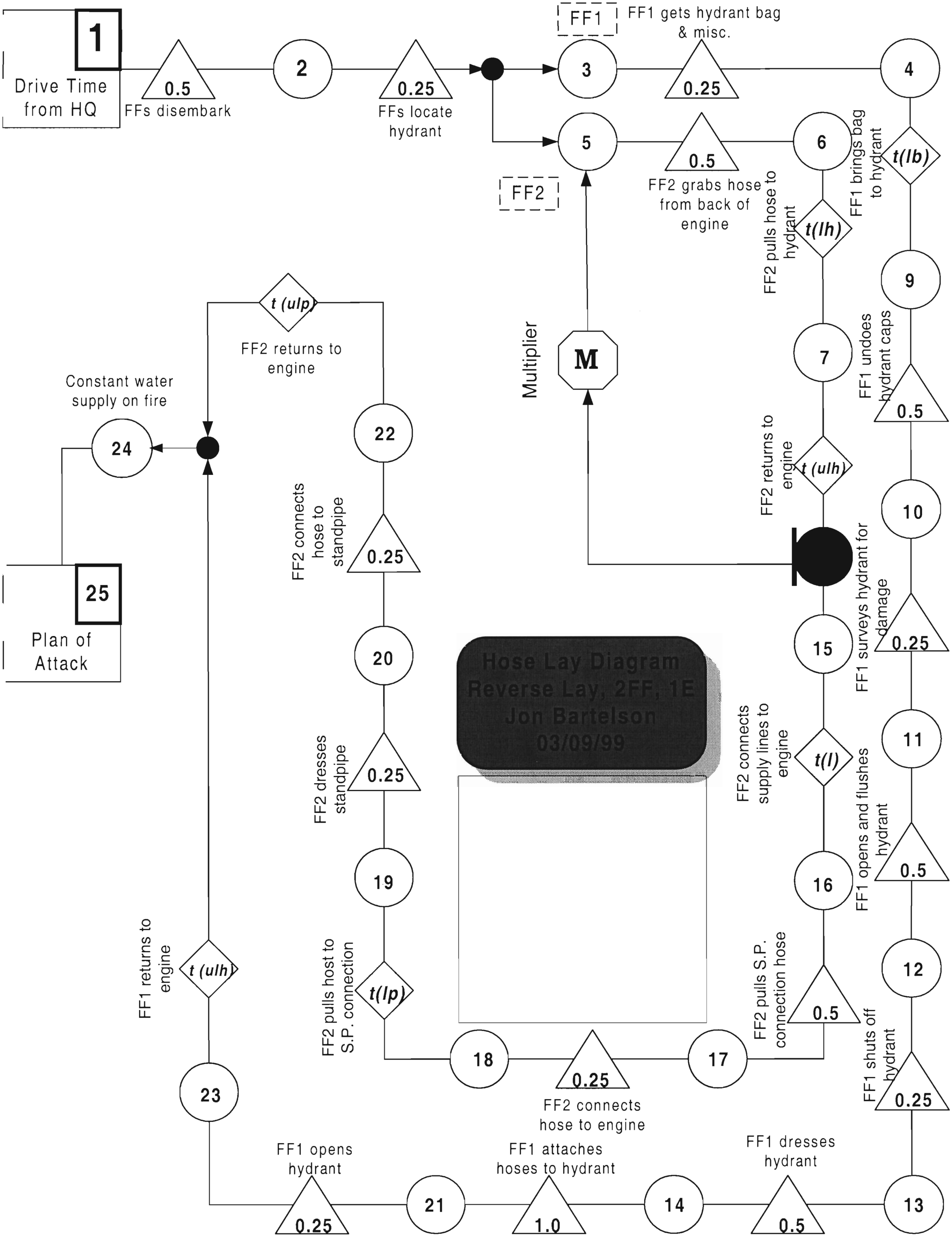
2nd Engine
1. FFA disembarks and proceeds to back of 2nd engine [0.5 m]
2. FFA grabs hose from back of 2nd engine [0.5 m]
3. FFA pulls hose until he reaches the 1st engine [t(ee) m] x
{note: hose size = 2,2.5,3,4,5,6 inches?}
4. FFA connects hose to outlet valves on 1st engine [0.25 m]
5. FFA returns to 2nd engine [t(eeu) m]
6. FFA attaches hose to intake valves [0.25 m]
7. FFA proceeds to the back of the engine [0.25 m]

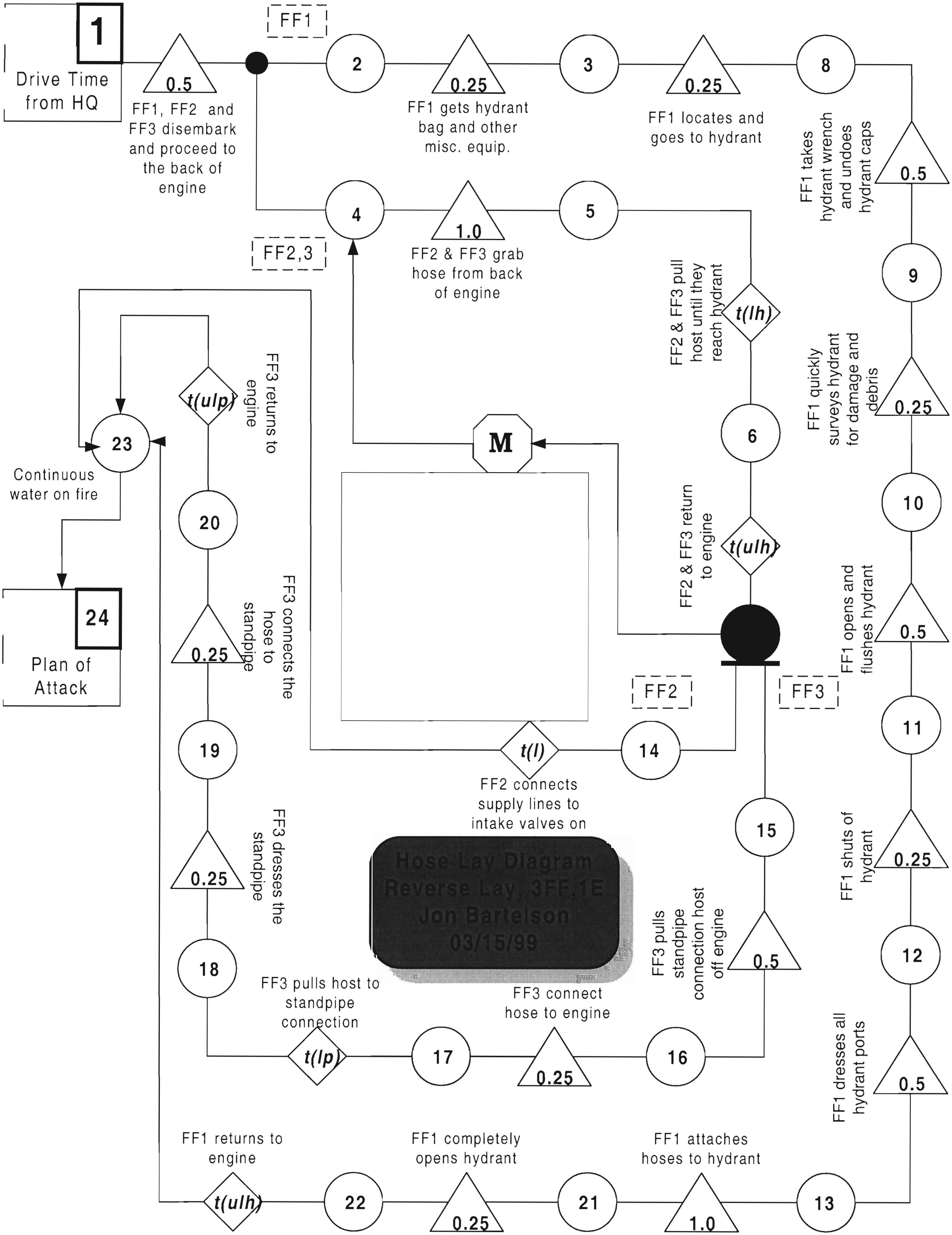
8. FFA pulls standpipe connection hose off engine [0.5 m]
9. FFA connects hose to engine [0.25 m]
