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Water Supplies for Residential Fire Fighting

AUSTRALASIAN FIRE AUTHORITIES COUNCIL

An Interactive Qualifying Project Report

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by

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Abstract

The purpose of this project was to present the Australasian Fire Authorities Council with a position for determining required water supplies for fire fighting purposes. Background research into United States fire codes and standards as well as interviews with Australian authorities helped to establish this position. The final result of the project was the determination of the minimum fire flow-requirements for residential developments.

Executive Summary

Recently in Victoria, there has been a major transformation in the methods by which water is distributed throughout the state. The governing agencies have moved from a primarily municipal system to a network of privatised organisations. Each private water authority is responsible for supplying water to a different area of Victoria.

Since the water suppliers have become privatised, their primary objective has become financial gain. For this reason, they are becoming more concerned with the quality of the domestic water, as opposed to the overall volume supplied to the system. Reducing the size of the pipes would theoretically increase the quality of domestic water by reducing stagnation. Concern has arisen regarding the intentions to reduce pipe sizes, as it may have an adverse effect on the long-term availability of water for fire fighting purposes.

The Water Services Association of Australia (WSAA) has recently published a proposed code of practice dealing with water infrastructure design. Current practice dictates that water infrastructures must be sufficient to supply the peak demand for domestic use once in a twenty-year period. The amount of water that is required for fire fighting is not taken into account anywhere in the code.

In the Literature Review section of the report, the background information conducted by the team on the topic of water supplies for fire protection was discussed. The majority of this information was obtained during the preliminary qualifying project at WPI. This included a review of U.S. Codes and Standards relating to distribution system design and required fire fighting water determination. Interviews with fire officials were also an integral aspect of familiarising the team with the fire protection industry. Once in Australia, the teams' first objective was to review reports that could be used to formulate a model to determine water supplies needed for fire fighting. The first report that was reviewed was the WSAA proposed code of practice. This code proposes a guideline for water infrastructure design standards to be imposed in Victoria. Another report studied was the MFESB Fire Water Requirements Project (MFESB, 2001). This report determined the minimum flow and pressure that are required to effectively operate different pieces of fire fighting apparatus.

The methodology section of the report identifies the methods used to gather information utilised in the formation of the model. This section was broken down into two distinct sub-sections, interviews and database research. Interviews were performed with both water design engineers of the water authorities, and fire officials at the Metropolitan Fire Brigade (MFB) and the Country Fire Authority (CFA). From the design engineers, specific information regarding current infrastructure design was obtained. Interviews with fire officials provided the team with information on standard operating procedures utilised by the two brigades upon arrival at a fire scene. Gathering data from the Australian Incident Reporting System (AIRS) database was also an important aspect of the methodology. By conducting searches for specific fields, statistics on the number of residential fires and the combinations of hoses used at each incident were obtained.

The results section of this report is the compilation of the data obtained from the literature review and methodology. This section includes a summary of the current design practices employed by the water authorities, the information gained on standard operating procedures of the fire brigades, and all of the data obtained from the AIRS database. Current design practices of the water authorities show that water infrastructures in residential developments are designed to accommodate a peak hourly demand of domestic water usage. The design does not account for water used for fire protection but rather assumes that there is enough water for the fire service. The standard operating procedures are the typical actions carried out by the fire brigades in the event of a fire, they were found to be similar between the MFB and the CFA. The standard operating procedures include the size hoses used and the procedures followed on the scene of a fire. Both brigades use 38 mm and 65 mm canvas hose lines. The MFB also uses rubber 25 mm high pressure hose reels in addition to the standard canvas lines. When the brigade arrives at the scene of a fire, a specific order of events is followed. These steps are outlined by the acronym RECEF. This stands for Rescue, Exposure, Containment, Extinguishment, and Fire Duty. Reports that were studied included the MFESB Water Requirements Project and the Fire Brigade Intervention Model. In addition to these reports, the Australian Incident Reporting System (AIRS) database also proved to be an extremely useful resource. A search of the database provided the team with information on the number of hoses utilised at residential fires in the years 1998, 1999 and 2000. The data also included the different hose combinations utilised at different fire situations along with information regarding to the confinement of the fires at time of intervention. The different water requirements for each hose combination were then determined from the MFESB Fire Water Requirements Project (MFESB, 2001).

The amount of fire water required by the fire service for a residential fire was then analysed using the standard operating procedures of the brigades, the data collected from the AIRS database and the MFESB Fire Water Requirements Project. It was determined that currently, the design practices of the water authorities provide a sufficient supply for fire protection. The water authorities currently design to a minimum flow of 30 l/s, as calculated from the minimum specifications set forth by the WSAA code. From the MFB data, 19.4 l/s was enough water to extinguish 100% of the fires in 1998,1999 and 2000. From these findings, it was determined that there is currently a sufficient amount of water for fire protection in residential areas.

It must be noted that this project examined only residential areas. In any area where there is a possibility for a combination of residential and industrial or commercial buildings, this study would need would need to be revised.

It has also been determined from the data that home fire sprinklers increase the percentage of fires that a certain flow will be sufficient to extinguish. This conclusion was based on limited information, however, and further studies in the area have been recommended.

This project revealed several areas of study that could be improved within the fire protection industry. The most important is the collection of Australian data on home fire sprinkler systems. A possible area for future work on the topic is also discussed. This work focuses on fire modelling, however, which was outside the scope of this Interactive Qualifying Project.

Authorship

For this report all team members, Taylor Jenkins, Justin Schmeer and Matthew Siska, have agreed that all work was divided evenly between them.

Taylor Jenkins was responsible for the majority of the set up and conduction of interviews with the water authorities and fire officials. He was also responsible for summarising the interviews after completion. Taylor was also the main contributor to the recommendations and conclusions sections of the final report.

Justin Schmeer was responsible for the majority of research conducted at the Metropolitan Fire Brigade. He was also responsible for analysing this data and was the primary author of the analysis section of the final report. After the necessary data were obtained from the interviews and research, Justin was responsible for reconstructing the data into more useable formats.

Matthew Siska was the main contributor to the results and methodology sections of the final report. He also contributed to the literature review and analysis sections. Matthew also participated in the majority of the interviews, as well as obtaining any follow-up information from the interviewees.

It must be noted that all team members have completed any sections not specifically mentioned above in a combined effort. Typically, when one team member was finished working on a section the other team members would edit and correct that section. By using this method, each team member had input on every section.

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1.0 Introduction

The purpose of this project was to develop an Australasian Fire Authorities Council (AFAC) position for water supply management. The specific goal of this project was to present the AFAC with a position for required fire fighting water supplies for the construction of new Greenfield sites.

Recently the water supply authorities in Australia have changed from an organisation based on municipal service to privately owned organisations. Local, state and federal authorities have pressured these organisations with commercial and social responsibilities. This pressure has resulted in new performance requirements. These requirements include a higher quality drinking water, reduced water usage and lower costs for design and installation for water supply systems. These alterations have raised concern with the Australasian Fire Authorities Council (AFAC), as well as other organisations, regarding the amount of water that will be available for fire fighting purposes in the future.

The Australasian Fire Authorities Council (AFAC), formerly the Australian Fire Authorities Council, was established on July 1, 1993. Their goal was, and remains, to provide better collaboration between the Australian fire and emergency services and land management agencies, particularly in the exchange of strategic information and the development of national positions. Many challenges have presented themselves to the AFAC since its conception. One such challenge is that of water supply systems for the purpose of fire protection. Since there were currently no specific design methods for determining fire water requirements, the AFAC had no basis for restricting the water authorities from reducing the amount of water they provide.

There are several key points that were addressed in this project. The first issue is the current design practices of the water authorities. The second issue addressed dealt with the fire authorities, specifically the standard operating procedures followed at the scene of a fire. This project included but was not limited to these issues. A project dealing with water supplies available for residential fire fighting is in the interest of many people. An inadequate water supply is a risk that applies to all homeowners. The excessive use of water, however, is a concern to the water supply authority and the new requirements that have been set forth.

To conclude, this project will set forth standards for necessary water supplies for fire protection in Greenfield sites in Victoria and possibly throughout the country. It has the potential to be used as a guideline for future developments and other fire protection needs.

2.0 Literature Review

2.1 Introduction

The determination of a water supply for fire fighting must consider several key points. The codes that govern water supply and their applications in fire fighting are of great importance. United States codes and standards such as National Fire Protection Association (NFPA) standards and the Uniform Fire Code are of great importance in the determination of required water for fire protection. No similar codes exist in regards to residential areas in Australia, the design of water infrastructure systems is a self-regulated entity by individual water authorities. Guidelines have been proposed by the Water Services Association of Australia in its Water Reticulation Code in order to standardise the water infrastructure systems.

Reports were also examined to help determine the needs of the fire brigade. The Metropolitan Fire and Emergency Services Board conducted a study to determine the amount of fire water needed to effectively operate fire fighting equipment (MFESB, 2001). The Fire Brigade Intervention Model and the Scottsdale, Arizona home sprinkler studies were also examined in order to better understand the needs of the fire brigade.

2.2 Codes

2.2.1 Introduction

In the United States there are sets of guidelines and standards used in designing, updating, and maintaining fire protection, prevention, and suppression systems. The most frequently used set of guidelines and standards are developed and updated by the National Fire Protection Association (NFPA). The NFPA began the development of these standards when it was first founded in 1896. Technical committees, consisting of individuals from different areas of professional expertise, oversee the maintenance of a particular standard. Four years after a standard is approved it is reviewed with one of three outcomes; it is revised, approved again or withdrawn. When the time arrives for a standard to be reviewed, the technical committee will receive proposals to change the text of the document. The technical committee will vote on these proposals, and publish the document as a draft proposal. The draft proposal is submitted to public comment. The technical committee then reviews the comments and either creates another draft proposal or submits the standard for approval (NIST, 2001). As knowledge in the fire protection industry grows, the standards continue to evolve into more precise and useful tools to be used in fire prevention. These standards are simply a recommended practice for fire protection and fire prevention. However the governing authority (national, state or local) can adopt these standards into law at which point they become codes and are no longer recommended but required. Many of the standards of the NFPA are also included in the United States National Fire Code.

The Uniform Fire Code (UFC) is another frequently used set of standards. The UFC is published by the International Fire Code Institute (IFCI), and endorsed by the Western Fire Chiefs Association, the International Association of Fire Chiefs, and the International Conference of Building Officials. The IFCI is an organisation that allows all groups and individuals interested in fire safety and prevention to contribute to code development and keep up to date on current issues. Like the NFPA standards, this set of codes contains several requirements pertaining to the fire safety of new and existing buildings and premises. Topics discussed in this code include fire hydrants, automatic sprinkler systems, fire alarm systems, and fire department access.

NFPA standards 1231 (recently renumbered as NFPA 1142) 14, and 1141, and Uniform Fire Code sections 903.3, and 903.4.2 directly relate to hydrant specifications and requirements. There are many codes in the United States regarding the water requirements for residential areas. Australian standards can vary greatly from those of the United States, especially in regards to residential fire fighting.

2.2.2 Fire Flow

The first step in designing a new domestic fire fighting water supply is determining the minimum amount of water that must be supplied to the system. There are various ways that this supply value can be calculated. The Uniform Fire Code (UFC) refers to the rate of a water supply, measured at 140 kPa (20 psi) residual pressure, which is available for fire fighting, as the fire flow (UFC, 1997). Section 5-1.1 of NFPA 1231 (1993) and section 3 of UFC (1997) elaborate on how the fire flow can be increased or decreased depending on the needs and practicality of a particular development. In both of these sections the final decision is left up to the authority having jurisdiction.

2.2.3 NFPA Minimum Water Supply Model

Some ways of determining minimum water supply for structures first take into account the volume of the entire structure. NFPA 1231 (1993) states that the area used to determine the volume of a building is called the fire area. The fire area is the total floor area of all floor levels within the exterior walls and under the horizontal projections of the roof of a building. This is calculated by multiplying the length by the width and then that value is multiplied by the sum of the heights of each floor.

An Exposure Hazard is defined as "structure within 15 m (50 ft) of another building and 9.3 m^2 (100 ft^2) or larger in size" by NFPA 1142 (1999, p4). For a structure without an Exposure Hazard, finding the minimum water supply is simple.

To find the minimum water supply, the volume of the structure is divided by the dimensionless Occupancy Hazard Classification Number (OHCN). This number is "A series of numbers from 1 through 7 that are mathematical factors used in a formula to determine total water supply requirements" (NFPA 1142, 1999, p5). This number is determined based on the estimated occupancy hazard. For example, a one family home would be classified as a Light Hazard Occupancy and a value of 7 would be assigned to it, whereas a distillery would be classified as a Severe Hazard Occupancy, and assigned a value of 1. The higher the OHCN value a building is assigned, the less water is required to extinguish the fire.

This value is then multiplied by the Construction Classification Number (CCN); The NFPA classifies all buildings by their construction type on a scale of I-V and then assigns a Construction Classification Number ranging from 0.5 to 1.5 (NFPA 1231, 1993). Section 4-2 of NFPA 1231 (1993) explains the differences that determine the construction rating a structure will receive. For instance, a structure constructed of non-combustible materials such as brick would be classified as a Type 1 (Fire Resistive) Construction. This brings a Construction Classification Number of 0.5, whereas a building constructed mainly of wood would be considered a Type V (Wood Frame) Construction, and would entail a Construction Classification Number of 1.5. This means that a structure receiving a higher rating requires more of a water supply. The final value obtained is the minimum water supply needed for the structure. For a structure with an Exposure Hazard, the minimum water supply is determined by multiplying the value for a building without an Exposure Hazard by 1.5. This new value is the required minimum water supply for a structure with an Exposure Hazard. This value is a volume of water. The resulting equations are:

$$MinimumWaterSupply = \frac{TotalVolume}{OHCN} \times CCN$$

Equation 1: Minimum Water Supply without an Exposure Hazard

$$MinimumWaterSupply = \frac{TotalVolume}{OHCN} \times CCN \times 1.5$$

Equation 2: Minimum Water Supply with an Exposure Hazard

2.2.4 Uniform Fire Code Minimum Fire Flow

The Uniform Fire Code presents a table called the Minimum Required Fire Flow and Flow Duration for Buildings (UFC, 1997), provided in appendix B. This table is similar to that presented in NFPA 1142 (1999). The criteria that are used to determine the fire flow requirements in this UFC table are the fire rating, which is determined by the materials used in the construction, and the fire area. By using the two values on this table, the required fire flow that needs to be applied and the duration of time that the flow needs to be sustained can be found. This UFC table is similar to the NFPA equation, however they are difficult to compare directly as the UFC model examines the fire area and the NFPA model examines structure volume.

2.2.5 Sprinkler Systems

The Uniform Fire Code includes reductions in required fire flow when a fixed fire protection system is installed in a structure. One of these fixed protection systems is a home sprinkler system. This system is installed in a building to aid in the automatic suppression of fires. When a fire activates these devices, water is applied to the fire. Since the sprinklers activate before the fire brigade is able to arrive at a fire, the system helps to stop small fires before they escalate. In doing so the amount of fire flow that would otherwise be required is reduced. The UFC (1997) allows the fire flow to be reduced in two cases. For one- and two-family dwellings, according to the UFC (1997), a reduction in required fire flow of 50 percent, as approved by the fire authority in charge, is allowed when the building is provided with an approved automatic sprinkler system. The UFC (1997) allows that in buildings other than one- and two-family dwellings, a reduction in required fire flow of up to 75 percent, as approved by the local fire authority, is allowed when the building is provided with an automatic sprinkler system.

2.2.6 Hydrant Specifications

Once the required fire flow has been decided upon, the water must be delivered to a location that is within reach of the fire. The most efficient way to do this is by using fire hydrant delivery systems. There are two major classes of hydrants, pressurised and drafting. Each of these two classes can be broken down into wet barrel and dry barrel hydrants. Wet barrel, pressurised hydrants are the only relevant class of hydrants for this project, however there is a discussion of drafting hydrants contained in Appendix A.

Since placing a fire hydrant in front of every building in a development would be unpractical and extremely costly, there are certain standards that are followed when deciding on a location. The NFPA has standards regarding the size, placement, colour markings, and pressure requirements for pressurised hydrants.

The most basic method of determining hydrant spacing is to use a table such as Table A-III-B-I of the UFC (1997), shown in appendix B. By examining the required fire flow for a building, one can determine how many hydrants will be needed to supply that building. This table also allows the user to determine what the average spacing between the hydrants should be, as well as the maximum distance from any point on the street to a hydrant. By following this procedure for every building in a development, the developer can determine the exact number and location of fire hydrants to be placed on the distribution system.

Hydrant spacing and fire flow are not the only criteria that must be observed when designing a hydrant system. It is also important that all the hydrants in a particular district are marked alike, and are visible to the fire department at all times. Because of these visibility stipulations, most fire hydrants are painted bright red or other easily seen colours (NFPA 1141, 1998). Another guideline that must be followed is the protection of fire hydrants. For instance, if there are fire hydrants located in a parking lot they must be protected by barriers so that they can not be damaged. Another hydrant specification is the threads that the hoses attach to. These threads must be all uniform so that any fire department can quickly connect to them, and if for some reason the thread is different, the hydrant must be equipped with thread adaptors (NFPA 1141, 1998).

2.2.6.1 Australian Standard 2419.1 – Fire Hydrant Installations

This Standard is a guide that sets forth the requirements for design, installation, and water requirements for fire hydrants mainly in commercial areas. According to the standard, the hydrant system shall be a wet pipe system having its supply valve open and water pressure maintained at all times. In most situations, plans and specifications of the proposed hydrant system must be submitted for approval by the authority having jurisdiction before any construction can begin (AS 2419.1, 1994).

There are also provisions to where external hydrants may be placed. Firstly, these hydrants must be located so that they are accessible to fire brigade personnel. Secondly they may not be closer than 10 m (33 ft) from the wall of any building unless the regulatory authority deems it necessary. This provision is in place for two reasons, to protect the fire fighters from radiant heat as well as to protect them from building collapse. The third provision in placing fire hydrants is that parking, or loading and unloading of vehicles must not obstruct them. All hydrant outlets must have hose connections not less than 65 mm (2.5 in.) nominal diameter and shall comply with local fire authority requirements (AS 2419.1, 1994).

Fire mains must also comply with certain Australian Standard guidelines. Mains must be of a nominal size of 100 mm (4.0 in.) with certain exceptions. The nominal size must be 150 mm (6.0 in.) if the effective height of the building exceeds 25 m (82 ft.), and must be 80 mm (3.2 in.) anywhere a branch main connects a single hydrant outlet to a main (AS 2419.1, 1994). Fire mains must also meet certain reliability requirements. "Not less than 50% of hydrants in any one fire compartment remain operable at design pressure and flow at all times. Not less than 75% of all hydrants in a building remain operable at design pressure and flow at all times" (AS 2419.1, 1994, p15).

2.2.6.1.1 Required System Performance

Required pressure to an operating hydrant also must follow a set of guidelines. "Water supply to a fire hydrant installation shall be capable of maintaining sufficient residual pressure, measured at the hydrant outlet, when flowing at 10 l/s (160 GPM), whilst the required number of hydrants are simultaneously operating to overcome the pressure losses of the equipment likely to be connected by the local fire authority" (AS 2419.1, 1994, p18). If the required pressure cannot be met, then either a pump or an elevated tank must be installed (AS 2419.1, 1994). The residual pressure in any case shall not be less than 200 kPa (29 psi) (AS 2419.1, 1996).

2.2.6.1.2 Comparison to U.S. Standards

These Australian standards are similar to U.S. standards in some respects however they do vary. The main sizes in the Australian standard are different from those of the U.S. In the United States 200 mm (8 in.) and 150 mm (6 in.) mains are the primary sizes used while in Australia the main sizes are 150 mm (6 in.) or 100 mm (4 in.). Another difference is that the Australian standard states that the residual pressure cannot drop below 200 kPa (29 psi) while the U.S. standard states that the residual pressure cannot drop below 140 kPa (20 psi). These values are comparable although not identical. The Australian standard provides for smaller main sizes at a higher residual pressure, the U.S. standard provides for larger mains at lower residual pressures. With the changes in pipe size and the corresponding pressure change between the two standards, if the same volume of water is provided to both systems the flows are kept roughly the same.

2.2.7 Insurance Services Office, Inc. (ISO)

In the United States the Insurance Services Office, Inc (ISO) systematically evaluates the fire fighting capabilities of a town or city based on criteria relating to the local fire brigade and the town water supplier. The ISO then supplies statistical and underwriting information for the property/casualty insurance industry with this evaluation.

The ISO has a rating system, called the Fire Suppression Rating Schedule, which evaluates fire departments on a scale of 10 to 1. The Fire Suppression Rating Schedule is used to conduct the evaluation by grading the different criteria pertaining to the individual fire department. The fire department being evaluated is graded on three major criteria. The first criterion is receiving and handling. This criterion examines the methods and the efficiency with which the department handles incoming calls as well as how effectively crews are dispatched to the fire. This feature accounts for 10% of the total department grade given by the ISO. The next criterion is the fire department itself. The ISO grades the overall department on various criteria including manpower, response time, flow capacity, and equipment quality. This criterion accounts for 50% of the total grade. The remaining 40% of the grade is determined by the water supply that is available for fire protection. If there is a greater volume of water than specified by the minimum NFPA water supply guidelines and a good method of handling and distributing the water, a higher grade will be awarded. When all of these criteria have been evaluated, the ISO presents the department with a rating. This rating ranges from 10-1, with 10 being the lowest and 1 being the highest. Once the rating has been presented, it is used by insurance agencies in determining the insurance rates for the town or city that was evaluated. Towns contact the ISO service if they feel they need to be re-evaluated. A re-evaluation can be either a benefit or a cost depending on the situation of the fire department in question. Usually a department will request a re-evaluation after they have upgraded a part of the department. This allows the town or city to achieve a better overall grading and in doing so lower the insurance costs for the town (ISO, 1980).

2.2.8 Water Reticulation Code of Australia

2.2.8.1 General

The proposed Water Reticulation Code of Australia is a draft document. There has been no precedent in the area of design of water reticulation systems in Australia. This code "covers the planning, design, and construction of reticulation mains and service pipes up to and including DN 375" (WSA 03-1999, p5). DN375 is a nominal diameter of 375 mm (15 in.). This means that this code applies to all mains up to a nominal diameter of 375 mm (15 in.); any mains that are larger than 375 mm (15 in.) in nominal diameter would not be included in this code. The specific aims of this code are to improve the overall quality of the water, reduce costs in the planning, design and construction of the infrastructure, and improve the efficiency and incorporation of new technology into the infrastructure. The proposed code also hopes to provide better collaboration between the water agencies and the suppliers. These benefits will hopefully be the result of this single technical document (WSA 03-1999).

When designing a water supply system, certain primary objectives must be considered. These considerations include the water agency's policies, the hydraulic adequacy, the ability of the system to maintain acceptable water quality, the structural strength, Occupational Health and Safety (OH&S) requirements, environmental requirements, environmental and community impacts, the "fit for purpose" service life of the system, minimising the "whole of life" cost, and the consideration of each component's resistance to internal and external corrosion or degradation (WSA 03-1999, p24). Other considerations will include material used as well as future system expansion (WSA 03-1999).

The first step to be taken when designing a water distribution system is to survey existing supplies. This will include gaining information from the water authority regarding acceptable connection points, as well as available flow, pressure, the minimum and maximum allowable operating pressures, and special requirements for fire fighting purposes (WSA 03-1999). The developer must ensure that sizes and materials of the pipes are correct, and that all details of the system such as valves and hydrants are labelled and in acceptable positions. The developer must further ensure that pressures and flows are within the acceptable range and provide detailed plans showing the layout and route of the mains and alignments (WSA 03-1999).

2.2.8.2 Main Sizing, Pressure and Flow Requirements

When determining the size of a main, the required flows at peak demands are considered. Specifically, "Mains shall be the minimum size necessary to ensure that residual pressures due to peak demands are not less than the minimum specified by the water agency." (WSA 03-1999, p35) Most Water Agencies have standardised the minimum pipe diameters to be DN100 for residential areas and DN150 for industrial and commercial zones (WSA 03-1999). These minimum diameters have been established to provide adequate flow rates and pressures for residential use, which includes sinks, showers and toilets (WSA 03-1999). Smaller mains may be considered in branches or dead ends where the water may have a tendency to stagnate. The design pressure is another part of the system that must also be considered. The maximum design pressure may be determined using the following equation (WSA 03-1999):

$$DP = MSP + SA - LGLPM$$

Equation 3: Equation for Maximum Design Pressure

Where:

DP = Design Pressure, m

MSP = Maximum Supply Pressure, m

SA = Surge Allowance, m

LGLPM = Lowest Ground Level of Proposed Main, m

The surge allowance will be the pressure associated with a pumped main. This maximum design pressure will be used to determine the selection of pipe materials and classes, pipe fittings and classes, and design of thrust and anchor blocks (WSA 03-1999).

