# SPACE AND COST IMPACT REPORT BASED ON THE 2024 BC BUILDING CODE ADAPTABLE AND EARTHQUAKE DESIGN PROVISIONS

Prepared for

Ministry of Housing and Municipal Affairs
Building and Safety Standards Branch
Victoria, BC

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# 1.0 INTRODUCTION

## 1.1 Ministry of Housing and Municipal Affairs Preamble

Investing in safer and more accessible housing delivers long-term benefits to all people living in B.C.

Shifting demographics and the desire of more Canadians to age in place emphasizes the importance of ensuring that available housing meets the needs of an increasingly diverse population. Because B.C. is the most earthquake-prone region in Canada, there is a risk of a highly damaging earthquake. Natural Resources Canada (NRCan) estimates the probability of a megathrust quake on the coast of B.C. in the next 50 years is between 10 – 15 per cent, with the likelihood rising over time. The need for safe, accessible housing is ever present in B.C.

In 2022, nearly 30 percent of British Columbians over the age of 15 had one or more disabilities that limited their daily activities. We know that with age, there comes an increased prevalence of disability[1.] Population projections for B.C. estimate a 6 per cent increase in the proportion of people aged 65 and over by 2048[2]. This demographic shift indicates a greater need for more accessible housing. As needs change over time, housing should be easily adaptable to meet those needs.

The 2024 British Columbia Building Code (BCBC) adaptable dwelling unit and earthquake provisions have been adopted to make living spaces more accessible to more people and improve the life safety and resiliency of buildings.

<u>Adaptable Dwelling Unit Provisions</u>

The BCBC provisions have been enacted in the context of and alignment with the 2020 National Building Code (NBC) research that reflects how people interact with the built environment. The *Accessible British Columbia Act* was passed in June of 2021, with the commitment to prioritize more accessible homes, buildings, infrastructure and public spaces and support people with disabilities to meaningfully participate in their communities.

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[1] Source: Statistics Canada Canadian Survey on Disability 2022 https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3251

[2] Source: Statistics Canada: Population projections: Interactive Dashboard Population Projections for Canada, Provinces and Territories: Interactive Dashboard

Adaptable dwellings help people through every stage of life. Not only do they provide accessible housing for people living with disabilities, they also help parents with children in strollers, those experiencing life changing illnesses or temporary or permanent injuries, multigenerational families, and seniors who may wish to age in place.

Adaptable dwellings provide accessible entrances, more clearance space to support mobility, accessible controls, switches, and features to suit occupants' needs, thereby offering greater comfort and accessibility.

The adaptable dwelling unit requirements of the 2024 BCBC aim to reduce future retrofitting costs and help people to stay in their homes through illness, injury, and aging. Adaptable dwellings also provide inclusive spaces for all people to visit and participate in social gatherings and events, which they may otherwise be prevented from doing.

Cost of not building adaptable

The long-term savings of building adaptable at the outset greatly outweighs preliminary costs. Costly and disruptive renovations and retrofits can be avoided if the right kind of housing is constructed in the first place.

Not having a unit that meets the needs of residents can result in disruptive and preventable relocations, create financial hardship, as well as social and emotional impacts. Having inadequate manoeuvring space in a residence can often cause interior damage to a rental unit, resulting in costs for landlords and loss of damage deposits for tenants.

The costs associated with not constructing adaptable buildings extend beyond financial renovation costs, and encompass social and cultural dynamics, as well as environmental sustainability. The adaptable dwellings unit requirements not only mitigate these inherent costs but also foster innovation and social inclusion.

> "The BC adaptable dwelling unit and earthquake provisions represent the needs of all British Columbians. Delivering adaptable dwellings represents real change that requires informed design and a willingness to create homes for people of all ages and abilities."
>
> - Brad McCannell, Vice President Access and Inclusion, Rick Hansen Foundation

> "The Architectural Institute of British Columbia (AIBC) supports the adaptable dwelling unit provisions to be implemented in the BC Building Code in March 2025 as they meaningfully contribute to the well-being of our communities. They support the diverse needs of people – not only for those living with disabilities, but also parents with young children, people experiencing illnesses or injuries, and seniors. While the modest space increase has an impact on construction costs in the short term, over the life cycle of the building, the cost is negligible."
>
> "Codes, standards, and professional practice are continually evolving to match science, innovation, and changing societal needs. To comply with these standards and preserve public safety, engineering and geoscience professionals are required to meet new and evolving requirements. Engineers and Geoscientists BC is committed to supporting high standards of professional and ethical practice amongst our registrants."
>
> - Ramin Seifi, P.Eng., FEC, MCIP, RPP, R.I. Director, Professional Practice, Standards and Development, Engineers and Geoscientists British Columbia

Earthquake Provisions

It is not possible to predict the exact timing or scale of the next major megathrust earthquake in British Columbia, however according to National Resources Canada (NRCan) thirteen such major megathrust type events have been identified in the last 6000 years, an average of one every 500 to 600 years, the last one was 300 years ago[3]. Given the risk of a major megathrust quake and the risk of other smaller, more frequent earthquakes the life-safety and structural integrity of our buildings and more importantly the people who reside in them is of paramount importance.

The primary objective of the BCBC 2024 earthquake provisions is to prevent structural collapse of buildings in the event of an earthquake. The 2020 NBC, upon which the 2024 BCBC is based, has been updated to correct design deficiencies that existed in the 2015 NBC as well as to reflect the new scientific data on the predicted locations and severity of earthquakes, which could be more severe than previously thought. The intention is not to raise the bar for building design but simply to maintain the same level of performance given the updated earthquake hazard data and deficiencies identified in the 2015 NBC.

[3] National Resources Canada, questions and answers on megathrust earthquakes https://www.earthquakescanada.nrcan.gc.ca/zones/cascadia/qa-en.php

For most buildings, the performance goal is to prevent the loss of life through collapse prevention. The BCBC does not require most buildings to be designed so that they would be re-inhabitable after the predicted maximum severity earthquake, although the buildings may still be inhabitable after smaller earthquakes. For larger earthquakes, substantial renovation or even tear down may be required. Buildings that are essential to the provision of services in the event of a disaster such as hospitals, police, and fire stations, intended for use as post-disaster response, are designed to be occupiable post-earthquake.

The updated changes will make buildings and occupants safer by using the best earthquake science to design buildings to withstand structural collapse in the predicted maximum severity earthquake and prevent injuries and death. Furthermore, the updated changes will make buildings targeted to be functional or occupiable post-earthquake more likely to achieve these post-earthquake performance objectives.

> "The 2024 BCBC includes important updates to the earthquake design provisions. Two examples are new serviceability requirements that will improve the chance that hospitals will still function after a major earthquake and new life safety requirements that help reduce the increased risk in modern highrise buildings with unusual architectural form."
>
> - Dr. Perry Adebar, PEng, Professor of Structural Engineering, The University of British Columbia

> "Further to the comments above, the 2024 BCBC includes new serviceability requirements that will improve the chance that schools will be occupiable after a significant earthquake, and includes design requirements to improve performance in buildings with significant irregularities, such as sloping columns and unusual vertical shapes. BCBC 2024 will incorporate the 'best science' regarding earthquake hazard in BC, with provisions to enable the use of site-specific soil information to better estimate the ground shaking at each and every site."
>
> - John Sherstobitoff, P.Eng., Principal Seismic & Structures, Ausenco; also Chair for 10 years of the NBC committee responsible for the issuance of the earthquake design provisions in NBC 2020.

Space and Impact Study

Recognizing the critical role of Building Codes in fostering equitable, resilient, and sustainable communities, this study was commissioned to examine the space and cost impacts of the adaptability and earthquake provisions on large, complex buildings, and identify opportunities to creatively and effectively apply the provisions to building design.

The province continues to work with the building sector, experts, developers, design professionals and local governments to support the delivery of safer, more accessible buildings and homes while balancing housing supply and affordability.

The province extends its gratitude to the consultants, local governments, development industry professionals, accessibility advocates, and other interest holders who contributed their expertise and perspectives to this study.

We acknowledge with gratitude that this report was produced on the traditional unceded territories of the xʷməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), and səlilwətaɬ/Selilwitulh (Tsleil-Waututh) Nations, we respectfully honour their cultures and traditions and all the unique Indigenous Peoples and Nations across the province.

## 1.2 Scope of Study

The scope of this study is to analyse the space and cost impacts associated with the new earthquake and adaptable dwelling units requirements in the 2024 BC Building Code (BCBC), for larger multi-family buildings (e.g. midrise and towers) including a comparative analysis between the 2018 and 2024 requirements, and the cost impacts of following the requirements at the point of construction

It is assumed the reader has a general familiarity with the new BCBC 2024 adaptable and structural provisions.

The scope of this study is limited in nature based on time and budget constraints however has been endeavoured to be based on providing reasonable representative averages to help inform the general impact of implementing the BCBC 2024 new earthquake and adaptable dwelling unit requirements and provide industry with information to assist in further project specific analysis, if required.

It is not possible to consider every type of unit design or floor plate configuration as units and buildings come in all different shapes and sizes and each developer and architect has their unique styles and profile dependent on the shape of the building. We instead aim to provide analysis of average unit sizes and unit programming that are frequently seen in the market as the basis of the study. Section 2.0 further outlines the adaptable dwelling unit designs used in the analysis. For the purposes of this study only market housing has been considered.

Similarly, it is not possible to consider all building types and methods of construction for the earthquake analysis. Analysis is based on most common and critical building typologies reflecting various selection locations across the province. Section 3.0 further outlines the typologies used in the earthquake analysis.

A cost impact analysis for the adaptable dwelling unit and earthquake design provisions is also intended to be completed. Refer to Appendix C for the attached costing report.

The unit sizes and building archetypes in this study have been developed with input from developers and other industry professionals through targeted consultation sessions. Similarly, methodology of floor area measurement used in this report are based on industry standards discussed at these collaboration sessions.

The results of this work will be used to inform the development of an Illustrated Design Guide with unit plans to illustrate efficient and compliant space designs for adaptable dwelling unit provisions to assist industry in implementation.

## 1.3 Study Team

This study has been a joint undertaking involving Public Architecture + Design Inc. providing architectural design input, WHM Structural Engineers providing structural design input, BTY Group providing cost analysis, and GHL Consultants Ltd. providing project coordination and Code expertise in cooperation with the Ministry of Housing and Municipal Affairs staff at the Building and Safety Standards Branch. Appropriate peer review of the Earthquake Design Assessment will be provided by RJC Engineers Victoria Office.

# 2.0 ADAPTABLE DWELLING UNIT SPACE STUDY

## 2.1 Background

The BCBC 2024 now prescribes larger apartment buildings to have 100% adaptable units. This means that in addition to meeting accessible requirements in common areas, every unit within an applicable building must comply with the BCBC 2024 adaptable dwelling unit requirements.

The focus of the adaptable dwelling unit half of the study is with regards to the BCBC 2024 Code requirements that impact floor area, including but limited to:

1) Door clearances / door clear opening width
2) Path of travel through unit
3) Bathroom clearances (i.e. space at sink, toilet, shower, bathtub)
4) Bedroom clearances (i.e. space beside bed and at closet)
5) Kitchen clearances (i.e. turning area and space at sink)
6) Earthquake change impact on overall building Area

The primary goal of this adaptable space study is to assess the space impacts of the BCBC 2024 Code requirements on the applicable building and unit types.

The space planning solutions presented in this report are not intended to establish new standards for the design and construction industry. Rather, the goal is to demonstrate the impact of the changes, provided information to inform further analysis, and opportunities that arise from the adoption of the new Code requirements.

## 2.2 Design Baseline

### 2.2.1 Unit Sizes

The typical unit ranges below have been determined from an analysis of common market units and developed in consultation with industry professionals facilitated by the Ministry of Housing and Municipal Affairs. As a result, the target size for each unit type reflects average sizes seen in common markets in the province.

**Table 2.2.1 – Baseline Unit Sizes**

| Unit Type | Typical Range (sq ft) | 2018 Baseline (sq ft) |
|---|---|---|
| Micro Unit | 300 – 325 | 305 |
| Studio | 350 – 490 | 380 |
| 1 Bedroom | 500 – 580 | 500 |
| 1 Bedroom + Flex | 580 – 640 | 600 |
| 2 Bed + 2 Bath | 650 – 800 | 725 |
| 3 Bed + 2 Bath | 905 – 975 | 935 |

### 2.2.2 Unit Programming

The functional program for each unit was developed based on an analysis of typical market units and through consultation with industry professionals, facilitated by the Ministry of Housing and Municipal Affairs. The program elements for each unit remained the same for baseline and adaptable unit versions. Typical elements are noted in the following table.

**Table 2.2.2 – Unit Program**

| Unit Type | Element |
|---|---|
| Micro Unit & Studio | Entry closet |
| | Bathroom – 3-piece |
| | Laundry |
| | Kitchen |
| | Bedroom (Murphy bed) + closet |
| | Small flex area for dining, media, working |
| 1 Bed & 1 Bed + Flex | Entry closet |
| | Bathroom – 3-piece |
| | Laundry |
| | Kitchen |
| | Dining |
| | Living room |
| | Bedroom + walk-in closet |
| | Flex room (in 1-Bed + Flex Only) |
| 2 Bed + 2 Bath | Entry closet |
| | Bathroom – 3-piece |
| | Laundry |
| | Kitchen |
| | Dining |
| | Living room |
| | Bedroom 1 + walk-in closet |
| | Bedroom 2 + walk-in closet |
| | Ensuite |
| 3 Bed + 2 Bath | Entry closet |
| | Bathroom – 3-piece |
| | Storage |
| | Laundry |
| | Kitchen |
| | Dining |
| | Living room |
| | Bedroom 1 + closet |
| | Ensuite – 4-piece |
| | Bedroom 2 + closet |
| | Bedroom 3 + closet |

## 2.3 Methodology

The study began with an analysis of previous adaptable unit studies, provided by Ministry staff, prepared by private sector developers and consultants with expertise in market housing development. BC Housing design guidelines were also considered, but it was determined that this study would focus on market developments only.

Following the analysis, the baseline units and typical floor plans meeting the program requirements and target were developed, with input from Ministry staff and the consultant team. The methodology for measuring unit area was established to be the exterior face of exterior cladding, centreline of demising walls, centre line of corridor walls, and 200 mm of any abutting concrete structural walls consistent with industry norms as discussed in the collaboration sessions.

Draft unit programs, unit target areas, unit plans, typical block floor plans and area measure methodology were reviewed by Ministry staff and interest holders involved in consultation sessions. Written feedback from interest holders was provided and incorporated in the study and plans wherever practical and within the scope of the study.

Revised unit plans were then used to develop baseline and adaptable detailed schematic floor plans for a light wood frame mid-rise and concrete tower, with the area impact of the 2024 adaptable requirements on the unit area were then compared with the 2018 baseline.

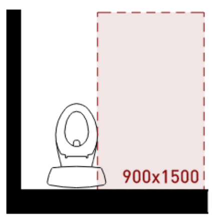
Refer to Section 4.0 for more information on the adaptable and earthquake cumulative space study.

As noted previously, this study does not analyse all possible unit types or building configurations given the time and scope of the study.

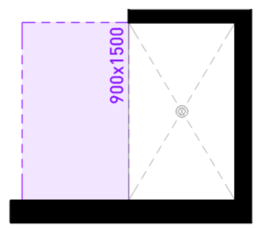
To maintain the concept of ‘liveability’ or ‘marketability’ each unit living area are generally consistent between the baseline and adaptable dwelling units. The study does not attempt to address how adaptable requirements for bathrooms, kitchens and bedrooms impact ‘liveability’ or ‘marketability’, because these characteristics are location specific and subject to changes in market preferences. In addition, specific impacts on revenue are not within the scope of this contract as it is impractical to quantify within the limitations of this contract and given that the impact on revenue varies greatly by region and by specific building design. The analysis provided, including a breakdown of the impacts on specific living areas can be used to inform further project specific costing analysis that includes revenue impacts.

It should be noted that the code does not prescribe the size, placement or type of furniture within a unit. Any furniture placement in images within this study are for demonstrative purposes only and are not intended to be prescriptive.

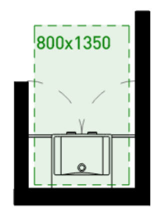
A consistent graphic approach was used to allow applicable clear areas to be tracked and identified. These are reproduced below for clarity and are reflected in the adaptable units under Section 2.4.



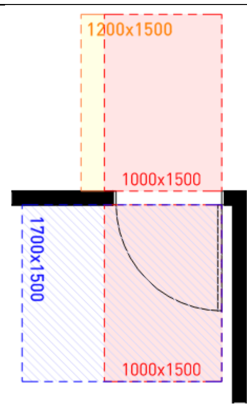

**Water Closet Clearance**
(Dark Red)



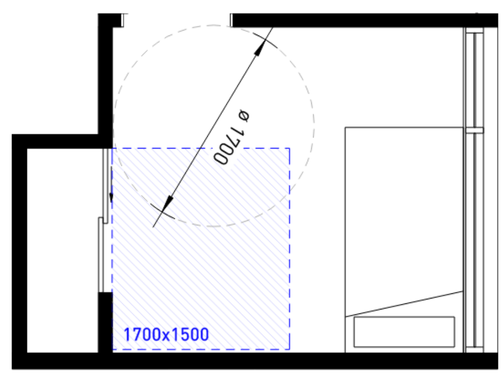

**Shower Clearance**
(Purple)




**Sink Clearance**
(Green)




**Door Clearances**
(Blue – Pull Side)
(Yellow – Push Side)
(Red – Rough-in Power Door Operator)




**Bedroom/Kitchen Turning Clearances**
(Blue)

## 2.4 Findings

Micro units and studios require an increase in size to accommodate adaptable dwelling unit requirements. All other unit types studied are able to accommodate adaptability requirements within the existing baseline square footage area with layout reconfigurations. Floor plans can be found below as subsections to Section 2.4 or as larger format drawings found in Appendix A.

**Table 2.4-A – Unit Floor Area Impact Comparison**

| Unit type | BCBC 2018 | BCBC 2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Micro Unit | 305 | 330 | 25 | 8.2% |
| Studio | 380 | 388 | 8 | 2.1% |
| 1 Bed | 500 | 500 | 0 | 0 |
| 1 Bed + Flex | 600 | 600 | 0 | 0 |
| 2 Bed + 2 Bath | 720 | 720 | 0 | 0 |
| 3 Bed + 2 Bath | 935 | 935 | 0 | 0 |

**Table 2.4-B – Unit Room Area Change Comparison**

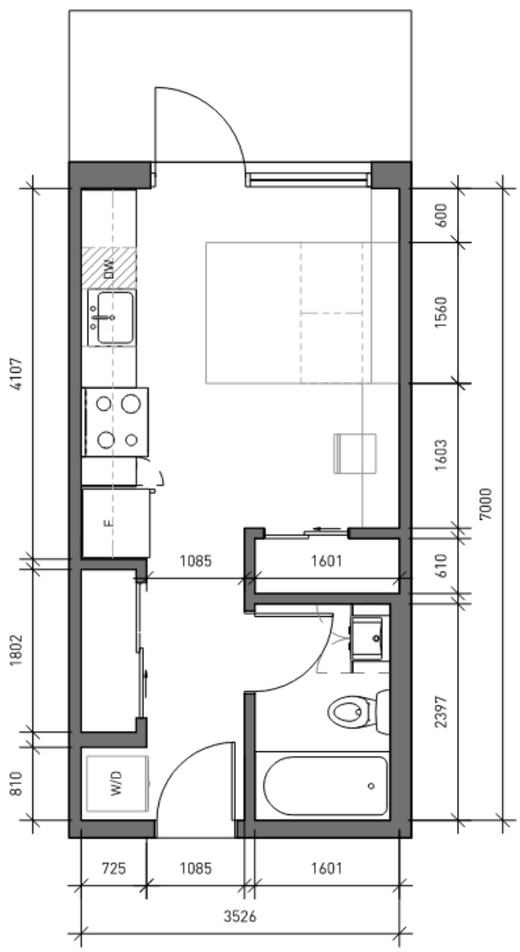
| Unit type | BCBC 2018 | BCBC 2024 | Change |
|---|---|---|---|
| | sq ft | sq ft | sq ft |
| Micro Suite | 305 | 330 | 25 |
| - Kitchen, Living, Dining, Circulation | 183 | 198 | 15 |
| - Primary Bathroom | 39 | 52 | 13 |
| - Storage | 22 | 13 | -9 |
| Studio | 380 | 388 | 8 |
| - Kitchen, Living, Dining, Circulation | 256 | 243 | -13 |
| - Primary Bathroom | 39 | 52 | 13 |
| - Storage | 16 | 22 | 6 |
| - Washer / Dryer | 9 | 7 | -2 |

| Unit type | BCBC 2018 sq ft | BCBC 2024 sq ft | Change sq ft |
|---|---|---|---|
| 1 Bed | 500 | 500 | - |
| - Kitchen, Living, Dining, Circulation | 253 | 250 | -3 |
| - Primary Bathroom | 39 | 52 | 13 |
| - Bedroom | 93 | 89 | -4 |
| - Storage | 30 | 29 | -4 |
| - Washer / Dryer | 10 | 7 | -3 |
| 1 Bed + Flex | 600 | 600 | - |
| - Kitchen, Living, Dining | 253 | 243 | -10 |
| - Circulation | 29 | 38 | 9 |
| - Primary Bathroom | 39 | 52 | 13 |
| - Bedroom | 93 | 89 | -4 |
| - Flex Room | 59 | 55 | -4 |
| - Storage | 35 | 30 | -5 |
| 2 Bed + 2 Bath | 720 | 720 | - |
| - Circulation | 20 | 34 | 14 |
| - Primary Bathroom | 42 | 52 | 10 |
| - Storage | 60 | 33 | -27 |
| 3 Bed + 2 Bath | 935 | 935 | - |
| - Kitchen, Living, Dining | 294 | 270 | -23 |
| - Circulation | 78 | 100 | 22 |
| - Primary Bathroom | 41 | 60 | 19 |
| - Storage | 27 | 7 | -20 |

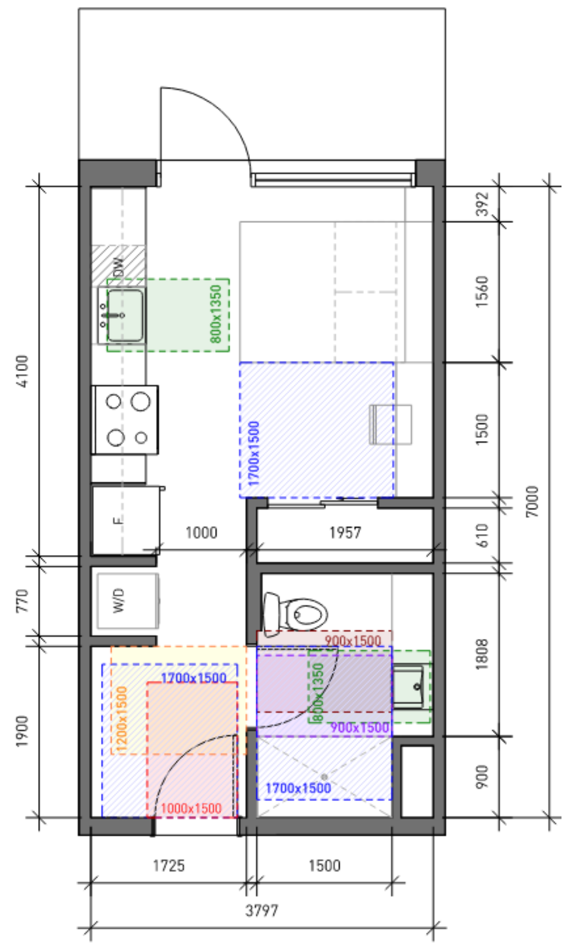
NOTE: Rooms or spaces not identified in table above have no sq ft change.

