Smart Growth on the Ground

FOUNDATION RESEARCH BULLETIN: Squamish

Research compiled by:

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FLOODPLAIN DEVELOPMENT AND CONSTRUCTION

1.0 Introduction

Where development within a floodplain occurs, specific design measures must be taken into account to prevent potential structural damage and loss of life.

Flood damage reduction consists of two basic techniques - structural and non-structural. Structural has historically been the most desired technique since it modifies the flood and "takes floods away from people" by measures such as channels, dykes, and dams. Non-structural flood damage reduction techniques basically "take people away from floods" leaving the flood to pass unmitigated.[1]

This document addresses structural and land-use designs which may help reduce loss in the event of a flood.

2.0 Squamish Background

Downtown Drainage Study[2]
Downtown Squamish has had a history of drainage challenges mainly due to its flat topography, low elevation and tidal influences. It is part of the Squamish/Mamquam alluvial fan, roughly defined by the BC Rail spur line on the west, the Mamquam Blind Channel on the north and east and Cattermole Slough and Cattermole Creek to the south. The area is currently protected from high tide levels by a dyke system and tide gates.

Most of the small scale drainage problems in the downtown area result from damaged, infilled or inadequate ditches, swales and culverts and poorly graded or low-lying lots. Increased maintenance of culverts and ditches would alleviate these problems to some extent.

Known areas of flooding include:

- The Wilson Crescent area
- The area in the vicinity of the retention pond
- The area south of Vancouver Street near Cleveland Avenue and Second Avenue

Runoff from an average event is predicted to fill the pond, the major ditches and pipes, and limited flooding and ponding are expected to occur.
Ponding and flooding of low-lying lots is expected and many lots would only have a limited amount of freeboard above the water levels during extreme rainfall and high tide events.

There are two feasible options for dealing with flooding in downtown Squamish:
1) Increased storage capacity for runoff for the duration of the high tides; and
2) Discharge by pumping.

Future development, if conventionally designed, will create more rainwater runoff, but will increase current runoff levels only slightly since much of the catchment is already developed. It is recommended that future developments should limit runoff to predevelopment peak flows through on-site storage facilities. Refer to the Drainage Study for more specific details on the current drainage status within downtown Squamish.

Future development in the downtown will include commercial, mixed-use, residential, live-work and green-space[3], therefore it is necessary to provide a set of recommendations and guidelines for construction within the floodplain.

Cheekye River Terrain Hazard and Land Use Study[4]

The Cheekye Fan is an 8.3km^2 area formed at the confluence of the Cheekye, Cheakamus and Squamish Rivers. Because of their inherently unstable nature alluvial fans should not be developed, though there is mounting pressure to develop the fan area for residential, industrial and recreational purposes. The fan is subject to natural hazards, primarily debris flow and flooding. For details on risks associated with flooding please refer to Foundation Research Bulletin #6.

Flood Hazard Area Land Use Management Guidelines[5]

Flood protection measures can be applied to new buildings, manufactured homes and units, modular homes or structures on existing lots.

The following are the minimum requirements which should be considered to guide flood-plain development:

Flood plain setbacks: to keep development away from areas of potential erosion and avoid restricting the flow capacity of the floodway. These are measured from the natural boundary[6] unless otherwise specified.

Flood Construction Levels (FCLs) are used to keep habitable spaces (including residential, business and industrial uses) and storage areas above flood levels. These are typically referenced as an elevation above the natural boundary. The designated floods, and the designated flood level, are used in determining the FCL.

The designated flood: refers to a flood which may occur in any given year, of such magnitude as to equal a 200-year recurrence interval, based on a frequency or regional analysis.

A designated flood level: is the observed or calculated water surface elevation for the designated flood.

