

1.0 Summary

House Type	Wood frame house with concrete base
Year of Construction	1966
Floor Area	Upper Floor – 128.48 m ² Main Floor – 126.07 m ²
Location	Kitsilano, Vancouver, B.C.
Soil Type	C
Liquefaction Potential	Very low
Retrofit Priority Rank	M
Seismic Deficiencies	<ol style="list-style-type: none"> 1. Upper floor diaphragm needs improvement 2. Upper floor exterior E-W LDRS needs improvement 3. Roof diaphragm needs improvement
Life-Safety Retrofit Features	<ol style="list-style-type: none"> 1. Upper floor E-W exterior LDRS retrofit: <ul style="list-style-type: none"> • Tear down the front wall of the living room and remove the window for new shear walls • Rebuild the wall to blocked plywood shear wall 2. Roof diaphragm retrofit: <ul style="list-style-type: none"> • Upgrade the ceiling/roof diaphragm with new blocking, plywood boards, and nailing/spike details • Reinforce the connection between the new diaphragm and the walls 3. Upper floor diaphragm retrofit: <ul style="list-style-type: none"> • Upgrade the ceiling/roof diaphragm with new blocking, plywood boards, and nailing/spike details • Reinforce the connection between the new diaphragm and the walls
Retrofit Cost Estimates	\$114,169 \$449 /m ²

Main Floor:	1,357 sq.ft.
Upper Floor:	1,383 sq.ft.
Total:	2,740 sq.ft.
Garage:	228 sq.ft.
Deck:	245 sq.ft.



Figure 1: Architectural drawing of the house

2.0 Assessment Report

2.1 Vertical Load-Bearing Supports (VLS)

VLS Type	Timber platform construction
VLS Design Drift Limit	6.0%
Supports Description	The floor boards and joists, which act as a platform, are fastened over beams supporting the structure. The structural walls transfer the load from the roof and ceiling to the floor and the foundation. The perimeter of the house is supported by concrete walls.

2.2 Lateral Demand Resisting Systems (LDRSs)

2.2.1 Upper Floor LDRS

Shaking Dir.	Location	Prototype No.	Description	Max. DDL	Capacity
N-S	Exterior	W-3	Gypsum wallboard	2.5%	26.31% Ws
	Interior	W-3	Gypsum wallboard	2.5%	9.45% Ws
E-W	Exterior	W-3	Gypsum wallboard	2.5%	6.15% Ws
	Interior	W-3	Gypsum wallboard	2.5%	10.55% Ws

- Comments**
- All exterior walls are assumed to be built with 140 mm wide diagonal board (shiplap) sheathing with 2 – 64 mm common nails at supports
 - All interior walls are assumed to be built with 140 mm wide transverse board (shiplap) sheathing on framing at 400 mm c/c
 - All walls are assumed to be properly connected to the diaphragms
 - Ws is the cumulative seismic weight of the structure (255.0 kN), which includes the weight of walls, roof, and snow

2.2.2 Main Floor LDRS

Shaking Dir.	Location	Prototype No.	Description	Max. DDL	Capacity
N-S	Exterior	C-4	Squat concrete wall	1%	271% Ws
	Interior	W-3	Gypsum wallboard	2.5%	2.67% Ws
E-W	Exterior	C-4	Squat concrete wall	1%	163% Ws
	Interior	W-3	Gypsum wallboard	2.5%	2.65% Ws

- Comments**
- Most of the exterior walls are made out of concrete (25 MPa strength, 2350 kg/m³ density) with approx. 30 mm thickness which has a very high shear capacity compared to wood
 - All interior walls are assumed to be built with 140 mm wide transverse board (shiplap) sheathing on framing at 400 mm c/c
 - All walls are assumed to be properly connected to the diaphragms and foundation
 - Ws is the cumulative seismic weight of the structure (1354.8 kN), which includes the weight from upper floors, weight of walls, diaphragm, live load, and snow

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2.3 Diaphragms

2.3.1 Roof Level Diaphragm

Shaking Direction	Prototype No.	Description	Span	Max. Movement	Capacity
N-S	D-3	Flexible diaphragm – horizontal boards	15.9 m	75 mm	10.91% Wd
E-W	D-3	Flexible diaphragm – horizontal boards	8.1 m	75 mm	5.53% Wd

