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A HISTORICAL PERSPECTIVE ON BUILDING HEIGHTS AND AREAS IN THE BRITISH COLUMBIA BUILDING CODE

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1.0 INTRODUCTION AND SCOPE OF REPORT

This report has been prepared at the request of the Building and Safety Policy Branch of the Office of Housing and Construction Standards in British Columbia, and responds to three questions pertaining to the basis and development of the height and area requirements for combustible residential construction in the current edition of the British Columbia Building Code (2006 Edition). The three questions are:

1. What is the historical rationale for limiting the height and area of combustible residential construction to 3 storeys for an unsprinklered building and 4 storeys for a sprinklered building?

2. How has the building code, relative to the construction requirements for residential construction, adapted to recognize the benefits of sprinklering? And does sprinklering a residential building provide a new rationale for reconsidering the underlying assumptions affecting height and area of a building?

3. Is there a different rationale underlying the assumptions in the International Building Code (United States) vis-à-vis height and area compared to those in the BC Building Code and is it possible to use these IBC assumptions to reconsider the rationale for our height and area calculations?

Answering these questions requires an examination of the historical record of code development in Canada and the United States. The Canadian building code system is similar to that of the United States in its origin and application. In both countries the “model code” is developed by committee and adopted at a provincial or state level with local modifications.

The BC Building Code (BCBC) has been based on the National Building Code of Canada (NBC) since 1987. Prior to that the NBC was adopted outright with minor modifications made usually at the municipal level. The system in the United States resulted in several model codes being developed, three of which were recently amalgamated into the International Building Code.

Within the Canadian or American code development, the height and area limitations can be traced back to the same root origins; therefore, the premises of the codes are the same. It is the subsequent development and changes to the code that differ. To consider the origin of the 2006 BCBC requirements, an examination of the historical height and area limitations in the NBC and US model codes is required.

The first edition of Canada’s National Building Code was published in 1941 and was based on the US model codes available at that time. The development of the Canadian and US model codes originated out of a need to regulate construction on a national basis. Most of the requirements in both the Canadian and US building codes were developed based on large city regulations in existence at the time of their development, with the intention of limiting large catastrophic fire events such as conflagrations or fires with large life loss.

This report will illustrate that the height and area requirements were primarily developed as a passive measure to mitigate the perceived risk to life and property in the early 1900's – and were based on the understood capabilities of the fire departments at that time. The information has been assembled from numerous sources with an approximately similar date of publication. Not all of these sources can be linked directly to development of the requirements in one particular model code since the development process is not apparent, and documentation of the process is not available. Nevertheless, when examining the technical documents available at the time of their

development, there are appreciable consistencies that can be used to make strong inference as to the development of the height and area requirements.

2.0 ORIGINS OF THE NATIONAL BUILDING CODE OF CANADA

An examination of the development of the National Building Code of Canada (NBC) is important when considering the technical basis for the requirements contained within. The early development of the NBC was strongly linked to the development of the US model building codes at that time to reduce any reproduction of work already completed and recognizing similarities in construction conditions.

The British North America Act (previously the Constitution Act) delegated the responsibility of building regulation to the provinces and territories. Prior to the development of the first model building code in Canada in 1941 (1941 NBC), municipalities were often tasked by the Provinces and Territories with building regulation. Large municipalities (cities) had the resources to develop building regulations, and needed them to regulate the construction booms in the larger cities at the turn of the century. Smaller cities and towns did not have the resources or technical ability to develop building regulations, and often had none. These local building regulations were specific to the local needs, and varied from city to city. Some requirements had a technical rationale, others were based on assumptions or were simply an approximation or estimation at the time they were developed. This local type of building code development made for an inconsistent system of regulation and led to inconsistency and confusion in the construction industry within Canada. Similar problems were occurring in the United States albeit, several decades earlier. An excerpt from a US Senate Committee on Reconstruction and Production relative to the condition in the States in the 1910's suggests that:

> *The building codes of the country have not been developed upon scientific data, but rather on compromises; they are not uniform in principle and in many instances involve an additional cost of construction without assuring more useful or more durable buildings.*

Development of a model building code was first contemplated in Canada in the 1920's; however, was abandoned because there was no Canadian organization in a position to write suitable specifications[1]. At the same time, development of a model code was underway in the United States. The process was re-initiated in Canada in the 1930's by several construction associations in discussion with the National Research Council of Canada (NRC). An associate committee was formed in 1932 with an initial task of unifying the building codes throughout the country. In 1937 Mr. A.F. Gill of the NRC prepared a paper, "A National Building Code," outlining work at that time on development of a model code and recommended an approach to bringing such a code document together[2]. In recommending an approach, Gill's paper identified the large amount of work completed in the United States relative to a model code and suggests that given the similarities between the United States and Canada, that:

> *any building code authority in Canada could do no better than adhere to the procedure followed by American authorities and take advantage of their recommendations.*

Gill was referring to the development of model building regulations under the authority of the Department of Commerce in their "Elimination of Waste Series," comprised of several documents published between 1923 and 1935. These documents were prepared under the technical direction of the Bureau of Standards[a], and based largely on existing "large city" regulations with refinements

[a] The Bureau of Standards became the National Bureau of Standards and eventually the National Institute of Standards and Technology today.

made where supported by technical information available at the time of their adoption. Most of these requirements originated from the local codes that existed in New York, Philadelphia, Boston, Chicago and Baltimore. These were all cities in which large conflagrations had occurred, accelerating the development of local building regulations.