Table 1: Guidelines for development of setbacks in flood hazards areas

	Downtown Squamish	The Ocean (Howe Sound)	Small Lakes, Ponds, Swamps and Wetland areas	Watercourses[7]	Smaller Watercourses	Alluvial Fans*
Setback		Buildings should be setback **15m** from the natural boundary of the oceans. Landfill or structural supports to be **7.5m**, where the frontage is protected from erosion.	Minimum **7.5m** from the natural boundary of the lake, pond, swamp or marsh.	Minimum **30m** from the natural boundary of any watercourse, except in the case of dykes. The setback requirements may be increased in the case that a watercourse has demonstrated extensive flooding and/or has significant bank erosion and/or depth of flooding.	May be reduced to **15m** from the natural boundary of the watercourse provided the floodway is not obstructed.	Determined as per setbacks for watercourses (above).
Flood Construction Level (FCL)	Minimum **2.6m** above the natural boundary of any nearby watercourse	Minimum 1.5m above the natural boundary of the ocean.	Elevation requirement may be reduced to **1.5m** above the natural boundary of the lake, pond or adjacent swamp or marsh area.	To be such that the underside of the floor system thereof is no less than the flood level.	To be at an elevation greater than **1.5m** above the natural boundary of the watercourse.	Where the hazard is low, the building should be elevated to a minimum of **1m** above the general elevation of the surrounding ground on concrete foundation.

***Development of alluvial fans should be discouraged, and the land should be retained in non-intensive uses such as parks, open-space recreation, and agriculture.*

Table 2: Guidelines for development of FCL's for special land types and uses

	FCL
Areas Protected by Dykes	Should meet minimum FCLs prescribed for the water body adjacent to the dyke)
Public Recreation, Institutional Buildings, Parks & Open Space	Institutional and closed-sided recreational buildings and/or equipment damageable by floodwaters require full floodproofing. Recreation shelters, stands, campsite washhouses and other outdoor facilities susceptible to only marginal damage by floodwaters do not require floodproofing by elevation.
Industrial Areas	Industrial uses shall be located with the underside of a wooden floor system or the top of the pad no lower than the FCL minus freeboard. Certain industrial activities where the use of the waterfront is a necessary part of the operation and would not adversely affect a floodway or significantly increase flood elevations, may be reduced.
Manufactured homes or units	Located on a natural ground surface or on the top of a concrete or asphalt pad that is at or above the FCL. An exception may be made where a manufactured home or unit is located on, and secured to, a poured-in-place concrete perimeter footing, in which case the FCL shall apply to the top of the footing wall.
Parking	As vehicles can be moved to higher ground, floodproofing may not be necessary to prevent water damage in parking areas, provided pedestrians have an unobstructed exit.
Elevation by Landfill	Where landfill is used to raise the natural ground elevation, it should be adequately compacted and the toe of the landfill slope should be no closer to the natural boundary than the prescribed setback. The face of the landfill slope should be protected against erosion by water and debris.

3.0 Design strategies for flood protection

Floodproofing

Floodproofing is the alteration of land or other precautions taken to reduce flood damages. This may include adding fill to raise the elevation of a building site, structural measures such as foundation walls or columns to raise a building, or a combination of fill and structural measures.[8]

There are several methods for floodproofing buildings. In selecting a method of floodproofing, consider the following:[9]

- characteristics of the flood hazard
- physical conditions at the site

Figure 1: A Wet-floodproofed home[12]

- building's function, operation and use
- type and condition of the building.

Basic floodproofing techniques include:[10]

• *Wet floodproofing:* Allows the basement to flood while keeping the habitable portions of the structure above the floodline.

• *Dry floodproofing:* The entire building is made water-tight. Examples include:

- Elevation: Raising the foundation above the flood level using fill or supports
- Sealing all openings below the floodline, either temporarily or permanently

• *Green infrastructure / Sustainable urban drainage:* Allows designated open spaces to become temporary water receivers in a flood event. Examples include:

- Constructed retention and detention ponds
- Constructed or existing wetlands
- Absorbent green infrastructure (swales, etc)
- Use of public infrastructure, vacant lots and open spaces

Figure 2: Elevated industrial building[14]

• *Dykes and floodwalls:* Surrounding the building with floodproof masonry or concrete walls or dykes/berms.

Wet floodproofing measures

Accepts that water will enter the building. It is the deliberate flooding of a structure to balance the water pressure on the interior and exterior walls and floors (Figure 1).

This method of floodproofing is most often used only as a last resort to prevent building collapse because of the time and cost of cleaning up and drying out after the flood.

Flooding of a structure's interior is intended to counteract hydrostatic pressure on the walls, surfaces and supports of the structure by equalizing interior and exterior water levels during a flood[11].

Dry floodproofing

Refers to measures used to keep water out of buildings, such as elevation by piers and other supports, waterproofing, fill, floodproof walls and berms/dykes and relocation.