- Comments**
- Roof diaphragm is assumed to be built with 64 mm to 89 mm thick T&G decking (with no side spikes) spanning about 2 m between supporting beams
 - The maximum movement is governed by 2.5% drift limit of the 3 m wall height
 - Wd is the lumped seismic weight at the diaphragm's level (197.0 kN), which includes the weight of roof, snow, and half of the wall's

2.3.2 Upper Floor Diaphragm

Shaking Direction	Prototype No.	Description	Span	Max. Movement	Capacity
N-S	D-3	Flexible diaphragm – horizontal boards	15.9 m	30 mm	5.43% Wd
E-W	D-3	Flexible diaphragm – horizontal boards	8.1 m	30 mm	5.51% Wd

- Comments**
- Upper floor diaphragm is assumed to be built with 64 mm to 89 mm thick T&G decking (with no side spikes) spanning about 2 m between supporting beams
 - The maximum movement is governed by 1% drift limit of the 3 m wall height
 - The diaphragm is assumed to be composed of 2 systems in the N-S direction and 4 systems in the E-W direction
 - Wd is the lumped seismic weight at the diaphragm's level (791.4 kN), which includes half of the wall's weight above and below the diaphragm, the weight of diaphragm, live load, and snow

2.4 Risk Assessment Results

Element	Shaking Dir.	Loc.	Prototype No.	Capacity	PDE/PSE	RPR
Roof Level	N-S		D-3	10.91% Wd	1.7%	L
Diaphragm	E-W		D-3	5.53% Wd	4.3%	M
Upper Floor LDRS	N-S	Ext.	W-3	26.31% Ws	0.4%	L
		Int.	W-3	9.45% Ws	1.6%	L
	E-W	Ext.	W-3	6.15% Ws	2.5%	M
		Int.	W-3	10.55% Ws	1.4%	L
Upper Floor Diaphragm	N-S		D-3	5.43% Wd	3.6%	M
	E-W		D-3	5.51 % Wd	4.4%	M
Main Floor LDRS	N-S		C-4	271% Ws	< 0.2%	L
	E-W		C-4	163% Ws	< 0.2%	L
Maximum					4.4%	M

Comments

- The LDRS on the main floor is governed by the concrete walls. Since the probability of the concrete walls exceeding 1% drift is less than 0.2%, the wood interior walls are unlikely to fail when the concrete walls are still standing.

Seismic Deficiencies

- Upper floor diaphragm needs more resistance as the diaphragm's lumped weight is significantly increased due to the weight of the concrete walls (medium priority)
- Roof level diaphragm and exterior E-W upper floor LDRS need to be improved (medium priority)

Main Floor: 1,357 sq.ft.
 Upper Floor: 1,383 sq.ft.
 Total: 2,740 sq.ft.
 Garage: 228 sq.ft.
 Deck: 245 sq.ft.

