



**Corridor of Comprehensive Knowledge**



# **BEFORE THE FLAMES ARRIVE**

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## Preface

This fictional story follows a newly arrived family through its first wildfire warning. Scientific principles and prevention guidance are based on official FireSmart and research sources. The numerical values are educational assumptions and must not be used as a wildfire forecast, engineering specification, property assessment, or substitute for local instructions or professional advice.

## 1) Their first summer

The Miller family had moved into their new home in a small community in British Columbia's interior less than three months earlier. Their street ended near a slope covered with dry grass and pine trees.

Rachel, the mother, was a civil engineer. She tended to examine measurements, materials, and practical constraints before making a decision. Her husband Daniel was a nurse in a hospital emergency department and paid close attention to preparation, response time, and the consequences of delayed action.

Their sixteen-year-old daughter Sophie enjoyed science and mathematics.

Ethan, their twelve-year-old son, noticed details that others often missed, from a change in the sound of a sprinkler to the tracks of small animals in the garden soil.

Ethan also had mild asthma. It rarely affected his daily life, but wildfire smoke could aggravate his symptoms.

The family had previously lived in a coastal city. They had seen wildfires in the news, but they had never had to decide what a distant fire might mean for their own home.

On a hot, dry afternoon, every phone in the house sounded almost at once.



**Figure 1)** Rachel drew back the curtain. A thin layer of smoke rested above the distant hills.

A wildfire was spreading in the region. Conditions could change quickly. Residents were advised to prepare to leave and follow official updates.

Rachel drew back the curtain. A thin layer of smoke rested above the distant hills. Daniel read the notice again. The fire front was still several kilometres from the neighbourhood. At first, that distance felt reassuring. If the fire itself was still far away, why should the house already be at risk?

Sophie followed a link in the alert to official wildfire-preparedness information. One section explained that wind-driven embers could reach buildings before the main fire front. She paused over the description. How could a small burning fragment remain aloft and travel so far?

### Question 1 (Ember Motion in Wind)

In an educational model, an ember enters a wind current 300 m above the ground.

Assume that:

- its constant horizontal speed is 10.0 m/s,
- its constant downward speed is 1.50 m/s
- a house is 1.60 km downwind.

- How long does the ember remain airborne?
- How far does it travel horizontally during that time?
- At what height is it when it passes above the house?
- In real conditions, what factors could change its motion, time aloft, and landing point?

### Solution 1

The time aloft follows from the vertical motion:

$$t = \frac{h}{v_s} = \frac{300 \text{ m}}{1.50 \text{ m s}^{-1}} = 200 \text{ s}$$

The horizontal distance is

$$x = ut = (10.0 \text{ m s}^{-1})(200 \text{ s}) = 2000 \text{ m} = 2.00 \text{ km}$$