The minimum design pressure will be based on the minimum residual pressure needed for a development and head losses due to the daily demands (WSA 03-1999). According to

Table 2.2 of the WSA code (1999), the maximum operating pressure for a residential area is 800 kPa (120 psi) or 80 m, while the corresponding minimum pressure is 200 kPa (29 psi) or 20 m. Industrial standards are very similar except that the minimum operating pressure for an Industrial application is 250 kPa (36 psi) or 25 m. Acceptable flow velocities within the main range from 0.5 to 2.0 m/s (0.15 to .61 ft/s). Stagnation is prevented through the limit of a minimum velocity. Turbulence and surges are prevented through the limit of a maximum velocity value. Flows outside this range will present problems to the network as a higher pressure will cause more maintenance costs and a lower pressure will not provide enough water.

Almost no consideration was also given to fire flow requirements. The Water Reticulation Code states, " Where the local planning authority identifies an abnormal potential demand for water for fire fighting purposes, the designer, with the agreement of the Water Agency, shall notify the relevant fire authority of the need to identify alternate emergency water supply sources" (WSA 03-1999, p37). The minimum sized main which can have a fire hydrant attached to it is 100 mm for a residential application (WSA 03-1999).

Generally, demand requirements can be based on consumption records for similar consumer groups in the region or on previous records for the group in question. Other criteria to be taken into account when determining the demand will be the time of year as well as the time of day, and the typical distribution of demand over a 24-hour period under peak conditions. The peak hourly demand rates for some metropolitan areas in Australia are listed in Table 6 of this document. The maximum daily demand is typically based on the estimated total usage over a 24-hour period, but can be modelled as an 8-12 hour period at the peak hourly demand (WSA 03-1999).

When the total height variance for a location of a development extends beyond the allowable operating range, or 50-60 m in elevation, the system must be divided into zones

(WSA 03-1999). Each zone may have its own reservoir tank and reticulation network. Pressure Reducing Valve zones (PRV zone) may also be applied to these areas in which the specific pressure delivered to an area may be monitored (WSA 03-1999).

2.2.8.3 Fire Hydrants

Hydrants may be used for either fire fighting or operational procedures. The hydrants may be used to supply the fire brigade with water in the event of a fire, and may also be used to flush out a system. Hydrants may sometimes be used for chlorination purposes and to allow the escape of trapped air (WSA 03-1999). Hydrants may only be installed on mains with a minimum of DN100.

There are three main types of hydrants. "Spring hydrants are attached directly to the main using a flanged hydrant riser. Spring hydrants are installed in a hydrant box and cover and use a standpipe incorporating a built-in push-rod system to operate the hydrant mushroom" (WSA 03-1999, p77). "Screw hydrants incorporate a screw down valve seat assembly within the hydrant which is operated by a standard valve key. The valve seat assembly may be integral within the hydrant body or may be provided using a separate control valve assembly, the flanged outlet to which a hydrant or hydrant outlet is bolted. The hydrants are attached directly to the main using a flanged hydrant riser. Screw hydrants are installed on buried pipelines in a hydrant box and cover and use a standpipe to direct the flow of water" (WSA 03-1999, p77). "Pillar hydrants extend above ground for easy access and are used typically in Central Business District (CBD) areas and in specific locations in rural areas. The type and style should be in accordance with Water Agency practice" (WSA 03-1999, p77).

Most standard spring hydrants operate with a DN80 flange size, but are also available in DN100. Screw hydrants are only available in flange size DN80 (WSA 03-1999). Hydrant spacing may be referred to in table 4 in Appendix C of this document. In Victoria the hydrant spacing given for residential areas is 200 m. In rural areas, however, "hydrants should be located at street intersections and opposite access ways to bush reserves and fire trails. Hydrants in bush fire prone areas and in areas where vegetation may obscure a below ground hydrant, shall be an above ground type to the requirements of the local Water Agency" (WSA 03-1999, p79). Hydrants should also be placed as close as possible to stop valves as to ease maintenance procedures, and at low points on the mains so as to facilitate drainage (WSA 03-1999). Hydrants should also be placed within 1.5m of the end of all permanent and temporary sections with DN less than or equal to 100 mm, this allows for ease of system flushing (WSA 03-1999).

2.3 Study Reviews

2.3.1 Fire Water Requirements Project

The Built Environment Policy Group of the Metropolitan Fire Emergency Services Board (MFESB) conducted a recent study that was meant to provide Fire Safety personnel within the MFESB with minimum pressures and flows needed for the proper functioning of fire fighting equipment. This study was compared with the adopted standard, Australian Standard 2419.1 'Fire Hydrant Installations – System Design and Commissioning'. The MFESB suggests that a safety factor of 10 to 20 percent be used. This safety factor is an adjustment that increases the values found by this project to account for limited sample of test results, the possibility of failure of some of the equipment and system variances. The study provides important insight to the amount of firewater required for a standard fire fighting operation.

The research for the test was performed in three separate areas. The first was to determine the performance requirements of hand-operated equipment. The second involved calculating the water requirements of fire appliances to achieve optimum equipment operation. The last area is to determine the water requirements of specialist fire appliances to achieve optimum equipment operation. The pumper trucks used were Mark III pumpers. These trucks have an on-board tank with a capacity of approximately 1300 L.

2.3.1.1 Part 1- Street Feed Hydrant

Part 1 of the project had one pumper truck simulate a street feed hydrant. A street feed hydrant is any hydrant that is connected into the street water main. This hydrant can be one of three varieties. The first type is a Fire Plug. This is an underground hydrant that needs a standpipe connection to be utilised. The second type of hydrant is a "L" Type Hydrant. This type of hydrant has an upside down "L" shape at the top and is housed in a metal cover. The final type of hydrant is a pillar hydrant. This is much the same as an "L" shape hydrant without a metal cover. The pumper truck simulated a hydrant by allowing for numerous flows and pressures. Various hand held appliances were then attached directly to the pumper truck to simulate being attached directly into a street feed hydrant. The hand held appliances included; includes 65 and 38 mm diameter hoses, High Pressure (HP) Hose reels, high-rise branch, Task Force Tips (TFT), ground and appliance mounted monitors. A panel of three experienced fire officials evaluated the streams coming out of the hand held appliances as to whether they were an "effective firefighting stream" (MFESB, 2001). When the stream was found to be effective, the flow and pressure of the outlet was recorded from flow and pressure meters. The results of these tests are contained in Tables 1 and 2 (MFESB, 2001).

Table 1: Minimum Flow and Pressure for an Effective Stream (MFESB, 2001)

Hose lengths (x 30 m)	Diameter of Hose (mm)	Type of Branch	Flow (l/s)	Pressure at Pumper (kPa)	Pressure at Branch (kPa)	Effective Distance (m)
Hand Held Fire Fighting Lines						
1	65	TFT*	5	710	700	25-30
2	65	TFT	5	710	680	25
3	65	TFT	5	730	680	28
4	65	TFT	6	800	690	25
1	50	TFT	4	700	675	25
2	50	TFT	4	725	675	20
3	50	TFT	4	750	675	25-26
4	50	TFT	4	775	675	20-25
1	38	TFT	2	650	600	16-17
2	38	TFT	2	675	580	14
3	38	TFT	2	700	560	13
4	38	TFT	2	800	580	14
1	38	ANGUS**	0.5	475	455	9
2	38	ANGUS	1	700	660	13-14
3	38	ANGUS	0.5	625	575	20-23
4	38	ANGUS	0.8	900	800	14

3	38	12.5 mm***	2	550	400	10
4	38	12.5 mm	2	550	350	9

* TFT refers to a Task Force Tip

** ANGUS refers to ANGUS High Rise Pack Branch

*** 12.5 mm is the Standard Plastic Branch

Table 2: Minimum Flow and Pressure for an Effective Fog Pattern (MFESB, 2001)

Hose lengths (x 30 m)	Diameter of Hose (mm)	Type of Branch	Flow (l/s)	Pressure at Pumper (kPa)	Pressure at Branch (kPa)	Effective Distance (m)
Hand Held Fire Fighting Lines						
1	65	TFT	7.5	-	300	-
2	65	TFT	7.5	600	560	-
3*	65	TFT	-	-	-	-
4*	65	TFT	-	-	-	-
1*	50	TFT	-	-	-	-
2	50	TFT	8	875	625	-
3	50	TFT	9	800	525	-
4**	50	TFT	8.5	875	525	-
1**	38	TFT	5	1000	810	-
2**	38	TFT	4.5	1100	750	-
3**	38	TFT	4	1100	725	-
4**	38	TFT	4.5	1100	675	-
1*	38	ANGUS	-	-	-	-
2*	38	ANGUS	-	-	-	-
3*	38	ANGUS	-	-	-	-
4	38	ANGUS	3	1000	600	-
3*	38	12.5 mm	-	-	-	-
4*	38	12.5 mm	-	-	-	-

* The Fog Pattern was not tested

** "-" Represents tests where wind interfered with the test and no effective values were found

2.3.1.2 Part 2- Operational Water Truck

Part 2 of the project was conducted using one pumper truck, functioning as an operational water pumper, connected to another pumper truck, functioning as a street feed hydrant. The test was run with both single feed lines and twin feed lines from the street feed hydrant truck to the operational water pumper. A single feed line is when one hose connects the hydrant to the operational water pumper; a twin feed line is when two hoses connect two hydrants to the operational water pumper. The flow was varied at the outlet of the truck simulating a hydrant. For each flow value into the operational water pumper a corresponding residual pressure at the hydrant outlet was recorded from a pressure meter. The results of these tests are contained in Tables 3 and 4.

Table 3: Flow and Pressure from Single Feed into a Pumper Truck (MFESB, 2001)

Flow (l/s)	Single Feed 30 (m)	Single Feed 60 (m)	Single Feed 90 (m)	Single Feed 120 (m)
	Residual Pressure in Hydrant			
3 (minimum)	60	70	75	80
4	70	80	90	110
5	75	100	110	140
6	75	120	140	175
7.5	110	160	180	240
10	220	250	275	370
12	270	320	375	490
14.5 (maximum)			490	

*All Pressures are in kPa
**Only 90 m was tested for 14.5 l/s

Table 4: Flow and Pressure from Twin Feed into Pumper (MFESB, 2001)

Flow (l/s)	Twin Feed 30 (m)	Twin Feed 60 (m)	Twin Feed 90 (m)	Twin Feed 120 (m)
	Residual Pressure in Hydrant			
3 (minimum)	30	40	40	50
4	40	50	60	60
5	50	60	60	75
6	50	70	75	90
7.5	70	80	90	120
10	80	110	120	150

12	80	130	150	210
15	125	175	210	275
17	100	125	200	300
20	100	150	300	375
25 (maximum)	200	250	350	450

*All Pressures are in kPa

2.3.1.3 Part 3- Specialist Devices

The third part of this project looked at the flows needed for specialist appliances, such as plastic branches. This portion of the testing is not relevant to this project, as the equipment tested in this section would not be used to combat a residential fire.

2.3.1.4 Comparison with Australian Standard 2419.1

The major goal of the MFESB study was to determine the minimum flows and pressures required to effectively operate various pieces of fire fighting apparatus. These values were then compared with the operating pressures of fire hydrants currently required by the standard AS 2419.1. Table 5 documents these results.

Table 5: Comparison of Operating Pressures Required by AS 2419.1 and Fire Fighting Appliance Requirements

Hydrant Condition	AS 2419.1 Operating Pressures (kPa)	MFESB TEST RESULTS: Required Operating Pressure (kPa)	
External hydrant or standpipe; fed from a street water supply; accessible by a fire service pump appliance; unassisted outlet pressure at10 l/s	200	Single Feed 220–370	Twin Feed 80–150

(MFESB, 2001, p15)

For a pumper truck obtaining its water supply from an external street feed hydrant at 10 l/s, a minimum pressure from the hydrant is required for the truck to operate properly. This pressure is 220 kPa for a single feed line and 80 kPa for a twin feed line. There is a variation in the pressure needed in the two types of feeds because they are both dependent on the length of the feed line, which can vary from 30 m to 120 m. The shorter length feeds require less pressure because there is less friction loss. The current operating pressure required by AS 2419.1 is 200 kPa. This operating pressure offers an adequate supply for a twin feed line, however it is not adequate for a single feed line.

2.3.1.5 Conclusion

Through the combination of the results of Parts 1 and 2 of the Fire Water Requirements Project the flow and residual pressure from a street feed hydrant can be calculated. The flow necessary from the attack line, or lines, dictates the flow and pressure that the pumper truck provides, as well as the flow and corresponding pressure needed from the hydrant. The pressure of these attack lines can be found in Table 1. The sum of the flows from of all of the combined attack lines is the flow necessary from the street feed hydrant to supply the operational water pumper. The pump in the operational water truck will provide the pressure that is required to supply the attack lines. The pressure needed in the feed line, and therefore supplied by the street feed hydrant, to the operational water pumper is tabulated in Tables 3 and 4.

2.3.2 Fire Brigade Intervention Model- FBIM

2.3.2.1 General

There are three main components that comprise a well-managed incident. These components that must be considered are the phases prior to the incident, during the incident, and after the incident (AFAC, 1997). The main position of any fire analysis is to assume a worst-case scenario, and to consider the probabilities of transitions to different stages. The worst-case scenario is to assume that the house is fully engulfed, there is risk of the fire spreading and there are people trapped in the building (AFAC, 1997).

2.3.2.2 Modelling

Various models may be applied to aid in the representation of a fire. These models include evacuation, tenability, hardware performance, and radiation transfer (AFAC, 1997). The evacuation model helps to determine the average evacuation times for different residences. The tenability model considers how adverse the impacts of a fire become on the occupants of the dwelling (AFAC, 1997). The radiation transfer model is also extremely important in that it models the fire's impact on the adjoining properties by looking at the radiative flux of the upper layer and analysing its impacts on other properties, fire fighters, and occupants (AFAC, 1997).

The Fire Brigade Intervention Model is a series of 16 step-by-step flow charts that document the total amount of time needed for full engagement and extinguishment of a fire. The first chart determines the time for initial brigade notification. Two charts that determine the time needed for dispatch resources and firefighters to respond follow the first chart. The fourth chart calculates the time to reach fire scene (kerb side), and two subsequent charts determine the time needed to assess fire location and don safety equipment. The seventh chart determines the time needed to assess the fire, followed by a chart to determine the time to travel to set up area. The ninth chart calculates the time for fire fighter travel internally, and then two charts to calculate the time for initial water set up and subsequent water set up. The twelfth chart determines the time for search and rescue. The thirteenth and fourteenth charts determine the time for property protection and salvage. The fifteenth chart calculates the time to control and extinguish the fire, and finally the sixteenth chart determines the time needed to protect the environment (AFAC, 1997).

The FBIM allows the user to calculate the response time of the fire brigade from the time of detection of the fire to the time water is initially supplied to the fire. The longer the response time of the fire brigade the more involved the fire will be. A more involved fire will require more water to extinguish than a fire that has not evolved as long.

2.3.3 Automatic Sprinklers: A 10 Year Study

Very few studies have been conducted to determine this fact in the performance of home sprinkler systems. However, one study that did examine the performance of home sprinkler systems is that of Scottsdale, Arizona. This report examined a ten-year case study of the performance of home sprinkler systems. The study was conducted because it has been established that sprinkler systems can have a positive impact on the fire protection of large facilities. This impact raised the question of whether the benefits of sprinkler systems can also apply to residential buildings. This report examined the costs and benefits of the home sprinkler systems after a five year period. This report found that, in the ten year period, when one or two sprinkler heads are activated in a fire, the fire is controlled or extinguished 92% of the time (Ford, 1997).

2.4 Summary

Research into water distribution systems and their components provided the background necessary to understand the infrastructure of a residential water supply system. Through the review of U.S. standards that deal with water supply systems for fire protection, insight was gained into the criteria used when calculating the water requirements. By evaluating the Water Reticulation Code of Australia, it was discovered that almost no provisions are presently made for water for fire protection.

Several studies have recently been conducted which are of great importance to this topic. The first study was the Fire Water Requirements Project, completed by the Built Environment Working Party of the MFESB (MFESB, 2001). This project provides values for the required flow out of a hydrant that are needed to produce an adequate flow for different pieces of fire fighting apparatus. Coupled with information gained on Standard Operating Procedures for the type and number of apparatuses responding to a fire, a value for the required flow out of a hydrant may be determined. The information gained from the literature review served as both the criteria for the model constructed in this project as well as to supply the engineering tools needed to construct it.

3.0 Methodology

3.1 Introduction

The collection of useful and meaningful data is completely dependent on a properly organised methodology. This section includes a list and discussion of all the methods used to collect and analyse information in this project. Interviewing was the main method of obtaining information that was not readily available in literature.

Since this project deals with water supply for fire protection, the research has focused on two distinct groups. These groups include the fire authority and the water suppliers. Information obtained from the fire authorities includes specifics on standard operating procedures, hydrant spacing and relevant technical reports conducted within the organisation. From the water authorities, current methods regarding water infrastructure design and costs have been gathered.

The final objective of this project was to identify the applicable criteria relating to the determination of required fire flow in a new residential development. These criteria were then transformed into a model that could be used to determine this required flow. The model allows the user to analyse the potential for fire in the structure being examined. The results of this analysis are then correlated into values for the required flows and pressures.

3.2 Fire Department

Fire Authorities were an integral part of this project. In Victoria, there are two main fire brigades, the Country Fire Authority (CFA), and the Metropolitan Fire and Emergency Services Board (MFESB). The MFESB is responsible for suburban Melbourne and the Central Business District (CBD). The CFA is responsible for all other areas of Victoria. Since the brigades utilise the water supply to combat fires, their specific concerns must be addressed. The water supply demands of the fire brigades need to be addressed so that the fire fighting equipment can function properly and fires can be attacked in an effective manner. The project team obtained detailed information about the standard operating procedures followed and equipment used at the site of a fire. These procedures were obtained from interviews conducted with officials at both the MFESB and the CFA. The information obtained from these sources is important in order to establish the amount of water needed.

Contacts in the Metropolitan Fire Brigade and Country Fire Authority were immediately accessible during this project. The interviewees included commanders, senior station officers, operations officers, and engineers. Through interviews with the commanders, operations officers, and senior station officers, knowledge of the standard operating procedure and equipment capacity of the fire brigades was obtained. The engineers were able to provide information on the requirements of the equipment as well as data on equipment function and operation. Additional information pertaining to the standard operating procedures was readily available through training and operating manuals available at the MFESB training centre in Melbourne.

3.3 Water Supply Authorities

Due to the recent privatisation of the water authorities in the state of Victoria, there has been a major change in the methods of water distribution. While Melbourne Water still owns all of the actual resources, they sell the water to the individual water agencies such as Western Water, City West Water, South East Water, and Yarra Valley Water. These organisations are responsible for the design, installation and maintenance of water reticulation infrastructures. They are also responsible for the regulation of the infrastructure with suggestions from guidelines set forth by the Water Reticulation Code of Australia (WSA 03-1999). Information obtained from the water agencies included current methods for water system design, the provisions made for fire protection, and subsequent costs of the systems on a per lot basis.

Through interviews with design engineers at City West Water, South East Water, and WBCM Consultants Ltd., the project team obtained knowledge of the current water infrastructure design criteria applied in Victoria. The proposed WSAA Water Reticulation Code aided in the understanding of current design criteria, as several water agencies have already begun to use this proposed code. The project team completed the interviews attempting to gain information relating to a base model for a current water system installed in a new development in Victoria. The last objective of the interviews and research was to obtain specific costs on a per lot basis for infrastructure design.

3.4 Reports

Many additional reports were available to the project team upon their arrival in Melbourne. Examinations of these reports provided the team with useful information pertaining to operational procedures practiced within the State of Victoria. The reports familiarised the team with current fire fighting practices in the area, and provided a good base for the model.

One report studied was titled the Fire Brigade Intervention Model (FBIM) (AFAC, 1997). This particular report analysed the different criteria affecting the time it took for a fire brigade to respond to a fire. This report was recommended to the team by a fire engineer in the MFESB as a document that would affect fire flow determination and could be applicable to the team's project.

An additional report documenting the minimum required flows and pressures to provide effective operation of different fire apparatus was also provided by the MFESB. This report is entitled the Fire Water Requirements Project and was conducted by members of the

Built Environment Policy Group, a group comprised of fire engineers and senior station officers from the Metropolitan Fire and Emergency Services Board (MFESB, 2001). The results of this report were used in conjunction with the information gained about standard operating procedures to determine the final value for the required fire flow. By determining the number and type of hose lines applied to a fire for different scenarios, the required flows and pressures needed to effectively operate that equipment were added together to achieve the final required value. The National Fire Protection Agency (NFPA) also employs a model for determining minimum required water supply (NFPA 1142, 1999). Their model is based on four types of classifications, each carrying a value that affects the final outcome of water required. Through the examination of this model, specific rationale behind the criteria used was discovered. By learning about the basis of the NFPA model, the aspects applicable to the team's model were determined.

3.5 Model

One of the goals of this project was to develop a model that could be used to determine the required fire flow for a new development depending on one of two basic scenarios. The first scenario considers fires in buildings with out home sprinkler systems installed. The second scenario considers fires in buildings that have home sprinkler systems installed. The probability of each scenario will be based on data gathered from the Australian Incident Report System (AIRS) database for the MFB and the WPI Home Sprinkler Project (Gilman et. al, 2001). Based on the information gathered, the likelihood of each scenario could be determined. Once the standard operating procedures for each scenario were determined, the corresponding flow requirements were calculated from the MFESB Fire Water Requirements Project.

3.6 Summary

Specific issues addressed include both the demands for domestic water supply and fire water supply based on a Greenfield site. This information was gathered in several steps. The first step was to identify the specific criteria that were included in this model. This was completed through background research on the subject of water requirements for fire protection. The second step was to perform interviews with the water authorities. These interviews helped to determine what considerations were being made for fire protection as well as information on design specifications of reticulation systems. The third step was to interview fire officials with operational experience and obtain knowledge about the procedures that are taken by a fire brigade at the scene of a fire. The next step was to incorporate this knowledge with the information obtained from the AIRS database. Using the MFESB Fire Water Requirements Project, minimum flows and pressures to effectively supply different pieces of fire fighting equipment were assigned to the data. This resulted in a determination of how much supply water is required from a hydrant to provide an adequate stream for fire protection. This water supply determination covers potential fire scenarios in residential developments, but does not encompass possible fire scenarios in an industrial or commercial application. Additional considerations need to be made to determine the flow requirements for industrial and commercial applications.

The final step in the development of the model was to compare the result of the model with the current design allowances. The current design allowances for new residential developments were derived through interviews with the water authority design engineers and through the WSAA Water Reticulation Code (WSA-03, 1999). Through the determination of the current allowances for flow and pressure in new developments, it can be decided whether or not the current systems are adequate for the required fire water demand.

4.0 Results

4.1 Introduction

This chapter will discuss the results of the project. These results are categorised into three topics. The first topic is the current design of water infrastructure. This includes pressures, flows, hydrant spacing, and fire provisions. The second topic is the standard operating procedures of the two fire brigades, the Metropolitan Fire Brigade (MFB) and the Country Fire Authority (CFA). This topic includes the procedures followed when a brigade arrives to the scene of a fire. The third topic is data on residential fires received from the AIRS database.

Information was gathered through a variety of sources. A great deal of information for the results was gathered through reviews of projects that have been completed by the Australasian Fire Authorities Council (AFAC) and the Metropolitan Fire and Emergency Services Board (MFESB). Other information was obtained from interviews with officials in the water authorities, the fire services, the developer of the Eynesbury Station site, and consulting engineers. Summaries of these interviews are in Appendix D.

4.2 Current Water Infrastructure Design

The current method of water infrastructure design considers three major factors: flow, pressure and main size. The proposed Water Services Association of Australia (WSAA) Water Reticulation Code of Australia presents a set of guidelines for the various private water authorities. It is stated in the Water Reticulation Code that these guidelines are suggested for water authorities that do not have their own standards already in place (WSA 03-1999).

4.2.1 Flow

The current design criteria for the determination of water flow consider peak flows. Charles Balette, a design engineer of South East Water, stated that the required maximum flow for the system is based upon the peak hourly demand that will occur once in a twenty-year period (Balette, 2001). The water agencies have been monitoring the peak flow values over the past few years. From these values, a standardised number for the peak hourly demand in a twenty-year period can be used as a basis for design. The values presented in the WSAA Water Reticulation Code are shown in Table 6 (WSA 03-1999). Some water authorities, such as South East Water, have already adopted this proposed code as their primary design criteria.