Using the "Elimination of Waste Series" as a recommended technical basis, the first complete version of the National Building Code of Canada was published in November of 1941 (1941 NBC). Construction technology, materials and methodologies constantly change. Since the development of the 1941 NBC, technological advances resulting from the Second World War made revisiting the NBC important to verify it was still fulfilling its intended purpose. As a result, two dozen Canadian individuals with relevant expertise were selected from representative geographical locations within Canada to form an Associate Committee whose purpose was (and still is) to promote uniformity of building regulations throughout Canada and to maintain the NBC as an up-to-date and progressive document[3].

The purpose behind the continued development of the NBC by the Associate Committee is to embrace new technologies, materials and methodologies. This has occurred throughout the development history of the NBC with significant development in areas such as spatial separation, interconnected floor space and highrise requirements. However, the NBC has not changed significantly relative to allowable building heights and areas. The most appreciable changes relative to residential construction have occurred within the last 20 years, and will be discussed in more detail in a **Section 3.0** of this report.

The difficulty with making any changes to existing building code requirements is having an understanding of the historical rationale of those requirements. This is especially true for the legacy requirements that predate the development of the 1941 NBC that were adopted with minor modifications, as is the case for the height and area requirements. Formulating a means for reassessing those requirements within the context of a new technology, materials or methodologies is difficult, without their original objective and basis for development.

The purpose of the following sections of this report is to outline the origin and basis for the development of the height and area requirements, relative to combustible residential construction, in the US and Canadian model codes by answering the 3 questions posed.

3.0 QUESTION 1: HISTORICAL RATIONALE

Question 1:

> *What is the historical rationale for limiting the height and area of combustible residential construction to 3 storeys for an unsprinklered building and 4 storeys for a sprinklered building?*

3.1 BUILDING HEIGHT

Building height has been regulated in parts of the United States, UK and Canada since the late 1800's. Initially the purpose of regulating building height was to enhance natural lighting and ventilation for purposes of health. However, this typically was not the case for residential wood framed buildings whose height was restricted more for purposes of fire-fighting and egress. For example, the London Building Act of 1894 allowed the London County Council to require special escape facilities from new buildings over 18 m in height with the need to use fire resisting materials for high buildings. After some fires in 1899 the Metropolitan Fire Brigade reported that a height of 15 m was the limit of rescue by ladders, and the London Building Acts (Amendment) Act 1905 reduced the limit from 18 to 15 m and applied the control to existing buildings as well[4].

Similar requirements were implemented in the US in the early 1920's. The building code published by the National Board of Fire Underwriters of New York suggested that[5]:

> *It is generally conceded that five stories is the maximum height to which water can be thrown effectively by a fire department from the street level, and that 50 feet is the maximum distance inside a building which can be reached by a stream through a window. These facts have been a governing consideration in the establishment of the limits of heights and areas in this Code. In addition, the width of the street upon which a building fronts and the height of the building should be considered; a building endangers adjacent property in proportion to its size and proximity to other property.*
>
> *The term street as here used, is a public thoroughfare at least 20 feet wide.*
>
> *The areas given in this section are based upon an average street width of 60 feet. For less than this width, it does not appear unreasonable to require sprinklers for even smaller areas than herein given, particularly for buildings over two stories high. This could well be placed in the hands of the Chief of the Fire Department.*

The ability of a fire department to fight a fire was largely dependent on the available equipment and capability of that particular department. In North America, fire departments had (and still have) varied capabilities and resource allocations. This potential diversity in fire department capability was addressed more specifically as outlined in the "Recommended Minimum Requirements for Fire Resistance in Buildings" (1931 NBS) reference document from their "Elimination of Waste Series," which stated that:

> *The height at which construction requirements should become more drastic from a fire-resistance standpoint is determined very largely by the height above which a city fire department can not cope successfully with fire from the exterior of a building because of limitations of water pressure and apparatus. This limit will vary to some extent in different cities, and building codes should vary accordingly[6].*

For residential construction, the 1931 NBS document recommended a building height of 2 storeys for unprotected wood frame, 3 storeys for masonry and wood joist, and 4 storeys for heavy timber construction. These types of construction differ from current construction types in the NBC; however, are clarified for the purposes of establishing what type of construction should be considered as combustible versus noncombustible and protected versus unprotected in Canada[7]:

> *Combustible construction is usually considered to be conventional wood frame or heavy timber construction. Conventional wood frame construction is described in considerable detail in Section 9.23 of the NBC. Heavy timber construction is a special category of combustible construction and is considered to be acceptable where combustible construction having a ¾ h fire-resistance rating would normally be required.*

The consistency in building height from the change between heavy timber and protected ¾ hour construction can be seen in the historical changes to the NBC, as shown in **Table 1** below.

Table 1: Building Height Limitations in the NBC.

NBC	Construction	Unsprinklered	Sprinklered
1941	Wood frame	2	2
	Masonry and Wood frame	3	3
	Heavy Timber	4	4
1953	Non-protected Combustible	1	1
	Protected Combustible ¾ hour rating	2	2
	Heavy Timber	3	3
1960 to 1985	¾ hour Fire Separation	3	3
1990 to 2005	¾ hour Fire Separation	3	3
	1 hour Fire Separation	3	4

The change in allowable building height for heavy timber in the 1953 NBC is consistent with that for combustible construction having a ¾-hour fire-resistance rating in the later editions of the NBC. From the 1953 edition of the NBC to the current edition, the height limitation of a combustible residential building was 3 storeys unless it was sprinklered, which in 1990 permitted 4 storeys.