### 2.4.1 Micro Unit

**Image 2.4.1 - Micro Unit Comparison Plans**




**Micro Unit – BCBC 2018**
Unit Area: 305 sq ft

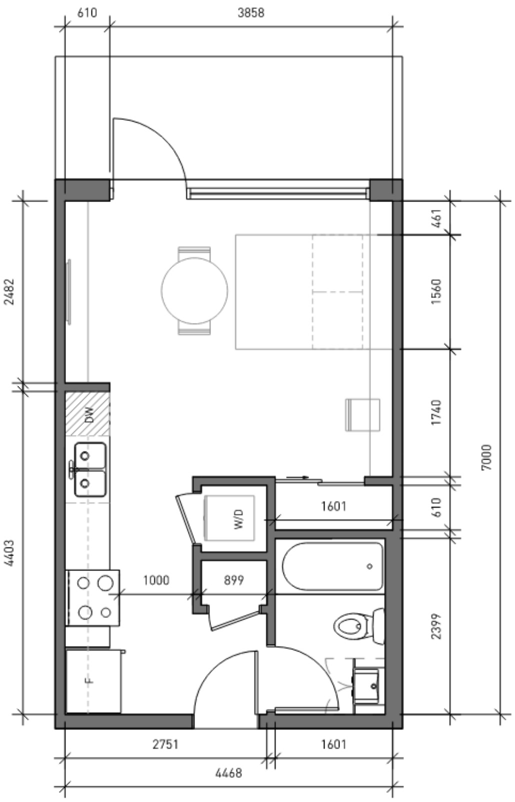



**Micro Unit – BCBC 2024**
Unit Area: 330 sq ft

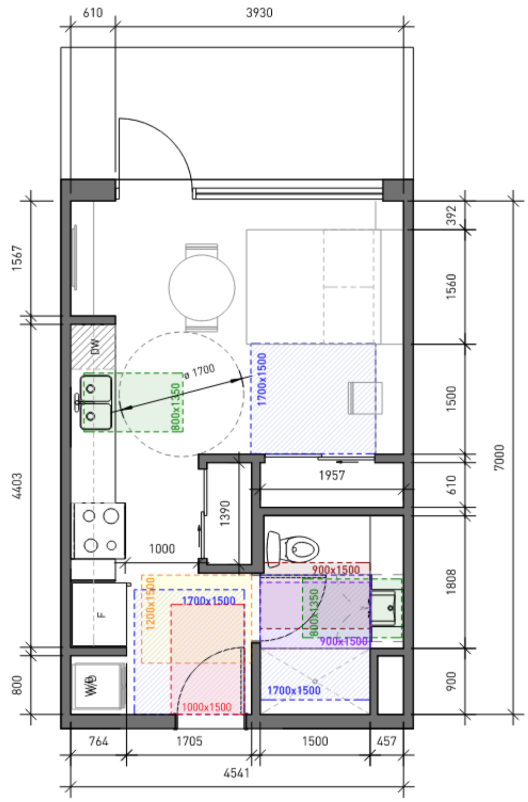
The micro unit requires the largest increase in unit area of the unit types studied. This was driven by an increased size of bathroom, larger clearances at entry door, bedroom closet and beside the bed. To alleviate the impact of the entry door clearance, the enclosed entry closet was removed.

### 2.4.2 Studio

**Image 2.4.2 - Studio Comparison Plans**




**Studio – BCBC 2018**
Unit Area: 380 sq ft

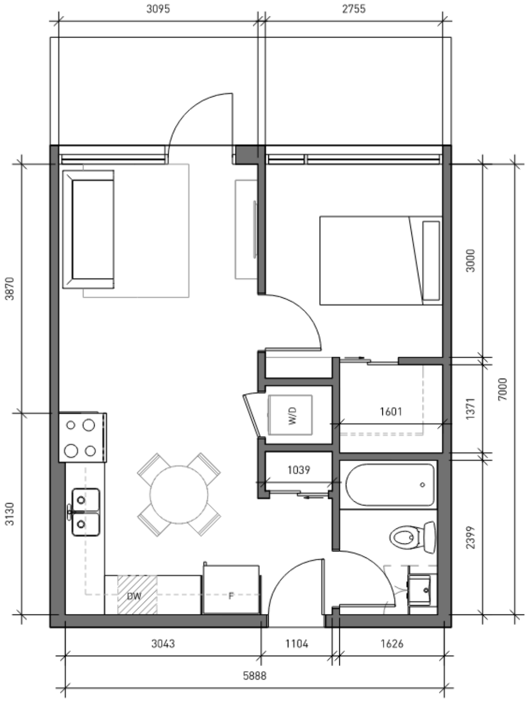



**Studio – BCBC 2024**
Unit Area: 388 sq ft

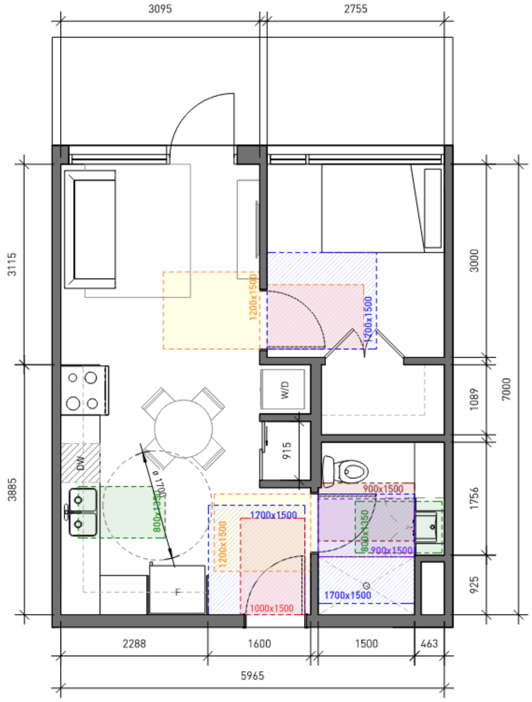
The studio unit required a modest increase in floor area to accommodate a larger bathroom and clearances at the entrance door. These impacts can be alleviated by having an open laundry closet. Achieving clearances at the entry door resulted in a reduction in length of media wall, which could be alleviated by providing a rough-in for a power door operator (not shown).

### 2.4.3 One Bedroom

**Image 2.4.3 - One Bedroom Unit Comparison Plans**




**1 Bed – BCBC 2018**
Unit Area: 500 sq ft

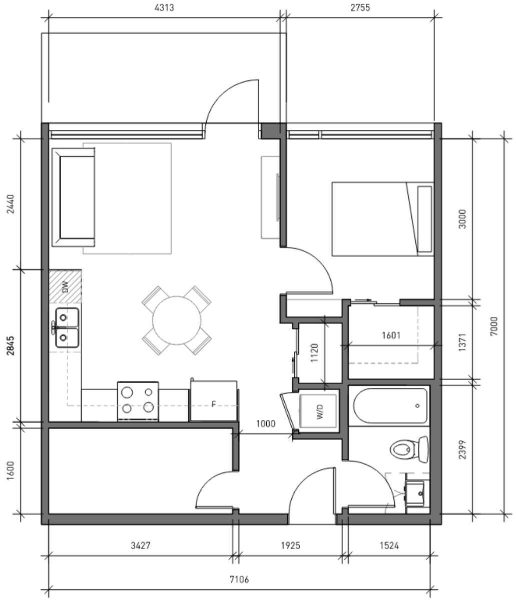



**1 Bed – BCBC 2024**
Unit Area: 500 sq ft

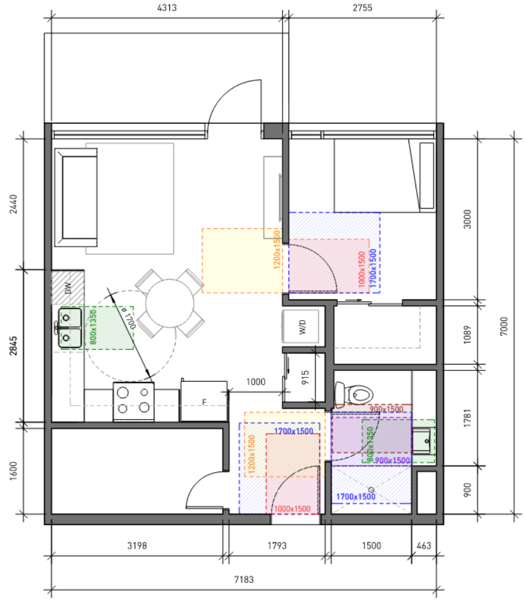
The one bedroom unit did not require any increase in floor area to accommodate the adaptable dwelling unit provisions. Design strategies include changing from an enclosed to an open laundry closet. Achieving clearances at the entry door resulted in a moderate decrease in entry closet size, from 1039mm to 915mm, and a greater encroachment of kitchen millwork into the living area, which may be addressed by provision of an automatic door operator (not shown).

### 2.4.4 One Bedroom + Den

**Image 2.4.4 - One Bedroom + Den Unit Comparison Plans**




**1 Bed + Flex – BCBC 2018**
Unit Area: 600 sq ft

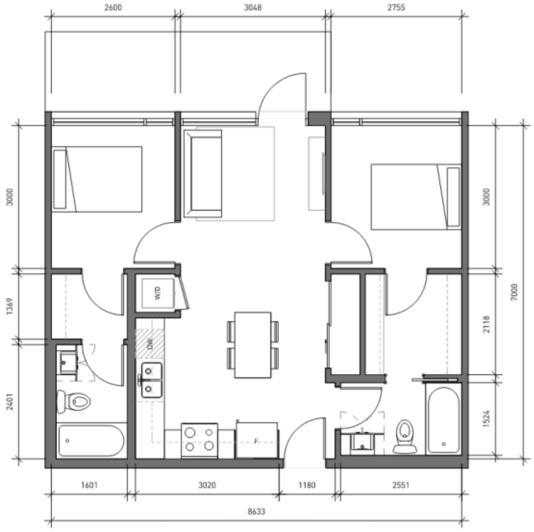



**1 Bed + Flex – BCBC 2024**
Unit Area: 600 sq ft

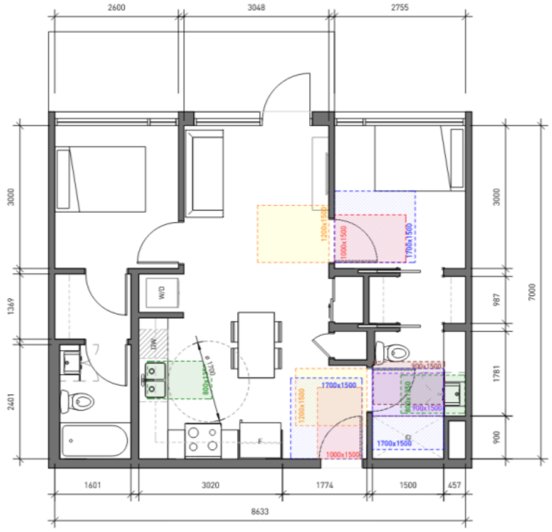
The one bedroom with den did not require any increase in unit floor area to accommodate the adaptable dwelling unit provisions. Flex space may be sized differently as desired to meet needs. The suite entry and bathroom were redesigned to accommodate door/turning area clearances, and the walk-in closet dimensions were adjusted, from 1601mm by 1371mm to 1963mm by 1089mm.

### 2.4.5 Two Bedroom + Two Bath

**Image 2.4.5 - Two Bedroom + Two Bath Unit Comparison Plans**



**2 Bed + 2 Bath – BCBC 2018**
Unit Area: 720 sq ft

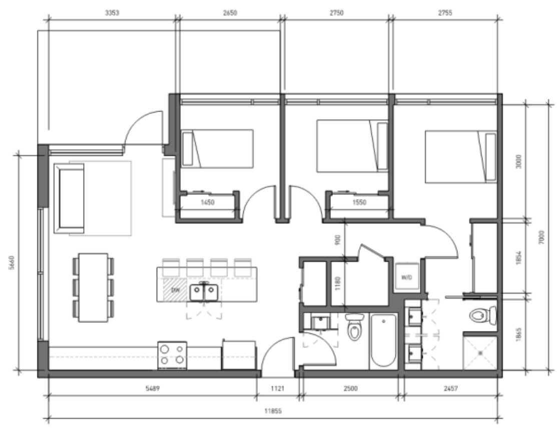


**2 Bed + 2 Bath – BCBC 2024**
Unit Area: 720 sq ft

The two bedroom two bathroom did not require any increase in unit floor area to accommodate the adaptable dwelling unit provisions. The suite entry and bathroom were redesigned to accommodate door and turning area clearances, and walk-in closet dimensions were adjusted, from 2028mm by 2118mm to 2028mm by 987mm.

### 2.4.6 Three Bedroom + Two Bath

**Image 2.4.6 - Three Bedroom + Two Bath Unit Comparison Plans**



**3 Bed + 2 Bath – BCBC 2018**
Unit Area: 935 sq ft

**3 Bed + 2 Bath – BCBC 2024**
Unit Area: 935 sq ft

The three bedroom two bathroom did not require any increase in unit floor area to accommodate the adaptable dwelling unit provisions. The suite entry and bathroom were redesigned to accommodate door and turning area clearances. The design also changed the orientation of the adaptable bedroom and the closet within to accommodate clearances within a similar area. The kitchen is revised to remove the island along with moderately reduced storage space from 27 to 7 sq ft.

## 2.5 Conclusion

The BCBC 2024 adaptable dwelling unit provisions increased the gross area of micro units and studios by approximately 25 and 8 square feet respectively. The gross area of one bedroom, two bedroom, and three bedroom units did not increase at all. Modifications to the larger unit layouts allow the adaptable features to be included without impacting the overall unit area or functional program elements.

Floor space impacts can be minimized by considering the following:

- Overlapping of required clear floor spaces
- Introducing of rough-in power operated door to reduce required door clearances
- Introducing manual sliding doors to reduce required door clearances (Note: sliding doors require thicker, service free walls)
- Introducing non-fixed kitchen islands
- Introducing the ability to adapt a bathroom with a tub or shower into a curbless shower in future to allow clear floor spaces to encroach into shower space

The study found that living space, and unit amenities like storage, closet and laundry space can be provided in adaptable units, with a modest impact on floor area for the smallest units. The adaptable washrooms, bedrooms and kitchens that can be reconfigured at a modest cost to meet a resident's changing needs, allowing them to remain safe and comfortable in their home, preventing displacement due to illness, injury or aging.

## 2.6 Recommendations

The below recommendations, for further analysis and consultation with the accessibility and development community as possible options provide additional flexibility in unit design and use of space while maintaining an acceptable level of adaptability of dwelling units for one's current or future needs. It is noted that CSA B652 "Accessible dwellings" (2023) has been updated and provides some additional design options.

(a) Clear Floor Space at Door:

Requirement: Provide a clear floor space on either side of the dwelling unit entry door and to the bedroom and bathroom.

Recommendation: Additional clear floor space options could be developed depending on the approach to the door as considered in CSA B651 "Accessible design for the built environment" (2023).

(b) Power Door Operator Rough-In Clear Floor Space at Door:

Requirement: Maintain a clear space the width of the door by 1500mm deep.

Recommendation: Revise the need for a 1500mm clear floor space depth based on the consideration that there are different approaches to door considered in CSA B651 (2023) where no clear space is specified once a power operated door is provided.

(c) Toilet Transfer Space:

Requirement: Maintain a clear transfer space beside the toilet with no fixed element located within the space at occupancy.

Recommendation: Provide consideration to transfer space in front of the toilet with the additional ability to provide a transfer space beside the toilet in future.

(d) Toilet Adjacent to Wall:

Requirement: Toilet to be located adjacent to a wall that is of sufficient size to provide backing for grab bars.

Recommendation: Provide an option where a toilet is not adjacent to a wall but is provided with alternative grab bar backing arrangement.

# 3.0 EARTHQUAKE DESIGN SPACE STUDY

## 3.1 Background

The BCBC 2024 has adopted changes to the earthquake and structural provisions found in Part 4 of the Code from the NBC to better reflect current understanding of earthquake effects. The BCBC 2024 includes a substantial update of the earthquake hazard information to reflect current seismicity knowledge and establish compatibility with modern hazard maps in other jurisdictions. Most of the Part 4 changes were already enacted at the time of writing this report, however the Province has provided a transition period; allowing the adaptable dwellings and earthquake design provisions to come into effect March 10, 2025. The transition period provides local governments, the construction industry, education providers, as well as government time to produce training and education materials.

The earthquake design study was developed with regards to the provisions of Part 4 of the BCBC and the referenced design standard. Terminology in the report is consistent with terminology defined in the Code and referenced standards.

There are numerous changes to the seismic[4] provisions of Part 4 to better reflect current understanding of seismic effects, but the focus of this report is the key impacts summarized below:

1) Seismic spectral data is obtained via an internet database based on specific street address instead of including the spectral data in list format organized by municipality.
2) Seismic demands are often increased from the previous Code depending on location and soil properties which can amplify or dampen seismic motions.
3) Sites with softer soils may have a larger amplification of seismic motions than equivalent soils in previous editions.

The soil beneath a structure significantly impacts the seismic forces it receives. Soils amplify ground motions, with softer soils creating more amplification than harder soils. This effect is captured in BCBC 2018 and 2024 with site classes which categorizes soils based on soil properties, typically given by the Geotechnical Engineer of Record.

[4] Earthquake and seismic wording are used interchangeably

**Image 3.1 – Table 4.1.8.4.-B Site Class Definitions from BCBC 2024**

**Table 4.1.8.4.-B**
**Site Classes, S, for Site Designation $X_S$**
Forming Part of Sentence 4.1.8.4.(3)

| Site Class, S | Ground Profile | Ground Profile Characteristics | | |
|---|---|---|---|---|
| | | Average Shear Wave Velocity in Top 30 m, $V_{s30}$, in m/s (1) | Average Standard Penetration Resistance in Top 30 m, $\bar{N}_{60}$, in Blows per 0.3 m | Average Undrained Shear Strength in Top 30 m, $\bar{s}_u$, in kPa |
| A | Hard *rock* (2) | $V_{s30} > 1\,500$ | n/a | n/a |
| B | *Rock* (2) | $760 < V_{s30} \le 1\,500$ | n/a | n/a |
| C | Very dense *soil* and soft *rock* | $360 < V_{s30} \le 760$ | $\bar{N}_{60} > 50$ | $\bar{s}_u > 100$ |
| D | Stiff *soil* | $180 < V_{s30} \le 360$ | $15 < \bar{N}_{60} \le 50$ | $50 < \bar{s}_u \le 100$ |
| E | Soft *soil* | $140 < V_{s30} \le 180$ | $10 < \bar{N}_{60} \le 15$ | $40 < \bar{s}_u \le 50$ |
| | | Any ground profile other than Site Class F that contains more than 3 m of *soil* with all the following characteristics:<br>plasticity index, PI > 20,<br>moisture content, w ≥ 40%, and<br>undrained shear strength, $s_u$ < 25 kPa | | |
| F | Other *soils* (3) | $V_{s30} \le 140$ | $\bar{N}_{60} \le 10$ | $\bar{s}_u \le 40$ |
| | | Any ground profile that contains<br>liquefiable *soil*, quick and highly sensitive clay, collapsible weakly cemented *soil*, or other *soil* susceptible to failure or collapse under seismic loading,<br>more than 3 m of peat and/or highly organic clay,<br>more than 8 m of highly plastic *soil* (with PI > 75), or<br>more than 30 m of soft to medium-stiff clay | | |

Site Class A provides the least amplification, while site class E provides the most amplification. Site class F requires site specific geotechnical evaluation which is outside the scope of this study.