10. FFA pulls hose to standpipe connection [t(lp) m]
11. FFA dresses the standpipe [0.25 m]
12. FFA connects hose to standpipe [0.25 m]
13. FFA returns to engine [t(ulp) m]
14. FFA opens outlet and inlet valves [0.5 m]
15. Continuous water arrives on fire [total]

4FF,2E
1st Engine
1. FF1, FF2, FF3 disembark and proceed to the back of engine [0.5 m]
2. FF1,FF2, FF3 locate the nearest stationary object [0.25 m]
3. FF1 gets hydrant bag and other misc. equipment [0.25 m]
4. FF2 & FF3 grab hose from the back of engine [1.0 m]
5. FF2 & FF3 pull hose until they reach the stationary object [2 * t(lh) m]
x {note: hose size = 2,2.5,3,4,5,6 inches?}
6. FF2 & FF3 return to engine [t(ulh) m]
7. FF2 & FF3 repeat stps 4-6 for each add'l supply line [multiplier]
8. FF1 takes hydrant wrench and undoes hydrant caps [0.5 m]
9. FF1 quickly surveys hydrant for damage and any debris inside [0.25m]
10. FF1 opens hydrant and flushes hydrant [0.5 m]
11. FF1 shuts off hydrant [0.25 m]
12. FF1 dresses all hydrant ports with gates, wyes, siameses, caps [0.5 m]
13. FF1 ataches hoses to the gates, wyes, siameses [1.0 m]
14. FF2 connects supply lines to intake valves on engine [t(l) m]