Table 6:Typical Peak Hourly Demand Rates

(WSA 03-1999, p41)

Demand Type	Typical demand rate	Adelaide	Ballarat/Bendigo	Brisbane	Canberra [1]	Darwin	Gold Coast	Hobart	Melbourne/Geelon	Newcastle	Perth	Sydney	Gippsland
Residential													
High Density	L/s/100 units	4.23	3	6	3[2]	9.8 [6]	7.75		3		9.7	3	[3]
1000 m^2 lots	L/s/100 lots	9	9	15	15	15.6 [6]	7.75		10		18.7	12	2.5
500 m^2 lots	L/s/100 lots	6.34	6	10	7.5	15.6 [6]	5.81		8		14	6.5	2.5
Commercial	L/s/ha	1.19	0.5	0.4	0.6-1.1	1.1	1.21		0.6		0.7	0.9	[3]
Public Utilities													
Schools	L/s/ha L/s/school	0.25	0.25	2	1.1	1.7	[4]		0.23			4 HS 2 PS	[3]
General Public Purpose	L/s/ha	0.25	0.1	1	0.75		[4]		0.2			0.1	[3]
Hospitals	L/s/day L/s/ha	0.25	400	1000	1.7		1870		900		938	1500	[3]
Reserves													
Parks	L/s/ha		0.1	0	1.5	3.5	[4]		0.2			0.1	[3]
Golf Courses	L/s/ha		0.1	0	1.5		[4]		0.05			0.1	[3]
Market Gardens	L/s/ha			0			[4]		0.2			0.25	[3]
Pastures	L/s/ha			0			[4]		0.01			[3]	[3]
Gardens	L/s/ha			0	1.5		[4]		0.32			0.25	[3]
Other													
Fire Demand	L/s/hydrant		10	[5]	12.5				10			10	

Notes:

[1] Canberra's Figures include an allowance for irrigation.

[2] High Density residential figure based on 200 m^2 units.

[3] Assessed individually.

[4] Average day demand rate.

[5] 25 L/s from 2 adjacent hydrants, 45 L/s from 3 adjacent hydrants.

[6] Assume Peak Factor of 3.5

In the calculation of peak hourly demands, the following equation is used:

$$PeakHourlyDemand = AverageHourlyDemand(onPeakDay) \times PeakFactor$$

Equation 4: Peak Hourly Demand Calculation

Note 6 from the table above states that in some cases a peak factor of 3.5 is used. For populations over 10 000 a peak factor of 2 is used, for populations below 2 000 a peak factor of 5 is used.

The Water Reticulation Code states that 10 l/s is supplied for fire demand. This value is not considered in the design of the water infrastructure, as stated by Bruce Collins of City West Water and Charles Balette of South East Water (Collins, 2001 and Balette, 2001). This value is assumed to be included in the design and is not specifically addressed.

Other agencies such as City West Water design to values determined within their agency. Bruce Collins, a design engineer of City West Water, stated the his agency currently designs to 8.5 l/s/100 houses for 500 m^2 lots, 6.0 l/s/100 houses for 300 m^2 lots and 2.5 l/s/100 houses for high-density areas (Collins, 2001). The flow for 500 m^2 lots is slightly higher than that of the proposed code, however the flow for high-density areas is slightly lower than the proposed code.

Still, other water authorities do not design for a specific flow, as stated by Mary Tissaaratchi of Western Water. This particular agency designs to a specific pressure and does not concern itself with the flow resulting from this pressure (Tissaaratchi, 2001).

4.2.2 Pressures

The second consideration in the design of a water infrastructure is the pressure of the water in the water mains. The WSAA Water Reticulation Code presents guidelines for the operating pressure limits. The limits for a residential development are a minimum of 200 kPa (20 m) and a maximum of 800 kPa (80 m). These values are presented in Table 7.

Table 7: Operating Pressure Limits

(WSA 03-1999, p37)

Allowable Operating Pressure	Residential Pressure	Industrial/ Commercial Pressure
Maximum	800 kPa (80 m)	800 kPa (80 m)
Minimum	200 kPa (20 m)	250 kPa (25 m)

Individual water authorities are able to design to their own standards if they have different design standards from the Water Reticulation Code (WSA 03-1999). Bruce Collins stated that design pressures are usually an internal design standard (Collins, 2001). This means that the pressure is determined within the individual authority. He further stated that the pressures are adopted to ensure that a minimum flow rate can be delivered to the customers. Collins then stated that City West Water currently designs to 150 kPa (15 m) for residential areas (Collins, 2001). Charles Balette and Mary Tissaaratchi, of South East Water and Western Water respectively, stated that their agencies design to the Water Reticulation Code specification of 200 kPa (20 m) (Balette, 2001 and Tissaaratchi, 2001).

4.2.3 Pipe Size

The final aspect in the design of water infrastructure is the diameter of the main. The major factor in selecting the main diameter is that the minimum diameter be large enough to ensure that the residual pressure due to peak demands is not less than the pressure stated by the water authority. The Water Reticulation Code provides an empirical guide for pipe sizing in Table 8.

Table 8: Empirical Guide for Pipe Sizing (WSA 03-1999, p35)

Nominal Diameter of Main DN	Capacity of Main (single direction feed only)			
	Residential (lots)	Rural Residential (lots)	General/ Light Industrial (ha)	High Usage Industrial (ha)
100	40	10		
150	160	125	23	
200	400	290	52	10
225	550	370	66	18
250	650	470	84	24
300	1000	670	120	35
375	1600	1070	195	55

The code also states that most individual authorities have standardised pipe diameters of 150 mm and 100 mm. The maximum diameter of pipe discussed in this code is 375 mm. South East Water and City West Water both design using main diameters similar to the diameters provided by the Water Reticulation Code. Western Water limits the diameter of water mains to 225 mm (Franklin, 2001).

4.2.4 Fire Services

The Water Reticulation Code of Australia makes little consideration for fire fighting water supplies. The design flow is considered to include a "basic contribution to basic fire fighting capability" (WSA 03-1999, p35). A uniform result was found in all water authority interviews when asked about fire fighting provisions. The water authorities assume that when an infrastructure is designed to meet the peak demand, there is an adequate supply for fire fighting water. If the fire authority does not have enough water to adequately fight a fire, the water authority is not responsible, as they have met their own domestic design requirements

(Collins, 2001 and Balette, 2001). From a risk management perspective, fire water is not the responsibility of the water authority. If the water authority feels that there is an abnormal need for more fire water, the water authority only needs to inform the fire authority that an alternate water source needs to be identified (WSA 03-1999).

Hydrant spacing is another aspect of fire service provisions of a water infrastructure system. The current accepted standard for hydrant spacing in the residential Melbourne area is 200 m (660 ft), however the origins of this standard are not known. Mark Swiney, senior station officer of the Metropolitan Fire Brigade (MFB), and Wayne Bradborn, commander of the Western Zone of the MFB, stated that it is unknown why the standard is 200 m (Swiney, 2001 and Bradborn, 2001). Peter Egan, an inspector with the MFB, stated that the origins of this code are not written down anywhere (Egan, 2001). Egan states that this code has always just been an accepted industry standard. Charles Balette and Bruce Collins, of South East Water and City West Water respectively, also stated that they were unsure of the origins of the 200 m (660 ft) standard (Balette, 2001 and Collins, 2001). Dave Nicholson, director of community safety at the MFB, stated that this standard is derived from the fact that historically the fire brigade carried 200 m of hose on the fire wagons (Nicholson, 2001). The Water Reticulation Code has adopted this accepted Melbourne standard of 200 m. The maximum hydrant spacings of several water authorities are provided in Table 9.

Table 9: Maximum Hydrant Spacings (WSA 03-1999, p80)

Water Agency	Residential Areas	Commercial and Industrial Areas	CBDs	Rural Areas
	M	M	m	m
ACTW	90 and 60	60 and 45	45	180
Barwon Water	200	120		400
Brisbane Water	80	80		200
City West Water	200	120	50	500
DPW & S - NSW				
DNR Queensland	80	80		
Gippsland Water	90	90	90	200
Gold Coast Water	80	80	80	80
Gosford City Council	60	60	60	
Hunter Water	100-120	100-120		180-220
PAWA - NT	120	100		300
SA Water	150	80		400
South East Water	200	120	50	500
Sydney Water	120	120	45-55	180-220
Tasmania	90	70	60	
Water Corporation. WA	120	120	100	400
Yarra Valley Water	200	120	50	500
AFAC recommendation	90	70	50	180

4.2.5 Cost of Infrastructure per Lot

The current cost of water main infrastructure varies with the many aspects of the land being developed. Steve Copland, manager of urban development from the Urban Land Corporation, stated that the cost of water main infrastructure includes an application fee, a fee for insurance and finally a headwork fee (Copland, 2001). This headwork fee incorporates only physical aspects of the infrastructure. These physical aspects include a hookup cost to an existing main, the increase in the cost to supply water, chlorination stations, pump stations, dams and finally the physical installation of the main. The cost of water infrastructure per house in a development can vary by the aspects of the development. A higher density development will cost less per house than a more rural development. This decrease in cost is due to less length of water mains needed to connect all of the houses in a development according to Steve Copland (Copland, 2001). Robert Mitchell, a managing director, and Greg Sheath, a project manager, both of WBCM Consulting Limited stated that the cost of installing a water main is generally estimated to be seventy five percent of the diameter of the main in Australian dollars per meter of main (Mitchell and Sheath, 2001). An example of this is a 100 mm main would cost seventy-five dollars Australian per meter to install. The cost of installing a hydrant to the infrastructure varies by the time it is installed. Charles Balette of South East Water stated that the cost to install a hydrant at the same time as the infrastructure is approximately AUD$600 (Balette, 2001). However installing a hydrant in an existing water infrastructure system costs approximately AUD$2000. The average cost per lot to the developer, according to WBCM Consulting Limited, is approximately AUD$1500. The developer then recovers this cost through the customer when the lot is purchased. Bruce Collins of City West Water estimated the cost per lot to be approximately AUD$2000 (Collins, 2001).

4.3 Standard Operating Procedures For Fire Fighting

4.3.1 MFB Standard Operating Procedures

Every procedure carried out by the Metropolitan Fire Brigade follows a certain order of events. The methods that are practiced are documented in the Standard Procedures Manual. The Standard Procedures Manual is made up of three smaller manuals, The Standard Practices Manual, Operational Procedures Manual, and The Senior Officers Instructions. This procedure manual was developed by the Operations/Administration department of the MFESB to provide information pertaining to policy and other related matters (MFESB, 1999).

For this project, only the sections pertaining to procedures followed in the event of a residential house fire are needed. This information pertains to the operations that are followed in establishing the water needed to supply the attack lines to a fire as well as the procedures taken in establishing the attack lines themselves. Through several interviews with officers at the MFESB training college, consisting of commanders and senior station officers, and information obtained from the Standard Procedures Manual, the exact procedures of the MFB were obtained.

Greg Bawden, commander of structural fire safety at the MFB training facility, stated that after a notification call has been received for a residential house fire a first alarm is sounded (Bawden, 2001). What this means is that two primary units are dispatched to the scene. The two primary units are dispatched from two different firehouses, in opposite directions, so they do not follow the same route to the scene of the fire. This procedure is followed so if there are any unforeseen obstacles from one direction, both units will not be held up. A primary unit for a residential house fire is a pumper truck, which carries a crew of three fire fighters. These three fire fighters are a hose operator, a pump operator, and an officer in charge (OIC). The pumper trucks at the MFB are Mark III or Mark IV pumpers. There is very little difference between the two trucks. Each pumper truck has a 1300 L water tank, which is the initial water supply for all fire fighting operations.

Mark Swiney and Peter Egan both stated that all MFB trucks carry 210 m of hose. This length is ample to reach all points between two hydrants, as current hydrant spacing is 200 m (Swiney, 2001 and Egan, 2001). Peter Egan stated that a MFB truck carries fourteen 30 m lengths of 65 mm hose (Egan, 2001). Seven of these lengths are pre-connected into one 210 m hose. This hose is long enough to reach from one hydrant to the next so that the length of the hose covers all areas in between the hydrants. This also leaves seven lengths of hose that are able to connect to the pump and be used as attack lines.

Mark Swiney, a senior station officer at the MFB, and Greg Bawden both stated that when a primary unit arrives at the scene of a fire, the responding fire fighters follow a standard onsite procedure called RECEF (Swiney, 2001 and Bawden, 2001). RECEF stands for Rescue, Exposure, Containment, Extinguishment, and Fire Duty. The first step, Rescue, means that if there are any people still trapped in the building rescuing them is the first priority. The second step is Exposure. An exposure is any structure or vegetation, with a high risk of igniting. The National Fire Protection Association (NFPA) considers an exposure hazard to be within 15 m of the fire (NFPA 1142, 1999). If the exposure is in danger of igniting due to flames or heat from the affected building, the first hose line is directed at that exposure. By putting a hose line on the exposure it is cooled and the chances of it igniting are reduced. Once all exposures are protected the next step is considered. This step is Containment. This means that fire is contained within the walls of the burning building, and further contained to the room of origin. If there are any flames protruding from windows, doors, etc., they are the first to be attacked. The next step is called Extinguishment. This step is combating the fire until it is completely extinguished. The last step that the fire fighters must complete is Fire Duty. This deals with salvaging any undamaged property, and overhauling the structure. Some activities involved in this step include cutting holes in the floor to drain water, placing tarpaulins over undamaged furniture, and protecting the surrounding environment from contaminated water run-off.

The first operation of the pump operator is to start the pump located on the pumper truck. This pump supplies water to the first lines to be utilised in the fire fighting operation. Mark Swiney and Greg Bawden stated that high-pressure hose reels (HPHRs) are the first two lines used at the scene of a fire (Swiney, 2001 and Bawden, 2001). The HPHR is a 25 mm rubber hose that can withstand water pressures up to 3500 kPa. A single fire fighter can operate these hoses. There are two of these hoses, each 60 m in length, on all MFB pumper trucks. The HPHRs are already connected to the pump so that no time is wasted in connecting a hose to the pump. This type of hose is one of the most effective for small house fires because it is easily manoeuvrable and can deliver large amounts of water at a high pressure, approximately 5 L/s at 3500 kPa. Mark Swiney stated that these hoses are typically run at 3000 kPa, which supplies 4.2 L/s of water. Each primary unit is capable of supplying water to one HPHR for approximately five to ten minutes, depending on the pressure used, at 3000 kPa the water supply will last for a little over five minutes. While this HPHR is being used, the pump operator and fire fighters from the second arriving primary unit connect the first primary unit to a fire hydrant. When the second unit arrives at the scene of the fire the primary objective is to ensure that the first unit has enough water to fight the fire. This can happen in one of three methods according to Greg Bawden (Bawden, 2001). Which method is used is determined by the status of the fire. If the fire is nearly out and the first unit has water remaining, the second unit can opt to not add to the water supply. This allows the second unit to remain fully capable of responding to another alarm. Another option is that if the fire is under control, however the first unit is low on water, the second unit can connect its storage tank to the first pumper and allow the first pumper to work off of the second storage tank. The final option is if the fire is not controlled. In this case the second unit would connect a second hydrant supply line to a different hydrant. Once the water supply of the first unit is established the second unit would help attack the fire with additional lines and assist in the Fire Duty.

When there is an exposure near the building on fire a line is dedicated to this exposure. By the RECEF procedure any exposures receive the first hose line. A second hose line will then be used to attack the fire. Greg Bawden stated that if an exposure is in danger after an attack has already begun on the fire a new line will need to be applied quickly to this exposure (Bawden, 2001). This line will commonly be a 65 mm hose line. This 65 mm line will be used to cool the exposure until there is no danger of it igniting. Then, if necessary, the line will be used as an additional attack line on the fire.

4.3.2 CFA Standard Operating Procedures

Similar to the MFB, the Country Fire Authority (CFA) has certain procedures that they follow when responding to residential house fires. These procedures are not documented in a manual, but they are an integral part of the training process for the CFA fire fighters.

The procedures followed when responding to a typical residential house fire were the most relevant to this project. In order to obtain information about these procedures Kevin Pettit, an operations officer from the CFA, was interviewed. Pettit stated that the operating procedures used by the CFA were almost identical to those used by the MFB (Pettit, 2001). He then went through several typical residential house fire scenarios.

Pettit stated that when a notification call came in to the brigade, a first alarm is sounded (Pettit, 2001). This means that two units are dispatched to the fire scene. The typical units that are dispatched to residential fires are called pumpers. These pumpers each carry about 1800 L of water to the fire, and are staffed by 3 fire fighters. When the first unit arrives on the fire scene the officer in charge (OIC) assesses the situation using a technique called RECEO. The first step of this procedure is called Rescue. During this step, the officer in charge determines if there are any people still trapped within the building. If it is determined that there are no lives at stake, the officer in charge proceeds to the second step. This step, called Exposure, is when the OIC scans the perimeter for any other buildings or areas covered by brush that may ignite due to heat from the fire. If there are any exposures that must be attended to, a 65mm hose will be applied directly to the exposure. The third step is called Containment. In this step the OIC focuses on containing the fire to the building that is currently affected. Once the fire is deemed sufficiently contained, the fire fighters will focus on the fourth step in the process, Extinguishment. The last and final step is Overhaul, when the fire fighters remove extra water in the building and salvage whatever they can.

Standard CFA pumpers, as noted before, are equipped with 1800L tanks for use upon first arrival to the fire. If the fire is confined to the room of origin at the time of brigade intervention, one 38mm hose will be applied directly to the fire. If the OIC feels that there is a need for more hoses, a second 38mm hose will also be applied. High-pressure hose reels are rarely applied, as the CFA trucks are not normally equipped with them. If the fire has spread beyond the room of origin, but is still contained to the structure of origin, a 65mm hose will supplement the two 38mm hoses. The 65mm hose cannot be applied however, until the second appliance arrives, as there are not enough personnel to operate three hoses.

4.3.3 Comparison

There are many similarities and differences between the operating procedures of the MFB and the CFA. Since this model will be utilised for all of Victoria, it is necessary to compare the two brigades.

The methods followed when each brigade arrives at the scene of a fire are essentially the same. When a notification call comes in to either brigade, a first alarm is sounded. Both brigades dispatch two primary pumper units to the fire scene carrying three fire fighters. The pumpers differ only slightly in the amount of water and the types of hoses carried on them. The CFA pumpers carry 1800 L of water, whereas the MFB pumpers carry only 1300 L. The MFB primarily uses a High Pressure Hose Reel (HPHR) as its first attack line, while the CFA employs a 38mm hose line. If there are exposure hazards, the two brigades act slightly differently. The MFB will apply water to the exposure using one of the HPHRs, while the CFA will use a 65mm hose line. The model will incorporate the more conservative procedures between the two brigades, thus accounting for the maximum amount of water either would ever need.

4.4 MFB Data

The following data were obtained from the AIRS database at MFESB.

Table 10: MFB Hose Use Data

HPHR= High Pressure Hose Reel 38mm=38mm canvas hose 65mm- 65mm canvas hose	Total Flow (L/s)	Object of Origin	Area of Origin	Room of Origin	Floor of Origin	Structure of Origin	Beyond	Totals	% of Total Fires
Total Fires:		70	292	225	71	263	57	978	
1-38mm	2	1	2	1	1	1	0	6	1%
2-38mm	4	0	0	2	0	2	0	4	0%
1HPHR	4.2	60	235	120	18	30	6	469	48%
1-65mm	5	0	0	0	0	1	0	1	0%
3-38mm	6	0	0	0	0	1	0	1	0%
1HPHR & 1-38mm	6.2	3	12	9	0	5	2	31	3%
4-38mm	8	0	0	0	0	1	0	1	0%
1HPHR & 2-38mm	8.2	0	0	1	0	0	0	1	0%
2HPHR & 2-38mm	8.2	0	2	1	1	2	0	6	1%
2HPHR	8.4	6	34	75	31	107	19	272	28%
1HPHR & 1-65mm	9.2	0	0	1	0	0	0	1	0%
2HPHR & 1-38mm	10.4	0	1	2	0	5	2	10	1%
3HPHR	12.6	0	4	7	15	27	5	58	6%
2HPHR & 1-65mm	13.4	0	0	1	2	2	0	5	1%
1HPHR & 2-65mm	14.2	0	0	1	0	0	0	1	0%
2HPHR & 2-65mm	18.4	0	0	0	0	2	0	2	0%
3HPHR & 1-38mm	14.6	0	0	0	0	1	2	3	0%
3HPHR & 2-38mm	16.6	0	0	0	0	2	0	2	0%
4HPHR	16.8	0	1	2	3	46	10	62	6%
Other: Greater than 16.8 L/s								42	4%
Other:									
2HPHR & 2-38mm & 1-65mm	17.4	0	0	0	0	1	0	1	0%
3HPHR & 1-65mm	17.6	0	0	0	0	5	1	6	1%
3HPHR & 3-38mm	18.6	0	0	0	0	1	0	1	0%
3HPHR & 1-38mm & 1-65mm	19.6	0	0	0	0	1	1	2	0%
5HPHR	21	0	0	0	0	5	0	5	1%
4HPHR & 1-65mm	21.8	0	0	0	0	3	2	5	1%
3HPHR & 2-65mm	22.6	0	0	2	0	1	0	3	0%
4HPHR & 4-38mm	24.8	0	0	0	0	1	1	2	0%
6HPHR	25.2	0	1	0	0	6	4	11	1%
4HPHR & 2-65mm	26.8	0	0	0	0	0	1	1	0%
6HPHR &1-38mm	27.2	0	0	0	0	2	0	2	0%
5HPHR & 2-65mm	31	0	0	0	0	1	1	2	0%
6HPHR & 3-38mm& 1-65mm	36.2	0	0	0	0	1	0	1	0%

Individual Flows:
HPHR = 4.2 L/s
38mm = 2 L/s
65mm = 5 L/s

Assumptions:
HPHR operating at 3000 kPa
All hose configurations are 60m in length

4.4.1 Explanation of Metropolitan Fire Brigade Data

4.4.1.1 Introduction

The data received from the MFB through the Australian Incident Reporting System (AIRS) database are shown in Table 10. These data cover the calendar years 1998, 1999 and 2000 and only refer to the fires in which hoses were actually utilised. The data are arranged according to the confinement of the fire at the point of brigade intervention, and the different hose set-ups used at each different scenario. The actual number of fires in residential dwellings in the same three year period was 2748 fires, this number accounts for fires in which a hose was utilised as well as fires that were extinguished without a hose.

4.4.1.2 Hose Set-ups

The different hose combinations are listed in the left column of Table 10. According to the standard operating procedures gathered from officials at both the CFA and the MFB, it was discovered that three types of hoses are utilised when combating residential fires. These types include a high-pressure hose reel (HPHR), which is a 25 mm line that is typically operated at approximately 3000 kPa, a 38 mm canvas line, and a 65 mm canvas line. The number of times each hose combination was utilised is correlated with the level of confinement of the fire.

4.4.1.3 Total Flow

The total required flow for each hose combination was calculated using the values from the MFESB Fire Water Requirements Project (2001). The values obtained from the study provided the team with the minimum pressures and flows required to effectively operate different pieces of fire fighting apparatus. Through simple processes of addition, the required flows for the different combinations were established.

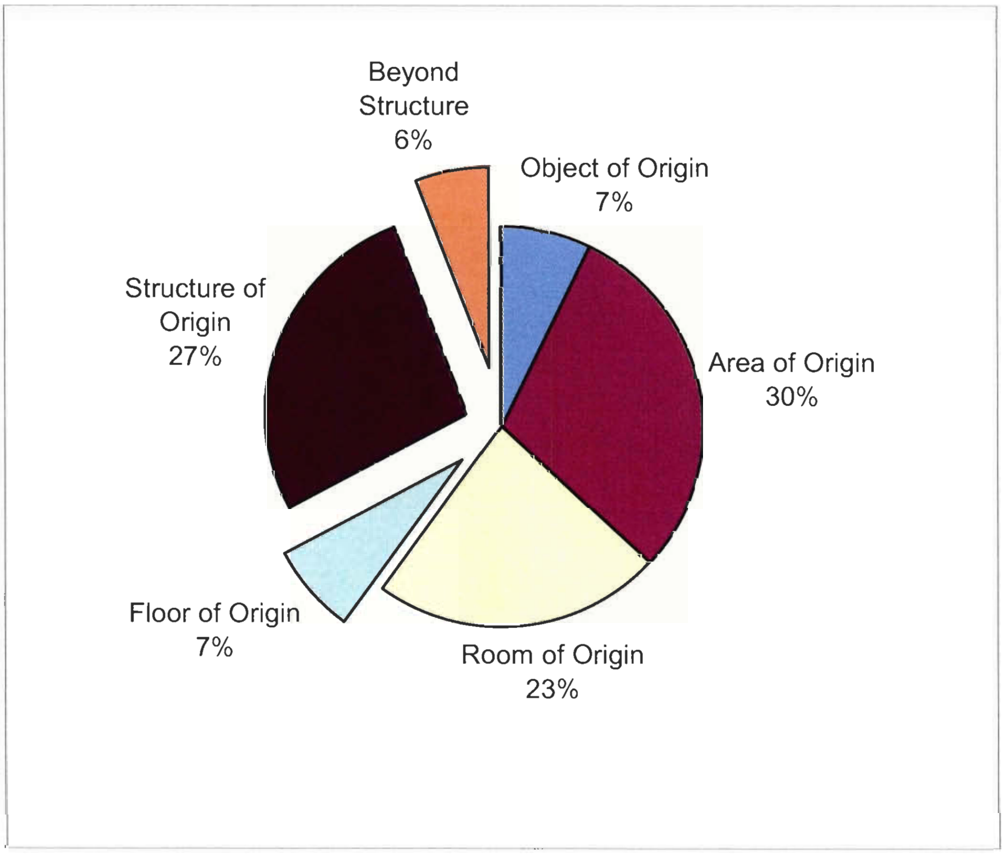
Several assumptions were made in the designation of the flows for each hose combination. Mark Swiney and Greg Bawden, both of the MFESB, stated that the HPHRs are most commonly operated at a pressure of 3000 kPa (Swiney, 2001 and Bawden, 2001). This operating pressure results in a flow of 4.2 L/s. The flow of all HPHRs is assumed to be 4.2 L/s as this is the most common operating flow. Another major assumption is that all hoses are operating at the minimum flow needed to achieve an effective fire fighting stream as defined by the MFESB (MFESB, 2001). A third assumption was that all other hoses utilised were two 30 m lengths, or 60 m. This assumption was made because the HPHRs only come in lengths of 60 m, and assuming that all the other hose sizes used a length of 60 m made all the lengths uniform. Also the number of 30 m lengths used has very little effect on the flow required to create an effective stream. The number of lengths has a much greater effect on the amount of pressure that needs to be provided by the pump (MFESB, 2001). The pressure required from the hydrant is discussed in the analysis section of the report. Using the MFESB Fire Water Requirements Project (2001) the minimum flow required in a 38 mm hose was determined to be 2 L/s and the flow required in a 65 mm hose was determined to be 5 L/s.

