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Revision History

Revision	Date	Author	Comment
Master	February 2014	Integrated Planning	Guideline created and adopted by Council

1 FLOOD RESILIENT HOUSING GUIDELINES

1.1 APPLICATION OF THE GUIDELINES

The Flood Resilient Housing Guidelines support the development controls contained in the Lake Flooding and Tidal Inundation (Incorporating Sea Level Rise) section of the Lake Macquarie Development Control Plan (DCP). Where an applicant is unable or elects not to meet the finished floor height provisions contained within the Lake Flooding and Tidal Inundation (Incorporating Sea Level Rise) section of the DCP, these guidelines are to be used to determine an appropriate alternative design solution.

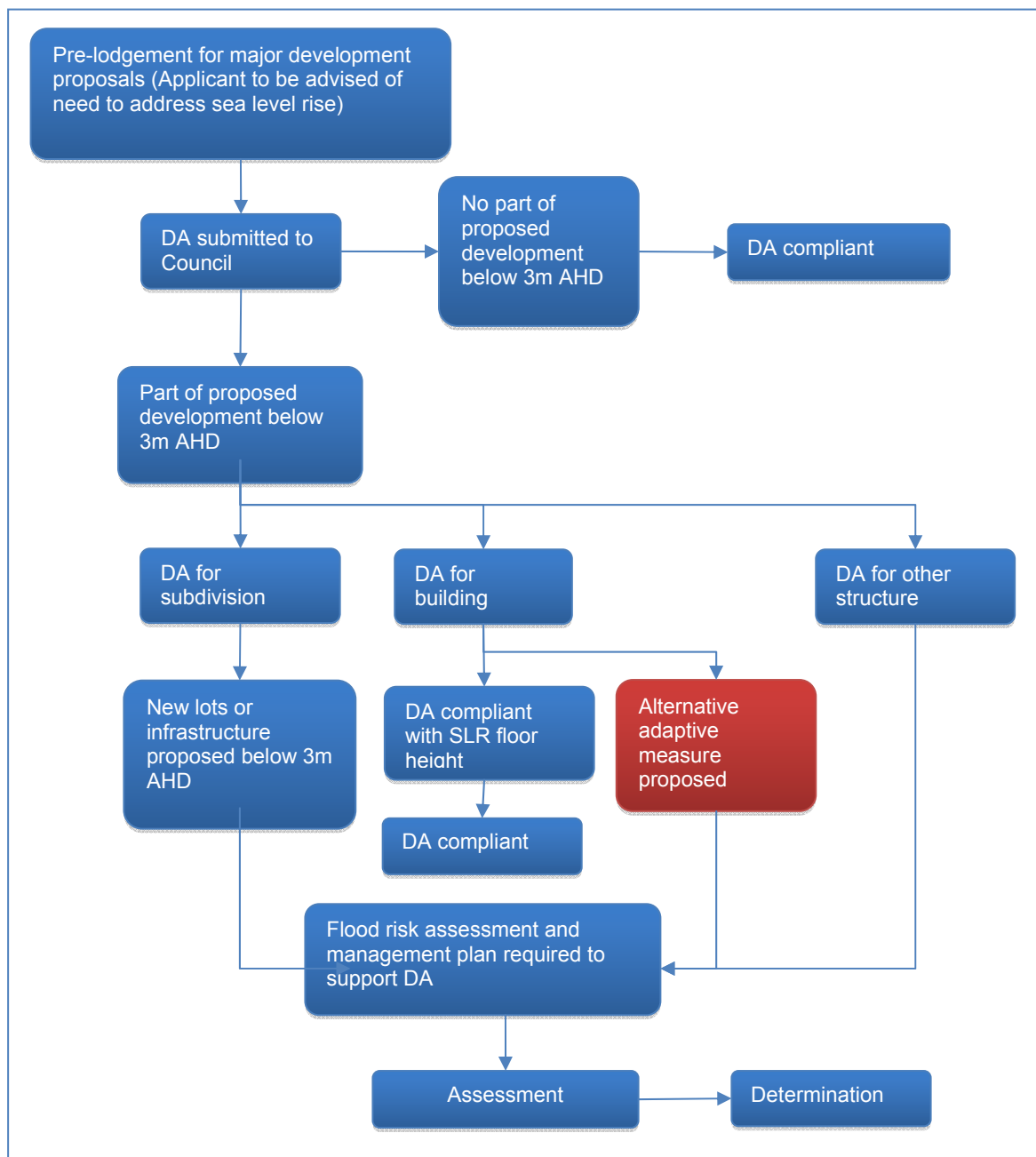


Figure 1 - Diagram showing the LMCC Procedure for Assessing Development Proposals on Land Affected by Sea Level Rise

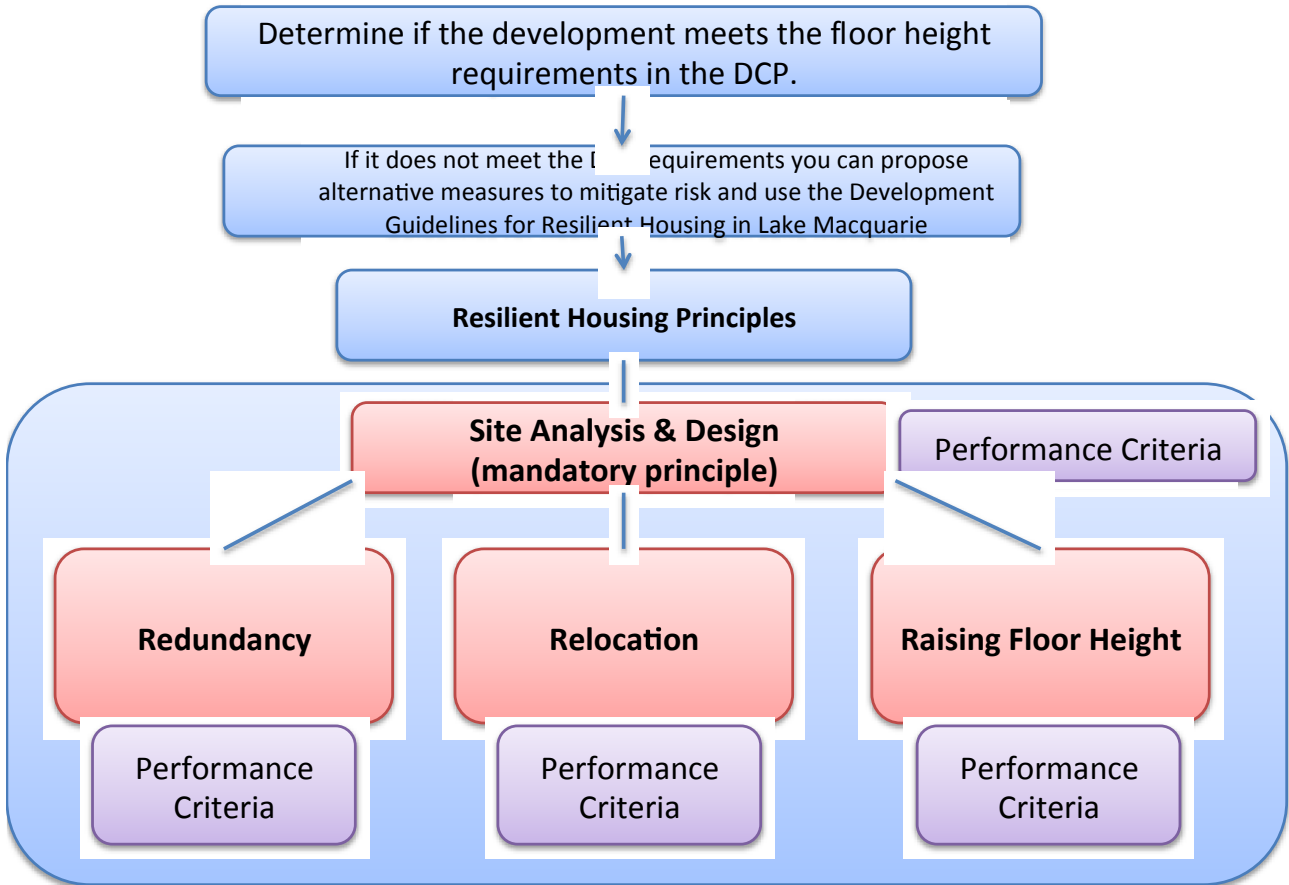
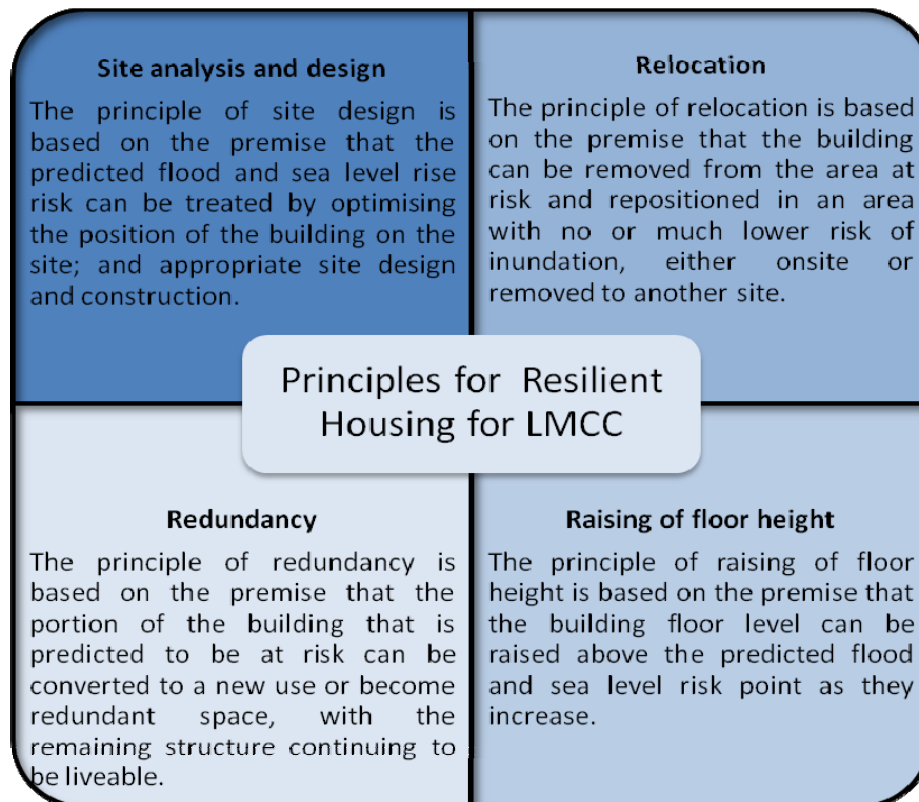


Figure 2 - Applicable development assessment process for Lake Flooding and Tidal Inundation (Incorporating Sea Level Rise) section of the Lake Macquarie Development Control Plan

1.2 DESIGN PRINCIPLES FOR FLOOD RESILIENT HOUSING

To achieve resilient housing that has in-built adaptability and flexibility in relation to flooding and tidal inundation, four principles have been developed:



1.3 DERIVATION OF PRINCIPLES

The following section describes each principle, its derivation and the evidence upon which it is based.