Permitting 4 storeys in building height for a combustible residential building equipped with an automatic sprinkler system recognized the benefits of sprinklers in controlling fires and the effects of fire. This benefit was the basis for allowing the additional storey of building height, which was identified in a paper presented by J.R. Mehaffey on "Combustibility of Building Materials," at a seminar on "Designing for Fire Safety - The Science and its Application to Building Codes," which states that:

> *Evacuation and fire fighting activities are assumed [in the 1985 NBC] to proceed more smoothly in sprinklered buildings, in buildings of fewer storeys and smaller area, and where there is direct access for fire fighters from more sides.*

Quantifying the benefit associated with the provision of sprinklers will be discussed in more detail in **Section 4.0** of this report.

3.2 BUILDING AREA

The limitations on building area have a much more complicated historical basis than for height. The area limitations were first contemplated at a time when city wide conflagrations were not an uncommon occurrence in the United States and Canada. One fire in particular, occurred in Baltimore Maryland in 1904, resulting in approximately $50 million in damage to the city. The National Fire Protection Association conducted a review of the fire damage on a building-by-building basis and made recommendations on various aspects of fire prevention. One of the observations was that[8]:

> *[l]arge unbroken floor areas assist the spread of fire and serve to augment its severity. Buildings of considerable area and having large quantities of combustible contents should be subdivided by substantial brick fire walls sufficient to form a positive barrier to the spread of fire.*
>
> *It was noticeable even in office buildings that the damage was generally greatest where there were large offices without any subdividing partitions.*

This observation identified large unbroken floor areas as a risk to significant fire spread back in the early 1900's. Another large conflagration occurred in 1906 after an earthquake in San Francisco. Similar observations were made following an assessment of the damages of that fire. Specifically[9]:

> *The subdivision of floor areas will largely serve to prevent strong draughts of air from one side or portion of a building to another side or portion, thereby greatly avoiding the hazardous conditions of severe exposure fire or wide-spread conflagration. It was found in both the Baltimore and San Francisco conflagrations that fire not only swept through undivided floors with greater rapidity than in divided areas (as would naturally be expected), but with greater intensity as well. In other words, each horizontal story becomes a flue, the length of which is the distance from the window openings lying nearest the exposure to those in the opposite wall.*

Building area limitations were developed to address egress, fire department access, fire spread within the building and to adjacent buildings. This was identified in a handbook on "Fire Prevention and Fire Protection as Applied to Building Construction," which suggested that subdivision of large floor areas by fire-resisting walls, aside from the question of egress, was intended[9]:

1. *To localize or confine internal fire, so that it need not spread beyond the unit of area in which it originates, thus effectively limiting the fire damage and consequent financial loss.*
2. *To minimize the damage resulting from severe exposure or conflagration conditions, by breaking up large undivided floor areas into efficiently surrounded units.*
3. *To aid fire-department work in the extinguishment of fire.*

One of the earliest known references to limiting the floor area of a building is the 1901 edition of the New York Building Code. This code limited the area of a store, factory, hotel or lodging house based on the number of egress stairs provided by units of 5000 square feet[10]. The basis for limiting the building area to 5000 square feet in New York was justified as follows[9]:

> *It has been pointed out that the volume and intensity of fire, and the rapidity with which it will gain headway, are all vastly greater in large areas than in small ones. It*

> *is also a much more difficult matter for a fire department effectively to surround and fight a fire of large area. Much valuable time is lost in running long lines of hose, in addition to which, smoke conditions are often so bad that the actual location of the fire cannot either be found, or reached if found. There is a limit to the ability of firemen to inhale smoke or withstand heat, and once this limit is reached, the offensive operations of extinction cease, the firemen are put on the defensive, and the fire is master of the situation. These considerations would point to the desirability of fixing what might be termed the maximum area which can be efficiently handled by a city fire department. "As a working unit, 5000 square feet has been suggested, with a limit of 100 feet in any direction (or a rectangle 50 by 100), which is as large an undivided area as the experience of the New York Fire Department indicates to be within the capacities of effective fire department operations."*

The 5000 square foot limit was based on the experience of the New York Fire Department. Since the restriction on building area was formed on the basis of the capability of the responding fire department, applying an area restriction on a national basis required a survey of the experience of various fire departments. This type of survey was conducted in 1913 relative to factory buildings[11], and focused on factory buildings because their construction up to the 1920's was long thought of as posing a grave danger to life and property. The Author of the paper surveyed over 100 fire chiefs representing cities with a population over 20,000. The results of the survey are summarized in **Table 2** below.

Table 2: Results of Fire Chief Survey.

Type of Building	Height (Storeys)	Area between Firewalls (ft²)
Non-fireproof, not sprinklered	3	6,000
Fireproof, not sprinklered	5	10,000
Non-fireproof, sprinklered	5	13,000
Fireproof, sprinklered	8	20,000

* Average storey height was 12 to 13 feet.

The height and areas outlined in **Table 2** form the basis for many future height and area limitations, and was re-interpreted by subsequent building code committees as it applied more generally to the conditions within the US and Canada. Note that the areas permitted for sprinklered buildings were approximately twice that for buildings without sprinkler protection. This is discussed in more detail in the following section of this report.

One of the earliest references to limiting area (and height) for residential construction appears in the twenty fourth annual report (1920) of the NFPA Committee on Building Construction[12]. This report defined apartment house construction requirements based on three types of construction, as shown in **Table 3**.

Table 3: Building Area Limitations Proposed by the NFPA Committee on Building Construction.

Design Feature	Type of Construction		
	Grade A	Grade B	Grade C
Use of Wood	None permitted	Trim, finish, and floor surface	Permitted for any purpose other than lath and supporting structural members
Height	125 ft	100 ft	75 ft
Area	7500 ft²	6000 ft²	5000 ft²
Floor Separations	3-hours	2-hours	1-hour

The basis for limiting building area was intended to promote rapid egress, limit fire spread, and aide in fire suppression activities. This was considered paramount where the building structure was of combustible material that may potentially contribute to the growth and spread of a fire, and was the primary reason that additional floor area was permitted where the wood framing was protected by appropriate surface cladding such as gypsum board.