15. FF1 completely opens the hydrant [0.25 m]
16. FF2 opens outlet and inlet valves [0.25 m]
17. FF1 returns to 1st engine [t(ulh) m]

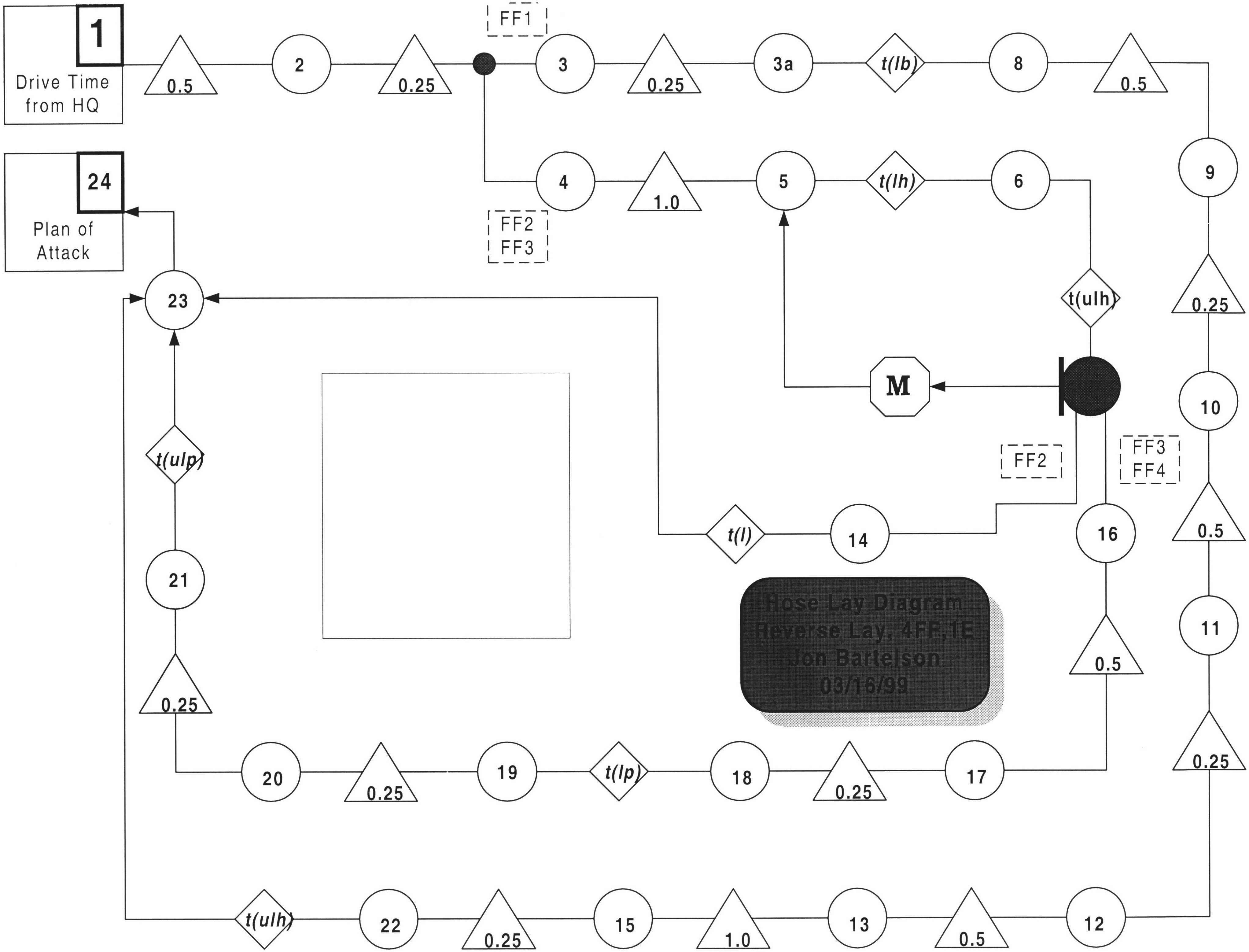
2nd Engine
1. FFA disembarks and proceeds to back of 2nd engine [0.5 m]
2. FFA grabs hose from back of 2nd engine [0.5 m]
3. FFA pulls hose until he reaches the 1st engine [t(ee) m] x
{note: hose size = 2,2.5,3,4,5,6 inches?}
4. FFA connects hose to outlet valves on 1st engine [0.25 m]
5. FFA returns to 2nd engine [t(eeu) m]
6. FFA attaches hose to intake valves [0.25 m]