Principle 1. Site analysis and design

The principle of site design is based on the premise that the predicted flood and sea level rise risk can be treated by optimising the position of the building on the site; and appropriate site design and construction.

Site analysis and design is a principle common to all resilient houses in response to sea level rise and flooding. It is intended that Principle 1 be applied to all developments in combination with the other principles as appropriate and desired. The basis of site analysis and design is utilising the site appropriately and designing for inundation impacts. A resilient home can be built by ensuring that the site will maximise the way water will enter and flow across the property and minimise impact on the building. These factors need to be considered:

- Site analysis: assess the site soil type and structure, surface water run-off or ponding, safest point of the site for building, drainage measures and appropriate outlets.
- Site design: utilise the safest part of the site, design appropriate protection works.

There are detailed requirements in the BCA for “structural resistance to the action of liquids, ground water and rainwater ponding by requiring compliance with Australian Standards for structural design. The performance requirements with respect to surface water are designed to ensure that if the ponding of surface

water occurs then drainage and disposal of surface water must be conveyed to an appropriate outfall and avoid water damaging or entering a building” (ACBC, 2005). Site design should utilise these requirements as a minimum standard.

LMCC engaged Clouston Associates to develop principles for adaptable foreshore protection works. These principles should be linked and referenced to Principle 1 in the final guidelines. The designs followed six principles:

1. Conserve and rehabilitate foreshore biodiversity and natural processes.
2. Protect the foreshore from recession.
3. Conserve and enhance public access.
4. Conserve scenic values.
5. Ensure treatments are sustainable and flexible over time.
6. Ensure treatments do not adversely affect neighbours (Clouston, 2012).

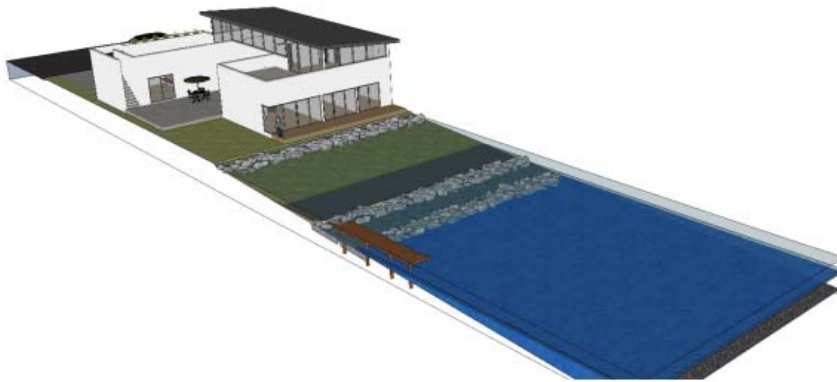


Figure 3 - Foreshore protection using sloping rock revetment showing staged retreat as foreshore recedes, with protection for the maximum expected hazard close to the protected asset (Clouston, 2012)

Principle 2. Relocation

The principle of relocation is based on the premise that the building can be removed from the area at risk and repositioned in an area with no or much lower risk of inundation, either onsite or removed to another site.

The need to relocate onsite can be avoided by siting new developments on the lowest risk area of the site. However, this is not always possible due, for example, to connections to infrastructure, relationship to neighbouring developments, or structural dependence on existing structures. The ability to remove a building from the hazard zone when the risk threshold is reached allows for development to occur on at-risk coastal land, knowing that the building can still be utilised due to its in-built ability to be deconstructed and reconstructed as required. Research indicates that modular buildings and pre-fabricated buildings are quite common for purposes other than removing from a hazard and there is a large body of knowledge and prototypes for designing around removability.

Omi (2007) presented a prototype “self-standing self-build” infill unit to propose a method of realising adaptable buildings, which includes prefabricated, modular ‘infill’ elements that remain structurally separate from the ‘skeleton’ of the building and as a result provide flexibility of assembly, disassembly or reconfiguration as required (Dave *et al.*, 2012).

Designing a building to be relocatable results in specific requirements to:

- Ensure adequate structural integrity.
- Ensure safety and amenity are not compromised.
- Ensure building materials selected are practical and affordable for relocation, for example, brick veneer cladding limits the ability to pick up parts of a building and move it with ease.

- Ensure a route and access for removal.
- Give consideration to the site for relocation.

Principle 3. Raising of floor height in future

The principle of raising of floor height is based on the premise that the building floor level can be raised above the predicted flood and sea level risk point as they increase.

Raised floor heights are a common approach to managing flood risk and sea level rise risk for new buildings. In northern NSW large numbers of existing wooden buildings have also been raised subsequently to reduce flood damage (Smith, 1981). The principle of the ability to raise the floor height in future is about allowing development to occur at the same floor level as other buildings and connect to existing services while the risk level is acceptable, but incorporating the ability to raise the floor height when the flooding risk becomes unacceptable.

Three alternative construction solutions are considered as acceptable solutions to raising of floor height:

1. Bearer and joist construction on piers and piles.
2. Increasing the height of concrete slab foundation.
3. Floatable foundations.

It is envisaged that the most practical solution to Principle 3 is to build bearer and joist construction on piers and piles due to the expected ease in raising the floor height and the ability to easily reconnect services.

However, other solutions exist and have in fact been implemented or planned for in the Lake Macquarie LGA including the raising of floor level through increasing the height of the concrete slab foundation.

Concrete slab construction limits the ability to raise the foundation. However, it is possible to increase the floor height by adding material to the base foundation to result in an overall higher floor height. This solution requires specific design features to allow for the future floor height including increased window sizes, door sizes and connection to services. See section 5.1.4 for a case study of the Lake Macquarie Yacht Club that has implemented this solution.

Building materials should be lightweight to allow for ease of raising with foundations designed specifically to withstand water saturation. Krebich et al. (2005) identified elevated configuration and flood adapted use as some of the key building precautionary measures that may mitigate losses in flood-prone areas.

Floatable homes, those with floatable foundations, are considered to be an acceptable solution to the principle of raising the floor height because they have a type of foundation which is based on land most of the time and simply embraces floodwater and floats. In the context of Development Guidelines for Resilient Housing for Lake Macquarie, floatable foundations are defined as:

The lowest and supporting layer of a structure that is designed to raise the structure when inundated with water. A floatable foundation will be based on dry land in resting position and become buoyant in response to water and support the structure above the water level.

International research highlights two types of floatable foundations. One uses guide beams at either end of the house, allowing water to flow underneath the house and the house to float; and the second using a dock model where a basement foundation is built with a house inside that rises when flooded.

See Appendix E for further guidance on floatable foundations.

See Case Study at Appendix F for more details on building using this principle.

Principle 4. Redundancy

The principle of redundancy is based on the premise that the portion of the building that is predicted to be at risk can be converted to a new use or become redundant space, with the remaining structure continuing to be liveable.

In particular, long-lived assets such as multi-residential buildings should include lower floors that allow change of use when required, for example, from residential to car parking or storage. A structure has a better chance of surviving future higher than anticipated loads if the structure is technically redundant, that is, it has more elements than strictly needed.

For instance, a multi-residential building could have the bottom floor as car parking or storage to allow making that level/area redundant in future. Another example is the 'flood-aware' two-storey house that reduces major structural damage and allows residents to store valuable contents upstairs at the time of a flood. This design includes a full brick ground floor as a structural enhancement, which will also improve recovery after floodwaters have receded (Hawkesbury-Nepean Floodplain Management Steering Committee, 2006).

See Case Study at Appendix G for more details on building using this principle.

1.4 PERFORMANCE CRITERIA AND ACCEPTABLE SOLUTIONS FOR ADAPTABLE BUILDINGS

The following tables describe the Performance Criteria and Suggested Acceptable Solutions for each principle. Additional guidance is given through the provision of considerations and case studies.

It is intended that all developments meet Principle 1 and at least one of Principles 2, 3 and/or 4.

Principle 1. Site analysis and design: The principle of site design is based on the premise that the predicted flood and sea level rise risk can be treated by optimising the position of the building on the site; and appropriate site design and construction.

Performance Criteria	Suggested Acceptable Solutions	Considerations and Case Study
The principle may be achieved where:		
P1.1 The development has an inundation risk site analysis undertaken that considers increased tidal flow, prolonged inundation and rising groundwater.	A1.1 The site analysis includes: <ul style="list-style-type: none"> • Topography and height above AHD. • An estimate of potential incoming and outgoing direction and velocity of floodwaters. • Soil type and structure with regard to foundation stability. • Drainage properties. • The safe movement of people in or out of the building during inundation. • A Flood Management Study. Identify where floodwaters will drain and ensure the development does not impede floodwaters or negatively impact on neighbouring properties or public land. 	<ul style="list-style-type: none"> • If land is in a low hazard area or subject to specific lake hazards, proponents can undertake site analysis based on lake hazards the site is expected to experience. • See Clouston 2012 study for more measures on adaptable site protection measures.
P1.2 Site utilisation: The development is designed to maximise natural protection and be built on the safest part	A1.2 The site design takes into account the natural features of the site: <ul style="list-style-type: none"> • Build on safest part on the site. • Site design includes appropriate foreshore setback for long-term resilience. 	<ul style="list-style-type: none"> • Must have regard to site coverage and unbuilt areas. • Note that to plan for soil types and flow velocities a flood study (including

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
of the site.	<ul style="list-style-type: none"> • Ensure that adequate regard is given to the properties of the soil types under potential flood inundation, drainage and the impact from flow velocities (i.e. doesn't erode under flow conditions). • Demonstrate that foundations are structurally sound and will not be compromised by being sunk into different layers of stratum (such as rock, clay, organic soils or sand), that may be compromised by ground water or flooding. Applicable to sites where cut and fill is required, and pier and beam construction is to be used. • Protect exposed areas, including embankments. • Areas of the site potentially exposed to flooding (such as lower ground areas) should be used for non-emergency access roads and amenity areas. • Evacuation access: ensure safe access from the site for evacuation. The driveway should provide easy exit from the house and should be as high as possible along its full length to provide the longest period for evacuation. • Replant cleared land areas to restore habitat, prevent erosion, and minimise tidal flow, where possible. 	hydrodynamic forces) would need to be conducted as flow conditions are not designed for in these performance criteria.
P1.3 The site is designed to incorporate effective floodwater management and foreshore recession management.	<p>A1.3 The site design incorporates appropriate building protection measures including (linked to A1.1 Flood Management Study):</p> <ul style="list-style-type: none"> • Landscape features – particular landscaping components may impede or increase the velocity of the flow of stormwater across a property, such as stone or sleeper barriers. • Avoid building on areas where there is likely to be significant tidal flows or drainage channel flows that could cause hydrodynamic forces, debris impact and foundation instability due to erosion. 	