The building area limitations in the 1941 NBC were based on the same principles as those developed several decades earlier in the United States, and remained relatively consistent with subsequent editions of the NBC. However, small changes to allowable building areas were made between the 1941 NBC and the current edition. These changes are shown in **Table 4** and discussed in more detail below.

Table 4: Building Area Limitations in the NBC.

NBC	Construction	Unsprinklered		Sprinklered	
		Height (Storeys)	Area (m²)	Height (Storeys)	Area (m²)
1941	Unprotected Wood frame	1	750	1	1500
		2	500	2	1000
	Masonry and Wood frame	1	750	1	1500
		2	500	2	1000
		3	500	3	1000
	Heavy Timber	1	2250	1	4500
		2	1500	2	3000
		3	1500	3	3000
		4	1500	4	3000
1953	Unprotected Wood frame	1	500	1	1000
	¾ hour rating	1	1800	1	3600
		2	600	2	1200
	Heavy Timber	1	2400	1	4800
		2	800	2	1600
		3	800	3	1600

NBC	Construction	Unsprinklered		Sprinklered	
		Height (Storeys)	Area (m²)	Height (Storeys)	Area (m²)
1960 to 1965	¾ hour rating	1	1000	1	2000
		2	600	2	1200
		3	600	3	1200
1970 to 1985	¾ hour rating	1	1200	1	2400
		2	900	2	1800
		3	600	3	1200
1990	¾ hour rating	1	1800	1	3600
		2	900	2	1800
		3	600	3	1200
	1 hour rating	1	2400	1	4800
		2	1200	2	2400
		3	800	3	1600
		NOT PERMITTED		4	1200
1995 to 2005	¾ hour rating	1	1800	1	5400
		2	900	2	2700
		3	600	3	1800
	1 hour rating	1	2400	1	7200
		2	1200	2	3600
		3	800	3	2400
		NOT PERMITTED		4	1800

A review of the area limitations in **Table 4** suggests that an increase in building area is permitted where:

- an automatic sprinkler system is provided throughout the entire building;
- a greater level of structural protection is provided;
- the number of storeys in building height is limited; and,
- the number of streets facing is increased.

The increase in building area where an automatic sprinkler is provided throughout the building was permitted to be twice as much as a building without sprinklers from the 1941 NBC to the 1990 NBC, and three times as much for the 1995 and 2005 editions of the NBC. The benefit of providing sprinkler protection and associated increase in building height and area will be discussed in more detail in the next section of this report.

Increasing the structural fire protection to 1-hour permitted an increase of 33% in building area from that required for ¾-hour protected construction. This was relevant to the 1953, and 1990 to 2005

editions of the NBC. The NBC recognized the benefit of passive fire protection in the form of fire separations. This was outlined in the 1995 Users' Guide, which states that[13]:

> *In smaller buildings of combustible construction, the most important consideration is that the occupants can vacate the building safely by means of protected egress paths. Provided all the occupants are safe, the fire department may decide that control of the fire spread to other buildings is an adequate response and that it will not be practicable to save the property itself after the occupants have left.*
>
> *By adding suitable protection to combustible framing, various levels of fire-resistance rating can be achieved. The NBC 1995 recognizes the use of protected wood framing having fire-resistance rating values of up to one hour.*

As outlined in the previous section of this report, an increase in building height is expected to pose an increased hazard to egress and fire fighting capability. Subsequently, as the height of a building increased, the allowable area was reduced, as shown in **Table 5**. The percentages are based on the allowable building area for a single storey having the same type of construction. The trend in the changes in base building area as the number of storeys is increased is by thirds, quarters or both. For the 1990 to 2005 editions of the NBC the allowable area was inversely proportional to the number of storeys in building height.

Table 5: Reduction in Building Area with Increased Building Height.

Construction	NBC	Height (Storeys)	Area (m²)
Unprotected Wood Frame	1941	1	100%
		2	66%
Masonry and Wood frame	1941	1	100%
		2	66%
		3	66%
Heavy Timber	1941	1	100%
		2	66%
		3	66%
	1953	1	100%
		2	33%
		3	33%
		4	33%
¾ hour rating	1953	1	100%
		2	33%
	1960 to 1965	1	100%
		2	60%
		3	60%
	1970 to 1985	1	100%
		2	75%
		3	50%

Construction	NBC	Height (Storeys)	Area (m²)
	1990 to 2005	1	100%
		2	50%
		3	33%
1 hour rating	1990 to 2005	1	100%
		2	50%
		3	33%
		4	25%

As shown in **Table 6**, it is important to note that other than for heavy timber construction in the 1941 NBC, the permitted building area for the maximum height of combustible construction allowed ranges between 500 and 800 m². The permitted building area from edition-to-edition of the NBC is consistent for ¾-hour protected construction, which remains at 500 to 600 m² from the 1941 NBC to the current edition. This area is consistent with that recommended by the NFPA Committee on Building Construction[12], and the survey of fire chiefs in the US[11].

Table 6: Building Area at Maximum Building Height.