Soil amplification factors changed significantly between BCBC 2018 and 2024. As an example, forces for a building designed for some of the more difficult soil conditions in Victoria, soil class D, will see an increase of seismic force of approximately 180% from the BCBC 2018 to the 2024. This represents the upper end of force increase encountered in the province. A more detailed comparison of various sites is presented in table format, refer to Section 3.3 of this report.

This report attempts to summarize the space and cost impacts associated with the key changes to earthquake provisions of Part 4 for typical residential buildings.

## 3.2 Design Baseline

The following typologies and locations have been selected for analysis as the most common multi-family residential developments in BC based on consultation with industry professionals and Ministry staff. These, based on industry feedback, are as follows:

1) Light wood frame townhouses
2) 6 storey light wood frame mid-rise
3) 20 storey cast-in-place concrete tower

Townhouses, as smaller and lighter buildings, are not as strongly affected by seismic forces as larger buildings. Townhouses are also exempt from adaptability changes in the Code. For these reasons, townhouses are not included in this report.

In addition to the building types noted above, the following special cases were explored based on stakeholder feedback:

1) 18 storey concrete core with CLT floors instead of concrete slabs
2) 40 storey concrete tower in Burnaby
3) 12-15 storey concrete tower in site class D/E in Victoria

In summary, the following case studies were analysed:

1) 6 storey wood frame mid-rise
2) 20 storey concrete tower
3) 18 storey mass timber tower (concrete core with CLT floors)
4) 40 storey concrete tower in Burnaby
5) 12-15 storey concrete tower in Victoria

### 3.2.1 Limitations of Design Examples

A large range of building types and locations are considered in the scope of this study. To carry out this study in a reasonable timeline and to simplify the results for the end user, the buildings were made as simplistic as possible. As an example, none of the residential buildings included commercial podium, ground floor amenity space, or sloping site. It is important to note that the structural findings are not meant to establish expectations as to the size and location of structural elements in future buildings. The structures selected are merely used as a benchmark for the purpose of estimating the relative impacts on the structure due to code change. Structural requirements in a proposed development can significantly vary depending on the specific size, geometry, dead load assumptions, and complexity of any future building. Furthermore, the structural design is preliminary in nature and detailed analysis to Tender level of detail may result in some changes to design decisions.

### 3.2.2 6 Storey Wood Frame Mid-Rise

This prototype has 5 wood framed suspended floors and an unoccupied wood roof structure. Refer to Section 3.4 for the typical floor arrangement and structural wall locations. The floor to floor height is 10’-0”.

Most buildings of this type start on a suspended concrete structure below grade. The concrete portion of the building was not included in the study. For wood frame buildings starting on grade, seismic forces below grade are negligible and do not govern the structural design of concrete portion. the study focuses on impacts to the above grade wood frame and its lateral force resisting system (wood shearwalls).

Earthquake design inherently requires an understanding of the weight of the building and structural design principals. The following provides the assumptions used in this study, consistent with typical building design.

The wood floor design weight in pounds per square foot (psf) is 41psf (2kPa) which includes self weight, 1-1/2” concrete topping, 2 layers of 5/8” type X drywall encapsulation, and allowance for miscellaneous mechanical and other finishes. Partition loading allowance was 15psf for seismic conditions which is greater than the minimum of 10psf as per Part 4 of the Code. Live load is 40psf (1.9kPa) for residential occupancy as prescribed in Part 4 of the Code.

The roof design weight is 20psf (1.0kPa) which includes self weight, flat roof allowance, and miscellaneous mechanical and other finishes. As prescribed in the code an allowance for 25% snow load is also included and varies depending on the site. Half of the seismic partition load is also added to the roof level as seismic weight.

Shearwalls for the wood frame building consist of conventional stud walls with wood based sheathing with force modification factors of Rd = 3.0, and Ro = 1.7 as prescribed in Part 4. Corridor shearwalls are used for longitudinal building forces (X direction) and Party Walls are used for the transverse direction (Y direction). Refer to Figure 3.2 for typical shearwall assemblies for Corridor and Party Walls used for this study.

### 3.2.3 20 Storey Concrete Tower

The 20 storey concrete condominium has 19 suspended concrete floors and an occupied roof slab. Refer to figures in Section 3.3 for the typical floor arrangement and wall locations. The floor to floor height is assumed to be 9’-10” which is common in residential towers. The building area is 8,500 sq ft for the purposes of the earthquake study.

Most concrete towers start on a concrete podium and parking structure. The podium and parking structures are not included in the study. Modelling the effect of above grade podium levels would require podium level floor plate designs, and additional cores to support the podium levels, both were outside the scope of this study. Modelling parking structures requires additional information such as the number of parking levels, and soil properties that were outside the scope of this study. Including below grade effects would slightly reduce the period of the building. Ignoring below grade effects produces a conservative design, ie. A building designed ignoring below grade effects is still structurally sufficient when including below grade effects. the study focuses on the above grade tower and associated lateral force resisting system (LFRS). Core foundations were also included in the study assuming that the overturning moment in the LFRS is constant below the first storey.

The floor design loads assume 8” thick concrete slabs with 25psf (1.2kPa) superimposed dead loading for finishes and M&E, and 10psf partition load as per Part 4. Live load is 40psf (1.9kPa) for residential occupancy as per Part 4.

The roof design load also assumes a 10” thick concrete slab but allows for 100psf

(4.8kPa) to account for concrete pavers, roofing material, and some fixed planters. 25% of snow load is assumed to be included in 100psf (4.8kPa), consistent with standard design practice.

The LFRS for the concrete towers consist of a centralized stair/elevator walls with ductile cast-in-place concrete. The base concrete strength used is 45Mpa but is increased as needed in locations with very high seismic forces and is decreased where practical to 35MPa for Design Group 4 and 5 for a more realistic design.

#### 3.2.4 12-15 Storey Concrete Tower

Analysis of 12 and 15 storey concrete towers were also performed for Design Group 1 with the intent of reducing the seismic forces by using a lighter building. We found the difference in seismic forces between a 12 and 15 storey tower to be ~10%, so the results were combined in this study.

#### 3.2.5 40 Storey Concrete Tower

Preliminary analysis of a 40 storey tower in Burnaby found that the building was wind governed and not seismically governed with BCBC 2024 seismic loads. Meaning at this height the wind forces would dictate the design of the concrete core, there would be no difference in core sizes between the different Codes at the schematic design stage. As per the code, this building would also require wind tunnel analysis to determine wind loads, which is not within the scope of this study. Based on the above a study for a 40 storey concrete core design was not developed for seismic purposes.

### 3.2.6 18 Storey Mass Timber Tower

The tallest mass timber building prescribed in Part 3 of the Code is 18 storeys. For simplicity a mass timber building was studied by using the same building as the 20 storey concrete tower but substituting the concrete slab with a 5ply 175mm (6-7/8") thick CLT panel. The only difference is the reduced self weight, but all other assumptions remained the same.

To simplify the analysis, a 20 storey building was used in this study. We expect an 18 storey building to have a ~5% reduction in seismic forces and wall thicknesses, compared to the 20 storey building reviewed in this study which is, in our opinion, negligible.

It should be noted that mass timber high-rises with concrete cores are a relatively new technology with significantly less design development than conventional structural systems. Detailed analysis and design of mass timber-concrete hybrid structures and its associated challenges are beyond the scope of this report.

## 3.3 Methodology

Based on feedback from industry professionals, the following areas were to be considered for analysis: Victoria, Richmond, North Vancouver, Surrey/Langley Skytrain route, and Kelowna.

The purpose of this study is to analyze the impact at these locations for site soil classifications A through E. In order to manage the volume of work and amount of data output from the study, we combined location and soil classification into "Design Groups" (DG) such that there would not be more than 20% difference from the design value used for the group and any site included in the group.

The design groups were determined separately for the 6 storey light wood frame mid-rise and the 20 storey concrete tower based on assumed building period of 0.5s and 2.0s respectively. This resulted in different design groups for wood frame and concrete as summarized in the tables below.

### 3.3.1 Wood Frame Mid-Rise Design Groups

**Table 3.3.1-A – Design Group 1:**

| Location | Seismic Site Classification |
|---|---|
| Victoria | C, D, E |

**Table 3.3.1-B – Design Group 2:**

| Location | Seismic Site Classification |
|---|---|
| Victoria | B |
| Richmond | C, D, E |
| North Vancouver | C, D, E |
| Surrey/Langley | C, D, E |

**Table 3.3.1-C – Design Group 3:**

| Location | Seismic Site Classification |
|---|---|
| Victoria | A |
| Richmond | B |

**Table 3.3.1-D – Design Group 4:**

| Location | Seismic Site Classification |
|---|---|
| North Vancouver | A, B |
| Richmond | A |
| Surrey/Langley | A, B |
| Kelowna | E |

**Table 3.3.1-E – Design Group 5:**

| Location | Seismic Site Classification |
|---|---|
| Kelowna | C, D |

### 3.3.2 Concrete Tower Design Groups

**Table 3.3.2-A – Design Group 1:**

| Location | Seismic Site Classification |
|---|---|
| Victoria | D, E |

**Table 3.3.2-B – Design Group 2:**

| Location | Seismic Site Classification |
|---|---|
| Victoria | B |
| Richmond | C, D, E |
| North Vancouver | C, D, E |
| Surrey/Langley | C, D, E |

**Table 3.3.2-C – Design Group 3:**

| Location | Seismic Site Classification |
|---|---|
| Victoria | A, B |
| Richmond | C |
| North Vancouver | C |
| Surrey/Langley | C |

**Table 3.3.2-D – Design Group 4:**

| Location | Seismic Site Classification |
|---|---|
| North Vancouver | A, B |
| Richmond | A, B |
| Surrey/Langley | A, B |
| Kelowna | D, E |

**Table 3.3.2-E – Design Group 5:**

| Location | Seismic Site Classification |
|---|---|
| Kelowna | C |

### 3.3.3 Wood Framed Design Process

The wood framed design seismic design was carried out in accordance with CSA-O86 *"Engineering Design in Wood"* using proprietary spreadsheets. The key processes can be summarized as follows:

- Rd = 3.0 and Ro = 1.7[5] for conventional wood based sheathed stud walls.
- Seismic Forces to each storey determined using the static method in Part 4 and the prescriptive building period based on building height.
- Seismic forces assigned to each wall according to tributary area assuming flexible diaphragm behaviour.
- Shearwall strength determined in accordance with CSA-O86.
- Overturning forces amplified as per CSA-O86 for design of tie-down systems and diaphragm design.
- Building deflections calculated with iteration procedure using calculated building period and wall deflections calculated as per CSA-O86.
- Wind loads checked and more severe of wind or seismic forces are used for design.

### 3.3.4 Concrete Design Process

The concrete design process was carried out using commercially available and widely used 3D modelling software in accordance with Part 4 and associated CSA-A23 *"Concrete Materials and Methods of Concrete Construction / Test Methods and Standard Practices for Concrete"* design standard. The key process can be summarized as follows:

- Dynamic Analysis (Response Spectrum Method) in accordance with Part 4.
- Rd= 4.0 and Ro=1.7[5] for coupled wall direction assuming ductile concrete shearwalls.
- Rd= 3.5 and Ro =1.6 for non-coupled direction, also assuming ductile concrete shearwalls.
- Log-log interpolation of response spectrum was studied but found to be insignificantly different from linear interpolation for building periods under 2s.

[5] Rd and Ro are factors used to account for reduction in seismic force and additional strength dependant on the type of construction. Higher values are associated with better structural performance. Rd is the ductility factor which represents the ability of a building to dissipate seismic energy through damage to the structural system. Ro is the overstrength factor which represents additional strength the structural system has from different sources such as the difference between design values and real material properties.

- Coupled headers are 2′-6″ (750mm) in depth assuming a 7′-4″ (2.24m) door rough opening height.
- Concrete thickness was confirmed but rebar was not designed. The overstrength for shearwalls was assumed to be 3.0 based on previous project experience.
- Rotational demand was assumed to be 0.12 based on past project experience.
- Rotational demand was calculated for Design Group 1 - 2024 designs to reduce rotational demand.
- For Design Group 1 - 2024, it was assumed mass irregularity per Article 4.1.8.6 due to a heavy roof assembly could be avoided, making the building regular. Dynamic forces were scaled to 0.8V per Sentence 4.1.8.12.(8).
- Wind loading was checked and the more severe of seismic or wind forces were used for design checks.

## 3.4 Findings

In all design groups there is an increase in force level when comparing the 2018 BCBC to the 2024 BCBC. As a result there is always an increase in structural requirements which may or may not be a significant cost depending upon the location. The most significant increase was in design group #1 where a significant design change was required for both 6 storey wood frame and concrete tower buildings.

### 3.4.1 Wood Frame Mid-Rise

The building structure is described in the table below. In all cases, the nail density and tie-rod sizes increased from the 2018 to the 2024 version due to an increase in shear. For the purposes of this study only potential space impacts has been outlined below.

**Table 3.4.1-A – 6 Storey Wood Frame Comparison**

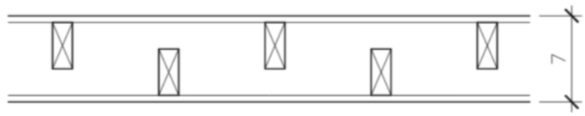
| DESIGN GROUP | 2018 Design | 2024 Design Changes |
|---|---|---|
| 1 | Double sided sheathed stud walls required up to 5th storey for both party and corridor walls | New two row stud wall with each stud with double sided sheathed for corridor walls |
| 2 | Double sided sheathed stud walls at 2nd and 3rd storey in both party and corridor walls | Double sided sheathed stud walls at 2nd to 4th storey in both party and corridor walls. |
| 3 | One sided sheathed stud walls throughout | Double sided sheathed stud walls at 2nd and 3rd storey for corridor walls |
| 4 | One sided sheathing stud walls throughout | Double sided sheathed stud walls at 2nd storey for corridor walls |
| 5 | One sided sheathing stud walls | No change other than increase in nail density and tie-rod size |

Earthquake design area for interior and demising walls is consistent. Changes noted in the table for earthquake design are capture change in corridor wall type between BCBC 2018 and 2024.

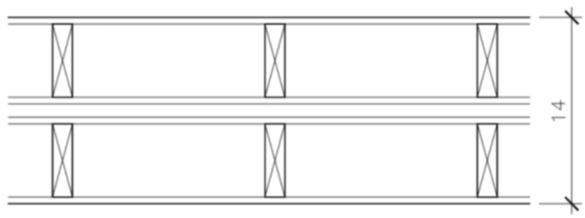
**Table 3.4.1-B – Wood Frame Mid-Rise Cumulative Area Impacts**

| | BCBC 2018 | BCBC 2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Design Group 1 | 204 | 408 | 204 | 50% |
| Design Group 2 to 5 | - | - | - | - |

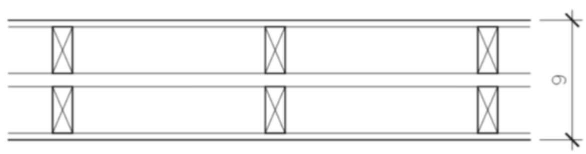
**Table 3.4.1-C – Wood Wall Schedule**



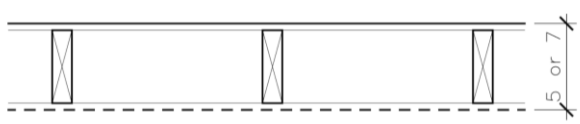

**W1 – Corridor Shearwall**
- 2x4 studs staggered on 2x6 wall plates
- Sheathing on both sides of walls




**W2 – Corridor Double Shearwall**
(Design Group 1 - 2024 Only)
- Two rows of 2x6 studs
- Sheathing on both sides of each stud row

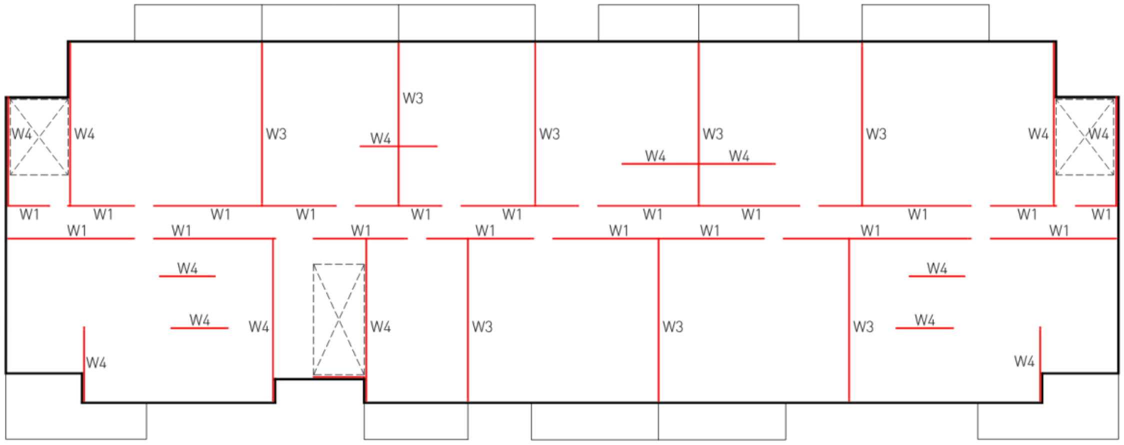



**W3 – Party Wall Shearwall**
- Two rows of 2x4 studs
- Sheathing on outside face of each row

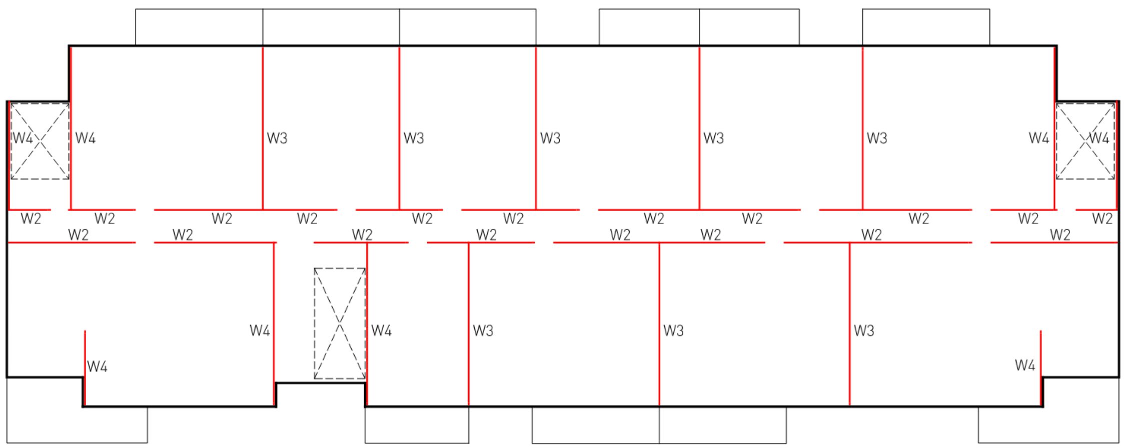



**W4 – Interior/Exterior Shearwall**
- 2x4 (interior) or 2x6 (exterior) studs
- Sheathing on one or both sides of wall

**Image 3.4.1-A – Wood Frame Mid-Rise Design Group 1 Comparison Plan**



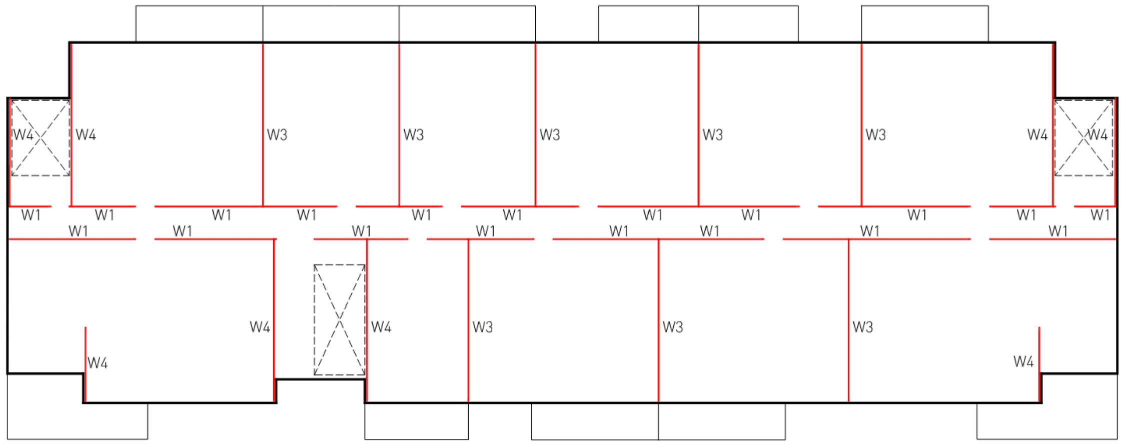
**Design Group 1 – BCBC 2018**



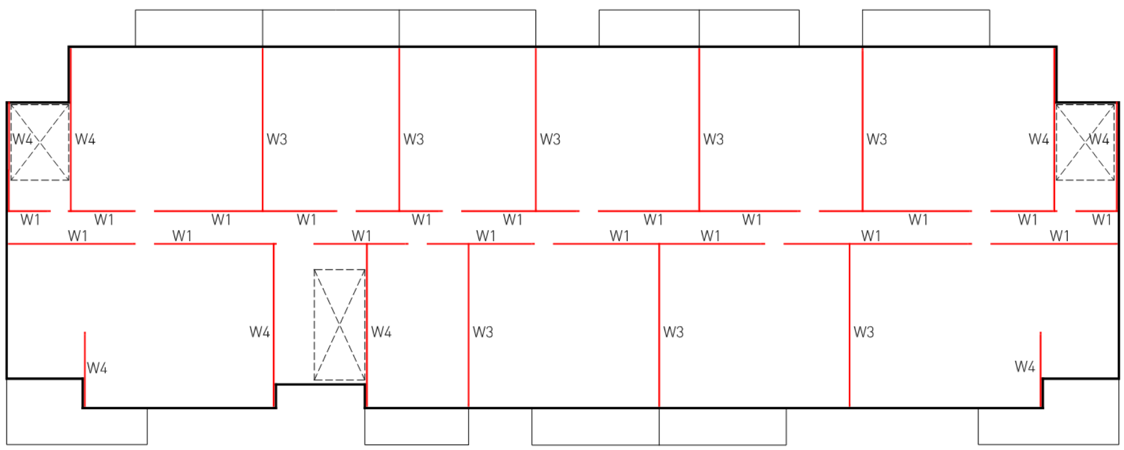
**Design Group 1 – BCBC 2024**

The typical wood-frame walls used in such projects at corridors 2x6 walls with 2x4 staggered studs (W1) were found to be structurally unfeasible under Design Group 1 - 2024. To meet seismic demands, double walls with 2x6 studs (W2) in each corridor wall were required. Wall segments needed sheathing on both sides, resulting in a total of four sheathing layers per wall. Each segment also required end stud packs and steel tie-downs. Consequently, the design incorporated double walls in both corridor and party walls from 2nd to 4th storey. Additionally, small segments of walls at corridors or interior locations became unsuitable as shear walls due to excessive deflection, necessitating the exclusive use of longer wall segments as shear walls to meet the 2.5% drift limit.

