A Cost-Benefit Analysis of Home Sprinkler Systems

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A Cost-Benefit Analysis of Home Sprinkler Systems

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Abstract

The purpose of this Interactive Qualifying Project was to conduct a cost analysis of home sprinkler systems for a Greenfield site in Victoria, Australia. This report was presented to the Australasian Fire Authorities Council with conclusions about the provision of, and proposed cost of home sprinkler systems in Greenfield sites. Research was conducted about home sprinkler system costs and codes in the United States and New Zealand. In addition, a cost-benefit model on home sprinkler systems in the United States, by Rosalie Ruegg and Sieglinde Fuller, was reviewed to determine possible methods of identifying costs and benefits of home sprinkler systems. To accurately analyse the costs and benefits of home sprinkler systems in Victoria, a cost-benefit model was created. Eynesbury Station in Melton, Victoria was used as a case study to determine the current costs and benefits of home sprinkler systems

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We give special thanks to John Philip, the Eynesbury Station developer, for his willingness to provide valuable Greenfield site information for our study, as well as his willingness to pioneer the possibilities of the use of home sprinkler systems in Eynesbury Station.

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Finally, we would like to recognise and give our special thanks for the efforts of our Worcester Polytechnic Institute advisors, Professor Holly K. Ault and Professor Jonathan R. Barnett. Their assistance in preparation of the project, as well as their constant support and constructive criticism has been of tremendous help in preparing this cost-benefit analysis in the most effective and professional manner.

Executive Summary

The purpose of this report is to research the costs and the benefits of home sprinkler systems for use in Greenfield sites in Victoria, as well as examine the possibilities of life savings, injury prevention, and property savings. With the possible costs and benefits collected, a model was developed for application to a Greenfield site case study. For this case study, a net cost or benefit to a homeowner in a Greenfield site, and to the Greenfield site community were calculated. A Greenfield site is a large plot of land that will be developed with a large number of homes. The use of home sprinkler systems within these homes would assist the local fire authorities, specifically the Country Fire Authority, in fire suppression and protection.

The research of this study has shown that on average, in the Country Fire Authority (Victoria) area, one person will die in a single-family dwelling fire every 50 days. Between 1998 and 2000, this amounted to 22 fatalities in the Country area of Victoria. It is evident that the need for a fire suppression system exists, for the preservation of life, property, and the prevention of injury. Fire sprinkler systems, as a fire protection device, have made a positive impact in the United States and will be investigated for application in Victoria, in this report.

Home sprinkler systems are unique in that they are partial coverage systems, which only cover areas of the home where most fatal fires originate. The Australian Fire Incident Reporting System (AFIRS) database reports that between 1998 and 2000, 82% of all fatal fires originated in the areas of the home excluding the ceiling space, toilets, bathrooms, and attached structures. In addition to being partial coverage systems, home sprinkler systems are unique because their water supply is distributed through the domestic, cold water supply network within a home. This eliminates the need for extra valves, extra hardware, and maintenance, thus becoming very cost-effective.

Many reports and databases were used to thoroughly research all of the costs and benefits of home sprinkler systems, and provide evidence to show that these systems are beneficial. The Ruegg-Fuller cost-benefit model was helpful in considering fields of interest to collect costs and benefits. In addition, the BRANZ New Zealand 2000 report, BRANZ Australia 2001 Interim report, and Beever and Britton 1999 report were helpful in suggesting assumptions and permissible omissions for the study. To complement this research, the AFIRS database at the Country Fire Authority was analysed, and many interviews were held with various plumbers, fire service officials, water authorities, and insurance providers.

The cost-benefit model created in this study includes all of the costs and benefits that a Greenfield site homeowner may incur, as well as the costs and benefits that will affect the Greenfield site community. For the purposes of this study, the Greenfield site community includes the homeowners, homebuilders, the developer, and the local fire service. Possible costs that were included in the model were purchase and installation, water supply fees to the homeowner, and the cost of possible covenants, to name a few. Some of the major benefits included fire provision savings, life, injury, and property savings. This report discusses various costs and benefits in the United States that currently do not have an impact in Victoria. These areas, including insurance benefits and road infrastructure savings, are important because they may be utilised or considered in the future. In addition, changes in water supply infrastructure had been believed to yield a benefit. However, in Victoria, where water supplies may not be sufficient to supply home sprinkler systems, extra costs to increase water pressure may be applicable.

To provide a user-friendly method to utilise the cost-benefit model, a program was developed using Microsoft Access®. This program allows the user to input individual costs or benefits into various fields, and obtain detailed cost summaries including net homeowner and net community benefits. Also available with the program are multiple sensitivity graphs. These can be used to analyse and predict the net costs or benefits to the homeowner or community by varying the value of particular costs or benefits, such as fire provision savings or water supply infrastructure savings. A combined sensitivity graph is also obtainable, and it displays the net cost or benefit depending upon a varying cost-benefit model period. For example, this allows the user to estimate how long it may take the total benefits to overcome total costs in their particular analysis.

In this report, the cost-benefit model is applied to the Greenfield site of Eynesbury Station, in Melton, Victoria. This new sub-division will consist of approximately 1,200 large homes, with the intent that each home will have a home sprinkler system for additional fire protection. The cost-benefit analysis is projected over the average time of occupancy for a resident in a home in Victoria. It was determined in this case study that a significant amount of the homeowner's total cost is a result of the cost of purchase and installation of the home sprinkler system. The overall community cost for Eynesbury Station is also primarily comprised of the cost of purchase and installation of home sprinkler systems in the 1,200 homes. The benefits of home sprinkler systems in Eynesbury Station, over the period of the analysis, are fairly small for the homeowner.

The benefits for the community are much more significant, and highly impact the overall outcome of the net community benefit. In the CFA area, fire service is principally comprised of volunteers. However, in densely populated areas, it may be necessary to upgrade a volunteer brigade to a career brigade. The application of home sprinkler systems to all houses may make it possible for a volunteer brigade, rather than a career brigade to protect Eynesbury Station. The net benefits over the period of the analysis, under this scenario, would be A$12.3 million to the community. The case study also established that 0.125 lives would be saved in Eynesbury Station during the period of analysis, which is defined as the average occupancy period in a new home (8.8 years).

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Authorship

The completion of this Interactive Qualifying Project was a combined effort by all group members. The research and analysis were performed in a collaborative manner, where each member contributed thoughts, ideas, and opinions to develop this report. The primary contributions of each member can be stated, but do not reflect their entire efforts towards this project. Specifically, Evan Gilman wrote large portions of the cost section in the literature review, the cost-benefit model, and case study. Toby White wrote large portions of the benefit section of the literature review, cost-benefit model, and case study. Andrew Woodward wrote all appendices to the report, performed the majority of statistical data analysis, and created the cost-benefit model computer program.

1 Introduction

The sponsor of this Interactive Qualifying Project is the Australasian Fire Authorities Council (AFAC). AFAC was established in July of 1993 as the Australian Fire Authorities Council, to provide better collaboration between Australian fire services and land management agencies. In particular, the goal of AFAC is to improve the exchange of strategic information between agencies and develop national positions regarding fire safety. In 1996, the New Zealand and Hong Kong fire services joined the Australian Fire Authorities Council, changing the name to the Australasian Fire Authorities Council. The current membership of AFAC includes 23 members and 8 associate members, representing all Australian agencies (Australasian Fire Authorities Council, 2001).

To support their goals for the 1999-2004 period, AFAC created several strategy groups to focus efforts in specific areas of fire protection. These groups were Community Safety, Operational Services, Volunteer and Employment Management, Business Management and Strategic Information Management. The primary support for this Interactive Qualifying Project comes from the Community Safety Strategy Group. According to AFAC, "the Community Safety Strategy Group has been established to advise AFAC on matters which relate to the cost effective methods of increasing the communities' actual and perceived level of safety and protection of life and property from exposure to fire and emergency incidents," (Australasian Fire Authorities Council, 2001). Some of the important activities that the Community Safety Strategy Group are involved in include, fire safety, fire prevention, and community education. For the 2001/2002 year, the Community Safety Strategy Group has developed strategies that directly relate to the availability of water for fire-fighting activities.

These strategies include:

- Promoting the installation of detection and alarm systems and automatic sprinkler systems that will reduce the potential for loss of life and property, especially in the home.
- Fostering nationally consistent approaches to performance-based, fire engineered designs and incorporate the use of the Fire Brigade Intervention Model (FBIM).
- Promoting an 'all hazard/risk management' approach to community safety.

- Developing a national approach to management of dangerous goods and hazardous substances.
- Continuing to develop national positions and guidelines for the rural/urban interface (Llewellyn, 2001).

The purpose of this Interactive Qualifying Project is to address the Community Safety Strategy Group's strategy of promoting and installing automatic sprinkler systems in homes. During the 1999/2000 year a related study of home fire sprinkler systems was conducted by the New Zealand Fire Service that explored the possibility of a fire sprinkler system design that could be installed in a new three-bedroom house for around NZ$1,000 (A$833[1]). This report identified a cost effective solution for the design and installation of a home fire sprinkler system that is supplied by the home's domestic cold water supply (Llewellyn, 2001). It must be noted that only partial home coverage by the sprinkler system was considered in the report. In particular, it was proposed that sprinkler heads should only be installed in the bedroom, living room and kitchen.

A similar study of home sprinkler systems is of need in Australia. The task of this Interactive Qualifying Project is to assist the Community Safety Strategy Group of AFAC by "investigating the provision of and preparing a detailed cost analysis for a Home Sprinkler Protection Package to a Greenfield residential/domestic development site," (Llewellyn, 2001). The specific issues to be addressed in this cost analysis include:

- Costing for the Home Sprinkler Package
- The minimum domestic water requirements for home fire sprinklers
- Potential infrastructure cost savings
- Fire Service provision potential savings
- Impacts on standards of fire cover
- Covenants on properties

To complete this Interactive Qualifying Project, research was conducted in Melbourne, Australia. In addition, important agencies such as the Country Fire Authority, the Metropolitan Fire and Emergency Services Board, local water authorities, land developers, sprinkler system manufacturers and installers, and other stakeholders were consulted. A final report was created and presented to AFAC including a detailed analysis of

1 The currency conversion that will be assumed through out the literature review will be A$1.00 is equal to NZ$1.20.

all costs and benefits to the homeowner who purchases the sprinkler system, and the entire Greenfield site community.

2 Literature Review

Sprinkler systems have protected industrial buildings, factories, schools and other public buildings for over a century (United States Fire Administration, 1999). Installing a sprinkler system is like stationing a private fire fighter in the building, with essentially very little maintenance. The latest advancements of sprinkler system design have allowed low cost sprinkler systems to be installed in homes. The newest home sprinkler systems are supplied by domestic water sources that are shared with residential plumbing fixtures. To adequately supply the home sprinkler system, the home's cold water supply network is properly designed to allow for the high flow that is required when a home sprinkler system is in operation. To differentiate from sprinkler systems that protect commercial or industrial buildings, sprinkler systems within one to two family dwellings will be referred to as home sprinkler systems in this report.

This literature review discusses the costs and benefits associated with home sprinkler systems. In addition, a cost-benefit model of home sprinkler systems in the United States, by Rosalie Ruegg and Sieglinde Fuller (Ruegg-Fuller, 1984), is explained for its methods in effectively identifying and comparing all of the costs and benefits to a homeowner that installs a sprinkler system in a new home. Appendix A and Appendix B should be referred to for basic information on sprinkler system components and water requirements.

2-1 Costs

2-1.1 Home Owner

2-1.1.1 Purchase and Installation

In the U.S., the Home Fire Sprinkler Coalition suggests that the total purchase and installation costs of a home sprinkler system will comprise 1 to 1.5 percent of the cost of a new home (Home Fire Sprinkler Coalition, 2001). In general, this cost is considered to be about the same amount that a homeowner would spend on an upgrade in carpeting a new home. More specific estimates of the costs of home sprinkler systems are often given in a cost per square foot of home (Home Fire Sprinkler Coalition, 2001). Rahmanian determined from a 1988 report that the sprinkler system cost per square foot of home in a new single family dwelling in Montgomery County, MD, would be US$1.17 per square foot (A$25.19[2]

2 The currency conversion that will be assumed through out the literature review will be A$1.00 is equal to US$0.50.

per square metre) (Rahmanian, 1995). In other areas like Scottsdale, AZ, where sprinkler systems are mandatory in new homes, the cost per square foot has dropped significantly during the past ten years. For example, in 1986, the cost for a new, custom home sprinkler system in Scottsdale was US$0.89 per square foot (A$19.16 per square metre). In 1996, the cost dropped to US$0.70 (A$15.07 per square metre), (Ford, 1997).

There are several costs associated with the installation of a home sprinkler system. In general, these costs include a standard connection fee to the public water supply, and labour costs of installing the sprinkler system components by a contractor. As previously described, new home sprinkler systems are often supplied by the home's cold water supply. For this reason, there should only be a one-time connection fee to the city water supply that will supply both the cold water supply and the home sprinkler system in a new home. A 1995 report by Rahmanian in New Zealand reports that the connection fee to a public water main in Christchurch generally costs between NZ$500 (A$417) and NZ$1,500 (A$1,250). The large range in connection fees is primarily dependent upon how far the house is from the public water main. Most cities will charge an additional cost per metre that the house is from the water main, to account for pipe and labour costs (Rahmanian, 1995).

The labour cost of installing a home sprinkler system in a new home constitutes the largest cost of the entire home sprinkler system package. When installing a sprinkler system, a contractor must design and engineer a system for the home, obtain approval by a certified individual, install all the sprinkler components, and make a profit on the job. In general, the total cost of work done by the contractor comprises 60% of the overall cost of the home sprinkler system (Tamim, 1992). Depending upon country and region, the price of installing a home sprinkler system can vary greatly. For the purposes of an example, Rahmanian determined a labour cost of NZ$70 (A$58) per sprinkler head in New Zealand in 1995. This cost does not include approval by the town to install the sprinkler system (Rahmanian, 1974).

To meet current standards in countries like the United States and New Zealand, a contractor must have their sprinkler system plan approved by an authority. In the U.S., the state or city must define a proper authority because there are no national requirements for home sprinkler system inspections. Nor has one been defined by the National Fire Protection Association (NFPA), which is an organization in the U.S. that develops standards for fire service and fire safety. The cost of such an approval inspection in the United States therefore depends upon the inspection requirements defined by a particular state or city. In New Zealand, the Fire Protection Inspection Services Limited (FPIS) inspects sprinkler systems on behalf of the Insurance Council of New Zealand. For a one-time approval inspection of a home sprinkler system, the FPIS charges a fee of NZ$250 (A$208) (Rahmanian, 1973).

Tamim states in his 1992 report entitled, "Cost-Benefit Analysis of Residential Sprinkler Systems in Single Family Dwellings," that the contractors he interviewed did not explore the economics of scale. However, Tamim does suggest that engineering and approval costs of new home sprinkler systems could be significantly reduced if the sprinkler systems were to be installed in a large development of similar houses (Tamim, 1992). In a large development consisting of homes that are of the same design, it is possible that a contractor may engineer one home sprinkler system and then apply it to every house. Similarly, the approval of the sprinkler system design should only have to be done once, saving the cost of an approval for every house.

2-1.1.2 Existing Home

Installing a home sprinkler system in an existing home is far more costly than installing a system in a new home. The reason for this higher cost is attributed to the fact that installing a sprinkler system in an existing home is more time consuming (Rahmanian, 1995). The cold water supply in the existing home may not be adequate to supply the home sprinkler system. In this situation, it is likely that a separate piping system must be installed in the home to supply the sprinkler system. Such a system would require all of the costs previously outlined for a new home. Costs for retrofitting a home sprinkler system in an existing home must be determined on a home-by-home basis because of the possible differences in the existing water supply design.

2-1.1.3 Routine Inspection and Maintenance

The NFPA does not provide standards for the inspection of home sprinkler systems in the U.S. The NFPA does, however, recommend that routine inspections and maintenance be performed on home sprinkler systems. Appendix A-1-4 of NFPA 13D states that it is the responsibility of a homeowner to properly maintain a sprinkler system. Appendix A-1-4 offers a list of recommended procedures for monthly home sprinkler system inspections, including:

- Visual inspection of all sprinklers, to ensure against obstruction of spray
- Inspection of all valves to ensure that they are open

- Testing of all water flow devices
- Testing of the alarm system, where installed
- Operation of pumps where employed
- Checking of the pressure of air used with dry systems
- Checking of water level in tanks

Special attention is also needed to ensure that sprinklers are not painted, either at the time of installation or during subsequent redecoration. When sprinkler piping or areas next to sprinklers are being painted, the sprinklers should be protected by covering them with a bag, which should be removed immediately after painting is finished (NFPA 13D Sec A-1-4, 1999).

Depending upon equipment needed, routine maintenance should not be a significant cost to the homeowner if inspections are self-performed. However, many organizations and businesses in the United States offer routine inspections of home sprinkler systems for a fee. For example, the city of Rohnert Part, California offers a home sprinkler system inspection by the Fire Prevention Bureau for a cost of US$40 (A$80) per hour (Fire Prevention Bureau, 2001).

2-1.2 City/Town

2-1.2.1 Inspections

In the U.S., a city or town requiring an approval inspection or annual inspection of home sprinkler systems must provide a qualified person to perform the inspections. NFPA 13D suggests that an authority with jurisdiction should perform sprinkler system inspections. According to NFPA 13D, an "authority with jurisdiction" may be "a federal, state, local or other regional department or individual such as a fire chief; fire marshal; chief of fire prevention bureau, labour department, or health department; building official; electrical inspector; or others having statutory authority" (NFPA 13D, A-1-3, 1999). Depending upon the authority with jurisdiction in a town or city, there will likely be cost to the city to pay the authority to remain qualified and perform sprinkler system inspections.

2-2 Benefits

This section discusses the many benefits that can be gained by homeowners and/or the city or town when home sprinkler systems are used. Many references are made to Ford's Scottsdale Report on its ten-year study of home sprinklers in newly constructed homes in the city of Scottsdale, Arizona (Ford, 1997). Scottsdale has an ordinance that requires home sprinklers be installed in any new home, and the results are very beneficial for study. The benefits of having a home sprinkler system are valuable to show interested parties the payback that results with these home protection devises.

2-2.1 Home Owner

Some very important concerns that a homeowner might have when investigating the benefits of home sprinklers systems would be insurance premium rates, property loss reduction, and the prevention of injury and fatality.

2-2.1.1 Insurance

Homeowners insurance is an important necessity to people who own homes. Premiums on insurance are typically based on the age of a home and steps made towards making the home safer. The installation of a home burglary prevention system reduces premiums because the risk of break-in is reduced substantially. A home sprinkler system also reduces home damage due to fire, and can also result in lower insurance premiums.

With the installation of a home sprinkler system, most homeowner insurance companies in the United States will provide an attractive discount on insurance policy premiums. Westbrook Financial Service, Inc. of Scottsdale, Arizona, grants between a 5 and 8% premium discount to homes with sprinkler systems (Westbrook, 2001). The primary factor in percentage reduction of premiums is based on completeness of the home sprinkler coverage. A higher discount percentage is awarded to homes with full sprinkler coverage, defined as being covered in areas such as closets, pantries, bathrooms, and attached structures such as a garage. The difference in discount between full and partially covered homes is typically about 2%, though C.N.A. Insurance and Hartford Insurance of Phoenix, Arizona, have a differential of 5% (Wick Pilcher Insurance Agency, 2001). As seen in Table 1, some other home insurance agencies will discount up to 14%. Savings of up to 14% on insurance premiums can save a homeowner a considerable amount of money. The premium reduction is an excellent benefit and incentive for homeowners who have or are considering installing a home sprinkler system.

Insurance Company & Location	Local Sprinkler Ordinance?	Insurance Premium Reduction
First Colorado Insurance Colorado	No	Flat reduction of 14% for sprinklers, Fire extinguishers, and alarms.
Westbrook Financial Service, Inc. Scottsdale, Arizona	Yes	Reduction ranges from 5% to 8%
Classic Insurance Scottsdale, Arizona	Yes	Reduction up to 10%
Martos Insurance San Francisco, California	Yes, in nearby Limerick, CA	Full sprinkler coverage- 10% reduction Partial coverage- 8% reduction
**C.N.A. Insurance Phoenix, Arizona	Yes, in nearby Scottsdale, AZ	Full sprinkler coverage- 13% reduction Partial coverage- 8% reduction
**Chubb Insurance Phoenix, Arizona	Yes, in nearby Scottsdale, AZ	10% Flat rate reduction
**Hartford Insurance Phoenix, Arizona	Yes, in nearby Scottsdale, AZ	Full sprinkler coverage- 13% reduction Partial coverage- 8% reduction
Norm Maul Insurance Agency Phoenix, Arizona	Yes, in nearby Scottsdale, AZ	Full sprinkler coverage- 10% reduction Partial coverage- 8% reduction
Northeast Insurance Worcester, Massachusetts	No	Rate ranges from 10-12%
Winchester Insurance Agency Auburn, Massachusetts	No	Full sprinkler coverage-10% Partial sprinkler coverage-12%
West Boylston Insurance Agency, Inc. West Boylston, Massachusetts	No	Full sprinkler coverage-12% Partial sprinkler coverage- 8%-10%

Table 1: Insurance Premium Reductions for Fire Sprinklers

2-2.1.2 Reduction of Property Loss

Property loss due to fires can be devastating to homeowners and their families. The addition of home sprinkler systems can be used to help minimize the extreme damage caused by fires in the home. Without home sprinkler systems, fires can reach the stage of flashover much more easily. The result is more of the home being damaged, and less of a chance to repair what was damaged because of the intense burning that occurred.

Home sprinkler systems are very effective in the protection of property loss. Most fires that occur in sprinkler-protected homes are prevented from reaching the stage of flashover. Because the fires stay localised, the damage is contained to a single room and there is much less fire and water damage. Property loss due to fires in homes has been reduced as much as 90% in some communities due to home sprinkler systems.

In Scottsdale, Arizona, property loss savings have been extremely high in comparison with communities that do not include sprinkler system ordinances. The average loss in property due to fire in Scottsdale during their ten-year study from 1985-1995 was US$17,067 (A$34,134) for homes without sprinkler protection, and an astonishingly low US$1,945 (A$3,890) for homes equipped with home sprinkler systems (Ford, 1997). Scottsdale is one of many U.S. cities that have a sprinkler ordinance, in which sprinklers must be installed into any new home during construction. Data presented in the Scottsdale report shows that the city of Scottsdale had a total property loss due to fire of 63% less than that of other cities with populations between 100,000 and 250,000 people (Ford, 1997). This savings in fire damage due to the protection of home sprinkler systems is very impressive. The benefits of home sprinkler systems can even be carried one step beyond property savings, to the savings of life and prevention of injury.

2-2.1.3 Savings of Life/Health

The most important purpose of a home sprinkler system is the prevention of injury and fatalities. With the addition of a home sprinkler system, someone within a home with a fire incident may have more time to escape, thus minimising injury and preventing death.

Home sprinkler systems are known to play a significant role in reducing injuries and fatalities due to residential fires. Because 80% of fire related deaths happen in residential buildings (Lia, 2001), reducing the chances of fatalities or injury in the home is one of the most important tasks of a home sprinkler system. As mentioned in section 2-2.1.2, home sprinklers operate quickly enough to suppress a fire before flashover. They can also act quickly enough to actually sustain life within the room of origin (Koski, 2000). The ordinance set forth in Scottsdale has resulted in ten years of non-fatal, residential fires because of the high reliability of home sprinkler systems. In addition, the ten-year study reports that eight lives were saved as a result of home sprinkler systems (Ford, 1997).

In New Zealand, extensive research has been performed on home sprinkler systems by Duncan and Wade, sponsored by the BRANZ Resource Centre for Building Excellence. The BRANZ 2000 report estimated that the number of deaths that would occur without home sprinkler systems was about 6 in 1,000 fire incidences. The BRANZ reports also estimates that this number would be reduced to 1.2 in 1,000 incidences if home sprinkler systems were present in the home. Likewise, the number of fire related injuries in fires would be reduced from 40 per 1,000 incidences to 15 injuries per 1,000 incidences (Duncan and Wade, 2000). It is evident that the number of injuries and fatalities due to fire are greatly reduced by the presence and help of a home sprinkler system.

2-2.2 City/Town

For the city or town, home sprinkler systems can reduce the cost of fire provision, infrastructure, and water supply. Because the sprinklers are fast acting, reliable, and use minimal resources, they are very beneficial to a city or town and save money within the area where home sprinkler systems are used.

2-2.2.1 Fire Service Provision Savings

Fire provision or fire cover is a very crucial element in timely responses to fires. Fire departments must set a standard time in which they feel will be quick enough to save lives and property in a burning building.

In the NFPA's draft of Standard 1710, "Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments," it is stated that the standard for response time for the first engine company is four minutes or less to 90% of the homes in its jurisdiction (NFPA 1710 Sec 4.1.2.1.1, 2001). The alternative gives eight minutes or less for the arrival of the initial full alarm assignment to 90% of the covered homes in its jurisdiction (NFPA 1710 Sec 4.1.2.1.1, 2001). For the purpose of the standard, full alarm assignment capabilities are based on response to a house with square footage of no more than 264-m^2 (NFPA 1710 Sec A.5.2.3.2.1, 2001). Life support systems also have a standard of eight minutes or less to arrive on the scene of the fire suppression incident (NFPA 1710 Sec 4.1.2.1.1, 2001).

With the help from home sprinkler systems, response time may be relaxed, and may be able to expand a station's jurisdiction or its response time. Fire cover is a very important factor in saving lives and property, and home sprinkler systems can play a major role in making more time for victims to get out of a burning house, and for the first engine company to arrive.

2-2.2.2 Infrastructure Savings

The savings of infrastructure due to home sprinkler systems in the United States covers a wide range of areas. A residential sub-division mandating home sprinkler systems can save fire fighting equipment, water main size, number of fire hydrants and hydrant maintenance. Other savings that can be taken into account are narrower road widths and the lengthening of roads ending at a cul-de-sac.

Because of the quick response of the home sprinkler system, many fires are extinguished even before the first fire trucks arrive. Since response time of fire fighting personnel is not as critical, set-up time for the fire fighters can be elongated. In addition, the number of fire fighters needed to respond to a fire in a United States home with a sprinkler system can be reduced by as much as one-half. This reduction of fire fighting personnel, in turn, results in a reduction of fire fighting apparatus needed per incident (Residential Fire Safety Institute, 2001).

In the United States, the number of fire hydrants necessary in a residential sub-division with standard home sprinkler systems may also be reduced. In Scottsdale, the number of hydrants needed in new subdivisions was essentially cut in half. Instead of the mandatory maximum distance between the hydrants set at 600 feet (197 metres) apart, the mandatory distance is now set at 1,200 feet (394 metres). This saves US$2,000 (A$4,000) per new fire hydrant and installation, and reduces maintenance needs due to fewer hydrants within a given residential sub-division (Koski, 2000). Pre-existing hydrant layouts would not be redesigned, and the maintenance would not be reduced with the existing hydrants if home sprinkler systems were retrofitted into existing homes. However, if a new sub-division design called for fewer hydrants, the comparable cost in maintenance to a design with the usual number of hydrants would be much less. The Scottsdale report showed that the total number of hydrants in the city could actually be reduced by a third (Ford, 1997).

Reducing the number of fire stations would also lower the overall infrastructure costs. It was projected that the city of Scottsdale would be able to reduce its fire department by three stations, saving US$6,000,000 (A$12,000,000) in capital costs and US$1,000,000 (A$2,000,000) in annual costs (Koski, 2000). These reductions were not put forth in the ten years that the study in Scottsdale was being completed. However, in the first seven years of the study, no new fire stations were added, despite the growth in population. Only two stations were added in the final three years, after the increased population deemed it necessary (Ford, 1997). In 1995, after the study was completed, there were eight fire stations in the city, which is less than normally expected given that the population was approximately 175,000 people (Koski, 2000).

Along with the potential to save on the number of fire stations, the savings in the water supply infrastructure were also projected to extend to US$7,500,000 (A$15,000,000) within the distribution system of Scottsdale (Koski, 2000). However, there has not been a redesign in water mains within subdivision layout as of yet, and the typical main size remains at 200 mm (8-inch) (Jacobson, 2000). Common practice in U.S. land development water main layout is to reduce the water main to 100 mm (4-inch) after the last hydrant, if there is no chance of extending the road beyond the cul-de-sac or end of the road (Boulette, 2001). The reduction in the number of hydrants and extended spacing would allow for 217 metres (about 1/8 of a mile) of 200 mm (8-inch) main to be replaced by 100 mm (4-inch) main at the end of each road, resulting in some infrastructure savings.

Other savings within the infrastructure system have to do with the road systems, the arteries of the fire department. With less demand on fire fighting personnel and trucks, roads can be reduced in width because of less traffic due to emergency vehicles. Roads can be designed to allow for one fire truck rather than two side by side. In Scottsdale, the width of roads being constructed has been narrowed from 10.5 to 9.2 metres (32 to 28 feet). In addition, the length of the roads to the cul-de-sacs has been allowed to increase from their original length restriction. The reason the length of road is restricted when a cul-de-sac is constructed at the end of it, is that there is only one entrance to the road. Emergency vehicles have to drive the entire length of the road in order to turn around for positioning. Since the response time of fire fighters can be relaxed with the help of home sprinkler systems, the length of the road leading to a cul-de-sac can be lengthened. The length of the roads to the cul-de-sac has been extended from 197 to 656 metres (600 to 2,000 feet) in Scottsdale (Koski, 2000). The narrowing of the roads saves money in road building, paving, and maintenance. The lengthening of road allows more road length per cul-de-sac, hence saving land space and construction money to build the cul-de-sac. The savings in land space can result in more lots per sub-division, which has allowed Scottsdale to increase its housing density by four percent (Koski, 2000), thus reducing the infrastructure cost per capita.

The reduction in road materials, hydrants, and the need for a full fire fighting unit, as well as apparatus, can be substantial in city or town savings. The greatest benefits of these savings can be seen in cities that start to develop ordinances that require home sprinklers, such as Scottsdale, Arizona.

2-2.2.3 Water Supply Savings

The savings in water by home sprinkler systems is quite impressive compared to the water usage of manned fire hoses. Specifically, home sprinkler system heads have less water flow than manned fire hoses, thus using very little water in comparison.

Home sprinkler systems attack fires almost immediately. In most cases, a home with a sprinkler system will never become fully involved, or reach the burning status of flashover. In fact, in Scottsdale's ten-year study, only one or two sprinklers were needed to extinguish 92% of fires that occurred (Ford, 1997), while 98% of the fires only required a maximum of three activated sprinklers (Jacobson, 2000). Similar statistics resulted in home sprinkler use in New Zealand, where 82% of the fires were extinguished by two or fewer sprinklers (America Fire Sprinklers Association, 2001). As well as the appealing fact that most fires are extinguished with only a few sprinklers, home sprinkler systems also use only a fraction of the water that would be required by fire fighters using typical, 44 mm (1-¾-inch) hoses, with Task Force nozzles. In the city of Scottsdale, Arizona, a study was performed on 38 fire incidences, where comparisons were made between sprinklers and two hoses with Task Force nozzles. The sprinklers, releasing water at 95 litres per minute (25 gallons per minute), were found to have used an average of 1,350 litres (357 gallons) of water per incident. In contrast, the two fire hoses release water at 756 litres per minute (200 gallons per minute) each, for an average of 18,462 litres (4,884 gallons) per incident (Ford, 1997). The large differences in water use are not only due to the differences in flow, but are directly related to response time as well. Because the sprinklers activate almost instantly with the presence of fire, they can extinguish the fire very quickly. In a best-case scenario, a fire department will arrive at a fire, on average, after three to four minutes. By this time, a fire will have most likely reached the stage of flashover, and will require a greater amount of water to be extinguished. On average, home sprinkler systems can save over 90% of the water used by two hoses at a fire. The reduced flow rate plays a major factor in this reduction, as well as the reduction of running time, which results in less fire damage and water damage.

2-3 Ruegg-Fuller C-B Model

In 1984, Rosalie Ruegg and Sieglinde Fuller published a cost-benefit model to assess the economic efficiency of a residential fire sprinkler system. This model is cited and discussed in several newer reports on home sprinkler systems such as, "Cost-Benefit Analysis of Residential Sprinkler Systems in Single Family Dwellings," by Tamim in 1992 and "An Analysis of Domestic Sprinkler Systems for Use in New Zealand," by Rahmanian in 1995. The Ruegg-Fuller model estimates the individual costs and benefits associated with owning, operating and maintaining a home sprinkler system. These estimates are combined using mathematical equations to provide the homeowner with a decision tool for determining if he should install a home sprinkler system. For the purposes of this literature review, Ruegg and Fuller's approach to assess costs and benefits of home sprinkler systems, as well as the assumptions made in the creation of the model, will be summarised. The Ruegg-Fuller cost-benefit model should be referred to directly for any exact data or equations.

2-3.1 Costs Model

2-3.1.1 Component Cost Estimates

To determine the purchase and installation costs associated with a new home sprinkler system, the Ruegg-Fuller model proposes several methods. In order to compare the cost estimates produced by each method, it is assumed that the sprinkler system to be installed will be adequate as defined by NFPA 13D-1980 (Ruegg-Fuller, 1984). Additionally, all costs are evaluated over a thirty-year period to account for costs that may be present after the initial purchase and installation of a home sprinkler system.

The first method to determine the purchase and installation cost of a home sprinkler system, as proposed by Ruegg and Fuller, is to analyse the cost of every component of the sprinkler system and the cost of installing that component in the house. As described by the report, the cost of components depends upon the size of pipe, pipe material, necessary fittings and sprinkler heads required to complete the system. Installed costs per component of an example home sprinkler system are determined in the report by information given in the MEANS Building Construction Cost Guide 1982. It is stated in the report that the prices obtained for installed components include overhead and profit (Ruegg-Fuller, 1984).