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
	<ul style="list-style-type: none"> • Consideration of pumping system to manage inundation and increased tidal events. • Protection works such as floodgates, earth bunds, use of swale and flood fences with impermeable bases. • Driveways or paths made of permeable material so water can drain away easily. <p>Drains, water inlets and outlet pipes are fitted with non-return valves to help prevent water entry.</p>	
<p>P1.4 Structural integrity: Protection works and foundations are designed to withstand predicted hazard impacts.</p>	<p>A1.4</p> <ul style="list-style-type: none"> • Foundations, piers and piling are designed to maintain structural performance with increasing levels of groundwater and reduced drainage. • Foundations, piers and pilings are designed to maintain structural performance when inundated with saltwater. • The future stability of the site should be considered in the choice of foundations. Consider soil types in order to assess soil saturation characteristics. 	
<p>P1.5 Retain connection to infrastructure and services: Any adaptations made to the site must be able to connect to services.</p>	<p>A1.5</p> <ul style="list-style-type: none"> • Site adaptations such as cut and fill must consider the ability to connect to services easily. • Drainage plans must consider impact of prolonged inundation on service connection and operation where prolonged inundation is a risk. 	

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
P1.6 Practicality of build and future resilience mechanisms.	A1.6 Site design and protection works must be practical <ul style="list-style-type: none"> • Site design and protection works must not impact negatively on public or private property. • Site design and protection works must not rely on Council undertaking improvement works such as added drainage. 	
P1.7 Flood-resilient materials	A1.7 <ul style="list-style-type: none"> • Materials used for site protection and design should meet saltwater requirements. 	<ul style="list-style-type: none"> • Based on the assumption that all Lake Macquarie hazard areas are at risk of saltwater inundation.

Principle 2. Relocation: The principle of relocation is based on the premise that the building can be removed from the area at risk and repositioned in an area with no or much lower risk of inundation, either onsite or removed to another site.

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
<p>P2.1 The building design facilitates relocation.</p>	<p>A2.1 Modular buildings</p> <ul style="list-style-type: none"> The development is made up of modular parts that remain structurally separate from each other to be demountable or movable as a composite structure when the agreed trigger is reached. To achieve a modular building, joints need to be expressed (non-hidden) and non-structural to facilitate ease of removal and relocation. Party walls must be constructed with clear separation (e.g. if timber frames – double studs with clear gaps). <p>A2.1.1 - Design for disassembly</p> <p>The development is designed to be disassembled and relocated when the agreed trigger is reached. Note also that:</p> <ul style="list-style-type: none"> Joints are accessible and expressed. Individual components can be removed and are readily transportable. A disassembly plan is presented with the Development Application (DA), including instructions on how to deconstruct. Lightweight building materials and designs are used to facilitate the removal, transport and relocation of the building. The building is constructed from lightweight products and does not include any high mass components such as structural masonry or concrete products. Unless the proponent can demonstrate 	<ul style="list-style-type: none"> Highly dependent on desired design as not suited to large multi-storey heavy development. Suits small one-storey multi-residential unit developments. Suits single detached dwellings. Suits low, medium, high lake flooding hazard levels. Potentially not suited to high-density development due to possible access constraints to disassemble and remove parts. Relocation: need to ensure that removing the building doesn't sterilise the site from other options. Structural masonry is probably less able to be moved than say precast concrete panels as the latter can be bolted together whereas the former usually rely on rebar connections.

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
	the weight of any one building component does not exceed the maximum lift-able weight of a normal crane.	
P2.2 Structural integrity The building is designed to be robust and durable enough to withstand the relocation process.	A2.2 Independent parts <ul style="list-style-type: none"> • Individual building parts are independently robust, and do not rely on any other building part for their structural integrity. • A building part may be a whole block of rooms, a room or an individual component like a floor or wall, and must be structurally robust as its own system. Where possible, structural integrity must be demonstrated by warranty or product statements from the manufacturer. • Elements once disconnected from the adjacent elements can be moved without incurring damage to the element. Lifting points must be strategically placed. A2.3 <ul style="list-style-type: none"> • Footings and foundations must be flood-resilient. 	<ul style="list-style-type: none"> • AS/NZS 1170.0 (Structural design actions – general principles) • AS/NZS 1170.1 (Structural design actions – Permanent, imposed and other actions) • AS/NZS 1170.2 (Structural design actions – wind actions)
P2.3 Compliance to development regulations to ensure amenity and liveability.	A2.3 Identify applicable regulations <ul style="list-style-type: none"> • Any amendment to the building must be liveable and result in a fully compliant residential building in accordance with LMCC DCP and LEP. • Relocated building must comply with DCP and LEP in new location. If relocated in the LMCC area the building is not exempt from any development control in place for new location. 	If the building is relocated it will have to comply with controls and regulations applicable at the time.

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
<p>P2.4 Retain connection to infrastructure and services.</p>	<p>A2.4 The planned relocation must allow for reconnection to infrastructure and services at new location. The development must include a plan for disconnection and reconnection of services</p> <ul style="list-style-type: none"> • The development must include a plan for water reconnection and the water connection to the house, and should be designed to be readily disconnected and easily reconnected at a new location. • The development must include a plan for sewer reconnection and the sewer connection to the house should be simple (ideally one pipe out), and designed to be readily disconnected and easily reconnected at a new location. • The development must include a plan for electricity or gas reconnection with the connection to the grid being simple (ideally one connection), and designed to be readily disconnected and easily reconnected at a new location. • The development must include a plan for access with entry and exit points to the house being designed in such a way that they can readily connect to new access points or be readily reconfigured. Site-specific entry and exit, relying on particular features, should be avoided. <p>A2.4.1 The building has meter boxes and electrical points located above inundation level to allow continued connection to services</p>	<ul style="list-style-type: none"> • Affordability of Council maintaining services is a significant issue that is being considered as part of broader adaptation strategies. • In high-risk areas, backflow valves should be installed on service piping to prevent waste leakage during inundation.
<p>P2.5 Practicality of build and future resilience mechanisms: the planned relocation must be practical.</p>	<p>A2.5.1 Practicality</p> <p>The planned relocation must be practical and achievable:</p> <ul style="list-style-type: none"> • Site access must allow practical and achievable relocation process. • Evidence that it could be transported (e.g. it fits on a truck, standard width). 	<ul style="list-style-type: none"> • Consider what is involved in reconstructing building. • Removal/relocation does not sterilise site from future options to build another 'adaptable building'. • Consideration must be given to

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
		<p>alternative site.</p> <ul style="list-style-type: none"> • A solution that includes deconstruction down to individual building products is not considered very practical.
<p>P2.6 Flood-resilient design: the building must use flood-resilient design.</p>	<p>A2.6 Flood-resilient design includes the following considerations:</p> <ul style="list-style-type: none"> • Design and construct wall cavity to ensure adequate ventilation and access for cleaning. • Allow water entry and exit through vents and/or flaps to balance internal and external water pressures. • Design foundations against erosion and differential settlement. • Use non-absorbent meter box. • Protect and anchor tank insulation such as polystyrene panels. • Protect frame from failure and bottom sliding. For locations where there may be a high frequency of flooding or there is a chance of saltwater flooding, use stainless steel or other high durability ties with angled surfaces to promote run-off. • Use horizontal sheeting for internal cladding to reduce replacement costs if impacted by flooding. 	<ul style="list-style-type: none"> • The Australian Resilience Taskforce (ART) will provide information on built environment resilience initiatives and data on building materials. • The Building Resilience Knowledge Database (BRKD) is an online database that rates the resilience of building materials to inundation. It is suggested that developers, builders and homeowners using the guidelines refer to the BRKD to determine appropriate resilient building materials. www.buildingresilience.org.au
<p>P2.7 Flood-resilient materials: the building components potentially exposed to flooding must</p>	<p>A2.7 Building materials specified for use in buildings in flood-prone areas should be resilient and the source referenced in the DA. Light weight flood resilient materials are preferable to facilitate relocation ease and protect against flood</p>	<ul style="list-style-type: none"> • The Australian Resilience Taskforce (ART) will provide information on built environment resilience initiatives and

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
use flood-resilient materials.	events until relocation occurs.	<p>data on building materials.</p> <ul style="list-style-type: none"> The Building Resilience Knowledge Database (BRKD) is an online database that rates the resilience of building materials to inundation. It is suggested that developers, builders and homeowners using the guidelines refer to the BRKD to determine appropriate resilient building materials. www.buildingresilience.org.au

Principle 3. Raising of floor height: The principle of raising of floor height is based on the premise that the building floor level can be raised above the predicted flood and sea level risk point as they increase.