**Image 3.4.1-B – Wood Frame Mid-Rise Design Group 2 to 5 Comparison Plan**




**Design Group 2 to 5 – BCBC 2018**




**Design Group 2 to 5 – BCBC 2024**

### 3.4.2 Concrete Tower

**Table 3.4.2-A – Concrete Tower Area Impact Comparison**

| | BCBC 2018 | BCBC 2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Design Group 1 | 930 | 1,300 | 370 | 39.8% |
| Design Group 2 | 822 | 1088 | 266 | 32.4% |
| Design Group 3 | 812 | 850 | 38 | 4.7% |
| Design Group 4 | 728 | 756 | 28 | 3.8 |
| Design Group 5 | 676 | 676 | 0 | 0.0% |

**Table 3.4.2-B – Percent Comparison of Total Shearwall Thickness**

| Baseline Tower | Comparison Tower | Total Cantilever Direction % Increase in Wall Thickness (a) | Total Coupled Direction % Increase in Wall Thickness (b) |
|---|---|---|---|
| DG 1 - 2018 | DG 1 - 2024 | *81% | 95% |
| DG 1 - 2018 12-15 Storey | DG 1 - 2024 12-15 Storey | *60% | 89% |
| DG 1-2024 20 Storey | DG 1 - 2024 12-15 Storey | *0% | -8% |
| DG 2 - 2018 | DG 2 - 2024 | 71% | 87% |
| DG 3 - 2018 | DG 3 - 2024 | 14% | 13% |
| DG 4 - 2018 | DG 4 - 2024 | 21% | 9% |
| DG 5 - 2018 | DG 5 - 2024 | $0% | $0% |

* = No cantilever wall system in design
$ = Min 14” thick wall was sufficient
DG = Design Group
(a) = Cantilever Direction Thickness
(b) = Coupled Direction Thickness

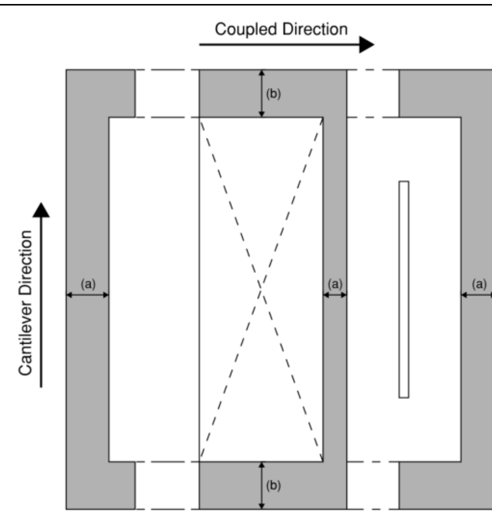
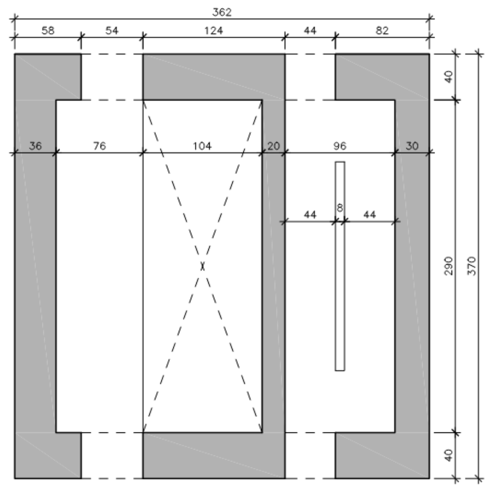
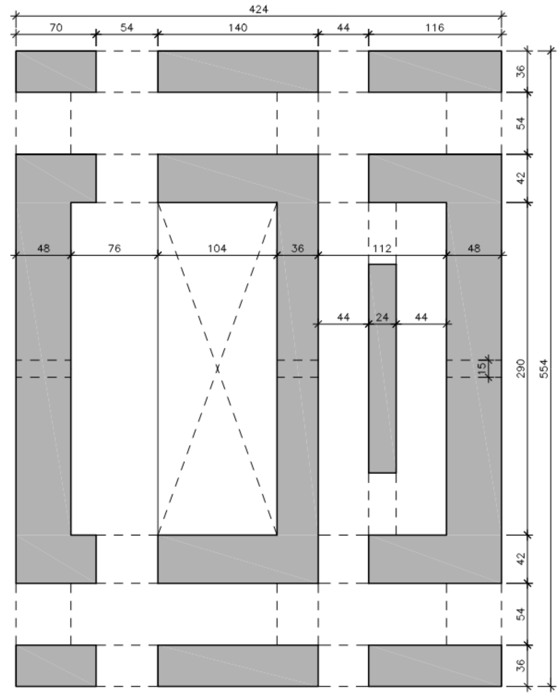


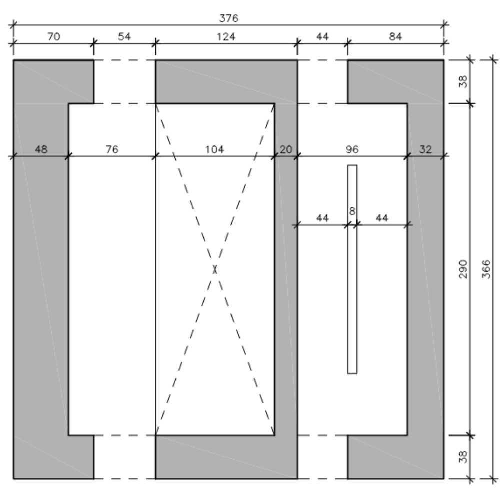
**Image 3.4.2-A – Concrete Tower Design Group 1 Comparison Plans**



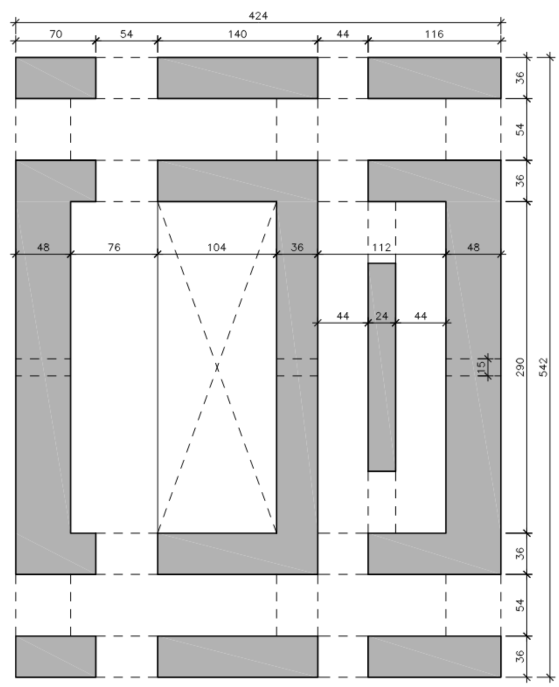

**20 Storey - BCBC 2018**




**20 Storey - BCBC 2024**



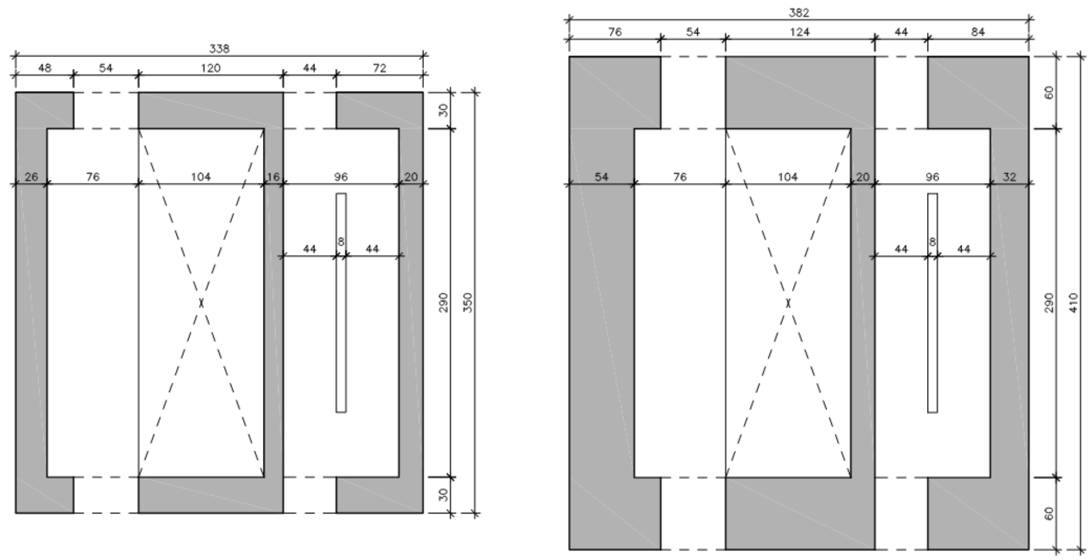

**12-15 Storeys - BCBC 2018**




**12-15 Storeys - BCBC 2024**

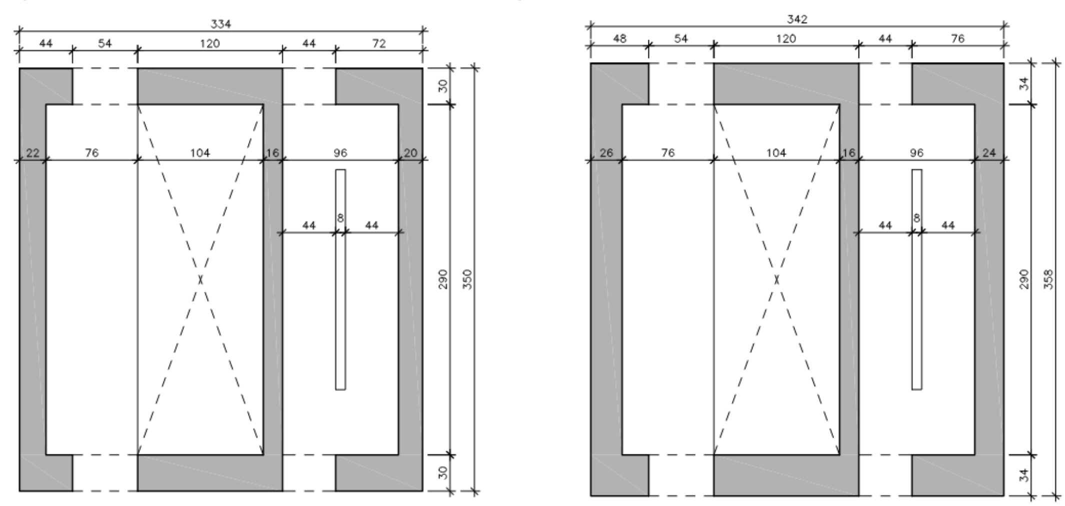
A conventionally shaped core for Design Group 1 was found to be structurally unfeasible. Additional hallway walls were required primarily to not exceed a 5ft thick wall, which was considered non-constructable for this study. Splitting the walls also allowed for a 20% increase in RdRo in the “cantilever” direction and reduced the stiffness in the “coupled” direction, helping to mitigate the feedback loop effect of increased wall thicknesses decreasing period, therefore increasing wall thicknesses again to accommodate the increased seismic force. Slits in the middle of the cantilever walls were required to meet the necessary degree of coupling of a ductile coupled wall system and achieve the RdRo increase, while having minimum impact on the shear capacity of the walls. These openings may be investigated with further study to better coordinate with entrances to units.

**Image 3.4.2-B – Concrete Tower Design Group 2 Comparison Plan**



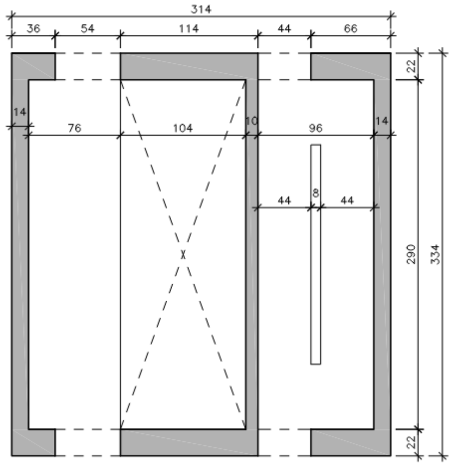

**BCBC 2018** **BCBC 2024**

**Image 3.4.2-C – Concrete Tower Design Group 3 Comparison Plan**

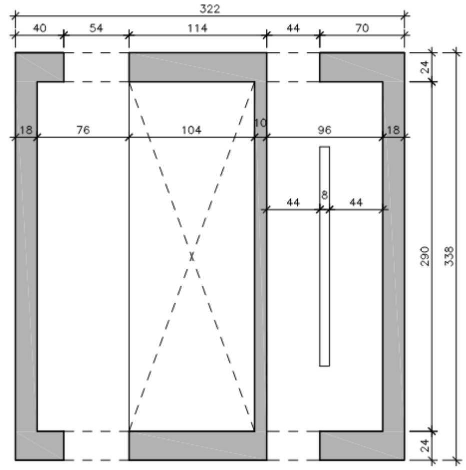



**BCBC 2018** **BCBC 2024**

**Image 3.4.2-D – Concrete Tower Design Group 4 Comparison Plan**

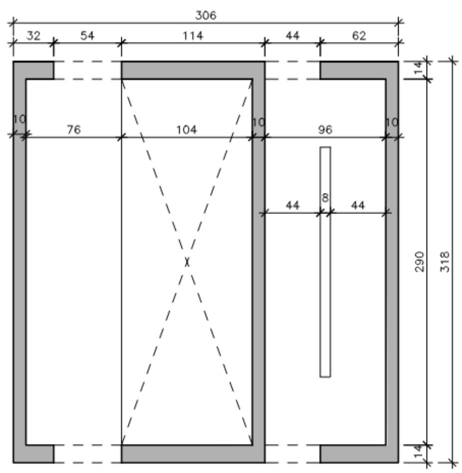



**BCBC 2018**




**BCBC 2024**

**Image 3.4.2-E – Concrete Tower Design Group 5**




**BCBC 2018 & 2024**

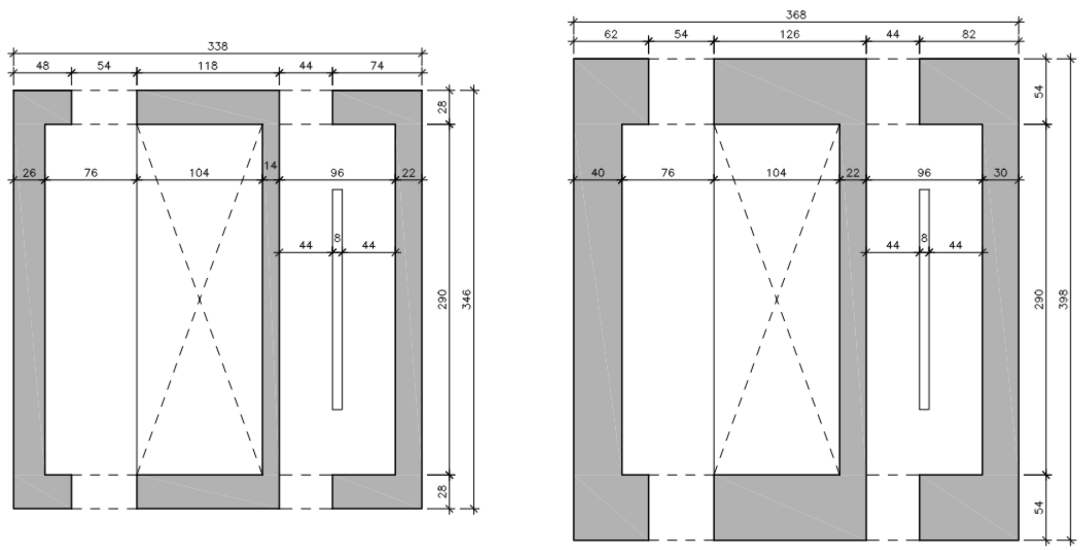
### 3.4.3 Mass Timber Tower

**Table 3.4.3 – Mass Timber Tower Area Impact Comparison**

| | BCBC 2018 | BCBC 2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Design Group 1 | 812 | 1,017 | 205 | 25.2% |
| Design Group 2 | 742 | 909 | 167 | 22.5% |
| Design Group 3 | 715 | 761 | 46 | 6.4% |

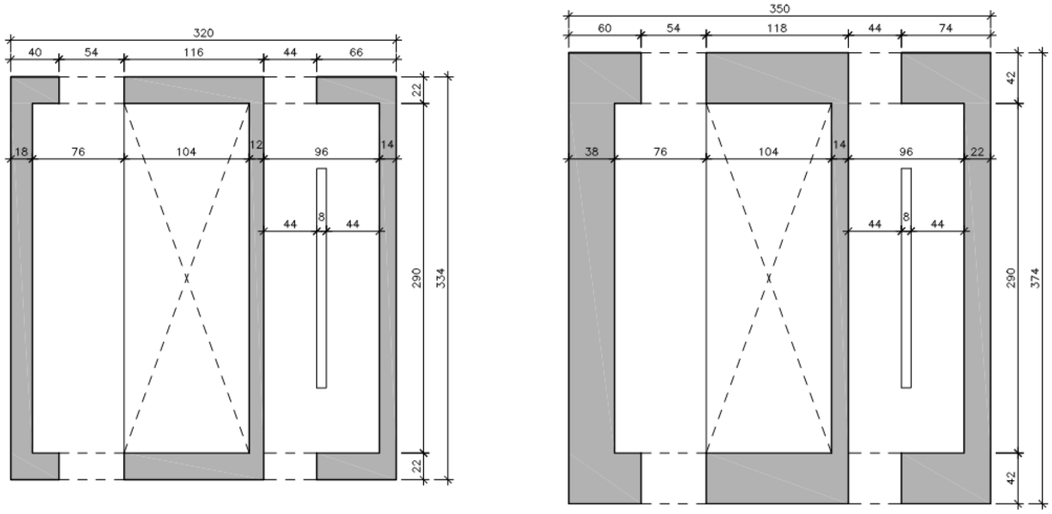
Our analysis found that the seismic weight of Cross Laminated Timber (CLT) floor systems was about ~55% less than that of a concrete floor system. However, the concrete core itself provides considerable mass. Furthermore, the building fundamental period decreases with reduced mass which increases forces. The end result is a ~30% decrease in wall thickness for Design Group 1, 2, and 3.