Ruegg and Fuller propose that a second method of determining the purchase and installation cost of a new sprinkler system is to obtain an estimate from a person who is knowledgeable in the field. Specifically, the Ruegg-Fuller report uses purchase and installation cost estimates generated by the president of the National Automatic Sprinkler and Fire Control Association (Ruegg-Fuller, 1984). Using this method of cost analysis, the total cost of purchasing a home sprinkler system is found by adding the total cost of components to the total cost of installation (Ruegg-Fuller, 1984).

The third proposed method for determining purchase and installation costs of a new sprinkler system is to estimate the total purchase and installation cost based on a cost per square foot of home. A more accurate cost may also be estimated based upon a cost per square foot of home protected by sprinklers. Again, investigative reports and studies are used to determine the cost of a sprinkler system. For purposes of an example, the Ruegg-Fuller report includes average costs per square foot of home based upon a 1981 report done on the cost of sprinkler systems in San Clemente, California (Ruegg-Fuller, 1984).

2-3.1.2 Financing and Tax Effects

Once the base costs of purchasing and installing a home sprinkler system are determined, the Ruegg-Fuller cost-benefit model describes possible cost adjustments and additions. Depending upon financing rates and discounts, it may be advantageous for a homeowner to finance the purchase of his home sprinkler system. The financed cost of a home sprinkler system is determined by amortizing the loan over its specified life and borrowing rate (Ruegg-Fuller, 1984). Ruegg and Fuller also point out that the owner of a home or rental unit who is purchasing a home sprinkler system may deduct the interest payments made on a loan used to finance the sprinkler system from his taxable income (Ruegg-Fuller, 1984). In addition, the cost of the home sprinkler system may be altered by the depreciation of system acquisition costs if a resale of the home occurs (Ruegg-Fuller, 1984). It should be taken into considerations that ahomeowner's property tax may also increase because a home sprinkler system increases the value of his home. The Ruegg-Fuller model estimates the additional cost of a property tax increase per year, using a straight-line obsolescence rate. The property tax increase is then summed for thirty years to determine the total additional cost applied to the homeowner for installing a home sprinkler system (Ruegg-Fuller, 1984). It should be noted that depending upon a homeowner's financial situation and sprinkler system payment plan, financing and tax effects might create monetary benefits instead of costs to the homeowner.

2-3.1.3 Other Potential Costs

Depending upon the rules and regulations of a town or city, there is a possibility that additional costs and fees may be added to the purchase and installation costs of a home sprinkler system. Ruegg and Fuller point out that some areas of the United States charge fees for a homeowner that installs larger pipe to supply his home sprinkler system. The reason for such a fee is that a larger pipe size gives the potential of higher than normal water usage (Ruegg-Fuller, 1984). However, as Ruegg and Fuller point out, if a home sprinkler system is installed in a home, the town will likely save water because the sprinkler system is effective and efficient at extinguishing a fire. For the purposes of the Ruegg-Fuller cost-benefit model, this potential cost is omitted from the general case scenario. However, in areas where a homeowner might be subjected to additional costs and fees, they must be considered in the total cost of the home sprinkler system (Ruegg-Fuller, 1984).

2-3.1.4 Operation Costs

The Ruegg-Fuller model decomposes the cost of operating a home sprinkler system into possible water costs, water damage costs, and electricity costs for sprinkler systems with pumps. Water costs can be estimated only if there is a meter to measure the flow of water while a sprinkler system is in operation. Multiplying the flow rate by the approximate time that the sprinkler is in operation will give an approximate amount of water used, which can be assessed at the current cost per gallon (Ruegg-Fuller, 1984). Water damage costs can be created if a fire causes a sprinkler to activate, or the sprinkler is activated accidentally. It is assumed in the Ruegg-Fuller model that the cost of water damage done during a fire would be much less than the possible damage done if the sprinkler system was not present. For this reason, the model determines water damage costs to equal zero because of the possible savings in property (Ruegg-Fuller, 1984). Contrarily, water damage costs due to accidental activation have a potential for being very great (Ruegg-Fuller, 1984). Because this cost is indeterminate and the chance of accidental sprinkler activation is so small, the Ruegg-Fuller model assumes this cost is negligible (Ruegg-Fuller, 1984). Electricity costs for a sprinkler system that requires a pump are also assumed negligible because they would be very small, and the chance of sprinkler activation for any reason is so small (Ruegg-Fuller, 1984).

Total operating costs as defined by the Ruegg-Fuller model are the sum of the costs due to water use, water damage and electricity use. Ruegg and Fuller suggest that the potential operating costs of a home sprinkler system are so small that they can be neglected from the total sprinkler system cost calculations (Ruegg-Fuller, 1984).

2-3.1.5 Maintenance, Repair and Replacement Costs

The Ruegg-Fuller model considers maintenance costs to a home sprinkler system to be estimated as the cost of an annual inspection. It is assumed in the model that this annual inspection is performed by a qualified inspector and is estimated to take an hour (Ruegg-Fuller, 1984). The cost for such an inspection is determined by multiplying the hourly wage of the inspector by the inspection time and the marginal income tax rate to the owner (Ruegg-Fuller, 1984).

Ruegg and Fuller also consider the costs due to repair and replacement of sprinkler system components. It is determined in the report, however, that repair costs should be eliminated by routine replacement of important components, i.e. sprinkler heads. The model assumes that half of the sprinkler heads in a home will be replaced over a thirty-year period (Ruegg-Fuller, 1984). The cost of replacement of sprinkler components is estimated by summing hardware costs and the hourly labour wage multiplied by the length of replacement time, and the marginal income tax rate of the owner (Ruegg-Fuller, 1984).

2-3.2 Benefits Model

After establishing a method to determine costs, the Ruegg-Fuller cost-benefit model attempts to associate a monetary value with all of the possible benefits that a homeowner may realise because of installing a sprinkler system. The primary direct benefits outlined in this model are the reduced risk of death, injury and property loss. In addition, the indirect benefits outlined in the model are lower insurance costs, possible lower property taxes and reduced housing costs (Ruegg-Fuller, 1984).

2-3.2.1 Reduced Risk of Death and Injury

Ruegg and Fuller extensively discuss the benefits of reduced risk of death and injury due to a home sprinkler system in their report. It is pointed out in the report that assigning a dollar value to a life or injury is a subjective decision-making process that will not go without controversy. Nevertheless, Ruegg and Fuller determine that "the approach considered most consistent with economic theory is based on the willingness-to-pay concept," (Ruegg-Fuller, 1984). The willingness-to-pay value of a life is determined by the amount of money that an individual is willing to pay to reduce his risk of death or injury by a given fraction. Using data from surveys that questioned respondents about their willingness to pay, Ruegg and Fuller outline two possible means of assigning a dollar value to human life and injury.

The first method to assign a dollar value to life, as described by Ruegg and Fuller, is to directly use data from dependable surveys. For example, the Ruegg-Fuller model analysed data from a survey that determined most people value their life between US$250,000 and US$1,000,000 (A$500,000 and A$2,000,000). Taking an average, the Ruegg-Fuller model places the value of life at US$500,000 (A$1,000,000). Similarly, the assumed value per injury averted is US$20,000 (A$40,000).

The second method for determining life and injury value is to calculate the present-value-cost per life saved as well as the number of injuries averted by home sprinkler systems (Ruegg-Fuller, 1984). The homeowner can therefore compare his own value to the calculated value of life and possible averted injury. To accurately evaluate the effectiveness of a home sprinkler system for saving lives and injury, two conditions of sprinkler performance are considered: first, the case of a sprinkler system in a home without a smoke alarm present, and second, the case of a sprinkler system operating in cooperation with a smoke alarm (Ruegg-Fuller, 1984). The basis for considering the two described conditions is to account for the ability of a smoke alarm to alert people of a fire so that they may escape before injury or death is caused. In such a case, the home sprinkler system may not be responsible for saving lives, but only for saving property losses.

2-3.2.2 Reduced Risk of Property Loss

Ruegg and Fuller treat the reduced risk of property loss separately from the previously described direct benefits of home sprinkler systems because they propose that there is less uncertainty in assigning a dollar value to property loss. The monetary benefits due to reduced risk of property loss are defined in the model as the savings in uninsured and non-refundable property loss costs. These benefits are calculated by multiplying the predicted fraction of reduced property loss attributable to the sprinkler system, by the probability of a fire occurring and the estimated dollar value of the possible property loss. A conversion factor is then multiplied by the outcome to convert yearly savings over a 30-year period to a present value cost (Ruegg-Fuller, 1984).

2-3.2.3 Reduced Risk of Indirect Loss

Indirect costs of residential fires are considered in the Ruegg-Fuller model to be the costs to a homeowner that are a result of a fire, excluding direct property or health costs. Ruegg and Fuller use the results of an analysis performed in 1977 by Princeton University and Mathematica Policy Research, to determine the monetary cost of indirect losses. Included in the analysis are the costs of temporary shelter, missed work, extra food, demolition, legal expenses, transportation, emotional counselling, childcare and other costs. Additionally, the analysis estimates values for the actual "out of pocket" money spent on the indirect losses, which is some fraction of their total. Ruegg and Fuller determine the benefit of sprinkler systems to save indirect losses by calculating the expected indirect costs of a fire in a home without a sprinkler system or smoke alarm. This cost is then compared to the expected indirect costs of a fire in a home with a home sprinkler system and a smoke alarm.

2-3.2.4 Insurance Cost Savings

At the time of completion of the Ruegg-Fuller cost-benefit model, insurance savings due to home sprinkler systems were not standardised or even consistent throughout the U.S. In their report, Ruegg and Fuller state that, "the estimate of sprinkler benefits from reduced fire insurance premiums appears at this time to be tentative, at least in some regions of the country" (Ruegg-Fuller, 1984). Nevertheless, Ruegg and Fuller do provide a model for assessing possible insurance savings due to home sprinkler systems. As outlined by Ruegg and Fuller, insurance cost savings is a combination of a reduction in insurance rates and premiums. Similar to calculations of reduced risk of indirect loss, the two conditions of a home with only a sprinkler system or a home with both a sprinkler system and smoke alarm are considered. Total insurance cost savings are calculated knowing the discount in premiums and insurance rates, the amount of coverage on the structure and the amount of coverage on the contents (Ruegg-Fuller, 1984).

2-3.2.5 Municipal Cost Savings

Ruegg and Fuller suggest that there may also be potential property tax savings to a homeowner who lives in an area where home sprinkler systems are standard. Ruegg and Fuller again point out that estimating the average value of potential municipal savings costs is difficult because of the high number of variables. For the purposes of their cost-benefit model, the municipal cost savings returned to the owner are assumed to be the savings of not building and maintaining a fire station in a new development of houses with home sprinkler systems. To determine this value, an estimated cost of a new fire station is calculated for a new residential development without home sprinkler systems. It is assumed that the existing fire cover in the area can meet the needs of a new development with home sprinkler systems. This assumption is made on the fact that generally, response times can be lengthened due to the ability of the home sprinkler system to contain the fire (Ruegg-Fuller, 1984). The savings of not building and maintaining a fire station in the sprinklered development are then divided by the number of houses in the development to determine a potential cost savings per home (Ruegg-Fuller, 1984).

2-3.2.6 Federal and State Incentives

The last monetary benefit considered by the Ruegg-Fuller model is homeowner savings due to government incentives. It is noted by Ruegg and Fuller that at the time of their report, there were no federal government incentives for homeowners that wished to install home sprinkler systems. However, at the time, Bill 878 was proposed by Senator Howard Cannon that would provide a 20 percent tax credit for sprinklers installed in those properties that were also eligible for the regular investment tax credit (Ruegg-Fuller, 1984). Realising that a federal tax credit is a possible benefit from home sprinkler systems, Ruegg and Fuller use the proposed tax credit of Bill 878 for some example cases of their cost-benefit model.

2-3.3 Cost-Benefits Comparison

It is realised by the Ruegg-Fuller cost-benefit model that not all of the expected costs or benefits of home sprinkler systems will apply to every homeowner that is considering the installation of such a system. To account for differences in sprinkler packages, present fire protection equipment, municipal costs and savings, federal tax credits, insurance policies and if the home is owner-occupied or rented, Ruegg and Fuller illustrate ten different possible home cases (Ruegg-Fuller, 1984). The cost-benefit model is then applied to determine the net benefits of a home sprinkler system in each case. A comparison of the ten cases provides a homeowner with knowledge of what particular benefits or costs may make the resulting net benefits positive or negative. Figure 1 is table copied directly from the Ruegg-Fuller report that summarises the ten case studies analysed. The right hand column of the table displays the net benefits or net costs for each case. Below the table in Figure 1, the assumptions made to determine costs and benefits are briefly described.

Figure 1: Table from Rueggg-Fuller Report (Ruegg-Fuller, 1984)

Summary of Nine Hypothetical Case Studies of Residential Sprinkler Systems

Case Illus-trations	ASSUMPTIONS: Type/Size or Piping[a]: Plastic 1/2"	Type/Size or Piping[a]: Copper 1 1/4"	Smoke Detector[b]: Present Before Sprinkler Installed	Smoke Detector[b]: Not Present Before Sprinkler Installed	Local Taxes: No Municipal Savings and No Waivers	Local Taxes: Municipal Cost Savings and Waiver of Property Tax[c]	Federal Tax Credit[d]: No	Federal Tax Credit[d]: Yes	Water Demand Charge[e]: No	Water Demand Charge[e]: Yes	Insurance[f]: Yes	Insurance[f]: No — Savings Attributed to Sprinkler System: Yes	Insurance[f]: No — Savings Attributed to Sprinkler System: No	Occupancy[g]: Owner Occupied	Occupancy[g]: Rental House	Life-Cycle Net Benefits or Losses (Present Value $ Rounded to Nearest $100)
I	X		X		X		X		X		X			X		-1,500
II	X		X			X	X		X		X			X		-100
III	X		X			X		X	X		X			X		+200[h]
IV		X	X		X		X		X		X			X		-3,500[i]
V		X	X		X		X			X	X			X		-5,500[j]
VI	X		X		X		X		X			X		X		+900
VII	X		X		X		X		X				X	X		-1,600
VIII	X			X	X		X		X		X			X		-1,200
IX	X		X		X		X		X		X				X	-800

xv

[a]To provide sensitivity analysis of the results to pipe type and size, a low end of the range of piping cost is represented by 1/2" plastic piping, and a high end of the range is represented by 1 1/4" copper piping. In practice, the piping could be of mixed sizes and would likely fall in the middle of this range in most cases; i.e., 3/4" piping of either plastic or copper would likely be more typical than 1/2" or 1 1/4". The estimated purchase and installation cost (after taxes and financing) is $1,445 for system with 1/2" polybutylene piping, and $3,270 with 1-1/4" copper piping.

[b]Loss reduction attributable to sprinklers is lower if sprinklers are added to smoke detectors than if sprinkler impact is measured alone, but in almost all situations sprinklers would be used only in conjunction with smoke detectors.

[c]Municipal cost savings reflect a pass-through to the homeowner of $1,173 in present value dollars from a total present value cost avoidance of $1,256,300 on fire station construction and related services over 30 years.

[d]The credit of 20 percent of initial costs is modeled after pending legislation, e.g., U.S. Senate Bill 878, U.S. House Bills HR. 1958 and HR. 73795.

[e]A water demand charge may be levied by some U.S. utilities for connecting a house equipped with a sprinkler system to the municipal water system; case V includes a connection fee of $2,000.

[f]Insurance is assumed to cover 80 percent of any property loss. The premium is reduced by 2 percent for smoke detectors and by an additional 13 percent for sprinklers, as suggested at the time of this study by the Insurance Services Office (an advisory organization to U. S. insurance companies).

[g]Tax deductions on depreciation and operating and maintenance costs are allowed for rental property; it is assumed that the landlord receives a rent premium reflective of the tenant's reduced risk of fire loss.

[h]This represents an optimistic case because it is based on there being a Federal tax credit of 20 percent in addition to a property tax reduction to reflect a pass-through of municipal savings from reduced fire station costs.

[i]This represents a pessimistic case because it is based on copper pipe of a large size which in practice would seldom be used throughout a system.

[j]This represents an extremely pessimistic case because it is based both on the use of oversized copper pipe and on there being a sizable water demand charge imposed by the municipality.

2-4 BRANZ Australia Study

The Building Research Association of New Zealand (BRANZ) conducted a study on Cost-Effective Home Fire Sprinkler Systems for New Zealand in 2000 (Duncan et all, 2000) and is currently completing a similar study in Australia in 2001 (Duncan et all, 2001). The objective of these studies was to find a low-cost sprinkler system that would reduce the occurrence of injury and fatalities, as well as property damage due to fire in the home. In order to feasibly conduct the analysis of the home sprinkler package, some specific assumptions and tradeoffs were made to simplify the analysis, as well as to define the benchmark to which the analysis was completed.

The benchmark home designs that were used in the draft of the BRANZ Australia, 2001, were a single level, three bedroom home, and a two story, 4 bedroom home, both provided by AVJennings of Australia. The study incorporates a multi-purpose sprinkler system within the home, using partial coverage rather than full coverage. A partial coverage sprinkler system, as defined by BRANZ, is a sprinkler system where sprinkler heads are not installed in the bathroom, toilet, wardrobe, cupboard areas and ceiling cavities. A full coverage sprinkler system may include sprinkler heads in all of these areas. Although full coverage provides greater protection in the home, a partial coverage system is deemed adequate for the purposes of the BRANZ study because the origin of most fires (62%) and even more fatal fires (88%) occur where partial coverage systems are implemented (Duncan and Wade, 2001). Large cost savings in materials and installation result in this trade-off.

The BRANZ report sets other criteria to define the multi-purpose system. The system is designed for a pressure of 500 kPa through a 25 mm feed from the water main in the street. This feed is larger than the 15 mm feed that is required if the water serves only the other domestic purposes alone. No control valve set is required for the multi-purpose system because it is integrated with the potable, cold water supply network, and backflow prevention is not required with this set up. In addition, the system's hydraulic calculations are based on the operation of two sprinkler heads (Duncan et al, 2001).

An important note in the BRANZ report cautions that the multi-purpose sprinkler system cannot be used as a substitute for smoke alarms. Independent sprinkler systems, which receive water though a separate source than the domestic supply, are usually equipped with a flow alarm that activates if the sprinkler system is activated. Because the multi-purpose sprinkler system is supplied by the cold water supply network, which flows frequently, a flow alarm cannot be used, thus making smoke alarms a crucial component to the fire protection system.

The result of the BRANZ Australia 2001 Interim study is a cost-benefit analysis of multi-purpose sprinkler systems in both the three-bedroom and four-bedroom home. The cost effectiveness of these sprinkler systems is determined by the calculation of a cost per life saved (Duncan et al, 2001). This report defines the cost per life saved as the total costs minus savings, divided by the expected number of lives saved due to multi-purpose sprinkler systems. For the purpose of the BRANZ Australia 2001 Interim study, the costs of multi-purpose sprinkler systems include installation costs and maintenance costs, while savings include injury savings and savings in property loss. A risk assessment is performed to study the reduction in fire injuries and fatalities due to multi-purpose sprinkler systems so that these benefits can be properly factored into the cost per life saved calculation.

2-5 Information Required for the Creation of a Cost-Benefit Model

To create a cost-benefit model for home sprinkler systems in Greenfield sites, all of the costs and benefits to a homeowner or developer must be identified. These costs and benefits may be a direct or indirect result of the installation of home sprinkler systems. The following is a summary of the expected costs and benefits of home sprinkler systems that were considered to create a cost-benefit model.

2-5.1 Greenfield Site Information

It is necessary to collect specific information for the development plans of the homes in the Greenfield site. This information is valuable because it directly affects the potential costs and benefits of home sprinkler systems. Specifically, information should be collected on the number of homes and the size of homes that will be built. In addition, the size of the Greenfield development should be considered for its potential in saving design, plumbing and installation costs for the simultaneous construction of homes with sprinkler systems, and reducing the needed fire service provisions for the Greenfield site.

2-5.2 Water Requirements

Once a basic sprinkler system design is obtained for homes in Greenfield sites, water requirements for the sprinkler system must be investigated. These water requirements include the required pressure and flow for optimal performance of a home sprinkler system. In addition, the availability and reliability of current water supplies for Greenfield sites should be determined. This information will help identify any particular costs or benefits of supplying water to home sprinkler systems and ensures that those systems installed in Greenfield sites will be adequately supplied.

2-5.3 Home Owner Costs

New home sprinkler systems incur several costs to the homeowner. The largest and most obvious cost is due to the purchase and installation of a new sprinkler system (Rahmanian, 1995). This cost will be passed from a homebuilder to the homeowner in the sale of a home. For the purposes of this report, purchase and installation costs include any design or approval fees, possible city and town fees, and the installer's price for purchasing and installing all sprinkler system components. If covenants are present on a homeowner's land, additional legal fees may be passed from the developer to the homeowner that ensures that every Greenfield site home complies with covenants relating to sprinkler systems.

2-5.4 Costs to the City or Town

Several costs to the city or town can be identified if a Greenfield site is developed. Although it is hoped that home sprinkler systems will save money by reducing the needed water supply and infrastructure, it is possible that a city or town may be required to modify their water supply system to meet the requirements of sprinkler systems. Such modifications would incur some costs to the city or town. It is also likely that a city or town will be required to pay for code enforcement in areas where sprinkler systems are mandatory. Specifically, the city or town may need to hire qualified inspectors to perform routine inspections of home sprinkler systems to ensure that they are operating correctly.

A city or town may also feel the need to educate homeowners in Greenfield sites about the proper use and maintenance of home sprinkler systems. Paying for education will help ensure that sprinkler systems can be relied upon to save fire fighting equipment and personnel in areas where Greenfield sites are present. Even with properly educated homeowners, there is still a chance of sprinkler system malfunction or accidental activation. Especially in large developments where every home is sprinklered, there will likely be a new cost of fire fighter response to false alarms or accidentally activated home sprinkler systems.

2-5.5 Infrastructure Cost Savings

The potential for infrastructure cost savings is a benefit that would be directed towards the city and developer. These savings have the potential to affect the homeowner if the developer decides to pass the savings on. Savings of water supply infrastructure would be the result of a reduction in the number of fire hydrants needed due to extended allowable spacing in between each fire hydrant. With the reduction of fire hydrants, there would be a direct decrease for maintenance needed for a given developed area. In addition, if the water mains in the developed area were reduced in size due to home sprinkler system use, material costs would also decrease. Such a decrease would be dependent on the reduction of fire hydrants, as well as a reduction in the needed flow per given water main.

Possible roadway construction savings may also be a result of the installation of home sprinkler systems. Road width may be minimised, and the length of the road leading to a cul-de-sac may be extended, giving land developers more accessible and sellable land. At that point, the decision could be made to increase the number of lots for a given plot of land, and the land developer or owner could increase profit or pass the savings down to the buyer of each land lot.

Home sprinkler systems may also reduce the number of fire stations needed around a Greenfield site. These savings could be passed down to the developer and to the homeowner by way of tax reductions. If the numbers of fire stations are not immediately reduced, the rate at which new stations are added may be reduced. This should provide monetary benefits to the homeowner by way of decreasing the rate of tax increase to pay for the building and manning of new stations.

2-5.6 Savings in Fire Provision

The potential for savings in fire provision would directly affect the city or town, providing the possibility of reduced taxes to the homeowner. Home sprinkler systems should cause a reduction of needed fire fighting equipment such as engines and apparatus. In addition, there could also be a reduction in needed manpower to fight fires in homes where sprinkler systems are present. Like stations, the immediate reduction of manpower may not be necessary, but the reduction of the rate of hire may be the benefit.

2-5.7 Direct Homeowner Benefits

There are also several direct benefits to a homeowner in a Greenfield site. Some of these benefits or savings are related to the homeowner's insurance. The installation of home sprinkler systems may directly result in lower insurance premiums. Additionally, the potential for property damage savings the event of a fire is a great benefit to the homeowner. It is also possible that the savings of life and the prevention of injury can be assigned monetary values as benefits to the homeowner.

2-6 Literature Review Summary

This literature review discussed the potential costs and benefits that would be a result of home sprinkler systems in the United States. In doing so, major studies completed in the United States and New Zealand were reviewed in an effort to sufficiently cover the all of the possible information regarding the costs and benefits of the home sprinkler systems. This information was of great importance in determining the required fields of research necessary to completing a thorough cost-benefit analysis for home sprinkler systems in Victoria, Australia.

3 Methodology

The purpose of this Interactive Qualifying Project was to conduct a cost-benefit analysis of home sprinkler systems for Greenfield sites in Victoria, Australia. Currently, home sprinkler system technology is limited in Victoria. Specifically, sprinkler systems are rarely installed in homes, and current sprinkler system designs do not utilise water from the cold water supply. For this reason, this analysis estimated the potential costs and benefits of a home sprinkler system that are supplied by a home's domestic cold water supply network. To accurately account for all of the costs and benefits associated with a home sprinkler system, a cost-benefit model was created. Specifically, the model addresses the costs and benefits to a homeowner, developer, water authority, and fire service.

Several different types of resources were used to gain specific information about new development construction in Victoria, fire protection systems, and the expected costs and benefits pertaining to home sprinkler systems. The primary resources used for this analysis were reports, databases and human sources.

3-1 Reports and Databases

As previously outlined, the Ruegg-Fuller cost-benefit model provides a method to apply monetary values to the costs and benefits of a home sprinkler system in the U.S. Although the Ruegg-Fuller model was created in 1984, and the current costs and benefits of home sprinkler systems have changed, the model was a good reference for the creation of the cost-benefit model in Victoria. In particular, the Ruegg-Fuller model provided a basis for identifying the primary sources of costs and benefits of sprinkler systems.

In addition to the Ruegg-Fuller model, other reports and studies conducted on home sprinkler systems in the United States, New Zealand, and Australia were used. In particular, the New Zealand BRANZ 2000 report (Duncan et al., 2000), the Australia BRANZ 2001 report (Duncan et al., 2001), and the Scottsdale, Arizona, report (Ford, 1996) were used to identify important sources of information, as well as identify specific assumptions and analysis techniques used to analyse home sprinkler systems. Information from these reports was also used to assist experts in determining expected costs and benefits of home sprinkler systems in Greenfield sites.

Information was also collected from the Australia Fire Incident Reporting System (AFIRS) provided by the Metropolitan Fire and Emergency Services Board (MFESB) and the Country Fire Authority (CFA). This database provided specific information about injury and fatalities due to fire, as well as fire occurrence and place of origin in a home. The CFA's Geographic Information System Department also provided estimates of the number of dwellings and population in all of Victoria. In addition, Australia Insurance Statistics, Limited, provided useful statistics regarding average fire insurance claims and premiums for homeowner insurance policies in Victoria. Several insurance companies also provided statistics from their databases about industrial fire sprinkler malfunction and accidental activation.

3-2 Interviews and Discussions

Interviews were the primary method used to obtain information to create the cost-benefit model and apply the case study. Specifically, face-to-face interviews were conducted with a number of local experts to obtain information about the costs and benefits of home sprinkler systems. Each interview focused on questions created prior to the interview and a summary of each interview was created for reference and documentation purposes. The people interviewed included: the Greenfield site developer, building contractors, water authorities, fire service officials, plumbers, insurance providers, and the WPI Water Supplies Group[3].

3-2.1 Developer

The developer was very useful in providing specific information pertaining to the Greenfield site, for use as a case study. In particular, information regarding the details of the development was obtained, such as the size of the development, number of house lots, and orientation of the house lots. In addition, information regarding the development process, such as the phases of the project and phase priority, was discussed. The road layout of the development was also obtained to estimate fire fighter response times. In addition, some important references were provided by the developer, including the city council, the town planner and the water supply consulting firm that designed the water supply system for the Greenfield site development.

3-2.2 Contractors

The contractors were helpful in identifying costs of infrastructure construction, and other issues specific to road construction. In particular, infrastructure data and information was obtained to compare with the information collected from the water authorities. Also,

[3] A Worcester Polytechnic Institute Interactive Qualifying Project was completed on the topic of *Water Supplies for Residential Fire Fighting,* (Jenkins et al, 2001).

information regarding possible road design alterations was discussed with civil contractors. Specifically, details on road width standards were covered, as well as the possibility of redesign if home sprinkler systems were installed in an entire development. Likewise, the same issues were discussed pertaining to road lengths that terminate at cul-de-sacs or tees.

3-2.3 Plumbers

Plumbers were interviewed to estimate the costs of designing and installing a domestic water supply system with and without a home sprinkler system. Specific home design plans were provided to several plumbers to ensure that the purchase and installation estimates of home sprinkler systems were reasonable. In addition, a discussion with plumbers identified proper maintenance procedures for home sprinkler systems.

3-2.4 Fire Service Officials

Fire service officials were interviewed to collect information regarding homeowner education, fire cover, approval of infrastructure and placement of covenants on new properties. Persons responsible for providing community education at the MFESB and CFA were interviewed to determine the cost of possible programs to educate homeowners about the proper use and maintenance of home sprinkler systems. The Geographic Information System Department of the CFA provided specific information regarding the fire cover of Greenfield sites, including response times and current fire brigade location. This information was then taken to officials at the CFA to determine the need for a new brigade at the Greenfield site and an estimated cost for a career fire brigade versus a volunteer fire brigade at the site.

Officials at the CFA were also contacted for information about placing covenants on new property to ensure an adequate level of fire protection. These officials also provided information about who enforces covenants on property and what the costs of those enforcement measures might be.

3-2.5 Water Authorities

Water authorities in the Melbourne area of Victoria were helpful in providing valuable information about water supply infrastructure as well as information about the cost of the actual water supply. To aid the water authorities, details about the Greenfield site design considerations were provided, such as house density and location. Infrastructure specifications were acquired, as well as information on the billable recipients to the infrastructure. The water authorities also identified maintenance issues regarding water supply infrastructure.

Details about current water supply requirements were obtained from different water authorities for comparison. Minimum water flow rates and pressures were gathered, as well as the cost of water to hydrants and to individual dwellings. Finally, water authorities provided information about the design of water supply infrastructure based upon worse case conditions of water use, such as peak flow periods, which are helpful in considering water availability and reliability.

3-2.6 Water Supplies Group

The WPI Water Supplies Group was able to supply information regarding fire fighting water supplies. In particular, the model that this group provided helped determine reductions in needed fire fighting water supplies to a development with home sprinkler systems. This information was then used to determine costs or savings in water supply infrastructure in Greenfield sites.

3-2.7 Insurance Providers

Insurance providers were interviewed to determine possible insurance benefits to homeowners with home sprinkler systems. Specifically, the Insurance Council of Australia and Royal Sun Alliance Insurance were contacted to discuss current homeowner insurance benefits available to owners of sprinkler systems. In addition, these organizations suggested what would be required of home sprinkler system performance before home insurance benefits would be possible in Victoria.

3-3 Cost-Benefit Model and Case Study

After the various resources were consulted or interviewed, the resulting data and information were sorted and used to develop the cost-benefit model. Different variables were created in the model to help identify the specific costs and benefits, with and without home fire sprinkler systems in a Greenfield site. The model was then applied to a specific case study, and the outcome revealed the overall costs and benefits pertaining to Greenfield site homeowners and the Greenfield site community. In addition, a cost per life saved for the Greenfield site was calculated for the purpose of comparison with other reports.

4 Cost-Benefit Model

The intent of this cost-benefit model is to provide a method to identify and sum the individual costs and benefits that are a direct result of the installation of home fire sprinkler systems in homes in Greenfield sites. The result of this cost-benefit model is a net dollar value cost or benefit to the average homeowner in a Greenfield site, as well as the entire Greenfield site community. For the purposes of this cost-benefit model, the Greenfield site community includes the Greenfield site developer, homebuilders, homeowners, local government, and the fire service responsible for providing fire protection to the Greenfield site. For comparison with similar studies in the United States, New Zealand and Australia, this cost-benefit model provides methods to determine the cost per life saved, due to the installation of home sprinkler systems in Greenfield site homes.

Included in the following cost-benefit model are variables that identify important costs and benefits of home sprinkler systems to consider. A Microsoft Access® program was used to sum all of the costs and benefits with appropriate equations when dollar values for each variable were estimated.

4-1 Home Sprinkler System Design and Assumptions

The fire sprinkler system studied in this analysis will be referred to as a home sprinkler system. This fire sprinkler system design is almost identical to those fire sprinkler system designs studied in the BRANZ Australia 2001 Interim (Duncan et al, 2001) and BRANZ New Zealand 2000 (Duncan et al, 2000) reports. It is important to note that a home sprinkler system will not fully comply with current Australian Standard 2118.5 for domestic sprinkler systems. As a result, the application of home sprinkler systems will only be considered in single-family dwellings.

A home sprinkler system has several characteristics that make it different from current residential or domestic home sprinkler systems in Australia. In particular, a home sprinkler system is integrated with a home's cold water supply network. Therefore, the sprinkler system piping and control valves are part of the domestic cold water supply, removing the need for additional valves and backflow devices. In addition, flow alarms cannot be used with home sprinkler systems because water frequently flows through the domestic water supply network.

It is assumed in the analysis that home sprinkler systems will be supplied with potable water from a water supply system in the Greenfield site development. It is also assumed that this water supply system will provide adequate pressure and flow for a home sprinkler system, from a 25 mm tap in the development's water main. This tap size is an increase from the common 20 mm tap size required for domestic water supplies. Similar to the Australian Standard for domestic sprinklers, the Greenfield site water supply system should provide an adequate pressure and flow to supply home sprinkler systems in combination with cold water supply networks for 95% of the time, or 67% of the maximum static water pressure available (AS 2118.5 Sec 2.3.2.2, 1995). For this reason, the pressures and flows of a Greenfield site water supply system may need to be increased from the average water supply system in current developments in Victoria if the homes are equipped with home sprinkler systems.

Similar to the requirements of Australian domestic sprinkler standard, home sprinkler systems will be designed to allow adequate pressure and flow at the sprinkler heads when up to 12 L/min of the domestic water supply is being used for domestic purposes (AS 2118.5 Sec 2.3.2.1, 1995). This extra flow of water is intended to account for normal domestic usage such as the operation of appliances, toilets, or showers at the time of sprinkler activation. In addition, home sprinkler systems will be designed to have adequate pressure and flow at the sprinkler heads when a maximum of two sprinkler heads activate simultaneously.