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
<p>P3.1 The building design facilitates raising of the floor level above the specified AHD.</p>	<p>A3.1 The building is designed on bearer and joists on piers</p> <p>The development is constructed using a bearer and joist construction on piers and the structure can be raised using jacks or a crane so that the pier and floor height can be increased.</p> <ul style="list-style-type: none"> • A plan detailing how the building will be raised in future must be submitted with DA. <p>A3.1.1 The building is designed to allow for additional floor height by adding to existing floor with new material</p> <p>In buildings where there is a concrete slab ground floor, and where it is anticipated that it may be possible to achieve a floor height above the risk level by increasing the floor height with an additional layer of concrete, ceiling, door and window heights must allow for additional height of floor.</p> <ul style="list-style-type: none"> • DA submissions must be marked with allowance for additional floor height, and all future window and door heights must comply with DCP. <p>A3.1.2 Development independent of any external structure</p> <ul style="list-style-type: none"> • To achieve the principle of raising, the building must be structurally independent of any external structures such as garages, sheds, workshops. <p>A3.1.3 The building is designed with a floatable foundation that will allow the structure to become buoyant as flood waters rise</p>	<ul style="list-style-type: none"> • Lake Macquarie Yacht club case study. • Where adaptation includes fill, wall cavity should include drainage. • Extra thickness of slab can mean greater bearing pressures on the foundation beneath. <p>Floatable foundations have a specific set of considerations need to be factored into building and site design. See Appendix E for further guidance.</p>

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
	<ul style="list-style-type: none"> The building is designed with a foundation that allows the house structure to lift from the foundation and become buoyant as flood waters rise while being guided on guide posts. There are currently two models for designing in this way. Appendix E provides further guidance. 	
<p>P3.2 Structural integrity: the building is robust enough, and designed, to facilitate raising.</p>	<p>A3.2 The building has specific jacking points/connections that are clearly marked to ensure it can be raised and held while the building is being raised</p> <p>Where it is intended that the building be raised in the future there should be clear instructions for how the building is to be raised (crane/jack):</p> <ul style="list-style-type: none"> ‘Raising plans’ should be specified and lodged with DA. These should include where any beams should be placed for raising using a crane, or where the jacking points are to be. The building itself should be clearly labelled with points for insertion of beams for raising and/or jacking points. Lightweight building materials should be used to facilitate raising. <p>A3.2.1 Where the intention is to raise the floor height with more material, the foundations should be designed and constructed to withstand the additional load</p> <p>A3.2.2 If utilising a floatable foundation the super structure and foundation must have structural integrity:</p> <ul style="list-style-type: none"> The superstructure must be designed to tolerate movement when the rising with flood waters. Foundations should be designed based on a thorough soil analysis including the tolerance to high levels of ground water and long periods of inundation. 	<ul style="list-style-type: none"> AS/NZS 1170.0 (Structural design actions – general principles) AS/NZS 1170.1 (Structural design actions – Permanent, imposed and other actions) AS/NZS 1170.2 (Structural design actions – wind actions)

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
P3.4 Compliance to development regulations to ensure amenity and liveability.	A3.4 Identify applicable regulations <ul style="list-style-type: none"> • Building must comply with DCP both pre and post-raising. 	
P3.5 Retain connection to infrastructure and services.	A3.5 The planned raising of the floor height must have flexible connections or allow for re-connection to infrastructure and services at new height. The development must include a plan for disconnection and reconnection of services (unless reconnection is unnecessary due to the use of flexible connection piping). <ul style="list-style-type: none"> • Plan for water reconnection; the water connection to the house should be designed to be readily disconnected and easily reconnected at a raised new building height. • Plan for sewer reconnection; the sewer connection to the house should be simple (ideally one pipe out), and designed to be readily disconnected and easily reconnected at a raised new building height. • The development must include a plan for electricity or gas reconnection with the connection to the grid being simple (ideally one connection), and designed to be readily disconnected and easily reconnected at a new location. • Plan for access; entry and exit points to the house should be designed in such a way that they can be readily reconfigured to connect to raised access points. A3.5.1 The building has meter boxes and electrical points located above inundation level to allow continued connection to services	<ul style="list-style-type: none"> • Evacuation access. • Affordability of Council maintaining services. • Impact of prolonged inundation on services.
P3.6 Practicality of build and future resilience: the planned raising of the floor height must be practical.	A 3.6 Implementation of the raising plan should be practical <ul style="list-style-type: none"> • The planned raising must use practical means. For example, raising the building using a crane and beams or by using hydraulic jacks. 	

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
P3.7 Flood-resilient design: The building must use flood-resilient design.	A3.7 Flood-resilient design includes the following considerations: <ul style="list-style-type: none"> • Design and construct wall cavity to ensure adequate ventilation and access for cleaning. • Allow water entry and exit via vents and flaps to balance internal and external water pressures. • Design foundations such as slab on ground against erosion and differential settlement. • Use non-absorbent meter box. • Protect and anchor tanks insulation such as polystyrene panels. • Use articulation joints to limit cracking from uneven foundation movement Provide generous venting through foundation walls to balance hydrostatic forces. • Protect frame from failure and bottom sliding. For locations where there may be a high frequency of flooding or there is a chance of saltwater flooding, use stainless steel or other □high durability ties with angled surfaces to promote run-off. • Horizontal sheet fixing can reduce replacement costs. 	<ul style="list-style-type: none"> • The Australian Resilience Taskforce (ART) will provide information on built environment resilience initiatives and data on building materials. • The Building Resilience Knowledge Database (BRKD) is an online database that rates the resilience of building materials to inundation. It is suggested that developers, builders and homeowners using the guidelines refer to the BRKD to determine appropriate resilient building materials. www.buildingresilience.org.au
P3.8 Flood-resilient materials: the building components potentially exposed to flooding must use flood-resilient materials.	A3.8 Building materials specified for use in buildings in flood-prone areas should be resilient and the source referenced in the DA. <ul style="list-style-type: none"> • Lightweight building materials should be used to facilitate ease of raising. 	<ul style="list-style-type: none"> • The Australian Resilience Taskforce (ART) will provide information on built environment resilience initiatives and data on building materials. • The Building Resilience Knowledge Database (BRKD) is an online

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study
		<p>database that rates the resilience of building materials to inundation. It is suggested that developers, builders and homeowners using the guidelines refer to the BRKD to determine appropriate resilient building materials.</p> <p>www.buildingresilience.org.au</p>

Principle 4. Redundancy: The principle of redundancy is based on the premise that the portion of the building that is predicted to be at risk can be converted to a new use or become redundant space, with the remaining structure continuing to be liveable.

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study Example includes what the development scenario is suited to.
<p>P4.1 Parts of the building at risk from permanent inundation or sea level rise are able to become redundant space if an increase in floor level heights is required.</p>	<p>A4.1 Lower floor space becomes redundant</p> <p>In a two-storey house or multi-residential unit block the lower floor space becomes redundant as accommodation if an increased floor level height requirement is implemented:</p> <ul style="list-style-type: none"> • The upper floors are independent from the lower floor. • There is separate access to the upper floors. • The upper floor accommodation is compliant with DCPs independent from the lower floor space. • DA includes an illustrated plan demonstrating how upper floor can function independently after the lower floor is adapted to a new use or made redundant. • Straight and wide stairs with treads and risers of comfortable proportions to facilitate relocation of contents from ground to upper floors. 	<ul style="list-style-type: none"> • The traditional 'Queenslander' homes. • Multi-residential buildings may include lower floors that allow change of use when required, from residential to car parking or storage. • Lower floors may be in the form of a standard two-storey home or a split-level home that may be on a sloping section.
<p>P4.2 Structural integrity: the building is robust enough to allow for redundant space to support the building in an environment where increased frequency of flooding and periods of inundation are the</p>	<p>A4.2 The building remains structurally sound</p> <p>Where it is intended that the building has redundant space that can support the structure the foundations and/or piers must:</p> <ul style="list-style-type: none"> • Have enough strength to support the structure in changed soil conditions as saturated soils could lose bearing strength. • The lower floor structure must be strong enough to withstand potential 	<ul style="list-style-type: none"> • AS/NZS 1170.0 (Structural design actions – general principles) • AS/NZS 1170.1 (Structural design actions —Permanent, imposed and other actions) • AS/NZS 1170.2 (Structural design

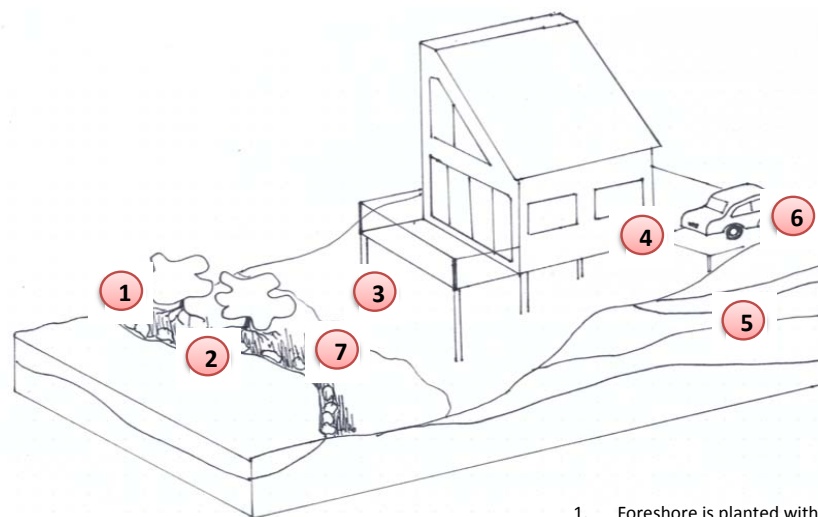
Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study Example includes what the development scenario is suited to.
norm.	<p>submersion in water for long periods and retain structural integrity to support house.</p> <p>Cavity brick (double brick) or masonry walls for the lower storey of two-storey homes in areas of deep inundation should include:</p> <ul style="list-style-type: none"> • Water entry strategy – where emphasis is placed on allowing water into the building, facilitating draining and consequent drying. Provide for ingress of water to balance hydrostatic forces inside and outside the walls via vents and flaps (which are compatible with the energy conservation requirements). • Also include openings into the cavity brick walls to facilitate removal of silt from the cavity. 	<p>actions – wind actions)</p> <ul style="list-style-type: none"> • May mean boring holes in the abandoned storeys.
P4.3 Compliance to development regulations to ensure amenity and liveability.	<p>A4.3 Identify applicable regulations</p> <ul style="list-style-type: none"> • Ensure compliance with development regulation at the time. The building with redundant space must comply with LMC DCPs once redundancy plan is implemented. 	<ul style="list-style-type: none"> • Amount of living space. • Ratio of bathrooms.
P4.4 Retain connection to infrastructure and services.	<p>A4.4 The planned redundancy must allow for good ongoing connection to infrastructure and services</p> <ul style="list-style-type: none"> • Plan for water connection to remain unaffected. • Plan for sewer connection to be unaffected. • Plan for electricity or gas connection to be unaffected. • Plan for access; entry and exit points to the house should be designed in such a way that they can be readily changed to account for changed 	<ul style="list-style-type: none"> • Evacuation access. • Affordability of Council maintaining services. • Impact of prolonged inundation on services.