The time required to reach the house is

$$t_h = \frac{1600 \text{ m}}{10.0 \text{ m s}^{-1}} = 160 \text{ s}$$

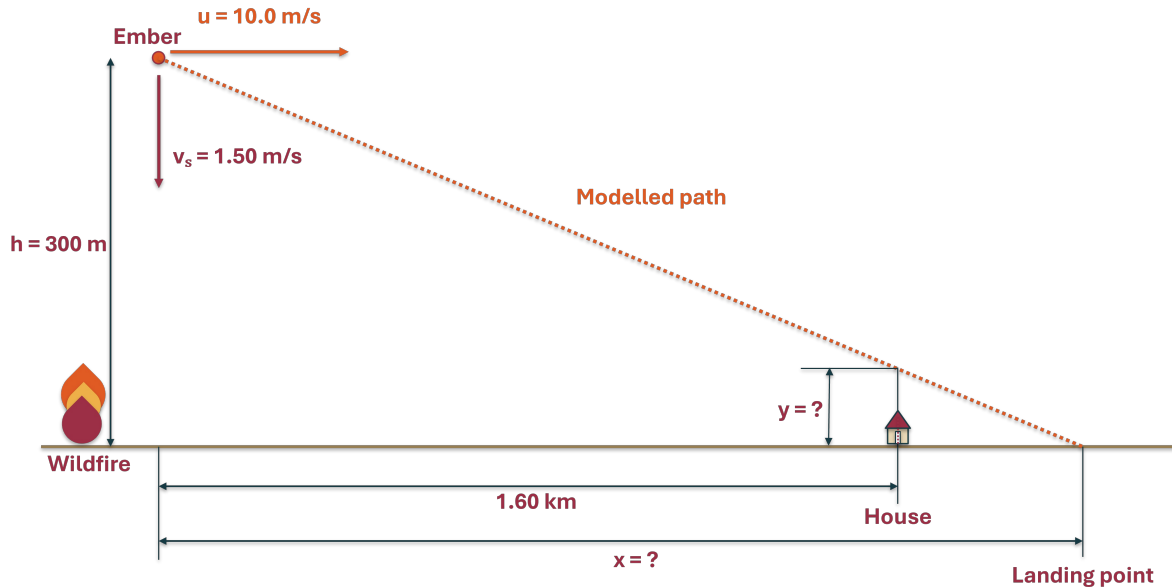
During that time the ember descends

$$\Delta y = (1.50 \text{ m s}^{-1})(160 \text{ s}) = 240 \text{ m}$$

Its modelled height above the house is therefore

$$y = 300 \text{ m} - 240 \text{ m} = 60 \text{ m}$$

Changing wind speed and direction, rising hot air, turbulence, ember shape and mass, rotation, combustion, humidity, precipitation, and terrain can all alter a real ember's path. A real exposure requires substantially more information than this two-component model.



**Figure 2)** Simplified model of ember transport with constant horizontal and downward velocities. The house is  $1.60 \text{ km}$  downwind;  $y$  represents the ember's height above the house, and  $x$  its total horizontal travel distance. *Not to scale.*

## 2) Visitors before the flames

"The fire front is not the only threat," Sophie said. "Wind and rising hot air can carry embers away from the fire. Some may reach roofs, gutters, vents, or the ground beside a wall long before the flames arrive."

Research and experience from fires at the boundary between wildland and developed areas show that embers are a major source of structure ignition. Whether ignition begins depends on both the ember exposure and the vulnerabilities where embers land [1,2].

Daniel looked again at the distant smoke. The distance no longer felt as reassuring as it had a few minutes earlier. He gathered the family's prescription medicines, including Ethan's inhaler, along with their medical information, first-aid supplies, documents, and water. Rachel checked the evacuation route and the fuel in the vehicle. Sophie and Ethan gathered what they would take with them.

When Ethan went outside to collect his shoes, he stopped beside the south wall. The garden soil was covered with wood chips. A light rain the previous night had left part of the cover damp, but the area sheltered beneath the roof overhang had already dried.

He picked up a few damp pieces. "Could this still catch fire if an ember landed here?" Sophie turned one damp chip over in her hand. Water would have to warm and evaporate before the wood beneath it could continue heating as quickly. The comparison sounded simple, but she wanted to know how large the difference might be.

Ethan returned the chips to the soil. A few metres away, Rachel closed the vehicle's cargo door.



### Question 2 (Moisture and Heating Energy)

Compare two 25.0 g samples initially at 20 °C. The dry sample contains 25.0 g of dry woody material. The damp sample contains 20.0 g of dry woody material and 5.0 g of water. Use the following deliberately simplified data:

- specific heat capacity of wood: 1.70 J/(g·°C),
- specific heat capacity of water: 4.18 J/(g·°C),
- latent heat of vaporization of water: 2260 J/g,
- modelled onset of wood pyrolysis: 300 °C,
- boiling point of water: 100 °C.

- a) Estimate the energy required to bring the dry sample to the modelled pyrolysis-onset temperature.
- b) Estimate the energy required to heat the dry matter in the damp sample, heat its water to 100 °C, and vaporize all the water.
- c) If each sample receives 25.0 kJ, how much energy remains after these steps?
- d) What does the comparison reveal about moisture, and what additional factors matter in real ignition?