Home sprinkler systems are designed to be a life safety device. Figure 2 shows that in the CFA region, 82% of all fatal fires between 1998 and 2000 originated in the bedroom, kitchen, lounge, and laundry. This percentage is based upon 18 fatalities that occurred in these areas, out of 22 total fatalities in single-family homes. To significantly minimise fire fatalities in homes, yet reduce the cost compared to current domestic sprinkler designs, home sprinkler systems are partial coverage systems. Specifically, home sprinkler systems have sprinkler heads in every area of the home, excluding all bathrooms, toilets, wardrobes, cupboards, and ceiling cavities. Supportive data from the BRANZ New Zealand 2000 report suggest that home sprinkler systems may be even more effective at saving lives in New Zealand. According to this report, between 1986 and 1994, as many as 88% of domestic fatal fires occurred in the bedroom, kitchen, lounge and dining room (Duncan et al, 2000).

Where accidental fatal fires start in single-family homes

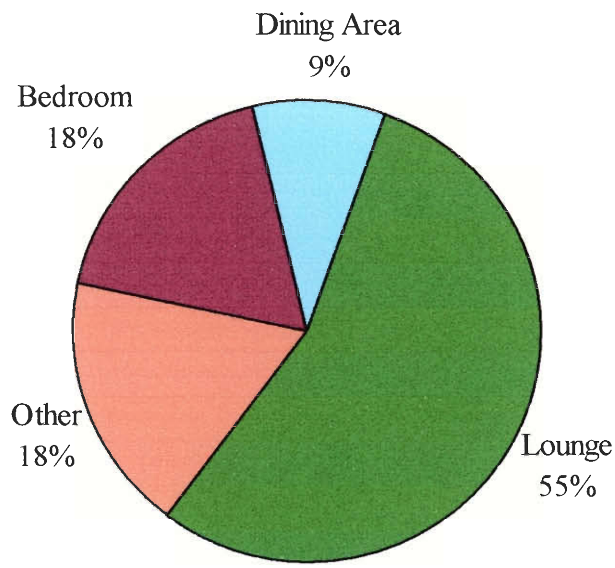

Figure 2: Where accidental Fatal Fires Started in the CFA Region between 1998 and 2000

In addition, it is expected that home sprinkler systems will significantly reduce property damage due to fires in single-family dwellings in Greenfield sites. Figure 3 displays data from the CFA region between 1998 and 2000, which reports that 74% of the 4,977 fires that occurred in areas of single-family dwellings that home sprinkler systems will cover. Again, the BRANZ New Zealand 2000 report provides supportive data of this area of origin percentage from data collected by the New Zealand Fire Service. According to these data, 76% percent of domestic fires start in the bedroom, lounge, kitchen and laundry in New Zealand (Duncan et al, 2000).

Area of Origin of Single-Family Home Fires

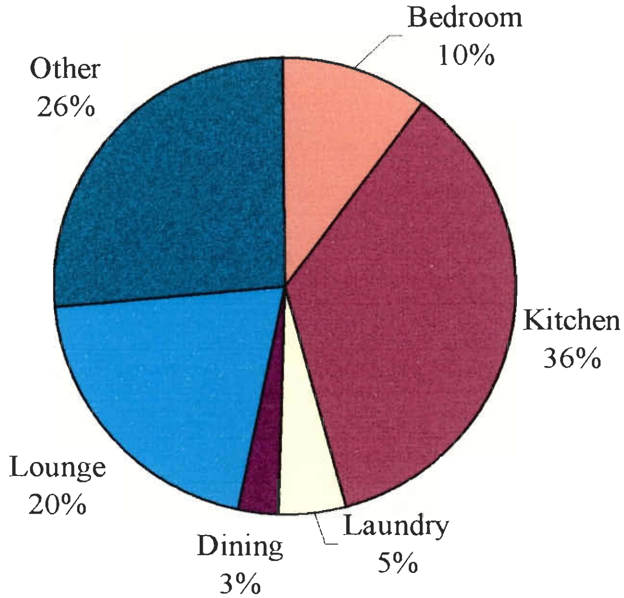

Figure 3: Area of Origin of Single-Family Home Fires in CFA Region between 1998 and 2000

This study assumes that the cost-benefit model should analyse the costs and benefits of home sprinkler systems for the average period of homeownership in Victoria. According the Australian Bureau of Statistics, this average time-period (YRS)[4] is 8.8 years[5] (Australian Bureau of Statistics, 2001). Analysing home sprinkler systems for this period allows the inclusion of particular costs and benefits that may occur annually or periodically over time. In addition, this ensures that all costs will be allocated to original homeowners and not to subsequent homeowners.

This model also considers inflation of costs and benefits over time. According to data from the Australian Bureau of Statistics, the average annual inflation rate for eight major cities in Australia, between the years of 1990 and 2000 was 2.23%. Similarly, the average annual inflation rate for Melbourne between these years was 2.18%. To remain consistent with these data, this cost-benefit model assumes an average annual inflation rate (INF) of 2.2% for the state of Victoria.

4-2 Cost Model

This cost model addresses the possible costs to the Greenfield site homeowner and Greenfield site community because of the installation of home sprinkler systems in every

[4] Symbols with the format of (XXX) indicate variables used in the equations found in Table 5.
5 This value is calculated by averaging the time of occupancy of homeowners with mortgages, without mortgages, renters, and others (Australian Bureau of Statistics, 2001).

home of a Greenfield site. To accurately account for all costs due to home sprinkler systems, this cost model individually discusses the direct costs to the developer, homebuilders, homeowners, and the fire service.

4-Step 1 To the Developer

Direct costs to the developer, due to the installation of home sprinkler systems in Greenfield sites, will be highly dependent on the development's water supply infrastructure needs. In Section 5-Step 6.a, it is discussed that water supply infrastructure could incur costs or benefits to the developer. Apart from this possible cost, the other costs to developers will be the result of advertising and promoting home sprinkler systems. This cost model assumes that costs to the developer due to the installation of home sprinkler systems will be passed directly to homeowners.

4-Step 1.a Advertising

To successfully promote the benefits of home sprinkler systems in Greenfield sites, the Greenfield site developer may need to conduct research regarding effective marketing strategies for home sprinkler systems. From this research, the developer could then create a homeowner awareness program or an information package that will help inform potential Greenfield site homeowners about the effectiveness and reliability of home sprinkler systems. In addition, this package may also inform homeowners about the mechanics of home sprinkler systems and how they are utilised to fight fires in a community. If this information is relatively brief, and included in the advertising materials for the entire home, there may only be minimal cost due to the advertising of home sprinkler systems. Total costs due to the advertising of home sprinkler (ADV) should be estimated by the developer of the Greenfield site.

4-Step 2 To the Builder

This model assumes builders will construct homes on Greenfield site properties. These builders may be hired by the developer or homeowners that purchase property in the Greenfield site. For this reason, the builder will be the first to pay for the cost of purchasing, installing, and approving a home sprinkler system in a Greenfield site home. This model assumes that the builder will incorporate the cost of home sprinkler systems into the building cost, which the homeowner will ultimately pay.

In Victoria, it is necessary to be certified to work with the domestic potable water supply to install a home sprinkler system. For this reason, any installer of a home sprinkler system must be certified to install domestic water supplies in addition to domestic sprinkler systems. This model assumes that a builder will hire plumbers that are certified to install domestic potable water supplies and domestic sprinkler systems. In addition, using plumbers to install home sprinkler systems will eliminate the need for builders to hire additional sub-contractors to install sprinkler systems.

4-Step 2.a Purchase and Installation

To save money, a builder may design home sprinkler systems and purchase materials for those systems in bulk. In addition, a builder may set a flat price to the plumber for installing home sprinkler systems in Greenfield site homes. In this case, builders should estimate the cost of design, materials, and installation of home sprinkler systems. However, because home sprinkler systems are new in Victoria, this model assumes that plumbers are the most qualified party to estimate the cost of purchasing and installing home sprinkler systems due to their experience with domestic cold water supply systems. Specifically, this cost model analyses the cost of designing, providing materials, and installing home sprinkler systems. It must be noted that some plumbers do not separately estimate these three costs. Instead, the plumber may estimate the total price of purchasing and installing a home sprinkler system (TPI).

4-Step 2.a.i Design

To calculate the net cost of the design of a home sprinkler system, the plumber should determine the cost of designing the domestic cold water supply alone (CWD). This design will include all pipe work, a common 20 mm tap and water meter, and necessary valves and fittings. The plumber then determines the cost of designing a domestic supply with an integrated home sprinkler system (CDC), including the increased tap and meter, sprinkler components, and additional pipe work and hardware. The difference of these two costs determines the net cost of designing only the home sprinkler system (SDC). Included in the home sprinkler system design process are the pipe layout and hydraulic calculations if deemed necessary. In homes of identical design, the design cost may be reduced because pipe layout could be the same.

4-Step 2.a.ii Materials

To determine the cost of materials for a home sprinkler system, the cost of materials for the domestic cold water supply network (CWM) should be estimated separate from an estimate for the cold water supply system that includes the integrated home sprinkler system (CMC). The difference in these two totals will be the cost of materials for the home sprinkler system (SMC). An itemised cost breakdown of materials is preferred so that the individual material costs of the cold water supply system and the cold water supply system integrated with the home sprinkler system can be compared.

Material costs for the cold water supply system (CWM) and the cold water supply system with the integrated home sprinkler system (CMC) should include all materials to adequately supply water from the street water main. These materials include water main tapping materials, a water meter, piping, valves, fittings, sprinkler heads and other hardware. The water authority should provide the cost of an appropriately sized water meter for each system. For a domestic cold water system only, the tapping and meter size is typically 20 mm in Victoria (Collins, 2001). It is assumed that a 25 mm tap in the street water main will provide sufficient pressures and flows to supply a home sprinkler system. Due to the increased flow demand of a home sprinkler system, pipes running within the home may be increased in size, which will create an increased cost. Extra piping will also be required to construct the spurs that supply the home sprinkler heads.

The common, certified, pipe materials that may be used for home sprinkler systems are post-chlorinated polyvinyl chloride (CPVC) and copper. These two materials are very similar in cost; however, CPVC is easier to work with (Hocking, 2001). Steel pipe may also be an option because it was traditionally used for commercial sprinkler applications. However, steel pipe is not preferred because the installation cost is much higher than that of copper or CPVC (Hocking, 2001).

4-Step 2.a.iii Installation

Plumbers should be consulted, to determine the exact cost of a particular home sprinkler system design. Similar to design and material costs, plumbers estimate the cost of installing a standard cold water supply system (CWI) and the cost of installing a home sprinkler system integrated with the cold water supply network (CIC). The total cost of installation for the sprinkler system alone (SIC) is the difference between these two costs.

Generally, installation will consist of two major tasks; pipe work within the house and the excavation and backfilling of the trench from the water metre to the house. It is common for these tasks to be estimated separately. The time for installation of a home sprinkler system in a single home may be as much as twice the time of a basic domestic installation. However, for a Greenfield site, it is expected that the time of installation will be reduced for homes that are constructed simultaneously by the same builder. This time reduction can be attributed to the ability to pre-cut pipe lengths for similar home designs, and even pre-assemble fittings to those pipes for home sprinkler head piping connections.

Increased costs in installing home sprinkler systems integrated with cold water supply systems versus standard cold water supply systems are due to several factors. First, installation requires time for more pipes to be connected and for the installation of sprinkler heads. Second, installation time may increase because of working with increased material sizes. In addition, the plumber must return after the ceiling is finished to install the new sprinkler heads, adding more time to the installation.

4-Step 2.b Approvals and Initial Inspection

In Victoria, a plumber must issue a certificate of compliance to the builder after a domestic cold water system is installed. It is expected that a certificate of compliance must also be issued for a home sprinkler system that is integrated with a domestic cold water supply system. Currently, for domestic cold water systems, the Plumbing Industry Commission absorbs the cost of approval of the design, but the builder must pay for the certificate. The cost of the certificate may vary, depending on the particular plumber performing the design and installation. The certificate of compliance guarantees against faulty materials and workmanship for ten years, and certifies that the system complies with applicable Australian Standards. The Plumbing Industry Commission chooses at random, 5% of all work done by plumbers in Victoria to inspect at no charge, to check for compliance and quality of work.

The Plumbing Industry Commission has suggested that the certificate of compliance cost will not increase due to the extended approval of a home sprinkler system. The plumbers doing the labour, however, may increase the cost of the certificate of compliance to cover their increased cost of insurance (McBride, 2001). The plumber's insurance increase would be a result of the increased risk with designing and installing home sprinkler systems. However, once the plumber has increased the cost of a certificate of compliance, the cost of this certificate will most likely be constant, whether the plumber has installed a sprinkler system or just a domestic water supply (McBride, 2001). If in the future there are additional approval fees for a home sprinkler system and cold water system combined, this cost (CAI) should be estimated by subtracting the approval cost of only a cold water supply system (CWA), from the approval cost of a combined home sprinkler and cold water system (SAI).

4-Step 3 To Homeowner

Several direct costs to a Greenfield site homeowner will occur because of the installation of a home sprinkler system in a Greenfield site home. In particular, these direct costs may include water supply fees, sprinkler system activation water costs, and maintenance costs.

4-Step 3.a Water Supply Fees

Currently there are no additional monthly water supply fees by the water authority for an increased water main tap or water meter. The water authority responsible for supplying water to the Greenfield site should determine possible monthly fees created in the future. The cost of monthly fees (SWF) should be calculated by taking difference between the cost of a monthly fee for a tap and meter of a domestic water supply system (CWF) and a monthly fee for a tap and meter of a home sprinkler system integrated with a domestic cold water supply system (CSF). This difference in cost should then be summed for all months of each year, and multiplied by the number of years (YRS) in the cost-benefit model period.

4-Step 3.b Sprinkler Activation Water Costs

The water authority responsible for supplying water to the Greenfield site determines water usage costs. Because home sprinkler systems are supplied by the home's domestic cold water supply system, a homeowner would be charged for the water used when his home sprinkler system activates. This cost (AWC) can be calculated by multiplying the amount of water used by the sprinkler system (SPF) by the cost per kilolitre (COW) determined by the water authority, the probability of the sprinkler system activating and the number of years in the cost-benefit model time period (YRS). To estimate the average amount of water used when a home sprinkler system activates, data from the Scottsdale, Arizona report (Ford, 1997) can be used. During the ten years of home sprinkler presence in Scottsdale, Arizona, the average amount of water used by a home sprinkler system was 790 litres (Ford, 1997). The probability of a home sprinkler system activating can be estimated as the probability of a fire occurring in a Greenfield site home (PFO). This variable is discussed later in the "Benefits to Homeowner" section.

4-Step 3.c Maintenance

For the purposes of this cost model, it is assumed that there is no annual maintenance required for home sprinkler systems. This assumption is based on several facts about home sprinkler systems. First, home sprinkler systems are supplied by a home's cold water supply network. Currently, there no are procedures in practice for the maintenance of a home's cold water supply network. Simply adding sprinkler heads should not alter the need for annual maintenance to the water supply system. This assumes that home sprinkler heads do not require any maintenance.

AS 1851.3 – Maintenance of Fire Protection Equipment, Part 3: Automatic Fire Sprinkler Systems suggests that at least ten sprinkler heads in a system be inspected, pressure tested and tested for operating characteristics after 24 years (AS 1851.3, Sec. 4.2, 1997). NFPA 25 – Standards for the Inspection, Testing and Maintenance of Water Based Protection Systems suggests that fast response sprinkler heads used in a residential application be tested after 20 years (NFPA 25, Sec. 2-2.1.2, 1998). For these reasons, it is assumed that home sprinkler heads require no maintenance or even testing for the period of this cost-benefit model. Moreover, it has been suggested by Tyco International, that the Underwriters Laboratory, Factory Mutual, and the Scientific Services Laboratory do not recognise a finite life of a sprinkler head (Thomas, 2001). For this reason, the only impact on the life of a sprinkler head would be environmental effects such as aggressive atmospheres, temperature and pressure fluctuations, and physical impacts such as painting (Thomas, 2001).

Secondly, as stated in the BRANZ New Zealand 2000 report, "faults within the system would be more readily identified as there would be a constant flow of water through the piping" (Duncan et all, 2000). If a home sprinkler system is faulty, the homeowner will be aware of the problem because it will be evident in the performance of the home's cold water supply network. In addition, statistics in the United States show that the rate of sprinkler head malfunction is 1 in 16 million (Koski, 2000). For this reason, a homeowner can be reasonably sure that if the home's cold water supply network is functioning properly, the home sprinkler system will also function properly in the case of a fire.

4-Step 4 To Fire Service

Although there will be an overall benefit to the fire service from the installation of home sprinkler systems in Greenfield site homes, there are several costs to the fire service due to the installation of home sprinkler systems. Specifically, it is the responsibility of the fire service to pay for homeowner education programs and notices in Greenfield sites.

Currently, homeowners in Victoria do not directly pay for the services provided by the CFA. Insurance companies in Victoria supply a majority of funds for the CFA, while the state government supplies the remainder. For this reason, this model assumes that any costs to the fire service, because of home sprinkler systems, will not be passed on to the homeowner.

4-Step 4.a Homeowner Education Programs and Notices

Fire service officials at the MFESB and CFA have suggested that a homeowner education program for homeowners at Greenfield sites will be necessary. The purpose of this homeowner education program should be to educate homeowners about the mechanics and proper use of home sprinkler systems (Rhodes, 2001). In addition, the program should attempt to provide awareness about the importance of home sprinkler systems, and their role as a community fire protection device in a Greenfield site (Taylor, 2001).

The cost of a homeowner education program will depend upon the materials, human resources, and time required creating and implementing the program. Suggested methods of providing homeowner education include a plaque mounted in the home, a brochure given to Greenfield site homeowners, and an optional day or evening program hosted by the fire service where community safety can be discussed (Rhodes, 2001). The fire service should estimate the costs of a homeowner education program (HED). Included in these costs should be the cost of necessary materials, the cost of design and implementation time by paid officials, and the cost of renting a location and supplying refreshments if necessary.

4-Step 5 Other Costs

There are several costs to the Greenfield site community, as the result of the installation of home sprinkler systems. Because home sprinkler systems are new to Victoria, this model does not assume that these costs will be incurred on any specific party of the Greenfield site community. In particular, the costs of placing covenants on Greenfield site property and then enforcing those covenants may be incurred on the developer, fire service, or local government of the Greenfield site. However, to provide a conservative estimate of all costs to the homeowner, it is assumed that these other costs will be passed on to homeowners in Greenfield sites.

4-Step 5.a Covenants

It is assumed by this model that the fire service will plan its provisions and coverage based upon the fact that every home in a Greenfield site has a home sprinkler system. For this reason, it is important to ensure that every home in the Greenfield site will be protected by a home sprinkler system. Currently, the CFA cannot place conditions on land after the developer sells it, unless the land is in a Wildlife Management Overlay (Fox, 2001). It is possible, however, that the CFA can make an agreement with the Greenfield site developer to place a covenant on the title of every property sold in the Greenfield site to require that every home has a home sprinkler system. In such an event, a lawyer should estimate the cost of creating a covenant for Greenfield site properties (COC). In addition, the Land Titles Office should estimate the cost of attaching covenants to the title of each property (POC). It is also important to estimate the administrative costs of the CFA and Greenfield site developer to discuss the covenant and arrange for it to be written and placed on properties (CAC). It is likely that this cost may be difficult to estimate because the CFA is not currently involved in any similar processes to mandate the use of other fire protection devices.

For reasons provided in the "Code Enforcement and Inspections" section of this model, it may be beneficial for the local government to place a covenant on the Greenfield site property instead of the Greenfield site developer. In such a case, the local government may still collaborate with the CFA to create an appropriate covenant for Greenfield site properties. For this reason, the CFA should still estimate administrative costs associated with creating the covenant. The local government should also estimate administrative costs associated with the covenant, in addition to estimating the cost of placing the covenant on Greenfield site properties. Total costs of covenants (TCC) are the sum of costs to create the covenant (COC), place the covenant on properties (POC) and administer the creation and placement of the covenant by the parties involved (CAC).

4-Step 5.b Covenant Enforcement and Inspections

It is assumed by this model that there will be a cost associated with enforcing any covenants placed on Greenfield site property. In particular, it is expected that an inspection of new Greenfield site homes will be conducted to ensure that home sprinkler systems are present and have been installed properly.

Generally, covenant enforcement is the responsibility of the party placing that covenant on new properties. In the case where the CFA makes an agreement with the developer to place a covenant on Greenfield site property, it may be the CFA's responsibility to enforce that covenant (Fox, 2001). The CFA should therefore estimate the cost of enforcing a covenant on a Greenfield site property (EPP). The total costs of covenant enforcement (CEC) will be the cost of enforcing a covenant on a Greenfield site property, multiplied by the number of properties in a Greenfield site (NOP). Presently, the CFA is not involved in the enforcement of any covenants and it may be difficult for the CFA to estimate this cost. In addition, because covenant enforcement is new to the CFA, a separate body may be more appropriate to place and enforce covenants on Greenfield site property.

Currently in Victoria, the local government is responsible for hiring or providing a building surveyor to inspect the construction of new homes and ensure that all covenants placed by the local government are abided by. For this reason, the local government may be the appropriate body to place a covenant on Greenfield site property. In such a case, the local government could use the same building surveyor to inspect home sprinkler. Such an arrangement would save the CFA time and effort to create a covenant enforcement policy and program. For the purposes of this cost model, cost of covenant enforcement and inspections (CEC) should be estimated by the party that is expected to place and enforce a covenant on Greenfield site property.

4-3 Benefit Model

Similar to the cost model, the benefit model addresses the possible benefits that will be received by the Greenfield site community because of the installation of home sprinkler systems in every home of a Greenfield site. The model individually discusses each possible benefit that will directly affect the developer, builders, homeowners, fire service and local government of the Greenfield site.

4-Step 6 To Developer

The initial processes of incorporating home sprinkler systems in a development begin with the infrastructure of the development, particularly water supply and road infrastructure. The developer is responsible for these two initial developmental stages, and will be the initial recipient of any benefits or cost savings. This model assumes that the developer will pass on some portion of these costs or savings to Greenfield site homeowners. This portion of costs or savings should be estimated as a percentage of the total costs (DBP) or savings that will be passed on the Greenfield site homeowners.

4-Step 6.a Water Supply Infrastructure Savings

In cities such as Scottsdale, Arizona in the United States, home sprinkler systems have been shown to be effective in suppressing a fire in a home (Ford, 1997). For this reason, the peak demand of water required from a nearby fire hydrant may be reduced, hence possibly reducing the size of the required water main in United States developments. Any changes in fire fighting water infrastructure requirements due to the use of home sprinkler systems in a Greenfield site should be determined by the fire service. Depending upon design practices, the water authority should estimate infrastructure savings due to reductions in hydrants and water main size. Water supply infrastructure savings (WIS) should be estimated as the difference in cost of water supply infrastructure to a development with home sprinkler systems (IWS) and without home sprinkler systems (IOS).

In Victoria, water supply infrastructure requirements are not currently determined based upon the pressure and flow required for fire fighting (Balette, 2001). Instead, the requirements for water supply infrastructure are determined by water authorities, as the maximum domestic usage expected in a 20-year period (Balette, 2001). For this reason, there may not be any reduction in the water supply infrastructure in a development with home sprinkler systems. The possibility of an increase in water supply infrastructure cost exists if the available pressures and flows to the Greenfield site are insufficient to supply home sprinkler systems. Methods to increase pressures and flows may include the use of an elevated water tank or booster pump in the Greenfield site. Costs due to an increase in water supply infrastructure in a Greenfield site can be estimated by the previously described method to estimate water supply infrastructure savings.

4-Step 6.b Road Infrastructure Savings

Although some reports in the United States suggest that there may be savings in road infrastructure in a development, it is unlikely that there will be savings in road infrastructure in Victoria. Even if home sprinkler systems can suppress a fire, requiring less of emergency vehicle response times and equipment, the demand for other emergency rescue vehicles cannot be ignored. In addition, road design standards in Victoria are not entirely based on emergency vehicle travel, but depend upon on the size of large commercial vehicles that will be present in Greenfield sites. For this reason, this model assumes that road infrastructure will not be altered due to the presence of home sprinkler systems in Greenfield sites in Victoria.

4-Step 7 To Homeowner

Benefits to the homeowner due to the installation of a home sprinkler system include a greater probability of life savings, injury savings, and property savings. In addition, the homeowner may have a reduction in home insurance premiums due to the increased level of fire protection in the home.

To estimate life savings, injury savings and property savings, the chance of a fire occurring in a home must be considered. An analysis of data from the CFA reveals that between 1998 and 2000, the total number of fires in residential dwellings in the CFA district was 1,830. The average total number of residential dwellings in the CFA district between these years was 983,631. The probability of a fire occurring (PFO) in the CFA district is found by dividing the number of fires in dwellings by the total number of dwellings, resulting in 1.86 fires per 1000 dwellings annually. This model does not address the change in probability of fires due to the psychological effects such as the increased carelessness with fire due to the reliance of home sprinkler systems.

4-Step 7.a Life Savings

To estimate a dollar value of life savings due to home sprinkler systems in Greenfield sites, a value of human life must be estimated. Several reports such as the Ruegg-Fuller Cost Benefit Analysis do estimate a dollar value of human life. However, such an estimate does not go without controversy. Some may argue that the value of a human life is infinite; therefore, the benefits of installing home sprinkler systems in Greenfield sites could never be out weighted by the costs. To avoid discussion and controversy, this cost-benefit model will not estimate a dollar value of human life. Therefore, life savings due to home sprinkler systems cannot be estimated. However, this model will include an estimate of the number of lives saved (NLS) due to home sprinkler systems in Greenfield sites.

A problem arises in the analysis of fire fatality data available from the CFA and the United States, because the presence of smoke alarms in homes with and without sprinkler systems is often not reported. Smoke alarms alone have been proven as an effective life safety device. For this reason, the capability of home fire sprinkler systems as a life safety device, when used in combination with smoke alarms, can only be extrapolated from available data.

Due to the lack of sprinklers in residential occupancies in Victoria, there are limited data for fires within sprinklered buildings. An analysis of civilian deaths in the United States between 1988 and 1997 states that sprinkler systems have been shown to reduce the death rate per thousand fires in single-family homes from 9.8 to 5.1. This is a 48% reduction due to home sprinkler systems (Rhor, 2000). However, this percentage does not state whether smoke alarms were working in combination with home sprinkler systems or not. In addition, this data may be misrepresentative of sprinkler system success, because the average annual number of fires in sprinklered buildings was only 1,800, whereas the number of fires in non-sprinklered buildings was 252,800.

Perhaps a better representation of the ability of home sprinkler systems to reduce fatalities is to analyse data in all residential buildings in the United States. Data from the report by Rhor estimates that sprinkler systems reduced the number of fatalities in residential buildings by 77% (Rhor, 2000). This percentage should be a better approximation of sprinkler success because only 0.7% of fires occurred in single-family dwellings with sprinkler systems, whereas 2.5% of fires occurred in residential buildings with sprinkler systems between the years of 1988 and 1997 (Rhor, 2000).

The Ruegg & Fuller Cost–Benefit Analysis predicted that civilian deaths in one- and two-family dwellings in the United States would be reduced by 82% when smoke alarms and sprinklers were installed (Ruegg-Fuller, 1984). For comparison, this report also estimated that civilian deaths in one- and two-family dwellings where smoke alarms were present, would be reduced by 63% due to the installation of home sprinkler systems (Ruegg-Fuller, 1984).

For the purposes of this cost-benefit model the assumed annual percent reduction of civilian fatalities (PFR) in single-family dwellings in Victoria is 77%. This percentage has been chosen because even though it applies to all residential buildings, it is derived from the proven success of sprinkler systems in the United States. In addition, this percentage is calculated from a larger data set than single-family dwellings in the United States, and should therefore be the better representation of home sprinkler system success.

The CFA reports that there were 41 fire fatalities in single-family homes between 1998 and 2000. In addition, the number of fires in single-family homes during this time was 4,997. Dividing this number of fire fatalities by the number of fires in homes, results in a probability of 8.2 fire fatalities per 1000 fires. Multiplying the probability of fire occurring (PFO) by the probability of a fire fatality per 1000 fires will result in the probability of a fire fatality occurring per million dwellings, annually (PFD). This probability is 15.33 fire fatalities annually, per million single-family homes. The expected number of lives saved (NLS) can be calculated by multiplying the number of dwellings (NOP) in a Greenfield site by the annual probability of a fire fatality per dwelling (PFD), the expected annual percent of fatality reduction (PFR) due to home sprinkler systems, and the number of years in the benefit model time period (YRS).

4-Step 7.b Injury Savings

Unlike life savings, this benefit model will estimate injury savings due to home sprinkler systems because a dollar value cost of injury due to fire can be estimated by hospital bills. According to data used in the Beever and Britton report from the Victorian In-Patient Minimum Dataset for 1993-1994, the average direct cost per fire injury in Victoria was A$6,740. Assuming the inflation rate of 2.2%, the expected average direct cost per fire injury (CPI) in Victoria in 2001 is A$7,849. This cost does not include pain and suffering or time lost at work due to a fire injury.

Currently, there is little data available for Victoria or the United States to determine the annual percent reduction in fire injuries (PRI) due to home sprinkler systems. However, the Ruegg-Fuller Cost-Benefit analysis estimates that the annual percent reduction of fire injuries in one and two-family dwellings with sprinkler systems but no smoke alarms is 46%. The Ruegg-Fuller analysis also estimates the annual percent reduction of fire injuries in one- and two-family dwellings with sprinkler systems and smoke alarms is also approximately 46%. Depending upon data available at the time this model is used, the annual percent reduction of fire injuries due to home sprinkler systems should be estimated (PRI).

To calculate the estimated savings in fire injuries (IJS) in Greenfield sites, the annual probability of a fire injury occurring (PFI) must be calculated. The annual probability of fire injury occurring (PFI) can be calculated by dividing the total number of fire injuries by the number of fires in single-family dwellings in the CFA region each year. Between 1998 and 2000, the average number of fire injuries per year in single-family dwellings was 310. Also, during this time, the average number of fires per year in single-family homes was 4,997. Using these values, the annual probability of a fire injury occurring (PFI) in a Greenfield site is 115.9 per million dwellings.

The expected dollar value savings in fire injuries per home, due to home sprinkler systems in a Greenfield site (IJS) is calculated by multiplying the annual probability of an injury occurring (PFI) by the expected percent reduction in injuries (PRI), the average cost per injury (CPI), and the number of years in the benefit model time period (YRS).

4-Step 7.c Property Savings

To calculate the dollar value savings in property damage (PPS) due to home sprinkler systems, the annual percentage of expected property damage reduction (PDR) must first be estimated. Data collected in the United States between 1988 and 1997 show that property losses in all residential buildings were reduced by 42% due to sprinkler systems (Rhor, 2000).[6] The report on automatic sprinkler systems in Scottsdale, Arizona, between 1985 and 1996 reports that average property damage per fire incident was reduced by 88.6% in buildings with sprinkler systems versus buildings without sprinkler systems (Ford, 1997). Additionally, The Ruegg and Fuller Cost-Benefit analysis estimates that sprinkler systems in one- and two-family dwellings can reduce direct property losses by 70% (Ruegg & Fuller, 1984). For the purposes of this cost-benefit model, a conservative annual percent reduction in property damage (PDR) due to home sprinkler systems was chosen to be 70%.

Estimated property damage savings (PPS) to the homeowner can be calculated by multiplying the annual percent of property damage reduction (PDR) by the number of years in the benefit model time period (YRS), by the average property damage (APD) in a home without sprinkler systems, and the annual probability of fire occurring in a home (PFO). Table 1 shows data reported by Insurance Statistics of Australia (ISA) for the average domestic insurance claim for fire damage. Between July 1996 and June 1999, the average claim was A$12,141 for fires that occurred in residential buildings in Victoria Country. Table 2 shows that an analysis of CFA fire incident reports found that the average property loss between 1998 and 2000 was A$25,174[7]. Given these data, and knowing the expected size and value of properties in a Greenfield site, the expected average property damage due (APD) to fire should be estimated.

Buildings	$9,033.39
Contents	$3,107.49
Total	$12,140.88

Table 2: Average fire insurance claims between July 1996 and June 1999 for Victoria Country

		Year			
Item	**Source**	**1998**	**1999**	**2000**	**Average**
Property Loss	CFA FIRS	$18,041	$20,839	$20,883	$19,921
Content Loss	CFA FIRS	$5,118	$4,959	$5,683	$5,254
Total Loss	CFA FIRS	$23,159	$25,798	$26,566	$25,174

Table 3: Average fire damage recorded for the CFA

4-Step 7.d Home Insurance Savings

Currently there are no insurance benefits given to homeowners with home sprinkler systems in Victoria. The reason is that home sprinkler systems have not been shown to

6 Note that these data do not suggest the level of sprinkler protection in residential properties in the United States.

7 On average, the property damage was only reported for 49% of fires in the CFA region between 1998 and 2000.

decrease average fire damage claims in Victoria. For insurance companies to grant a reduction in homeowner insurance premiums, home sprinkler systems would have to significantly impact the statistics collected by insurance companies to show that they reduce home building and contents damage (Kaiser, 2001). It is also possible that a single insurance company may begin granting insurance benefits to homeowners with home sprinkler systems, as a marketing scheme to increase business. In the United States, the beginning of insurance benefits for residential sprinkler systems began as a marketing scheme (Barnett, 2001). It is expected that once a single company begins granting insurance benefits, other companies will follow to remain competitive.

If insurance companies began granting insurance benefits to homeowners with home sprinkler systems, those benefits would most likely be minimal in comparison to the homeowner's total insurance premium. Table 4 shows the average percent of the total insurance premium income that insurance companies[8] paid out for fire damage between July 1996, and December 1999, for Victoria. It is assumed that this percentage reflects the amount of a homeowner's insurance premium that accounts for the fire coverage portion of their home insurance policy[9]. The average amount of premium paid for the fire coverage portion of a homeowner's insurance policy was then A$12.03 and A$8.43 in the country and metro areas of Victoria, respectively. If an insurance company were to give a discount to a homeowner with a home sprinkler system, this discount would likely be some percentage reduction in the amount of insurance premium that accounts for fire damage coverage.