— Gypsum Wallboard Walls

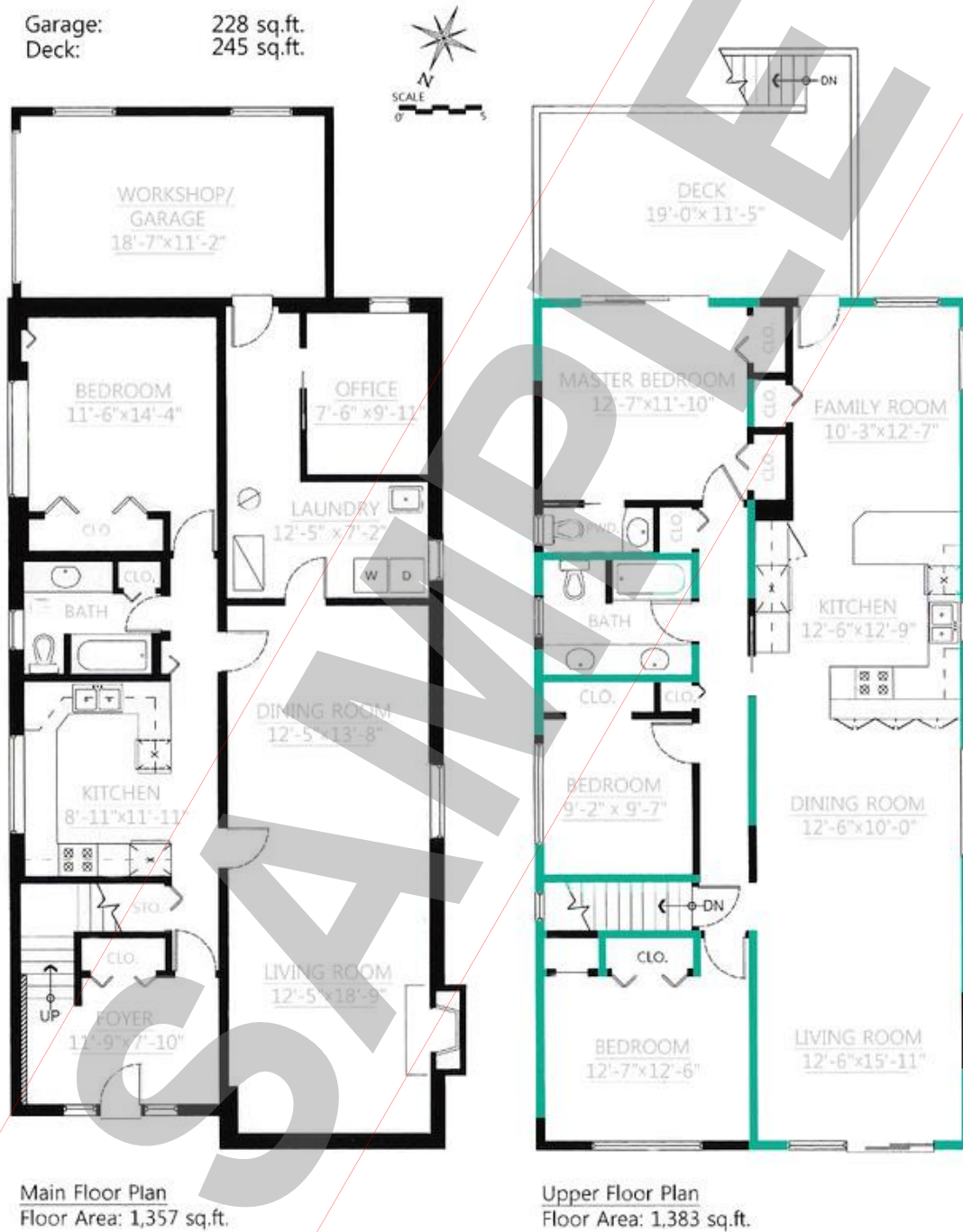


Figure 2: Locations of the structural walls

3.0 Retrofit Plan

3.1 Retrofit Concept

Considering that the governing PDE of the house is > 10% (H-1 priority), a life-safety retrofit plan is recommended to lower the PDE to less than 2%. This plan addresses the seismic deficiencies mentioned in the previous section:

- Upper floor E-W exterior LDRS retrofit:
 1. Tear down the front (north) wall of the living room and take out the window, while keeping the glass door and the rest of the walls intact.
 2. Rebuild the wall blocked plywood shear walls, redo electrical/mechanical, finish the interior and exterior of the new walls.
- Roof level diaphragm:
 1. Remove existing ceiling board from the upper floor, T & G decking, and insulation while trying to maintain as much electrical / mechanical / lighting / sprinklers / alarm in place.
 2. Install new plywood blocking to existing joists, install new plywood boards, return the insulation material and electrical / mechanical in place.
 3. Reinforce the connection between the diaphragm and the walls.
 4. Rebuild the ceiling board, finish the ceiling, return the lighting / sprinklers / alarm back in place.
- Upper floor diaphragm:
 1. Remove existing ceiling board from the main floor, carpet/flooring on the upper floor, T & G decking, and insulation while trying to maintain as much electrical / mechanical / lighting / sprinklers / alarm in place.
 2. Install new plywood blocking to existing joists, install new plywood boards, return the insulation material and electrical / mechanical in place.
 3. Reinforce the connection between the diaphragm and the walls.
 4. Rebuild the ceiling and floor board, finish the ceiling and floor, return the lighting / sprinklers / alarm back in place.