4.4.1.4 Confinement

The data received from the AIRS database was divided into categories based on the confinement of the fire. The specific categories utilised for this data set were object of origin, area of origin, room of origin, floor of origin, structure of origin, and beyond the structure of origin.

Confinement to the object of origin simply means that the fire had not spread from the object that had originally ignited. Confinement to the area of origin means that the fire has spread beyond the object of origin to include other some of the other objects in the room. The only difference between this type of confinement and confinement to the room of origin is that if the fire is confined to the room of origin all the combustible contents in the room are burning but the fire has not spread to other rooms. Confinement to the floor of origin means that the fire has progressed beyond the room of origin but has not yet spread to other floors. The last two classifications of confinement are confinement to the structure of origin, or the fire spread beyond the structure of origin. The distribution of each type of confinement is illustrated in Figure 1.

Figure 1: Confinement of Fires



The number of fires in which a hose was applied was 978 out of a total number of fires of 2748. This equates to 36% of fires requiring the use of a hose.

4.5 **Fire Brigade Intervention Model** (FBIM)

4.5.1 Introduction

The Fire Brigade Intervention Model (FBIM) is a document that contains a working model that can be used as an aid in determining the time for fire brigade operations (AFAC, 1997). This model also contains a scientific analysis with various assumptions pertaining to the cooling capacity of water. The committee responsible for the development of this model was composed of different fire agency members from Australia and New Zealand. The members come from many different engineering backgrounds including applied science, building surveying, mathematics, and business administration.

The working model is broken up into sixteen flow charts, each specific to a certain area of fire brigade operations. By inputting certain criteria, one can determine the time it takes to complete each individual operation. When a time has been established for each operation, the individual times can be combined to produce the total response time. Each separate chart is explained by identifying the required input criteria and the final output.

These FBIM charts are efficient methods of determining the total time required for fire brigade operations. However not all of the charts will apply to this project. The first several charts calculate the time from the fire detection up to when the first water is applied to the fire. This includes the travel time to the scene of the fire, time to set up the equipment needed to fight the fire, the time for the officer in charge to assess the fire and finally the time to initially apply water to the fire. The remainder of the charts within the FBIM pertain to operations of the brigade that are not essential to this project.

5.0 Analysis

All of the data collected applied strictly to residential areas and it must therefore be noted that this project examined only residential areas. In any area where there is a possibility for a combination of residential and industrial or commercial buildings, additional data would need to be used and this study would need would need to be revised.

5.1 Analysis of Data

The data originally obtained from the MFB database were categorised into six sections based on the containment of the fire at the time of extinguishment. A major obstacle in the interpretation of the information was to restructure the data into a format that was more applicable to the specific goals of the project. For this reason, it was decided that the data would be categorised by the number of appliances that were utilised in each fire. Once the data were broken down into distinct sections based on the number of appliances that were used at a fire, specific conclusions about the amount of water required could be drawn. It must be noted that all the conclusions drawn are representative only of the data provided by the AIRS database of the MFESB, as the FIRS database of the CFA does not catalogue the information needed for this project. For this reason, conclusions may be skewed and not representational of Victoria as a whole.

5.2 Required Flow

In order to structure the data into categories based on the number of appliances that responded to a fire, some critical assumptions were made. All primary appliances dispatched to residential fires by the MFESB are Mark III or Mark IV pumper trucks. Each of these primary appliances is equipped with two high-pressure hose reels (HPHRs). The assumption is made that the number of HPHRs that were used dictated the total number of appliances that were utilised in each situation. This means that when one or two HPHRs were utilised, they both originated from the one appliance. When three or four HPHRs were necessary, two HPHRs came from the first appliance and the remaining came from an additional appliance. In the cases where five or six HPHRs were used, three appliances were present. The first two appliances would account for four of the HPHRs and the third appliance would account for the remaining HPHRs. The HPHRs are utilised for their efficiency. The HPHRs are efficient in that water can be applied to the fire faster because they are pre-connected to the pump and are easily manoeuvred within a building. By MFESB standard operating procedures the HPHRs are always the first lines utilised at the scene of a fire. Once these lines have begun to operate, the officer in charge determines the need for additional lines. These lines are either HPHRs from a second or third appliance, or canvas hoses (38 mm or 65 mm). Each pumper truck is equipped with connections for up to eight canvas lines so that in the event that extra canvas lines are needed they will be connected to the first appliance. By standard operating procedures, the first appliance would have established a hydrant feed before any additional canvas lines are utilised. An additional reason that the canvas lines are connected to the first pumper truck is that the first appliance on scene will be located in the best position to fight the fire. According to the AIRS data, the MFESB never usesmore than four canvas lines in addition to the HPHRs. For these reasons it is assumed that all canvas hoses used at the scene of a fire will be connected to the first appliance.

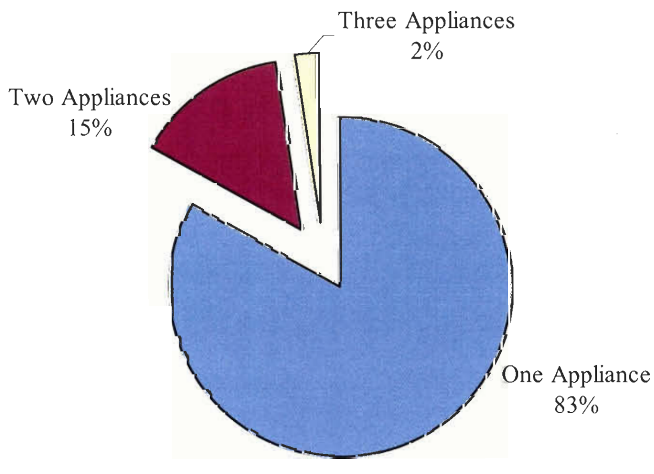
Table 11 presents all of the residential fires in 1998, 1999 and 2000 that required the use of a hose. There were 978 residential fires that required a hose out of a total number of 2748 residential fires.

Table 11: Hoses Used and Flows Needed by Number of Appliances

HPHR = High Pressure Hose Reel 38mm = 38mm diameter canvas hose 65mm = 65mm diameter canvas hose	Flow of Appliances (L/s)	Object of Origin	Area of Origin	Room of Origin	Floor of Origin	Structure of Origin	Beyond	Total	
Total Fires:		70	292	225	71	263	57	978	
One Appliance:								812	83%
1-38mm	2	1	2	1	1	1	0	6	0.739%
1-65mm	5	0	0	0	0	1	0	1	0.123%
1HPHR	4.2	60	235	120	18	30	6	469	57.8%
1HPHR & 1-38mm	6.2	3	12	9	0	5	2	31	3.82%
1HPHR & 1-65mm	9.2	0	0	1	0	0	0	1	0.123%
1HPHR & 2-38mm	8.2	0	0	1	0	0	0	1	0.123%
1HPHR & 2-65mm	14.2	0	0	1	0	0	0	1	0.123%
2-38mm	4	0	0	2	0	2	0	4	0.492%
2HPHR	8.4	6	34	75	31	107	19	272	33.5%
2HPHR & 1-38mm	10.4	0	1	2	0	5	2	10	1.23%
2HPHR & 1-65mm	13.4	0	0	1	2	2	0	5	0.616%
2HPHR & 2-38mm	8.2	0	2	1	1	2	0	6	0.739%
2HPHR & 2-38mm & 1-65mm	17.4	0	0	0	0	1	0	1	0.123%
2HPHR & 2-65mm	18.4	0	0	0	0	2	0	2	0.246%
3-38mm	6	0	0	0	0	1	0	1	0.123%
4-38mm	8	0	0	0	0	1	0	1	0.123%
Two Appliances: (First, Second)								145	14.8%
2HPHR, 1HPHR	8.4, 4.2	0	4	7	15	27	5	58	40%
2HPHR & 1-38mm, 1HPHR	10.4, 4.2	0	0	0	0	1	2	3	2.07%
2HPHR & 1-38mm & 1-65mm, 1HPHR	15.4, 4.2	0	0	0	0	1	1	2	1.38%
2HPHR & 1-65mm, 1HPHR	9.2, 4.2	0	0	0	0	5	1	6	4.14%
2HPHR & 2-38mm, 1HPHR	8.2, 4.2	0	0	0	0	2	0	2	1.38%
2HPHR & 2-65mm, 1HPHR	18.4, 4.2	0	0	2	0	1	0	3	2.06%
2HPHR & 3-38mm, 1HPHR	14.4, 4.2	0	0	0	0	1	0	1	0.689%
2HPHR, 2HPHR	8.4, 8.4	0	1	2	3	46	10	62	42.7%
2HPHR & 1-65mm, 2HPHR	13.4, 8.4	0	0	0	0	3	2	5	3.45%
2HPHR & 2-65mm, 2HPHR	18.4, 8.4	0	0	0	0	0	1	1	0.689%
2HPHR & 4-38mm, 2HPHR	16.4, 8.4	0	0	0	0	1	1	2	1.38%
Three Appliances: (First, Second, Third)								21	2. 15%
2HPHR, 2HPHR, 1 HPHR	8.4, 8.4, 4.2	0	0	0	0	5	0	5	24%
2HPHR & 2-65mm, 2HPHR, 1HPHR	18.4, 8.4, 4.2	0	0	0	0	1	1	2	9.5%
2HPHR, 2HPHR, 2HPHR	8.4, 8.4, 8.4	0	1	0	0	6	4	11	52%
2HPHR & 3-38mm& 1-65mm, 2HPHR, 2HPHR	19.4, 8.4, 8.4	0	0	0	0	1	0	1	4.8%
2HPHR &1-38mm, 2HPHR, 2HPHR	10.4, 8.4, 8.4	0	0	0	0	2	0	2	9.5%

Table 8 organises the different hose configurations by the number of appliances needed to supply the hoses at the scene. An assumption is made that there is enough manpower to utilise all of the hoses at one time. The number of HPHRs used, as discussed before, dictated the number of appliances used. The hoses used were then assigned to the proper appliance. No more than two HPHRs were assigned to any one appliance and all canvas hoses were assigned to the first appliance. The maximum required flow for each appliance is listed next to the hose combinations. The first appliance will require the most water, as it will have the most hoses connected to it. This means that the flow of water required to supply the first appliance will be the greatest flow. In addition, it will be the minimum amount of water needed to flow from the hydrant. The number of times that one, two and three appliances were needed was analysed and presented in Figure 2.

Figure 2: Number of Appliances Used



From the AIRS data, 83% of the fires in which a hose was utilised only required one appliance, 15% of fires required two appliances and 2% of the fires required three appliances. The flow of water required by the first appliance in each hose combination is presented in Figures 3,4 and 5.

Figure 3: Flow Required by One Appliance

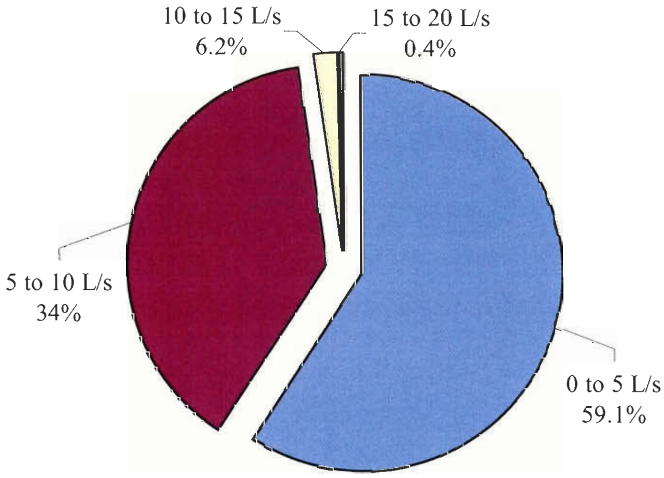


Figure 4: Flow Required by the First of Two Appliances

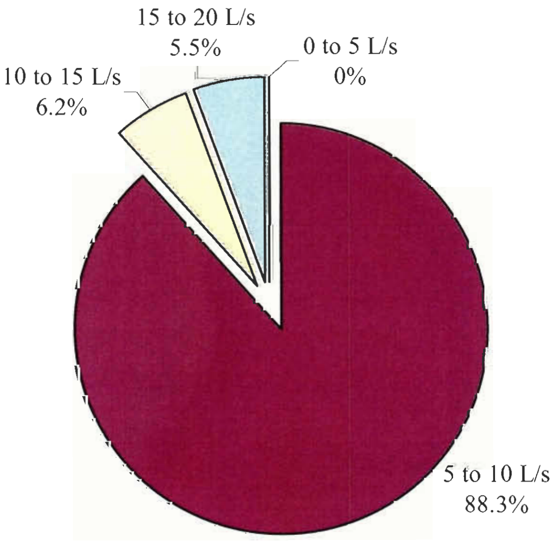


Figure 5: Flow Required by the First of Three Appliances

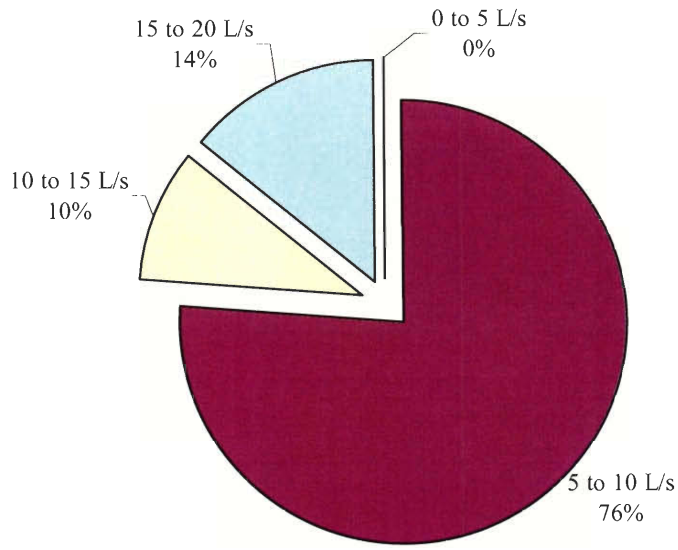


Table 12 shows the percentage of fires that a specific hydrant flow would be able to extinguish. This table uses the water flow value assigned to each particular hose combination to determine the percentage of times that flow value was required over the three-year period. The hose combinations used are those of the first appliance of all three scenarios for the number of appliances used. A percentage was then calculated that determines the number of residential fires that would be able to be extinguished using a particular flow. Since the hose combinations are arranged in order of increasing flow, a percentage of fires that required a flow equal to or less than a particular flow for extinguishment is determined. For example, a flow of 8.4 L/s would be an adequate flow to supply any hose combinations that require a lesser flow. This flow is therefore able to extinguish all fires that required a lesser flow. As a percent based on the number of times each hose combination was used, the 8.4 L/s could extinguish 94% of the fires that required the use of a hose.

Table 12: Flows needed Residential Fires Utilising a Hose

Hose Combination	Flow (L/s)	Times Used	Percent
1-38mm	2	6	1%
2-38mm	4	4	1%
1HPHR	4.2	469	49%
1-65mm	5	1	49%
3-38mm	6	1	49%
1HPHR & 1-38mm	6.2	31	52%
4-38mm	8	1	53%
1HPHR & 2-38mm	8.2	1	53%
2HPHR	8.4	408	94%
1HPHR & 1-65mm	9.2	1	94%
2HPHR & 1-38mm	10.4	15	96%
2HPHR & 2-38mm	12.4	8	97%
2HPHR & 1-65mm	13.4	16	98%
1HPHR & 2-65mm	14.2	1	99%
2HPHR & 3-38mm	14.4	1	99%
2HPHR & 1-38mm & 1-65mm	15.4	2	99%
2HPHR & 4-38mm	16.4	2	99%
2HPHR & 2-38mm & 1-65mm	17.4	1	99%
2HPHR & 2-65mm	18.4	8	100%
2HPHR & 3-38mm& 1-65mm	19.4	1	100%

Table 13 was developed in a similar manner to Table 12. However, Table 13 examines all 2748 residential fires from the years 1998, 1999 and 2000 since 64% of all residential fires during this period did not require the use of a hose for extinguishment. The remaining 36% of the fires required the use of a hose; it is assumed that the appliance was supplied from a hydrant. The percentage of fires that can be extinguished by a particular flow of water was established in Table 9. By using this calculated percentage, the percentage of all fires that can be extinguished with a particular flow can be calculated in a similar fashion.

This percentage is calculated by multiplying the value obtained from Table 12 by a factor of 36%, and then adding that new value to 64% . For example, a flow of 8.4 L/s is able to extinguish 94% of residential fires that required a hose. This percent is then multiplied by 36%, resulting in a percentage of 34%. This calculated percent is then added to 64% resulting in a final percentage of 98%. This means that according the AIRS data, 98% of all residential fires can be extinguished by a flow of 8.4 L/s or less.

Table 13: Flows Needed for All Residential Fires

Hose Combination	Flow (L/s)	Times Used	Percent	Percent of All Fires
1-38mm	2	6	1%	65%
2-38mm	4	4	1%	65%
1HPHR	4.2	469	49%	82%
1-65mm	5	1	49%	82%
3-38mm	6	1	49%	82%
1HPHR & 1-38mm	6.2	31	52%	83%
4-38mm	8	1	53%	83%
1HPHR & 2-38mm	8.2	1	53%	83%
2HPHR	8.4	408	94%	98%
1HPHR & 1-65mm	9.2	1	94%	98%
2HPHR & 1-38mm	10.4	15	96%	99%
2HPHR & 2-38mm	12.4	8	97%	99%
2HPHR & 1-65mm	13.4	16	98%	99%
1HPHR & 2-65mm	14.2	1	99%	99%
2HPHR & 3-38mm	14.4	1	99%	100%
2HPHR & 1-38mm & 1-65mm	15.4	2	99%	100%
2HPHR & 4-38mm	16.4	2	99%	100%
2HPHR & 2-38mm & 1-65mm	17.4	1	99%	100%
2HPHR & 2-65mm	18.4	8	100%	100%
2HPHR & 3-38mm& 1-65mm	19.4	1	100%	100%

The flow of the water required by each of the hose combinations is equal to the flow required from the hydrant. This means that the flow from a hydrant that is able to extinguish a percentage of residential fires is equal to the flow required from the hose combination used to attack that percentage of fires. For example, a flow of 19.4 L/s from a single hydrant would be able to extinguish 100% of the residential fires that occurred in the years 1998, 1999 and 2000.

5.3 Required Pressure

For all flows of water through a confined space such as a water main, a fire hydrant or a fire hose, there is an associated pressure. This pressure is needed to adequately produce the specified flow. When specifying pressures needed in a fire hydrant, it is most common to identify the residual pressure. Residual pressure is the pressure that remains at the outlet of a hydrant while water is flowing through the supply lines to the attack pumper (Eckman, 1994). For this reason, it can be assumed that if the water requirements for the primary appliance are met, the requirements for the secondary appliances connecting into different hydrants will also be met. The MFESB Fire Water Requirements Project calculated the residual pressure that is associated with a given flow necessary in a fire hydrant necessary to provide an adequate supply to the attack pumper (MFESB, 2001). A primary appliance can have either single or twin feed lines connecting it to a hydrant. This project assumes that for flows less than 14.5 L/s a single feed line is utilised. This assumption is made because this project is aimed at a conservative estimate of the minimum flow required from a single hydrant. The feed line is also assumed 120m long. Once again, this is a conservative estimate. Since hydrant spacing is a standard 200m in residential developments, this assumption provides a length of hose that sufficiently covers any area between the 200m spacing. Since a single feed line to the attack pumper has been assumed Table 3, in section 2.3.1.2 of the Literature Review, is used.

Table 3: Flow and Pressure from Single Feed into a Pumper Truck (MFESB, 2001)

Flow (l/s)	Single Feed 30 (m)	Single Feed 60 (m)	Single Feed 90 (m)	Single Feed 120 (m)
	Residual Pressure in Hydrant			
3 (minimum)	60	70	75	80
4	70	80	90	110
5	75	100	110	140
6	75	120	140	175
7.5	110	160	180	240
10	220	250	275	370
12	270	320	375	490
14.5 (maximum)			490	

*All Pressures are in kPa
**Only 90 m was tested for 14.5 l/s

However, for a single feed line, the maximum flow tested by the MFESB was 14.5 L/s. For this reason another assumption must be made. This assumption is that when a flow greater than 14.5 l/s is required, a twin feed line will be used. Information for this feed is presented in Table 4 of section 2.3.1.2 of the Literature review.

Table 4: Flow and Pressure from Twin Feed into Pumper (MFESB, 2001)

*All Pressures are in kPa

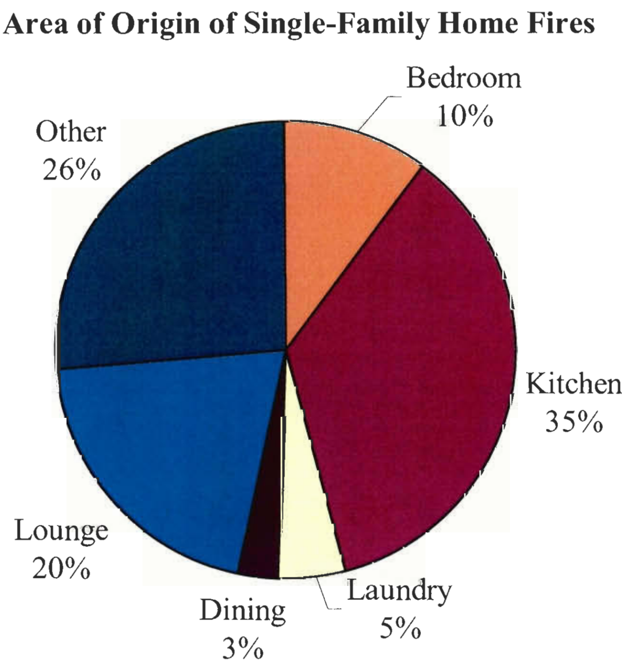
Flow (l/s)	Twin Feed 30 (m)	Twin Feed 60 (m)	Twin Feed 90 (m)	Twin Feed 120 (m)
	Residual Pressure in Hydrant			
3 (minimum)	30	40	40	50
4	40	50	60	60
5	50	60	60	75
6	50	70	75	90
7.5	70	80	90	120
10	80	110	120	150
12	80	130	150	210
15	125	175	210	275
17	100	125	200	300
20	100	150	300	375
25 (maximum)	200	250	350	450

These two tables show the pressure needed for a particular flow. Not every flow is stated in the tables. To find the pressure needed for a flow not stated in the tables, an estimation needs to be used. This estimation can be found by rounding the flow to the next highest value contained in the chart or an interpolation can be made between two values on the chart to find the needed pressure.

5.4 Home Sprinkler System Concessions

From to the WPI Home Fire Sprinklers Project (Gilman et al, 2001), home fire sprinklers would be installed in the bedroom, the kitchen, the laundry room, the dining room, and the lounge.

Figure 6: Area of Origin of Single-Family Home Fires in CFA region between 1998 and 2000



From the CFA data shown in Figure 6, 74% of fires in the CFA region in the past three years originated in a room that is covered by a home sprinkler. Assuming that the data gathered from the CFA database are representative of Victoria as a whole, it can be assumed that 74% of home fires originate in a room covered by a home fire sprinkler. One study examined the performance of home sprinkler systems in Scottsdale, Arizona. The Scottsdale report examined a ten-year case study of the performance of home sprinkler systems. As discussed in the Literature Review, the report found that when one or two sprinkler heads are activated in a fire, the fire is controlled or extinguished 92% of the time (Ford, 1997). When a sprinkler system activates, the heat release rate of a fire is considered to either remain constant or decrease (NFPA 92B, 1991). When the heat release rate decreases the fire size will also decrease and if the heat release rate remains constant once the sprinkler has activated, the fire is assumed to have stopped spreading. For the purpose of this report, a conservative estimate is to assume that if a home sprinkler is activated, the fire growth is held constant. If the fire growth rate is held constant, the fire will be stalled in the room of origin, and can be extinguished by a single high-pressure hose reel. For the purposes of this study, it will be assumed that the water supply in the tank on the appliance will be sufficient to extinguish the fire.