	Average Percent of Total Premium Income Paid Out for Fire Damage Claims	Average Amount of Premium Paid for Fire Damage Coverage
Victoria Country Building and Contents	8.51%	A$12.03
Victoria Metro Building and Contents	4.63%	A$8.43

Table 4: July 1996 – Dec. 1999 Fire Claim Data (supplied by Insurance Statistics Australia)

For the purposes of this benefit model, the method to estimate a dollar value savings due to homeowner insurance benefits (HIS) should begin by an insurance company estimating the possible discount as a percentage of a homeowner's total annual insurance premium (PPR). This discount can then be multiplied by the expected average annual home insurance

8 This applies only to insurance companies who submit data to the Insurance Statistics of Australia, LTD.
9 Ron Baxter, of the Insurance Council of Australia agreed that this assumption is correct in theory.

premium cost (AIP) in the Greenfield site, and the number of years in the benefit model period (YRS).

4-Step 8 To the Fire Service

The primary benefit to the fire service due to the installation of home sprinkler systems in Greenfield sites is fire provision savings. Fire provision savings refer to the fire resources that are made available to adequately protect a Greenfield site. In particular, fire provision may include fire stations, appliances, equipment and manpower. As described in Section 4-Step 4, costs to the fire service due to home sprinkler systems are not passed on to homeowners. Likewise, this benefit model assumes that savings to the fire service due to home sprinkler systems will not be passed on to homeowners in Greenfield sites.

4-Step 8.a Fire Service Provision Savings

To determine dollar value benefits to the fire service that provides protection to the Greenfield site, the cost of manning, operating, and maintaining an adequate fire brigade for a sprinkled and non-sprinkled Greenfield site must be analysed. A thorough analysis must be completed by the CFA to first determine if existing fire brigades can adequately protect the Greenfield site. This analysis will likely require a consultation from the Geographical Information Service (GIS) department at the CFA to provide data about current fire fighter response times. With this data, the CFA can then determine if the current response time is sufficient to provide acceptable protection to the Greenfield site. If the current response time is acceptable, the resources available at existing brigades must be verified. For example, there may need to be additional resources added to existing brigades such as pumpers, tankers and specialty equipment. This extra equipment may require extra storage space, thus requiring renovations or a redesign of existing stations.

If fire officials determine that a new fire brigade is needed to protect the Greenfield site, several considerations must be made to determine the size and location of the new brigade, as well as the resources that will be available at the new brigade. To determine fire provision savings, this should be estimated for a Greenfield site with and without home sprinkler systems. A major factor in determining possible cost savings is whether the new brigade should be a career or volunteer brigade if home sprinkler systems are present. Once a career or volunteer brigade has been chosen, the amount of appliances, equipment and manpower required should be determined by the fire service.

4-Step 8.a.i Creation of Fire Station

After the fire service has determined the requirements of fire provision to a Greenfield site, a costs analysis can be conducted. The primary initial cost of fire service provision to a Greenfield site will be the cost of a new fire station building. This cost includes the cost of purchasing a plot of land, obtaining permits and approvals, and all costs involved with the construction of a new fire station. The size and cost of a new fire station building will depend on the demand for protection of the new Greenfield site, whether the station will be career or volunteer, and the number of fire fighters expected to be positioned at the new fire station (Holyman, 2001).

As previously stated, it is possible that existing fire provision resources will be adequate to provide protection to the Greenfield site. In such a case, there will be no additional costs of fire stations due to the installation of home sprinkler systems in Greenfield sites. However, existing fire stations may need to be upgraded to provide the Greenfield site with adequate fire provision. In this case, any costs of renovating or adding to current fire station buildings should be estimated by the fire service.

It is expected that home fire sprinkler systems can be relied upon to provide some level of fire protection to the Greenfield site community. For this reason, new fire station building costs may be reduced in a sprinklered Greenfield site because there will be a reduced requirement for equipment and manpower to the site. To accurately estimate the savings in fire stations (FSS) due to home fire sprinkler systems in a Greenfield site, the cost of adding or renovating a fire station building for a Greenfield site without home sprinkler system (SOS) should be estimated. The savings in fire provision is the difference between this cost and the cost of adding or renovating a new fire station building for a Greenfield site with home sprinkler systems (SWS).

4-Step 8.a.ii Initial Purchase of Appliances and Equipment

The initial cost of fire fighting equipment needed to provide adequate fire protection to a Greenfield site will primarily depend upon the newly required appliances at a fire brigade. The required fire fighting appliances may include pumpers, tankers and specialty support vehicles. In addition, other equipment and fire fighting gear may be required to equip a new or improved fire brigade. This equipment may include personal protective gear, hoses, nozzles, and hand or power tools.

Similar to the size of a fire station building, the amount of fire fighting appliances and equipment necessary to protect a Greenfield site will be dependent upon the size of the

Greenfield site and current available fire fighting resources. The cost of new appliances and equipment[10] should be estimated by the CFA, based on recent purchases. The cost savings in equipment (FES) and appliances can be determined by taking the difference between the initial cost of equipment and appliances for a sprinklered, Greenfield site station (EWS), and a non-sprinklered Greenfield site station (EOS).

4-Step 8.a.iii Maintenance of Appliances, Equipment, and Fire Station

Maintenance costs of fire fighting appliances and equipment should include the cost of replacement as well as annual or periodic upkeep. Currently fire-fighting appliances in the CFA region have a lifetime expectancy of twenty-years. Therefore, for the purpose of this model it will be assumed that the fire fighting appliances will only be purchased once, without replacement, during the period of this analysis. The other equipment may have to be replaced multiple times in this period. In addition, it is expected that there will be some costs associated with the maintenance of appliances and equipment. These annual maintenance costs should be estimated by the CFA, based upon maintenance costs of current appliances and equipment in the CFA district. In addition, it is expected that there will be maintenance costs to the fire station housing the appliances and equipment. These costs should also be estimated by the fire service, and added to the costs of appliance and equipment maintenance, to obtain a total annual cost of maintenance (MSE). These costs should be estimated on an annual basis so that inflation can be accounted for during the period of the benefit model.

The annual savings in the maintenance (MSE) of fire fighting appliances, equipment and stations, due to the installation of home sprinkler systems in a Greenfield site should be estimated by subtracting the maintenance costs to a sprinklered Greenfield site (MWS) from that of a non-sprinklered Greenfield site (MOS).

4-Step 8.a.iv Manpower

Once the type of station has been determined, the associated costs for providing manpower can be determined. The manpower for a volunteer station is completely free; all the members volunteer their time as a service to the community. Conversely, the salary cost for a career station can be high. A career station must have 5.29 fire fighters per position, with four fire fighters on duty at a time. There is a significant cost to recruit and train each fire fighter at a new career brigade. This cost (RAT) should be estimated by the CFA. There are three major pay scales of fire fighters: a qualified fire fighter, a leading fire fighter, and an

[10] The total cost of equipment and appliances is considered in this model. The depreciation of these items is not considered over their life span.

officer. A qualified fire fighter has attended a 16-week training course to be properly trained in all aspects of fire fighting. A leading fire fighter is a qualified fire fighter with experience and leadership abilities. An officer is has been properly trained to make important decisions that affect fire ground operations. Typically, at the CFA, ten percent of each fire fighter's average salary is added to salary costs to account for the overtime that a fire fighter works. This overtime is typically due to filling in shifts that are not filled due to illnesses or holidays. Cost savings for fire fighters (FMS) in a Greenfield site fire brigade can be determined by taking the difference in annual cost of manpower (MPW) plus recruitment and training costs (RAT) for a sprinklered Greenfield site, from that of a non-sprinklered Greenfield site (MPO).

4-Step 9 Other Benefits

The local government also has the potential for benefits due to the use of home sprinkler systems in Greenfield sites. In particular, home sprinkler systems will reduce the water costs required to fight fires in Greenfield site homes. It is assumed by this benefit model that any savings to the local government will not be passed on to the homeowner of a Greenfield site.

4-Step 9.a Water Savings

The primary other benefit to the Greenfield site community, as a result of home sprinkler systems, is a savings in water supplies for fire fighting. The Scottsdale, Arizona report states that the average water used by the fire service to suppress a residential fire between the years of 1985 and 1996 was 12,440 litres (Ford, 1997). If a home sprinkler system will suppress most residential fires in Greenfield site, the estimated water savings per fire in Greenfield sites will be approximately 12,440 litres. Given that the probability of fire occurring (PFO) is 1.86 per 1,000 dwellings, annually, the expected annual savings in water supplies for fire fighting will be 23,140 litres per 1,000 dwellings.

Currently, water authorities accept the costs of water used from hydrants for fire fighting in Victoria. For this reason, a reduction in water used for fire fighting will be a direct savings to the water authority. However, to determine a dollar value savings to the water authority, a cost per kilolitre of water to the water authority is required. There are multiple variables affecting this cost, such as, the cost of purchasing, pumping, and treating water, which will change depending upon location in Victoria. For this reason, this cost-benefit model assumes that the cost per kilolitre of water to a water authority is indeterminate. Moreover, this cost per kilolitre must be less than the average cost of A$0.70

per kilolitre charged to homeowners, in order to make a profit. Because this cost is so small, the savings to a water authority due to a reduction in fire fighting water supplies will be minimal. For example, if the cost is A$0.60 per kilolitre to a water authority, the total expected savings in water supplies to a Greenfield site with 1,000 homes will be A$133, over an 8.8-year period. Compared to other community benefits described in this cost-benefit model, this benefit is considered insignificant and will therefore not be included in the total net community benefit calculation.

4-4 Equations and Calculations

4-4.1 Net Homeowner and Community Benefit

Table 5 displays the proper equations to sum the appropriate costs and benefits to Greenfield site homeowners and the Greenfield site community. To determine the net cost or benefit to Greenfield site homeowners, the combined homeowner costs are subtracted from the combined homeowner benefits, as shown in Equation 31 of Table 5. This calculation assumes that there will be net benefits to homeowners because of the installation of home sprinkler systems. For this reason, if the net result is a cost to the homeowner, this value will be negative. Similarly, to determine the net cost or benefit to the Greenfield site community, the combined community costs are subtracted from the combined community benefits, as shown in Equation 32 of Table 5. Again, a net community benefit is expected, so a resulting cost to the community will be a negative value.

4-4.2 Cost per Life Saved

This cost-benefit model also calculates the cost per life saved due to the installation of home sprinkler systems in Greenfield sites. Equation 33 of Table 5 displays the calculation of the number of lives saved in the Greenfield site community, over the period of the cost benefit model. The cost per life saved in a Greenfield site community is then calculated by dividing the net community benefits (may be a cost) by the number of lives saved, as shown in Equation 34 of Table 5.

#	Title	Equation	Variables
1	Total Developer Cost	$TDC = ADV$	TDC = Total Developer Cost ADV = Total Advertising Cost
2	Home Sprinkler Design Cost	$SDC = CDC - CWD$	SDC = Home Sprinkler Design Cost CDC = Combined Design Cost CWD = Cold Water Design Cost
3	Home Sprinkler Material Cost	$SMC = CMC - CWM$	SMC = Home Sprinkler Material Cost CMC = Combined Material Cost CWM = Cold Water Material Cost
4	Home Sprinkler Installation Cost	$SIC = CIC - CWI$	SIC = Home Sprinkler Installation Cost CIC = Combined Installation Cost CWI = Cold Water Installation Cost
5	Home Sprinkler Approval and Inspections Fees	$SAI = CAI - CWA$	SAI = Home Sprinkler Approval and Inspections Fees CAI = Combined Approval and Inspection Fees CWA = Cold Water Approval and Inspection Fees
6	Total Purchase and Installation Cost	$TPI = SDC + SMC + SIC + SAI$	TPI = Total Purchase and Installation Cost SDC = Home Sprinkler Design Cost SMC = Home Sprinkler Material Cost SIC = Home Sprinkler Installation Cost SAI = Home Sprinkler Approval and Inspections Fees
7	Total Builder Cost	$TBC = TPI$	TBC = Total Builder Cost TPI = Total Purchase and Installation Cost

#	Title	Equation	Variables
8	Home Sprinkler Water Supply Fees	$SWF = \sum_{n=1}^{YRS} \left(12 * (CSF - CWF)\right) * \left((1 + INF)^n\right)$	SWF = Home Sprinkler Water Supply Fees CSF = Combined Water Supply Fees (Per Month) CWF = Cold Water Supply Fees (Per Month) YRS = Model Time Period (years) INF = Inflation Rate
9	Total Activation Water Cost	$AWC = \left(\frac{COW}{1000}\right) * \left(\frac{PFO}{1000}\right) * SPF$	AWC = Activation Water Cost COW = Water Cost per Kilolitre SPF = Average sprinkler flow (litres) PFO = Probability of Fire Occurring
10	Total Direct Homeowner Costs	$THC = SWF + AWC$	THC = Total Homeowner Costs SWF = Home Sprinkler Water Supply Fees AWC = Activation Water Cost
11	Total Direct Fire Service Costs	$TFC = HED$	TFC = Total Fire Service Costs HED = Homeowner Education Cost
12	Total Cost of Covenants	$TCC = COC + CAC + (POC * NOP)$	TCC = Total Cost of Covenants COC = Creation of Covent CAC = Covent Administrative Costs POC = Placement of Covent NOP = Number of Properties
13	Total Cost of Covenants	$CEC = EPP * NOP$	CEC = Total Covent Enforcement Cost EPP = Covent Enforcement Cost per Property NOP = Number of Properties

#	Title	Equation	Variables
14	Total Other Costs	$TOC = TCC + CEC$	TOC = Total Other Costs TCC = Total Cost of Covenants CEC = Total Covent Enforcement Cost
15	Combined Homeowner Cost	$HomeownerCost = \left(\frac{TDC + TFC + TOC}{NOP} \right) + TBC + THC$	TDC = Total Developer Cost TOC = Total Other Costs for Greenfield Site NOP = Number of Properties TBC = Total Builder Cost THC = Total Homeowner Costs
16	Combined Community Cost	$CommunityCost = TDC + TFC + TOC + ((TBC + THC) * NOP)$	TDC = Total Developer Cost TOC = Total Other Costs for Greenfield Site TBC = Total Builder Cost THC = Total Homeowner Costs NOP = Number of Properties
17	Water Supply Infrastructure Savings	$WIS = IOS - IWS$	WIS = Water Supply Infrastructure Savings IWS = Water Infrastructure with Sprinklers IOS = Water Infrastructure without Sprinklers
18	Total Developer Benefits	$TBD = WIS$	TBD = Total Developer Benefits WIS = Water Supply Infrastructure Savings

#	Title	Equation	Variables
19	Injury Savings	$IJS = \sum_{n=1}^{YRS} \left(\frac{PFI}{1000000} \right) * PIR * CPI * \left((1 + INF)^n \right)$	IJS = Injury Savings PFI = Probability of Fire Injury per year per million dwellings PIR = Percent of Injuries Reduced Due to Home Sprinklers, annually CPI = Average Cost per Fire Injury YRS = Model Time Period (years) INF = Inflation Rate
20	Property Savings	$PPS = \sum_{n=1}^{YRS} \left(\left(\frac{PFO}{1000} \right) * PDR * APD \right) * \left((1 + INF)^n \right)$	PPS = Property Savings PFO = Probability of Fire Occurring per year per thousand dwellings PDR = Percent Property Damage Reduction ADP = Average Property Damage YRS = Model Time Period (years) INF = Inflation Rate
21	Home Insurance Savings	$HIS = \sum_{n=1}^{YRS} (PPR * AIP) * \left((1 + INF)^n \right)$	HIS = Home Insurance Savings PPR = Percentage Premium Reduction AIP = Average Annual Insurance Premium YRS = Model Time Period (years) INF = Inflation Rate
22	Total Direct Homeowner Benefits	$TBH = IJS + PPS + HIS$	TBH = Direct Homeowner Benefits IJS = Injury Savings PPS = Property Savings HIS = Home Insurance Savings

#	Title	Equation	Variables
23	Fire Equipment Savings	$FES = EOS - EOS$	FES = Fire Equipment Savings EWS = Equipment with Sprinklers EOS = Equipment without Sprinklers
24	Fire Manpower Savings	$FMS = \left(\sum_{n=1}^{YRS} \left((MPO - MPW) * \left((1 + INF)^n \right) \right) \right) + RAT$	FMS = Fire Manpower Savings MPW = Annual Manpower with Sprinkler MPO = Annual Manpower without Sprinklers YRS = Model Time Period (years) INF = Inflation Rate
25	Fire Station Savings	$FSS = SOS - SWS$	FSS = Fire Station Savings SWS = Fire Station with Sprinklers SOS = Fire Station without Sprinklers
26	Maintenance of Station and Equipment	$MSE = \sum_{n=1}^{YRS} (MOS - MWS) * \left((1 + INF)^n \right)$	MSE = Maintenance of Station and Equipment MWS = Annual Maintenance with Sprinklers MOS = Annual Maintenance without Sprinklers YRS = Model Time Period (years) INF = Inflation Rate
27	Total Fire Service Benefits	$TBF = FES + FMS + FSS + MSE$	TBF = Total Fire Service Benefits FES = Fire Equipment Savings FMS = Fire Manpower Savings FSS = Fire Station Savings MSE = Maintenance of Station and Equipment

#	Title	Equation	Variables
28	Total Local Government Benefits	$TBG = WCS$	TBG = Total Local Government Benefits WCS = Total Water Cost Savings
29	Combined Homeowner Benefits	$HomeownerBenefits = TBH + \left(\frac{TBD + TBG}{NOP}\right)$	TBD = Total Developer Benefits TBH = Total Homeowner Benefits TBG = Total Local Government Benefits NOP = Number of Properties
30	Combined Community Benefits	$CommunityBenefits = TBD + TFS + TBG + (TBH * NOP)$	TBD = Total Developer Benefits TBH = Total Homeowner Benefits TBF = Total Fire Service Benefits TBG = Total Local Government Benefits NOP = Number of Properties
31	NET HOMEOWNER BENEFIT	$NetHomeowner = HomeownerBenefit - HomeownerCost$	$NetHomeowner$ = Net Homeowner Benefits $HomeownerBenefit$ = Combined Homeowner Benefits $HomeownerCost$ = Combined Homeowner Costs
32	NET COMMUNITY BENEFIT	$NetCommunity = CommunityBenefit - CommunityCost$	$NetCommunity$ = Net Community Benefits $CommunityBenefit$ = Combined Community Benefits $CommunityCost$ = Combined Community Costs

#	Title	Equation	Variables
33	NUMBER OF LIVES SAVED	$NLS = \left(\frac{PFD}{1000000}\right) * NOP * PFR * YRS$	*NLS* = Number of Lives Saved *PFD* = Probability of Fire Fatality Occurring per million dwellings per year *PFR* = Percent of Fatality Reductions Due to Home Sprinklers *NOP* = Number of Properties *YRS* = Model Time Period (years)
34	COST PER LIFE SAVED	$CostPerLifeSaved = \frac{NetCommunity}{NLS}$	*CostPerLifeSaved* = Cost per Life Saved *NetCommunity* = Net Community Benefits *NLS* = Number of Lives Saved

Table 5: Table of Equations

4-5 Cost–Benefit Model Summary

The cost-benefit model described in Steps 1 to 9 of Section 4 is intended to provide a discussion of the costs and benefits expected to Greenfield site homeowners and the Greenfield site community, as a result of the installation of home sprinkler systems. Provided in this discussion are mathematical equations to determine dollar values for those expected costs and benefits. Data from several reports in the United States and New Zealand, as well as data from the CFA were used to suggest unknown values for important cost and benefit calculations. The result of these calculations is a net homeowner benefit, net community benefit, and cost per life saved. The application this model to a particular Greenfield site in Victoria will provide data to help determine whether home sprinkler systems should be installed in every home.

5 Case Study and Sensitivity Analysis

The purpose of this case study is to estimate the expected costs and benefits of home sprinkler systems in a current Greenfield Site in Victoria. To perform this case study, the cost-benefit model worksheet, created in Microsoft Access®, was used to sum the individual costs and benefits with the appropriate calculations. The following is a base-case study completed for a specific Greenfield site in Victoria. This base-case study relies upon the expected costs and benefits of home sprinkler systems determined by interviews and published reports.

Included in this case study is a sensitivity analysis of each cost and benefit. The intent of the sensitivity analysis is to suggest the outcome of the net homeowner and community costs and benefits, when a particular cost or benefit is varied. This information is displayed in a graph along with the discussion of each cost and benefit studied. Suggestions for variations in these values are provided in the cost-benefit model. The range of variation in each sensitivity analysis graph was chosen to represent realistic changes in expected costs and benefits.

5-1 Melton Greenfield Site Information

The Greenfield site chosen for this case study was Eynesbury Station in Melton, Victoria. At the time of this case study, Eynesbury Station was only in the initial planning stages of development. However, the developer (Philip, 2001) was able to provide adequate information to estimate costs and benefits to Eynesbury Station homeowners and the Eynesbury station community.

The expected size of Eynesbury Station is 2,500 acres. These development plans include between 1,200 and 2,000 single-family homes, each on lots between one-half and four acres in size. For the purpose of this case study, the number of properties (NOP) used to calculate costs and benefits for the Eynesbury Station community is 1,200. Figure 4 displays an approximate layout of the properties and roads in the development. It should be noted that these plans are expected to change before construction begins in the development site. For the purpose of this case study, these plans were adequate to suggest the size and layout of a typical, new, large development in Victoria.

At the time of this case study, there were not any available home plans for the expected homes in Eynesbury Station. However, it was suggested by the developer that the size and style of homes in Eynesbury station would be similar to homes in the Caroline

Springs development in Melton, Victoria. As suggested in Section 4-1, the average period (YRS) of homeowner occupancy in Eynesbury Station is assumed to be 8.8 years.

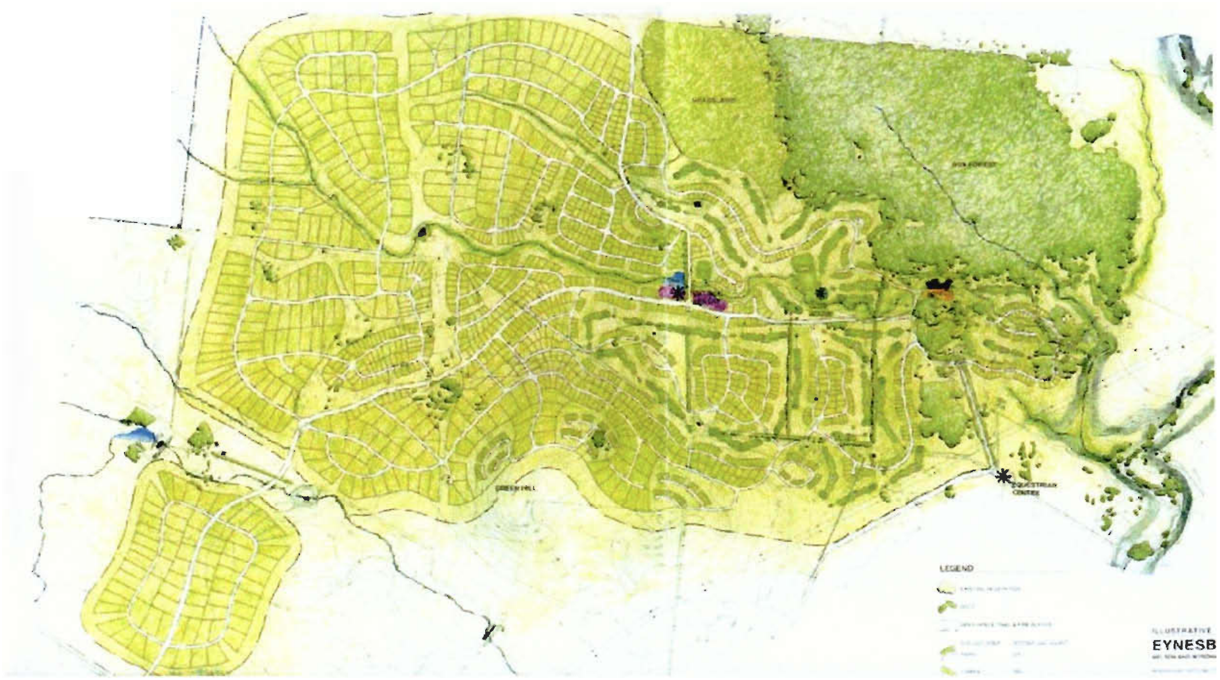

Figure 4: Proposed Eynesbury Station Development (Tract Consultants PTY, LTD, January 2001)

5-2 Results Summary

Table 6 displays the results of the Eynesbury Station base-case study. Included in this table are the expected costs and benefits to the Eynesbury Station homeowners and community. The calculation of each cost and benefit is discussed in the following base-case study description.

EYNESBURY STATION BASE-CASE STUDY RESULTS		
Item	**Cost to Homeowner**	**Cost to Community**
Developer Advertising	A$0	A$0
Purchase and Installation	A$3,324	A$3,988,608
Approvals and Inspection Fees	A$0	A$0
Water Supply Fees	A$0	A$0
Sprinkler Activation Water Costs	A$0.01	A$12
Homeowner Education Programs	A$0	A$1,000
Covenants	A$61	A$73,500
Covenant Enforcement and Inspections	A$0	A$0
Total	***A$3,385***	***A$4,063,120***
Item	**Benefit to Homeowner**	**Benefit to Community**
Water Supply Infrastructure	(A$42)[11]	(A$50,000)
Road Infrastructure	A$0	A$0
Injury Savings	A$4	A$4,800
Property Damage Savings	A$312	A$374,400
Home Insurance Savings	A$0	A$0
Fire Service Provision Savings	A$0	A$16,064,734
Total	**A$275**	**A$16,394,208**
Net Benefit	**(A$3,111)**	**A$12,331,088**
Number of Lives Saved in Greenfield Site per 8.8 years= 0.125		
Cost per Life Saved = (A$98,648,704)		

Table 6: Base-Case Study Results Summary

5-3 Costs

5-Step 1 To Developer

5-Step 1.a Advertising

For the purposes of this base-case study, it is assumed that the advertising costs (ADV) to the Eynesbury Station developer will be zero. As explained in 4-Step 1.a, a developer may feel that it is necessary to research and design an advertising strategy to market home sprinkler systems. However, there is a variety of information about the mechanics and performance of home sprinkler systems available from the NFPA, the Home Sprinkler Coalition in the United States, as well as home sprinkler system manufacturers. Moreover, large developers currently advertise many aspects of new developments. It is expected that advertisement of home sprinkler systems can be incorporated in these current advertising schemes, rather than requiring a new, separate advertising program for home sprinkler systems alone.

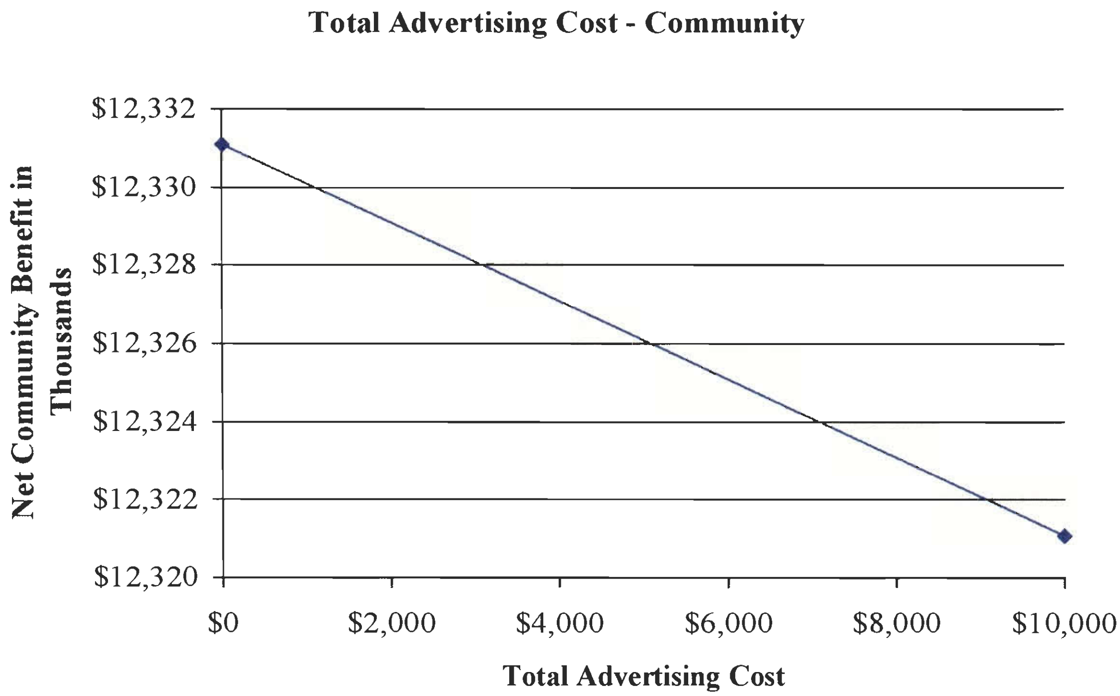

Figure 5: Sensitivity analysis of advertising costs to the community

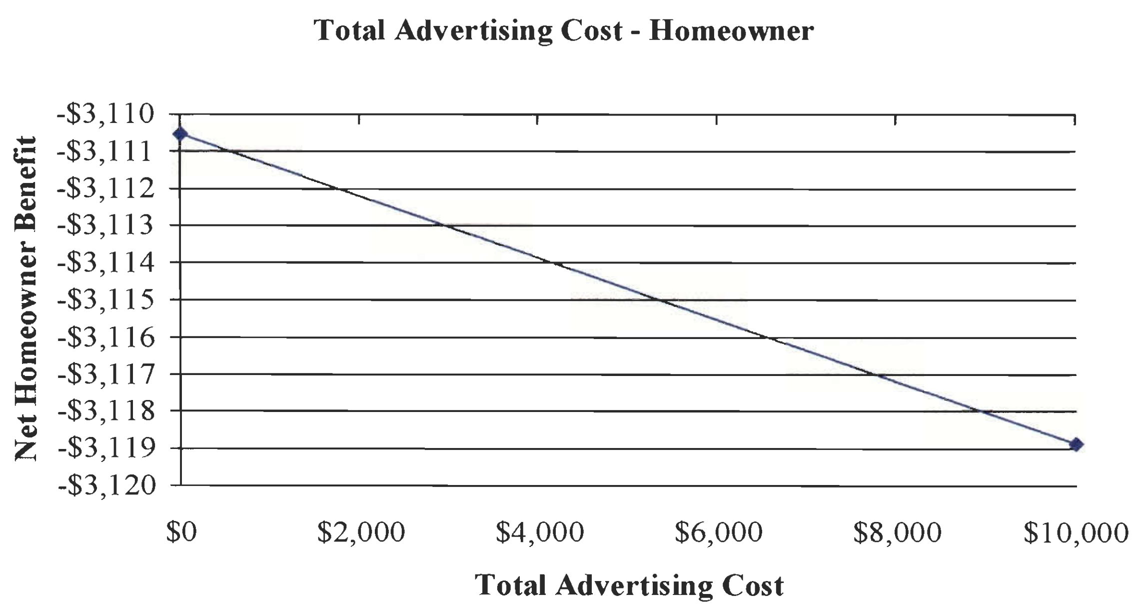

Figure 6: Sensitivity analysis of advertising costs to the community

11 Parenthesis surrounding a value indicate that that value is negative

5-Step 2 To Builder

5-Step 2.a Purchase and Installation

The cost of the purchase and installation of a home sprinkler system was estimated by the Master Plumbers Association and two private plumbers for this base-case study. The following is a description of each design and the resulting cost per home sprinkler head. From these values, an average cost per sprinkler head was estimated to determine the purchase and installation cost (TPI) to the homebuilder and to the Eynesbury Station community.

5-Step 2.a.i Design 1

The first home sprinkler system design was created for a three-bedroom, single-story home of 69.3 m^2 in area. Figure 7 displays a floor plan of the house with the expected home sprinkler design layout. This design, completed by BRANZ, called for a sprinkler head to be installed in each of the bedrooms, as well as the lounge, kitchen, dining room, and the hallway, using either copper or CPVC piping (Duncan, et al, 2000). The total number of sprinkler heads in this house design is seven. The total purchase and installation cost (TPI) of the home sprinkler system was estimated by the Master Plumbers Association of Australia to be about A$1000, or A$150 per sprinkler head. It should be noted that this house design, home sprinkler system design, and cost estimate are exactly the same as that used in the BRANZ Australia 2001 Interim report (Duncan et al, 2001).