7. FF3 pulls standpipe connection hose off 2nd engine [0.5 m]
8. FF3 connects hose to 2nd engine [0.25 m]
9. FF3 pulls hose to standpipe connection [t(lp) m]
10. FF3 dresses the standpipe [0.25 m]
11. FF3 connects the hose to standpipe [0.25 m]
12. FFA opens outlet and inlet valves [0.5 m]
13. FF3 returns to 1st engine [t(ulp) m]
14. Continuous water arrives on fire [total]

Successor: Plan of attack methods

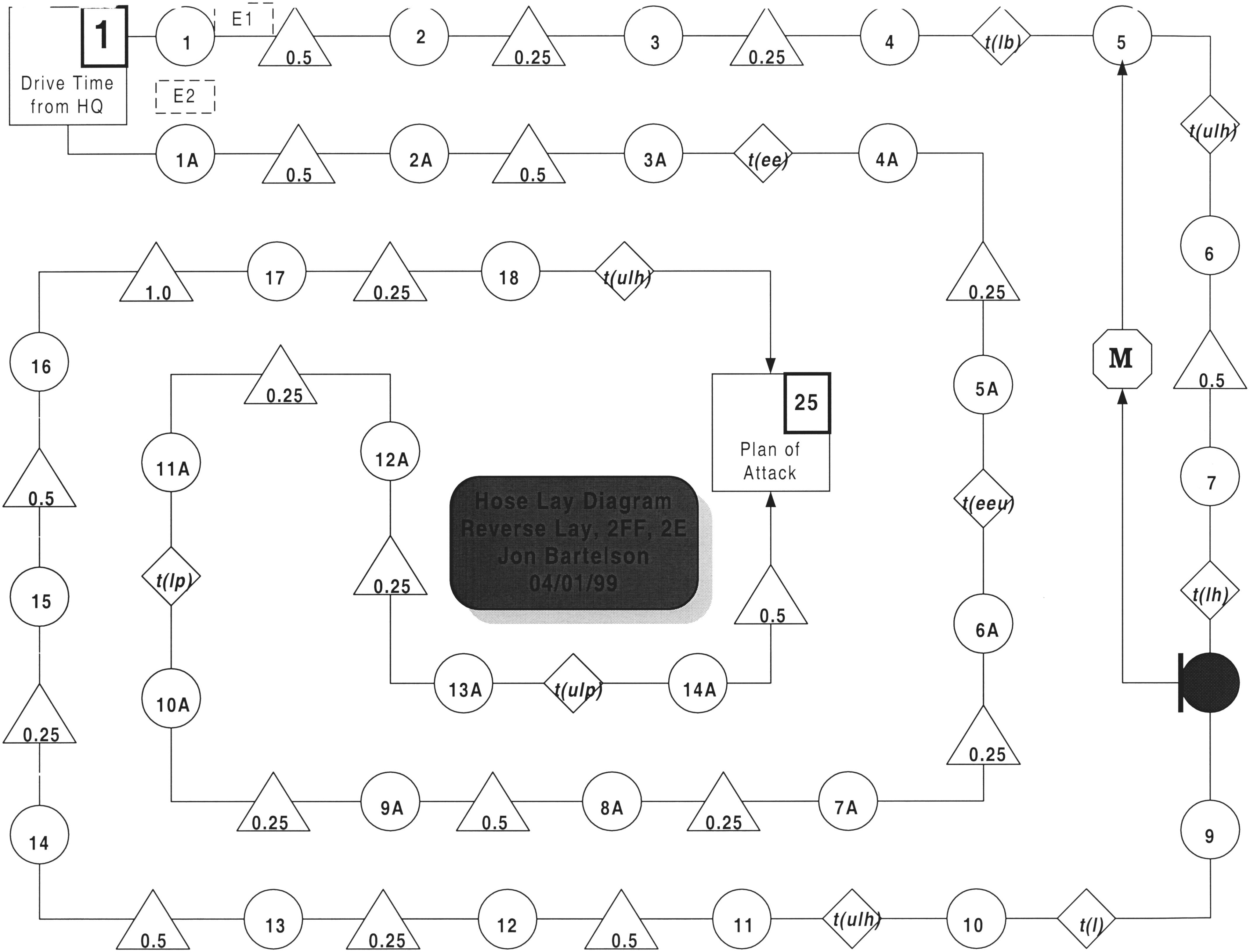

Hose Lay Diagram
Reverse Lay, 2FF, 1E
Jon Bartelson
03/09/99
1
Drive Time from HQ
0.5
FFs disembark
2
0.25
FFs locate hydrant
FF1
FF1 gets hydrant bag & misc.