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study Example includes what the development scenario is suited to.
	<p>conditions.</p> <p>A4.4.1 The building has meter boxes and electrical points located above inundation level to allow continued connection to services</p>	
P4.5 Practicality of build and future resilience mechanisms.	<p>A4.5 Practicality</p> <p>The planned redundancy must be practical and achievable:</p> <ul style="list-style-type: none"> • The planned redundancy must result in a house that is similar in terms of the accommodation it offers. • No more than 40% of the adapted house can be allocated as redundant based on floor area. 	<ul style="list-style-type: none"> • Bathroom requirements are met in unchanged accommodation. • Plan in redundant space upstairs – rooms may become bedrooms into the future. • Choosing to build a two-storey house instead of a single-storey with a similar floor area adds less than 10% to building costs (HBNBG).
P4.6 Flood-resilient design: the building must use flood-resilient design.	<p>A4.6 Flood-resilient design includes the following considerations:</p> <ul style="list-style-type: none"> • Design and construct wall cavity to ensure adequate opportunity to balance pressures. Allow water entry and exit via vents and flaps to balance internal and external water pressures. • Design foundations such as slab on ground against erosion and differential settlement. • Use non-absorbent meter box. • Protect and anchor tank insulation such as polystyrene panels. • Construct external ground floor walls in double brick or masonry for strength. • Improve brick wall stability through use of side fixed ties 	<ul style="list-style-type: none"> • The Australian Resilience Taskforce (ART) will provide information on built environment resilience initiatives and data on building materials. • The Building Resilience Knowledge Database (BRKD) is an online database that rates the resilience of building materials to inundation. It is suggested that developers, builders and homeowners using the guidelines refer to the BRKD to determine appropriate resilient building materials. www.buildingresilience.org.au

Performance Criteria The principle may be achieved where:	Suggested Acceptable Solutions	Considerations and Case Study Example includes what the development scenario is suited to.
	<ul style="list-style-type: none"> • Use articulation joints to limit cracking from uneven foundation movement. • Provide generous venting through brickwork to balance hydrostatic forces. • There should be no timber in abandoned floor. • Protect frame from failure and bottom sliding. For locations where there may be a high frequency of flooding or there is a chance of saltwater flooding use, stainless steel or other high durability ties with angled surfaces to promote run-off. 	
<p>P4.7 Flood-resilient materials: the building components potentially exposed to flooding must use flood-resilient materials.</p>	<p>A4.7 Building materials specified for use in buildings in flood-prone areas should be resilient and the source referenced in the DA.</p>	<ul style="list-style-type: none"> • The Australian Resilience Taskforce (ART) will provide information on built environment resilience initiatives and data on building materials. • The Building Resilience Knowledge Database (BRKD) is an online database that rates the resilience of building materials to inundation. It is suggested that developers, builders and homeowners using the guidelines refer to the BRKD to determine appropriate resilient building materials.

1.5 DIAGRAMS OF PRINCIPLES

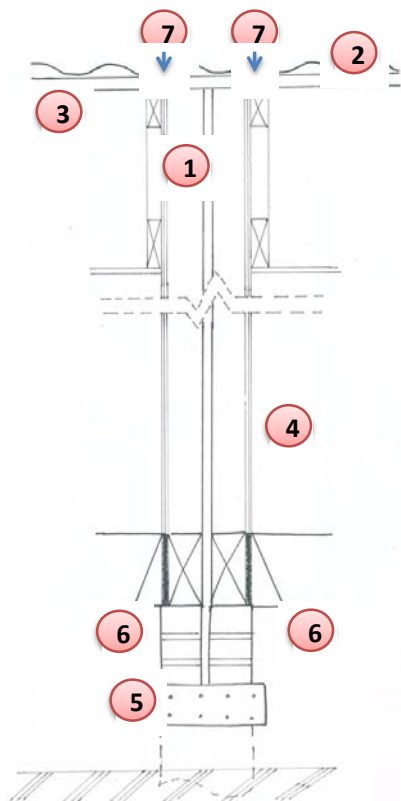
Principle: Site analysis and design



1. Foreshore is planted with appropriate plants to prevent erosion and buffer against tidal flow.
2. Embankments on the foreshore are protected against erosion.
3. Specially designed foundations withstand rising groundwater and inundation.
4. Building is positioned on safest point.
5. Soil assessment has been considered to factor in foundation design and groundwater levels.
6. Driveway and access point is on high point of section allow for safe access during inundation event.
7. Buffer area to allow for foreshore recession and/or construction of foreshore protection.

Figure 4 - Illustration of the principle of site design and analysis

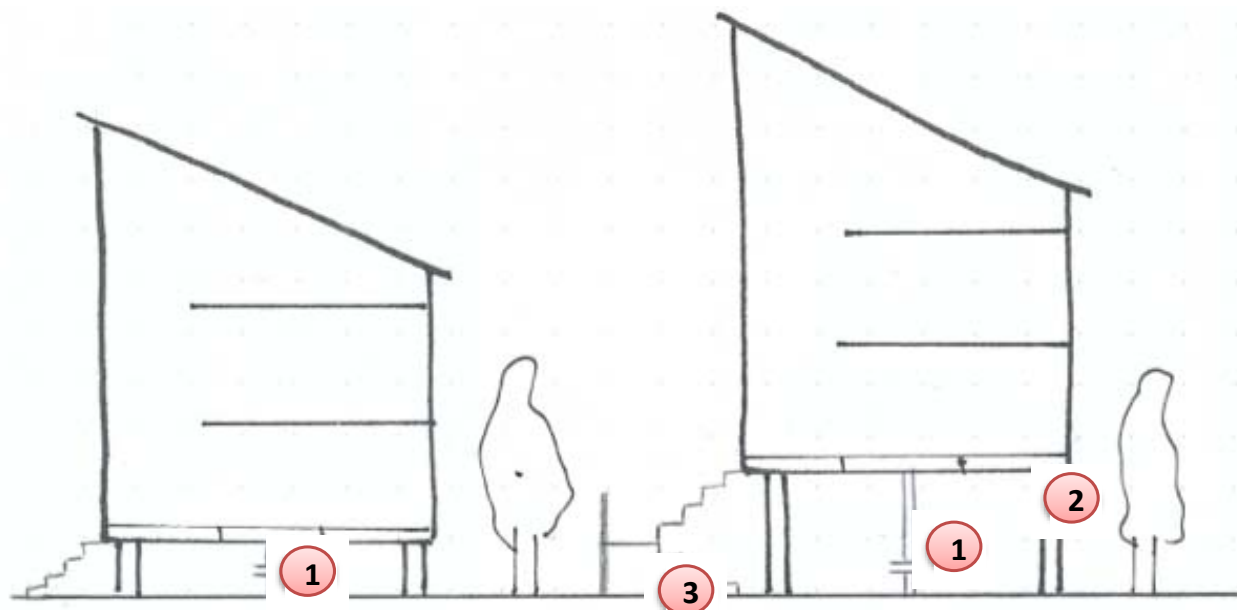
Principle: Relocation



1. Party walls are constructed with clear separation (eg, if timber frames - double studs with clear gaps).
2. Lightweight building materials and designs are used to facilitate the removal, transport and relocation of the building. The building is constructed from lightweight products and does not include any high mass components such as structural masonry or concrete products. Unless the proponent can demonstrate the weight of any one building component does not exceed the maximum lift-able weight of a normal crane Cladding on lower floor is flood resilient.
3. Individual building parts are independently robust, and do not rely on any other building part for their structural integrity.
4. Removal and relocation is practical.
5. Foundations are designed to cope with rising groundwater and permanent inundation.
6. Jacking points to allow raising of floor from foundations.
7. Lifting points to allow lifting of components onto transport to allow relocation of components.

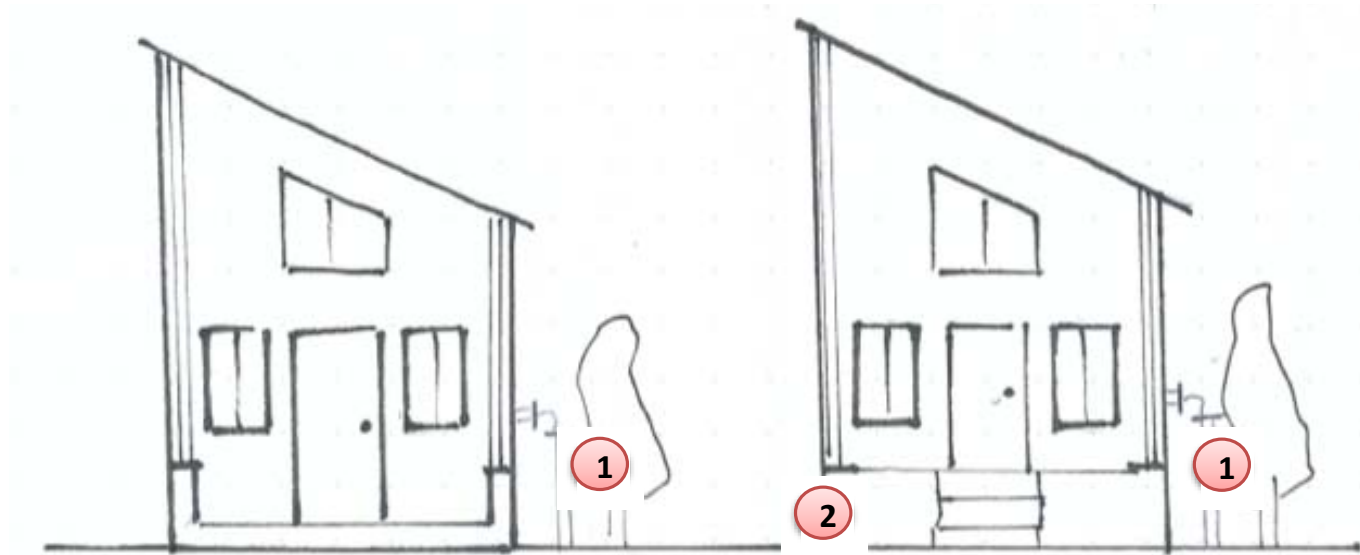
Figure 5 - Close-up cross-section of wall showing unjoined components