### Solution 2

- a) For the dry sample,

$$Q_D = mc\Delta T = (25.0 \text{ g})(1.70 \text{ J g}^{-1} (\text{°C})^{-1})(300 - 20)^\circ\text{C} = 11.9 \text{ kJ}$$

- b) For the damp sample, the dry matter is heated, the water is heated to 100 °C, and the water is vaporized:

$$Q_1 = (20.0)(1.70)(300 - 20) = 9.52 \text{ kJ}$$

$$Q_2 = (5.0)(4.18)(100 - 20) = 1.67 \text{ kJ}$$

$$Q_3 = (5.0)(2260) = 11.30 \text{ kJ}$$

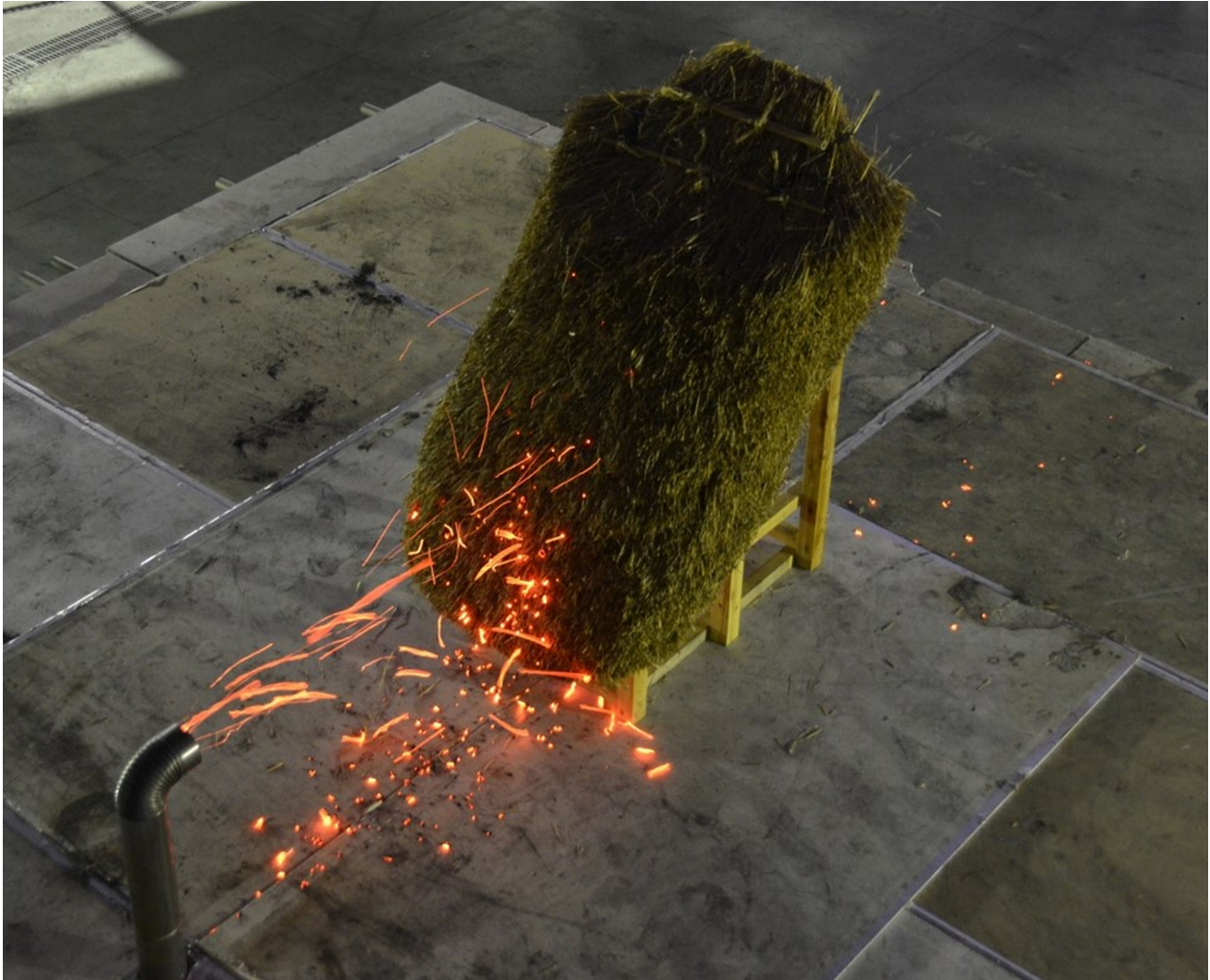
$$Q_M = Q_1 + Q_2 + Q_3 = 22.49 \text{ kJ}$$

- c) With 25.0 kJ supplied,

$$E_D = 25.0 - 11.9 = 13.1 \text{ kJ}$$

$$E_M = 25.0 - 22.49 = 2.51 \text{ kJ}$$

- d) Water redirects a substantial fraction of the incoming energy before strong heating and pyrolysis can continue. The calculation does not determine ignition probability. Heat flux, exposure duration, oxygen, airflow, surface area, composition, heat loss, and the production and mixing of pyrolysis gases also matter. Reported wood-surface temperatures before piloted ignition commonly fall around 300–400 °C, but ignition is a process rather than a universal temperature [3].