**Image 3.4.3-A – Mass Timber Tower Design Group 1 Comparison Plan**



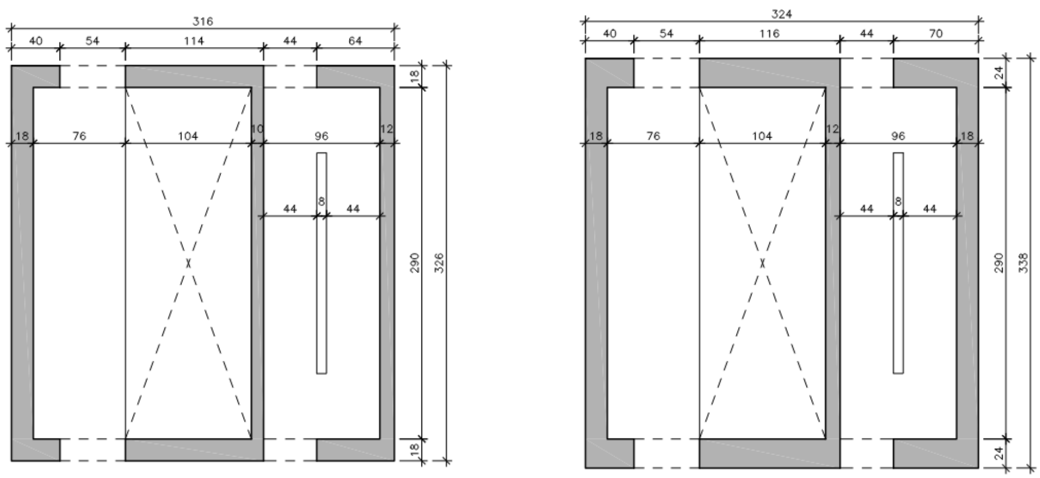

**BCBC 2018** **BCBC 2024**

**Image 3.4.3-B – Mass Timber Tower Design Group 2 Comparison Plan**




**BCBC 2018** **BCBC 2024**

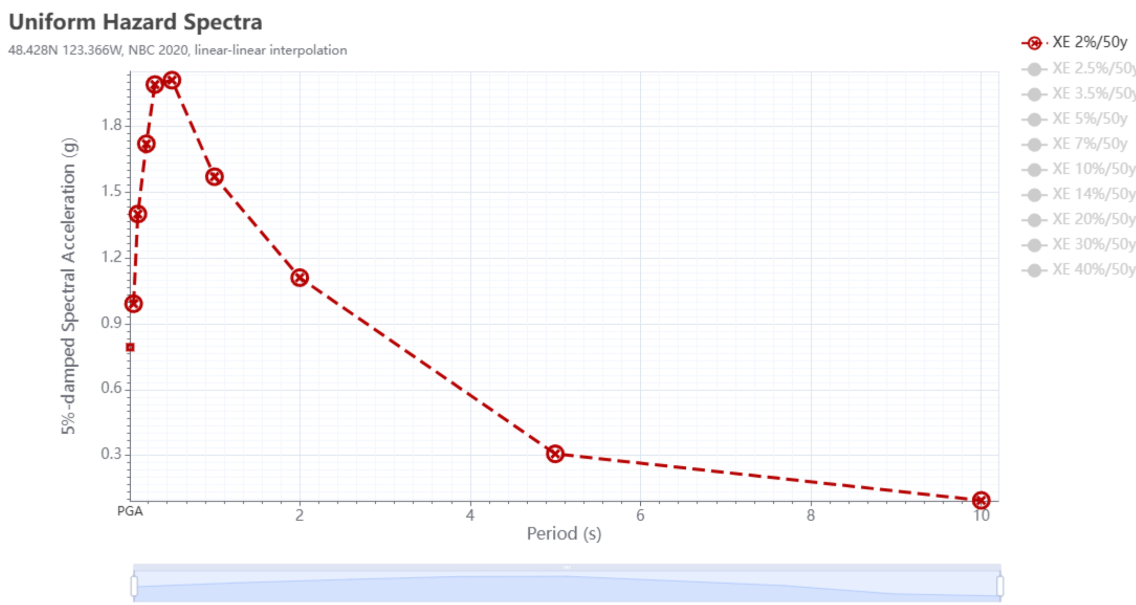
**Image 3.4.3-C – Mass Timber Tower Design Group 3 Comparison Plan**




**BCBC 2018** **BCBC 2024**

#### 3.4.4 12-15 Storey Concrete Tower

The difference between the 15 storey tower in comparison to the 20 storey tower is that the mass of the building is reduced. However, the shorter buildings have much lower building period of vibration which acts to increase the forces. The end result is that there is only a minor reduction in forces and concrete core size when comparing 15 storeys due to the steepness of the spectral demand curve at building periods below 2 seconds, see figure below.




For similar reasons, a 12 storey tower encounters the same issues of increasing seismic forces due to decreased fundamental period. Our analysis found that reducing to 12 storeys only reduced wall thicknesses ~10%, which for the purposes of this study were considered negligible. For this reason, the 12 and 15 storey options were grouped.

#### 3.4.5 40 Storey Concrete Tower

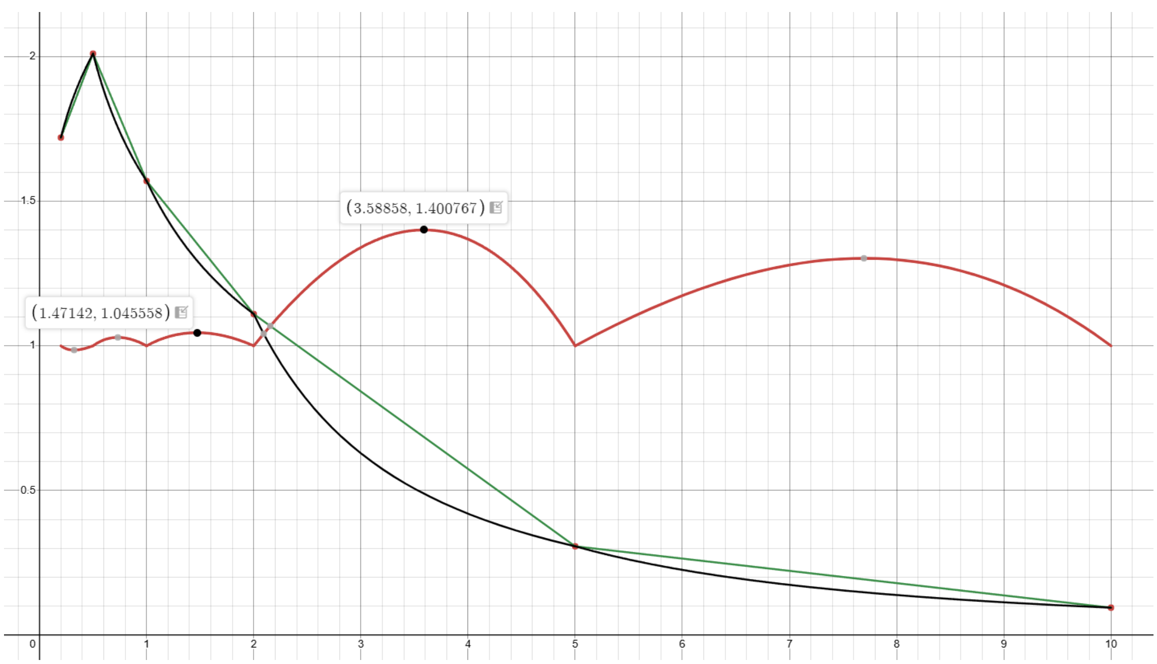
The 40 storey tower is strongly impacted by higher winds at higher altitudes, its large exposed areas to wind forces, and the tight deflection criteria for wind loading in the BCBC. Seismic deflections are permitted to be the height of the building divided thru by 40, ie H/40 (2.5%H). However, wind deflections are a magnitude of order tighter at H/500. Such buildings also have long fundamental periods, reducing seismic forces. We found for this study the wind deflection requirement governed over the seismic strength requirements.

### 3.4.6 Log-log Interpolation

NBC 2015 and 2020 give seismic acceleration values (Sa) at certain fundamental periods (T). These periods are 0, 0.2, 0.5, 2.0, 5.0, and 10 seconds. Designers are required to interpolate these values to find intermediate Sa values. NBC allows either linear interpolation, or log-log interpolation. Theoretically, log-log interpolation produces lower intermediate Sa values for decreasing response spectrum and would be preferred for design. In practice, the reduction vs linear interpolation is negligible at periods less than 2.0 seconds. The buildings considered in this study mostly had fundamental vibration periods below 2s and therefore were not significantly impacted by using log-log interpolation versus the faster linear interpolation. As such, we used linear interpolation for most of the designs.

In the figure below, green is linear interpolation, black is log-log interpolation, and red is the ratio of the two. Below 2s, it can be seen that linear and log-log interpolation are very similar.

**Image 3.4.6-B – Equations Resulting Graph**



### 3.4.7 Concrete Core Foundations

The concrete core foundations for the 20 storey concrete and 18 storey mass timber towers are summarized below.

**Table 3.4.2 – Core Footing Comparison – Concrete & Mass Timber Towers**

| Scenario | | 2018 BCBC | | | 2024 BCBC | | |
|---|---|---|---|---|---|---|---|
| **Design Group** | **Building Type** | **Length (m)** | **Width (m)** | **Depth (mm)** | **Length (m)** | **Width (m)** | **Depth (mm)** |
| 1 | Concrete | 27 | 27 | 3500 | 32 | 32 | 3500 |
| 1 | CLT | 22 | 22 | 3000 | 26 | 26 | 3000 |
| 2 | Concrete | 19 | 19 | 2500 | 24 | 24 | 2500 |
| 2 | CLT | 17 | 17 | 2250 | 20 | 20 | 2250 |
| 3 | Concrete | 14 | 14 | 2000 | 15 | 15 | 2000 |
| 3 | CLT | 14 | 14 | 1800 | 14 | 14 | 1800 |
| 4 | Concrete | 12 | 12 | 1800 | 12 | 12 | 1800 |
| 5 | Concrete | 11 | 11 | 1200 | 11 | 11 | 1200 |

## 3.5 Conclusion

The new seismic provisions have a significant impact to the lateral force resisting systems. It is our opinion that increases in seismic demand in Design Group 2 to 5, while significant, will not be onerous for industry to implement. However, the impacts to buildings in Design Group 1 (Victoria site class D & E) not only impact the cost, but also the space used by the structure. Conventional shearwalls are no longer adequate to handle the forces and require new solutions that are not normally used in structural design.

In Design Group 1, the advantages of lighter building solutions such as mass timber may become a viable option in the more extreme seismic locations/soil conditions.

Below is a list of options that may be considered for further refining and optimizing the earthquake design of a building:

(a) For mid-rise wood-frame construction in high seismic regions with poor soil conditions, design choices should focus on reducing the seismic weight of the building. This can be achieved by exploring options such as replacing the concrete topping with lightweight acoustic mats or removing the brick veneer from the building exterior. Architectural designs should also aim to provide longer shear wall segments at corridors by optimizing the distance between unit entry doors.

(b) Since the current industry-standard shear wall assembly for corridor walls was deemed unfeasible, alternative assemblies should be explored. One solution adopted in this study involves using doubling up of corridor wall segments. Other potential solutions could include mid-ply shear walls which is currently in the code.

(c) FP innovations is also researching a higher capacity conventional plywood sheathed shearwalls using 2 rows of nails equivalent to nailing panel edges at 1" o/c. Depending on the results of the research, there may be higher strength shearwall options available soon that do not require significant changes to the Architectural assembly of the wall.

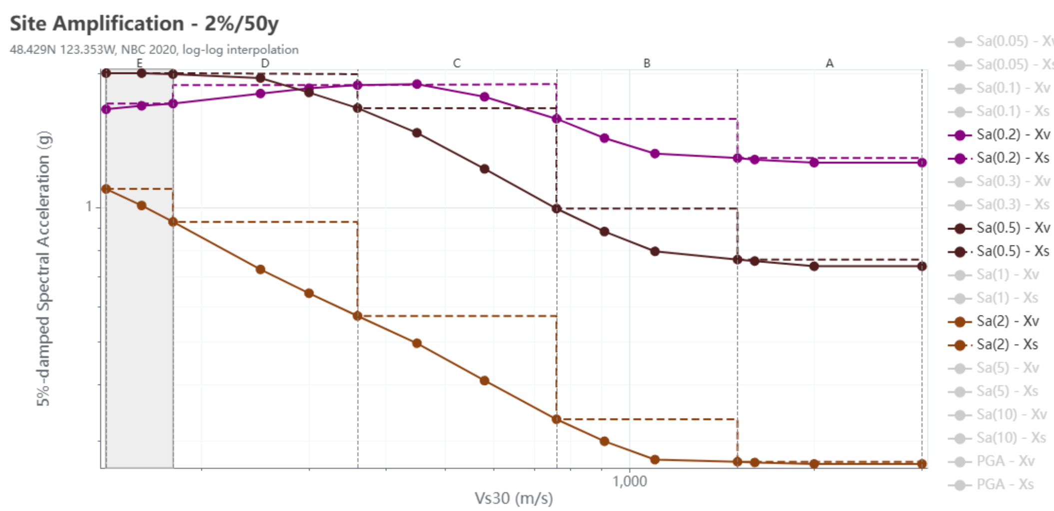
(d) The concrete tower buildings in this study have seismic structural systems that are considered "regular" in Section 4.1.8.6. This results in an expected 20% decrease in seismic force per Sentence 4.1.8.12.(8). In locations of high seimic demand, attempts should be made to confirm to the geometry limitations of a "regular" building whenever possible. We strongly recommend having these conversations with the client well be before the submission of development permit.

(e) More refined analysis and optimization may impact the structural design of the concrete towers in the detailed design phase. Possible impacts include:
- Refined overstrength calculation
- Below grade modelling to reduce stiffness and increase period
- Adding openings to the long side of the elevator to create futher coupling and softening of the structure to reduce period.
- Optimization of header geometry and rebar design to reduce overstrength
- Optimization of wall thicknesses per floor to reduce mass and stiffness

(f) Additional reduction in seismic force can be provided by the Geotechnical engineer depending on the specific soils encountered at a site. Additional geotechnical investigation may be worthwhile to reduce forces in a proposed building, examples are as follows:

- Using site specific Vs30 values can reduce soil amplification values. For example, for site class E Sa(2), potential reduction is 9% to 18% relative to using generic site class in calculations.

**Image 3.6 – Soil Amplification Plot from NBC 2020 Seismic Hazard Tool**




- Additional reduction can also come from performing a site response spectrum analysis (SRA). This is more involved and requires a significant investment but can yield significant reductions.

## 3.6 Recommendations

Review by the Code Committee of the 2.5% drift limit for normal importance buildings, particularly for wood frame. The Seismic Retrofit Guidance (SRG) produced by EGBC for upgrading of low-rise schools allows for a specific maximum drift values depending on the material of the gravity and/or lateral system. SRG guidelines allow less restrictive deflections for wood frame in comparison to conventional concrete structures as an example. Drawing upon the success of the SRG program, there may be possible justification for larger deflection limits for wood frame structures in the BCBC. This would greatly assist the feasibility of wood frame structure is Design Group 1 where deflections limited the design.

# 4.0 ADAPTABLE AND EARTHQUAKE CUMULATIVE SPACE STUDY

The BCBC 2024 contains changes to both adaptable dwelling unit and earthquake design provisions. This section of the report examines the cumulative effect on overall building floorplate size of these provisions.

The study examines two common construction typologies; a light wood frame mid-rise and a concrete tower. These typologies are interpreted to represent the typical forms of construction seen across the province. By comparing the general floor plates and unit floor plans of these two typologies, the report aims to quantify space planning changes and associated construction costs resulting from adaptability and seismic Code changes from baseline BCBC 2018 to BCBC 2024.

## 4.1 Design Baseline

Number of adaptable units: as the percentage of units required to be adaptable under BCBC 2018 could be set by individual jurisdictions, the baseline designs assume 0% adaptable to capture the greatest potential change in area.

### 4.1.1 Wood Frame Mid-Rise

The design baseline for the mid-rise building is a 6 storey light wood frame midrise. It is a commonplace linear building massing with a 1500 mm wide double-loaded corridor, a central elevator core with two elevators and two exit stairs at either end of the building. The unit mix includes a range of studio, one bedroom, two bedroom, and three bedroom units, as discussed with consultation groups, as follows:

**Table 4.1.1 – Wood Frame Mid-Rise Unit Mix**

| Unit type | Qty | Unit Mix (%) |
|---|---|---|
| Studio | 1 | 9 |
| 1-Bed | 2 | 18 |
| 1-Bed + Flex | 2 | 18 |
| 2-Bed + 2 Bath | 4 | 36 |
| 3-Bed + 2 Bath | 2 | 18 |
| Total | 11 | 100% |

### 4.1.2 Concrete Tower

The design baseline for the tower is a 20 storey concrete structure with a central concrete seismic core, including three elevators and two exit stairs in a scissor stair configuration. The 20 storey tower was selected because it is a common tower size in and around Victoria, the Fraser Valley and the Okanagan Valley. The unit mix includes a range of studio, one bedroom, two bedroom, and three bedroom units as follows:

**Table 4.1.2 – Concrete Tower Unit Mix**

| Unit type | Qty | Unit Mix (%) |
|---|---|---|
| Studio | 1 | 10 |
| 1-Bed | 3 | 30 |
| 1-Bed + Flex | 2 | 20 |
| 2-Bed + 2 Bath | 3 | 30 |
| 3-Bed + 2 Bath | 1 | 10 |
| Total | 10 | 100% |

## 4.2 Methodology

To allow the study to be completed within the time available the decision was made to examine the cumulative space impact for two of the reference Design Groups identified in Section 3.0.

Design Group 1 was selected to examine a worst case spatial impact, and Design Group 3 was selected to represent an average space impact for the new seismic requirements.

Typical floor plates were developed for each baseline building using the selected Design Groups to examine the cumulative impact of both adaptable and seismic requirements overall floorplate area.

For both baseline buildings, the impact of adaptable dwellings was minimal as one-bedroom and larger units were more easily adapted than micro unit and studio units. While an alternate baseline mix with a greater proportion of this units would amplify the contribution of adaptability on the cumulative space impact, the mix established following early consultation was carried forward.

## 4.3 Findings

### 4.3.1 Wood Frame Mid-Rise

**Table 4.3.1 – Wood Frame Mid-Rise Cumulative Area Impacts**

| | BCBC 2018 | BCBC 2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Design Group 1 | 8,770 | 9,020 | 250 | 2.9% |
| - Adaptable | 6,250 | 6,258 | 8 | 0.1% |
| - Earthquake | 204 | 408 | 204 | 50% |
| Design Group 2 to 5 | 8,766 | 8,790 | 24 | 0.3% |
| - Adaptable | 6,250 | 6,258 | 8 | 0.1% |
| - Earthquake | - | - | - | - |

Earthquake design area for interior and demising walls is consistent. Changes noted in the table for earthquake design are capture change in corridor wall type between BCBC 2018 and 2024.

Note: The adaptable and earthquake sq ft areas noted in the above table are not expected to equal the total sq ft area of its design group based on space for circulation and other factors.

**Image 4.3.1-A –Wood Frame Mid-Rise Design Group 1 Comparison Plan**


**Design Group 1 – BCBC 2018**
Building Area: 8,770 sq ft


**Design Group 1 – BCBC 2024**
Building Area: 9,020 sq ft

For Design Group 1, corridors increase in width to accommodate an additional wall plate supporting a row of 2x6 studs with two additional layers of sheathing. It is worth further noting that the additional sheathing requires both rows of studs to be sheathed on two sides, which would be challenging to construct using conventional construction methods and may require a move to prefabrication.

**Image 4.3.1-B –Wood Frame Mid-Rise Design Group 2 to 5 Comparison Plan**


**Design Group 2 to 5 – BCBC 2018**
Building Area: 8,766 sq ft


**Design Group 2 to 5 – BCBC 2024**
Building Area: 8,790 sq ft

Design Group 2 to 5 required no additional space to accommodate seismic provisions of BCBC 2024, so the cumulative spatial impact is the same as the adaptable dwelling unit impact.

### 4.3.2 Concrete Tower

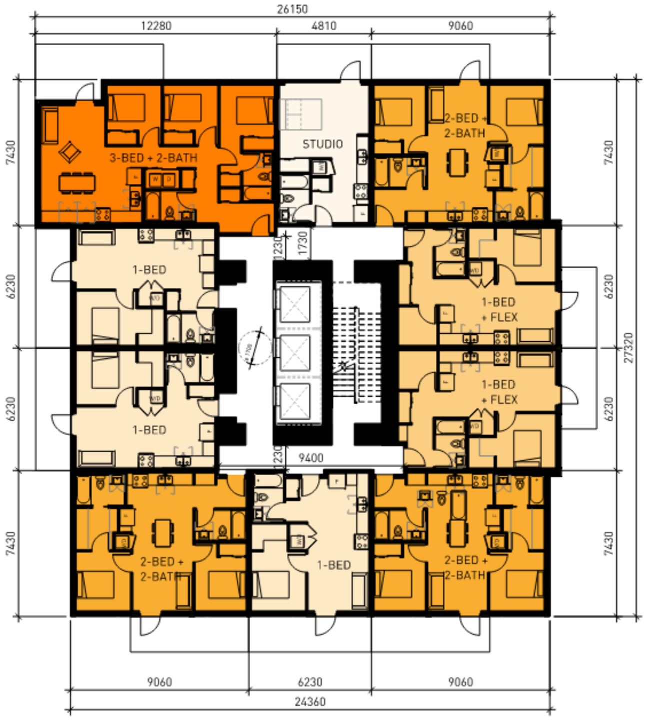
**Table 4.3.2 – Concrete Tower Cumulative Area Impact Comparison**

| | BCBC 2018 | BCBC 2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Design Group 1 | 7,368 | 7,746 | 378 | 5.1% |
| - Adaptable | 6,395 | 6,403 | 8 | 0.1% |
| - Earthquake | 930 | 1,300 | 370 | 39.8% |
| Design Group 2 | 7,260 | 7,534 | 5.1 | 3.8% |
| - Adaptable | 6,395 | 6,403 | 8 | 0.1% |
| - Earthquake | 822 | 1088 | 266 | 32.4% |
| Design Group 3 | 7,250 | 7,296 | 46 | 0.6% |
| - Adaptable | 6,395 | 6,403 | 8 | 0.1% |
| - Earthquake | 812 | 850 | 38 | 4.7% |
| Design Group 4 | 7,166 | 7,202 | 36 | 0.5% |
| - Adaptable | 6,395 | 6,403 | 8 | 0.1% |
| - Earthquake | 728 | 756 | 28 | 3.8 |
| Design Group 5 | 7,114 | 7,112 | 8 | 0.1% |
| - Adaptable | 6,395 | 6,403 | 8 | 0.1% |
| - Earthquake | 676 | 676 | 0 | 0.0% |

Note: The adaptable and earthquake sq ft areas noted in the above table are not expected to equal the total sq ft area of its design group based on space for circulation and other factors.