Construction	NBC	Peak Height (Storeys)	Area (m²)
Unprotected Wood Frame	1941	2	500
	1953	1	500
Masonry and Wood frame	1941	3	500
Heavy Timber	1941	4	1500
	1953	3	800
¾ hour rating	1953	2	600
	1960 to 2005	3	600
1 hour rating	1990 to 2005	3	800
		4	600*

* Corrected by dividing by sprinkler factor of 3 to get a baseline area

The changes in allowable building area from edition-to-edition of the NBC are shown in **Table 7** to **Table 9**, and are relatively minor. As shown in **Table 7**, the largest change occurs for protected construction with a structural fire protection rating of ¾-hour from the 1953 NBC to the 1960 NBC. The permitted area is almost reduced by half, but returns to what it was in the 1953 NBC by the 1990 NBC. The change in area permitted for a single storey of construction from the 1985 to the 1990 NBC brought the permitted area limitations in line with the intent that the allowable area was inversely proportional to the number of storeys permitted.

Table 7: Change in Building Area from Edition to Edition – 1 Storey.

Type of Construction	NBC	Area (m²)
Unprotected Wood frame	1941 to 1953	750
Masonry and Wood frame	1941	750
Heavy Timber	1941	2250
	1953	2400
¾-hour rating	1953	1800
	1960 to 1965	1000
	1970 to 1985	1200
	1990 to 2005	1800

As shown in **Table 8**, for a building height of 2 storeys, the 1953 edition of the NBC reduced the area permitted for heavy timber to nearly half of that permitted in 1941. This is the most significant reduction in building area from one edition to another for 2 storeys. Protected construction with a structural fire protection rating of ¾-hour was not recognized for 2 storeys in building height until the 1953 NBC where the permitted area remained at 600 m² until the 1970 NBC where it was increased to 900 m² and remained unchanged until the current version (2005 NBC).

Table 8: Change in Building Area from Edition to Edition – 2 Storey.

Type of Construction	NBC Edition	Area (m²)
Unprotected Wood frame	1941	500
Masonry and Wood frame	1941	500
Heavy Timber	1941	1500
	1953	800
¾-hour rating	1953 to 1965	600
	1970 to 2005	900

As shown in **Table 9**, for a building height of 3 storeys, the permitted building area varies for the different NBC editions as a function of construction type. The 1941 NBC only permitted 3 storeys in building height for masonry/wood frame and heavy timber construction, with three times the area permitted for heavy timber over masonry/wood frame. The 1953 edition of the NBC reduced the area permitted for heavy timber to nearly half of that permitted in 1941. Protected construction with a structural fire protection rating of ¾-hour was not recognized for 3 storeys in building height until the 1960 NBC where the permitted area remained unchanged at 600 m² until the current version (2005 NBC). Note that a structural fire protection rating 1-hour and 4 storeys in building height permits the same building area as the ¾-hour fire structural fire protection rating and 3 storeys in building height.

Table 9: Change in Building Area from Edition to Edition – 3 Storey.

Type of Construction	NBC Edition	Area (m²)
Masonry and Wood frame	1941	500
Heavy Timber	1941	1500
	1953	800
¾-hour rating	1960 to 2005	600

The NBC assumes that each building faces at least one street. Where a building faces 2 or 3 streets, the area increase is permitted to be 1.25 and 1.5 times the base area respectively. These factors originate from earlier versions of the NBC and US model codes prior to the 1941 NBC and have applied to unsprinklered and sprinklered buildings alike up to the 1990 Edition of the NBC. A change between the 1990 and 1995 editions of the NBC removed the "streets facing" factor for sprinklered buildings, allowing all sprinklered buildings to be considered to have the same allowable area for a building facing three streets with the doubling of that area for sprinklering.

Considering all of the factors permitting an increase in building area for a combustible residential building, the following formula can be utilized to establish the allowable building area in the current (1995) NBC:

$$A = \left(\frac{1}{H}\right) \cdot A_B \cdot S \cdot SF \cdot CF$$

Where:

A = Building Area (m²)
H = Building Height (Storeys)
A_B = Base Building Area (m²)
S = Sprinkler Factor
SF = "Streets Facing" Factor
CF = Construction Factor

Base Building Area (A_B)

The base building area for combustible residential construction is 1800 m²

Sprinkler Factor (S)

Unsprinklered = 1.00
Sprinklered = 2.00

Streets Facing Factor[b] (SF)

Facing 1 street = 1.00
Facing 2 streets = 1.25
Facing 3 streets = 1.50

Construction Factor (CF)

¾-hour fire rated structural components = 1.00
1-hour fire rated structural components = 1.33

[b] A factor of 1.50 should be applied if the building is sprinklered regardless of number of streets facing.

The trend in the 1941 NBC to 2005 NBC suggest that the allowable building areas have changed only slightly between editions of the NBC, with minimal difference from edition-to-edition for the highest permitted building height. The intent of limiting building heights and areas carries forward to today's codes as outlined in the Users' Guide to Part 3 of the 1995 NBC. Specifically[13]:

> *The NBC 1995 assumes that the higher the building or the larger the building area, the greater will be the problems of evacuation and of fire fighting. Hence, the requirements become more stringent as the building increases in height or area. On the other hand, the NBC 1995 assumes that when a building faces several streets from which the fire can be fought, or when a building is sprinklered, a lower value for structural fire protection is sufficient. The number of streets that a building faces is only relevant for buildings that are not sprinklered and are not more than six storeys in building height. Most fire fighting equipment cannot reach the upper storeys of higher buildings.*

3.3 SUMMARY

The historical rationale for limiting the height and area of buildings was to address safety to life and property where the greatest risk envisioned was conflagration. The limit to height and area for combustible residential construction was estimated to be 3 storeys with a building area of approximately 500 to 600 m² for an unsprinklered building, 4 storeys for a sprinklered building with an area 3 times the building area of an unsprinklered building. This is what was envisioned as reasonable based on early 1900's capabilities in:

- fire resistive construction in limiting fire growth and spread;
- fire resistive construction protecting egress facilities and distance required to travel to a point of safety outside of the building; and,
- fire fighting techniques and available equipment.