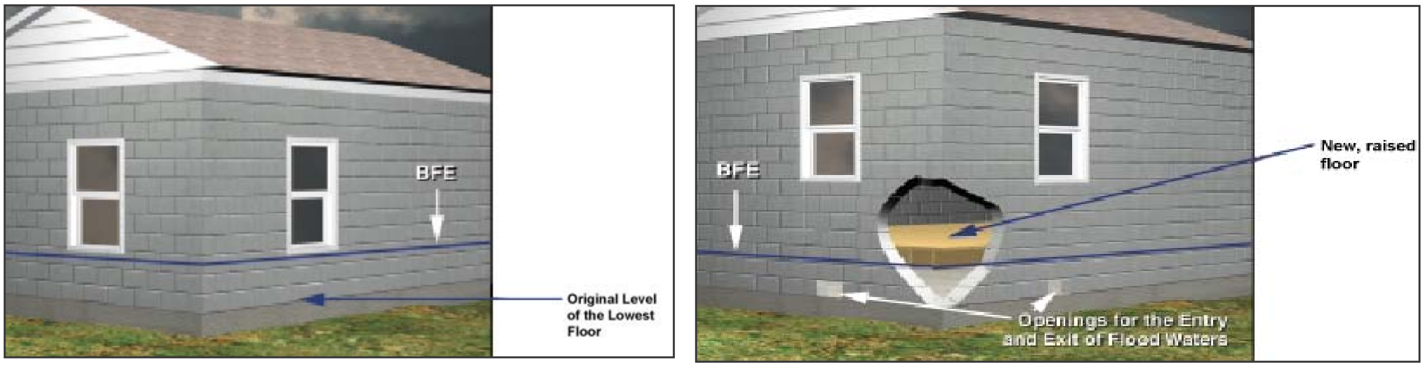
Elevated Buildings

In zones where flood hazards are less severe, buildings may be elevated either on an open foundation or on continuous foundation walls. Regardless of the type of foundation used, such buildings must be elevated so that their lowest floor is at or above the FCL (Figures 2, 3).

Figure 3: Elevated house[15]

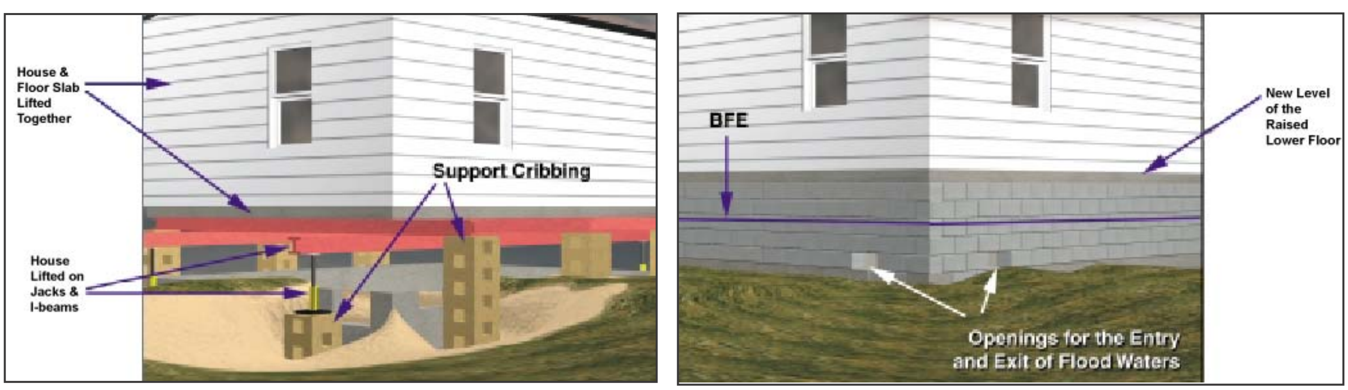
If continuous walls are used below the FCL, they must be equipped with openings that allow flood waters to flow into and out of the

area enclosed by the walls. Allowing the entry and exit of flood waters ensures that water pressures will be the same on both sides of the walls and reduces the likelihood that water pressure will cause the walls to fail.
The following diagrams illustrate three floodproofing techniques.[16]



Technique 1 Extend the walls of the house upward and raise the lowest floor.

Technique 2 Convert the existing lower area of the house to nonhabitable space and build a new second story for living space.



Technique 3 Lift the entire house with the floor slab attached, and build a new foundation to elevate the house.

Figure 4: Public park as flood control area[18]

Figure 5: Retention pond/Wetland with trail connection to school[19]

Figure 6: Constructed Wetland

Green infrastructure or sustainable urban drainage

Effective flood defense relies in part on giving the river space to expand into the adjacent landscape.