For Design Group 1, additional concrete walls are required on both sides of hallways adjacent to the core in order to meet seismic provisions. This results in an increase in floor plate size of approximately 380 sf over the baseline building.

**Image 4.3.2-A – Concrete Tower Design Group 1 Comparison Plans**




**Design Group 1 – BCBC 2018**
Floor Area: 7,368 sq ft


**Design Group 1 – BCBC 2024**
Floor Area: 7,746 sq ft

**Image 4.3.2-B – Concrete Tower Design Group 3 Comparison Plans**


**Design Group 3 – BCBC 2018**
Floor Area: 7,260 sq ft


**Design Group 3 – BCBC 2024**
Floor Area: 7,534 sq ft

## 4.4 Conclusion

In summary, the new adaptable unit and enhanced seismic requirements increased the gross floor area of Design Group 1 concrete building by approximately 380 sq ft. The gross area of Design Group 1 light wood frame and Design Group 3 concrete buildings modestly increased by approximately 2.9% and 5.1% respectively. The gross area of Design Group 3 light wood frame buildings had a minor increase that could be reduced with minor changes to architectural unit and floor plan layouts.

## APPENDIX A – FULL SCALE REPORT DRAWINGS

Image A-1- 6 Storey Midrise Floor Plate – Design Group 1, BCBC 2018

Image A-2 - 6 Storey Midrise Floor Plate – Design Group 1, BCBC 2024

Image A-3- 6 Storey Midrise Floor Plate – Design Group 3, BCBC 2018

Image A-4 - 6 Storey Midrise Floor Plate – Design Group 3, BCBC 2024

Image A-5 - 20 Storey Concrete Tower Floor Plate – Design Group 1, BCBC 2018

Image A-6 - 20 Storey Concrete Tower Floor Plate – Design Group 1, BCBC 2024

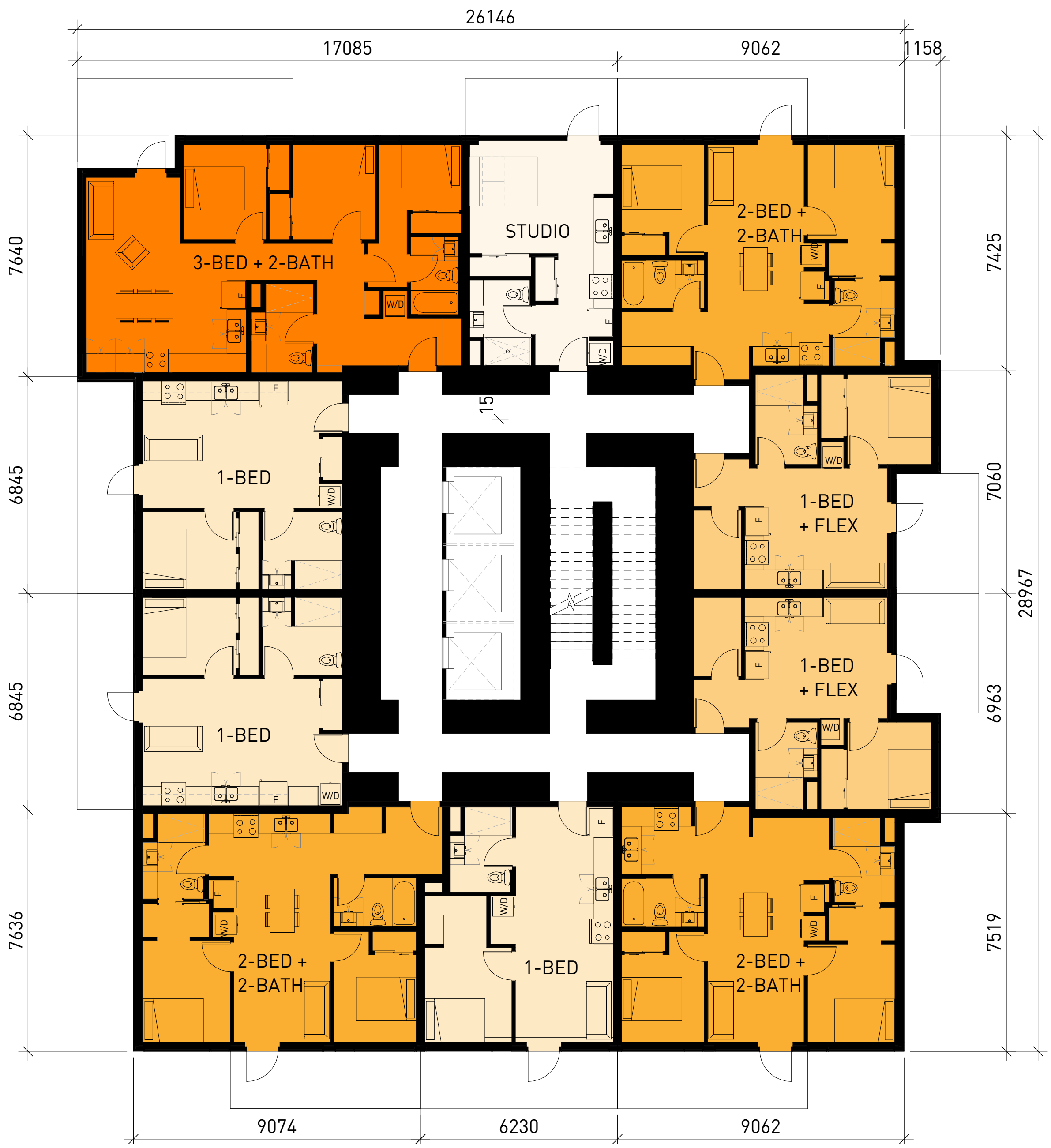


Image A-7 - 20 Storey Concrete Tower Floor Plate – Design Group 3, BCBC 2018

Image A-8 - 20 Storey Concrete Tower Floor Plate – Design Group 3, BCBC 2024

Image A-9 - Micro Unit - BCBC 2018 - Floor Area 305 sq ft

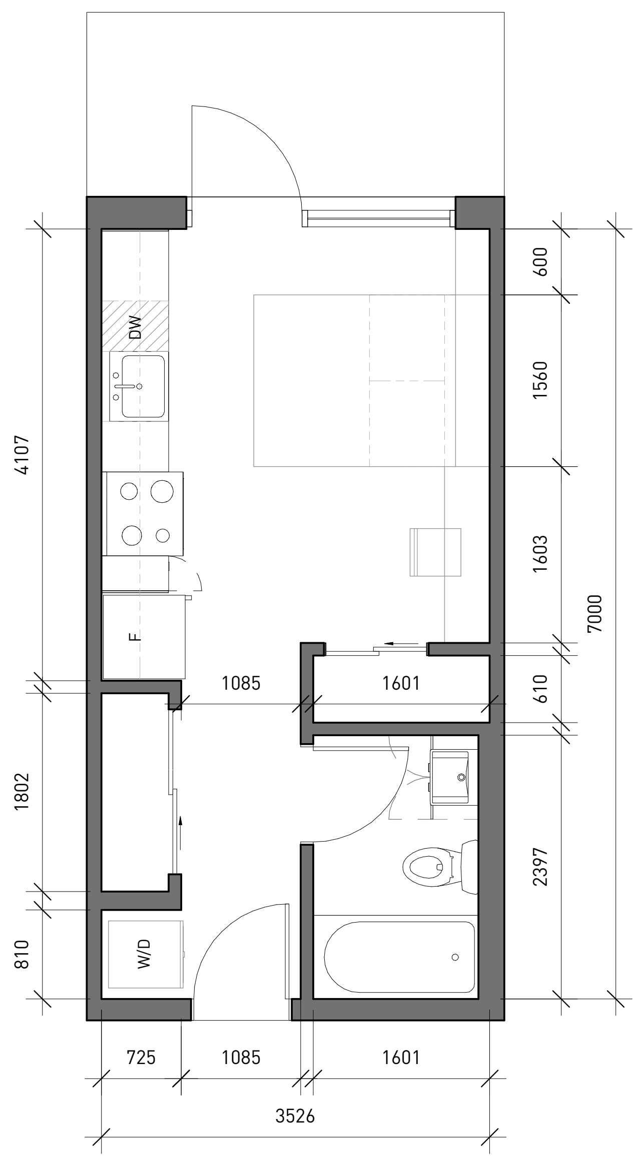


Image A-10 - Micro Unit - BCBC 2018 - Floor Area 330 sq ft

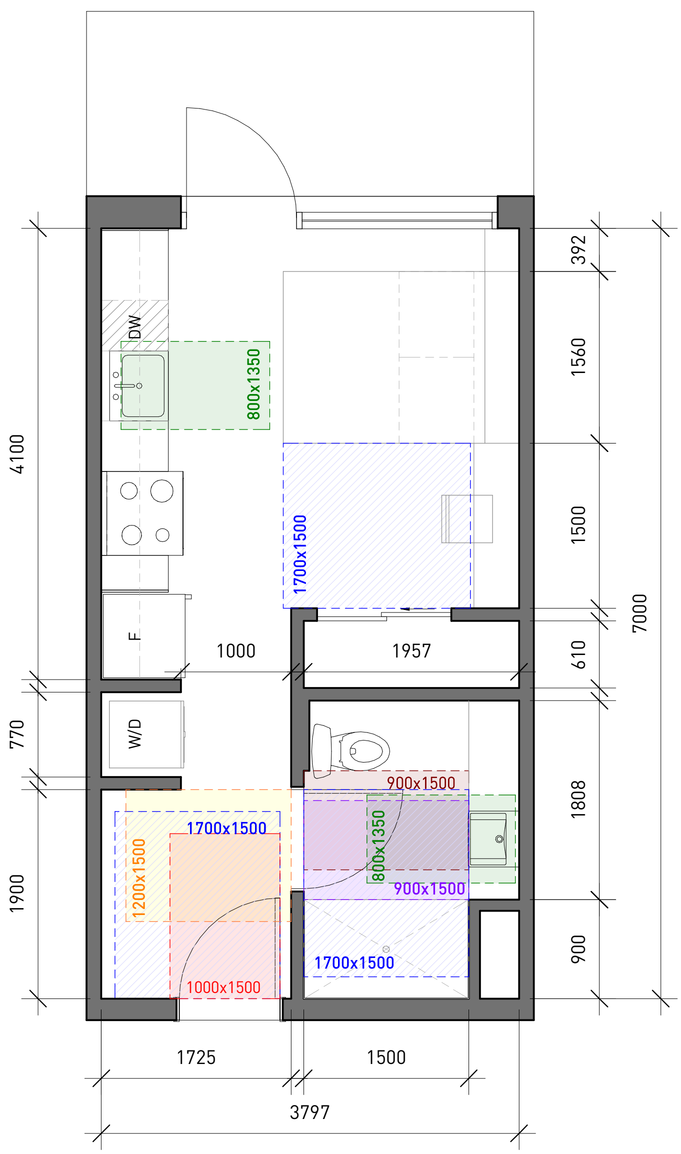


Image A-11 - Studio - BCBC 2018 - 380 sq ft

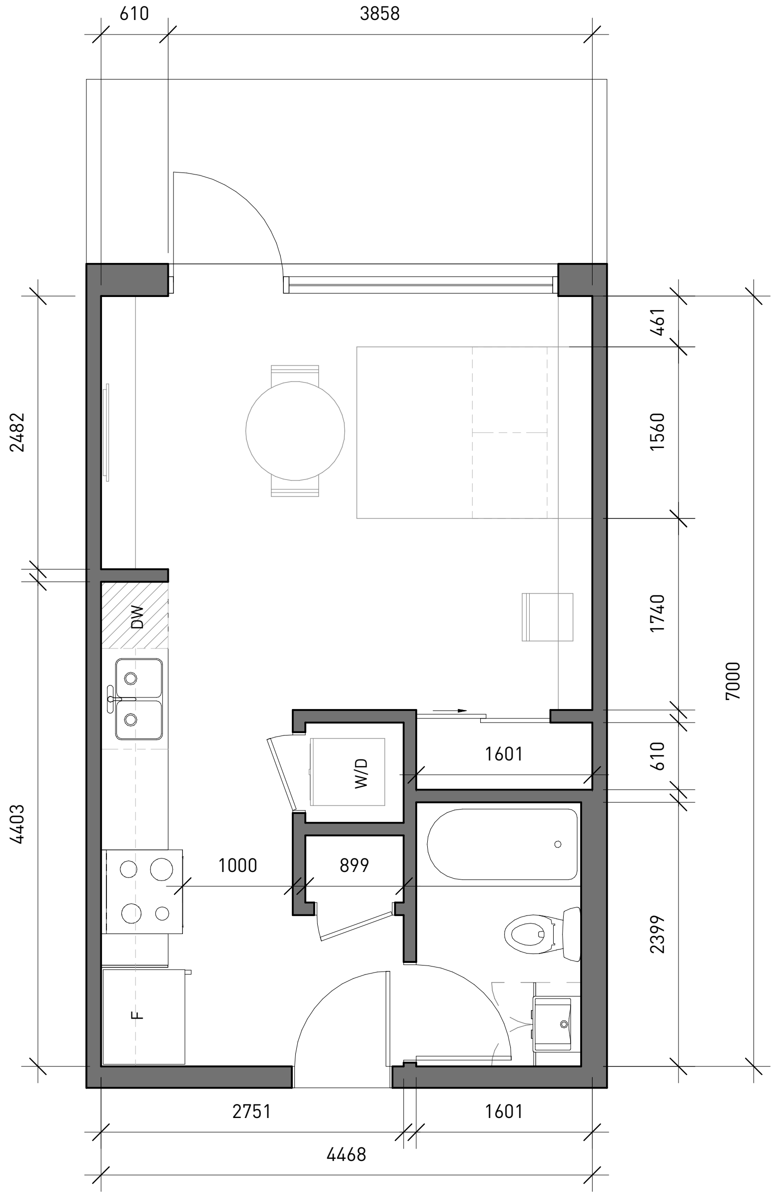


Image A-12 - Studio - BCBC 2024 - 388 sq ft

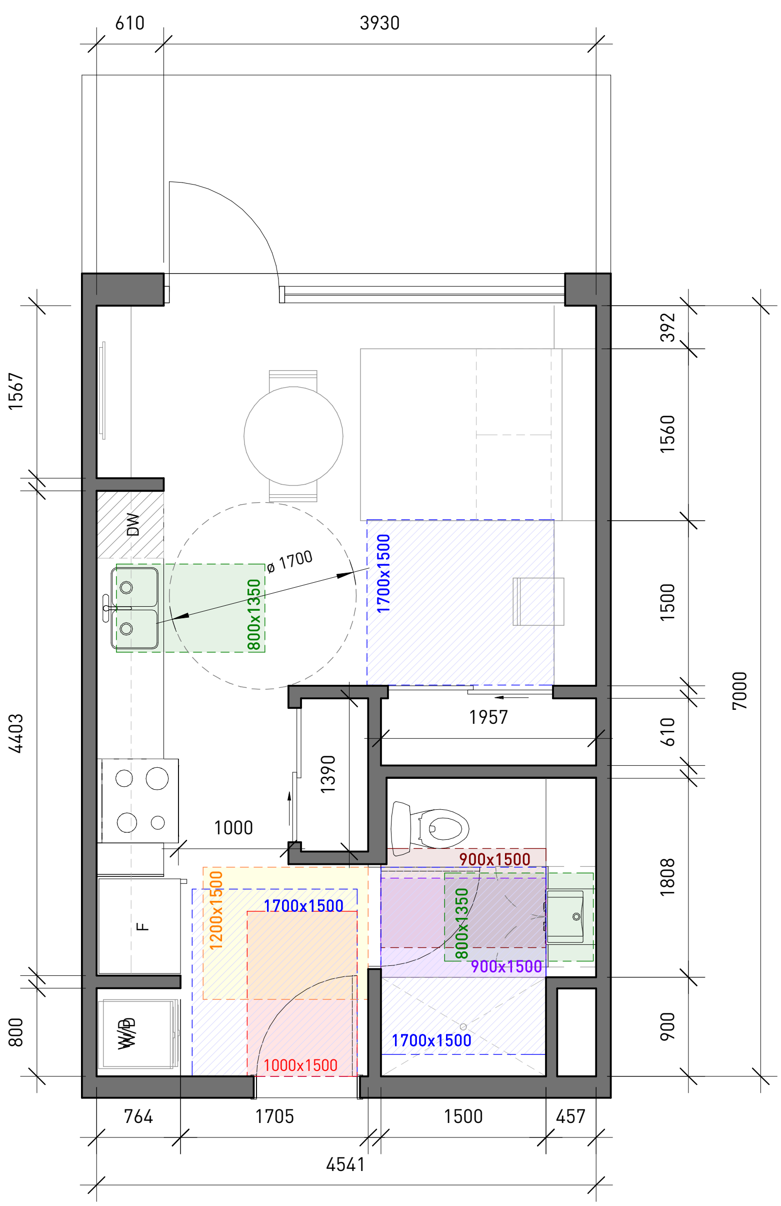


Image A-13 - One Bedroom - BCBC 2018 - 500 sq ft