Principle: Raising of floor height



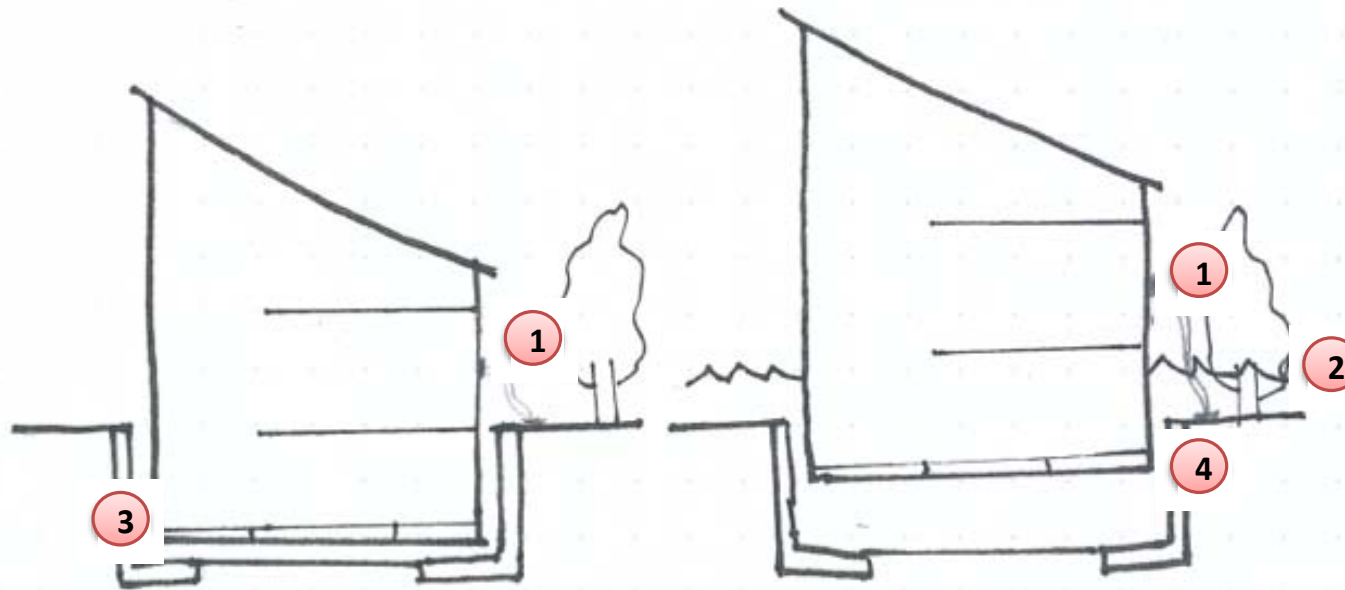
1. Adjustable or flexible connection to services.
2. Piers have been increased to raise floor height.
3. Access components have the ability to be increased to meet raised floor height.

Figure 6 - Side elevation showing pier and joist construction, highlighting the ability to increase the piles and raise the floor height



1. Adjustable or flexible connection to services.
2. Slab has been increased to raise floor height.

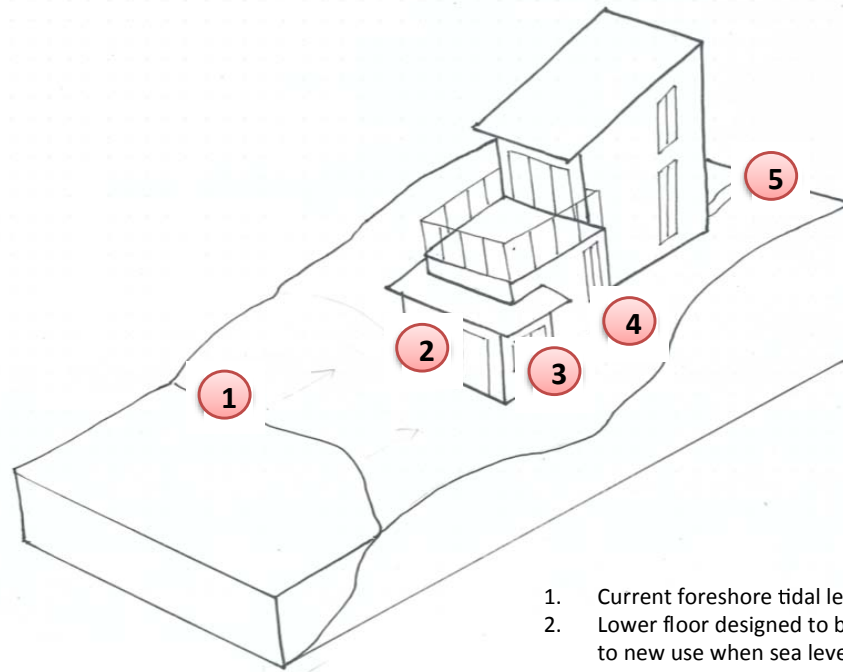
Figure 7 - Side elevation showing increased doors and windows to allow for increased floor height by adding material to the slab



1. Adjustable or flexible connection to services.
2. Temporary flooding.
3. Floatable foundation in resting position.
4. Floatable foundation raised as a result of water entering the base frame.

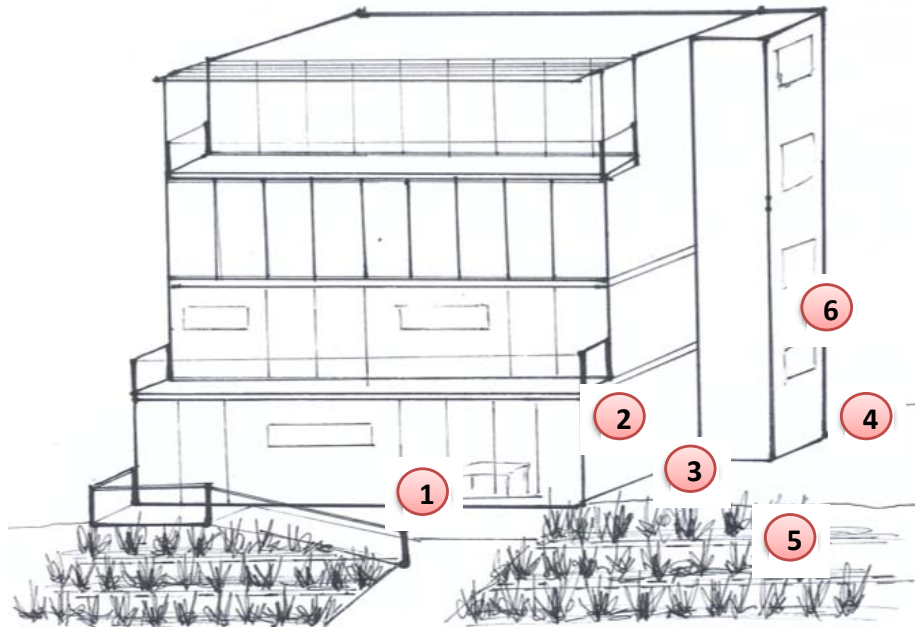
Figure 8 - Side elevation showing a floatable foundation type where the building is based on a frame that floats when temporarily flooded or in response to rising groundwater

Principle: Redundancy



1. Current foreshore tidal level.
2. Lower floor designed to become redundant or adapted to new use when sea level rises.
3. Cladding on lower floor is flood resilient.
4. Foundations are designed to cope with rising groundwater and prolonged inundation.
5. Safe access is provided by driveway on highest point of the section

Figure 9 - Illustration showing split-level house with lower level near foreshore and designed to become redundant once sea level rise or permanent inundation threshold is reached



1. Lower floor designed to become redundant or adapted to new use when sea level rises.
2. Flood resilient materials are used with concrete panel walling.
3. Foundations are designed to cope with rising groundwater and prolonged inundation.
4. Building is positioned on highest point of the site.
5. Landscaping provides buffer for flood waters.
6. Upper floors are accessible independently from lower floor .

Figure 10 - Illustration showing a multi-residential building with inbuilt redundancy

1.6 APPENDICES

Appendix A – Glossary of key terms

Term / Abbreviation	Definition
Adaptable	<p>Adaptability is the capacity for a building to accommodate effectively the evolving demands of its context, thus maximising its value through life.</p> <p>Design which avoids the personal and economic costs that accompany social dislocation.</p> <p>Flexibility, robustness, change of function, alternatives, low-tech, long-term perspective.</p> <p>Approaches towards change over time: Adjustable, versatile, convertible, scalable, refittable, movable.</p>
Adaptable building	<p><i>“An adaptable building is one which can be easily re-configured to respond to a change in hazard, if and when required. It allows the building to function safely over a range of scenarios, and the investment in additional risk mitigation can be timed to coincide with the increase in hazard, which may occur faster or slower than predicted. It may also allow construction in areas of high risk, where other buildings would fail or become dysfunctional.”(Giles 2012)</i></p>
Adaptable building design	<p><i>Adaptable building design is generally termed as a cost- effective design that enables a residential building, including townhouses and residential flat buildings, to be capable of accommodating substantial change over the building’s lifetime to enable continued occupation in response to the predicted sea level rise of 0.4m by 2050 and 0.9m by 2100.</i></p>
AHD	Abbreviation for Australian Height Datum
AEP	Abbreviation for Annual Exceedance Probability – indicates the chance of a particular flood occurring in any given year (probability) – a 1% AEP means there is a 1% chance of a flood occurring at this level in any given year eg a 1% flood wouldn’t occur very frequently but would have a very high water level, whereas a 90% AEP flood would occur quite often but would be relatively small.
Asset life of a development	<p>The asset life of a development refers to the length of time the buildings, landscape and services associated with a development remain functional and useable.</p> <p>With good maintenance and an ongoing viable use, most new developments and infrastructure constructed today could be expected to still exist at 2050, 2100 or later. The <i>NSW Floodplain Development Manual</i> requires Council to consider a broad range of issues including balancing the benefits of occupation of flood prone areas against the costs. This includes considering the impacts that flood floor levels have on the cost or restriction of development.</p> <p>For this reason, Council has agreed that most new development will be assumed to have an asset life to 2050, or 2100 for medium density housing where ownership and the construction style makes adaptation more difficult. At the end of the planned Asset Life the development can still be used, but it may become prone to flooding on a more frequent basis</p>

Term / Abbreviation	Definition
Foreshore	Land below 3m AHD with hydrological connection to Lake Macquarie.
Flexibility	The ability to be easily changed to suit new conditions.
Resilient	The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions (Allen S. et. al., 2012).
Resilient housing	A residential building and its component parts that can absorb, accommodate and recover from the effects of a given event (in this case flooding and tidal inundation) and has the ability to respond and adapt through re-configuration to changes in hazard levels, if and when required.
Adaptable House/Housing	The 'Adaptable House' is a term used by the Australian Standard AS4299 to refer to a house that adopts the idea of a 'Universal House' and in addition is able to be easily adapted to become an 'Accessible House' (Palmer & Ward 2008). The Universal House design includes features, fittings and products that can be utilised by people of all ages and abilities, without the need for any adaptation or specialised design. The 'Accessible House' is a house that meets the accessibility requirements of the Australian Standard AS1428.1.
DFE	Defined flood event
DFL	Defined flood level