**Figure 3)** A NIST firebrand generator exposes a model roof to a controlled ember shower.  
Credit: NIST, Reference 18EL012. NIST requests appropriate image credit.  
Source: <https://www.nist.gov/image/18el012firebrand-attack-thatched-roof-model.jpg>

### 3) Leaving and returning

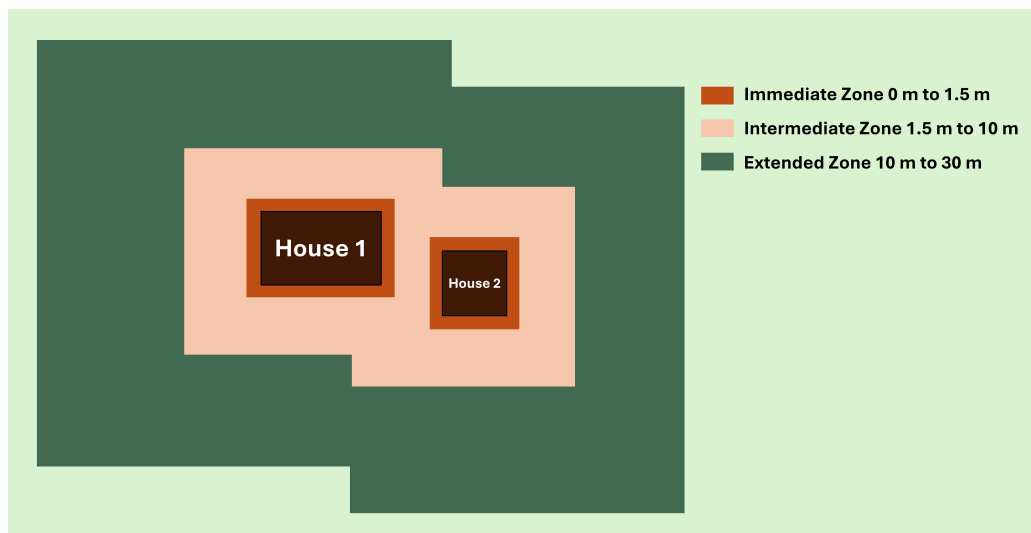
Sophie set the two energy totals beside each other. Moisture could absorb a substantial share of the incoming energy, but the comparison did not make wood chips safe. Rachel added that a material selected for the edge of a building had to be judged by its long-term behaviour, not by how it happened to feel after one light rain.

Another alert sounded. The neighbourhood was ordered to evacuate. The four family members entered the vehicle and left. Ethan watched the slope through the rear window. The smoke had darkened, although no flames were visible from their street.

Two days later, residents were permitted to return. The main fire front had not reached the neighbourhood. Several scorched patches marked the grass near the fence, and small blackened fragments lay in a corner of the yard. No one could know exactly when each fragment had arrived, how long it had burned, or why it had gone out.

A few days later, Maya Chen, a Local FireSmart Representative, visited the property. Before suggesting changes, she walked around the building with the family and asked them to point out places where an ember might collect or where fire might move toward the structure.

Her attention moved from the ground cover and space beneath the deck to the vents, roof edge, gutters, firewood, vegetation, and fence connection. “No single feature determines the outcome,” she said. “We look for possible pathways: where an ember could land, what might ignite first, and what else could connect that fire to the building.” Maya explained that the Home Ignition Zone begins at the structure and extends 30 m outward. It includes the Immediate Zone from 0 to 1.5 m, the Intermediate Zone from 1.5 to 10 m, and the Extended Zone from 10 to 30 m. Official guidance calls for a non-combustible Immediate Zone around the home and attached structures [4,5].



**Figure 4)** Simplified Home Ignition Zones around neighbouring structures.

Rachel studied the 1.5 m band around the house. It seemed narrow until she followed it around every wall and corner. From her engineering work, she knew that the final quantity could not come from width alone: corners, steps, slopes, drainage routes, existing hard surfaces, compaction, and access for installation would all affect the estimate.