No changes in the rest of the house.

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Upper Floor:	1,383 sq.ft.
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- Gypsum Wallboard Walls
- Blocked Plywood Shearwalls

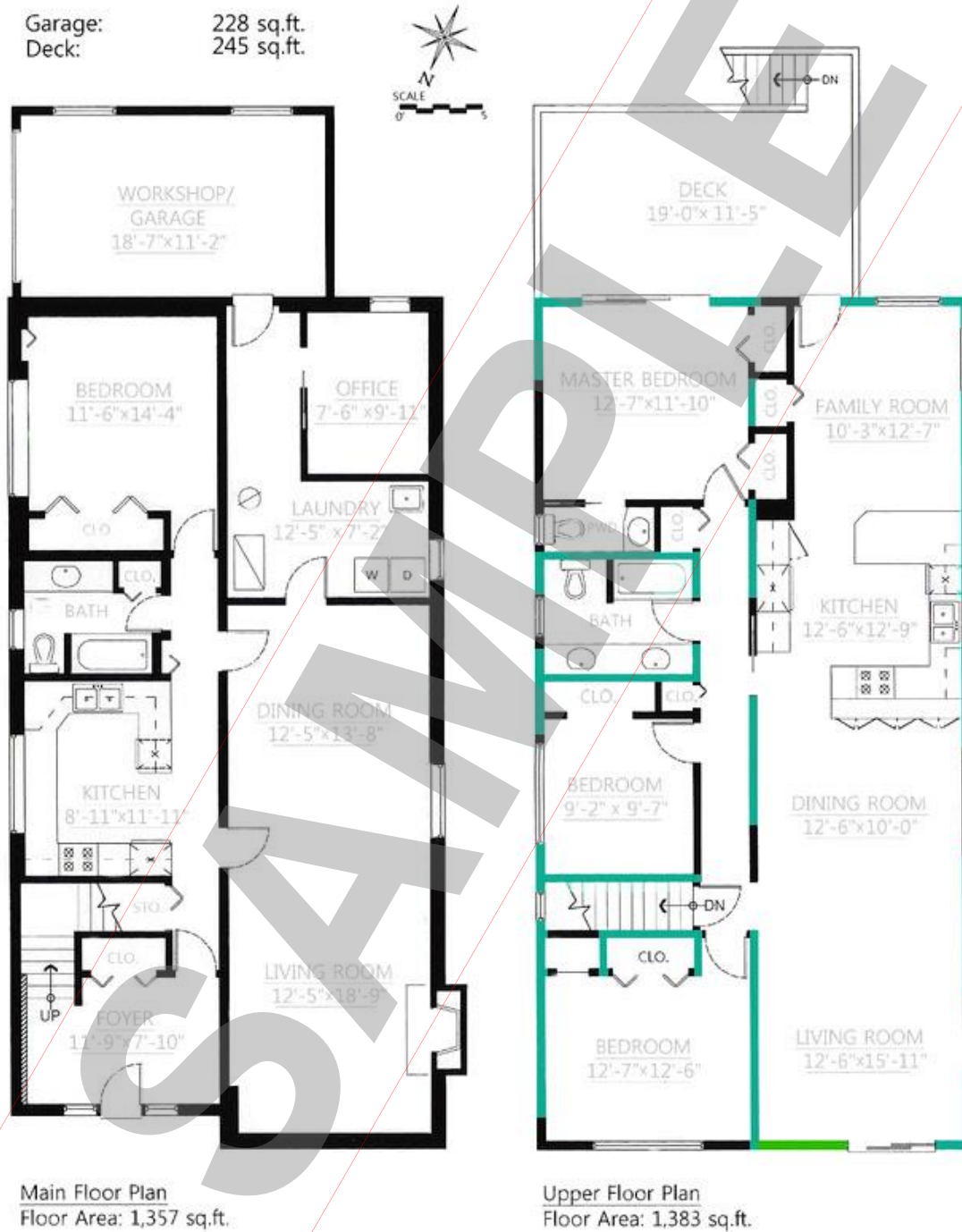


Figure 3: Locations of the retrofitted structural walls

3.2 Risk Assessment Results After Retrofit

Element	Shaking Dir.	Loc.	Prototype No.	Description	Capacity	PDE/PSE
Roof Level Diaphragm	N-S		D-1	Blocked plywood diaphragm	10.91% Wd	< 0.5%
	E-W		D-1	Blocked plywood diaphragm	5.53% Wd	0.9%
Upper Floor LDRS	E-W	Ext.	W-3	Gypsum wallboard	6.15% Ws	1.1%
Upper Floor Diaphragm	N-S		D-1	Blocked plywood diaphragm	5.43% Wd	0.7%
	E-W		D-1	Blocked plywood diaphragm	5.51 % Wd	0.9%

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4.0 Retrofit Cost Estimate

4.1 Construction Cost Summary

Description	Amount (\$)
A. Life Safety Retrofit	
1. New plywood shear walls (upper floor living room)	4,012
2. Roof diaphragm upgrade to blocked plywood diaphragm	22,998
3. Upper floor diaphragm upgrade to blocked plywood diaphragm	34,562
4. Interior wall top connections	4,600
5. Electrical & mechanical work	33,092
Sub-Total Construction Cost	99,264
Design Contingency	14,905
Total Construction Cost	114,169
Gross Floor Area	245.55 m ²
Unit Cost	449 /m ²

4.2 Construction Cost Breakdown

Description	Qty.	Unit	Rate (\$)	Amount (\$)
A. Main Floor Life Safety Retrofit				
1. <u>New plywood shear walls (upper floor living room)</u>				
Remove existing walls	5	m ²	25	125
New wood shear walls:				
38 x 140 @ 400 c/c stud & blocking	2	no.	85	170