Furthermore, it is assumed that a fire that activates the sprinkler system would be large enough to require extinguishment using a hose, if the room did not have sprinklers. If the fire is controlled by one or two sprinkler heads 92% of the time, as reported by Ford (1997), and 74% of home fires originate in a room fitted with a home fire sprinkler head, then 68% of home fires that would otherwise require extinguishment with a hose will either be contained or extinguished by home sprinklers. From the WPI Home Fire Sprinklers Project, a flow of 1.7 l/s is required to operate two home sprinkler heads (Gilman et al, 2001). This value would be required to extinguish 68% of residential house fires that otherwise would require use of a hose. This study thus assumes that the remaining 32% of hose fires either originate in a room not covered by a home sprinkler, or were not contained by the sprinkler system. To determine the amount water required for a single family home with a home sprinkler system, refer to Table 11.

Table 14: Required Water for Sprinklered Dwelling

Hose Combination for First Appliance	Flow (L/s)	Times Used	Percent	Percent of All Fires (No Sprinklers)	Percent of all Fires with Sprinklers
1-38mm	2	6	0.6	64.6	88.7
2-38mm	4	4	1.0	64.8	88.7
1HPHR	4.2	469	49.0	81.8	94.2
1-65mm	5	1	49.1	81.9	94.2
3-38mm	6	1	49.2	81.9	94.2
1HPHR & 1-38mm	6.2	31	52.4	83.0	94.6
4-38mm	8	1	52.5	83.1	94.6
1HPHR & 2-38mm	8.2	1	52.6	83.1	94.6
2HPHR	8.4	408	94.3	98.0	99.4
1HPHR & 1-65mm	9.2	1	94.4	98.0	99.4
2HPHR & 1-38mm	10.4	15	95.9	98.5	99.5
2HPHR & 2-38mm	12.4	8	96.7	98.8	99.6
2HPHR & 1-65mm	13.4	16	98.4	99.4	99.8
1HPHR & 2-65mm	14.2	1	98.5	99.5	99.8
2HPHR & 3-38mm	14.4	1	98.6	99.5	99.8
2HPHR & 1-38mm & 1-65mm	15.4	2	98.8	99.6	99.9
2HPHR & 4-38mm	16.4	2	99.0	99.6	99.9
2HPHR & 2-38mm & 1-65mm	17.4	1	99.1	99.7	99.9
2HPHR & 2-65mm	18.4	8	99.9	100	100
2HPHR & 3-38mm& 1-65mm	19.4	1	100	100	100

For the purpose of the project, it was assumed that a sprinkler would only be activated under the same conditions that would require a hose. The percentages in this table were calculated by first taking the 68% of the time the fire is controlled or extinguished in a sprinklered dwelling and then multiplying that by the 36% of residential fires that required a hose. Under these conditions, the flow requirements are equal to the follow through the sprinklers of 1.7 l/s. To account for the 32% of the time when sprinklers do not activate or control the fire, or the fire originates in an unsprinklered area of the dwelling, further calculations were made. The percentage of time a certain flow was sufficient was multiplied by 32% for the times the sprinkler did not activate, and that value was multiplied by 36% to include only fires that required a hose. This percentage was added to the first percentage, and was then added to the 64% of fires that did not require a hose.

An example of this is the calculation for the percentage of the time 4.2 l/s would be a sufficient amount in a sprinklered dwelling. The first step is to multiply 36% by 68% to determine the percentage of time the fire would be contained by the sprinkler. This yields a value of 24%. The next step is to account for the 32% of times when the sprinkler will not contain the fire. This is done by multiplying 49%, the percentage of fires where 4.2 l/s is sufficient, by 32% to account for the times sprinklers do not activate, and again by 36%, the percentage of fires where a hose was utilised. This produces a value of 6%. This value is added to 24% to achieve a total value of 30%. This 30% is the amount of time in the past three years when 4.2 l/s was a sufficient flow to extinguish a fire that required a hose in a sprinklered house. This value is then added to 64% of fires that did not require a hose, so that all fires are included yielding a value of 94%. This means that 94% of fires in sprinklered houses would require a flow of 4.2 l/s or less.

From the data, it was concluded that the installation of home fire sprinklers increases the percentage of fires that a certain flow can effectively attack

5.5 Comparison of Current Design Practices with Requirements of Fire Services

During the course of the project, insight into the current design practices of water supply systems was gained. From the WSAA code, a minimum operating pressure of 200 kPa was specified. It was also specified that hydrants are not installed on mains of less than

100mm. Bernoulli's equation can be applied to determine the water velocity according to these specifications.

$$\mathrm{P} * \frac{V^2}{2} + Z = \text{Change in Pressure}$$

Equation 5: Bernoulli's Equation

Where:

P = Density, kg/m^3

V = Water Velocity, m/s

Z = Change in Elevation, m

Inserting the values of 200 kPa and 100mm diameter from the WSAA code outputs a value of 6.3 m/s for the velocity of the water at the hydrant. An equation that relates flow to area and velocity is listed below.

$$Q = V * A$$

Equation 6: Continuity Equation

Where:

Q = Flow, l/s

V = Water Velocity, m/s

A = Cross Sectional Area of Pipe, m^2

Applying the velocity obtained from the equation above, this equation outputs a value of 49.7 l/s for the flow in the pipe. This value is an ideal situation, however, and does not account for any losses throughout the system. According to Jonathan Barnett, Professor of Fire Protection Engineering at WPI, a 40% loss in the system may be expected in order to calculate a more accurate flow (Barnett, 2001). Subtracting this 40% for losses in the system gives a final value of 29.8 l/s. This is the value that would be available under circumstances when the pressure is the minimum possible according to the WSAA code. For this reason, 29.8 l/s is assumed to be a conservative estimate for the flow in a hydrant during a peak daily demand.

From the MFB data, it was shown that 19.4 l/s was a sufficient flow to extinguish 100% of residential fires in the years 1998-2000. For this reason, it can be concluded that there is currently a sufficient amount of water for fire fighting purposes.

6.0 Recommendations

6.1 Improvement to Current Methods

During the course of the project, several possible areas of improvement were determined. The first area was potential improvement to the AIRS reporting system. Concerns were expressed about the recording methods for brigade response times. Information pertaining to the confinement of the fire is recorded, however it is very difficult to correlate this to brigade response time. If conclusions could possibly be drawn relating the fire size to the response time, the brigade intervention time could be included in the technical model began by the team. By including the intervention time of the brigade, specific characteristics of a development such as distance from the nearest brigade could be accounted for. This would make the model more site specific.

6.2 Suggestions for Future Work

Future work that may be completed would be to further examine concessions made for home fire sprinklers. In this report, it is assumed that if the fire originates in a room without a home sprinkler, or if the sprinklers do not activate correctly, the fire spreads throughout the rest of the house as if there were no sprinklers. In fact, it is possible that the fire would spread into a room with a sprinkler and would be contained. This would most likely require less water than if the house had no sprinkler system.

The team started work on a more technical approach to the determination of required fire flow. However it was decided that this approach required a more technical background than the team possessed. It is the teams' opinion however that this method would provide a more technical solution to the amount of fire water required. One aspect of this approach that must be researched further is the involvement of a fire at the time of brigade notification. Currently there is no data available on this topic, and the most conservative estimate would be to assume flashover in the room of origin at the time that the brigade is initially notified. This leads into another aspect of this approach that must be researched further. A fire cannot be modelled for how it spreads after the room of origin if detailed house plans are not available. The last major assumption that was made in the approach that must be researched further is one originally made by Rasbash (1986) and endorsed by the Fire Brigade Intervention Model of the AFAC. This assumption deals with diffusion flames, and how much water is required to extinguish a fire. Progress made by the team with regards to this technical approach is documented in Appendix C of this report.

7.0 Conclusions

Knowledge has been gathered and applied in the past four months, both at Worcester Polytechnic Institute (WPI) and in Melbourne. Background research was performed at WPI in order familiarise the team with the topic of water supplies for fire protection. This research focused primarily on distribution systems, different types of water supplies, and current methods for determining the required fire flow based on the specifications of a structure. Once a sufficient background was gained, a tentative methodology was formulated. This methodology was focused heavily on interviews with water suppliers, developers, and fire officials.

During the first week at the project centre, several points were learned to be contradictory to what was originally thought. At this beginning of this project it was believed that water for fire fighting was a major concern in water infrastructure design. It was also assumed that the developer would be a major contributor to the determination of required water for fire fighting, and the water supplier would only be important to the project from a cost perspective as they would be providing the water. It was soon determined that the developer had no responsibility in the design of the water infrastructure, and in fact it was the water supplier who was in charge of the design, installation, and maintenance of the system. More importantly, it was learned that water for fire fighting is of no concern to the water authorities. These findings significantly altered the methodology of this project. The focus turned to the water suppliers and determining what current design practices are utilised rather than concentrating on the role of the developer. The Australian Incident Reporting System (AIRS) database also altered the methodology. This database records specific data pertaining to all fire incidents. This database includes the type of fire, the level of confinement, the hoses utilised, as well as numerous other fields. After a discussion with representatives of the

Australasian Fire Authorities Council, the methodology was revised to include the current design practices of the water suppliers as well as the AIRS database.

Once the scope of the project was more clearly defined, the revised methodology was implemented and the necessary data were gathered. The majority of information was gathered through interviews with design engineers at the water authorities and fire officials at both the Metropolitan Fire and Emergency Services Board and the Country Fire Authority. All interviews were transcribed into brief summaries that were sent out for approval to eliminate any reporting inaccuracies.

Data obtained from the AIRS database relating to the number of hoses used for different fires were combined with the MFESB Water Requirements Project to provide values for the minimum required fire flow for each scenario (MFESB, 2001). This was accomplished by determining the minimum flow required to effectively operate each different piece of equipment, and then summing the flows for all the equipment used. These minimum fire flows were compiled into a tabular form that related a specific flow in litres per second to the percentage of fires it would have been a sufficient supply to extinguish. An example of this is that it can be interpreted from the data that 4.2 l/s of flow would be sufficient to combat 81.83% of all residential fires.

The final step was to compare the current design practices of the water authorities to the fire flow requirements that were extrapolated from the AIRS data, and to account for concessions that could be made for home fire sprinklers. This comparison showed the project team that currently there is enough water provided by the water authorities for the fire services even though it is not a factor in the infrastructure design. However, future conflicts may result from changes to the current water design criteria. The water authorities are currently examining the possibility of reducing pipe diameters and increasing the pressure so a high quality drinking water can be provided. Since water used for fire fighting is not a concern in the design of water infrastructures, the water authorities will reduce the flows and pressures to suit the needs of the consumer rather than the needs of the fire brigades. If pipes are reduced in diameter this will restrict the quantity of water that will be available for fire fighting purposes. This may prevent the fire services from being able to effectively fight a fire. A comparison of the current or proposed design practices of the water authorities and the water requirements of the fire services can be used to establish a minimum flow to which the water authorities are able to reduce their service.

From the MFB data gathered on residential fires in the years 1998-2000, it was determined that the maximum flow required to fight a residential fire was 19.4 l/s. A review of the specified size and pressures of water infrastructures from the WSAA Proposed Code of Practice showed that a flow of 29.8 l/s is available from a hydrant at a peak daily demand. This means that the current design standards of the water authorities that account for domestic usage also supply a sufficient amount of water for fire fighting purposes.

A study of the impact of home fire sprinklers on the amount of water required from a hydrant to fight a residential fire was also performed. It was found from the MFB data that the installation of fire sprinklers in a residential dwelling reduces probability that large amounts of water will be required from a hydrant. This conclusion is based on limited data, however. Currently there are no studies on the topic of how fires spread in houses equipped with home sprinklers when the fire originates in a room without a sprinkler. A fire would spread differently in a house equipped with home sprinklers than a house without them, and this would impact the amount of water required to combat the fire. For this reason, it is suggested by the team that further work be completed on the topic of fire water concessions for home fire sprinklers.

8.0 GLOSSARY

AFAC - Australasian Fire Authority Council

Appurtenances- the mechanical accessories employed in any function or complex scheme

Atmospheric Pressure- the weight of air, 14.7 psi (101.325 kPa) at sea level, decreases approximately 0.5 psi (3.447379 kPa) per 1000 ft. (304.8 m) of increased elevation.

Attack line- hose used to apply water to a fire

Authority Having Jurisdiction- the organisation or individual that has the authority to approve equipment, procedures, and activities within certain boundaries

AWWA - American Water Works Association

Check valve- a valve that only allows flow in one direction

Culture barometer- someone who is familiar with the culture surrounding research without a specific stake in the research

Culture broker- a person within the research scope that is able to help gain access to interviews and other research options

DR - Delivery Rate

Drafting- the process of taking water from a non pressurised source by creating a vacuum by use of a pump, which allows atmospheric pressure to force water through the line and into the pump

Exposure Hazard- A structure within 15 m (50 ft) of another building and 9.3 m^2 (100 ft^2) or larger in size

Fire flow- the rate of a water supply, measured at 20-psi (137.9kPa) residual pressure, which is available for firefighting

Friction loss- pressure loss caused by the friction of water against the waterway's surface as the water moves through the waterway

Frost line- the limit to the depth of penetration into soil by freezing temperatures

ft.- feet

Fusible element- a glass bulb or a metal link, which under the heat from a fire bursts or melts away

in.- Inches

ISO – Insurance Services Office

kPa – kilopascals

m- meters

MFESB - Melbourne Fire and Emergency Services Board

NFPA - National Fire Protection Association

NZFS - New Zealand Fire Service

Occupancy Hazard Classification Number (OHCN)- A series of numbers from 3 through 7 that are mathematical factors used in a formula to determine total water supply requirements of NFPA standard 1142.

Potable water- water that is certified for consumption by the proper authorities

psi- pounds per square inch

Residual Pressure- pressure remaining at a hydrant with water flowing through supply lines to the attack pumper

Response time- time from when an alarm is received

Tamping- the process in which the molten lead is conformed to the opening to form a watertight seal

TWS - Total Water Supply

UFC - Uniform Fire Code

Water hammer- banging noise heard in a water pipe following an abrupt alteration of the flow with resultant pressure surges

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Appendix A: Additional Background Research

A.1 Introduction

This appendix includes background information that has been researched in the beginning phases of the project. This information is relevant to a water supplies project, however it does not pertain to the specific goals of this project. It therefore has been placed in this appendix.

A.1.1 Water Supply Systems

A.1.1.1 Introduction

Water has several properties that make it the most common and primary fire-suppressing agent in use. These properties include excellent cooling and quenching rates, its relative abundance, the many forms in which it can be applied to a fire (such as a solid stream or a fine mist) and the fact that it is easily distributed due to its low viscosity (Corbett, 1991). This final property is observable in the many methods that can be used to provide water to the scene of a fire. Some of these methods include the use of distribution systems, fire hydrants, suction point supplies and home sprinklers. In these delivery methods the critical factors for firefighting are pressure, flow rate and the total quantity of water available from the water supply system.

A.1.1.2 Distribution Systems

The distribution system is the backbone of any water supply. Distribution system design is a highly specialised science in which the size of the pipe and pressure of the water are critical in the determination of water volume and flow. Too much pressure or too small a pipe will place unnecessary strain on the system, thus increasing maintenance costs. If the pressure in the pipes is too low, the flow will be insufficient.

The ability of a water system to adequately supply water for fire protection and domestic consumption is based upon several key factors. These factors include the carrying capacity of the system, which is the amount of water that can be carried by the system, and the friction losses incurred as the water passes through the system. Factors that can affect the carrying capacity include the size and length of the pipe, the pressure at the source, and the resistance to flow. Friction losses, valves, and the geometry of the pipe govern the resistance to flow. Pipes that bend and angle have larger losses than pipes that run straight (AWWA, 1989).

Designing and evaluating water systems considers three rates of consumption. These rates of consumption establish a base to which required fire flows can be added in designing a system or determining its adequacy. These rates include the average daily demand, the maximum daily demand, and the maximum hourly demand. The average daily demand is the average of the total amount of water used each day in a one-year period. The maximum daily demand is the maximum total amount of water used during any 24-hour period in a three-year period. The maximum hourly demand is the maximum amount of water used in any single hour of any single day in a three-year period (AWWA, 1989).

Water supply infrastructure can be subdivided into three major categories: grid systems, dead-end systems, and loop systems (AWWA, 1989). While the grid system is the most popular, all three are effective and may often be found working together in the same infrastructure. The grid system layout is divided into three major types of pipe: primary feeders, secondary feeders, and distribution lines. Primary feeders are the largest of the three running around the edge of the system. The primary feeders should form a loop roughly two-thirds of the distance from the centre of the community to the outskirts of the community

(AWWA, 1989). Branching off of the primary feeders in a grid system are the secondary feeders that are typically a few sizes smaller in diameter. Branching off of the secondary feeders are the distribution lines that will be used to feed the domestic needs of the community (AWWA, 1989). Spaced among these different lines are various valves, hydrants, and meters. The looping system formed by the primary feeders in a grid system makes pipe size calculations intensive, however it also keeps a constant flow that prevents water stagnation. In case of a pipe failure, the failing section can be shut down and the dwelling will still be supplied with water from the other side (Al-Layla, 1977).

A branching or dead end system layout is a series of mains, and sub-mains that branch out from a central line. It is a very simple method that incorporates a very simple design. Since the water is always in the same direction and only from a single source, the pipe sizes are very economical (Al-Layla, 1977).

Primary feeders, also called water mains, are the backbone of any successful water infrastructure. Mains can be negatively affected by a variety of troubles such as deterioration due to age, corroded lines, or poor maintenance. Another possible obstruction is the development of incrustations or deposits in the main. Incrustations can severely cut the amount of water that will be supplied by the system, as the incrustations will increase the losses due to friction. Culp and Wesner (1986) state that it is important to establish criteria for minimum and maximum system pressures occurring during the maximum hour demand. In some cases it is also desirable to establish maximum pressure fluctuations within specific areas of the water distribution system (Culp and Wesner, 1986). Typically, minimum acceptable water system pressures are 1,190 to 1,360 kPa (35 to 40 psi), and maximum pressures are 3,400 to 4,080 kPa (100 to 120 psi). A minimum system pressure of 1,190 to 1,360 kPa (35 to 40 psi) will normally ensure adequate flows to the individual consumers and allows for reasonable operation of home-type irrigation/sprinkler systems. A more desirable system pressure may be in the range of 1,700 kPa (50 psi). This level of system pressure provides adequate flows and working pressures for most typical residential and commercial uses. Maximum pressure limitations are desirable to minimise the additional cost of providing piping materials with adequate strength to cope with the high pressure (Culp and Wesner, 1986).

Culp and Wesner (1986) also state that water distribution system networks are expensive; and they are expected to be in service for long periods of time, without significant cost for maintenance, repair, or replacement. For these reasons, the construction and maintenance of water systems are equally as important as proper sizing and design (Culp and Wesner, 1986). The route onto which the pipe will be laid must also be an important consideration. Topographical, soil, and geological factors must be taken into consideration. Pipes should not be laid on rough or difficult terrain. The same precautions should be taken with land that may be prone to landslide or other hazards that could damage the pipe. When piping is installed, proper trenching, bedding, and back filling are required to properly protect the system (Culp and Wesner, 1986). Mains should follow the general contour of the ground, and should not ordinarily rise above the hydraulic gradient; otherwise there may be problems with drainage (Al-Layla, 1977). All installations should be constructed with the consideration for the need of repair in the future.

In determining pipe placements, several factors must be taken into account. Water pipes must be at least 3.0 m (10 ft) away from a sanitary sewer in a parallel installation, a parallel installation being one in which two pipes run parallel to each other throughout the system. The exception to this rule is that a water pipe may be set closer to a sanitary sewer line if the water pipe is elevated 0.46 m (18 in) above the sewer pipe. In a perpendicular crossing where a water line passes over domestic or municipal sewers, again the water pipe must be elevated 0.46 m (18 in) above the sewer pipe. A water pipe should never pass through or come in contact with any part of a sewer or manhole (Culp and Wesner, 1986).

A.1.1.3 Pumps

Water pumps are an integral part of any distribution system that draws water from a low source, or for any system that fails to meet the required flow or pressure. A pump should be designed for the volume of water that will be required as well as the accompanying pressure that may be needed. The work done by a pump may be expressed in a simple mathematical equation in the form

$$P'' = DgQH$$

Equation 7: Work done by a Pump

Where:

P'' = Work, watts

D = density of fluid, kg/m^3

g = acceleration due to gravity, m/sec^2

Q =rate of water flow, m^3/sec

H = manometric head or total head, m

The power required equals P'' divided by the efficiency of the pump. The efficiency can vary from 0.7 to 0.95 for a reciprocating pump, and from 0.4 to 0.85 for a centrifugal pump (Al-Layla, 1977).

Pumps are classified into several different categories: reciprocating pumps, hand pumps, and centrifugal pumps. Reciprocating pumps work on the principle of a piston moving back and forth in a cylinder. This cylinder is connected to a water line. The back motion of the piston creates suction, drawing up water and the forward motion of the piston provides pressure, forcing the water through the line. Reciprocating pumps can be single acting, double acting, or a differential plunger. A hand pump is only used in homes and is not applicable in a large-scale operation. A centrifugal pump pumps water using centrifugal force, specifically a large spinning wheel that propels the water out the discharge (Al-Layla, 1977).

A.1.1.4 Hydraulics

To calculate the pipe size required for the desired pressure and rate of flow, the flow hydraulics must be considered. Specifically, the head loss in a pressure pipeline system carrying water can be calculated using the following equation:

$$H_L = K_L \times (\frac{V^2}{2 \times g})$$

Equation 8: Equation for Head Loss

Where:

H_L = head loss, ft

K_L = head loss coefficient, dimensionless

V = velocity, ft/sec

g = acceleration due to gravity, ft/sec^2

(Culp and Wessner, 1986)

K_L varies depending on the type of system that is being calculated. Special losses of head are listed in appendix B (Culp and Wessner, 1986). The head losses incurred in a piping system may result from any combination of pipe friction, bends, reducers, valves, controls, branches, intersections, orifices, nozzles, and manifolds. The magnitude of this head loss is determined by the size of the pipe, the roughness of the pipe, the length of the pipe, the liquid viscosity and the loss through appurtenances within the system (Culp and Wessner, 1986). The head loss due to friction can be approximated using one of several formulas. These formulas include the Hazen-Williams, Darcy-Weisbach, or the Manning's. The Hazen-Williams formula is as follows:

$$V = 1.318 \times C_{HW} \times R_H^{0.63} \times S^{0.054}$$

Equation 9: Hazen-Williams Formula

Where:

V = velocity, ft/sec

C_{HW} = Hazen-Williams friction factor, dimensionless

R_H = hydraulic radius, ft

S = energy slope, ft/ft

The Hazen-Williams friction factor is shown in appendix B (Culp and Wessner, 1986, p 846).

The Darcy-Weisbach is given as:

$$H_{DW} = f \frac{L}{D} \frac{V^2}{2g}$$

Equation 10: Darcy-Weisbach Equation

Where:

H_{DW} = Head loss, m

f = Roughness coefficient, dimensionless

D = Diameter of pipe, m

L = Length of pipe, m

V = Average pipe velocity, m/sec

g = Acceleration due to gravity, m/sec^2

The Manning formula is:

$$V = \frac{1.49}{n} R^{2/3} S^{2/3}$$

Equation 11: Manning Formula

Where:

V = Velocity, ft/sec

n = Manning roughness coefficient, dimensionless

R = Hydraulic radius, ft

S = Energy slope, ft/ft

Values for the Manning roughness coefficient are given in appendix B (Culp and Wessner, 1986). These equations can also be altered to represent outlets, open channels, conveyance channels, weirs, baffles, and filters (Culp and Wessner, 1986).

A.1.2 Fire Hydrants

Being the main source of water for fire fighters arriving on the scene, fire hydrants are a critical aspect of any fire fighting operation. William Eckman suggests that fire hydrants are "the most reliable source of water for fire protection" (1994, p125). Pressurised hydrants are part of a water distribution system. This distribution system can be either a private system or a municipal system. Both systems are similar in design, however some private systems may be unable to supply the needed flow for the buildings they are installed to protect (Eckman, 1994). Uncertainty limits private systems. The methods involved in the construction of private systems makes them unreliable. In these private systems; pipes can be insufficient in diameter, the water capacity can be insufficient, cross connections are rarely used (cross connections allow water to flow from multiple directions) and private systems can be tied into other systems such as home irrigation systems, which can limit the flow to a hydrant (Eckman, 1994).

There are four factors that limit the operation of a fire hydrant system (Eckman, 1994):

1. The maximum production rate of a water source
2. The amount of water in storage
3. The distribution system
4. The installation and maintenance of the system

These factors are always involved in the operation of a hydrant system, however with proper planning of a system the effects of these limiting factors can be minimised.

Pressurised hydrants are most commonly found on public water systems. These hydrants require periodic maintenance. A public water system's primary goal is to provide the community with potable water. Potable water is water that is certified by the proper authorities to be of a high enough quality for drinking water. The installation and maintenance of hydrants for fire fighting is secondary to the supply of potable water. This neglect causes some fire hydrants to be of questionable reliability. With proper care and maintenance, however, hydrants can be a reliable water supply (Eckman, 1994).