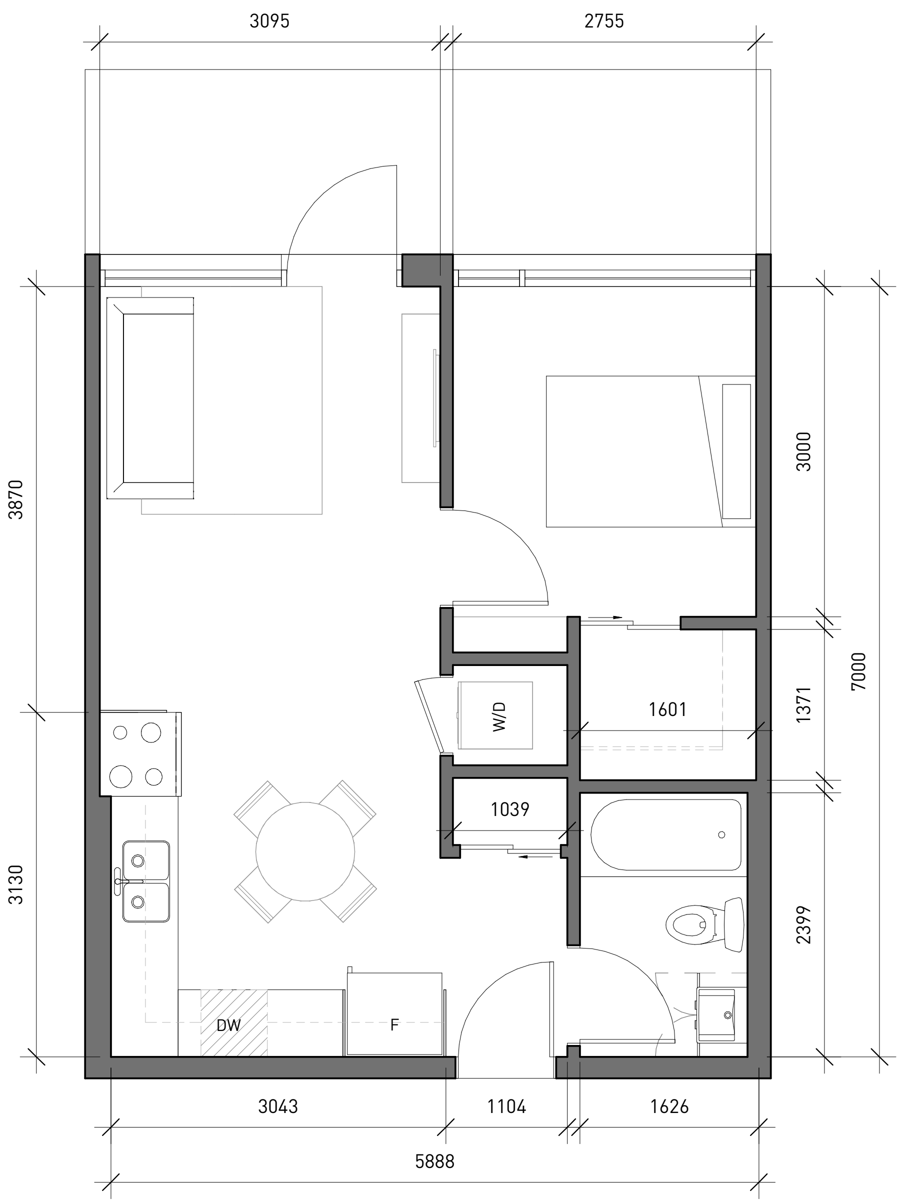


Image A-14 - One Bedroom - BCBC 2024 - 500 sq ft

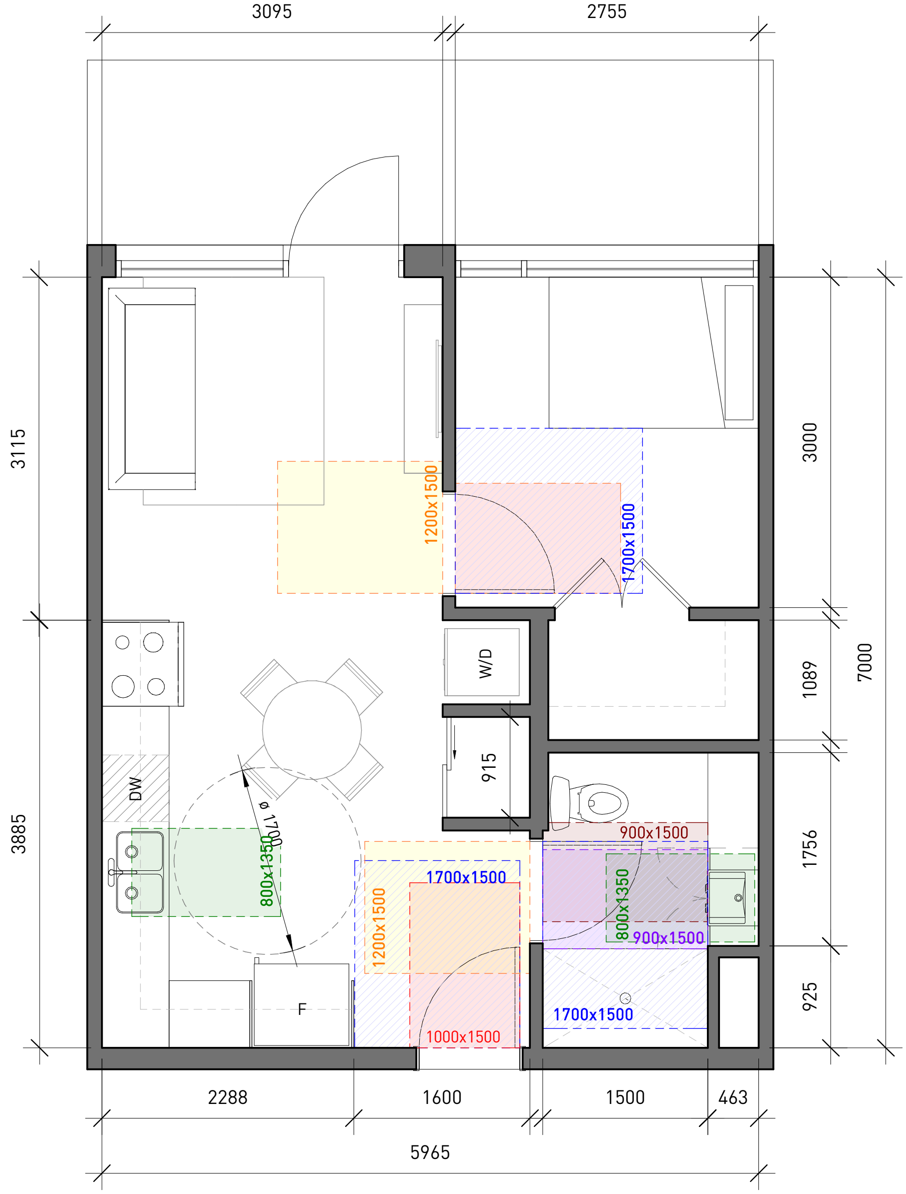


Image A-15 - One Bedroom + Flex - BCBC 2018 - 600 sq ft

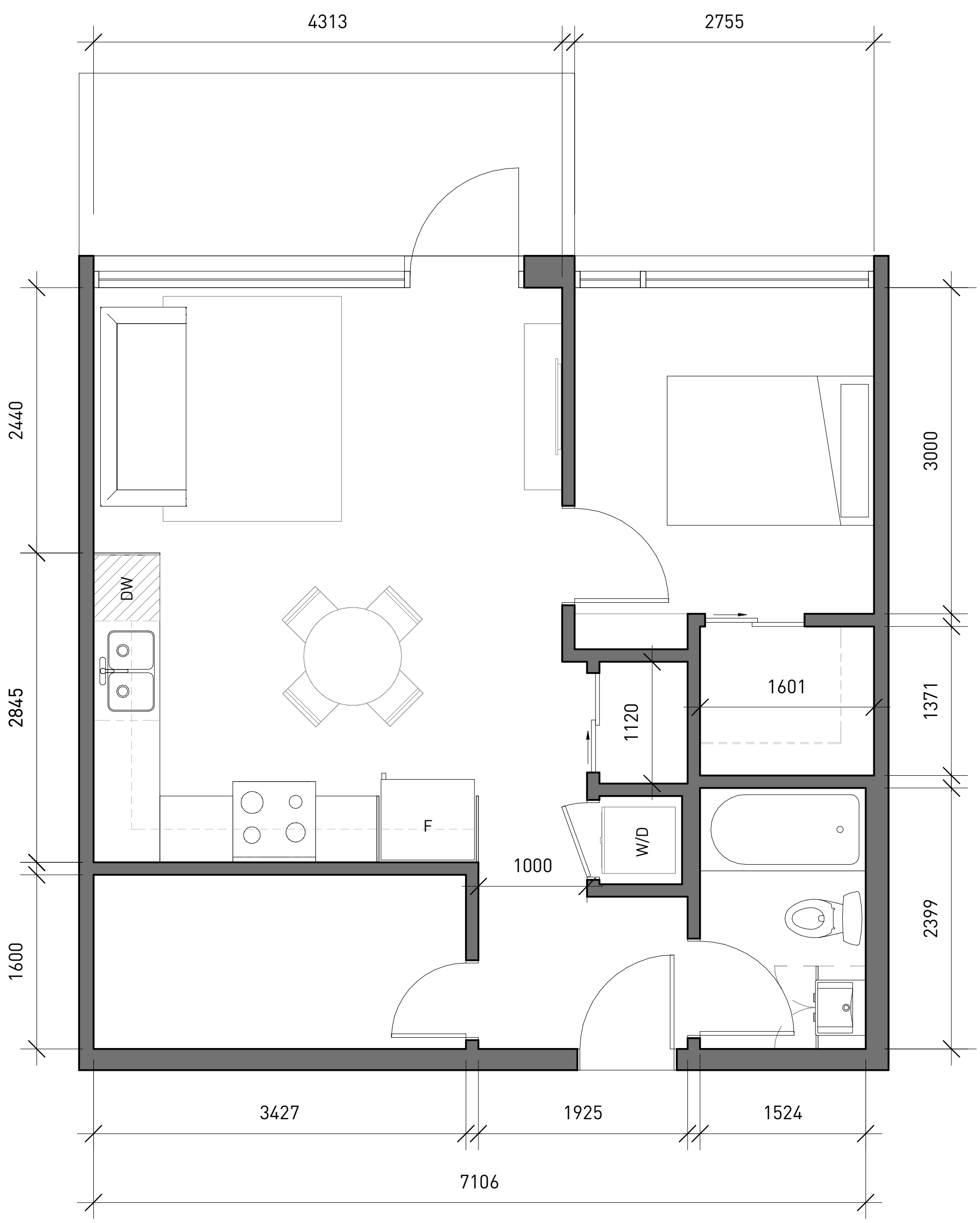


Image A-16 - One Bedroom + Flex - BCBC 2024 - 600 sq ft

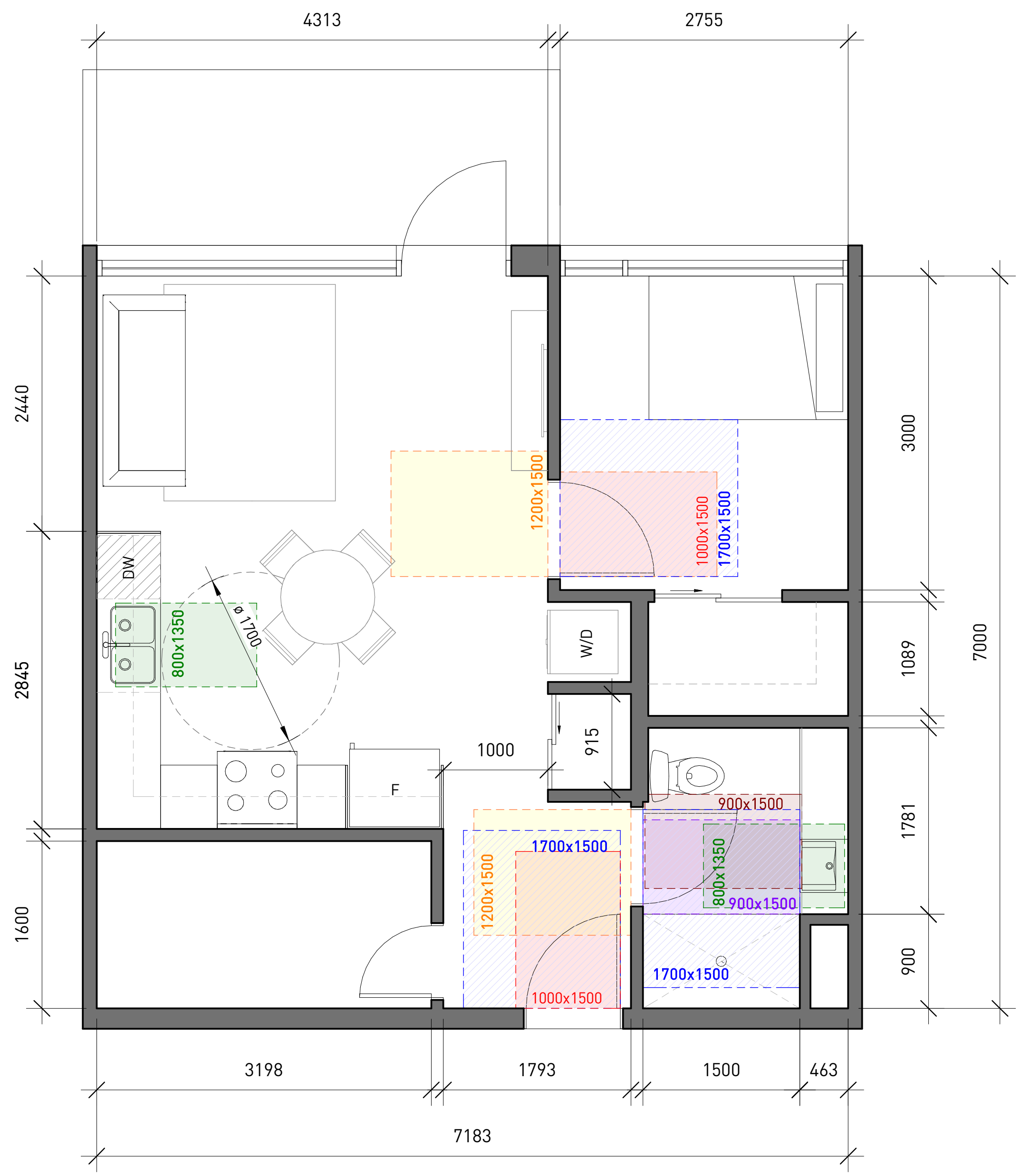


Image A-17 - Two Bed + Two Bath - BCBC 2018 - 720 sq ft

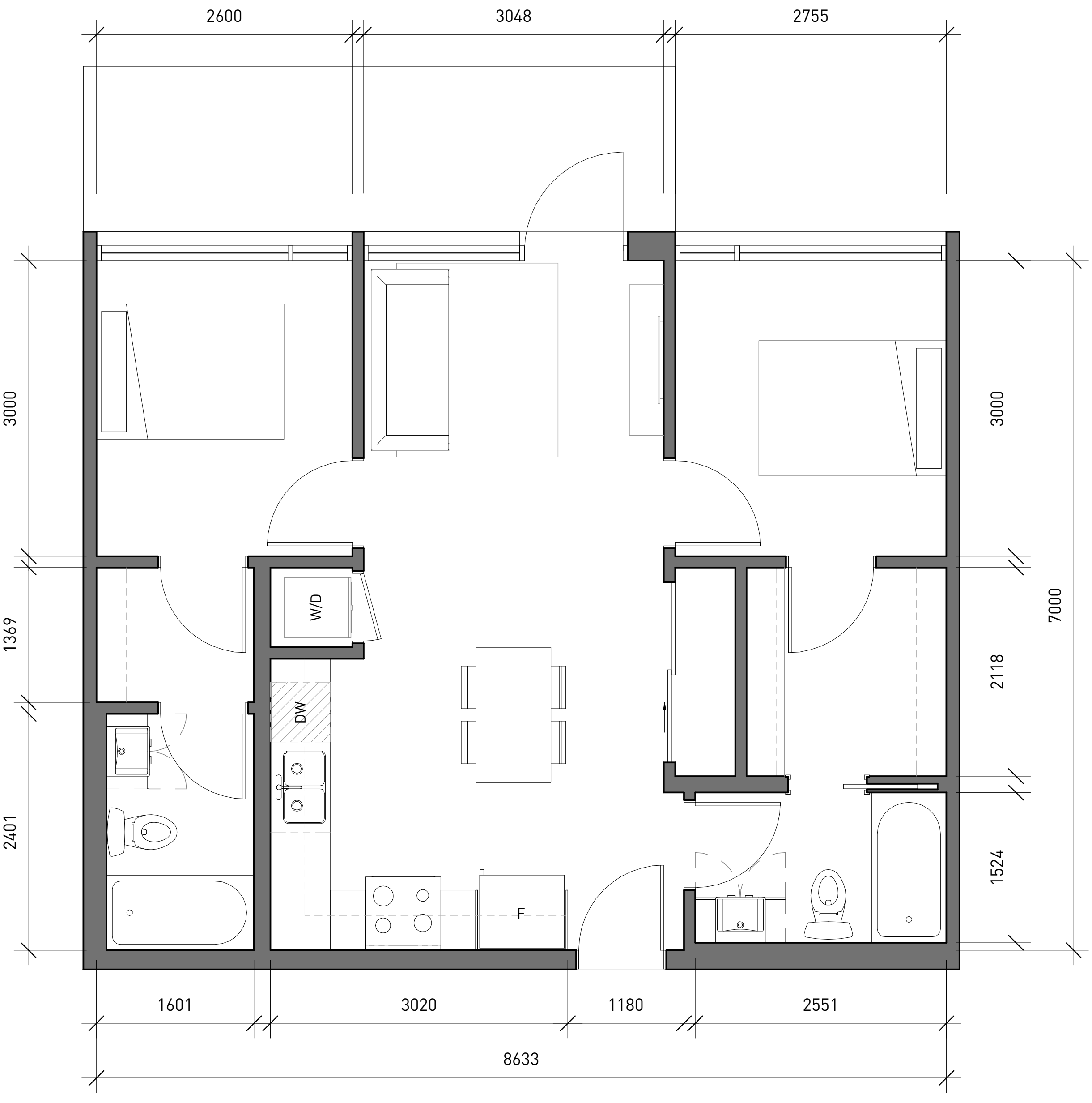


Image A-18 - Two Bed + Two Bath - BCBC 2024 - 720 sq ft

Image A-19 - Three Bed + Two Bath - BCBC 2018 - 935 sq ft

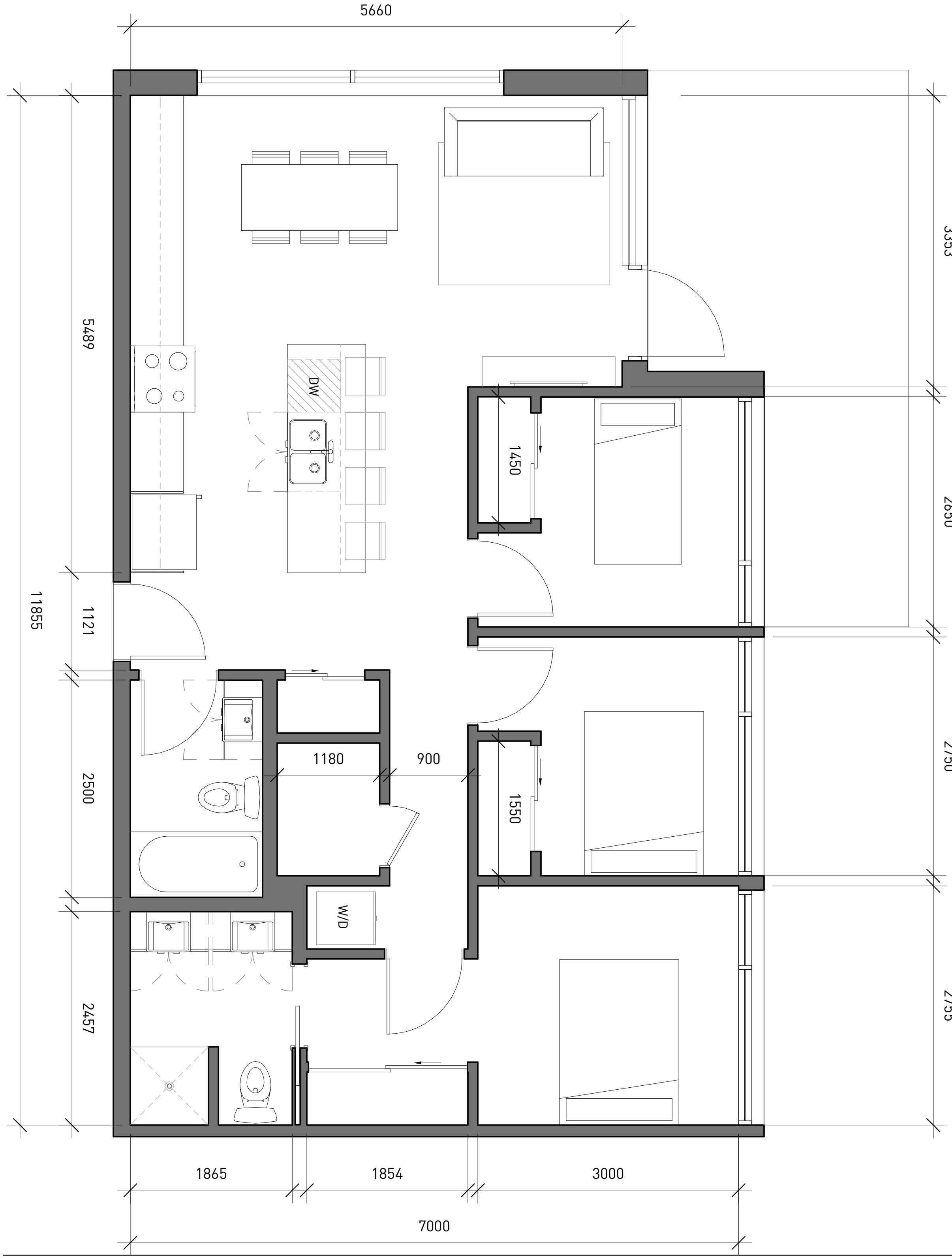
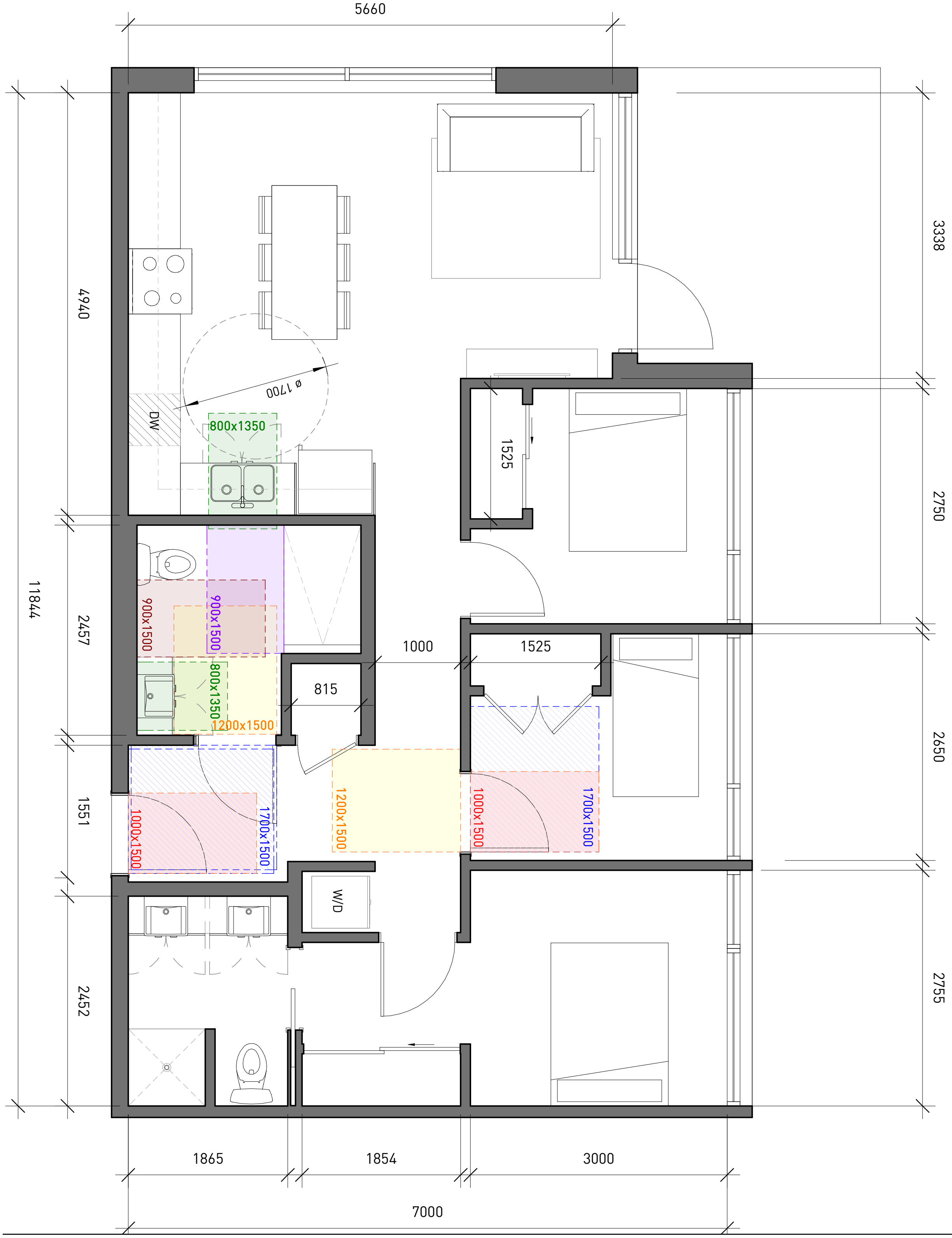


Image A-20 - Three Bed + Two Bath - BCBC 2024 - 935 sq ft



# APPENDIX B – RJC & WHM EARTHQUAKE DESIGN ASSESSMENT LETTERS

Yours truly,

READ JONES CHRISTOFFERSEN LTD.
**EGBC PERMIT TO PRACTICE NO. 1002503**

PROVINCE OF BRITISH COLUMBIA
L. M. PLETT
PROFESSIONAL ENGINEER
# 33536
DESIGNATED STRUCTURAL ENGINEER

2025.01.23 14:22:28-08'00'

Leon Plett, P.Eng., Struct. Eng., MIStructE, LEED® AP
Managing Principal

LP/sd

January 28, 2025

GHL Consultants Ltd.
700 W Pender Street, Suite 800
Vancouver BC V6C 1G8

**Attention:** Andrew Harmsworth

**Re:** **Structural Code Impact Review Response & Clarifications**
**BC Ministry of Housing – BCBC 2024 Space & Cost Study** **WHM # 24244**

Dear Mr.Harmsworth,

This is a letter to clarify and respond to comments summarized in the Structural Code Impact Peer Review Letter authored by Leon Platt from Read Jones Christoffereson Structural Engineers(RJC) dated January 23, 2024. RJC was provided with the following documents authored by Wicke Herfst Maver Consulting Structural Engineers Inc.:

- Draft Report "Space and Cost Impact Based on the 2024 BC Building Code Adaptable and Earthquake Design Provisions"
- Supporting Structural Calculations and Design Data

RJC confirmed the reasonableness of the design approach and design parameters used for the schematic structural design for both the wood frame and concrete buildings. Specific technical comments were made for both material types. The following section provides commentary explaining how WHM addressed each topic in the design and clarifies the implications for design of the respective structures.