12.7 mm plywood to both sides of walls	5	m ²	100	500
16 dia. Hilti HAS rod anchors @ 800 c/c c/w Hilti HIT RE500 adhesive anchor embed 150	2	no.	85	170
Redo wood dry wall skin	5	m ²	60	300
Redo exterior wood cladding	5	m ²	90	450
Paint to interior	5	m ²	12	60
Paint to exterior	144	m ²	13	1,872
Allowance for miscellaneous & make good	10%	%	3,647	365
			Sum	3,825
2. <u>Roof diaphragm upgrade to blocked plywood diaphragm</u>				
Remove existing ceiling board and T & G decking	128.48	m ²	25	3,212
New plywood blocking	102	no.	45	4,590
New 12.7 mm plywood boards for decking	128.48	m ²	50	6,424
New 9.5 mm plywood boards for ceiling	128.48	m ²	40	5,139
Latex paint to ceiling	128.48	m ²	12	1,542
Allowance for miscellaneous & make good	10%	%	20,908	2,091
			Sum	22,998
3. <u>Upper fl. diaphragm upg. to blocked plywood diaphragm</u>				
Carpet & flooring removal of upper floor	128.48	m ²	20	2,570
Remove existing ceiling board and T & G decking	128.48	m ²	25	3,212
New plywood blocking	102	no.	45	4,590
New 12.7 mm plywood boards for decking	128.48	m ²	50	6,424
New 9.5 mm plywood boards for ceiling	128.48	m ²	40	5,139
Latex paint to ceiling	128.48	m ²	12	1,542
New floor finish/carpet	128.48	m ²	80	10,279
Allowance for miscellaneous & make good	10%	%	33,756	3,376
			Sum	34,562

Description	Qty.	Unit	Rate (\$)	Amount (\$)
4. <u>Interior wall top connections</u>				
Allowance for steel angle connection	1	sum	4,600	4,600
			Sum	4,600
5. <u>Electrical & mechanical work</u>				
Electrical work	254.55	m ²	50	12,728
Mechanical work	254.55	m ²	80	20,364
			Sum	33,092

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