3
0.25
4
5
0.5
6
FF2
FF2 grabs hose from back of engine
t(lb)
FF1 brings bag to hydrant
t(lh)
FF2 pulls hose to hydrant
9
Multiplier
M
7
FF1 undoes hydrant caps
0.5
t (ulh)
FF2 returns to engine
10
0.25
FF1 surveys hydrant for damage
15
11
t(l)
FF2 connects supply lines to engine
0.5
FF1 opens and flushes hydrant
16
12
0.5
FF2 pulls S.P. connection hose
0.25
FF1 shuts off hydrant
17
0.25
FF2 connects hose to engine
18
t(lp)
FF2 pulls host to S.P. connection
19
0.25
FF2 dresses standpipe
20
0.25
FF2 connects hose to standpipe
22
t (ulp)
FF2 returns to engine
Constant water supply on fire
24
25
Plan of Attack
t (ulh)
FF1 returns to engine
23
FF1 opens hydrant
0.25
21
FF1 attaches hoses to hydrant
1.0
14
FF1 dresses hydrant
0.5
13



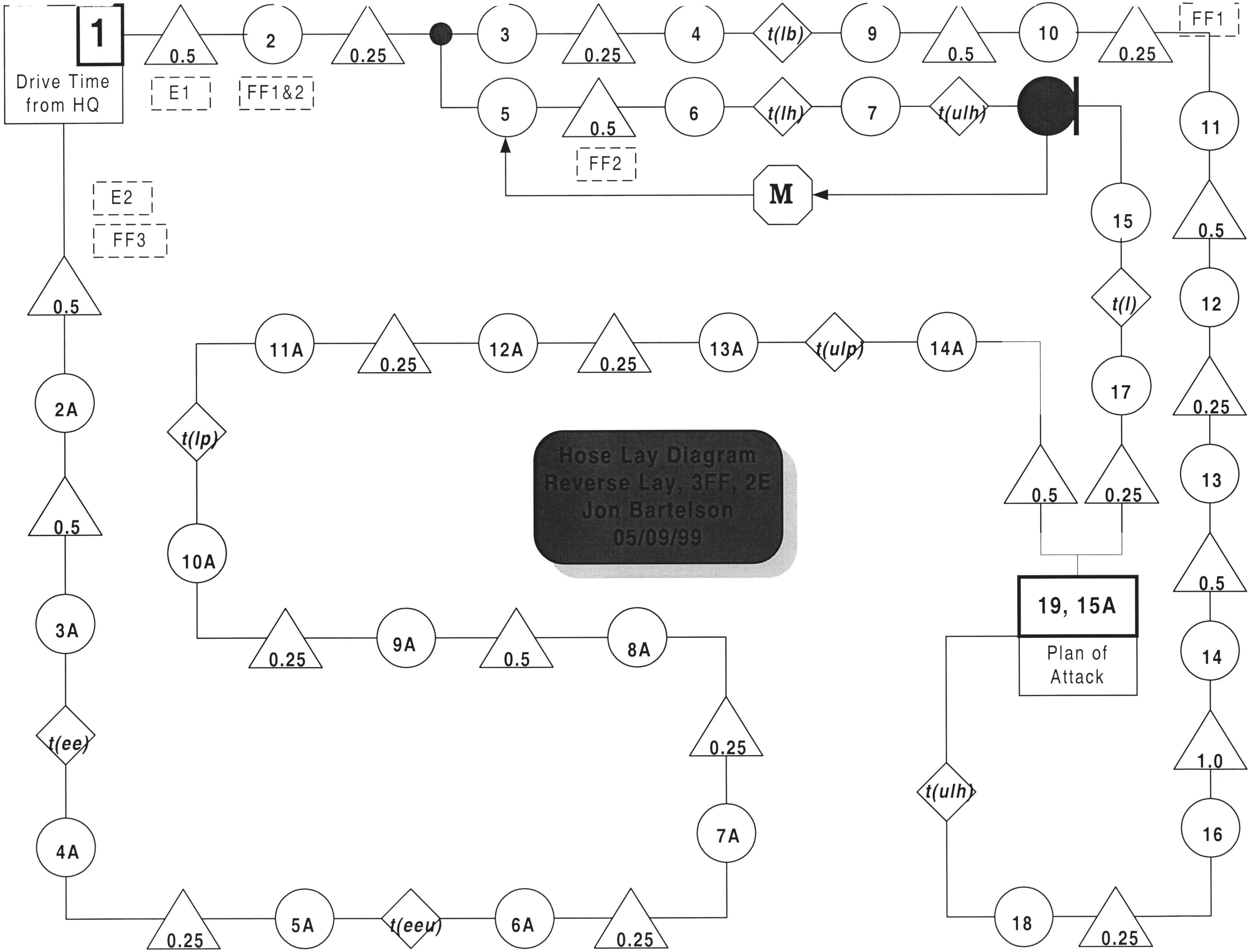
1
Drive Time from HQ
0.5
FF1, FF2 and FF3 disembark and proceed to the back of engine
FF1
2
0.25
FF1 gets hydrant bag and other misc. equip.