Since the early 1900's advances have occurred in building regulation, construction materials and techniques, effectiveness and reliability of fire alarm and sprinkler systems, and fire fighting tactics and equipment. These advances are reflected in the fire record, indicating a reduction of structure fires over the past century and the risk of conflagration significantly reduced. Consideration of these factors in light of current risks relative to fires in combustible wood frame buildings suggest a reassessment of the basis used to develop the height and area limitations in light of current construction techniques, materials and fire department capabilities.

4.0 QUESTION 2: SPRINKLERING

Question 2:

> *How has the building code, relative to the construction requirements for residential construction, adapted to recognize the benefits of sprinklering? And does sprinklering a residential building provide a new rationale for reconsidering the underlying assumptions affecting height and area of a building?*

The addition of sprinklers to a building currently allows for an increase in building area 3 times that for an unsprinklered building. The historical rationale for this increase spans over a century of considerations relative to sprinkler effectiveness in controlling the growth and spread of a fire. However, the increased allowance has been based on the experience and judgment of the code authors at the time of the changes, and has never been reconceptualized beyond its original basis to reflect a more modern understanding of burning behaviour, compartmentation, reliability of fire protection systems, and fire fighting capability.

Sprinklers were originally utilized to protect property with the intention of reducing insurance rates. Their effectiveness in limiting fire growth and spread was identified early on, but their importance to life safety was not recognized until the early 1900's. A handbook on sprinklers published in 1914 discussed the benefits of sprinklers to life safety[14]:

> *Up to a few years ago, sprinklers were more or less of an experiment but they have now been successfully used for 40 years and their efficiency can no longer be questioned. It is a noteworthy fact that in all the fires in sprinklered buildings, there has been practically no loss of life. In the Grover Shoe Factory fire in Brockton in 1907 it is true that several lives were lost but this was due primarily to the explosion of the boiler. In the Herald Building fire in Montreal in 1910, there was also a loss of life but this was due to the collapse of the building that preceded the fire. The records of the Factory Mutual Insurance Companies covering risks employing 1,500,000 people show only 12 deaths in sprinklered buildings in 38 years. Of these 3 were due to persons going back into a burning building to save property and 4 were firemen engaged in fighting the fire. There may be a few other isolated cases but they are so rare that they only go to prove the rule.*

Building code committees attempted to recognize the benefits of sprinklering by allowing relaxations of various requirements including, building height and area. However, the committees did not have enough technical information to quantify the benefit to life provided by sprinklers and often chose an arbitrary multiplication factor.

New York City recognized the benefit of sprinklers in a building ordinance for factory buildings, which suggested that[15]:

> *If a standard equipment of automatic sprinklers is installed throughout any building, the allowable floor area between fire walls may be greater by fifty per cent than those stated in this [ordinance].*

This factor was reconsidered by the NFPA Committee on Safety to Life who stated that:

> *The New York Law recognizes the value of sprinkler protection through a flat, Increase of 50 per cent in the number of persons who may be accommodated as determined by the available exits...Those of us who know sprinkler efficiency and the remarkable freedom from loss of life in sprinklered buildings feel that, this*

> *allowance might be doubled with safety-certainly as viewed comparatively. It is hoped that more and more legal recognition will be given the automatic sprinkler.*
>
> *The Committee recommended a 100 per cent increase in the allowable number of occupants for sprinkler protection which increase from the former 50 percent has now been made by the New York Law.*

The proceedings of the NFPA Twenty-Fifth Annual Meeting – Report of Committee on Building Construction[16], 1921 suggested an increase in area of 66 ⅔ percent for office buildings. A discussion at the committee meeting, demonstrating the arbitrary nature of applying a factor for sprinklering, suggests:

> *MR. BOONE: On the subject of area, 66 ⅔% increase, I note, is allowed where sprinklers are installed. I feel that in a sprinklered office building cut up in small sections, with numerous partitions on each floor, the area could be very materially increased. As a matter of fact, I have always held the opinion that considerations of area are almost blotted out by standard automatic sprinkler protection, and in view of this light occupancy in offices with small sections and numerous partitions, I thought that, perhaps, the area might be increased to more than 66 ⅔%, possibly 100%.*
>
> *MR. WOOLSON: The, Chairman appreciates the significance of that criticism. May I ask if you make the suggestion of 100%?*
>
> *MR. BOONE: I would make that suggestion as, a motion.*
>
> *The motion was adopted.*

No technical basis, other than what is written above, was provided to justify the increase from 66 ⅔% to 100% for building area where the building was sprinklered. The provision of an automatic sprinkler system for most occupancies in the US codes and NBC from this point forward allowed for an increase of 100% that permitted for a building without sprinklers. The NBC permitted a 100% increase in building area until the 1995 NBC, which permitted an increase of 200%.

An early version of the code change proposal to the 1985 NBC that permitted 4 storeys in building height for a combustible, unsprinklered residential building was based on the provision of 1-hour rated structural fire protection (sprinklers were not originally proposed). The basis for this change as indicated in the minutes of meetings of the Standing Committee on Fire Protection was as follows:

> *The NBC currently recognizes the safety of 1 hour rated construction for noncombustible buildings up to 6 storeys in building height and with areas ranging from 2000 m² for a 6 storey building to unlimited area for a 1 storey building.*
>
> *In view of the fact that the basic tests for fire-resistance rating are not predicated on the type of construction but are performance based it is considered that the proposed change permitting combustible framing with equal fire-resistance rating but whose area would be approximately 20 percent of that for a noncombustible building is a conservative approach.*
>
> *The model codes in the U.S.A. permit 4 storey residential buildings to be constructed with 1 hour rated wood frame construction. Studies of the fire death rate in multi-family residential buildings in the U.S.A. indicate that it is very low and that wood frame construction has not been identified as a problem.*

A staff note at the end of the minutes for the proposed code change stated that there was not enough statistical information on fires in combustible construction to accept the change without the provision of sprinklers.