Appendix B – Foreshore areas of Lake Macquarie below 3m AHD

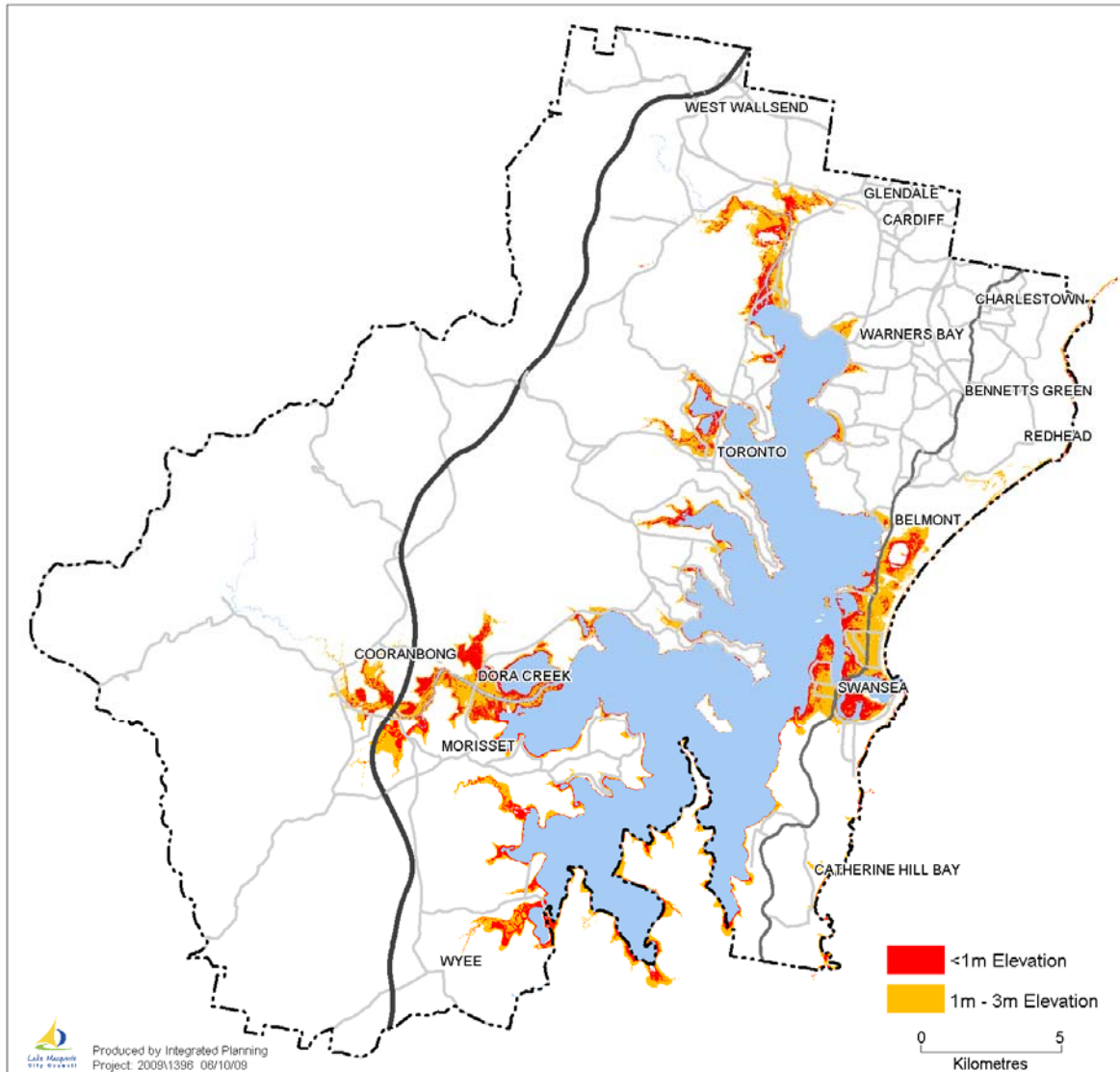


Figure 11 - Foreshore areas of Lake Macquarie below 3m AHD. These areas may become vulnerable to increased flooding if lake levels rise as projected to 2100, and areas below 1m AHD may become more vulnerable to permanent inundation

Appendix E – Floatable foundations

Floatable foundations are a suggested acceptable solution for raising of floor height in response to increasing risk from flood events and tidal inundation.

The principle of raising the floor height is based on the premise that the building floor level can be raised above the predicted flood and sea level risk point. Raised floor heights are a common, obvious and simple approach to managing flood risk and sea level rise risk for new buildings. The principle of raising the floor height at a point in the future is about allowing development to occur at the same floor level as other buildings and connect to existing services while the risk level is acceptable, but incorporating the ability to raise the floor height when the flooding risk becomes unacceptable.

Three alternative construction solutions are considered as acceptable solutions to raising of floor height:

1. Bearer and joist construction on piers and piles.
2. Increasing the height of concrete slab foundation.
3. Floatable foundations.

Floatable foundations are a new concept to manage risk associated with flooding. This section provides further information on floatable foundations to allow developers, builders and homeowners to gain an understanding of some of the technical considerations for designing and construction of a home with a floatable foundation.

Floatable homes, those with floatable foundations, are considered to be an acceptable solution to the principle of raising the floor height because they have a type of foundation which is based on land and simply embraces rising groundwater or floodwater and floats as the level rises.

The guidance provided in this section is to provide more detail on how floatable foundations can work and what sorts of issues need to be considered.

Definition of floatable foundations

In the context of Development Guidelines for Resilient Housing for Lake Macquarie, floatable foundations are defined as:

The lowest and supporting layer of a structure that is designed to raise the structure when inundated with water. A floatable foundation will be based on dry land in resting position and become buoyant in response to water and support the structure above the water level.

Note that there is a distinction between floating foundations and floatable foundations. A floating foundation is an industry term used to define a reinforced concrete slab that distributes the concentrated load from columns.

Considerations for floatable foundations

Designing and building with a floatable foundation requires additional considerations to ensure the durability, functionality and safety of the building.

Foundation and site considerations

- Soils are classified according to their stability. A soil assessment should be completed to determine the type and structure of the soil in order to determine whether a floatable foundation is feasible on the site and what sort of footing system should be used. Table 1 shows general definitions of site classes based on different soils in Australia.

- When designing the building, the allowable soil pressure¹ should not be exceeded and should take into account the building pressure and added water pressure during a flood event.
- Tolerance of superstructure to movement – the design and materials of the house should have the ability to absorb movement as it becomes buoyant during a flood event.
- Foundations should have an adequate factor of safety against uplift, sliding and overturning based on both the at rest position and the flooded position of the house.
- The applied load should be within the middle third of the footing – this is a general foundation consideration but must be considered with the additional loadings during a flood event and the impact of flood waters on the footings.
- Selection of an appropriate foundation system is dependent upon many factors. These factors may include:
 - soil conditions
 - groundwater conditions
 - surface conditions
 - structural loads
 - structural function (i.e. basement, cold structure, etc).

Table 1 - General Definitions of Site Classes, see As 2870 -2011 for full details

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes.
S	Slightly reactive clay sites with only slight ground movement from moisture changes.
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes.
H	Highly reactive clay sites, which can experience high ground movement from moisture changes.
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes.
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
*NB filled sites have other considerations	

Material considerations

¹ The maximum permissible pressure on foundation soil that provides adequate safety against rupture of the soil mass or movement of the foundation of such magnitude as to impair the structure that imposes the pressure.

- Detailed consideration should be given to the structural integrity of core components when exposed to water and saltwater if an issue. Saltwater and riverine flood waters will place additional stresses on building components as they may be susceptible to rusting and corrosion. The long-term effects of these weathering effects should be documented for the expected lifespan of the building.
- Any surface that will come into contact with water should be sealed against rot and moisture.

Functionality considerations

- Service connection: connection to services should be flexible and adaptable to ensure service connection can be maintained when the house rises in flood waters.
- The design should consider how the floatable foundation can be accessed if maintenance or repair is required.
- The design should consider whether excess water will need to be removed through pumping as flood water recedes and the need to clean silt from underneath or in the wet dock area should be considered.

Technical guidelines and standards

It is strongly recommended that architects engage with geotechnical and/or structural engineer early in the design process. A geotechnical engineer will be able to provide guidance on soil bearing capacities and suitable foundation materials and design.

- National Construction Code 2013
- [Standard – Construction of Buildings in Flood Hazard Areas, Australian Building Codes Board](#)
- AS/NZS 1170.0:2002 Structural design actions - General principles
- AS 2870-2011 Residential slabs and footings – Construction
- [Guide to Standards – Building and Construction](#)
- [Guide to Standards – Architecture](#)

Two types of floatable foundations

International research highlights two types of floatable foundations. One uses guide beams at either end of the house, allowing water to flow underneath the house and the house to float; and the second using a dock model where a basement foundation is built with a house inside that rises when flooded.

Houses on stilts or lengthened piles are very common across the world. However, creating floatable homes is a recent research area. The Dutch firm Dura Vermeer are credited with building the first buoyant houses in the village of Maasbommel along the Maas River. They rise as the water rises, keeping occupants and their possessions dry. When the floods subside, the houses sink to their original position. The houses float on hollow pontoons made of concrete and timber and service connection pipes and ducts are flexible.

Case study: Type A - Guide Beams: The FLOAT House

The FLOAT House is a prefabricated house that sits atop a raised base. It was developed to meet the needs of families in New Orleans's Lower Ninth Ward following Hurricane Katrina, and is a prototype for prefabricated, affordable housing that can be adapted to flood risk areas across the world. The FLOAT House was a collaboration of Morphosis Architects, the University of California, Los Angeles and the Make it Right Foundation.

The base or “chassis” of the FLOAT House integrates all mechanical, electrical, plumbing and sustainable systems, and will rise vertically on guideposts, floating up to 3.5 metres as water levels rise. The chassis acts as a raft which is guided and secured by two steel masts, anchored to the ground by concrete pile caps with six deep piles.