3
0.25
FF1 locates and goes to hydrant
8
0.5
FF1 takes hydrant wrench and undoes hydrant caps
9
0.25
FF1 quickly surveys hydrant for damage and debris
10
0.5
FF1 opens and flushes hydrant
11
0.25
FF1 shuts of hydrant
12
0.5
FF1 dresses all hydrant ports
13
1.0
FF1 attaches hoses to hydrant
21
0.25
FF1 completely opens hydrant
22
t(ulh)
FF1 returns to engine
4
FF2,3
1.0
FF2 & FF3 grab hose from back of engine
5
t(lh)
FF2 & FF3 pull host until they reach hydrant
6
t(ulh)
FF2 & FF3 return to engine
M
FF2
FF3
14
t(l)
FF2 connects supply lines to intake valves on
15
0.5
FF3 pulls standpipe connection host off engine
16
0.25
FF3 connect hose to engine
17
t(lp)
FF3 pulls host to standpipe connection
18
0.25
FF3 dresses the standpipe
19
0.25
FF3 connects the hose to standpipe
20
t(ulp)
FF3 returns to engine
23
Continuous water on fire
24
Plan of Attack
[redacted]



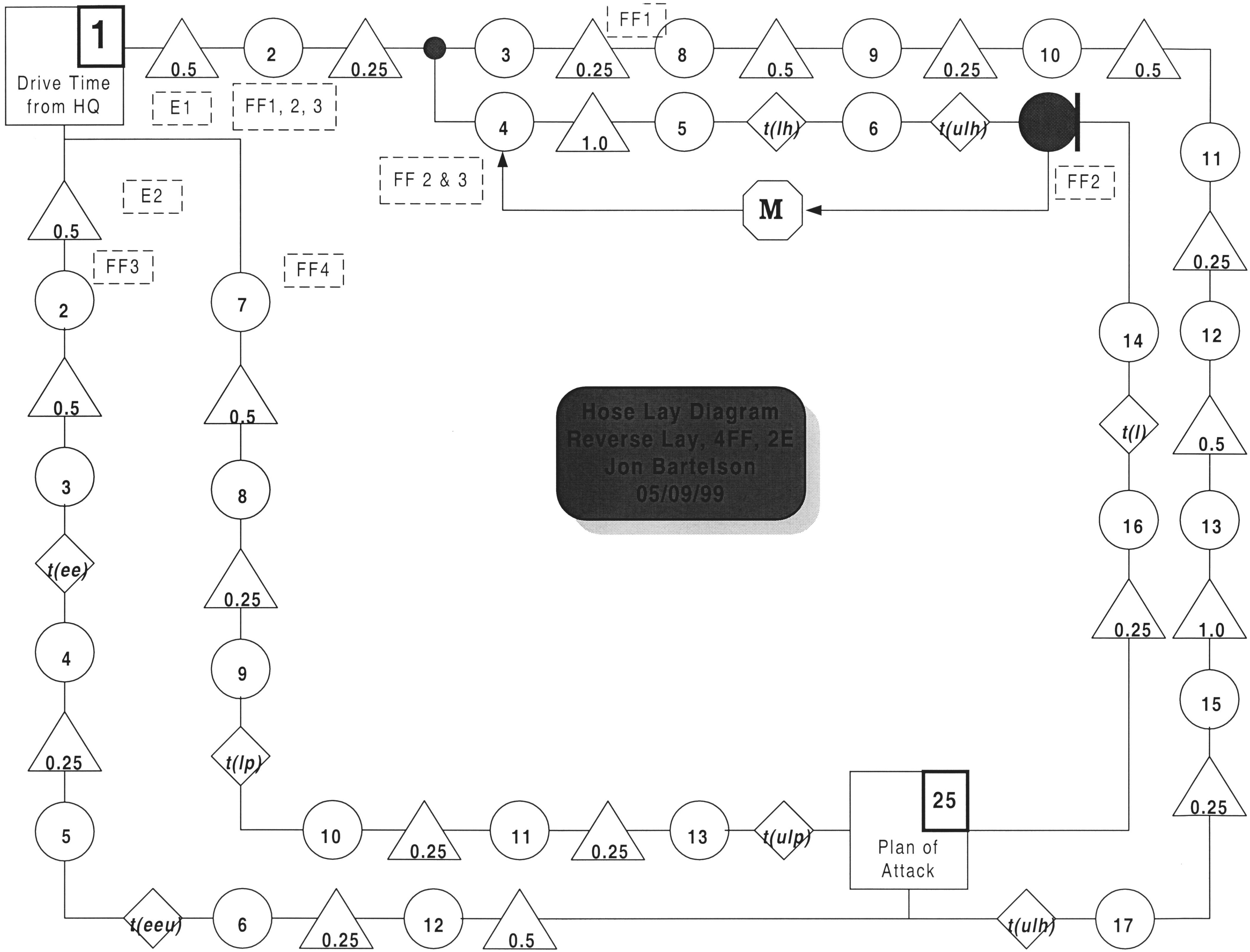
1
Drive Time from HQ
24
Plan of Attack
FF1
FF2
FF3
FF2
FF3
FF4
2
3
3a
4
5
6
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
0.5
0.25
0.25