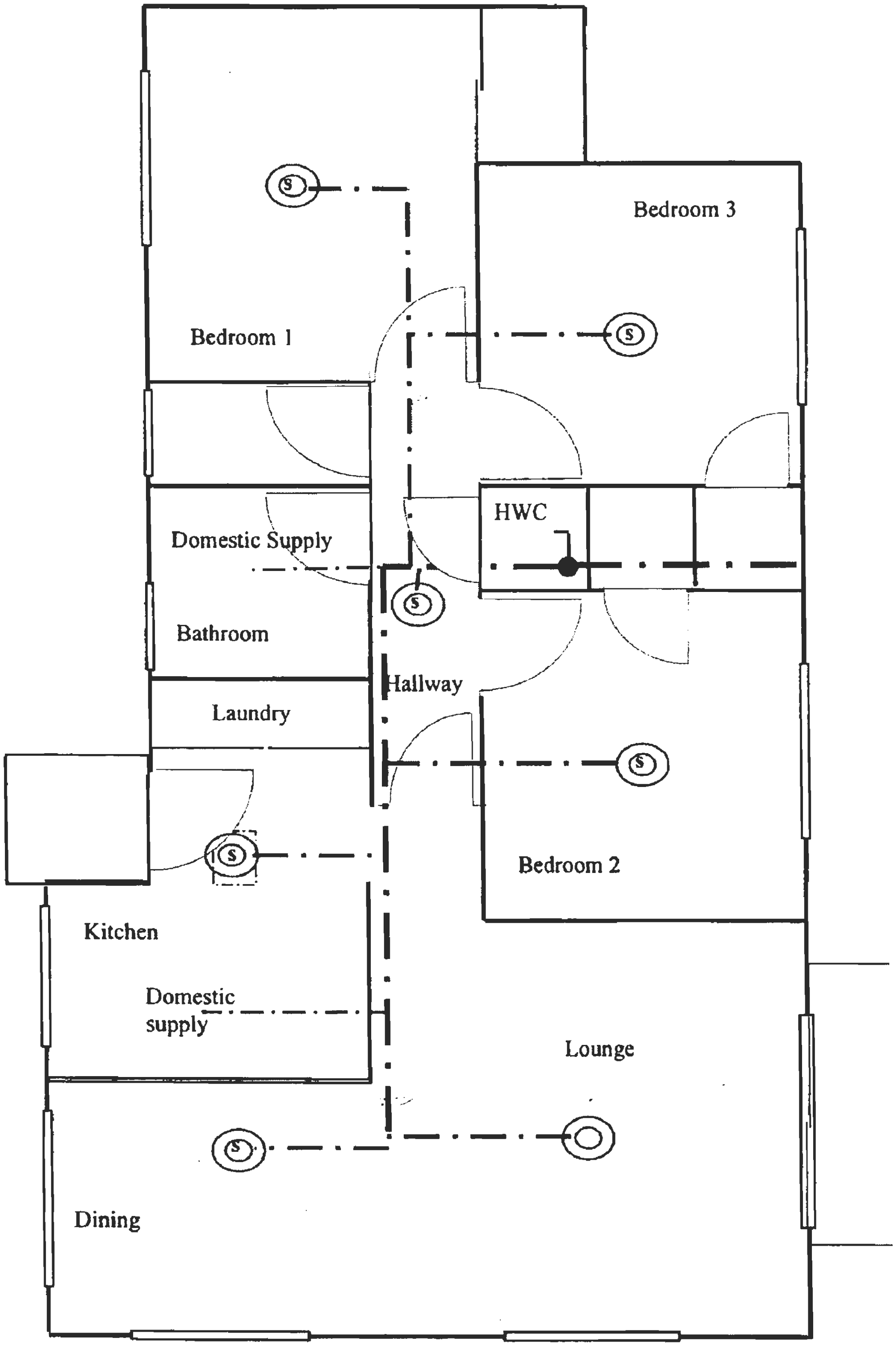

Figure 7: Home sprinkler system design by BRANZ (Duncan, et al, 2000)

5-Step 2.a.ii Design 2

Residential Fire Sprinkler Systems Pty. Ltd. completed a home sprinkler system design for a four-bedroom, single-story home. Figure 8 displays this typical design of a large single-story home that may be typical of those in Eynesbury Station. This approximately 250 m^2 home required 17 sprinkler heads, located in the bedrooms, lounges, kitchen, dining room, laundry room, and hallways. The piping materials that were used varied; with copper tube connecting the home to the water main, CPVC for the sprinkler reticulation and central domestic water supply network, and REHAU[12] (poly) for the potable water supply connections to the central CPVC supply. The cost for the entire system, including the cold water supply and the home sprinkler system, was A$5,225, while the domestic cold water supply, alone, costs A$1,200. The purchase and installation cost (TPI) of the home sprinkler system in this home design was A$4,025, or A$237 per sprinkler head.

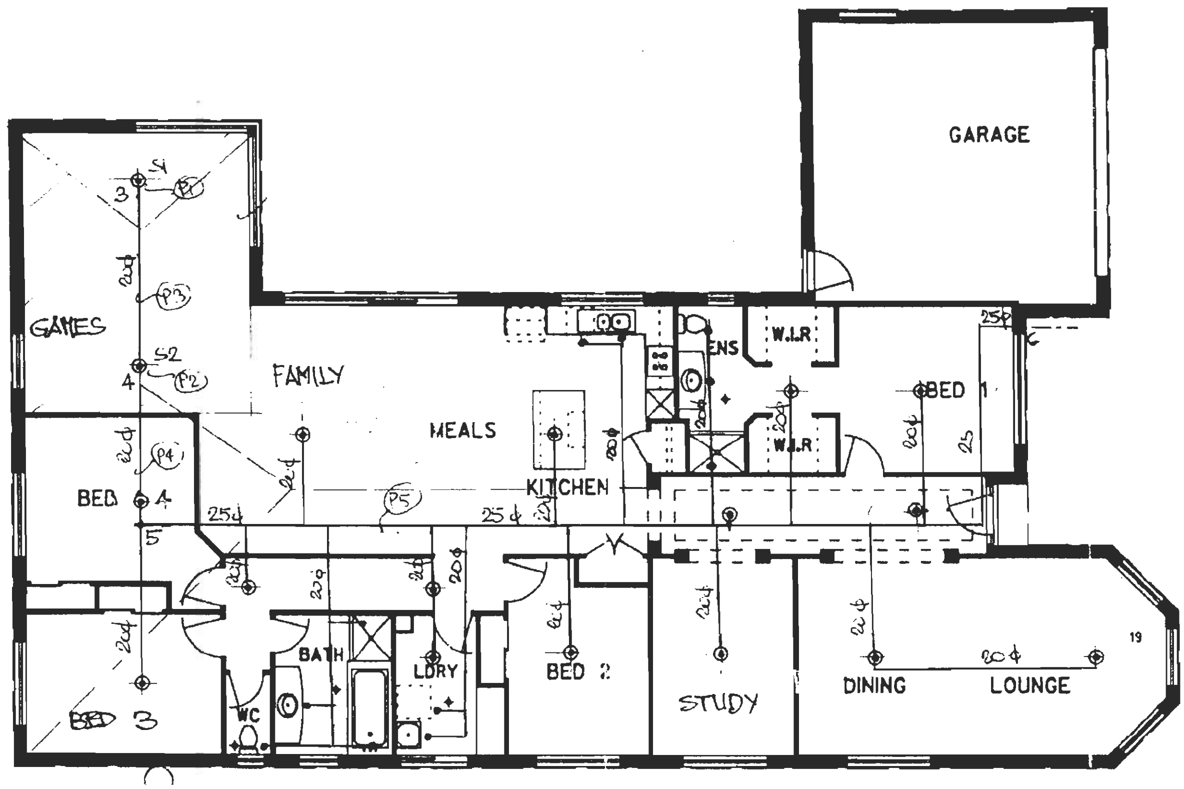

Figure 8: Home sprinkler system design by Residential Fire Sprinkler Systems Pty. Ltd., 2001. Home design supplied by AVJennings (AVJennings, 2001A)

5-Step 2.a.iii Design 3

Angus Eeles Plumbing designed a domestic cold water supply and a combined home sprinkler system and domestic cold water supply for a four-bedroom, two-story home. Figure 9 and Figure 10 displays a floor plan and home sprinkler system design for this two-story home, estimated at 310 m^2 in area. It was suggested that this home design would be typical of the larger homes built in Eynesbury Station. The entire home sprinkler system included 17

12 REHAU Industries manufactures AQUALOC® PVC Pressure Pipe, suitable for potable water supplies.
Footnotes continued to next page.

sprinkler heads, located in the bedrooms, dining area, lounge, kitchen, laundry, and the hallway, and was comprised entirely of copper piping. The domestic cold water supply alone, including the 20 mm tap into the water main, and the 20 mm water meter, has an estimated cost of A$3,038, including labour and design. The total cost of the domestic cold water supply with the integrated home sprinkler system, including a 25 mm tap and meter, was A$6,435. The difference in these two costs resulted in a total purchase and installation cost (TPI) of the home sprinkler system of A$3,397 for the sprinkler system, or A$200 per sprinkler head.

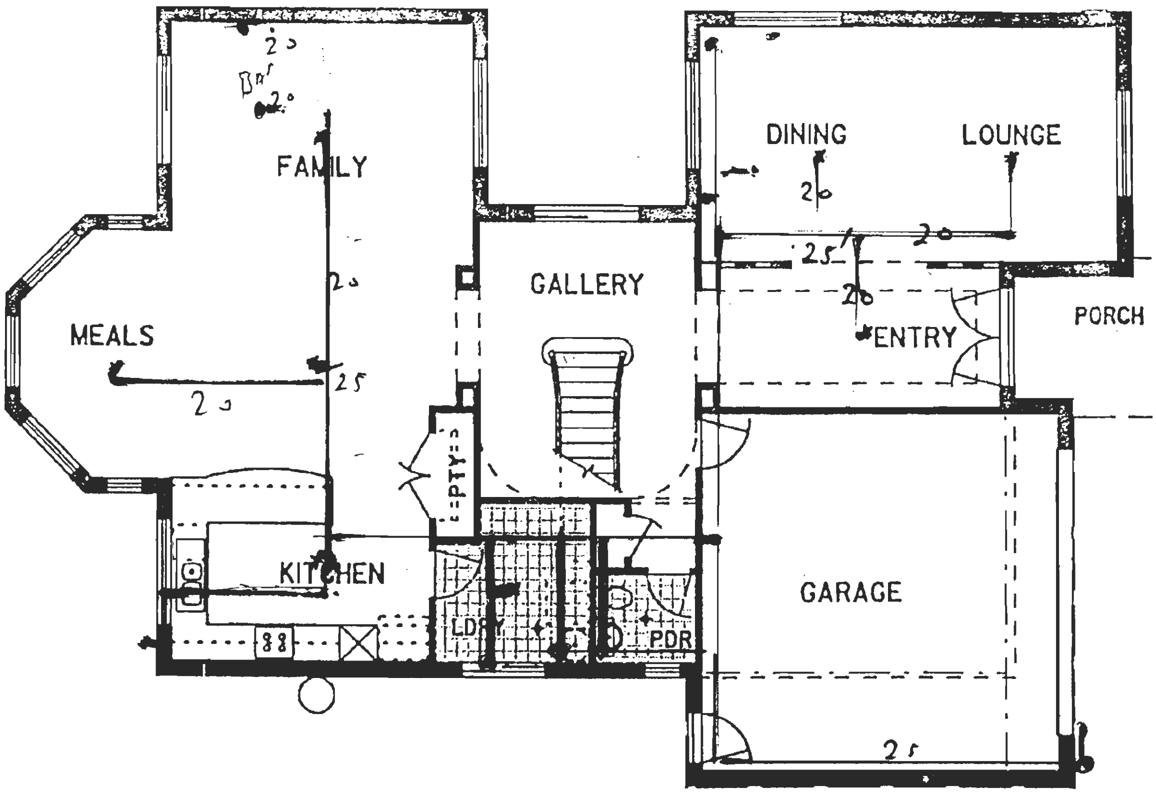

Figure 9: Home sprinkler system designed by Angus Eeles Plumbing first floor plan (Eeles, 2001). Home plan supplied by AVJennings (AVJennings, 2001B).

(REHAU Industries, 2001)

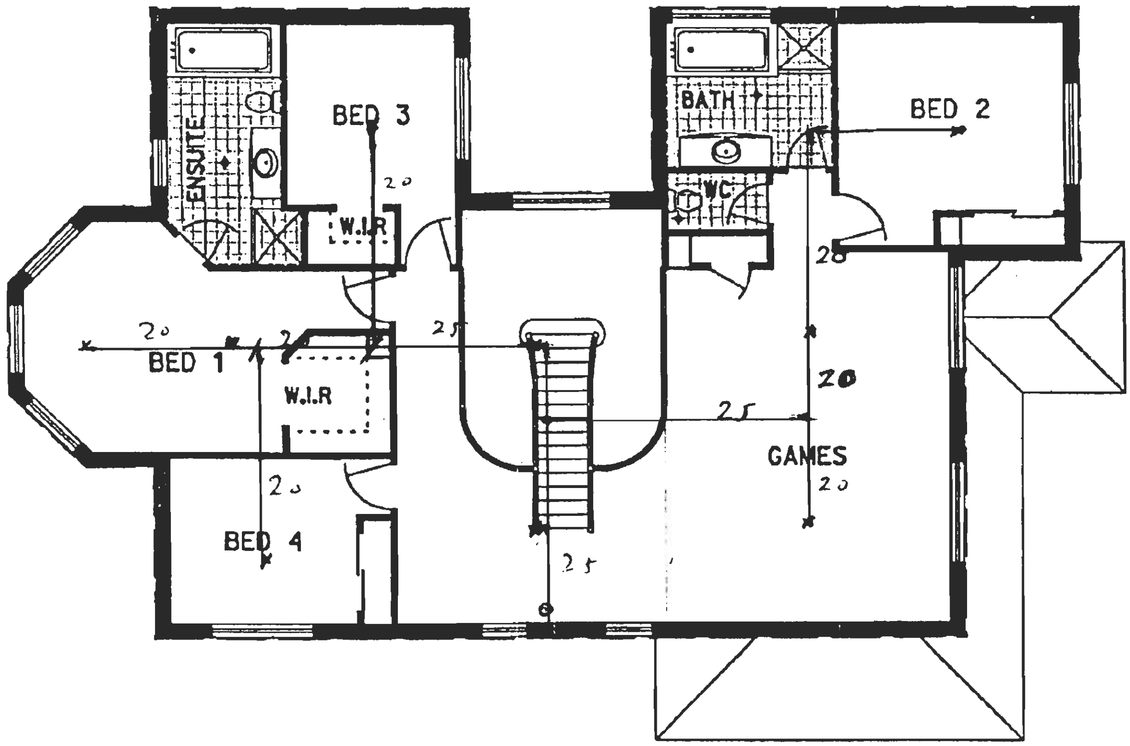

Figure 10: Home sprinkler system designed by Angus Eeles Plumbing second floor plan (Eeles, 2001). Home plan supplied by AVJennings (AVJennings, 2001B).

5-Step 2.a.iv Design, Materials and Installation

The design, materials, and installation will be discussed together for this analysis because of the differences in the estimated costs of the three designs. In particular, the costs of design in Design 1 and Design 3 were included with the materials and installation cost of the systems. The average cost for the home sprinkler system, in addition to the domestic cold water supply in these three designs is A$196 per sprinkler head. This cost is very close to that of Design 3, the two-story home, and is expected to be representative of the cost per sprinkler head for homes in Eynesbury Station. The difference between this cost per sprinkler head, and the cost per sprinkler head in Design 1 and Design 2 must therefore be addressed.

The single-story home in Design 1 is relatively small, and is conveniently sized for rooms to be covered by one sprinkler head only. For this reason, the cost per sprinkler head is lower than that of Design 2 or Design 3. Sprinkler coverage in a house with slightly larger dimensions in the lounge, for instance, may need to be increased from one to two, or even four sprinkler heads. In such a case, the costs of installation and materials will be significantly larger for only a small increase in home size.

The four-bedroom, single-story home in Design 2 is large compared to Design 1, and may be more typical of single-story homes built in Eynesbury Station. However, the cost per sprinkler head in this design was high compared to the other two designs. This is most likely due to a larger floor space area and more liberal sprinkler coverage in areas such as hallways. For example, unlike Design 1, Design 2 has two sprinkler heads in three of the rooms and two in each of the hallways. In addition, the labour cost of this design was a significant portion of the total home sprinkler system cost, increasing the cost per sprinkler head compared to Design 1 or Design 3.

It is reasonable to assume that the homes in Eynesbury Station will be large and will be comparable to Design 2 and Design 3. Therefore, this case study estimates that the average number of sprinkler heads in an Eynesbury Station home is 17, with an average cost per sprinkler head of A$196. The design, installation, materials, and tapping fees are all inclusive to this cost per sprinkler head, and this cost represents the additional cost of adding a home sprinkler system to the domestic cold water supply network. Therefore, the total average purchase and installation cost (TPI) of adding a home sprinkler system is A$3,324 per home, and A$3,988,608 for all 1,200 proposed homes in Eynesbury Station.

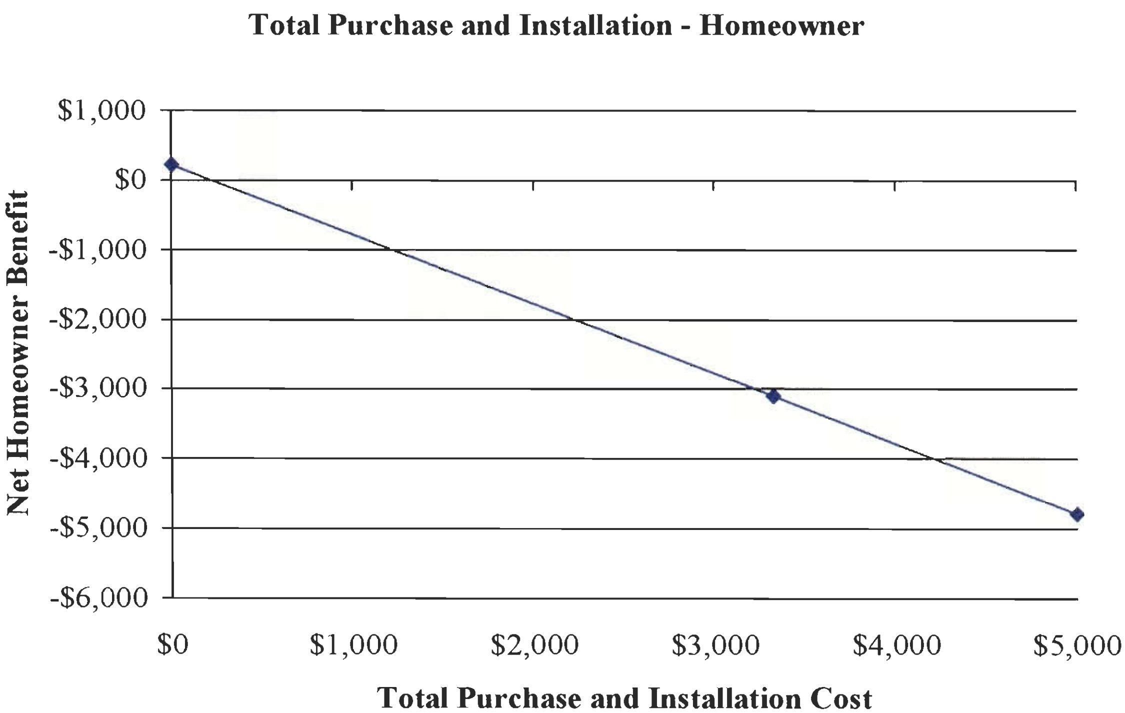

Figure 11: Sensitivity analysis of total purchase and installation cost to the homeowner

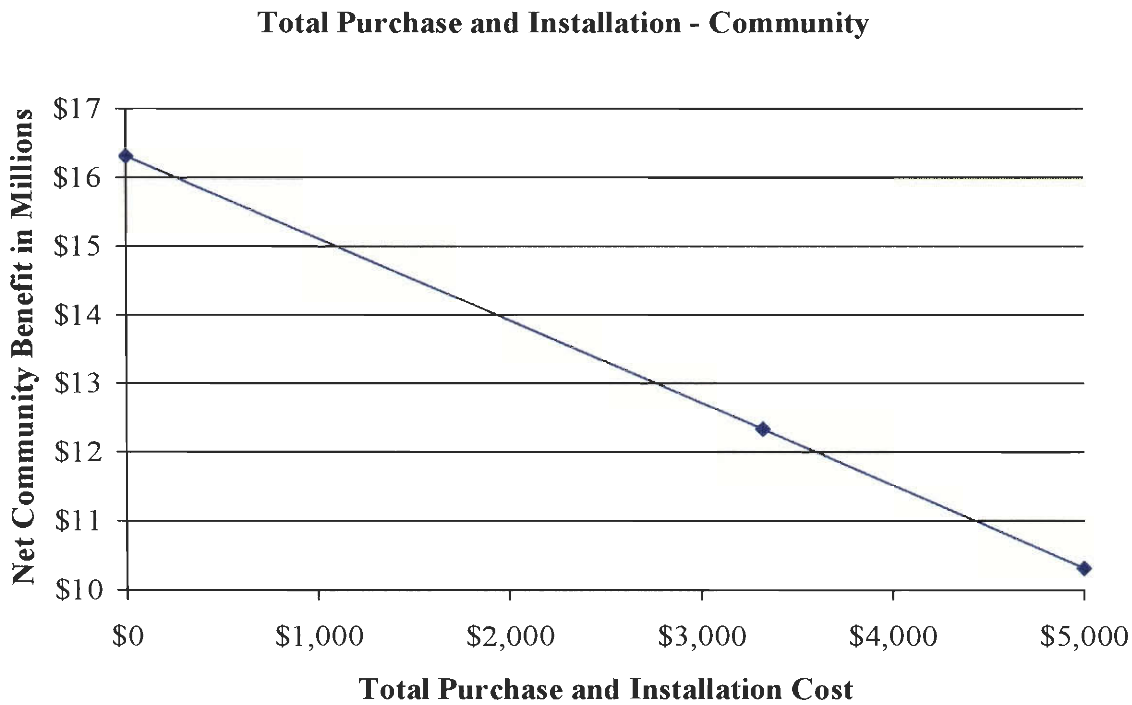

Figure 12: Sensitivity analysis of total purchase and installation cost to the community

5-Step 2.b Approvals and Initial Inspection

As explained in 4-Step 2.b, it is expected that plumbers may increase the cost of a certificate of compliance to cover added insurance costs of installing home sprinkler systems. However, if the cost of the certificate of compliance is increased, that cost will likely remain the same for the installation of a domestic cold water supply network versus a home sprinkler system in combination with a cold water supply network (McBride, 2001). For this reason, the assumption is made for this base-case study that there will be no added cost of approval and inspection fees (CAI) for home sprinkler systems in Eynesbury Station homes.

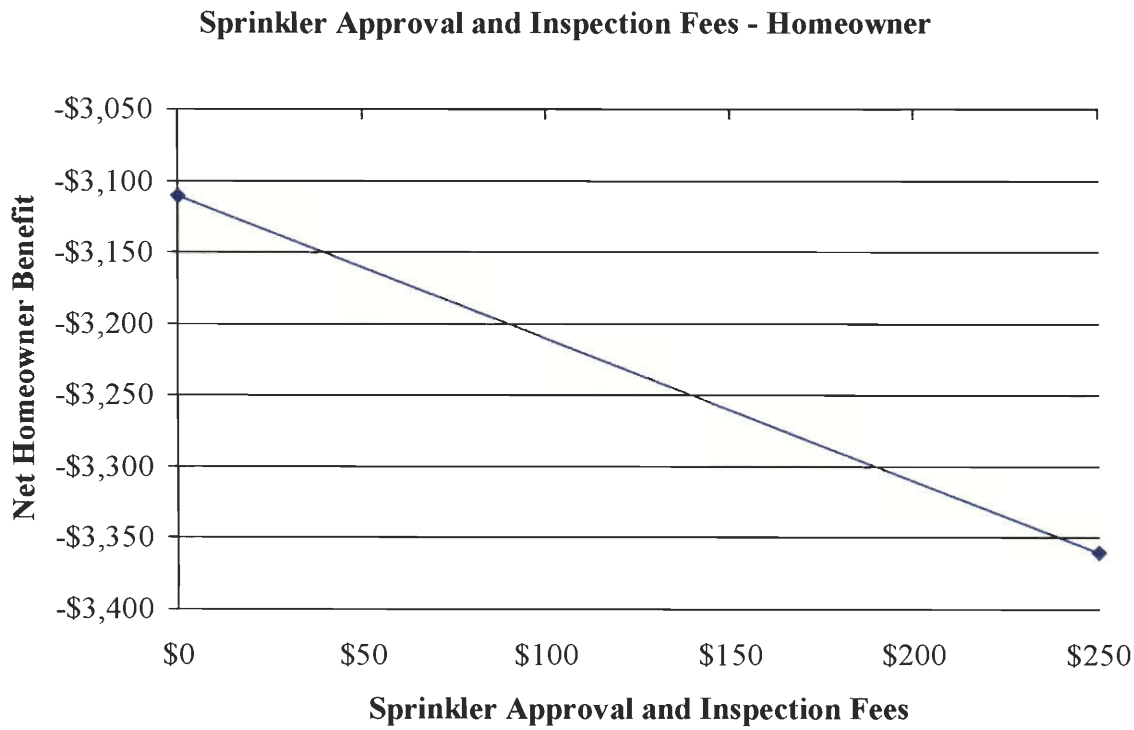

Figure 13: Sensitivity analysis of sprinkler approval and inspection fees to the homeowner

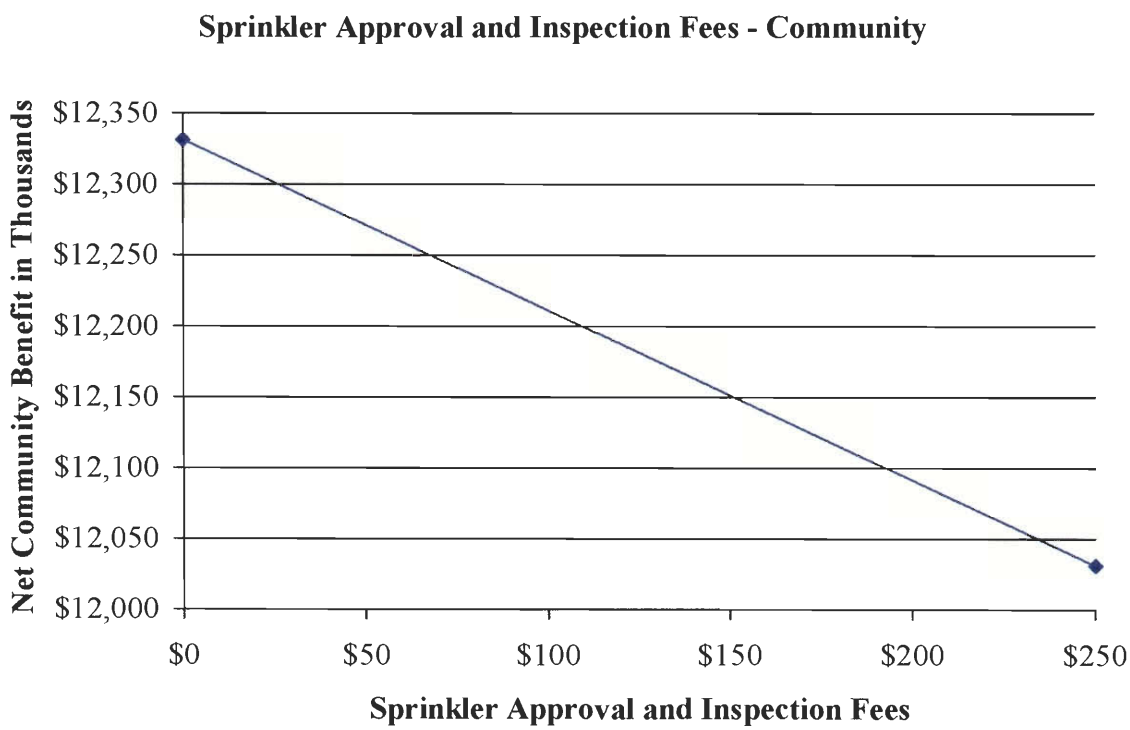

Figure 14: Sensitivity analysis of sprinkler approval and inspection fees to the community

5-Step 3 To Homeowner

5-Step 3.a Water Supply Fees

Western Water is the water authority responsible for supplying water to Eynesbury Station. Currently, Western Water does not charge a higher monthly fee for a 25 mm water meter (CSF) versus a 20 mm water meter (CWF). In addition, it was suggested by water authorities in Victoria that there would not be an increase in water fees for a homeowner with a home sprinkler system integrated with their domestic cold water supply. For this reason, the cost of monthly fees (SWF) is zero.

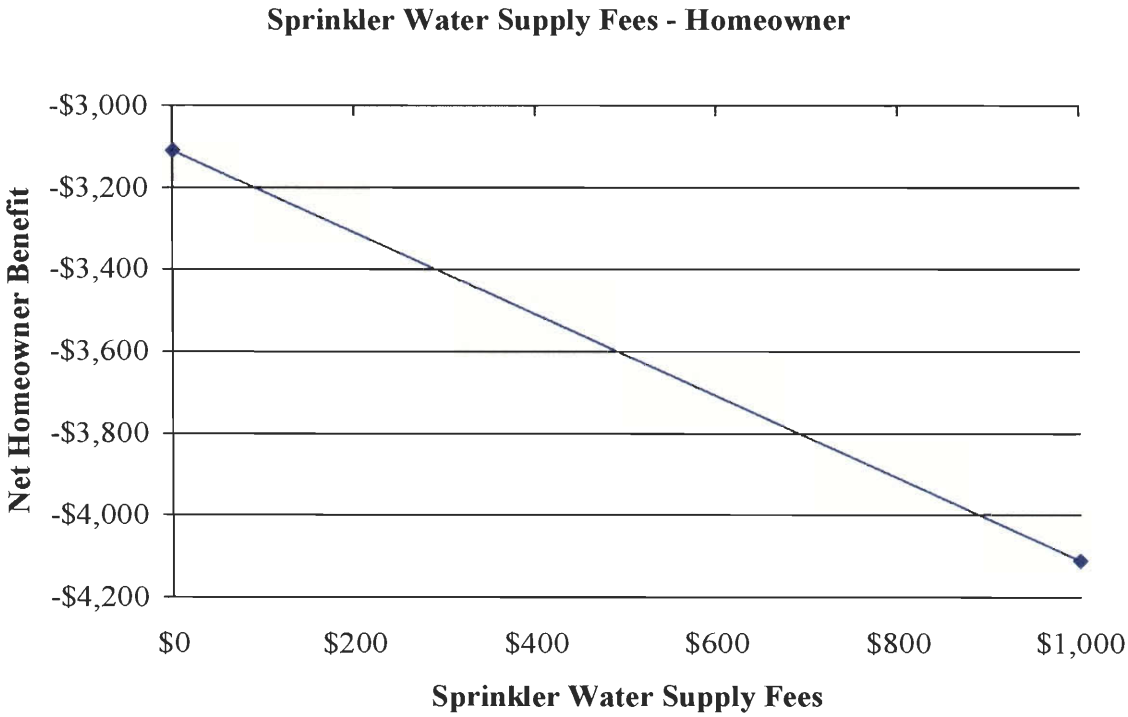

Figure 15: Sensitivity analysis of sprinkler water supply fees to the homeowner

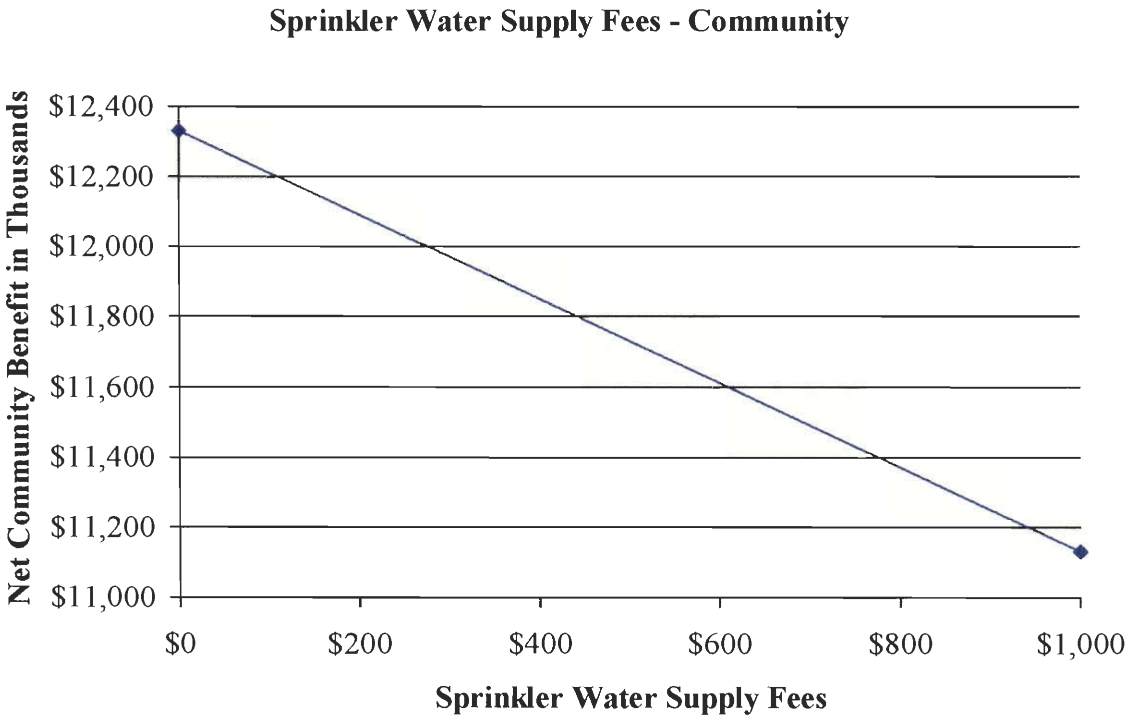

Figure 16: Sensitivity analysis of sprinkler water supply fees to the community

5-Step 3.b Sprinkler Activation Water Costs

As suggested in 4-Step 3.b, the approximate amount of water used when a home sprinkler system activates can be estimated from data supplied in the Scottsdale, Arizona report. This report determined that the average water used (SPF) when a home sprinkler system activated was 790 litres. The probability of fire occurring (PFO) in the CFA region of Victoria was estimated as 1.86 per 1000 dwellings annually. Water authorities in Victoria estimated the cost per kilolitre of water (COW) to be A$0.70. Using the equations described in the cost-benefit model, the average cost of sprinkler activation water (AWC) to the homeowner is A$0.01, and to the Eynesbury Station community is A$12, over the period of the cost-benefit model.