The landscape has a positive role to play in flood protection. The tree canopy can reduce the rate at which rain water reaches the ground. The sponginess of the soft green landscape is able to absorb and retain water. Reed beds and shallow ponds can act as temporary reservoirs following rainstorms and they can also help to filter dispersed pollutants and clean the water that drains off roads, roofs, car parks and agricultural land. Also, temporarily vacant land in urban areas frequently contributes by default to surface water management. Where such sites are compacted, they tend to become temporary shallow wetlands after rainstorms, whilst more porous areas serve as soak-aways[17]. In addition, ball parks, large fields and public parks can be used adaptively to accommodate flood water (Figure 4). Parking lots can also be designed with permeable paving, swales and other green infrastructure pockets to catch and infiltrate floodwater. Constructed detention ponds, retention ponds and wetlands can provide increased holding capacity as well, as shown in (Figures 5, 6).

Dykes and Floodwalls

Dykes are compacted earth embankments with moderate side slopes and a wide top that serve as barriers against floodwaters. Floodwalls are engineered barriers, usually concrete or masonry (Figures 7, 8). There are disadvantages to employing these methods for flood protection, including increased cost due to the need for interior drainage systems such as sump pumps. Also, the barriers must be constructed solidly enough to compensate for water pressure. Such structures must be used with caution as they can affect local drainage patterns, redistributing water and creating problems for others.[20]

Adapting Existing Buildings

When demolition is not an option, it is possible to retrofit existing buildings against floodwaters. The three primary methods are elevation, relocation, dykes and floodwalls.

Elevation
As previously discussed, elevation involves raising the lowest floor of the building at or above the FCL (Figures 9,10). For an existing building, this can be done by raising the entire house, or just raising the lowest floor, depending on the construction and foundation type and flooding conditions. However elevated houses can be more susceptible to wind and other environmental loads and may become "top heavy". Foundations should be fortified for extra carrying capacity to mitigate this extra stress.[21]

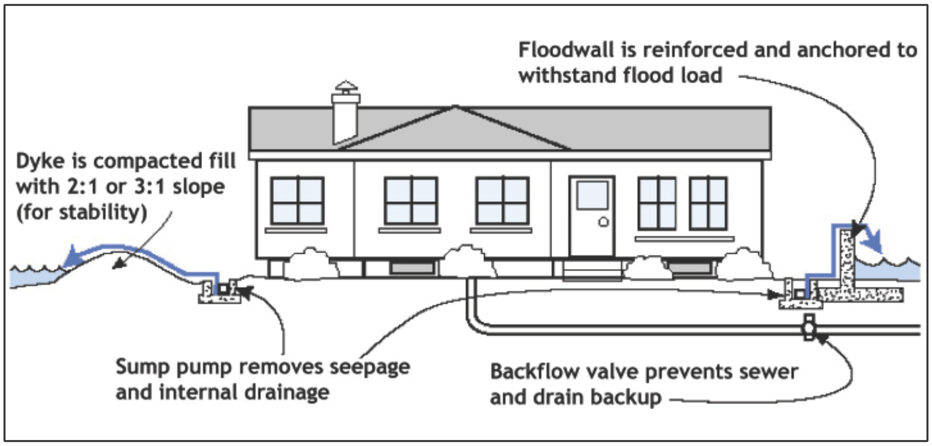


Figure 7: Section with floodwall and dyke

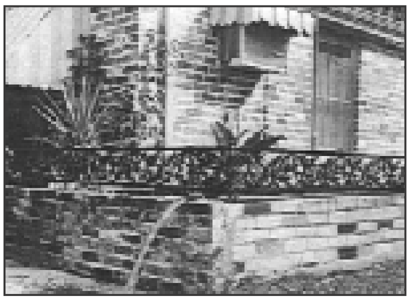


Figure 8: Floodwall as a landscape feature showing sump pump[22]

Figure 9 & 10: House before and after elevation[23]

Relocation
This adaptation essentially involves moving the entire house to higher ground. All types and sizes of buildings can be moved, either as a unit or in segments, though one-story frame houses are easiest and less expensive to move than masonry types. Generally, relocation is more expensive than elevation.