Pressurised hydrants exist in two varieties, wet barrel and dry barrel. Dry barrel hydrants are not pertinent to this project. Wet barrel hydrants are found in areas where the risk of freezing temperatures is negligible. These hydrants are filled with water right up to the release valve at the foot of the above ground hydrant.

Since pressurised hydrants are often located on public water systems, the amount of water available at any one time is limited by the normal water usage of that system. For example the amount of water available in the late hours of the night will be more than the amount of water available during peak usage hours (Eckman 1994). To compensate for this some systems maintain an amount of water reserved specifically for use in fire fighting (Eckman, 1994).

In regards to water flow for fire hydrants, the NFPA has set some stringent guidelines. According to the NFPA, fire hydrants shall be supplied by not less than a 150 mm (6 in) diameter main installed on a looped system or by not less than a 200 mm (8 in) diameter pipe if the system is not looped or the fire hydrant is installed on a dead end main exceeding 92 m (300 ft) in length (NFPA 1141, 1998). NFPA 1141 (1998) requires that dead end mains shall not exceed 184 m (600 ft) in length for main sizes less than 250 mm (10 in) in diameter. The American Water Works Association (AWWA) manual states that if the public water supply is to be used for fire suppression and a sprinkler system is not readily available, the supply available at a given point in the system must be no less than 32 L/s (500 GPM) at a residual pressure of 140 kPa (20 psi). This represents the amount of water required to provide for two standard hose streams on a given fire. In the judgment of many professionals, this is the minimum amount of water with which any fire can be controlled and suppressed safely and effectively (AWWA, 1989).

The function of a fire hydrant is measured by its ability to deliver the required fire flow. The fire flow, in gallons per minute, of a pressurised fire hydrant can easily be measured using a formula based on the pressure of the system at the outlet. This formula is (Mahoney, 1980, p148):

$$D = 29.32 \times d^2 \times \sqrt{P} \times C$$

Equation 12: Fire Flow from a Fire Hydrant

Where:

D = Discharge, gal/min

d = the inner diameter of the water outlet, in

P = the pressure of the outlet, psi

29.32 = this is the conversion from pounds per minute to gallons per minute

C = discharge coefficient, which is based on the shape of the outlet inside the hydrant, this value can be 0.9 for a smooth surface, 0.8 for a ninety degree edge or 0.7 for an edge with a lip, dimensionless (Mahoney, 1980).

To test the amount of flow available at different locations along a distribution system, a fire flow test is usually made. The manner in which this test operates is very simplistic. Water is discharged at a measured rate from some point in the system, usually a hydrant, and the corresponding pressure at other points in the system are calculated. The magnitude of the pressure drop at the other points in the system will be the deciding factor in whether or not the system capability is sufficient. It is customary to perform the test on the secondary branch mains (Casey, 1970).

A.1.3 Sprinkler Systems

A new trend in home fire protection is that of home sprinkler systems. These systems greatly reduce the possibility of a small fire escalating into a fully involved fire. A sprinkler system is series of pressurised, suspended pipes spread throughout a building, or more specifically a home. The fire flow from sprinklers is delivered by a series of nozzles spaced regularly over the length of the pipes (Factory Mutual Insurance Company, 1999).

A.1.1.5 Types

There are four types of sprinkler systems: wet pipe, dry pipe, pre-action and deluge. However only the wet pipe system is used in home sprinklers and applicable to this project.

The wet pipe system is the most common type of sprinkler system. Having all of the pipes filled with water under pressure is the main characteristic of this system. A sprinkler head is activated when the fusible element is broken. This fusible element is either a glass bulb or a metal link, which bursts under the heat of a fire. This fusible element is what holds back the pressurised water in the pipes. When it is broken the water in the pipes is able to flow out of the opening and is applied to the fire (Factory Mutual Insurance Company, 1999).

A.1.4 Suction Point Supply

In some areas there is no water distribution system. These areas need to utilise alternatives to fire hydrants. Suction point supply is one such alternative. A suction point supply is a water supply that utilises existing or pre-planned water reservoirs for fire fighting water. Suction point supply is also used as a supplement where not enough water can be provided for fire fighting by the existing water distribution system (Eckman, 1995). Utilising natural water reservoirs is a cost effective method of supplementing a deficient water distribution system because it is often cheaper to utilise this source than to update an existing system (Eckman, 1994).

A.1.1.6 Volume of a Natural Source

The first step in utilising a suction point supply is identifying a useable source. These sources can range from lakes or ponds, to streams, to household swimming pools (Eckman, 1995). These sources are often privately owned and utilising them would require the permission of the owner (Eckman, 1994). Once a source has been identified, it is necessary to calculate the total amount of water available through that source. This calculation only needs to be an estimate and not an exact figure. For this a simple formula can be used (Eckman, 1994):

$$L \times D \times W \times 1000 = V$$

Equation 13: Volume of a Natural Source

Where:

V= volume of the source

L= average length of the source, m

D= average depth of the source, m

W= average width of the source, m

1000 is the conversion factor from cubic metres to litres (Eckman, 1994).

If the source is a moving body of water such as a river the flow of the river must be evaluated rather than the capacity. This flow can be estimated using the following formula (Davis, 1986):

$$Q = D \times W \times V \times 1000$$

Equation 14: Flow of a Natural Source

Q = total flow of the source, L/s

D = the average depth of the source, m

W = the average width of the source, m

V = the velocity of the source, m/s

1000 is the conversion factor from cubic metres per second to litres per second (Davis, 1986).

A natural water source should have at least a 950 000 L (250 000 gal) capacity. This large quantity provides that factors such as droughts cannot ruin the supply (Hanley & Murchison, 2000). Also the use of a natural source should not destroy or disturb the ecosystem of the source (Hanley & Murchison, 2000).

A.1.1.7 Strainers and Water Quality

The operation of a suction point supply system requires a pump. This pump is needed to create a vacuum in the line between the source and the pump. This vacuum draws water through the line to the desired location. However, natural bodies of water are often cluttered with silt and debris. If these solid objects are drawn into the line and able to reach the pump, damage could be done to an expensive and necessary piece of equipment. To prevent this from happening it is suggested that a strainer be used on the end of a hose for a suction point supply (Eckman, 1994). This strainer should also be monitored during use to make sure that it does not become blocked with debris, which will inhibit the flow of the system (Eckman, 1994). The quality of the water is also an issue to be aware of. The quality of the water can damage the equipment of a suction point supply. For example if salt water is run through a pump, the salt in the water can accelerate the corrosion of the pump parts. For this reason suction point supply systems need to be back-flushed with clean water after every use (Eckman, 1994).

A.1.1.8 Minimum Depth

Another precaution in suction point supply is that of a minimum depth that the strainer should sit at in the water source. When the strainer is not deep enough the suction power of the pump can create whirlpools on the surface of the water. These whirlpools will allow air into the hose and pump. This air will decrease the efficiency of the supply and decrease the maximum water flow that can deliver (Eckman, 1994). When the pump is placed close to the bottom of a water source with loose debris on the bottom, a larger than normal amount of dirt and debris can interfere with the strainer and affect the performance of the supply system (Davis, 1986). To compensate for both of these factors, shallow placement and deep placement, it is useful to use a minimum depth requirement. Eckman (1994) suggests that at least 0.46 m (18 in.) of water surround the strainer on all sides. However Hanley and

Murchison (2000) suggest a minimum depth of 0.61 m (24 in.) on all sides. This second, more conservative, estimate would be a better choice as the extra 0.15 m (6 in.) will do no harm and only further insure the operation of the system. Eckman (1994) also mentions that when a water supply of sufficient depth cannot be found, a dam can easily be constructed out of common supplies found on a fire engine or surrounding the water source.

Another solution to overcome this depth issue is the use of a floating strainer. A floating strainer floats on the surface of the water. Water is drawn into the strainer through the submerged side of the strainer. This reduces the whirlpools that can form because the water has to be drawn around the float itself in order to enter the strainer. This float also keeps the strainer above the bottom of the water source (Eckman, 1994).

A.1.1.9 Drafting Hydrants

A suction point supply can be established quickly at any acceptable water source. In some instances permanent suction point supplies are established. These permanent suction point supplies are known as drafting hydrants (Eckman, 1994). Drafting hydrants consist of nothing more than permanently installed underground suction pipes. These pipes extend from the water of the water supply to a point on land. At this point the pipes come up from underground, either with a gradual rise or at a 90-degree angle. The pipes usually come to locations on the land, which are more accessible than the water supply itself (Davis, 1986). Drafting hydrants come in two varieties, wet and dry. A wet hydrant is one in which the hydrant is placed below the surface level of the water source. This causes the atmospheric pressure to force water through the suction pipe and to the mouth of the hydrant. Wet hydrants require pumps to provide an adequate fire flow. This is, however, a smaller pump than is required by the dry hydrant. Wet hydrants also require a shut off valve to stop the flow of the water caused by this atmospheric pressure (Eckman, 1994).

A dry hydrant is one that is installed above the surface level of the water source. This type of drafting hydrant is more common than the wet drafting hydrant. Like wet drafting hydrants a pump is required for the use in dry hydrants. However the pump is initially used to create a vacuum in the tube (Eckman, 1994). A vacuum is necessary because of the nature of a dry hydrant. The dry hydrant is installed above the surface level of the water source. This means that atmospheric pressure will only fill the pipe up to a level equal to the surface level of the water source. This leaves a volume of air in the pipe between the surface level of the water and the opening of the hydrant (Eckman, 1994). A vacuum is needed to draw the water up to the opening of the hydrant. The act of creating this vacuum is called priming. As stated by the NFPA, "a primer must be able to develop 56 cm (22 in.) vacuum in 30 seconds." (Eckman, 1994, p173). Once this vacuum has been created the water level in the pipe will rise to the opening of the pipe. This will allow water to flow into a suction hose attached to the hydrant. The purpose of the pump then is to provide enough power to give the required fire flow rate (Eckman, 1994).

There are many reasons to use a dry hydrant when suction point supply is the best option for fire fighting water. First dry hydrants are generally located in easily accessible locations versus the supply itself, which might be difficult to gain access to. Second, large lengths of suction hose are not needed between the pump and the hydrant since the hydrant is located in an accessible spot. Third, there is strainer built into the dry hydrant so that time is not wasted attaching a strainer to a suction hose. Fourth, because of the accessibility of the dry hydrant the pump can be positioned quickly and easily. Fifth, dry hydrants can permit a higher flow rate than can just a suction hose. Finally the number of personnel needed to operate a dry hydrant is less than that needed to operate a suction hose (Davis, 1986).

A.1.1.10 Static Supply

Another type of water supply system is that of a fixed water, or static supply system. Static supplies are generally man-made storage tanks, or cisterns, for use in fire fighting. These tanks can be established in almost any area. The tanks can vary in placement from being buried underground to being placed on the roofs of buildings (Eckman, 1994).
All storage tanks should meet specific guidelines to insure proper operation when they are needed. No partition should exist in the tank. It should consist of one continuous volume (Hanley and Murchison, 2000). Also all static supply tanks should have vent pipes. These vent pipes are a hook shape with the open-end facing down; this allows air into the tank without allowing any form of liquid such as rain into the supply. It is necessary for air to be allowed into to the tank because as the water is evacuated from the tank it will create a vacuum. As more water escapes the vacuum will increase pulling on the water and hindering the total flow of the system (Eckman, 1994). The tank must also have a fill pipe with a control valve to turn the flow of water on and off. This will allow the tank to be refilled after use and the control valve will prevent the tank from overfilling (Hanley and Murchison, 2000). An access tunnel needs to be provided into the cavity of the storage tank. This ensures that if there are problems with the operation of the tank, it is capable of being repaired (Hanley and Murchison, 2000). Hanley and Murchison (2000, p90) also suggest that any storage tank intended for use in a residential area have a capacity of at least 76 000 L (20 000 gal). Also in areas where freezing temperatures are a risk tanks should be buried underground. These tanks must be buried at a depth below the frost line (Hanley and Murchison, 2000).

The operation of a static supply system is much like that of other suction point supplies. In the case of an underground storage tank the operation is identical to that of dry hydrant. A pump must be used to prime the storage tank, and once the water has begun to flow the pump is needed to provide the proper pressure to the hose. When the storage tank is suspended above ground level in some manner, gravity is the primary source of pressure for the system. The pressure due to the elevation will increase as the height above the system increases. However, if this pressure is not enough, a pump can be used to provide enough pressure to meet the required fire flow (Eckman, 1994).

A.1.5 Dry Barrel Hydrants

Dry barrel hydrants are found in areas where freezing temperatures are a factor. These hydrants are supplied with water only up to the frost line between the foot piece and the barrel. A drain is located at the bottom of the barrel above the control valve seat for proper drainage after operation (NFPA 25, 1998, p7). The drain holes allow any water left in the hydrant after use to run out of the pipes at a level below the frost level, this prevents any water from freezing in the barrel and damaging the hydrant (Eckman, 1994).

A.1.6 Sprinkler Systems

There are many types of sprinkler systems other than those mentioned in the literature review. A second type of sprinkler system is a dry pipe system. This type of system is utilised in areas where freezing temperatures are a risk. The pipes of the system are filled with pressurised air, which keeps water out of the pipes and therefore prevents damage due to freezing water. When a fire breaks the fusible element, the air in the pipes is released through the sprinkler head. This allows water to enter the piping system and discharge through the sprinkler head (Factory Mutual Insurance Company, 1999).

The third type of sprinkler system is the preaction system. This system is similar to the dry pipe system. However, in this system heat or smoke detectors are also utilised. When a detector is activated, a control valve releases water into the pipes of the system. The water will remain in the pipes until the fusible element is broken. When the fusible element breaks water will be applied to the fire (Factory Mutual Insurance Company, 1999).

The final type of sprinkler system is a deluge system. This method operates the same as the preaction system, except for one difference; there is no fusible element. When the detector is activated and water enters the pipes, nothing holds the water in the pipes. The water is discharged through all of the sprinkler heads on the entire system simultaneously (Factory Mutual Insurance Company, 1999).

Sprinkler systems provide an immediate response to a fire. This reduces the response time that is needed by a fire department to arrive at the scene of a fire. By having a shorter response time, a fire can be controlled before it escalates into a fully involved fire (Factory Mutual Insurance Company, 1999).

A.1.7 Valves and Joints

The water-flow though the main will be governed by control valves. These valves can be as simple as a ball valve, or can be a more complex valve. These valves are generally evenly spaced along the length of the main to ensure that a problem with the pipe can be isolated without causing a major loss of pressure to the entire community. The valves can generally be accessed by use of a valve wrench. In some situations, an above ground valve box may access the valve. A check valve may be used in situations where water may be contaminated. By using a check valve, water is only allowed to flow in one direction so that infected water cannot backwash through the pipe and taint the existing supply. All control valves and check valves should be listed indicating the model and type of each valve used. Water control valves should not close in less than five seconds when operated at maximum possible speed from the full open position to avoid damage to piping by water hammer.

Water hammer is a banging noise heard in a water pipe following an abrupt alteration of the flow with resultant pressure surges. At least one control valve should be installed in each source of water supply except for fire department connections. Where there is more than one source of water supply, a check valve should be installed in each connection, with a control valve on each side of each check valve. Each control valve should be located where it is readily accessible and free of obstructions (NFPA 24, 1995).

Since pipe lengths must be kept to a workable size for the ease of installation, joints and other connections become a critical aspect of the water system. There are numerous types of joints that are applicable over a wide range of situations. Bell and spigot joints are used for both steel and cast iron pipes. The space in the joint is filled with yarn and then filled with molten lead and tamped. Tamping is the process in which the molten lead is conformed to the opening to form a watertight seal. A threaded joint provides a very strong connection where the seal is kept water tight through the use of a rubber gasket. A threaded ring with teeth is pushed in against the gasket to grip the outside of the spigot and hold the joint securely. A mechanical joint is also made water tight with the use of a rubber gasket. This mechanical joint is secured using a cast iron follower ring that connects to the bell end to make the joint secure. A flange joint has no male or female ends, the end of each pipe tilts upward to approximately a right angle. A rubber washer is placed in between and the outsides of the pipes are connected using clamps. This type of joint is well suited to high pressure and temperature variant applications. A welded joint is most commonly used in large diameter steel pipes. These joints are more difficult to construct because they require more skills for installation. (Culp and Wesner, 1986)

Appendix B: Tables Taken From Literature Review

Table 15: Manning Roughness Coefficient (Culp and Wessner, 1986, p848)

Table 26-3. Values of the Manning Roughness Coefficient.*

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL**	MAXIMUM
A. CLOSED CONDUITS FLOWING PARTLY FULL			
A-1. Metal			
a. Brass, smooth	0.009	0.010	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	0.024	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	0.010	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	0.013	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	0.014	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	0.013	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	0.016	0.018
g. Brickwork			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030
B. LINED OR BUILT-UP CHANNELS			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	0.012	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023

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Table 26-3 (Continued)

Table 25–3 (*Continued*)

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL**	MAXIMUM
6. Granite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	0.013	0.015
2. In cement mortar	0.012	0.015	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	—	0.500

Table 25–3 (*Continued*)

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL**	MAXIMUM
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080

Table 25–3 (*Continued*)

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL**	MAXIMUM
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The *n* value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	—	0.060
b. Irregular and rough section	0.035	—	0.100

Table 16: Uniform Fire Code: Minimum Required Fire Flow and Flow Duration for Buildings

TABLE A-III-A-1 MINIMUM REQUIRED FIRE FLOW AND FLOW DURATION FOR BUILDINGS

FIRE AREA (square feet) x 0.0929 for square meters					**FIRE FLOW (gallons per minute)****	**Flow Duration (hours)**
Type I-F.R. II-F.R.*	**Type II One-HR III One-HR.***	**Type IV-H.T. V-One-HR.***	**Type II-N III-N***	**Type V-N***	**x 3.785 for L/min.**	
0-22,700	0 - 12,700	0 - 8,200	0 - 5,900	0 - 3,600	1,500	2
22,701 - 30,200	12,701 - 17,000	8,201 - 10,900	5,901 - 7,900	3,601 - 4,800	1,750	
30,201 - 38,700	17,001 - 21,800	10,901 - 12,900	7,901 - 9,800	4,801 - 6,200	2,000	
38,701 - 48,300	21,801 - 24,200	12,901 - 17,400	9,801 - 12,600	6,201 - 7,700	2,250	
48,301 - 59,000	24,201 - 33,200	17,401 - 21,300	12,601 - 15,400	7,701 - 9,400	2,500	
59,001 - 70,900	33,201 - 39,700	21,301 - 25,500	15,401 - 18,400	9,401 - 11,300	2,750	
70,901 - 83,700	39,701 - 47,100	25,501 - 30,100	18,401 - 21,800	11,301 - 13,400	3,000	3
83,701 - 97,700	47,101 - 54,900	30,101 - 35,200	21,801 - 25,900	13,401 - 15,600	3,250	
97,701 - 112,700	54,901 - 63,400	35,201 - 40,600	25,901 - 29,300	15,601 - 18,000	3,500	
112,701 - 128,700	63,401 - 72,400	40,601 - 46,400	29,301 - 33,500	18,001 - 20,600	3,750	
128,701 - 145,900	72,401 - 82,100	46,401 - 52,500	33,501 - 37,900	20,601 - 23,300	4,000	4
145,901 - 164,200	82,101 - 92,400	52,501 - 59,100	37,901 - 42,700	23,301 - 26,300	4,250	
164,201 - 183,400	92,401 - 103,100	59,101 - 66,000	42,701 - 47,700	26,301 - 29,300	4,500	
183,401 - 203,700	103,101 - 114,500	66,001 - 73,300	47,701 - 53,000	29,301 - 32,600	4,750	
203,701 - 225,200	114,501 - 126,700	73,301 - 81,100	53,001 - 58,600	32,601 - 36,000	5,000	
225,201 - 247,700	126,701 - 139,400	81,101 - 89,200	58,601 - 65,400	36,001 - 39,600	5,250	
247,701 - 271,200	139,401 - 152,600	89,201 - 97,700	65,401 - 70,600	39,601 - 43,400	5,500	
271,201 - 295,900	152,601 - 166,500	97,701 - 106,500	70,601 - 77,000	43,401 - 47,400	5,750	
295,901 - Greater	166,501 - Greater	106,501 - 115,800	77,001 - 83,700	47,401 - 51,500	6,000	
"	"	115,801 - 125,500	83,701 - 90,600	51,501 - 55,700	6,250	
"	"	125,501 - 135,500	90,601 - 97,900	55,701 - 60,200	6,500	
"	"	135,501 - 145,800	97,901 - 106,800	60,201 - 64,800	6,750	
"	"	145,801 - 156,700	106,801 - 113,200	64,801 - 69,600	7,000	
"	"	156,701 - 167,900	113,201 - 121,300	69,601 - 74,600	7,250	
"	"	167,901 - 179,400	121,301 - 129,600	74,601 - 79,800	7,500	
"	"	179,401 - 191,400	129,601 - 138,300	79,801 - 85,100	7,750	
"	"	191,401 - Greater	138,301 - Greater	85,101 - Greater	8,000	

* Types of construction are based upon the building code.

** Measured at 20 psi (137.9kPa). See Appendix III-A, Section 2.

Table 17: Uniform Fire Code: Number and Distribution of Fire Hydrants

TABLE A-III-B-1 NUMBER AND DISTRIBUTION OF FIRE HYDRANTS			
FIRE - FLOW REQUIREMENT (gpm)	MINIMUM NO. OF HYDRANTS	AVERAGE SPACING BETWEEN HYDRANTS *,**,*** (feet)	MAXIMUM DISTANCE FROM ANY POINT ON STREET OR ROAD FRONTAGE TO A HYDRANT **** (feet)
x 3.785 for L/min.		x 304.8 for mm	
1,750 or less	1	500	250
2,000 - 2,250	2	450	225
2,500	3	450	225
3,000	3	400	225
3,500 - 4,000	4	350	210
4,500 - 5,000	5	300	180
5,500	6	300	180
6,000	6	250	150
6,500 - 7,000	7	250	150
7,500 or more	8 or more *****	200	120
* Reduce by 100 feet (30 480mm) for dead-end streets or roads			
** Where streets are provided with median dividers which can be crossed by firefighters pulling hose lines, or arterial streets are provided with four or more traffic lanes and have a traffic count of more than 30,000 vehicles per day, hydrants spacing shall average 500 feet (152.4m) on each side of the street and be arranged on an alternating basis up to a fire-flow requirement of 7,000 gallons per minute (26 495 L/min.) and 400 feet (122m) for higher fire-flow requirements.			
*** Where new water mains are extended along streets where hydrants are not needed for protection of structures or similar fire problems, fire hydrants shall be provided at a spacing not to exceed 1,000 feet (305m) to provide for transportation hazards			
**** Reduce by 50 feet (15 240 mm) for dead-end streets or roads.			
***** One hydrant for each 1,000 gallons per minute (3785 L/min.) or fraction thereof.			

Appendix C: Fire Modelling and Heat Release Rates

C.1 Abstract

This section documents the development of the teams' model before it was decided the model had become overly technical in nature. The team believes that this approach to the determination of required fire flow is a much more development specific model. This appendix will show the teams' progress with regards to research and modelling. The end of this appendix is a discussion of where the team's research finished, and why it was not completed. It will also include a section that will provide a basis for further research on this topic.

C.1.2 Introduction

This model uses many technical aspects of fire modelling, as well as certain fundamental assumptions of fire protection engineering. It roughly models the structure size as a fuel load, and takes into account whether or not the structure is equipped with home fire sprinklers. A t^2 approximation for the fire growth in the room of origin is utilised.

The model is broken down into 2 distinct sections. The first section considers a structure that is not equipped with home fire sprinklers, and the second section considers a structure with home sprinklers.

C.1.3 Model

C.1.3.1 Fire Brigade Intervention Model Chart Explanations

Chart 1. Time for initial brigade notification

This chart determines the time it takes from when the fire is first detected to the time it takes for the brigade to understand the required information to respond to the fire. The FBIM makes the assumption that the structure has functioning smoke alarms. The inputs for this chart include the type of detection system used, if a suppression system is installed, what type of connection exists between the building and the brigade, and the type of monitoring system that is used (AFAC, 1997).

Chart 2. Time to dispatch resources

This chart determines the time it takes for the brigade to dispatch the appropriate resources from the time when the information has been interpreted. The information that is used in this determination is the type of notification. The type of notification would be by either a telephone call or someone passing by the fire. If the notification is by a passer by the person must find a way to get in touch with the fire brigade, which would take more time than a phone call. It also determines if the call is taken at central communications or at the local fire station. This has a large impact on the total response time since a call taken at central communications must then be transferred to the local station (AFAC, 1997).

Chart 3. Time taken for fire fighters to respond to dispatch call

This chart determines the time it takes for the fire fighters to get dressed, assess the dispatch information, and leave the station. Input that is required includes whether the station is manned full time or volunteer. Also if the station happens to be a volunteer station, the time it takes the fire fighters to arrive at the station is included (AFAC, 1997).