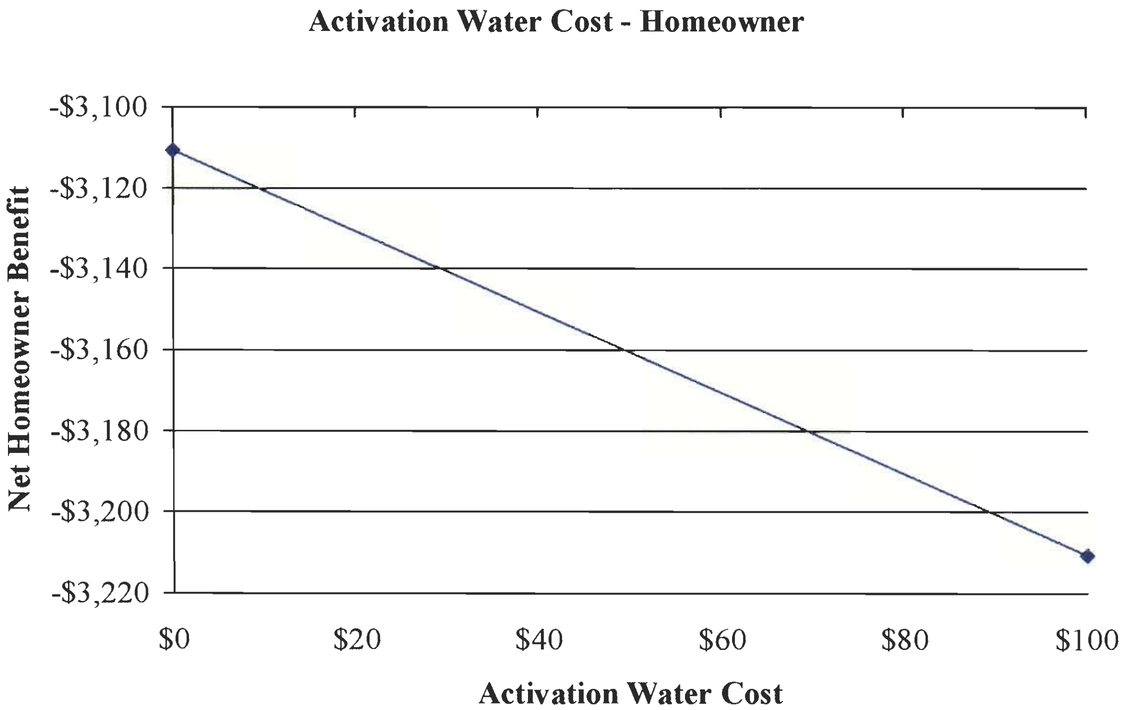

Figure 17: Sensitivity analysis of water activation cost to the homeowner

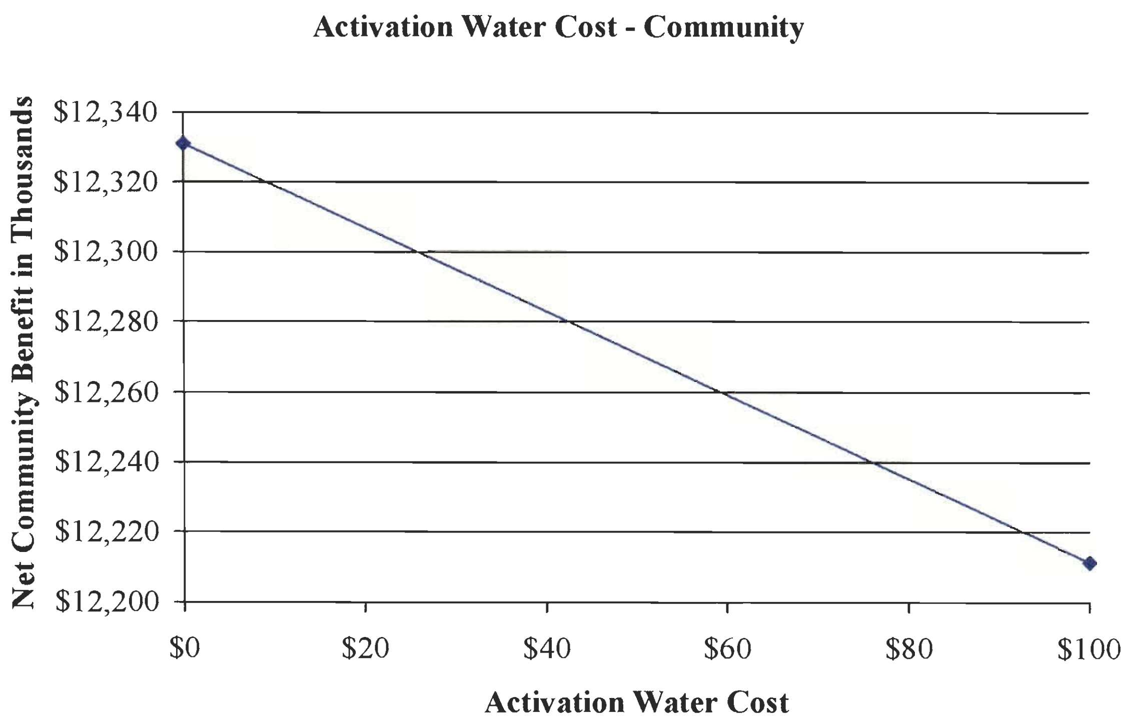

Figure 18: Sensitivity analysis of water activation cost to the community

5-Step 4 To Fire Service

5-Step 4.a Homeowner Education Programs and Notices

After discussion with community education officials at the MFESB (Taylor, 2001) and CFA (Rhodes, 2001), a suitable home sprinkler system education program was proposed for Greenfield site homeowners. The primary component of this education program would consist of a one page, double-sided, colour brochure that states important facts about home sprinkler system performance and proper use. The brochure might best be distributed as part of a larger homeowner safety packet, including general information about other fire safety measures and precautions of which Greenfield site homeowners should be aware (Rhodes, 2001). Devose (2001) suggested that a conservative cost estimate of creating 2000 home sprinkler system brochures would be A$1,000.

Additionally, it was suggested that an evening information session could be held for the Greenfield site community to provide information to homeowners about the importance of home sprinkler systems in protecting the entire Greenfield site development. The cost of providing an information session would likely be minimal because the session could be held at the local fire brigade, and presented by volunteer fire fighters or paid fire fighters that are normally on duty. Therefore, the total cost of homeowner education (HED) for this base-case study is estimated to be the cost of creating brochures at A$1,000.

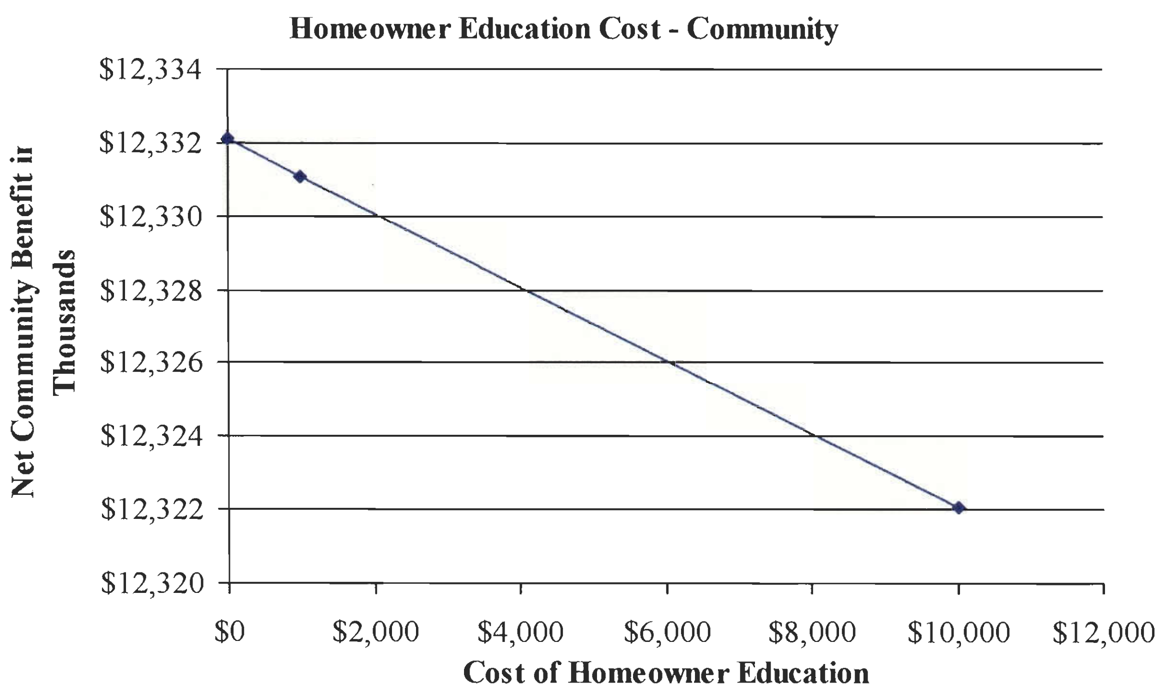

Figure 19: Sensitivity analysis of homeowner education costs to the community

5-Step 5 Other Costs

5-Step 5.a Covenants

As stated in 4-Step 5.a, there is currently no legislation that allows the CFA or local government to require that home sprinkler systems be installed in every home in a Greenfield site. It is the hope of many fire service officials at the CFA that in the future these requirements will be written into the building regulations for particular developments. This would require that a Greenfield site would have to be sprinklered, and building surveyors could enforce these regulations upon their normal inspection of new homes.

Wyndham City Council is the Council with jurisdiction over the Eynesbury Station development. As a result of discussions with officials at the CFA and Wyndham City Council, it was determined that for this base-case study of the Eynesbury Station development, the best way to currently require that home sprinkler systems are installed in all homes is to have the developer place a covenant on the title of every property.

There are three primary costs to the developer to place such covenants. These costs are the cost of creating a covenant (COC), the cost of placing that covenant on the titles of properties (POC), and administrative costs (CAC) of time and energy spent by the developer to arrange for covenant creation and placement. To estimate these costs for Eynesbury Station, a planning consultant and a lawyer were contacted. Both parties estimated the cost of creating a covenant (COC) to be A$500 (Jones, Barber, 2001). It must also be noted that the cost of creating a covenant will depend upon the experience of the lawyer creating the covenant. It is expected that a lawyer with experience in writing covenants related to fire protection would require less time than a lawyer with little or no experience in writing such covenants (Jones, 2001).

The titles office sets the cost of placing a covenant on a property (POC). This cost is estimated to be A$60 per property in the Greenfield site (Jones, Barber, 2001). In addition to this cost, administrative costs of placing covenants on new properties can also be a significant cost to a developer. For this base-case study, covenant administrative costs (CAC) are estimated to be A$1,000 per covenant, by Delfin Property Group, a leading developer of large sub-divisions such as Caroline Springs in Victoria. This cost includes the cost to follow up on homes that do not abide by the rules of a covenant. This cost may be considered a covenant enforcement cost, but for the purposes of this case study, it will be included in administrative costs. Combining this cost with the cost of creating a covenant, and the cost of placing covenants, the total estimated cost of covenants (TOC) to the Eynesbury Station homeowner and community are A$61 and A$73,500, respectively.

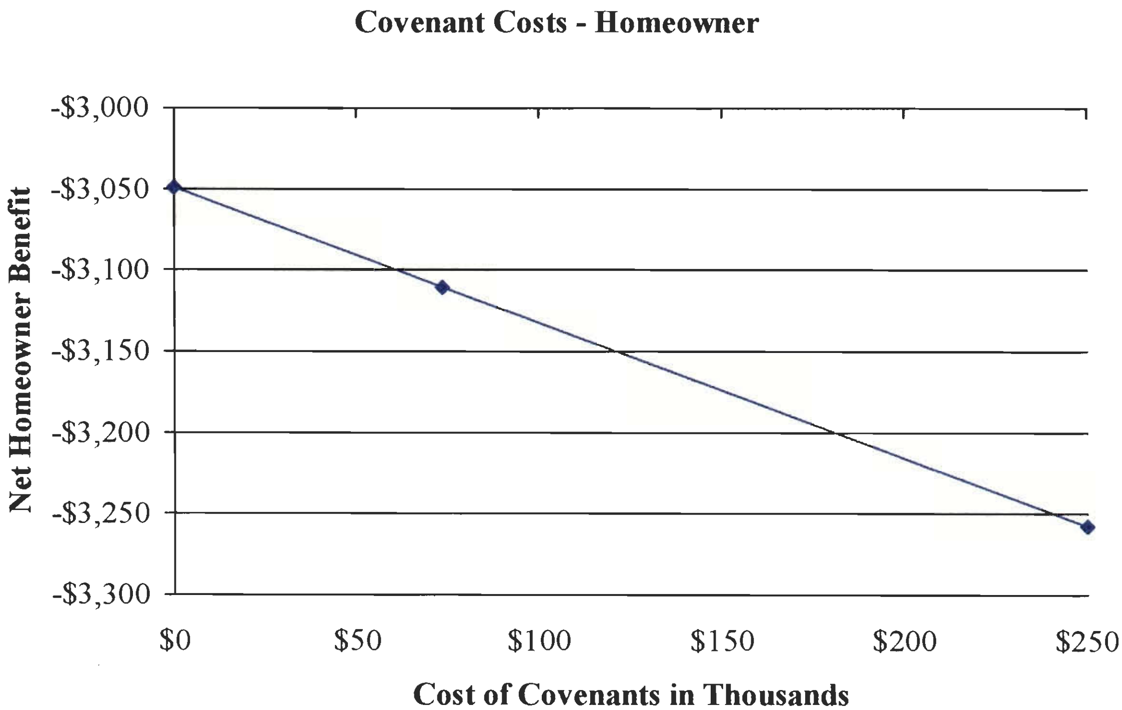

Figure 20: Sensitivity analysis of the cost of placing covenants on properties to the homeowner

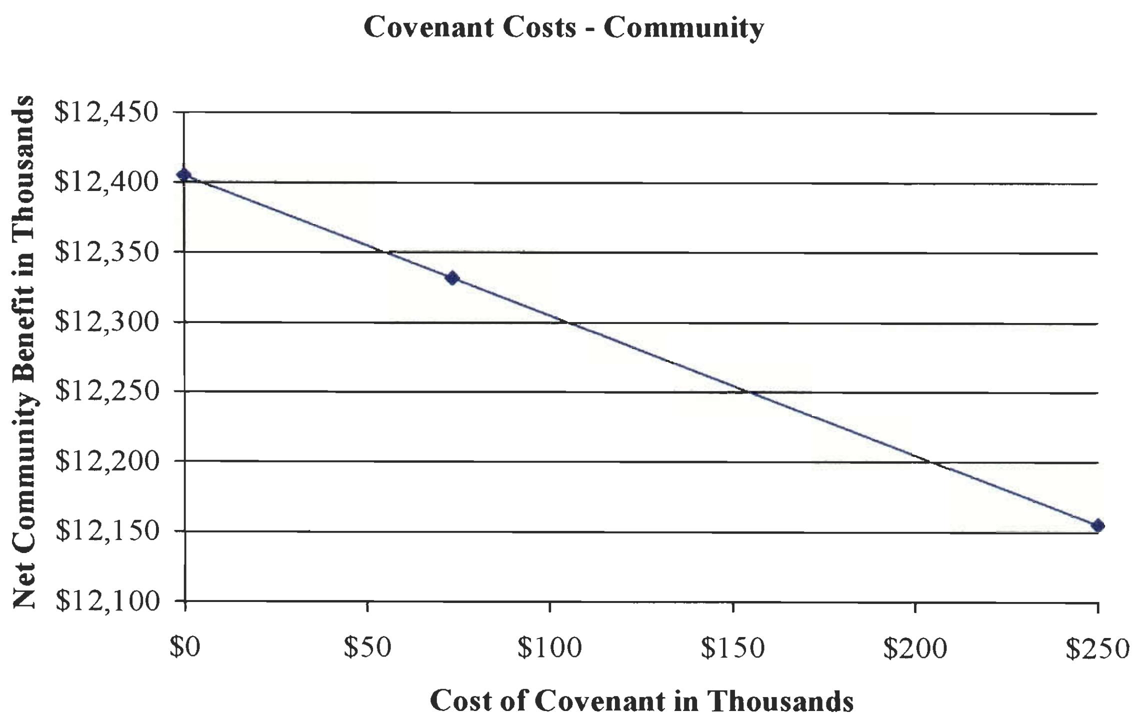

Figure 21: Sensitivity analysis of the cost of placing covenants on properties to the community

5-Step 5.b Covenant Enforcement and Inspections

As previously stated, if requirements were written into building regulations, requiring home sprinkler systems in Greenfield site homes, building surveyors could enforce those requirements. In such a case, a building surveyor's fee may increase due to the added time and expertise needed to inspect home sprinkler system. However, this is not the situation for the base-case study. Instead, it is known that the Wyndham City Council currently researches covenants on new properties, and alerts the proper party if a covenant is not within compliance (Cocks, 2001). Therefore, it is expected that if a home were not sprinklered in the Eynesbury Station development, building surveyors at Wyndham City Council would notify the Greenfield site developer. It was suggested by Wyndham City Council that there would not be any added costs of researching and inspecting a covenant enforcing home sprinkler systems in Eynesbury Station (Cocks, 2001). For this reason, it is assumed that the cost of covenant enforcement in the Eynesbury Station development (CEC) will be zero.

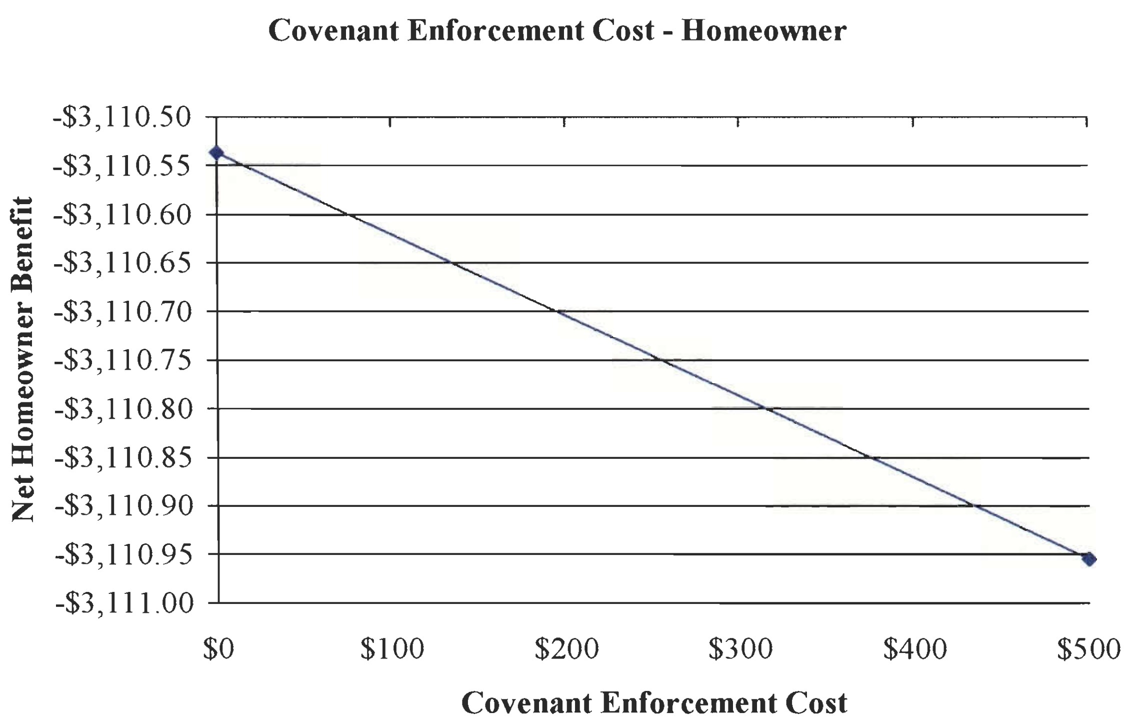

Figure 22: Sensitivity analysis of covenant enforcement cost to the homeowner

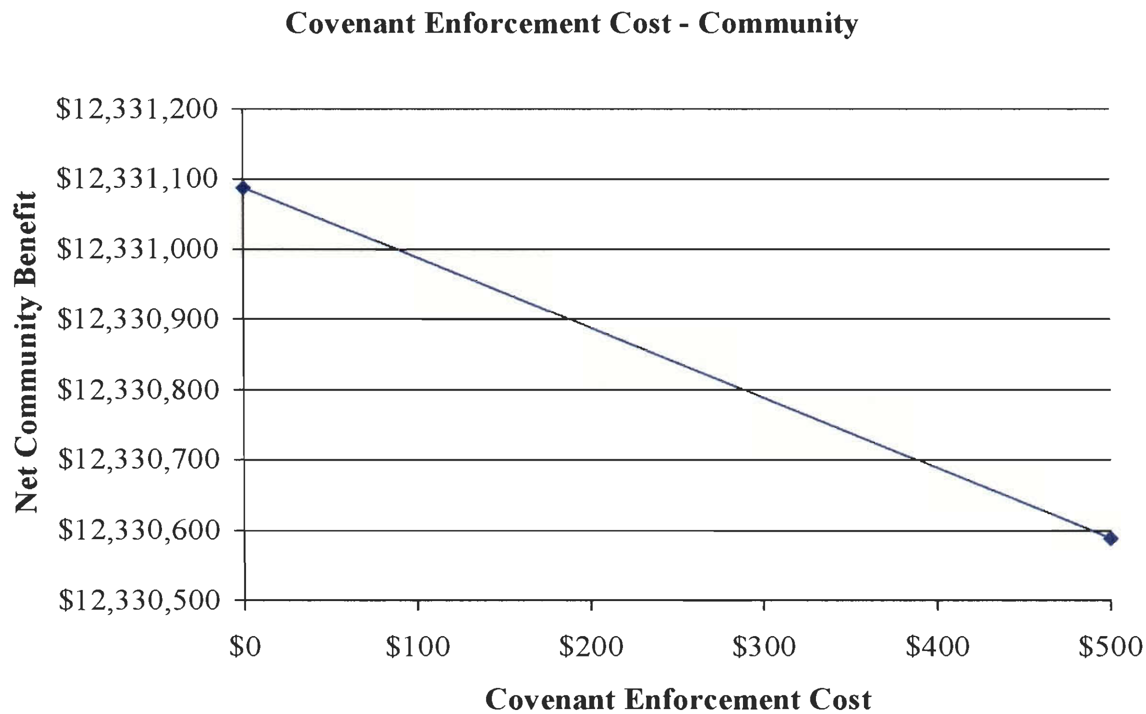

Figure 23: Sensitivity analysis of covenant enforcement cost to the community

5-4 Benefit Model

5-Step 6 To Developer

5-Step 6.a Water Supply Infrastructure Savings

It is evident that the Eynesbury Station Greenfield site may endure a net cost for water supply infrastructure rather than a savings. Several factors establish this result, including the lack of adequate water pressure available to all of Eynesbury Station, as well as the common practices of fire authorities, water authorities, and water infrastructure designers. It has been suggested by several water authorities in Victoria that the common minimum design pressure for water supply infrastructure is 200 kPa. This pressure is also stated in the new Water Reticulation Code for Victoria. For a large single-story home, Residential Fire Sprinkler Systems PTY. LTD. calculated the minimum required pressure at the water main tap, necessary for sufficient performance of two sprinkler heads, to be 332 kPa. For a large two story home, it was estimated that an additional 30 kPa be added for the increase in elevation. Accounting for some additional pipe friction loss, a conservative estimate of 400 kPa was chosen for the required pressure in the street water main for this base-case study (Hocking, 2001).

According to the WBCM Group, the infrastructure engineers for Eynesbury Station, the water reservoir in nearby Melton is sufficient to supply most of Eynesbury station with the required 400 kPa during peak demand hours. Also, a pressure and flow test performed on the water main that will provide Eynesbury Station with water, revealed that 540 kPa was available, through a 25 mm nozzle (Hunt, 2001). With minimal friction loss from the point of this test to the Eynesbury Station development, this pressure should be sufficient. However, it was suggested that additional testing be performed to determine the effect of peak demand and weather conditions on this available pressure (Hunt, 2001).

It is likely that a small number of lots in Eynesbury Station will not be provided with the required 400 kPa during the peak demand hours (Sheath, 2001). The water supply to these homes would require a small booster pump, which could be shared by the disadvantaged lots. The estimated cost of this type of pump was suggested to be approximately $50,000 (Sheath, 2001). A header tank will be necessary on site to intercept the flow from the 300 mm main from Melton, but this is not an additional cost due to home sprinkler systems.

Therefore, the total cost of infrastructure (WIS) due to the use of home sprinkler systems is estimated to be A$50,000 to the Eynesbury Station community, assuming one pump will adequately increase the water pressure to all of the disadvantaged lots. Because there are infrastructure costs instead of savings to the Eynesbury Station developer, it can be assumed that 100% of this cost of the additional infrastructure would be passed along to the homeowners. This cost is calculated to be an additional A$42 per Eynesbury Station homeowner.

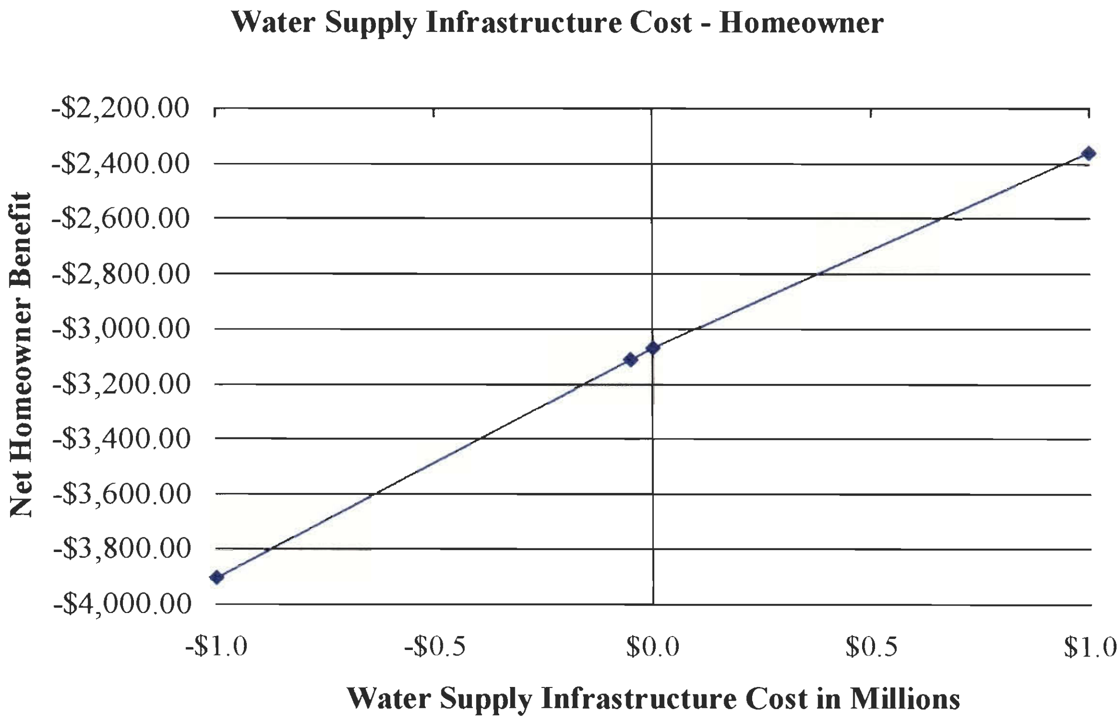

Figure 24: Sensitivity analysis of water supply infrastructure cost to the homeowner

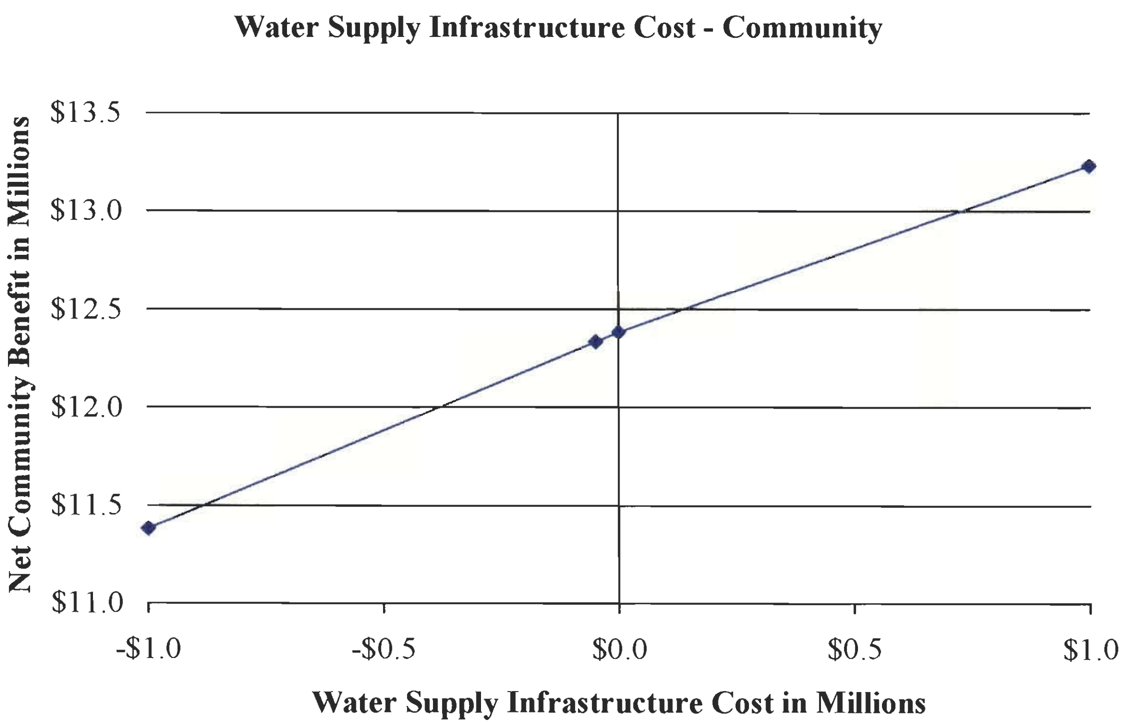

Figure 25: Sensitivity analysis of water supply infrastructure cost to the community

5-Step 7 To Homeowner

5-Step 7.a Life Savings

In 4-Step 7.a, the procedure to calculate life savings in Greenfield sites was described. To review, the annual probability of fire fatality occurring (PFD) was estimated to be 15.33 per million dwellings, and the percent of fatality reduction (PFR) due to home sprinkler systems to be 77%. Again, this percent of fatality reduction (PFR) is taken from data for sprinklered residential buildings in the Untied States between 1988 and 1997. Using these values, the expected number of lives saved in the Eynesbury station over the period of the cost-benefit model is 0.125, or one life every 70 years.

5-Step 7.b Injury Savings

As described in 4-Step 7.b, the cost benefit model estimates the probability of fire injury occurring (PFI) to be 115.9 per million dwellings from CFA data between the years of 1998 and 2000. Similarly, the average cost per injury (CPI) is estimated to be A$7,849. The cost-benefit model also reports that the Ruegg-Fuller analysis suggests that fire injuries can be reduced by 46% in one- and two-family dwellings with smoke alarms and sprinkler systems. As there are no further data available to estimate fire injury reduction due to home sprinkler systems, this case study estimates that the percent of fire injury reduction (PRI) in the Eynesbury Station Development will be 46%.

Given these values, the expected fire injury savings to a Greenfield site during the cost-benefit model time period are A$4 to the homeowner and A$4,800 to the Eynesbury Station community.