**WOOD FRAME COMMENTS:**

Three technical concerns were summarized in one sentence regarding the wood frame deflection predictions as follows: "Anticipated deflections for the current schematics may be higher than permitted by BCBC. Items such as detailed building weight calculations, re-distribution of forces due to wall stiffness, and flexibility of T-junctions should be reviewed in detailed design". WHM's comments are included separately for each specific technical point as follows:

1) The initial calculations underestimated the weight of partition walls which where close together taller than the typical 8′ height. WHM has since increased the partition wall dead weight allowance from 10psf to 15psf in the calculations. This impacted the forces and deflections but the difference was small enough that there was no change to the design.
2) The stiffness of the building was estimated based on % contribution of stiffness from each type of wall segment with varying lengths. Note that the approach is a simplification of reality and no attempt was made to model the re-distribution of

forces that may take place due to the different stiffness for each variation of wall length. It is important to note that WHM followed the BCBC and EGBC guidelines for 6 storey buildings which require iterative calculations of non-linear wall stiffness for a single wall element. Re-distribution of forces is a further refinement of analysis that could be studied at the discretion of the EOR on future buildings during working drawings. It is unclear to WHM if the re-distribution effect would increase or decrease the predicted building deflections, however RJC's report implies that there could be an increase.

3) WHM neglected the additional flexibility of adjoining walls at T-junctions in the calculations. This structural strategy relies on one of the walls to "pin-down" the wall resisting shear running perpendicular to it. As the primary wall tries to uplift it would push up on the perpendicular wall and there would be some deflection. However, in other projects WHM notes that the wall deflection can be small enough such that it is close to the elongation stretch of a single tie-down rod. However, this effect would have to be studied during working drawings of any building especially for shorter walls where the impact would be more significant.

**CONCRETE FRAME COMMENTS:**

Several separate technical comments were made with regard to the various concrete building designs.

| RJC Comment | WHM Response |
|---|---|
| Design group 1 and 2 are anticipated to have unacceptable rotational demand with the current openings indicated | Refinement to the openings in the core wall is expected in detailed design to address this concern. This is more significant in design group 1 and may require more significant changes to the core during working drawings. |
| Shear walls running in the north-south direction currently do not show openings. However, the wall thicknesses appear to utilize a smaller overstrength than what would be expected for this approach. | Additional openings in the north-south direction are likely to occur in a real building due to complicated egress requirements commonly encounted in mixed-use buildings. The overstrength was an estimation based on past experience and would need to be confirmed during working drawings. |
| Where a coupling beam terminates into an end or intersection of a wall, the length of wall being terminated should be 4'-0" at a minimum for constructability…… | The current wall termination is 3'-6" and may need to be extended during working drawings. Alternatively bar terminators could be used to achieve the development of the cross-header reinforcing in a shorter distance. The approach should be confirmed during working drawings. |
| Wall thickness of 14" or less are difficult to construct with diagonally reinforced headers. | WHM has seen the successful installation of cross-headers in 14" thick walls where there |

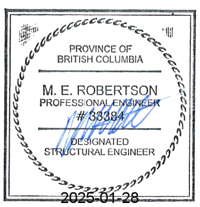
| | |
|---|---|
| | are lower seismic forces such as with design group 5. This would have to be confirmed during working drawings. |

**CONCLUSION:**

RJC raised several important technical points that should be considered during the detailed design of any concrete or wood frame building. Ultimately the review found that the design approach was reasonable for the limitations of this study for the 20 different conditions reviewed by WHM. Generally speaking, the implications of each technical point raised by RJC suggest that the final construction designs in a real building could be larger and more expensive. It is not clear if this would demonstrate a significant difference to the % delta in cost between 2018 and 2024 BCBC if further refinements were made to the study. Nonetheless, the peer review comments produced by RJC appear to support the overall conclusion of the seismic cost study. Both wood and concrete buildings in design group 1 (Victoria and similar regions) will be severely affected in terms of design and construction cost with the upcoming adoption of the 2024 BCBC Seismic provisions.

Sincerely,

**WICKE HERFST MAVER CONSULTING INC**




Mark Robertson, M.A.Sc., P.Eng., Struct.Eng,
Principal

Cc: Name of others cc'd
Encl: Appended documents

# APPENDIX C – ADAPTABLE AND EARTHQUAKE COST STUDY ANALYSIS

COST MANAGEMENT REPORT

# Space and Cost Impact Report Class D Estimate

REPORT NUMBER 1.0
JANUARY 30, 2025

PREPARED FOR:
Ministry of Housing and Municipal Affairs

Suite 300 – 30 East 6th Avenue, Vancouver, BC V5T 1J4
T 604 734 3126

# Contents



| Prepared By | Reviewed By | Date |
|---|---|---|
| Neill McGowan and Willie Yeung | Eldon Lau | 1/30/2025 |

# 1.0 Introduction

## 1.1 Instructions Received

This report has been prepared by BTY Group ("BTY") at the request of Ministry of Housing and Municipal Affairs (the "Client").

Ministry of Housing and Municipal Affairs (BSSB) has appointed GHL Code Consultant and its sub-consultants, of which BTY is one, to provide a report on the cost implications of the BCBC 2024 seismic and adaptability requirements. As part of this, BTY has prepared a Class D estimate of the construction costs associated with the 2024 BCBC . This cost report compares the costs of implementing code changes reviewed in the Space and Cost Study Report Based on the 2024 BC Building Code Adaptable and Seismic Requirements prepared by GHL Code Consultants, Public Architecture and WHM Structural Engineers and issued on January 13, 2025. The cost comparison is between requirements for residential, multi-family buildings in the 2018 and 2024 Codes, modelled for six areas in B.C. with diverse soil conditions and considered impacts on structural components and space requirements in different unit types and common areas. A variety of high-rise concrete towers have been reviewed, as well as a six-storey wood-framed model and a model with a concrete core and Encapsulated Mass Timber Construction (EMTC).

This report has been prepared in accordance with the scope of our Fee Proposal, dated September 9, 2024 and is subject to the terms of that appointment.

Information related to the Project for the purposes of this report was received by BTY on up to and including January 28, 2025.

Please refer to Section 12.0 for a list of information received in producing this report.

## 1.2 Report Reliance

BTY Group, its directors, staff, or agents do not make any express or implied representation or warranty whatsoever as to the factual accuracy of the information provided to us on behalf the Client, its subcontractors or agents, upon which this Report is based.

## 1.3 Reporting Qualifications

This Report has been prepared based on information provided to us up to the date of issue. BTY Group does not accept any liability or accountability for information that has not been provided, or made available to us, at the time of preparing this Report. Any advice, opinions, or recommendations within this Report should be read and relied upon only in the context of the report as a whole. The contents do not provide legal, insurance or tax advice or opinion. Opinions in this report do not an advocate for any party and if called upon to give oral or written testimony it will be given on the same assumption.

### 1.4 Contacts

Should you have any queries regarding the content of this report, please do not hesitate to contact either of the following:

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## 2.0 Executive Summary

### 2.1 Report Purpose

The purpose of this report is to provide a realistic estimate of the differences between 2018 BCBC and 2024 BCBC including the seismic and adaptable dwelling unit provisions.

The opinion expressed in this report has been prepared without the benefit of detailed architectural, structural, mechanical and electrical drawings and should, therefore, be considered a Conceptual Design (Class D) estimate. Based on the documents reviewed, our estimate should be correct within a range of approximately +/- 25%.

## 2.2 Overall Building Cost Summary

The following table summarizes the findings of this cost review for the concrete high-rise, concrete and CLT high-rise and wood mid-rise building models in each of the Design Groups (DGs):

| Description | 2018 | 2024 | Cost Premium | % |
|---|---|---|---|---|
| Concrete Frame Building (20-Storey) | | | | |
| DG1 | $44,914,900 | $52,152,200 | $7,237,300 | 16.1% |
| DG2 | $41,580,000 | $46,022,400 | $4,442,400 | 10.7% |
| DG3 | $39,843,800 | $40,644,500 | $800,700 | 2.0% |
| DG4 | $38,837,300 | $39,399,800 | $562,500 | 1.4% |
| DG5 | $38,431,700 | $38,847,700 | $416,000 | 1.1% |
| Concrete & EMTC Frame Building (20-Storey) | | | | |
| DG1 | $42,203,700 | $45,797,900 | $3,594,200 | 8.5% |
| DG2 | $40,339,100 | $43,069,200 | $2,730,100 | 6.8% |
| DG3 | $39,096,300 | $39,819,500 | $723,200 | 1.8% |
| Concrete Frame Building (15-Storey) | | | | |
| DG1 | $31,464,600 | $35,317,100 | $3,852,500 | 12.2% |
| Wood Frame Midrise (6-Storey) | | | | |
| DG1 | $13,712,400 | $16,613,400 | $2,901,000 | 21.2% |
| DG2 | $12,151,800 | $12,435,000 | $283,200 | 2.3% |
| DG3 | $11,597,400 | $11,964,600 | $367,200 | 3.2% |
| DG4 | $11,580,000 | $11,832,600 | $252,600 | 2.2% |
| DG5 | $11,277,000 | $11,427,000 | $150,000 | 1.3% |

These costs encompass both seismic and adaptable costs and are at 1st Quarter 2025 Vancouver unit rates.

# 3.0 Seismic Cost Summary

The following table summarizes the findings of this cost review for the seismic designs for the concrete high-rise, concrete and CLT high-rise and wood mid-rise building models in each of the Design Groups (DGs) reviewed:

| **Impact on Seismic Structural Components** | | | | |
|---|---|---|---|---|
| **Description** | **2018** | **2024** | **Cost Premium** | **%** |
| Concrete Frame Building (20-Storey) | | | | |
| DG1 | $8,502,900 | $15,324,200 | $6,821,300 | 80.2% |
| DG2 | $5,168,000 | $9,194,400 | $4,026,400 | 77.9% |
| DG3 | $3,431,800 | $3,816,500 | $384,700 | 11.2% |
| DG4 | $2,425,300 | $2,571,800 | $146,500 | 6.0% |
| DG5 | $2,019,700 | $2,019,700 | $0 | 0.0% |
| Concrete & EMTC Frame Building (20-Storey) | | | | |
| DG1 | $5,791,700 | $8,969,900 | $3,178,200 | 54.9% |
| DG2 | $3,927,100 | $6,241,200 | $2,314,100 | 58.9% |
| DG3 | $2,684,300 | $2,991,500 | $307,200 | 11.4% |
| Concrete Frame Building (15-Storey) | | | | |
| DG1 | $4,155,600 | $7,696,100 | $3,540,500 | 85.2% |
| Wood Frame Midrise (6-Storey) | | | | |
| DG1 | $3,526,200 | $6,315,600 | $2,789,400 | 79.1% |
| DG2 | $1,965,600 | $2,137,200 | $171,600 | 8.7% |
| DG3 | $1,411,200 | $1,666,800 | $255,600 | 18.1% |
| DG4 | $1,393,800 | $1,534,800 | $141,000 | 10.1% |
| DG5 | $1,090,800 | $1,129,200 | $38,400 | 3.5% |

For the concrete high-rise buildings (including those with EMTC) the comparison is focused on the concrete cores and their foundations.

For the wood-frame buildings, the comparison is focused on the shear walls.

Building area impacts have also been included for some of the models, as per the comparisons in Tables 4.3.1 and 4.3.2 of the main report.

## 4.0 Adaptability Cost Summary

The following table summarizes the findings of this cost review for the adaptability measures to be implemented in the concrete high-rise, concrete and CLT frame high-rise, and wood mid-rise building models in each of the Design Groups (DGs) reviewed:

| Description | 2018 | 2024 | Cost Premium | % |
|---|---|---|---|---|
| Concrete Frame Building (20-Storey) | | | | |
| DG1 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| DG2 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| DG3 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| DG4 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| DG5 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| Concrete & EMTC Frame Building (20-Storey) | | | | |
| DG1 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| DG2 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| DG3 | $36,412,000 | $36,828,000 | $416,000 | 1.1% |
| Concrete Frame Building (15-Storey) | | | | |
| DG1 | $27,309,000 | $27,621,000 | $312,000 | 1.1% |
| Wood Frame Midrise (6-Storey) | | | | |
| DG1 | $10,186,200 | $10,297,800 | $111,600 | 1.1% |
| DG2 | $10,186,200 | $10,297,800 | $111,600 | 1.1% |
| DG3 | $10,186,200 | $10,297,800 | $111,600 | 1.1% |
| DG4 | $10,186,200 | $10,297,800 | $111,600 | 1.1% |
| DG5 | $10,186,200 | $10,297,800 | $111,600 | 1.1% |

# 5.0 Adaptability Cost Comparison by Unit Size

The following table summarizes the findings of this cost review for the adaptability measures to be implemented in the concrete high-rise, concrete and CLT frame high-rise, and wood mid-rise building models in each of the Design Groups (DGs) reviewed. Greater detail is provided here to show the impact of making provision for future adaptability in each unit type:

| Description | 2018 | 2024 | Cost Premium | % |
|---|---|---|---|---|
| Concrete Frame Building (20-Storey) | | | | |
| Micro Unit | $90,900 | $96,100 | $5,200 | 5.7% |
| Studio Unit | $109,000 | $111,800 | $2,800 | 2.6% |
| 1-Bed Unit | $158,700 | $159,700 | $1,000 | 0.6% |
| 1-Bed + Flex Unit | $166,900 | $170,600 | $3,700 | 2.2% |
| 2-Bed + 2 Bath Unit | $204,700 | $206,100 | $1,400 | 0.7% |
| 3-Bed + 2 Bath Unit | $287,600 | $291,000 | $3,400 | 1.2% |
| Wood Frame Midrise (6-Storey) | | | | |
| Micro Unit | $71,800 | $74,500 | $2,700 | 3.8% |
| Studio Unit | $84,100 | $86,900 | $2,800 | 3.3% |
| 1-Bed Unit | $126,900 | $128,000 | $1,100 | 0.9% |
| 1-Bed + Flex Unit | $131,500 | $132,300 | $800 | 0.6% |
| 2-Bed + 2 Bath Unit | $159,700 | $161,000 | $1,300 | 0.8% |
| 3-Bed + 2 Bath Unit | $229,000 | $232,400 | $3,400 | 1.5% |

We note that the adaptability cost of the Micro unit is greater due to an increase of 25 S.F. in area and the Studio unit by 8 S.F., which has been included in the computation of the cost.

# 6.0 Basis & Assumptions

The construction estimate is based on the following list of assumptions:

1. That the work will be done under a general contract. On this basis, an allowance of 15% of trade construction costs has been included for the general contractor's general conditions, overhead and profit.
2. The estimates have been performed on a unit-by-unit and floor-by-floor basis and then multiplied by the number of floors stated in the tables.
3. The unit rates used are valid for Vancouver for the 1st Quarter 2025.
4. No allowance has been made for design, construction or escalation contingencies.

Please note that BTY is not qualified to act as a design consultant. The assumptions in our estimates should be reviewed and amended by the design team.

# 7.0 Exclusions

The construction estimate includes all direct and indirect construction costs derived from the drawings and other information provided by the Consultants, with the exception of the following:

1. Land costs,
2. Professional fees and disbursements,
3. Planning, administrative and financing costs,
4. Legal fees and agreement costs / conditions,
5. Building permits and development cost charges,
6. Furnishings and equipment,
7. Unforeseen ground conditions and associated extras,
8. General contractor bonding,
9. Phasing of the works and accelerated schedule,
10. Decanting & moving,
11. Erratic market conditions, such as lack of bidders, proprietary specifications,
12. Cost escalation past January 2025.

# 8.0 Areas

The following are the areas per floor for the various model buildings, as derived from Tables 4.3.1 and 4.3.2 of the main report:

### Wood Frame Mid-Rise Cumulative Area Impact

| Model | BCBC 2018 | BCBC2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Design Group 1 | 8,770 $ft^2$ | 9,020 $ft^2$ | 250 $ft^2$ | 2.9% |
| Design Group 2 to 5 | 8,766 $ft^2$ | 8,790 $ft^2$ | 24 $ft^2$ | 0.3% |

### Concrete Tower Cumulative Area Impact

| Model | BCBC 2018 | BCBC2024 | Change | |
|---|---|---|---|---|
| | sq ft | sq ft | sq ft | % |
| Design Group 1 | 7,368 $ft^2$ | 7,746 $ft^2$ | 378 $ft^2$ | 5.1% |
| Design Group 2 | 7,260 $ft^2$ | 7,534 $ft^2$ | 274 $ft^2$ | 3.8% |
| Design Group 3 | 7,250 $ft^2$ | 7,296 $ft^2$ | 46 $ft^2$ | 0.6% |
| Design Group 4 | 7,166 $ft^2$ | 7,202 $ft^2$ | 36 $ft^2$ | 0.5% |
| Design Group 5 | 7,097 $ft^2$ | 7,105 $ft^2$ | 8 $ft^2$ | 0.1% |

These area increases are a mixture of adaptability and seismic impacts, which have been included in their respective sections above.

# 9.0 Converting Existing Dwelling Unit to Adaptable

The following table outlines BCBC 2024 adaptable dwelling unit provisions, and the degree of difficulty associated in renovating an existing dwelling unit to meet the provisions in the Code. The level of difficulty in renovating correlates to how well costing can be determined. Elements that would have limited renovation difficulty are considered to have limited overall impact to the unit. As such, costing associated with these renovations can be determined relatively easily. High and moderate renovation difficulty items have the potential to have a larger impact, such as changes in unit design and layout. Costing associated with these renovations vary unit to unit and are harder to quantify.

| Code Requirement | | Renovation Difficulty |
|---|---|---|
| Doors & Path of Travel | | |
| | Door clear opening width | L |
| | Door clear floor space | H |
| | Rough-in power operated door | L |
| | Clear path of travel through unit | H |
| Bedroom | | |
| | Clear turning area adjacent bed | M |
| | Closet clear opening width | L |
| | Clear turning area at closet | M |
| Bathroom | | |
| | Toilet transfer space | H |
| | Clear space at sink | M |
| | Plumbing system for accessible sink | L |
| | Shower / bathtub size | H |
| | Clear space at shower / bathtub | H |
| | Plumbing system for accessible shower / bathtub | H |
| | Backing for grab bars | L |
| Kitchen | | |
| | Continuous counter | M |
| | Turn around area | H |
| | Plumbing system for accessible sink | L |
| Controls, Switches and Outlets | | |
| | Installation height | L |
| | Special outlet for future strobe | L |

Key:
H = High difficulty (Potentially requiring removal of walls or re-design of areas in unit)

M = Moderate difficulty (May pose challenges depending on unit layout)

L = Limited difficulty (Feasible changes that can be made to any unit)

# 10.0 Taxes

The estimates include the Provincial Sales Tax (P.S.T.) where applicable.

The estimates exclude the Goods & Services Tax (G.S.T.).

# 11.0 Pricing

This estimate has been priced at first quarter 2025 rates assuming a normal market. The unit rates utilized are considered appropriate for a project of this type, bid under a Design-Bid-Build model in an open market, with a minimum of five (5) bids, supported by a sufficient number of sub-contractors to ensure competitiveness.

The estimate allows for labour, material, equipment and other input costs at current rates and levels of productivity. It does not consider extraordinary market conditions, where bidders may be few and may include in their tenders disproportionate contingencies and profit margins.

# 12.0 Documents Reviewed

The following information was reviewed in preparing this report:

| Description | | Date |
|---|---|---|
| Report | | |
| | Space and Cost Impact Report | January 13, 2025 |

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