### Question 3 (Area of the Immediate Zone)

A rectangular house is 12.0 m long and 9.0 m wide. For an initial planning estimate, model the Immediate Zone as a uniform 1.5 m band with square corners around the house.

- Calculate the area of the Immediate Zone.
- If the zone is covered with a 6.0 cm layer of non-combustible gravel, calculate the required volume.
- If 12% extra material is ordered for compaction and waste, calculate the order volume.
- What real property features could change the required amount?



### Solution 3

$$\begin{aligned}L_{\text{outer}} &= 12.0 + 2(1.5) = 15.0 \text{ m} \\W_{\text{outer}} &= 9.0 + 2(1.5) = 12.0 \text{ m} \\A_{\text{outer}} &= (15.0)(12.0) = 180 \text{ m}^2 \\A_{\text{house}} &= (12.0)(9.0) = 108 \text{ m}^2 \\A_{\text{Immediate}} &= 180 - 108 = 72 \text{ m}^2 \\V &= (72 \text{ m}^2)(0.060 \text{ m}) = 4.32 \text{ m}^3 \\V_{\text{order}} &= 1.12(4.32) = 4.84 \text{ m}^3\end{aligned}$$

Actual requirements may vary with walls, decks, stairs, existing non-combustible surfaces, slopes, drainage, compaction, and property boundaries. The site must be measured before material is ordered.

#### 4) A pathway to the wall

Rachel continued around the house with Maya. The rectangular model gave them a useful first estimate, but both treated it as a starting point. Rachel began a site sketch showing the corners, steps, drainage routes, and existing hard surfaces that would have to be measured before any material was ordered.

On the west side, a wooden fence ran from the property boundary to the wall of the house. Maya placed her hand on the final panel. “If part of this fence ignites, the connection can provide a continuous combustible pathway to the structure.”

Part of the fence followed the boundary with the neighbouring property. Rachel asked whether changing it could affect the neighbours. Maya advised the family to discuss any work near the shared boundary first. Fire does not stop at a property line, and measures involving fences, vegetation, or storage are often more effective when neighbours coordinate them.

FireSmart guidance recommends a non-combustible break of at least 1.5 m between the wooden portion of a fence and a home.

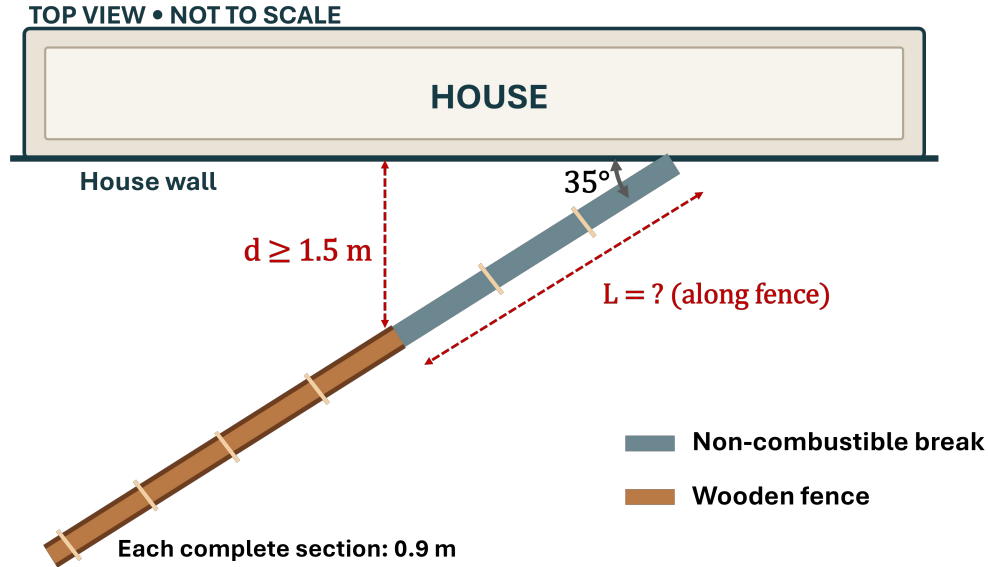
A metal gate or section can interrupt the combustible connection [6].