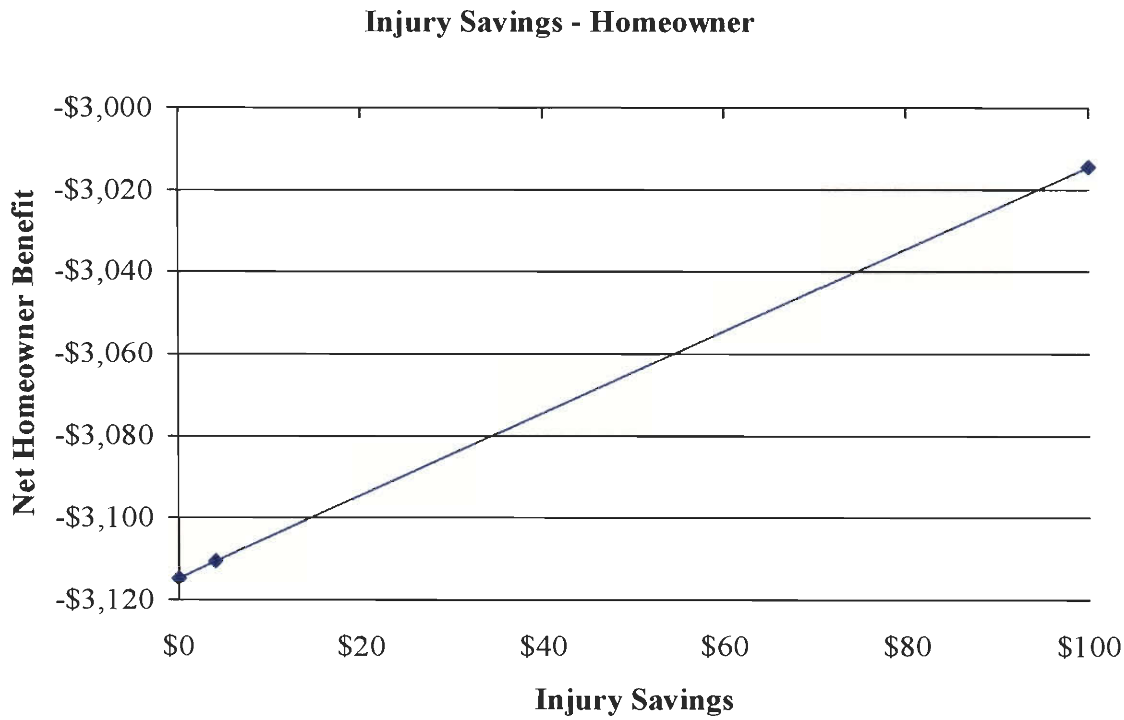

Figure 26: Sensitivity analysis of injury savings to the homeowner

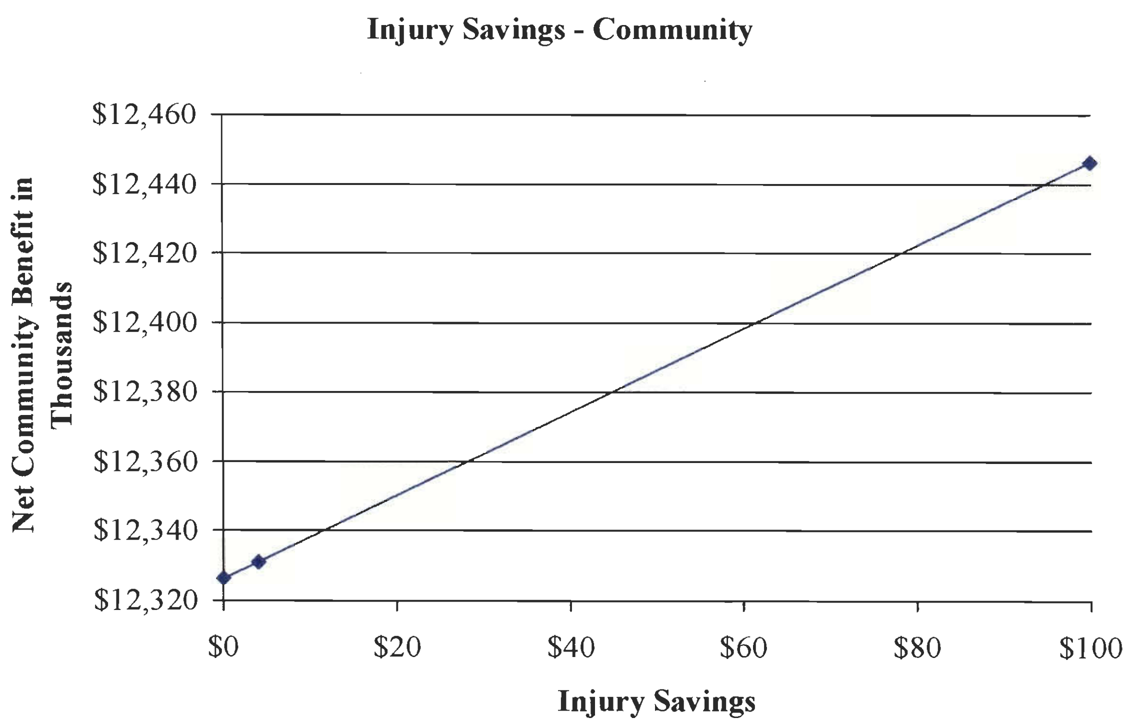

Figure 27: Sensitivity analysis of injury saving to the community

5-Step 7.c Property Savings

Using the data supplied by the CFA and Insurance Statistics Australia (ISA), estimations can be made for expected fire damage property loss in a non-sprinklered home. From 4-Step 7.c, the CFA recorded an average property loss of A$25,174.39 per fire incident between 1998 and 2000, while the average insurance claim amount supplied by the ISA was A$12,140.88 between 1996 and 1999. It is expected that property damage records of the CFA may be high because small fire incidences that could be handled by the homeowner were most likely not reported to the fire service. Likewise, the ISA data may present a small average property loss claim because small fire incidences were recorded. Because the homes in the Eynesbury Station Greenfield site will have above-average combined home and property values between A$250,000 and A$500,000 (Philip, 2001) it can be assumed that the average property losses due to fire will be higher than the average supplied by the CFA and ISA data. For the purpose of this case study, an average property loss value (APD) of A$25,000 per house was used. This value is generous, however, small fire incidences would probably have very little effect in property damage costs when comparing sprinklered and non-sprinklered homes. For this reason, home sprinkler systems would only have significance in reducing property damage in fires where the potential for extreme property damage is high.

The estimated property savings (PPS) is calculated by multiplying the average property damage (APD), by the number of years of the case study (YRS), the probability of fire occurring in the home (PFO), and by the percent reduction in fire damage (PDR) due to home sprinkler systems. As stated in 4-Step 7.c, the annual probability of fire occurring (PFO) in the home is 1.86 per 1000 homes and the percent reduction in fire damage due to home sprinkler systems (PDR) can be estimated at 70%. Using these values, the estimated property damage savings to Eynesbury Station homeowners is A$312, while the savings to the entire Eynesbury Station community over the period of the study is A$374,400.

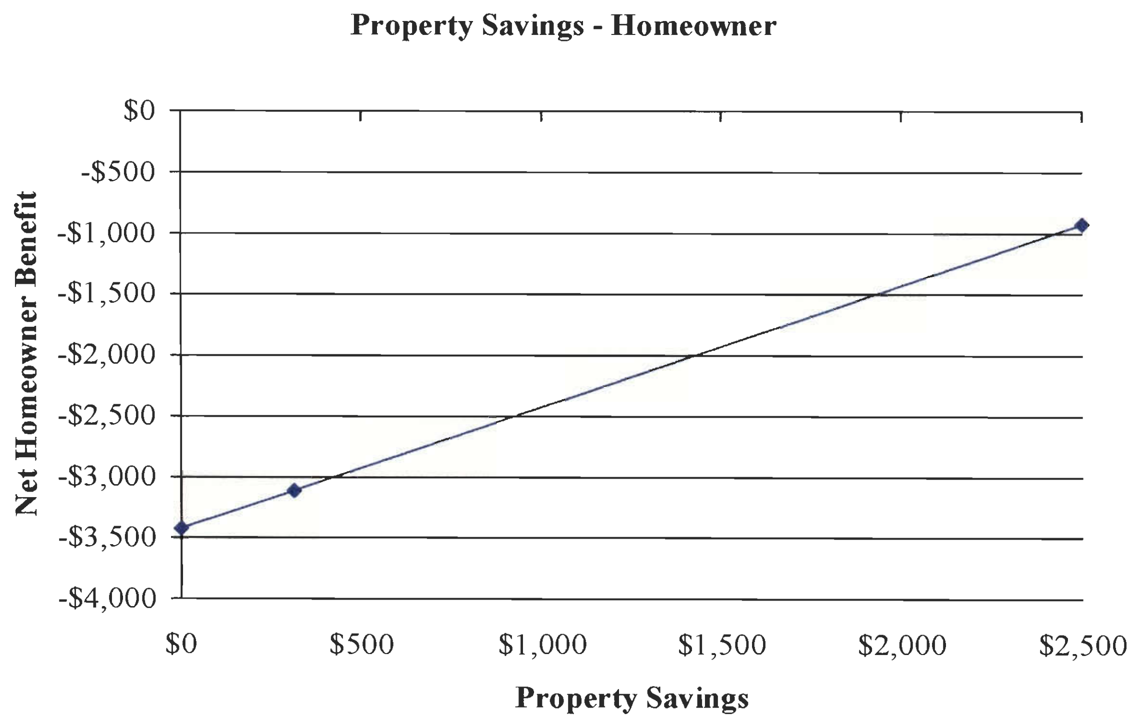

Figure 28: Sensitivity analysis of property savings to the homeowner

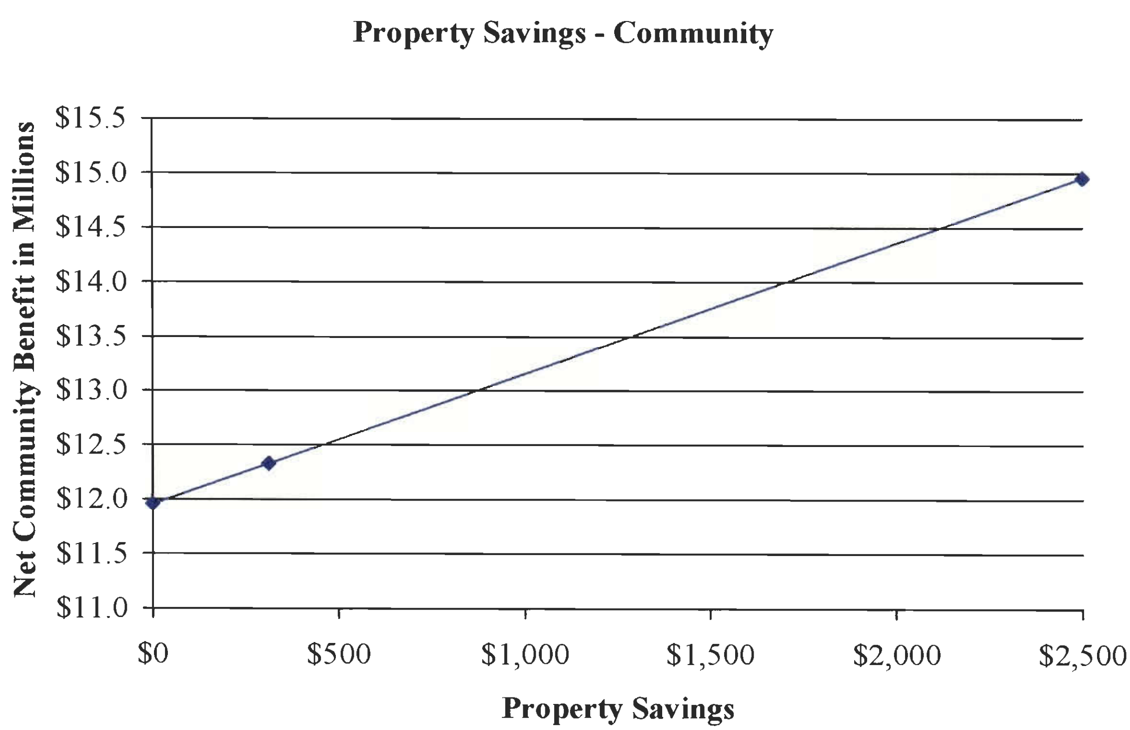

Figure 29: Sensitivity analysis of property savings to the community

5-Step 7.d Home Insurance Savings

As explained in 4-Step 7.d, there are currently no home insurance savings given to homeowners with home sprinkler systems in Victoria. Furthermore, home insurance savings will not be granted until home sprinkler systems make a significant impact upon fire property damage statistics collected by insurance companies. It was suggested by the Insurance Council of Australia that this impact would not occur for many years (Baxter, 2001). For the purposes of this base-case study, it is assumed that over the period of this model, there will be no home insurance savings (HIS) given to homeowners in Eynesbury Station.

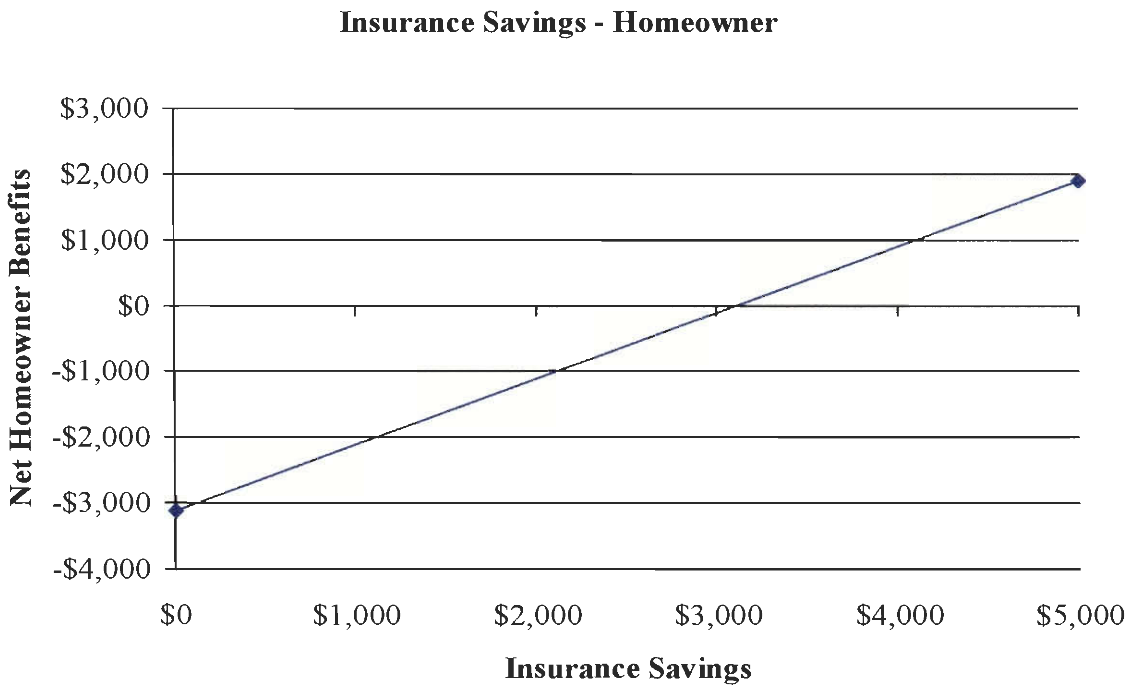

Figure 30: Sensitivity analysis of insurance savings to the homeowner

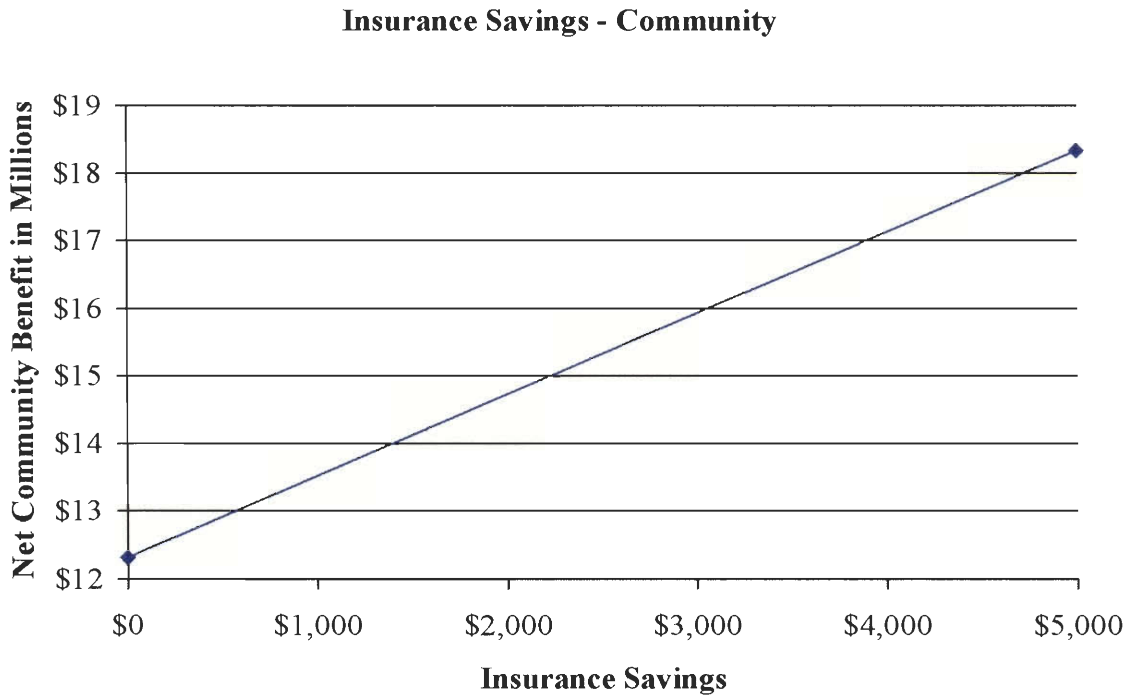

Figure 31: Sensitivity analysis of insurance savings to the community

5-Step 8 To Fire Service

5-Step 8.a Fire Service Provision Savings

To estimate fire service provision savings for Eynesbury Station, average costs of career and volunteer fire brigades in the CFA were used. Table 7 and Table 8 display these average initial and annual costs for career and volunteer fire brigades, respectively. The actual costs for fire provision to Eynesbury Station may be different than the average values listed in these tables, because these averages were determined for the entire CFA region and not Melton alone. However, for the purposes of this base-case study, these average costs should be sufficient to suggest the expected savings in fire service provision due to home sprinkler systems in Eynesbury Station.

CAREER FIRE BRIGADE	
Initial Costs	
Item	**Cost**
Fire Fighter Recruitment (per employee)	A$6,670
Qualified Fire Fighter Training (per employee)	A$11,300
Fire Station Building	A$1,800,000
Operations Officer Equipment	A$43,500
Type 3 Pumper Appliance	A$360,000
Tanker Appliance	A$170,000
Annual Costs	
Item	**Cost**
Qualified Fire Fighter[13]	A$55,156
Leading Fire Fighter	A$63,152
Officer Fire Fighter	A$73,805
Operations Officer	A$80,738
Operations Officer Equipment	A$21,000
Maintenance and Equipment (per employee)	A$4,300
CFA Headquarter Supervision	5% * each employee salary
CFA Regional Supervision	7% * each employee salary

Table 7: Career Fire Brigade Costs

VOLUNTEER FIRE BRIGADE	
Initial Costs	
Item	**Cost**
Fire Station Building	A$500,000
Annual Costs	
Item	**Cost**
Maintenance and Equipment	A$60,000

Table 8: Volunteer Fire Brigade Costs

After discussions with CFA officials in Melton, it was determined that a new fire brigade will need to be established to provide fire protection to the Eynesbury Station development. The choice between a new career fire brigade and new volunteer fire brigade will depend upon a number of factors. The first factor is the availability of community members to volunteer their time to a viable volunteer fire brigade. Second, the service delivery standard determined for this type of development may depend upon the inclusion of home sprinkler systems in single-family dwellings (Fox, 2001). Generally, a new volunteer fire brigade in the CFA region requires 25 volunteer fire fighters to have enough available personnel to always provide acceptable response time to a fire (Kelly, 2001). Eynesbury

13 These salaries for qualified, leading, and officer fire fighters include approximate costs of overtime, and higher duties required by those fire fighters or officers.

Station is aimed at wealthy customers that may be older and will most likely be less willing to become involved as volunteer fire fighters.

Home sprinkler systems are expected to reduce the consequences of fire in homes, thus reducing the risk of fatalities and property damage. For this reason, if home sprinkler systems are installed in all Eynesbury Station homes, response time to those homes may be less critical. This fact would have to be supported by a government decision to change the service delivery standard to a development with home sprinkler systems in the CFA region (Fox, 2001). Depending upon this decision, it may then be possible that a volunteer fire brigade will meet the necessary service delivery standard to Eynesbury Station, if home sprinkler systems were present. The establishment of a volunteer fire brigade would depend upon the ability of volunteer fire fighters in Eynesbury Station to meet the service delivery standard (Fox, 2001).

For the purposes of this base-case study, it is assumed that a viable volunteer fire brigade will be adequate to provide the necessary fire service to the Eynesbury station, if home sprinkler systems are present in every home. It is also assumed for this base-case study that a career fire brigade may be required to protect Eynesbury Station, if home sprinkler systems were not present in every home. Therefore, fire provision savings will be the difference in costs between a new career fire brigade and a new volunteer fire brigade. As explained in the cost-benefit model, these savings are a combination of the cost to create a new fire station, purchase equipment, maintain that equipment, and provide manpower to run the brigade.

5-Step 8.a.i Creation of Fire Station

As seen in Table 7 and Table 8, the average initial cost of a career fire station is A$1,800,000 and the average initial cost of a volunteer fire station is A$500,000 in the CFA region. The difference between these two costs provides an estimate of fire station savings (FSS) to the Eynesbury Station community of A$1,300,000.

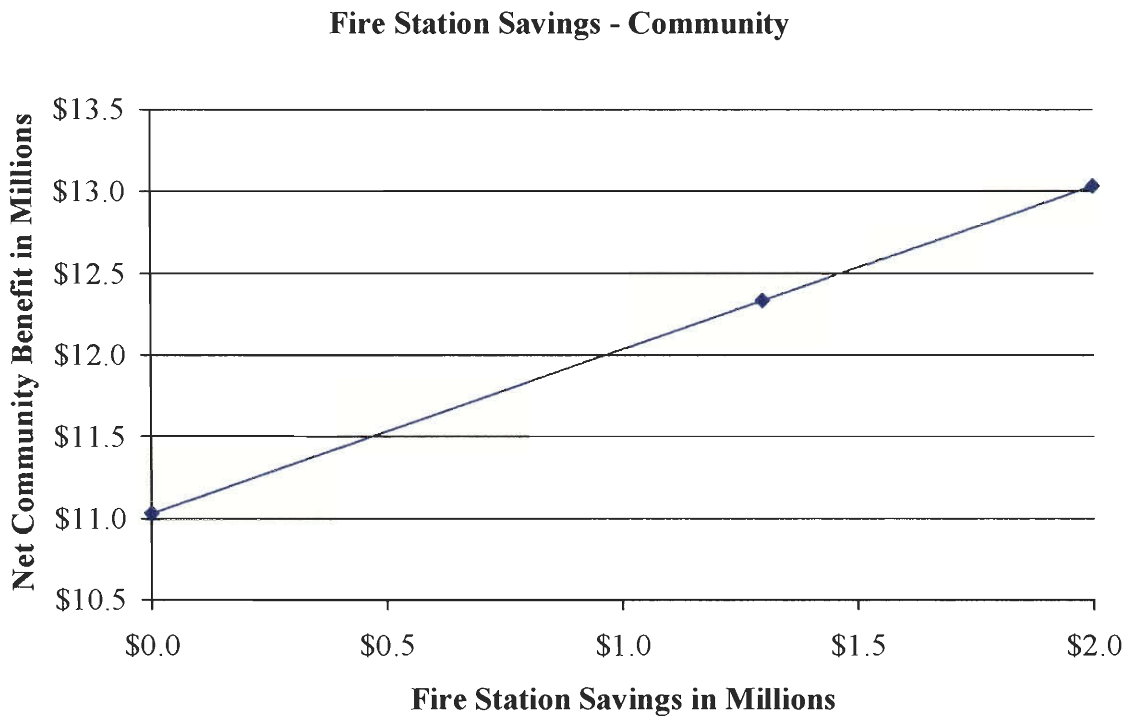

Figure 32: Sensitivity analysis of fire station savings to the community

5-Step 8.a.ii Initial Purchase of Appliances and Equipment

The cost of equipment at career and volunteer fire brigades in the CFA are estimated on an annual basis because there is continual maintenance and replacement of equipment each year. For this reason, the cost of equipment for career and volunteer fire brigades is included in the following section, Maintenance of Appliances, Fire Station and Equipment.

It was suggested by CFA officials in Melton, that the required appliances at a career fire brigade and a volunteer fire brigade would be roughly the same. Specifically, a new career and volunteer fire brigade would each require one new Type 3 pumper and one new tanker. The combined cost of these two appliances is approximately A$530,000. Due to the fact that this cost is the same for both fire brigades, the savings in fire provision due to a reduction in initial purchase of appliances and equipment (FES) is considered to be zero for this base-case study.

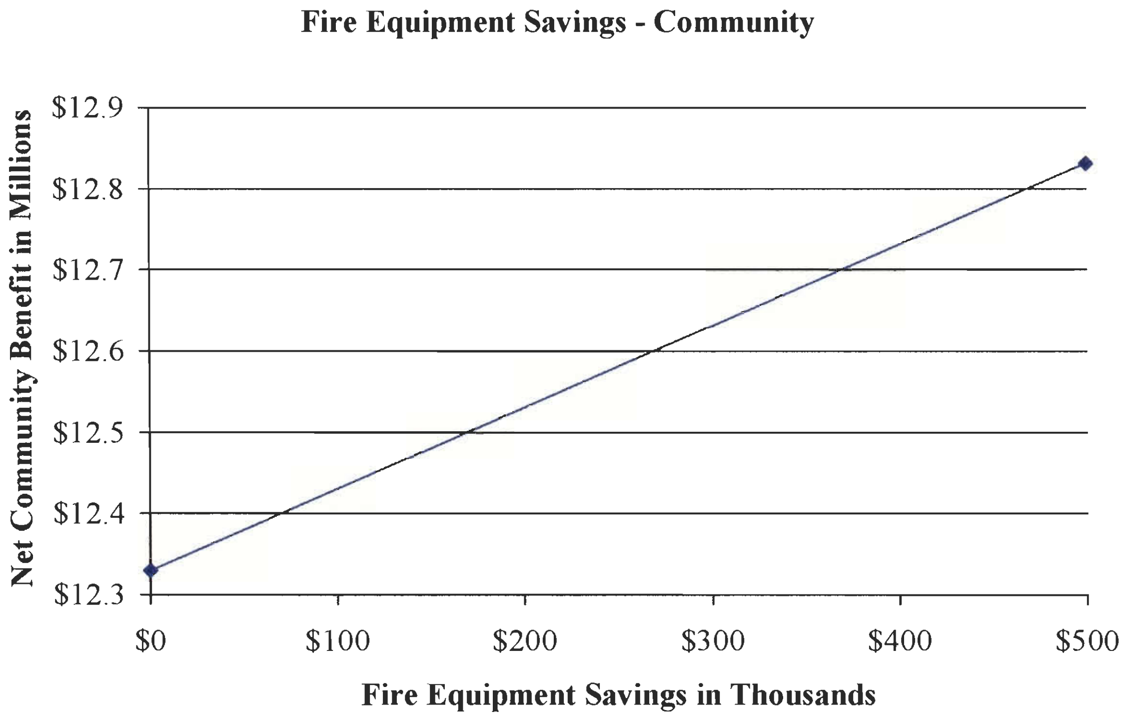

Figure 33: Sensitivity analysis of fire equipment savings to the community

5-Step 8.a.iii Maintenance of Appliances, Equipment, and Fire Station

As previously stated, the average costs of maintenance of appliances, equipment and fire station are estimated on an annual basis in the CFA. The cost of maintenance of a career fire brigade is estimated to be A$4,300 per employee, as seen in Table 7. For a new career fire brigade at Eynesbury Station, the expected manpower would consist of three qualified fire fighters and one officer fire fighter[14]. To fill one position throughout the year, the CFA estimates that 5.29 employees are required. This number of employees accounts for several time shifts, as well as time off and sick leave (Holyman, 2001). Therefore, there are 22 expected employees required to man a career fire brigade for Eynesbury Station. Annually, the maintenance cost for this career fire brigade would sum to A$94,600.

The annual maintenance cost of appliances, equipment and fire station for a volunteer fire brigade in the CFA is estimated to be A$60,000. For the purposes of this base-case study, the annual savings in maintenance (MSE) for a volunteer fire brigade over a career fire brigade would therefore be A$34,600. Over the period of this model, these savings would amount to a reduction in maintenance costs of A$331,878.

14 Currently the fire fighters union requires that a new career fire brigade in the CFA have at least four full time fire fighters on duty (Fox, 2001).

Maintenance of Station and Equipment - Community

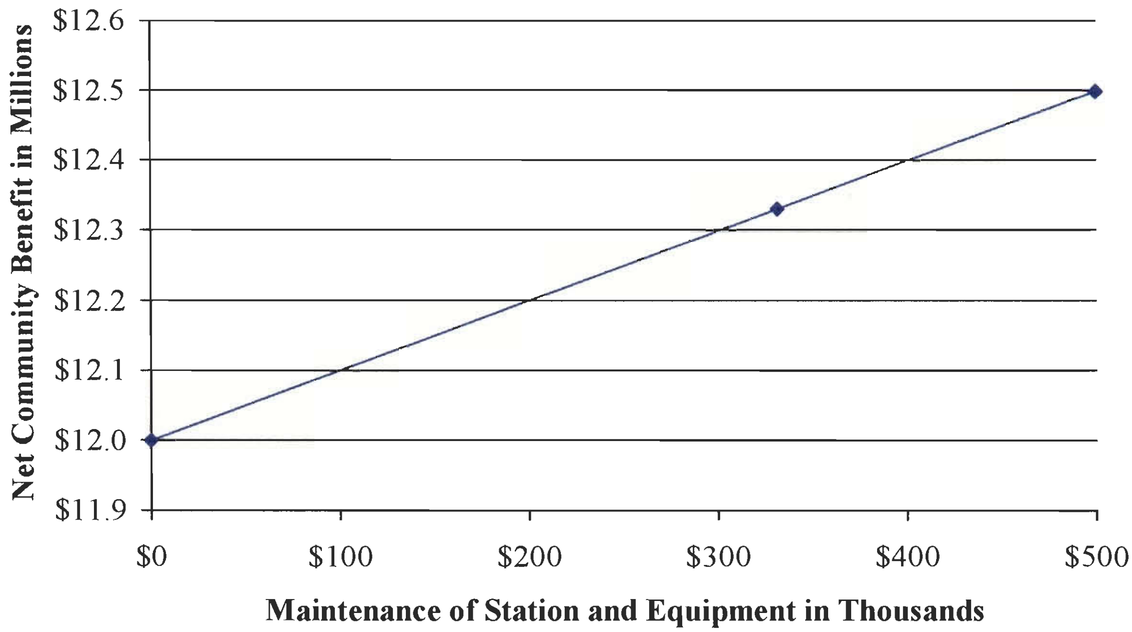

Figure 34: Sensitivity analysis of maintenance of fire station and equipment to the community

5-Step 8.a.iv Manpower

The initial costs of providing manpower for a career fire brigade in the CFA are due to employee recruitment and training. The combined cost of recruiting and training a new fire fighter is approximately A$19,790. The total cost to recruit and train (RAT) all 22 employees at a new career fire brigade to protect Eynesbury Station is then A$395,340. Rather than training 22 new fire fighters to man the career fire brigade, some experienced fire fighters may be relocated to the Eynesbury Station fire brigade. The approximate cost of relocating one fire fighter is A$16,000 (Holyman, 2001). However, the average rate of relocation is 5%, so for the purpose of this case study, it is assumed that no fire fighters will be relocated to man a career fire brigade at Eynesbury Station. Moreover, if fire fighters were relocated to Eynesbury Station there would be an added cost to replace their positions at existing brigades, resulting in similar costs place all new fire fighters in the development.

Table 7 displays the average salary of qualified fire fighters and officer fire fighters in the CFA region. For the this study, it is assumed that to cover all shifts at the career fire brigade, 17 qualified fire fighters and 5 officer fire fighters will be required. The annual cost for the salaries of these fire fighters is A$1,463,482. Included in this cost is the added cost of

CFA headquarters and regional supervision to a new career fire station in the CFA region. These costs are estimated as 5% and 7% of each employee's salary, respectively.

The total cost of manpower for a volunteer fire brigade is zero. For this reason, annual savings in manpower (FMS) from a volunteer fire brigade versus a career fire brigade are the total of paying salaries, and supervising the 22 expected fire fighters for the Eynesbury Station development. Including the cost of recruitment and training (RAT), the total cost of manpower over the period of this model is A$14,432,856.

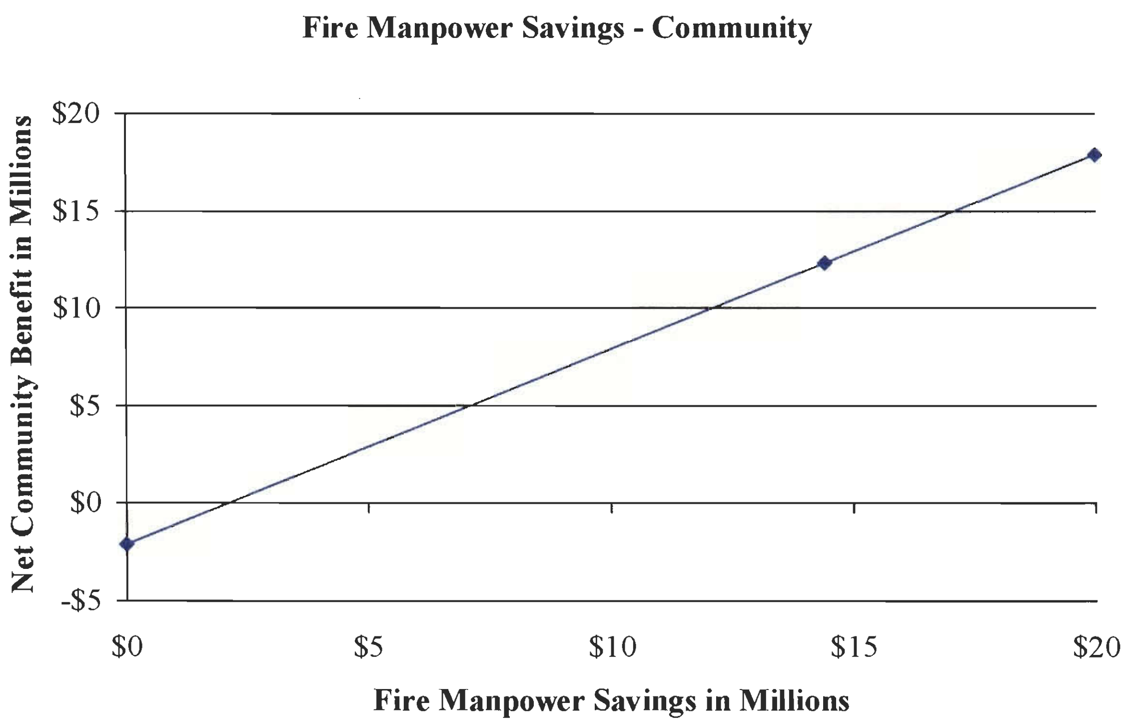

Figure 35: Sensitivity analysis of fire service manpower savings to the community

5-5 Net Homeowner and Community Cost or Benefit

Using the equations defined in Section 4-4, the total cost to an Eynesbury Station homeowner and the Eynesbury Station community are A$3,385 and A$4,063,120, respectively. Similarly, the total benefit to the homeowner and community are A$275 and A$16,394,208, respectively. Combining these total costs and benefits provides each Eynesbury Station homeowner with a net cost of A$3,111 and the Eynesbury Station community with a net benefit of A$12,331,088.

Figure 36 and Figure 37 displays sensitivity graphs of the change in net homeowner and community benefits over a varying cost-benefit model period. Note that the net homeowner and community benefits increase as the average occupancy period increases.