Chart 4. Time to reach fire scene (edge Side)

This chart determines the actual travelling time from the brigade to the scene of the fire. The chart takes into account whether the brigade chooses to use a percentile response. This percentile response it the average response time of the fire brigade from notification until arrival on the scene to ninety percent of the brigade coverage area. The percentile response is brigade-published data that should be readily available from the brigade statistics (AFAC, 1997). If the user chooses not to use the percentile response the user must input other information regarding the brigade. This information includes the distance that must be travelled, the average speed of the vehicles, and whether or not the emergency route is pre-defined (AFAC, 1997).

Chart 5. Time taken for initial determination of fire location

This chart determines the time it takes to locate the fire once the brigade has arrived on the site. The criteria that are taken into account include: Is travel within the site necessary? Is the fire visible on arrival? Are the premises occupied? Is forced entry required? Is an accredited fire warden present? And is fire brigade pre-planning documented (AFAC, 1997)?

Chart 6. Time taken to don safety equipment and gather necessary tools

This chart takes into account whether or not additional tools, and or safety equipment is required once at the fire scene. The output of this chart is the extra time required, if any, to obtain and utilise the equipment (AFAC, 1997).

Chart 7. Time taken to assess fire

This chart determines the time required for the officer in charge (OIC) to assess the fire scene once on site. The first question on the chart asks whether or not the location of the fire is obvious. If it is not, the height of the building comes into effect. If the building is greater than 3 stories, then extra time is required for the OIC to assess the situation. The final question asked is whether or not additional resources are required (AFAC, 1997).

Chart 8. Time taken to travel to set-up area

If the fire fighters are required to set up in a location other than the outside of a building (such as a shopping mall, or other large building) extra time must be added. This chart determines the time it takes to set up in an area other than area outside the building. The chart does this by taking into account criteria such as whether the building is evacuated, and whether or not safety equipment has been put on (AFAC, 1997).

Chart 9. Time taken for fire fighter travel

This chart determines the time it takes for the fire fighters to travel from the primary set-up area to the actual target. The chart takes into account the number of doors, lifts, stairs, and other obstacles that will be encountered. This chart is primarily intended for use with larger size buildings such as factories and shopping malls (AFAC, 1997).

Chart 10. Time taken to set up water for initial fire fighting protection

This chart determines the time that it takes for the fire fighters to set up the initial water to be used for fire protection. Questions asked as the user progresses through the chart are: Will fire attack occur from the fire appliance? Is the on board fire hose reel to be used? The time it takes to bring the hose reel to the fire area? Is the water supply from the fire appliance? Is additional water necessary for fire fighter protection (AFAC, 1997)?

Chart 11. Time taken to set up water supply requirements

This chart is used in determining the time it takes to determine whether the current water supply is adequate for the job on hand. If it is not enough water, an additional water supply must be located and utilised. The chart asked the user questions suck as: Is the water supply adequate? Are hydrants provided on the site? Are boosters provided? Are other water supplies available remote from the site? Are additional resources are required (AFAC, 1997)?

Chart 12. Time taken for search and rescue

In the instance where a person is still trapped in the burning house, a series of steps must be followed to locate and rescue them. The input to this chart includes: have fire fighter safety limits been exceeded in the enclosure? Is more than one search team available? Are more resources required? Are there any other questions regarding the safety of the fire fighters? The result from this chart is the time that the entire search and rescue process takes (AFAC, 1997).

Chart 13. Time taken to protect other property

This chart determines the time it takes to protect other property that is in danger of combustion due to exposure to the burning building. This chart asks questions such as: Is prevention of fire spread the only consideration? Is radiation to other property greater than 12.5 kW/m^2? Is there a large enough water supply availably to apply the required water to the property? Is aerial equipment required, and is the exposure protection successful (AFAC, 1997)?

Chart 14. Time taken to protect uninvolved contents (salvage operations)

This chart determines the time it takes for the fire fighters to protect all undamaged property on the premises. The inputs for this chart are: Are sufficient resources available at the fire scene? Is the heat release rate reducing over time? And does the strategy need reassessment? The outcome is the time it takes to cover equipment with tarpaulins, redirect water flow, cut holes (AFAC, 1997)?

Chart 15. Time taken to control and extinguish the fire

The product of this chart is the time it takes to completely extinguish the fire. The steps followed for this chart include, determining the fire size, assessing the heat release rate over time based on water application, determining if the heat release rate is decreasing over time, and determining if there is enough water available for control and extinguishment. The total output of this chart is the time to extinguish the fire (AFAC, 1997).

Chart 16. Time taken to protect the environment

This final chart determines the time it takes for the fire fighters to protect the surrounding environment at a fire scene. Input questions include: Does the fire impact the atmosphere and the water? Does water run off have the greatest impact? Does fire only impact on the atmosphere? Whether the fire can be allowed to burn out. The result is the time to protect the environment (AFAC, 1997).

C.1.3.2 Section 1 – No Home Sprinklers

C.1.3.2.1 Step A: Fire Brigade Intervention Time

The first step in the model is to determine the fire brigade intervention time. This can be done in any number of ways. One way is to use the Fire Brigade Intervention Model, or the F.B.I.M., which is a series of charts used in determining the intervention time. The model is endorsed by the Australasian Fire Authorities Council (A.F.A.C.). The specific steps and criteria used in the model are documented in the results section of this document. Another method that can be used to determine the response time is by using the average response time for the brigade having jurisdiction. Each brigade uses a response time with a 90% reliability, which means that they can respond in that time or less in all but 10% of fires in their area. The last method that could be used would be the G.I.S. system that determines the response time to kerb side based on distance of travel and several other factors. It must be noted that the time obtained from the F.B.I.M. model will include a much greater level of accuracy then the other two methods.

C.1.3.1.3 Step B: Fire Size Determination

This step will incorporate the fire growth approximation with the fire brigade intervention time. It can be done in one of 2 ways. The first method would be to assume that the fire has just reached established burning at the time of department notification. This approach assumes that the smoke produced by the smouldering stage of the fire has triggered the activation of a smoke or heat detector, or that the occupant is at home and is able to realise the smoke and contact the fire department. The second method is to assume that no one is home and the smoke detectors are not active. In this case, the room of origin can be modelled as flashed over by the time of the initial brigade notification. At this point flames will be protruding from the windows, and it can be assumed someone will see the flames and call the brigade. Both scenarios will be discussed after a brief introduction to pertinent background information.

1.3.1.3.1 Fire Growth Rates

In either scenario, the fire growth rate and the maximum heat release rate for the room must be determined. The size of the design fire is "determined based on an engineering analysis of the characteristics of the fuel, the effects induced by a fire, or both" (NFPA 92B, 1991 p13).

A t^2 fire is a basic fire model that varies proportionally with time, the rate of growth being classified by the fire type and the amount of fuel contained within. These classifications include slow, medium, fast, and ultra fast fires (NFPA 92B, 1991). The different classifications are defined by the amount of time it takes the fire to grow to a heat release rate of 1.055MW (NFPA 92B, 1991). An ultra-fast fire will reach this stage after 75s, a fast fire in 150s, a medium fire in 300s, and a slow fire will take 600s to reach 1.055MW. For practical applications, assumptions can be made that upholstered furniture, and thin plywood furnishings will burn at an ultra-fast rate. Wood pallets stacked 1.5 m (5 ft) high and cartons stacked 4.5 m (15 ft) will burn at a fast rate. Mattresses and various other cotton/polyester pieces are expected to burn at a medium rate, and materials that are difficult to ignite will burn at a slow rate.

A t^2 fire may be modelled as a fire where the heat release is evenly distributed over the entire ignited space, and the fire is assumed to be spreading as a circle with a steadily increasing radius (NFPA 92B, 1991). The t^2 graph may not be the exact representation of the fires to be modelled, but it is widely understood that it is an acceptable approximation for design considerations (NFPA 92B, 1991). The heat release rate for a time dependant fire is governed by the equation:

$$Q = a * t^{(n)}$$

Equation 15: Heat Release Rate Calculation

Where:

Q = heat release rate (kW)

T = time after ignition (sec)

a = fire growth constant (KJ/sec$^{(n-1)}$)

n = a positive exponent (Custer and Meacham, 1997)

For most residential applications, n will equal 2. It has been considered as such in the computations of the following table.

Table 18: Fire Growth Rate Constants for a T^2 Fire

Fire Growth Rate Constants for a T^2 Fire

Fire	**Growth Constants(KJ/sec$^{(n-1)}$)**
Slow	A =.00293
Medium	A =.01172
Fast	A =.0469
Ultra fast	A =.1876

C.1.3.1.3.2 Heat Release Rates

Heat release rates (HRRs) for different materials are becoming extremely important to any fire protection engineer, building official, or other technical specialist (Babruaskas, 1992). Current methods such as oxygen calorimetry can be used to evaluate HRRs for different materials quickly and efficiently. Oxygen calorimetry is based on the principle that amount of heat released from a fire is directly related to the mass of oxygen removed from the combustion flow stream (SFPE, 1995). This technique only requires a measurement of the flow rate and the mass of oxygen removed from the air. These factors are combined with the predetermined knowledge that 13.1 x 10^3 kJ of heat are released for every kg of oxygen consumed (SFPE, 1995).

C.1.3.1.3.3 Scenario A: Established Burning at Initial Notification

This scenario will be the simplest to calculate. It can be assumed that the beginning point of the t^2 approximation is at the point of established burning, the smouldering stage is not included. Another assumption that is a fast rate for fire growth is going to be modelled. This determination is decided on the basis that the main fuel source will be upholstered furniture that has a very fast growth rate. Plugging in a value for the intervention time in an Excel table will give the size of the fire at the time of brigade intervention.

Sample Table

Step A - Fire Brigade Intervention Time

1. Use either the Fire Brigade Intervention Model, the GIS system, or individual brigade response times to estimate the response time to the development.

Input
Time (sec): 520

Step B - Max Heat Release Rate for Sample Room

1. Add up HRR's for all furniture in room, include also walls and floors as fuel

Max HRR
(MW): 15

Step C - Peak Heat Release Rate determination

Heat Release Rate

at Intervention:
(MW) 12.00576 Fire brigade intercedes before flashover

**This equation squares the input time, and multiplies it

by the constant for a fast fire approximation (0.0444)

The program is set up using a simple "if" statement so that if the fire size at intervention found from the t^2 approximation is greater than the max HRR for the room, the fire is assumed flashed over and spreading to other rooms. If the fire has not reached that size yet, the room is not assumed to be flashed over.

It is realised that flashover in rooms is ventilation and not fuel controlled, but it is impossible for this application to model a ventilated fire. No concrete house plans are available. The only reasonable solution is to model a typical room based on furniture layouts and common sizes. Taking into account ventilation and modelling the fire more accurately before and after flashover could be the subject of further work on this topic.

C.1.3.1.3.4 Scenario B: Fire is Flashed Over By Time of Initial Brigade Notification

This type of scenario will obviously be much more difficult to calculate. Flashover can be approximated using the Method of Babruaskas. The Babruaskas model for predicting the energy at flashover stage is a very simple equation that accounts for the area of any openings in the room, and the height of those openings. Simply stated, the equation is:

$$\dot{Q} = 750 A_0 \sqrt{H_0}$$

Equation 16: Babruaskas Model

Where:

Q = Heat release rate (kW)

A_0 = Area of Opening (m^2)

H_0 = Height of opening (m) (SFPE 1991)

Babruaskas bases his method on several key assumptions. The first assumption is that the primary energy loss is to be radiation to 40% of the area of the wall. Other assumptions include a gas temperature for flashover of 873K, a specific heat of air of 1.0 kJ/kg*K, an emissivity of 0.5, and a correlation of roughly 50 between the compartment wall and the opening area (SFPE 1991). Most of the rest of the formula was found through fire tests and correlations from other data (SFPE 1991).

Since complete sets of house plans were not available to the team during their project, certain assumptions had to be made. A square room with dimensions roughly 5m by 5m was assumed. Based on a worst-case scenario, the room was assumed to have 1.5m^2 of openings, at a height of 1.8m. Plugging in these criteria achieves a value of 2025kW, or 2.025MW. Assuming a fast t^2 fire growth approximation, this value of 2.025MW can be linked to a burning time of 213.6 seconds before the fire brigade is even notified.

From here, complex modelling of the structure in question must be performed to accurately portray the fire spread and size at brigade intervention.

C.1.3.1.4 Step C: Water Determination (From F.B.I.M. Computation Sheets)

Another aspect of the Fire Brigade Intervention Model is the calculation of the heat absorption ability of one litre per second of water. The calculation is based on several assumptions. The first assumption is that the density of water is 1000 kg/m^3. This assumption states that 1 kg of water is equal to 1 L of water. The second assumption is that water for fire fighting is at 10°C. The calculation is then based on the amount of energy that is needed to bring one litre of water to a boil at 100°C. This calculation is:

$$Energy = (100-10)\times 0.00418 MJ/kg°C$$
$$Energy = 0.38 MJ/kg$$

Equation 17: Energy Needed to Bring 1 kg of Water to 100°C

Where 0.00418 MJ/kg°C is the heat capacity of water. The amount of energy then needed to vaporise 1 kg of water is next used:

$$Vaporization@100°C = 2.26MJ / kg°C$$

Equation 18: Energy of Vaporisation of Water

The kilogram of steam will then be heated to the temperature of the fire. Another assumption comes in at this point. It is assumed that flashover has occurred. The temperature of flashover is taken between 500°C and 600°C. The average, 550°C, of these two values is then used to find the final temperature of the steam. The calculation of this energy is:

$$\begin{aligned} Energy &= (550 - 100) \times 0.00201 MJ / kg°C \\ Energy &= 0.9 MJ / kg \end{aligned}$$

Equation 19: Energy Needed to Heat Steam to Flashover Temperature

In this equation 0.00201 MJ/kg°C is the heat capacity of steam. The total energy needed to transform 1 kg of water at 10°C into 1 kg of steam at 550°C is the sum of the energy needed to raise the temperature of water to 100°C, then the energy needed to vaporise the water and finally the energy needed to bring the water to the temperature of the fire.

$$\begin{aligned} TotalEnergy &= 0.38 + 2.26 + 0.9 \\ TotalEnergy &= 3.5 MJ / kg \end{aligned}$$

Equation 20: Total Cooling Capacity of 1 kg of Water

The assumed density of 1000 kg/m^3 allows for the conversion from 3.5 MJ/kg to 3.5 MJ/L. Since a watt equals one joule per second this final number allows for the conclusion that 1 L/s of water can theoretically cool 3.5 MW (AFAC, 1997).

The FBIM makes the assumption that only 30-35% of the released energy from diffusion flames needs to be removed to extinguish the fire. This assumption is based on D.J. Rasbash's work with diffusion flames (1986). Rasbash's study states that theoretically only enough water needs to be supplied to extinguish the combustion process above the surface of the fuel. This allows the amount of energy that one litre of water can cool to be multiplied by a factor of three. This results in the amount of energy that one litre of water can theoretically absorb to be 10.5 MW (AFAC, 1997). This assumption is extremely theoretical, however, and is not applicable in the opinions of several fire protection engineers.

Fire fighting ability is based on the operator and includes skill, equipment, conditions, fatigue, strength, experience as well as other factors. Since these factors are not easily modelled the FBIM assumes an efficiency for the application of water to the fire. The FBIM assesses this efficiency, in Australia, as 15% for an internal attack of the fire, 5% for an external attack of the fire and 10% for a combination of internal and external attacks (AFAC, 1997).

The FBIM also assumes that for its purposes an internal attack uses hose streams at 5 L/s, an external attack uses 10 L/s and a combination attack uses 10 L/s. It has been established that 1 L/s of water has the extinguishing capabilities of 10.5 MW. In an internal attack, the total extinguishing ability of one hose can be found by multiplying the flow of water from that hose by 10.5 MW. The resulting extinguishing capability is 52.5 MW. However an efficiency of 0.15 has been established for this application of water, so the resulting extinguishing capability of one hose is 7.88 MW.

$$ExtinguishingCapability = MinimumFlowRate \times 10.5MW \times Efficiency$$

Equation 21: Extinguishing Capability for a Hose

A similar approach can be applied to both the external and combination attacks with the results of 5.25 MW and 10.5 MW respectively (AFAC, 1997).

The FBIM then relates the value in megawatts of any fire to the flow needed to extinguish that fire. This correlation is done with a 10% range of uncertainty (AFAC, 1997). The FBIM assumes that if the cooling capacity of the water is greater than 110% of the given heat release rate the fire will extinguish. If the cooling capacity is within a 10% range of the heat release rate of the fire, the water is considered to keep the heat release rate at a constant level. Finally if the cooling capacity is less than 90% of the heat release rate it is assumed to have no effect on the fire. The flow of water needed for each type of attack is then calculated by dividing the assumed minimum flow from an attack hose by the calculated cooling capability of that attack method (internal, external or combination), the result is then multiplied by the heat release rate of the fire (AFAC, 1997).

$$NF = \frac{MF}{CCW} \times HRR$$

Equation 22: Water Flow Requirements

Where:

NF = needed water flow rate

MF = minimum flow rate of the hose

CCW = cooling capacity of water

HRR = heat release rate of a fire

By using the cooling capacity of the three types of attacks, the minimum flow rate needed to extinguish the fire, maximum ineffective flow rates can be calculated and flow rates that will keep the fire constant can be calculated. A sample calculation sheet using the FBIM calculation is provided below (AFAC, 1997):

Table 19: FBIM Calculation Chart

WATER REQUIREMENT CALCULATIONS

Location: Any House

Heat Release Rate (MW)	90% of Heat Release Rate	110% of Heat Release Rate
12	10.8	13.2

Cooling Capacity For:

	Efficiency	Flow Rate (l/s)	Heat Release Rate (MW)	Minimum Flow Rate (l/s)	Heat Release Rate (MW)
Internal Attack	15%	1	10.5	5	7.88
External Attack	5%	1	10.5	10	5.25
Combination	10%	1	10.5	10	10.5

Internal Attack

Water Requirements (*l/s*) For

Not Effective	Control	Extinguish
7.00	8.00	9.00

External Attack

Water Requirements (*l/s*) For

Not Effective	Control	Extinguish
21.00	23.00	26.00

Combination Attack

Water Requirements (*l/s*) For

Not Effective	Control	Extinguish
11.00	12.00	13.00

C.1.3.1.5 Step D – Adjustments

This section is extremely important to the model. This is the step in which the standard operating procedures of the brigade are accounted for. The main point of this section is whether or not there is an exposure hazard near the structure in question. An exposure hazard may take two forms, structural and vegetation. A structural exposure will be any building greater that $10m^2$ that is within 15m of the structure in question. A vegetation exposure will be dried out brush or vegetation within 25m of the structure in question.

From the examination of standard operating procedures, it was discovered that in the case of an exposure hazard, a line is applied directly to the exposure to reduce the temperature and prevent ignition. In most cases, this extra line will be a 38mm hose. From the water requirements project conducted by the MFESB, it is known that to properly supply a 38mm hose, a flow of 2 l/s at a pressure of 650kPA must be supplied.

In the case of an exposure hazard, the value of 2 l/s must be added onto the value obtained from step C. This is the value for required fire flow.

C.1.3.2 Section Structure Equipped with Home Sprinklers

C.1.3.2.1 Step A- Fire Size at Brigade Intervention

If the structure is fitted with home fire sprinklers, several key assumptions can be made. The first major assumption is that when a fire activates a sprinkler, the sprinkler will do one of two things. It will either begin to decay the fire until it is finally extinguished, or it will prevent the fire from growing any larger, thus keeping the heat release rate constant. For the purpose of a conservative model, it is assumed that the activation of a home sprinkler will impeded the growth of a fire, holding the heat release at the time of activation to a constant rate. Therefore, the most important aspect of home sprinklers with regards to fire flow determination will be the time elapsed after ignition that the sprinkler head will activate.

C.1.3.2.1.1 Sprinkler Response Determination

This model will be implemented during the planning phases of a development when there are no concrete design plans. For this reason, an average room must be used in the modelling process. This room will be roughly based on a room from the Caroline Springs development, under the assumption that the house plans in the Caroline Springs are going to be representative of other Greenfield homes.

Determining the type of sprinkler that would be utilised in a residential application was the first step in the determination of the activation time. From the BRANZ New Zealand (2000) report and research performed by the WPI Home Sprinklers Project (Gilman et al., 2001), it was found that for most residential applications, a Microfast Model M-4 Small Orifice Residential Pendant Sprinkler was utilised. Specific technical data from the Viking distributor are listed below.

Table 20: Viking Sprinkler Specifications

Sprinkler Temperature Classification	Nominal Sprinkler Temperature Rating (fusing point)	Ceiling Temperature at Sprinkler		
		Maximum Ambient Temperature Allowed(1)	Maximum Recommended Ambient Temperature(2)	Bulb Colour
ordinary	68° C (155° F)	46° C (135° F)	38° C (100° F)	Red
intermediate	79° C (175° F)	68° C (155° F)	65° C (150° F)	Yellow
1. Based on National Fire Prevention and Control Administration, Contract no. 7-34680 2. Based on NFPA-13. Other limits may apply depending on fire loading, sprinkler location, and other requirements Of Authority Having Jurisdiction. Refer to specific limitation standards				

Although the response time index (RTI) is not listed on this specifications sheet, a design engineer from the Viking distribution centre in western Australia confirmed that the RTI for this specific quick response head was $26(m*s)^{1/2}$. He also mentioned that the RTI for a standard residential head was $81(m*s)^{1/2}$

To determine the time at which the sprinkler head would activate, the fire-modelling program Detact was utilised. Detact is described by the National Institute of Standards and Technology website as "a program for calculating the actuation time of thermal devices below unconfined ceilings. It can be used to predict the actuation time of fixed temperature and rate of rise heat detectors, and sprinkler heads subject to a user specified fire that grows as the square of time. CT-T2 assumes that the thermal device is located in a relatively large area, that is only the fire ceiling flow heats the device and there is no heating from the accumulated hot gases in the room. The required program inputs are the ambient temperature, the response time index (RTI) for the device, the activation and rate of rise temperatures of the device, height of the ceiling above the fuel, the device spacing and the fire growth rate. The program outputs are the time to device activation and the heat release rate at activation. DETACT-T2 was written in BASIC and FORTRAN by D.W. Stroup" (NIST, 2001).

The first input for the Detact program is the ambient temperature of the room in question. A value of 18.3°C (65°F) was chosen as an estimated average room temperature. This was used as the input for the ambient temperature. The next input was the response time index (RTI) for the sprinkler head being modelled. As mentioned previously, the RTI for the Microfast model M-4is $26(m*s)^{1/2}$. The next input, the detector activation temperature, was available from the specifications page for the sprinkler. An intermediate temperature was selected for the temperature classification, thus leading to a maximum temperature rating (fusing point) of 79° C (175° F). The value of 79° C was the input for the fusing temperature.

The next step required an input for the detector rate of rise in °C/minute. The input for this step was zero because sprinklers do not have a rate of rise. This step would only be included if a smoke or heat detector were being modelled. The next two inputs to the model were the ceiling height and the detector spacing. The ceiling height was chosen to be 2.4 m (8 ft) on the basis that 2.4 m (8 ft) is an average ceiling height for most residential dwellings. The detector spacing was also chosen to be 3.7 m (12 ft). This value was chosen because the maximum area of coverage for this particular sprinkler was 4.9 m by 4.9 m (16 ft by 16 ft). Taking half of this distance gives 2.4 m (8 ft). This is the maximum allowable distance from a sprinkler head to a wall in a perpendicular direction. Assuming a sprinkler is centred in a room, spaced 2.4 m (8 ft) perpendicularly from a wall, the worst-case scenario would be a fire in the corner of that room. The maximum distance will be 3.7 m (12 ft), based on the assumption that the fire is located laterally from the fire in the farthest corner of the room. Another major assumption made in the determination of this value is that the sprinklers are installed and designed according to the specifications set forth by the distributor in regards to the maximum coverage area.

The final input for the model will be the estimated fire size. Since this is a t^2 version of Detact, slow, medium, fast, and ultra fast growth fires are provided as options. Paula Beever suggested a fast fire be chosen for this model on the assumption that in the worst-case scenario, a piece of upholstered furniture would be catching fire. This would have the greatest heat release rate, and would most likely be modelled at a fast growth fire.

<u>The outputs of the Detact model were:</u>
<u>Time to Activation</u>: 2.09 minutes (125 seconds)
<u>Heat Release Rate</u>: 0.7397 E+03 (kilojoules/second)
0.0711 E+03 (BTU/second)

This Detact model also calculates values for the rate of rise-actuated detector, but this value has no impact on the automatic sprinklers.

These steps will provide the user with an activation time, assuming established burning at time zero. This process can be very easily replicated for different sprinklers. The only variables will be the RTI and the activation temperatures.

C.1.3.2.2 Fire Size at Brigade Intervention

The fire size at brigade intervention is dependent entirely on the activation time of the home fire sprinkler. Once the sprinkler activates, the fire is assumed to be held to a constant rate, so that the fire brigade can then extinguish the fire. The activation time found through the Detact model above will be the input into the t^2 approximation to determine the fire size at activation.