#### Question 4 (Interrupting an Angled Combustible Pathway)

A wooden fence approaches the wall of a house at an angle of  $35^\circ$ . The fence is built from 0.9 m sections, and only complete sections can be removed or replaced. To interrupt the combustible pathway, the nearest remaining wooden section must be at least 1.5 m from the wall, measured along the shortest path.

- What is the minimum number of sections to replace?
- What total length of fence will be replaced?
- What will be the shortest distance between the remaining wooden fence and the wall?
- If each replacement section costs \$210 and installation costs \$95 in total, calculate the modification cost.
- Explain how this modification can reduce the possibility of fire reaching the house.





**Figure 5)** Top-view diagram of the angled fence and proposed non-combustible break. The shortest distance is measured perpendicular to the house wall. Not to scale.

#### Solution 4

- a) Let  $n$  be the number of complete sections replaced. The length along the fence is

$$L = 0.9n$$

The required 1.5 m separation is the perpendicular distance from the remaining wooden fence to the wall. Because the fence forms a  $35^\circ$  angle with the wall,

$$d = L \sin 35^\circ$$

The minimum-separation condition is therefore

$$0.9n \sin 35^\circ \geq 1.5$$

Solving for  $n$  gives

$$n \geq \frac{1.5}{0.9 \sin 35^\circ} \approx 2.91$$

Since only complete sections can be replaced, the result must be rounded upward.

$$n = 3$$

- b) The total length replaced is

$$L = 3(0.9) = 2.7 \text{ m}$$

- c) The resulting shortest distance from the wooden fence to the wall is

$$d = 2.7 \sin 35^\circ \approx 1.55 \text{ m}$$

- d) The modification cost is

$$\text{Cost} = 3(\$210) + \$95 = \$725$$

- e) **Fire pathway:** Replacing the portion nearest the house with non-combustible material interrupts the continuous wooden route to the wall. This can reduce direct flame spread along the fence. It does not remove the need to assess nearby vegetation, stored materials, radiant heat, embers, and other site-specific exposure factors.





### 5) A list longer than the budget

After speaking with the neighbour, the family decided to replace the portion nearest the house with metal sections. The neighbour also agreed to review vegetation near the shared fence.

Maya then pointed to dry leaves and pine needles in part of the gutters. “An ember may go out on bare metal,” she said, “but dry debris can provide the first fuel.” FireSmart guidance stresses regular gutter cleaning because embers can ignite accumulated dry material [7].

She also examined the attic vent, the firewood beside the shed, and several conifers in the Intermediate Zone. “Do not change everything without an order,” she said. “First identify the important vulnerabilities of this property. Then phase the work by urgency, cost, and feasibility.”

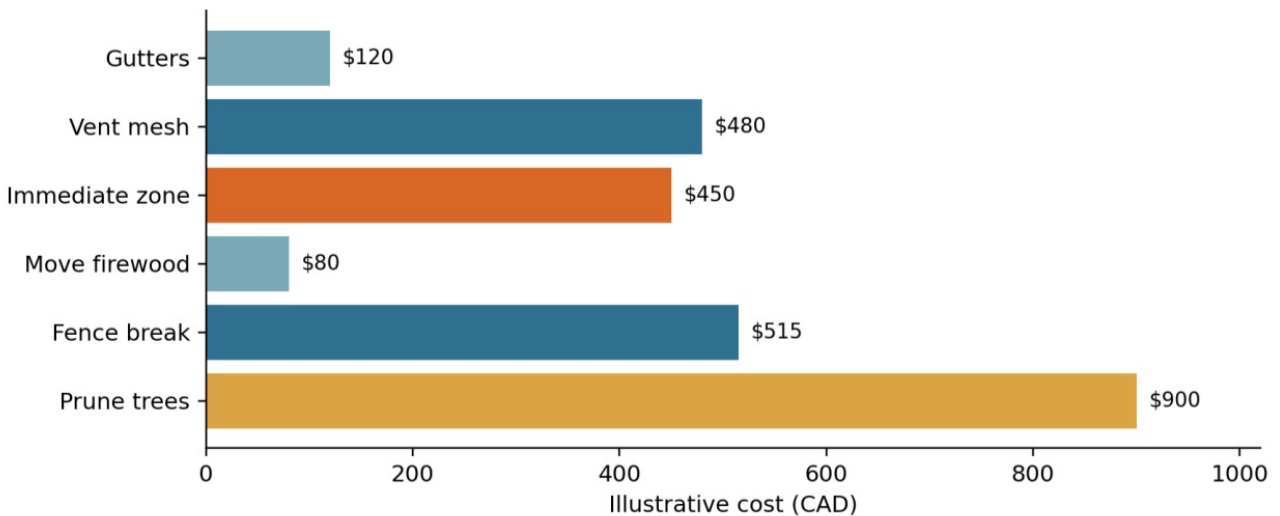
The final list included cleaning the roof and gutters, installing suitable vent mesh, removing wood-chip ground cover beside the wall, beginning the non-combustible Immediate Zone, interrupting the fence connection, moving firewood, and pruning selected vegetation. The budget would not cover everything at once.