As outlined in the previous section of this report, a change between the 1990 and 1995 editions of the NBC removed the "streets facing" factor for sprinklered buildings, allowing all sprinklered buildings to have the same allowable area as permitted for a building facing three streets.

Sprinklering a residential building does not provide a new rationale for reconsidering the underlying assumptions affecting the height of a building. The original rationale was arbitrary, and not based on quantifiable scientific data. More recent changes to the NBC (1990 to 1995 editions) recognized the benefit of sprinklering by increasing the allowable building height from 3 to 4 storeys and allowing the building to be considered to be facing three streets (regardless of the actual number of streets facing). A new rationale for reconsidering the underlying height and area of a building should be based on an assessment of current sprinklering capabilities and statistics.

5.0 QUESTION 3: RELATION TO IBC

Question 3:

> *Is there a different rationale underlying the assumptions in the International Building Code (United States) vis-à-vis height and area compared to those in the BC Building Code and is it possible to use these IBC assumptions to reconsider the rationale for our height and area calculations?*

The first International Building Code (IBC) was published in 1997 after three years of research and development by the International Code Council (ICC). The IBC was patterned after the three legacy codes, the BOCA National Building Code (BOCA NBC), Uniform Building Code (UBC), and Standard Building Code (SBC), in existence in the US at the time of the development of the first IBC. When developing the height and area limitations in the IBC, the ICC recognized the differences in the three legacy codes at that time, and didn't want to limit the construction of future buildings to less than was permitted by any one of the legacy codes. Thus, the ICC combined the building height and area requirements from the three legacy codes by selecting the maximum values. These are the values in use today.

The height and area limitations in the three legacy codes have the same origins as those of the NBC, developed in larger US cities in the early 1900's. These origins were studied by the committees developing the IBC and a task group formed by the National Fire Protection Association with the intention of developing NFPA 5000, "Building Construction and Safety Code". These groups identified that the height and area tables in the three legacy codes were derived from the same base document or simply traditional acceptance and there was no compelling fire data to support limiting height or area of a building beyond the mechanical properties of construction materials[17]. Building area limitations for different occupancies were based on modified versions of what was considered a standard building where area modifiers were multiplied by the standard building area having no relevance to fire risk, other than what was considered to be reasonable at the time of their development. It was argued that:

> *height and area requirements were the result of good science and contemporary fire protection engineering. However, contrary to popular belief, there is no technical justification for limiting building areas based upon fire risk. Further, there are no statistics to support the efficacy of current limitations. Rather, modern equipment to detect and control fire growth, limited travel distance, and protected exits have provided surprisingly good property protection. They have also provided exceptionally good life safety.*

This statement is not completely accurate. As outlined for Question 1 in this report, building height and area limitations were based on the capabilities and perceived risk at the time of their development. Since that time, capabilities have increased and risk has decreased, and the committees have not had a comparable survey to reconsider the original basis

The committees developing NFPA 5000 came to a similar conclusion on the origins of the height and area limitations in the existing codes that the available information to support height and area limitations was controversial at best. The NFPA committee, made up of representatives of the construction industry, proposed creating a new form of the height and area limitations. However, they failed to achieve a member consensus on the matter and reverted to the conventional height and area limitations. Since that time a new approach to building height and area limitation has been implemented into the 2003 edition of NFPA 5000.

The current version of the IBC allows for an additional storey for combustible residential construction where the building is fully sprinklered, provided the building is no greater than 60 feet high. Above this height the building would be considered a “high building." Based on a conversation with a representative of the American Forest & Paper Association, the additional storey permitted for combustible residential construction is an artifact of the UBC based on a revision to the height and area requirements made by the City of Seattle in the 1970's. This revision was eventually incorporated into the UBC and ultimately into the IBC.

It is our understanding from a discussion with a representative from the City of Seattle that no real technical study was completed on the subject and was likely a result of the regulatory impact on buildings in "hilly" Seattle when Seattle transitioned from the Seattle Building Code to the UBC with Seattle amendments. Seattle incorporated the UBC definition of storey and dropped Seattle's definition of First Storey.

The additional storey of combustible construction is the most significant difference between the current IBC and BCBC for residential construction. However, other than the additional storey permitted, there is no difference underlying the assumptions in the International Building Code (IBC) vis-à-vis height and area compared to those in the BC Building Code that would allow for a reconsideration of the rationale for the height and area limitations. However, a statistical examination of the impact of the additional storey of building height in Seattle may provide a mechanism to establish whether risk associated with the additional storey has been increased.

6.0 DISCUSSION & SUMMARY

This report has outlined the basis and history of the requirements pertaining to building height and area requirements for combustible residential construction in the current edition of the British Columbia Building Code (2006 Edition), based on three questions:

1. What is the historical rationale for limiting the height and area of combustible residential construction to 3 storeys for an unsprinklered building and 4 storeys for a sprinklered building?

2. How has the building code, relative to the construction requirements for residential construction, adapted to recognize the benefits of sprinklering? And does sprinklering a residential building provide a new rationale for reconsidering the underlying assumptions affecting height and area of a building?

3. Is there a different rationale underlying the assumptions in the International Building Code (United States) vis-à-vis height and area compared to those in the BC Building Code and is it possible to use these IBC assumptions to reconsider the rationale for our height and area calculations?