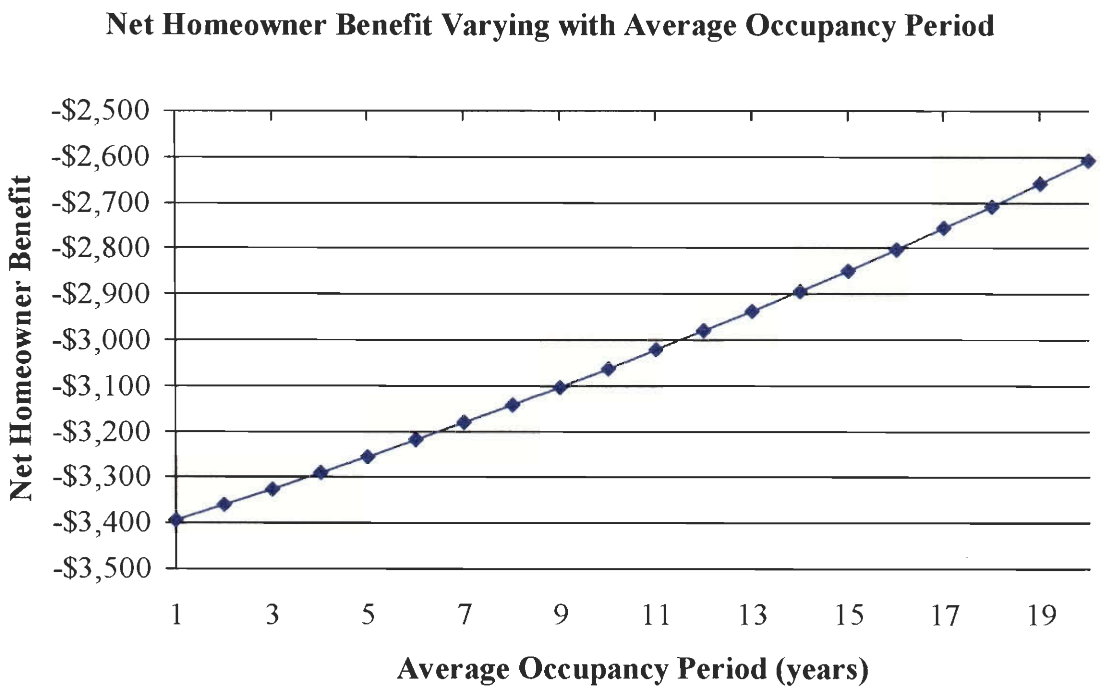

Figure 36: Sensitivity analysis of net homeowner benefit varying with average occupancy period

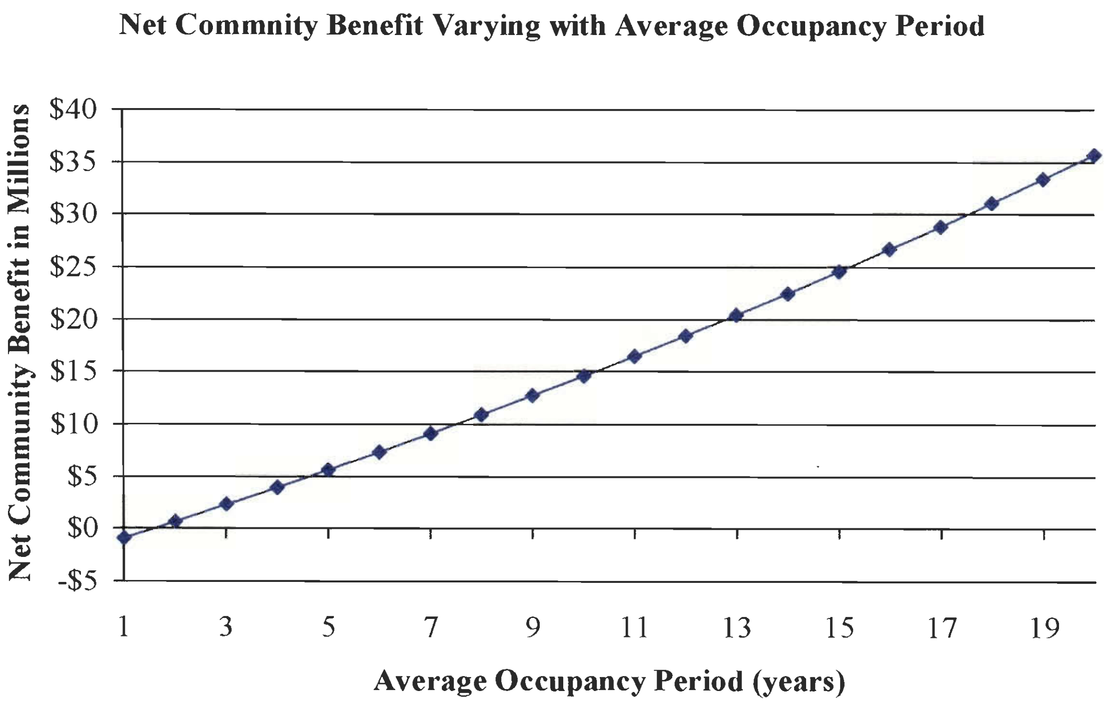

Figure 37: Sensitivity analysis of net community benefit varying with average occupancy period

5-6 Cost per Life Saved

The total expected number of lives saved in Eynesbury Station over the period of the cost-benefit model is 0.125. Dividing the net community benefit by this number of lives saved in the community, determines the total cost per life saved of -A$98,648,704. Because this cost is negative, there will be an expected benefit per life saved in the Eynesbury Station development. This cost per life saved is significantly different than the cost per life saved calculated in the BRANZ New Zealand 2000 report (Duncan et al, 2000), and the Beever and Britton report (Beever-Britton, 1999), because this case study considers more benefits to a community with home sprinkler systems.

5-7 Case Study and Sensitivity Analysis Conclusions

After conducting the base-case study for the Eynesbury Station development in Melton, Victoria, several conclusions can be made about the expected costs to the Eynesbury Station community and homeowners:

- The net community benefit due to home sprinkler systems in Eynesbury Station is expected to be positive. This net community benefit is approximately A$12,300,000.
- The primary factor in creating positive benefits for the Eynesbury Station community are fire service provision savings, estimated at A$16,100,000.
- Comparatively, the only major cost to the Eynesbury Station community is the purchase and installation cost of home sprinkler systems. These purchase and installation costs equate to approximately A$4,000,000.
- Because fire service provision savings are so great, it is likely that the net community benefit for Eynesbury Station will be positive, even if there is a small error in the base-case study estimates.
- The net benefit for homeowners in Eynesbury Station is expected to be negative. This negative benefit, (cost) is estimated to be A$3,111 per homeowner.
- The primary factor in creating negative benefits for homeowners in Eynesbury Station is an estimated purchase and installation cost of A$3,325 per homeowner.
- The largest, single, expected benefit to homeowners in Eynesbury Station is a reduction in property damage due to fire. This savings is estimated to be A$312 over the period of the study.
- The expected cost per life saved for the Eynesbury Station community is negative A$98,648,700. Note that this value is actually a benefit per life saved. This value may be difficult to compare with other reports because more cost and benefits were considered in the cost per life saved equation.

6 Summary and Conclusions

This study developed a cost-benefit model and applied the model to a base-case study of a Greenfield site in Melton, Victoria. From the information collected, and calculations performed in this study, several conclusions can be drawn:

- The expected costs and benefits of home sprinkler systems in Victoria are similar to the costs and benefits of home sprinkler systems in the United States.
- The primary differences in costs and benefits between Victoria and the United States include:
  - No expected homeowner insurance benefits in Victoria
  - No expected road infrastructure benefits in Victoria
  - Home sprinkler systems require a substantial water pressure in the street water main. In addition, water supply infrastructure in Victoria is not designed based upon fire fighting needs. Therefore, it is possible that there may be costs instead of benefits related to water supply infrastructure in a Greenfield site.
- Net monetary benefits to homeowners in Greenfield sites are expected to be negative due home sprinkler system purchase and installation costs.
- Net monetary benefits to Greenfield site communities are expected to be positive due to fire provision savings.
- Based upon data collected from the CFA between 1998 and 2000, 82% of fire fatalities occurred in rooms of single-family dwellings that will be protected by home sprinkler systems. Based upon data from the United States (Rhor, 2000), it is expected that home sprinkler systems will save 77% of fire fatalities in single-family dwellings with home sprinkler systems in Victoria.
- The cost per life saved due to the installation of home sprinkler systems in Greenfield sites is expected to remain negative. This means that there is expected to be both a savings in lives and a net community benefit in Greenfield sites.

7 Topics for Further Study

For further analysis of the costs and benefits of home sprinkler systems, the model created in this analysis could be applied to Greenfield sites in other states of Australia. To accurately apply the model outside of the Country area of Victoria, fire statistics should be collected from other fire services. In addition, cost and benefit information should be collected from the appropriate sources in a particular state. The results of further case studies may provide more data to support home sprinkler systems as a life safety and property saving device. Furthermore, it may be worthwhile to expand the scope of this cost-benefit analysis to include homeowners of new homes that are not part of a Greenfield site. Such an analysis could determine the costs and benefits of home sprinkler systems for homeowners that choose not to live in a large housing development.

As stated in this report, home sprinkler systems are a new concept in Australia. For this reason, it is important to analyse those characteristics of home sprinkler systems that make them different from current residential sprinkler system designs. For example, one primary difference from current residential sprinkler designs is that home sprinkler systems are partial coverage systems. In the United States and Australia, there is minimal data to prove the effectiveness of partial coverage sprinkler systems at saving lives in single-family dwellings. Studies such as this cost-benefit analysis can only suggest potential life and property savings of home sprinkler systems. For this reason, it is important to study home sprinkler systems in Australia, and other countries, to support the effectiveness of home sprinkler systems in single-family dwellings.

During this study, it has also become apparent that home sprinkler systems must be designed with care to ensure that sprinkler heads will operate effectively in the event of a fire. Unless there is a surplus of pressure available at the water main, it is crucial that hydraulic calculations be performed to guarantee that every sprinkler head in a home sprinkler system has adequate water pressure. Because home sprinkler systems are supplied by a home's domestic cold-water network, adequate water flow must also be available to sprinkler heads in the event of a fire. Fore this reason, further analysis of domestic water usage should be performed to determine the potential pressure and flow losses in home sprinkler systems due to domestic use at the time of a fire.

8 Glossary

Brigade – officers, crew and sub-brigades (CFA, 1995).

Fire authority – the authority responsible for fire prevention and extinction in the area concerned (AS 2484.2 Sec. 1, 1991)

Fire cover – The region that a fire brigade can respond to within designated response time limits

Fire hydrant – a fitting or assembly, connected to a water pipeline, which provides a valved outlet to permit a controlled supply of water to be taken for fire fighting (AS 2484.2 Sec. 2, 1991).

Fire provision – The equipment, manpower and utilities used by the fire brigade for fire protection.

Fire safety – safety against a fire, including fire protection, fire prevention and fire fighting (AS 2484.2 Sec.1, 1991).

Flashover – Occurs when flames flash over the entire surface of a room or area. The actual cause is attributed to the build-up of heat from the fire itself.

Greenfield site – A large, undeveloped plot of land where a housing development is planned to be built.

Home sprinkler system – A sprinkler system that only contains sprinkler heads in rooms where a high percent of fires and fire fatalities occur. Specifically, sprinkler heads are to be located in all areas of the house, excluding garage, closets, ceiling spaces, bathrooms, and cupboards or wardrobes. These sprinkler systems are supplied by homes cold water supply network, omitting the need for additional valves and backflow devises.

Incident action plan – a statement of objective and strategy approved by the Incident Controller (CFA, 1995).

Nutate – to rock, sway, or nod; usually involuntarily

Operations officer – the officer charged with the responsibility for implementing the Incident Action Plan (CFA, 1995).

Pumper – a mobile fire-fighting vehicle equipped with a large capacity pump, water tank and hoses – generally urban (CFA, 1995).

Response time – The time beginning when units are en-route to the emergency incident and ends when units arrive at the scene.

Service delivery standard – the accepted response time frame for the delivery of a fire service.

Single-family dwelling – An individual building occupied by one family. In this report, the single-family dwellings included a three-bedroom, single-story home, a four-bedroom single-story home, and a four-bedroom two-story home.

Smoke detector – a detector sensitive to particles or aerosols from combustion (AS 2484.2 Sec.3, 1991).

Sprinkler alarm valve – a non-returning valve that allows water to enter the installation and operate alarms when the installation pressure falls below the water supply pressure (AS 2484.2 Sec. 4, 1991) "Installation" refers to the portion of a sprinkler system downstream from, and inclusive of, the alarm valve (AS 2484.2 Sec. 4, 1991).

Sprinkler head – A device sealing an aperture in a pipe of a sprinkler installation; such device discharges water automatically in a predetermined pattern over a specified area when a predetermined temperature of the ambient atmosphere is reached (AS 2482.2 Sec. 4, 1991) "Installation" refers to the portion of a sprinkler system downstream from, and inclusive of, the alarm valve (AS 2484.2 Sec. 4, 1991).

Sprinkler system, dry pipe – a sprinkler system in which the pipes beyond the alarm valve are kept charged with a gas (normally air) until the alarm valve is actuated, allowing the system to fill with water (AS 2484.2 Sec. 4, 1991).

Sprinkler system, wet pipe – a sprinkler system in which the pipes beyond the alarm valve are kept charged with water (AS 2484.2 Sec. 4, 1991).

Static pressure – the pressure in a piping system when there is no flow or discharge of water (AS 2484.2 Sec.1, 1991).

Tanker – a mobile fire-fighting vehicle equipped with a water tank, pump and hoses – generally rural (CFA, 1995).

Task force nozzle – A combination nozzle for the end of a fire hose, which can spray a straight stream of water, or a wide misting spray.

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Appendix A Components

Home sprinklers are generally placed in all areas of a house except closets, bathrooms and hallways. Each sprinkler of the system is independently controlled so that when one sprinkler head activates, the other sprinkler heads will not activate unless they are also under the same fire conditions, preventing unnecessary damage. Home sprinkler systems activate when they encounter the heat generated by a fire and release a metal cap that is held in place by a glass bulb or metal link. Water flows through the pipe and out the nozzle, hitting a deflector that breaks up the stream to spray water directly on the burning materials (Home Fire Sprinkler Coalition, 2001). Since this process takes only a matter of seconds after a fire is ignited in a room, the response time of the sprinkler is much less than would be possible by any fire-rescue units, thus resulting in a greater chance of saving human life and damage caused by fire and water (United States Fire Administration, 1999).

A-1 Water Supply

The water supply is one of the most essential components of a home sprinkler system. Sprinklers must have an adequate supply of water for a given period to effectively control a fire before the fire department arrives. The primary water sources available are a public water supply, a privately owned elevated reservoir, or water supplied by pump. The most common water supply for a home sprinkler system is a connection to the public water main because the flow and pressure are sufficient to support sprinkler systems. Generally, a private main is used to connect the piping within the building to the public main. Public supplies are the most reliable and most consistently utilised means for providing a sprinkler with water (Bryan, 1990).

Elevated tanks are an alternative to a public main or are a primary source in rural areas where there is no public water supply. In some cases, an elevated tank may already be in operation and may be used for a home sprinkler system if it is verified that the tank has an adequate supply of water. As previously suggested, another water source is a pump that can draw water from a well, tank, or an open body of water such as a lake. Pumps may be either diesel or electric and must meet specific requirements to supply enough water to their respective recipients on the other end of the water line. To ensure that a pump will operate correctly in the event of a fire it must be properly maintained so there is an adequate volume of water for fire fighting efforts.

A-2 System Riser

When a public water supply is used, the private main enters the building and water flows through the control valve and meter, and then is divided to supply the domestic water and sprinkler system. A system riser is a section of piping that is between the water supply and the sprinkler main. The system riser contains the control valve, water meter, backflow prevention valve, pressure gauge, system drain and water flow alarm. Following the backflow prevention, valve the domestic water system is connected to the piping of the system riser. Water flows through a valve to allow the domestic water to be shut down for maintenance, without compromising the sprinkler system.

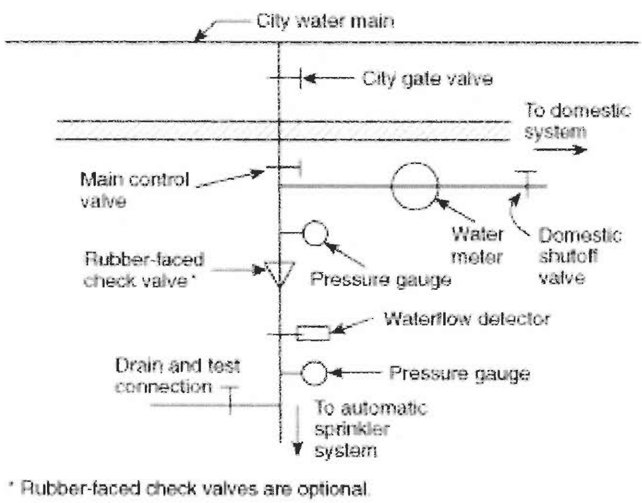

Figure A-1: Preferred system riser arrangement (NFPA 13D Figure A-2-2a, 1999)

Valves in a sprinkler system are very important, if they are accidentally closed this could cause a life-threatening situation. NFPA standards dictate that a valve is needed to allow for maintenance and to stop the flow after a fire has been extinguished. Each sprinkler system has a single control valve arranged to shut off both the domestic water and sprinkler system. The domestic system must have a separate shut off to allow for maintenance of the domestic water system without compromising the fire sprinkler system (NFPA 13D Sec 3-1.1, 1999). In other words, when the sprinkler system is shut off, the domestic water source will also be shut off. The control valve should be an indicating valve such as an outside screw & yoke (OS&Y), plug, butterfly or a ball valve (NFPA 13D Sec A-1-3, 1999). These types of valves allow quick verification that the valve is open. The control valve should be made tamper resistant by either chaining the valve open or having the valve monitored by an alarm company.

The water meter is a device to measure domestic water usage required by the water authority. A water authority is a private or public agency that is responsible for the maintenance and operation of the public water distribution system. This device restricts the volume of water that can be supplied to the sprinkler system and must be properly sized for the required flow. Common water meters such as BadgerMeter® operate by the motion of a disc that is transmitted by magnets to the register, which records the amount of water that is used. The disc moves freely and nutates on its own ball that is guided by a thrust roller. Water will flow through the meter's strainer and into the measuring chambers where it causes the disc to nutate (BadgerMeter, 2001). Water meters are necessary to measure the amount of water that is used but need to be calculated into the effective design of a sprinkler system.

A water authority commonly requires that a backflow device be installed to prevent contamination of the public water supply. A common backflow device is a double check valve assembly. Where there is no flow, the check valve will hold a minimum of one psi in the direction of the flow. When the water is flowing, the check valves open proportionally to the demand. In a backflow condition, both check valves will close until normal flow is resumed. Backflow valves must be properly sized to meet system demands. NFPA requires that there shall be means to provide a flow test downstream of all backflow prevention valves to verify that there is adequate water to supply the system (NFPA 13 Sec 5-15.4.6.1, 1999). Backflow devices are needed for the safety of the public but need to be factored into the design of the sprinkler system because they reduce flow.

A pressure gauge is an essential part of a sprinkler system because of its function to provide a reading of the pressure that is applied to the sprinklers. NFPA standard states that the pressure gauge must be installed to indicate the water pressure on the sprinkler system (NFPA 13D Sec 3-2, 1999). Maintenance requires a monthly inspection to verify adequate pressure in the system.

When the piping within the building for the sprinkler system is separate from the domestic piping there should be a water flow alarm. In the event that a sprinkler activates and the smoke alarm does not, the water flow alarm will activate when water begins to flow. This alarm is not required in dwellings where smoke alarms are installed by the National Fire Alarm Code, NFPA 72. However, if there is not a smoke alarm in the room where a fire occurs and a sprinkler activates the occupants may not be notified of a fire, this could cause a life threatening substitution. The combination of a water flow alarm and monitoring service by an alarm company will ensure that the fire department will arrive shortly after the sprinkler system has been activated.

The drain serves several purposes in a sprinkler system, including use during the testing and maintenance of the system. A drain is required on the sprinkler system side of the control valve. The drain can allow the system to be tested for performance (NFPA 13D Sec 3-1.2, 1999). The drain is used during maintenance to relieve water pressure so that a sprinkler may be replaced with minimal water damage. When a water flow alarm is installed on the sprinkler system, it may be tested by opening the drain valve, which simulates the flow of water to the sprinkler system. The drain valve is a simple component to the sprinkler system but it plays a vital role to ensure that the sprinklers will operate when needed.

A-3 Piping

The two different styles of sprinklers are wet pipe and dry pipe systems. A wet pipe system contains water at all times and will discharge water immediately when the sprinkler is activated. When the sprinkler system piping contains air or nitrogen under pressure it is referred to as a dry pipe system. When a dry pipe sprinkler activates it allows the air to escape and the water pressure will open a valve that is known as a dry pipe valve. Water then enters the system and exits through the sprinkler heads. An antifreeze sprinkler system is a wet pipe system where antifreeze solution remains in the pipes instead of water. If the sprinkler piping is exposed to freezing temperatures, the antifreeze solution will prevent the pipes from freezing. When the sprinkler is activated, the antifreeze solution is expelled out the sprinkler heads and water will follow (NFPA 13 Sec 1-4.3, 1999).

Piping is a very important part of the proper operation of a sprinkler system. Piping and fittings that are used in sprinkler systems may be of steel, copper, chlorinated polyvinyl chloride (CPVC) or Polybutylene (PB) pipe that meets American Society of Testing and Materials (ASTM) standards. All pipe systems must withstand a working pressure of no less than 175psi (1,207kPa) (NFPA 13D Sec 3-3.1, 1999). To improve the operation of the sprinkler system a fire department connection can be installed. This connection allows the fire department to pump water into the sprinkler system. When sprinklers are connected to the domestic plumbing and there is no fire department connection, the maximum working pressure must be not less than 897kPa (130psi) (NFPA 13D Sec 3-3.7, 1999). Proper selection of piping material is key to minimising the installation costs and maximising performance of a home sprinkler system.

Building construction and weather conditions must also be analysed in the design of a sprinkler system. When non-metallic pipe is installed in attics, adequate insulation must be provided so that the piping is not exposed to temperatures in excess of the pipe's rating (NFPA 13D Sec 3-3.2.1, 1999). Similarly, when plastic pipe is exposed to cold temperatures, it becomes very brittle and therefore must also be insulated properly. Sprinkler piping should be supported from structural members using methods that are required by local plumbing codes or in accordance with any listing limitations (NFPA 13D Sec 3-4.1, 1999). Different types of pipe must be supported at different intervals. Piping must be adequately secured so that movement is restricted upon sprinkler operation (NFPA 13D Sec 3-4.3, 1999). If a sprinkler moves or vibrates during operation, its effectiveness will be compromised.

Sprinkler systems may be designed and installed with several piping styles. A gridded system has parallel cross-mains that are connected to multiple branch lines. This pipe layout allows the operating sprinkler to receive water from both ends of the branch line while the branch lines help with the transfer of water between the cross mains. A looped system is a system with multiple cross-mains that are tied together. When a sprinkler operates in a looped system, the water is supplied by more than one path but the branch lines are not tied together (NFPA 13 1-4.3, 1999). When piping is added to form loops it greatly increases the available flow of water throughout the system.

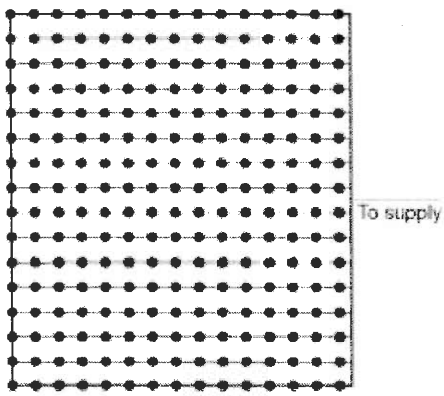

Figure A-2: Gridded Piping System (NFPA 13 Figure A-1-2.3a, 1999)

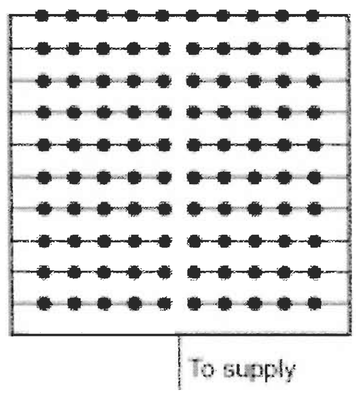

Figure A-3: Looped Piping System (NFPA 13 Figure A-1-2.3b, 1999)

CPVC piping is becoming an industry standard in residential sprinkler systems. CPVC pipe offers increased hydraulic capabilities, meaning that the pipe can flow more water and have lower pressure losses than steel pipe. CPVC can be easily connected to other sprinkler piping systems and requires no pre-cutting or expensive fabrication. Plastic pipe is resistant to rust, scale and foreign contaminant build-up and therefore requires less maintenance than metal pipes. The CPVC pipe is extremely flexible which also makes it very easy to install. Additionally, after installation, the homeowner will be pleased that the pipe does not sweat and collect condensation, and it is resistant to seismic activity, reducing pipe noise. There are several benefits to the installer when CPVC pipe is used such as being easily repaired or modified, easy to handle and transport, and the installation tools are very inexpensive. CPVC pipe must be installed in a wet system, which will affect the applications of plastic pipe in fire protection systems.

A-4 Sprinklers

There are several types of sprinklers on the market that offer different appearance and performance. The pendent style of sprinkler is the most common in home sprinkler systems. The pendent style sprinkler is designed in such a way that the water stream is directed downward against the deflector. Another type of sprinkler is a sidewall head that has special deflectors designed to discharge the water away from a nearby wall with a pattern similar to a quarter sphere and a small portion of water is applied to the wall behind the sprinkler. A recessed sprinkler may have all or part of the body, other than the shank head, mounted in a recessed housing. Concealed sprinklers are recessed sprinklers with cover plates so that the actual sprinkler is not visible. An upright head is installed so that the water is deflected upward against the deflector. A flush sprinkler has all or part of the body including the shank thread mounted above the plane of the ceiling (NFPA 13 Sec 1-4.5.3, 1999).

Figure A-4: Assorted Residential Sprinklers (Central Sprinkler, 2001j)

Sprinklers that are to be used in a home sprinkler system must be listed for a residential sprinkler usage. This listing is based on tests to establish the ability of the sprinkler to control residential fires under standardised fire test conditions. The correct type of sprinkler must be used for the application in a dry or wet pipe system (NFPA 13D Sec 3-5.1, 1999). Each sprinkler has a different activation temperature. The general classifications of temperature ratings include the following: the ordinary, temperature-rated, residential sprinkler with a temperature range of 57.2°C to 76.7°C (135°F to 170°F) that shall be installed where the maximum ambient ceiling temperature does not exceed 37.8°C (100°F) (NFPA 13D Sec 3-5.2.1, 1999); and the intermediate, temperature-rated, residential sprinklers that have an operation temperature between 79.4°C and 107.2°C (175°F and 225°F) and shall be installed where the maximum ambient ceiling temperatures are between 38.3°C and 65.6°C (101°F and 150°F) (NFPA 13D Sec 3-5.2.2, 1999). Activation temperature must be properly selected so that an accidental activation does not occur.

Homeowners are often very concerned with the appearance of the sprinkler system. To prevent the homeowner from compromising the performance, the sprinkler head frames are permitted to be factory painted or enamelled as an ornamental finish only by the manufacturer of the sprinkler (NFPA 13D Sec 3-5.4, 1999). Another major concern about home sprinkler systems is the rate of malfunction, or damage that the water may cause. Statistics show that 1 in 16 million sprinkler heads will malfunction in their designed life cycle (Koski, 2000), which is a negligible amount, given the reliability of home sprinklers as a whole.

Proper layout of a sprinkler is key to providing optimal protection. Each type of sprinkler has different coverage characteristics so the maximum coverage per sprinkler is defined by the manufacturer. The maximum coverage area for a single sprinkler shall not exceed 37.16 m^2 (400 ft^2) (NFPA 13 Sec 5-5.2.2, 1999). Sprinklers that are not designed to be mounted on the wall must be located a minimum of 100 mm (4-inches) from the wall (NFPA 13 Sec 5-6.3.3, 1999). Sprinklers cannot effectively control a fire unless they are placed in the proper locations.

Appendix B Water Requirements

B-1 Flow

For a home sprinkler system to operate effectively there must be an adequate flow of water. The major flow restriction is the water meter and the piping. A home fire sprinkler system must be properly designed to provide proper flows to the sprinklers to extinguish fires.

Home fire sprinklers systems are designed to discharge at least 68 litres per second (18 gpm) to any single sprinkler and a minimum of 49 litres per second (13 gpm) per sprinkler to the number of designed sprinklers (NFPA 13D Sec 4-1.1, 1999). Residential sprinklers are designed to have a maximum of two heads operating at a given time. When a sprinkler system and the domestic water system share the same source, the water needs of the domestic source must be taken into account (NFPA 13D Sec 2-3, 1999). The standard water consumption for a residential usage is minimal, but if there is more than one dwelling, there needs to be 19 litres per minute (5 gpm) added to determine the water main and meter sizes. Additional water usage such as a lawn irrigation system must be accounted for in the design of the sprinkler system.

Some water authorities have required sprinkler systems to be supplied by a separate main from the public main. Sprinkler and plumbing standards allow both to be supplied by a separate pipe as long as the pipe is sized properly (Residential Fire Safety Institute, 2001). In addition, this meter would never show any water usage unless there was a fire. However, the water authority commonly charges a fee for the connection to the water system.

The greatest flow restriction on a sprinkler system water supply is due to the water meter. To support this demand, a 20 mm (¾-inch) water meter needs to be installed. When the meter size is increased, the water authority charges a higher minimal fee because when a larger meter is requested, the authority automatically assumes that there will be more water used. A 15 mm (5/8-inch) meter can have a peak flow rate of 76 litres per minute (20 GPM), while a 20 mm (¾-inch) meter has a peak at 113 litres per mute (30 GPM) and a 25 mm (1-inch) meter has a peak flow rate of 189 litres per minute (50 GPM) (Water-Meters, 1999). The typical single family home without sprinklers will have a 20 mm (¾-inch) supply line from the water main, a 15 mm (5/8-inch) meter and 13 mm (½-inch) plumbing. A single family home with a home fire sprinkler system will most likely have a 25 mm (1-inch) supply line even if a 20 mm (¾-inch) supply line will provide the flow required. The home sprinkler systems always have a 20 mm (¾-inch) water meter because the 15 mm (5/8-inch) meter will not provide the minimum flow of 98 litres per minute (26 GPM) that the sprinklers require (Residential Fire Safety Institute, 2001b).

Friction loss in pipes is very important in designing a sprinkler system. Friction loss is a function of the roughness of the pipe which is affected by different products and manufacturing processes affect the interior wall properties. For example, lightweight steel pipe is often formed cold and has little opportunity for scale formation and roughening of the surfaces. Standard weight steel pipe is usually formed hot and may include scale and imperfections on the surfaces, thus will have a higher loss of pressure. When the surface finish is improved by ten percent, there will be a reduction of sixteen percent in the friction loss (Bryan, 1990). CPVC and copper pipe have improved flow characteristics and increased surface finish over steel therefore having less friction losses. The formula below shows how to calculate the pressure loss caused by frictional resistance.

$$p = \frac{4.52Q^{1.85}}{C^{1.85}d^{4.87}}$$

Equation A-1: Pressure loss caused by frictional resistance for empirical units (NFPA 13 Sec 8-4.2.1, 1999)

$$p_m = 6.05\left(\frac{Q_m^{\ 1.85}}{C^{1.85}d_m^{\ 4.87}}\right)10^5$$

Equation A-2: Pressure loss caused by frictional resistance for metric units (NFPA 13 Sec 8-4.2.1, 1999)

Where:

p = frictional resistance in psi per foot of pipe

p_m = frictional resistance in bar per meter of pipe

Q = flow in gpm

Q_m = flow in L/min

C = friction loss coefficient

d = actual internal diameter of pipe in inches

d_m = actual internal diameter in mm

Pipe Type	"C" Factor
Unlined Cast or Ductile Iron	100
Black steel (wet systems including deluge)	120
Galvanized (all)	120
Plastic (listed) all	150
Copper or stainless steel	150

Table A-1: Hazen-Williams "C" Values (NFPA 13 Table 8-4.4.5, 1999)

B-2 Pressure

Pressure is an important factor in the performance of a fire sprinkler system. When a sprinkler receives too much pressure the droplet size will be too small and will not effectively penetrate the fire plume to extinguish the fire. The maximum operating pressure is specific for each sprinkler because each sprinkler is designed with a different deflector, which affects the droplet size. Generally, maximum pressure is not a concern because when a sprinkler does not effectively control the fire additional sprinklers will activate, reducing the pressure per sprinkler head. Home fire sprinklers have a minimum operating pressure of 48kPa (7psi) (NFPA 13D Sec 4-1.1, 1999). A decreased pressure causes the sprinkler not to perform and spray water to the design limits. When multiple sprinklers are activated, the performance of the sprinkler system may be compromised because there will not be enough available water to meet the demands of the system. When several sprinklers are activated, the chances of successfully controlling a fire rapidly decrease. For the reasons described, the maximum and minimum pressure must be carefully designed for each individual home.

B-3 Source Reliability

The water supply for a home fire sprinkler system is very important so the fire can be controlled. A water supply source for a fire sprinkler system could be a connection to a reliable waterworks system, an elevated tank, a pressure tank with a reliable pressure source, or a stored water source with an automated pump (NFPA 13D Sec 2-2, 1999). Automatic fire sprinkler systems are required to have at least one automatic water supply. When the water supply comes from a stored source, it must supply the minimum water requirements for a minimum of ten minutes (NFPA 13D Sec 2-1). When a sprinkler system has a dependable water source, the chances of failure of extinguishment are rare.

Appendix C Codes and Standards

C-1 United States Standards

In the U.S., standards for the installation and performance of sprinkler systems are developed by the National Fire Protection Agency (NFPA). The NFPA standard that applies directly to home sprinkler systems is NFPA 13D: *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes,* that was updated in 1999. In addition, the NFPA has also created codes for non-residential sprinkler systems, including NFPA 13: *Standard for the Installation of Sprinkler Systems* updated in 1999 and NFPA 25: *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, that was revised in 1998. Similar standards have been created and based on NFPA standards in New Zealand and Australia.