Daniel separated the tasks the family could complete safely from those requiring specialized materials or professional installation. Cleaning the gutters and moving the firewood required little spending, while the vent mesh, fence modification, and ground surface involved larger costs. Some measures could be completed immediately, whereas others depended on earlier construction work. Sophie wondered whether several inexpensive improvements might provide more value than one costly project. Maya explained that any numerical comparison would be only a planning exercise and could not replace a property-specific assessment.

For this property, Maya identified the vent mesh and fence break as first-stage requirements. Rachel organized the remaining work by cost and construction sequence, while Sophie compared the combinations that would fit the available budget. The remaining actions would have to be scheduled.

**Table 1)** Hypothetical values for Question 5; not official FireSmart ratings.

| Action | Illustrative improvement                       | Cost  | Benefit |
|--------|------------------------------------------------|-------|---------|
| A      | Clean roof and gutters                         | \$120 | 9       |
| B      | Install suitable vent mesh                     | \$480 | 14      |
| C      | Begin the non-combustible Immediate Zone       | \$450 | 16      |
| D      | Move firewood to a suitable location           | \$80  | 8       |
| E      | Interrupt the wooden fence with metal sections | \$515 | 12      |
| F      | Prune or remove selected nearby conifers       | \$900 | 12      |



**Figure 6)** Illustrative costs used in Question 5.

### Question 5 (Selecting Actions Under a Budget)

A family has a budget of \$1,500. The hypothetical costs and educational benefit points are listed in Table 1. Actions B and E are required in the first stage.

- How much budget remains after the two required actions?
- Which feasible combination produces the greatest total educational benefit?
- How could a change in costs, budget, or professional priorities change the answer?

### Solution 5

- a)** The required actions cost

$$\$480 + \$515 = \$995$$

The remaining budget is

$$\$1500 - \$995 = \$505$$

- b)** Adding C gives

$$\text{Cost} = \$995 + \$450 = \$1445, \quad \text{Benefit} = 14 + 12 + 16 = 42$$

Adding A and D gives

$$\text{Cost} = \$995 + \$120 + \$80 = \$1195, \quad \text{Benefit} = 14 + 12 + 9 + 8 = 43$$

Adding A and C would cost \$1,565, while adding C and D would cost \$1,525; both exceed the budget. For the stated numbers, A + B + D + E gives the greatest feasible educational benefit, 43 points, at a cost of \$1,195.

- c)** The result depends on the stated costs, budget, benefit values, and required actions. A real property assessment and safety-critical vulnerabilities take priority over invented classroom points.



## 6) Next alert

The work took several weeks. Vent mesh was installed, the roof and gutters were cleaned, and Daniel moved the firewood and helped replace the wooden fence sections nearest the house with metal. Rachel measured the Immediate Zone to plan the work in stages.

The family also coordinated with the neighbours on vegetation and work near the shared fence, including regular removal of dry leaves and pine needles.

Late in the summer, another regional wildfire alert sounded on every phone. This time, the documents, vehicle, and evacuation route were already prepared. Daniel checked the emergency bags and loaded water; Rachel reviewed the official map; and Sophie and Ethan confirmed that their personal items were packed.

The wind shifted that evening, and the evacuation zone did not reach their street. By the next day, crews had slowed the fire's growth. The family did not take this as proof that the house was safe; the warning had simply tested an established plan.

The Millers could not control the dryness of the forest, the fire's intensity, or the wind. They could reduce pathways to their home, coordinate with their neighbours, and leave when instructed. Preparedness had begun long before the alert sounded.

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