C.1.3.2.3 Water Requirements

The water requirements will be determined using the same computations as explained above. The details of the analysis are explained in a previous section.

C.1.3.2.4 Adjustments

There will be no adjustments for this scenario, simply because the fire will be help at a constant rate and will not be a danger to any other structures, or rooms in the same house.

Appendix D: Interview Summaries

Sample Interview Questions
Fire Officials

1. What is the standard response to a fire alarm?
   a. How many appliances respond?
   b. How many fire fighters respond per appliance?
   c. What are the roles of the responding fire fighters?
2. What procedures are followed at the scene of a fire?
3. What diameter hoses are used to fight a house fire?
4. How many hoses are used to fight a house fire?
5. What is the procedure for connecting to the pumper truck to a hydrant?
6. How many hoses are connected to the truck?
7. How many different hydrants is the truck connected to?
8. Are any special considerations/operations made?
   a. For exposure hazards?
   b. For sprinkler systems?
9. Are there any instances where you have run out of water at the scene of a fire?
10. Are there any situations that you personally hate to see when you arrive at the scene of a fire?

Sample Interview Questions
Water Authorities

1. What is the typical process followed in the current water main infrastructure design?
    a. Main size
    b. Flow design
    c. Pressure design
2. What considerations are made for fire protection when designing a new development?
3. How are these considerations addressed in the new code of practice?
4. How does this differ from previous methods used in determining needed flow?
5. What is the cost per lot of installing the water main infrastructure?
6. What is the cost per fire hydrant?

James Fox
CFA
Manager of Community Safety
19 March 2001

This interview was conducted in the CFA station in Melton, Victoria. Mr Fox's job includes reviewing and improving the water infrastructure design plans for new residential development in that region of Victoria.

When the water infrastructure design is brought before the CFA for approval, the CFA makes sure that it follows certain criteria that they have developed in the past years. Mr Fox explained that currently, the water supply agencies did not take into account water supplies for fire protection. When designing the domestic water infrastructures, these agencies are more concerned with the quality of the water.

Mr Fox also talked about the growth rate in Victoria, currently 1.5%, and how this poses concern about the amount of water for fire protection. He then talked about the new Eynesbury Station development. He explained how this development is quite large in size, and that it is located a long distance from the nearest fire brigade. Since the development is so far from the brigades, the response time is severely increased. Due to this increase in response time, the CFA have decided that there are two options to be taken into account. The first option is to build a fire brigade on the outskirts of the new development. Paid fire fighters as opposed to volunteer fire fighters would most likely staff this brigade. The second option that is to be considered is to install residential sprinklers in each new home. Mr Fox explained that the cost for a new fire brigade would be approximately 1 million dollars a year, while the cost to install residential sprinklers has not yet been determined.

John Phillip
WoodHouse Pastoral Co.
General Manager
19 March 2001

John Phillip is the developer of Eynesbury Station, a Greenfield site in Milton, Victoria. After a brief introduction and a description of the projects, the specifics of Eynesbury Station were discussed.

The land on which the station will be built is approximately 20,000 acres, 2,500 acres of which will actually be constructed upon. It is expected that 1200-2000 homes will be built in this development.

Mr Philip explained that currently no plans are available for the development. He is still awaiting the permits to pass. He expects a wide range of residences and the development will also include several hotels. Currently WBCM Group is contracting the water infrastructure design. He provided the name of an individual at WBCM to be contacted.

With regards to hydrant spacing, he recommended the town planners for the area, TRACT. He also gave a contact for TRACT to get in touch with.

It was soon discovered that this developer was much less involved in the design process than was originally expected. This was his first development. The best approximation he could give us for design approximations was to look at the Caroline Springs Development, which is similar to his plans.

Charles Balette
South East Water Limited
Senior Engineer, Water Supply Planning
20 March 2001

The interview began with a discussion of the process for subdividing Greenfield sites. This process begins with a zoning phase in which the proposed land use is documented. When a developer wishes to proceed with a residential development, he lodges a plan of subdivision with council. The council then reviews the plans and sends the proposal out to utilities for review. One of those utilities, the retail water company, will then determine the water supply requirements for the proposal.

The criteria used in determining water supply requirements were discussed. South East Water design their systems based on peak day event water requirements. What this refers to is the highest daily consumption that could be experienced over a twenty-year period. The peak day demand for a typical property will be based on criteria such as drinking water, lawn sprinklers, showers, and so on. Mr Balette also explained that when reviewing the water supply requirement for a development, the area could be broken down into different distribution zones. The zone boundaries will be based on the elevation and layout of the development in order to facilitate the design of the water supply system. An example of this may be to make a boundary line at the top of a hill, or at the end of a branch main where the minimum required pressure would be the most difficult to achieve. By designing the system in order to supply the edges of these boundaries with the minimum required pressure, the designer ensures adequate pressure to the rest of the system.

The topic of water supply for fire protection was then discussed. Currently in metropolitan Melbourne there are no requirements for water companies to provide water for fire fighting purposes. Mr Balette stated repeatedly that water supply for fire fighting is "implied" in the sense that the water provided for domestic use in an urban water supply system is deemed to be adequate for fire fighting purposes. No additional allowance is made for fire fighting water within a residential area. However, in order to obtain a building permit for a commercial or industrial type of development, a developer has to obtain additional water supply data from the water agency. This information will enable the developer to design the necessary fire fighting facilities for the property.

With regards to the size of the water main, a minimum sized main will be 100 mm in diameter for residential requirements. If a developer is required by the water agency to install a main of a greater diameter to provide additional distribution capacity, he will be reimbursed the difference in cost between the larger main and the minimum 100 mm main.

Another topic discussed was distribution system maintenance. Mr Balette explained that the water authority is responsible for the maintenance of the water mains and the council is responsible for the cost of maintaining hydrants specifically required by council.

Mr Balette was later contacted via e-mail for additional information. Mr Balette stated that South East water currently designs infrastructure systems to the recommendations set forth in the Water Services Association of Australia Water Reticulation Code. Mr Balette also stated that currently a hydrant costs approximately AUD$600 to install with the water infrastructure. He also stated that when a hydrant is installed to an existing infrastructure the cost rises to approximately AUD$2000.

Bruce Collins
City West Water
Design Engineer
26 March 2001

The interview began with a brief overview of the specifications used when determining the required water flow. All infrastructures are designed for an accepted range of pressure, specifically between 15 and 100 metres. The minimum flow rate to be provided per property will be based on the size of the meter that regulates the water to the individual houses. This is a guaranteed amount. The required meter size for individual residences is 20 mm.

The next topic of discussion was that City West Water now designs a standard 100 mm main for all new residential developments. City West does also employ a similar policy to South East Water in the fact that if a main greater than 150 mm is required, the developer would be reimbursed for the extra cost.

The focus then turned towards peak hourly demands, and how they are calculated. Mr Collins stated that most of the values used in the design are gained through experience of working in the water industry, and that there are documented peak values for existing areas and new developments in the past several years. This data is based on 100 houses as a standard, and Mr Collins also stated that the average peak hourly demand has fallen from 10 l/s per house to roughly 8.5 l/s per house in the last 10 to 15 years. The development of a water reticulation system takes place in two phases, the planning phase and the design phase. The planning phase is based on sizing mains for the peak hourly demand requirements using hydraulic models for distribution zones. The design phase is primarily completed using the water reticulation code. The design phase deals with things such as location of the main, pipe materials, air valves, hydrants, valving, cross connections, thrust blocks etc. Maintenance of the systems was also discussed. Although city council claims ownership and provides maintenance for fire hydrants, the water suppliers install the hydrants. Another important point was that Mr Collins made it clear that it is expected that every fire hydrant will be capable of supplying at least 20 l/s of flow for fire fighting purposes at any one time. Other than that, the entire system is installed and maintained by the water supplier. The developer also pays a developer contribution. The developer contribution is a flat fee derived by the water supplier for each lot provided with a domestic water supply. A typical developer contribution will be in the range of AUD$2000 per lot plus the cost of installing the mains. Typical maintenance will be performed on an as needed basis. Maintenance will be necessary when tests show an inadequacy in the quality of the drinking water, or as emergency situations such as a burst pipe may arise. The water supplier, on a yearly basis, contracts out repairs. What this means is that the company hired out for the repairs is paid a flat rate for the year regardless of the amount of work needed during that year.

Mr Collins was later contacted via e-mail for additional information. Mr Collins stated that currently City West Water designs their systems to 8.5 L/s/100 houses for lots greater than 500 m^2 and 6.0 L/s/100houses for lots that are approximately 300 m^2.

Mr Collins was asked specifically about the design details of the Caroline Springs development, as City West Water is the water authority for this development. He was asked about this development because it is a close approximation of the Eynesbury Station Greenfield site. Mr. Collins stated that City West Water designed Caroline Springs to a peak flow of 102 L/s at a pressure of 150 kPa. However on an average day the development has a flow of 36 L/s in the water main.

Robert Mitchell
Managing Director
Greg Sheath
Project Manager
WBCM Consulting Ltd.
27 March 2001

Mr Mitchell is the Managing Director, and Mr Sheath is the project manager responsible for designing the domestic water infrastructure for the Eynesbury Estates project in Melton.

The interview began with a brief discussion of this project's goals, and the information that needed to be obtained during the interview. After this discussion, Mr Sheath stated that he didn't think that he could provide all of the information necessary. He then went on to describe the process that was being followed for the development of the domestic water infrastructure of this project. It was stated that the water authority overseeing this part of the project was Western Water. Western Water determines the water supply requirements/pipe sizes for the development based on a network analysis completed by its consultant, Montgomery Watson. WBCM then designs the actual layout of the piping system using the pipe sizes and requirements provided by Western Water.

Mr Sheath was then asked what the usual cost is for domestic water infrastructure. Mr Sheath stated that the rough price for pipelines is usually about 75% of the pipe diameter in dollars per meter. For instance, if a 100 mm pipe was to be installed the cost per meter would be approximately AUD$75.00. He also informed us that the average cost to supply a new residential lot with a domestic supply in a Greenfield subdivision development is approximately AUD$1,500.00 per lot. The average cost is based on a development density of 15 lots per ha and assumes that one section of main services lots on both sides of the road. This standard property water tapping pipe size is 20 mm; the minimum water supply design pressure for a reticulation main in the Melbourne metropolitan area is 15 m.

Mr Sheath also informed us that there is no account of the amount of water for fire fighting, but hydrants are installed at the discretion the water authority (generally at 200 m intervals for residential areas and 120 m interval for commercial/industrial areas).

The topic of "Grey Water" was also discussed. When asked about this, Mr Mitchell stated that "Grey Water" was to be used in this development for watering the golf courses and other means of irrigation.

Wayne Bradborn
MFESB
Western Zone
Commander
27 March 2001

This interview was conducted over the phone on the request of Rob Llewellyn. The objective of this interview was to establish the criteria presently used when determining hydrant spacing in new developments, and any other pertinent information that could be obtained.

Mr Bradborn informed us that currently there are no specifications for requirements of fire flow for new developments. The only aspect of design he must approve is the hydrant spacing. The only hydrant spacing as he described them was "200 m maximum for residential areas and 120 m maximum for commercial areas." He also mentioned that there were several other stimulations such as a hydrants must be located within 90 m of a booster pump, but that it would be better advised to confer with the officers in the structural fire safety division of the MFB on that topic.

Mark Swiney
MFESB
Structural Fire Safety
Senior Station Officer
28 March 2001

This interview was conducted at the MFESB training facility. Mark Swiney is currently a Senior Station Officer with 12 years of active duty, and 3 years at the training facility.

Mr Swiney informed us that for every house fire, it is standard operating procedure to respond to a house fire with two primary units. These units are either Mark III, or Mark IV pumpers, which are roughly the same model. Three fire fighters, an officer in charge, a pump operator, and a hose operator man each pumper truck. The first pumper on the scene takes the primary position for fire fighting, with the best access to both the house and nearest fire hydrant. The officer in charge assesses the scene looking first for anyone trapped inside. If there is no one trapped in the house, he checks for exposures such as vegetation or structures that are in a close proximity. The officer then makes a "call back" to the station to report the status of the situation, and to request additional fire apparatus if necessary. While the officer is assessing the situation, the pump operator begins the pump working and searches for a hydrant to hook up to the tanker. While this is happening, the hose operator begins to unravel a high-pressure hose reel. The high-pressure hose is a 25 mm hose made of rubber, and operating at an average pressure of 3000 kPa, and a flow of 250 l/m or 4.2 l/s. This high-pressure hose is used because it is easy for one man to operate, while applying a sufficient stream to the fire. After the second primary pumper arrives, the three fire fighters hook up a second line from an additional hydrant and start a second high-pressure hose from the first pumper. Mr Swiney told us that each pumper truck carries sixteen lengths of hose; seven are already connected into one hose 210 m in length, seven are arranged individually in trays and two are extra lengths. All of these hoses are 65 mm in diameter.

The officer in charge assesses the fire by examining the following criteria: the size of the building, the percentage of the building involved, if there is anyone trapped inside, and any exposures around the building. Mr Swiney also told us that there was a standard onsite procedure that the officer in charge follows at every house fire called the RECEF method. First the officer surveys the scene by looking to see if any people are still trapped in the house, R is for Rescue. Next the officer searches the area for any exposures, which includes surrounding bush as well as surrounding structures, E is for Exposure. Then the officer makes sure the fire is being contained within the walls of the involved structure, C is for Containment. Fourth, the fire is extinguished, E is for Extinguishment. Last the fire fighters perform "Fire Duty", which includes salvaging and overhauling the structure, F is for Fire-Duty.

When an exposure is encountered special considerations are made. If the exposure is in danger of igniting at least two hoses are used on the fire scene. This is to prevent the fire from spreading outside of the structure in question. A hose line is first dedicated to the exposure, before a hose is applied to the burning structure. Once the exposure is "cooled" and there is no longer a danger of it igniting the exposure hose is turned onto the burning structure. While the exposure is being "cooled" a second line is applied to the burning structure. Mr Swiney stated that another consideration to be made is for the length of the high pressure hoses. These hoses come only in one length of 60 m. This means that if a house has a large front yard or the house itself is large, the high pressure hoses may not be able to reach the rear of the house. Therefore an additional canvas line will need to be used if the fire is in the rear of the house. The canvas line is a standard length of 30 m however and number of canvas lines may be connected together to gain the desired length.

Mr Swiney then made personal comments pertaining to the scene of a fire. He stated that he does not like to see locked gates. These gates make it harder to access the house and be able to attack the fire. Also security gates and bars on the doors and windows of a house. These obstacles cause an increase in the time it takes to gain access into the house. Mr Swiney also commented that in his experience he has never run out of water at the scene of a fire. He has heard of other fire fighters running out of water, however this has always been at the scenes of industrial fires, not residential fires. He has never heard of someone running out of water while fighting a residential fire.

Mr Swiney later informed us, after the interview, that the current standard on hydrant spacing is 200 m for residential areas. He is unsure of why the standard uses this distance or where it came from. However he stated that there is already enough pre-connected hose to reach the second closest hydrant.

Steve Copland
Urban Land Corporation
Manager- Urban Development
29 March 2001

The interview began with a brief discussion of the Urban Land Corporation and their operations. The Urban Land Corporation is the biggest land developer in Victoria. They operate by first purchasing blocks of land. They then design the development and each block of land. Once the estate has been designed the design work for the water systems as well as all of the other systems is contracted out to various consulting firms through the Association of Consulting Engineers Australia (ACEA). This is a bidding process by several firms for the contracted work. The value of the bid is based on the complexity of the site as well as the physical work.

Mr Copland then explained the process for the installation of a water main. The first step is to apply with the water authority for the design and subsequent installation of the main. A fee is paid per lot. There are numerous elements associated with this cost, however for the water authority all of the costs are physical costs. That is none of the fee is used for environmental or societal costs. This fee covers the hook-up into an existing main (or cost to supply water in another fashion), the increase in the supply cost, the chlorination of the water, any additional pumping stations or dams that are needed as well as any other applicable costs to the water authority. Also a refund is paid to the developer to the extent that the water main is capable of also supplying other developments. However this refund is not paid until the end of the process so all costs up to this point are up front costs, and then the refund will be given. Also the fee paid to the water authority includes an application fee, a fee for insurance on the work (30 dollars per lot), and then the headworks fee. This headworks fee varies on a stepped scale according to the size of the lot.

The particulars of the Greenfield site and a comparison with Urban Land Co. sites were also discussed. Mr Copland commented that this Greenfield site in Melton was much larger than sites that the Urban Land Co. usually develops. The Urban Land Co. sites are higher densities than the Melton site. This higher density decreases the cost per lot as compared with the Greenfield site. This decrease in cost is caused by a decrease in the amount of pipe that is needed between lots.

Mary Tissaaratchi
Wester Water
Design Engineer
2 April 2001

Mrs Tissaaratchi was contacted via e-mail for information in relation to Western Water, which is the water authority with jurisdiction over the Eynesbury Station Greenfield site. Mrs Tissaaratchi stated that Western Water designs to 200 kPa (20 m) of residual pressure. Mrs Tissaaratchi also stated that Western Water designs to this pressure and not a flow. The flow is simply determined by the pressure.

Mrs Tissaaratchi also provided a booklet produced by Western Water in relation to water supply infrastructure.

Greg Bawden
MFESB
Commander- Structural Fire Safety
4 April 2001

The interview began with a discussion of the use of hydrants by the fire brigades. Mr Bawden stated, that any data analysed with regards to fire hydrant usage by the fire brigade needs to be done carefully. This care needs to be taken because a fire hydrant usage is a not a mandatory field when filling out a report. He also stated that almost all fire fighters consider using a fire hydrant to be when a hand held line is connected directly to the hydrant. Also fire fighters do not consider connecting the pumper truck to the hydrant to be use of the hydrant, they consider this situation to be working off of the pump. Therefore information regarding hydrant usage might say four in one hundred incidents utilised a fire hydrant, while in reality in almost all incidents that involve a fire the hydrant will be connected to the pumper truck.

Mr Bawden then discussed the standard operating procedures of the Metropolitan Fire Brigade. He stated that a house fire would typically be a first alarm fire. What this implies is two primary appliances, each with three fire fighters, will respond to the alarm. In a house fire the primary appliances are Mark III or Mark IV pumper trucks. These two trucks are fairly similar and both have a tank on board with approximately a 1300 L capacity. He also stated that the dispatch computer would dispatch the two appliances from the two closest firehouses in opposite directions. This is a safety precaution in that if there are any unforeseen obstacles, such as an accident, from one direction that can impede one truck, the second truck will not have to deal with the same obstacle. Mr Bawden also stated that two appliances are not guaranteed to respond. On high-risk days, such as total fire ban days, many of the appliances may already be engaged or the officer in charge (OIC) may mandate that only one appliance respond to first alarm.

Once the first appliance has arrived on the scene of a fire, the OIC will make a decision based on judgment. This decision is whether to call for a second alarm or to just use the first alarm. This decision is based on the size of the house, any exposures around the house, the construction of the house and also if a rescue is needed. While the OIC is making this judgment the pump operator is turning on the pump and then connecting the pumper truck to a fire hydrant. The third man on the truck is the hose operator. He will use a high-pressure hose reel (HPHR) to begin attacking the fire.

Once the OIC has decided on the alarm the RECEF method is followed. Mr Bawden stated that this method is similar for all fire services around Australia. The only difference would be in what the individual steps are called. RECEF is:

R- Rescue
E- Exposures
C- Containment
E- Extinguishment
F- Fire Duty

The rescue aspect is if any one is trapped in the house and needs to be rescued from the fire. Exposures are the second concern on scene. These are any building or vegetation with a danger of igniting from the burning house. Containment is to make sure that the fire is not outside of the structure and if there is to keep it inside of the house. Extinguishment is to put out the fire. Fire Duty is the aftermath of the fire. This is where salvage operations and overhauling the house.

Mr Bawden then talked about any case where a third line may be needed. He stated that the first two lines are nine times out of ten the two HPHR, which are 25 mm in diameter. If a third line is needed it will be a 65 mm line. He stated that when a third line is used there is usually a very good reason for it; therefore the largest line is used. This third line is usually used for exposures that are in danger of igniting after the attack on the fire has already begun, as well as a cover line. This third line needs to be applied quickly so that the fire will not be able to spread. Once the third line has completed the task it was utilised for it is always then turned on the fire and used as an attack line.

Mr Bawden also stated that when a second appliance arrives two connection scenarios might occur. The first is, the second truck may be connected to the first truck to utilise the 1300 L tank. The second truck will then be connected to a hydrant. This also allows the first truck to be connected to two hydrants. The second scenario is that the second crew will only attach a hose between the first truck and a hydrant.

Peter Egan
MFESB
Inspector
4 April 2001

This interview was a brief e-mail correspondence with Mr Egan in regards to hydrant spacing. Mr Egan stated that he spoke with several individuals and that hydrants are spaced 200 m for residential and 120 m for industrial. He stated that historically the MFB had seven lengths of 65 mm hose in each tray set. This was so three lengths would bring the brigade to the midway point between two hydrants and through the pumper truck. The other three lengths would then be used to reach the fire. He stated the seventh length was to allow for "shrinkage." When asked where this code is written he stated "it's not." It is been an agreed position that the industry has used for a long time.

Dr. Paula Beever
NZFS
Principal Fire Engineer
6 April 2001

Dr. Beever was recommended as an expert in the fire protection field, and as someone who had done a fair amount of work in modelling residential fires. The interview began with the mention of a thesis done by Simon Davis. This thesis was on the subject of relating fire-fighting water to heat release rates. Another report that was mentioned was a report by Dr. Beever and Alam for the Fire Code Reform Centre.

After a brief discussion of this model and the plans for implementation, the discussion turned to what classification of t^2 fire should be used. Dr. Beever stated that a fast fire should definitely be used to model a residential fire, if not an ultra fast fire. This is due to the large amount of fuel in the form up upholstered furniture. It was mentioned that this project attempted to model the fire growth rate by the individual development to make the model more development specific. She stated that her team also attempted the same step while they were doing a similar project, and the best criteria they could find to model the growth rate was the ventilation of the individual dwellings. It was stated that this would not be possible to this project solely because of the fact that the house plans are essentially non existent at the time in the process when this model would be utilised.

Dr. Beever mentioned that during the course of her research on this topic, they had used a similar strategy for attempting to determine the required fire flow for different fire scenarios. They also used the F.B.I.M. to represent the response time of the nearest fire brigade. What they found was that in almost all cases without home sprinklers, the room of origin was already in flashover stage by the time the fire brigade interceded. This meant to their research that calculating the fire brigade intervention time was almost a superfluous step. Dr. Beever recommended that the F.B.I.M. remain in the model of this project though. She mentioned the possibility of modelling a Caroline Springs house to determine how long it would take for two or three rooms to flashover. Interviews could then conducted officers at the MFB an the CFA to figure out at which point the officer in charge will determine the house is beyond saving and will focus on just controlling the fire from spreading to another dwelling. The next step would be if the F.B.I.M. time is greater than the time it takes for the fire to flash over two rooms, the attack from the fire brigade would only be to control the fire.

Kevin Pettit
CFA
Operations Officer
10 April 2001

Kevin Pettit is an operations officer for the CFA in Region Eight. Mr Pettit is in charge of the operations of twenty-seven brigades in the Westernport area in Victoria. Mr Pettit was interviewed to obtain information pertaining to the operating procedures practiced by the CFA. The interview began by explaining to Mr Pettit the main objectives of this project including the specific data that needed from him. This information included operating procedures used when the fire contained to the room of origin, spread beyond the room of origin, and when the entire house is engulfed.

When the fire is contained in the room or origin, the standard attack used by the CFA uses one or two 38 mm hose lines depending on the severity of the fire. These 38 mm hose lines are fitted with the typical TFT-125 branches that operate at an average pressure of 1200 kPa.

If the fire has progressed beyond the room of origin, the brigade will utilise a 65 mm hose in order to apply a larger quantity of water to the fire. Mr Pettit explained that if an internal attack is still a consideration they will attack the fire with an extra 38 mm hose due to its manoeuvrability. This method proved to be similar to the attack method used by the MFB given the same situation. The only difference between this method and that of a fully involved house, is that when the house is fully involved two 65 mm hoses will be used from outside.

Mr Pettit also stated that there are a few slight differences between the pumper trucks used by the two fire authorities. The standard pumpers used by the CFA carry 1800 L of water where as the MFB pumpers only carry 1300 L.

Mr Pettit was then asked about hydrant spacing for the CFA regions. He stated that the standard spacing for these residential areas is 200m. This spacing is uniform to the MFB spacing for the same types of areas. When asked about the origins of these standards, he replied that this spacing came from the Melbourne Metropolitan Board of Works many years ago. The standards have not been revised since then.

Exposures were the last topic covered in the interview. Mr Pettit was asked what the standard procedures were when an exposure is endangered. He told us that the CFA follows the same type of procedures as the MFB when evaluating a fire scene. They first address any concerns with rescuing persons trapped in the house, then take into account any exposures. If there are any exposures, they will use a 65 mm hose line to protect it.