Design Considerations

Refer to supplementary document: "Flood Hazard Management Plan: Background Report" by Klohn Leonoff for section and plan sketches showing the FCL and building in relation to the following floodproofing methods:

-Structural (raised)
  Residential (single and multi-family)
  Mixed-use Residential and Commercial
  Parking at-grade below building
-Fill
  Residential (single and multi-family)
  Institutional

-Combo of structural and fill
  Residential (single family)

4.0 Conclusion

When construction within a floodplain is unavoidable, specific measures must be taken to prevent loss of life and property. Existing and new building and property designs can incorporate and retrofit strategies to ensure that flood damage is kept to a minimum. Setbacks and flood control levels attempt to determine distances from waterbodies and their potential maximum flood levels. Building and site design can further incorporate techniques such as wet and dry floodproofing, green infrastructure/sustainable urban drainage and dykes and floodwalls to mitigate flood damage.

Notes

[1] http://www.usace.army.mil/inet/functions/cw/cecwp/NFPC/Nsfdr/NSFDR_Report.pdf
[2] The following information is extracted from the Executive Summary of the Squamish Downtown Drainage Study, March 2004.
[3] From Squamish 2000 plan zones.
[4] The information in this section is extracted from the *Cheekye River Terrain Hazard and Land Use Study: Summary Report*, March 1993.
[5] The information in this section is extracted from the *Flood Hazard Area Land Use Management Guidelines*, Ministry of Water, Land and Air Protection, Province of B.C., May 2004. Note that these guidelines are an abbreviation for the purposes of the design charrette event.
[6] *Natural Boundary* - The visible high watermark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, stream or other body of water a character distinct from that of the banks thereof, in respect to vegetation, as well as in respect to the nature of the soil itself. For coastal areas, the natural boundarry shall include the natural limit of permanent terrestrial vegetation. In addition, the natural boundary includes the best estimate of the edge of dormant or old side channels and marsh areas.
[7] *Watercourse* - Any natural or man-made depression with well defined banks and a bed of 0.6 metres or more below the surrounding land serving to give direction to a current of water at least six months of the year or having a drainage area of 2 square kilometres or more upstream of the point of consideration.
[8] *Floodplains, alluvial fans and Geotechnical Hazards*, Central Kootenay Regional District, http://www.rdck.bc.ca/planning/brochures/floodplain.pdf
[9] Adapted from Floodproofing: Protect Your Home against Flooding. Environment Canada and New Brunswick Department of Municipal Affairs and Environment, 1989. http:///www.ec.gc.ca/water/en/manage/floodgen/e_home.htm
[10] Environment Canada: http://www.ec.gc.ca/water/en/manage/floodgen/e_proof.html
[11] Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas, Federal Emergency Management Agency. http://www.fema.gov/pdf/fima/job14.pdf
[12] City of Lake Charles Louisiana; www.cityoflakecharles.com/.../flood_plan.asp
[13] FEMA: Homeowners Guide to Retrofitting: Six ways to Protect your House from Flooding http://www.fema.gov/pdf/hazards/hurricanes/sec3.pdf
[14] Accent Architects: www.accentarch.co.nz/Capabi/Industrial.htm
[15] NOAA Coastal Services Centre: Risk and Vulnerability Assessment Tool http://www.csc.noaa.gov/rvat/mitOpps.html
[16] Federal Emergency Management Agency: National Flood Insurance Program http://www.fema.gov/pdf/mit/bpat/fema347_ch2.pdf
[17] Office of the Deputy Prime Minister: Creating Sustainable Communities, London, England. http://www.odpm.gov.uk/stellent/groups/odpm_communities/documents/page/odpm_comm_026908-06.hcsp
[18] Photograph courtesy of Peter Kleiber: http://www.kleiberweb.com/images/thumbnails/benches.jpg
[19] Winfall Constructed Wetlands: http://www.nc.nrcs.usda.gov/features/Highlights/winfall.html
[20] FEMA: Homeowners Guide to Retrofitting: Six ways to Protect your House from Flooding. http://www.fema.gov/hazards/hurricanes/sec3.pdf
[21] FEMA: Homeowners Guide to Retrofitting: Six ways to Protect your House from Flooding. http://www.fema.gov/hazards/hurricanes/rfit.shtm
[22] http://www.usace.army.mil/inet/functions/cw/cecwp/NFPC/fpsys/ace9-10.htm
[23] County of Sonoma Community Development Commission: Flood Elevation Mitigation http://www.sonoma-county.org/cdc/floodelevGrant.htm

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