1.0
0.5
0.25
0.5
0.25
0.5
0.5
1.0
0.25
0.25
0.25
0.25
t(lb)
t(lh)
t(ulh)
t(l)
t(lp)
t(ulp)
t(ulh)
M
Hose Lay Diagram
Reverse Lay, 4FF,1E
Jon Bartelson
03/16/99



1
Drive Time from HQ
E1
E2
1
0.5
2
0.25
3
0.25
4
t(lb)
5
t(ulh)
6
0.5
7
t(lh)
9
t(l)
10
t(ulh)
11
0.5
12
0.25
13
0.5
14
0.25
15
0.5
16
1.0
17
0.25
18
t(ulh)
1A
0.5
2A
0.5
3A
t(ee)
4A
0.25
5A
t(eeu)
6A
0.25
7A
0.25
8A
0.5
9A
0.25
10A
t(lp)
11A
0.25
12A
0.25
13A
t(ulp)
14A
0.5
25
Plan of Attack
M
Hose Lay Diagram
Reverse Lay, 2FF, 2E
Jon Bartelson
04/01/99



Hose Lay Diagram
Reverse Lay, 3FF, 2E
Jon Bartelson
05/09/99
1
Drive Time from HQ
E1
FF1&2
E2
FF3
FF2
FF1
M
19, 15A
Plan of Attack
2
3
4
5
6
7
9
10
11
12
13
14
15
16
17
18
2A
3A
4A
5A
6A
7A
8A
9A
10A
11A
12A
13A
14A
t(lb)
t(lh)
t(ulh)
t(l)
t(ulp)
t(lp)
t(ee)
t(eeu)
0.5
0.25
1.0



Hose Lay Diagram
Reverse Lay, 4FF, 2E
Jon Bartelson
05/09/99
1
Drive Time from HQ
25
Plan of Attack
E1
E2
FF1
FF1, 2, 3
FF 2 & 3
FF2
FF3
FF4
M
t(lh)
t(ulh)
t(l)
t(ee)
t(eeu)
t(lp)
t(ulp)
0.5
0.25
1.0

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