The historical rationale for limiting the height and area of combustible residential construction to 3 storeys for an unsprinklered building and 4 storeys for a sprinklered building is based on an examination of risk and capability from the early 1900's. Advances in building regulation, construction materials and techniques, fire protection/detection and fire fighting techniques and equipment in addition to our current understanding of fire development and people behaviour provide a mechanism for re-examining fire risk associated with combustible residential construction and capabilities in mitigating that risk.

Sprinklering has permitted both an increase in building height for combustible residential construction and an increase in area. However, this increase has been based on simplified multiplication factors, with the most significant increase occurring in the 1990 and 1995 versions of the NBC allowing an additional storey of building height and tripled base building area. Early consideration of the protection afforded by sprinklers was made within the context of their effectiveness in factories and warehouses, where compartmentation was limited. Given:

- the changes in sprinkler technology and reliability;
- the larger pool of available sprinkler statistics;
- better understanding on theory and testing of sprinkler capabilities to control and suppress fires; and,
- increases in building compartmentation.

the benefit of sprinkler protection should be reconsidered relative to the underlying assumptions affecting height and area of a building.

A sprinkler system is an active fire protection system, expected to respond to a fire event. Passive fire protection (i.e., fire separation) does not require a specific response in order to achieve its objective. Active systems can fail to respond as intended due to poor installation or maintenance. Passive systems can fail to achieve their objective where installed inappropriately or compromised by installation of building services after occupancy of a building. A balance of both types of system help increase the reliability of a building in limiting growth and spread of fire.

Compartmentation was identified in early studies as an important consideration relative to the spread of fire and subsequently in the development of the height and area limitations, and was touched on at various points in the historical development of the US and Canadian codes[8,9,13,16]. The NBC has more recently recognized the benefit of compartmentation by allowing an increase in building height and area where a building is provided with 1-hour protected construction. However, the increase was an arbitrary estimation of the protection afforded by the increase in the fire rating.

The effects of compartmentation have not been studied recently within the context of revisiting building height and area limitations given new construction materials and methodologies, which have changed significantly over the past 100 years. These advances in compartmentation raise the question of what is the difference between a combustible and a noncombustile structural element (column, beam, floor assembly) having the same fire-resistance rating? If they pass the same test standard for fire endurance, does the combustible construction provide a greater level of risk?

The assumptions underlying the rationale for limiting building height and area in the International Building Code are the same as those in the BC Building Code. Changes to the UBC based on City of Seattle amendments and subsequently changes to the IBC incorporating these requirements have allowed for an additional storey in height for combustible residential construction. An examination of the fire statistics in Seattle may provide a mechanism to establish whether risk associated with the additional storey has been increased.

The underlying answer to all of these questions is a re-evaluation of risk and capability: what is the current risk to life and property and what are the current capabilities in dealing with the risk. The basis for the height and area limitations in the 2006 BCBC were developed nearly 100 years ago when city conflagration or large life loss were prominent considerations. The means for dealing with these risks, in part, was to limit the height and area of buildings to what the fire department of the time could reasonably handle. The statistical fire record has shown that the number of fires is decreasing, loss of life in fires has decreased, and the relationship of city-wide conflagrations to interior building design is not correlated in a reasonable way to building height and area.

In summary, there is a lack of definition to correlate the building area and height to the overall construction, compartmentation, and fire and life safety systems. The process can be summarized as follows:

- Building area and heights were based on a survey of fire services capabilities in the early 19th century. During this era,
    - The methods of construction were vastly different and methods of determining fire-resistance of structures were in their infancy.
    - The degree of building compartmentation that was factored into the reviews is not representative of residential construction in today's code.
    - Interior finishes were less controlled and flame-spread concepts were in their infancy. Wood was a more predominant ceiling finish, whereas gypsum board is a more common material for walls and ceilings in residences today.
    - Exiting, fire alarm systems, and evacuation plans were less regulated and less effective. Concepts on evacuation relative to building height were based on buildings with open or unprotected stairs and not fire separated stair shafts as required by today's codes.

  - The behaviour of people during a fire had not been studied and was therefore not understood.
  - To the extent that it exists today, fire services did not have breathing apparatus, fire fighter's stairs, aerial ladder trucks, addressable fire alarm systems, and floor plans. Hence, the building area and height rationalization based on hose stream penetration is not representative of today's capabilities.

- Over time, the NBC was revised to adapt to different formats, and, only in the later editions of the code was it modified based on fire research. However, the modifications were incremental and today's BCBC still coincides with the premise from early 1900's relative to allowable building height and area.
- Although the compartmentation of a building into several fire compartments was recognized to reduce fire development, its correlation to height and area was never fully addressed. The height and area requirements are essentially premised on the building being one fire compartment.
- The capabilities in analyzing overall fire growth and spread using test data, empirical correlations, and modern computer tools is not factored into methods of considering compartmentation relative to building height and area.
- Building height and area can be better correlated in a risk-based context using performance-based methodologies that address the potential fire development scenarios for a building. In buildings of combustible construction, this would include fires in a floor area, concealed spaces, and exterior to the building.

7.0 FUTURE RESEARCH

The following future research considerations are suggested based on the review summarized in this report:

- Examine fire statistics in combustible wood framed residential structures for sprinklered and unsprinklered buildings.
- Survey fire departments to establish capabilities.
- Review research relative to contribution of combustible wood framing in fire separations to the total energy.
- Examine height and area limitations and their historical basis in European Codes.
- Examine height and area limitations for noncombustible construction and other occupancies, particularly the use of unprotected steel where for the same building a ¾-hour fire resistance-rating would be required for combustible construction.

8.0 SOURCES OF INFORMATION

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