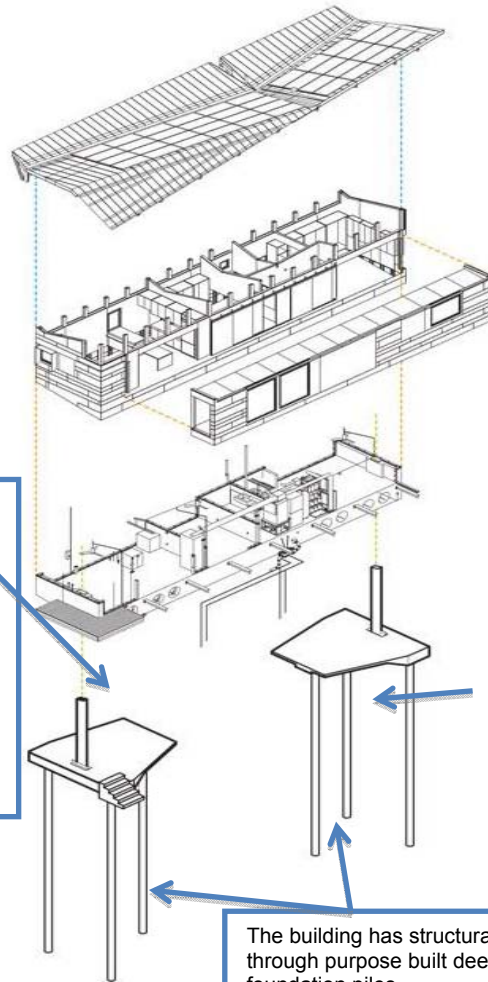
The FLOAT House is assembled on-site from pre-fabricated components that include:

- The modular chassis is pre-fabricated as a single unit of expanded polystyrene foam coated in glass fibre reinforced concrete, with all required wall anchors, electrical, mechanical and plumbing systems pre-installed. The chassis module is shipped whole from factory to site, via standard flat bed trailer.
- The piers that anchor the house to the ground and the concrete pads on which the chassis sits are constructed on-site, using local labour and conventional construction techniques.
- The panelised walls, windows, interior finishes and kit-of parts roof are prefabricated, to be assembled on-site along with the installation of fixtures and appliances. This efficient approach integrates modern mass-production with traditional site construction to lower costs, guarantee quality, and reduce waste.

Other features of this house include:

- Solar power system on roof.
- Rainwater collected from the roof is stored in the chassis for daily use.

The FLOAT House in New Orleans



The modular chassis is pre-fabricated as a single unit of expanded polystyrene foam coated in glass fibre reinforced concrete, with all required wall anchors, electrical, mechanical and plumbing systems

Steel masts act as guide poles for the building to slide up as flood waters rise.

The building has structural integrity through purpose built deep foundation piles.



Side elevation of the FLOAT House

The building complies with development regulations, ensuring amenity and liveability.

The building uses flood resilient materials.



Street frontage the FLOAT House

The building uses flood resilient design and does not trap flood

The building has flexible connections to services (water, gas,

Assembly components of the FLOAT House

Case study: Type B – Wet Dock Model: The Amphibious House

Baca Architects in London designed the Amphibious House in response to a design brief for a new home on an existing site with a high level of flood risk.

According to Baca Architects, an ‘amphibious house’ is a building that rests on the ground on fixed foundations. The upper part of the house is constructed from lightweight timber with a concrete basement level sitting inside a ‘wet dock’ consisting of a base slab and four retaining walls. Whenever a flood occurs the entire building rises up in its dock and floats there, buoyed by the floodwater. The house is designed as a ‘free-floating pontoon’ that is secured by four dolphins (permanent vertical posts) arranged close up to the sidewalls. The pontoon is sited within a wet dock comprising retaining walls and base slab. When flooding occurs the dock fills with water and the house rises accordingly (Baca Architects, 2013).

The site is landscaped with a terraced garden to assist with slowing flood waters and helping to manage run-off when water levels start to subside.

The Amphibious House was recently granted planning permission for construction on a island on the River Thames in Marlow which is a small town 50 kms from London. The Local Authority and Environment Agency supported this proposal because it was a replacement dwelling so flood risk was reduced on this site.

Artist impressions of the Amphibious House

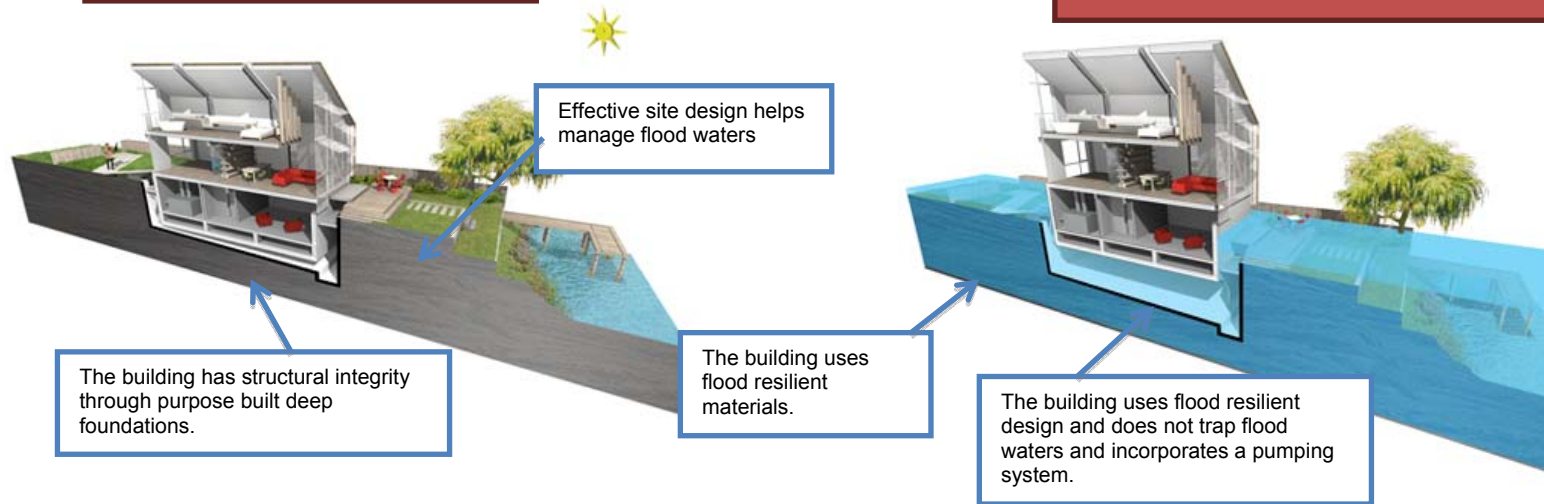


Flood Resilient Housing Guidelines

The Amphibious Home on River Thames, UK

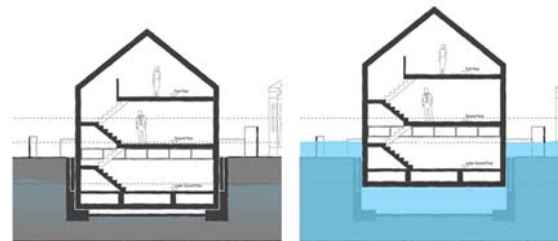
1. In resting position the house sits in a 'dock' that is built into a basement foundation.

2. As river levels rise during a flood, the dock is filled with water and the house foundation becomes a floating pontoon which raises with flood levels.



The building has flexible connections to services (water, gas, sewerage)

The building complies with development regulations, ensuring amenity and liveability.



Resting Position

Flood event

Appendix F – Case Study: Residential housing designed to allow raising of the floor height in future



Lake Macquarie foreshore areas offer picturesque backdrops to work, live and play and are highly sought after parcels of land. Development on this low-lying land is at risk from increased flood and tidal inundation and in this high-growth region there is a trend towards development intensification around the lake.

Managing risk - Development Guidelines for Resilient Housing for Lake Macquarie

To help manage this risk Lake Macquarie City Council (LMCC) has produced Development Guidelines for Resilient Housing for Lake Macquarie. Resilient housing, based on adaptability and flexibility, allows for buildings to respond to changing uses and hazards over time. The guidelines include principles for building resilient housing, along with a set of performance criteria and suggested acceptable solutions, and are designed to guide the industry, homeowners and LMCC staff on how best to plan for the future and develop resilient housing.

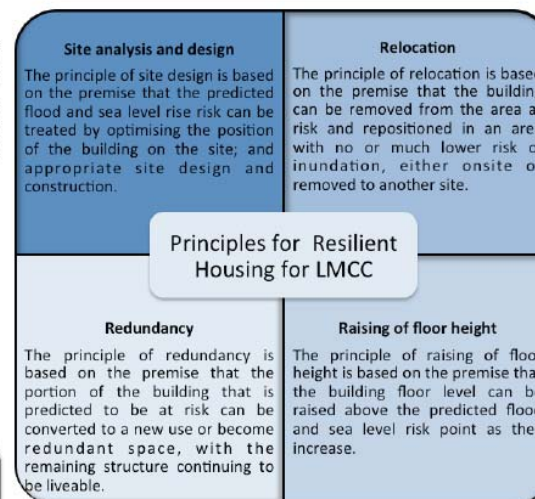
The Principles

The principles for Resilient Housing in Lake Macquarie are:

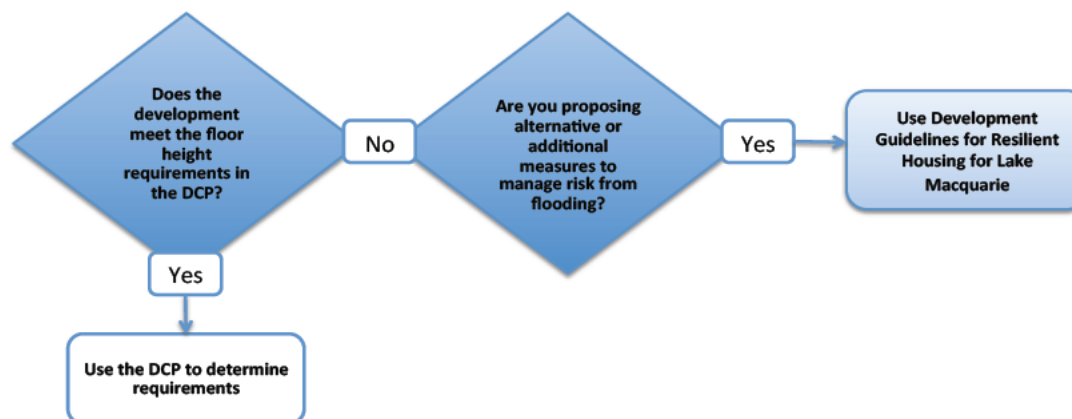
1. Site analysis and design (common to all resilient housing development)
2. Relocation
3. Raising of floor height
4. Redundancy

All resilient housing developments must use the principle of site analysis and design and then select other principle/s as appropriate to the site and/or desired house

This case study provides a summary and example of resilient housing using the principle of raising of floor height using bearer and joist construction including key design features, risk management and further resources.



Determining the requirement and context for using guidelines

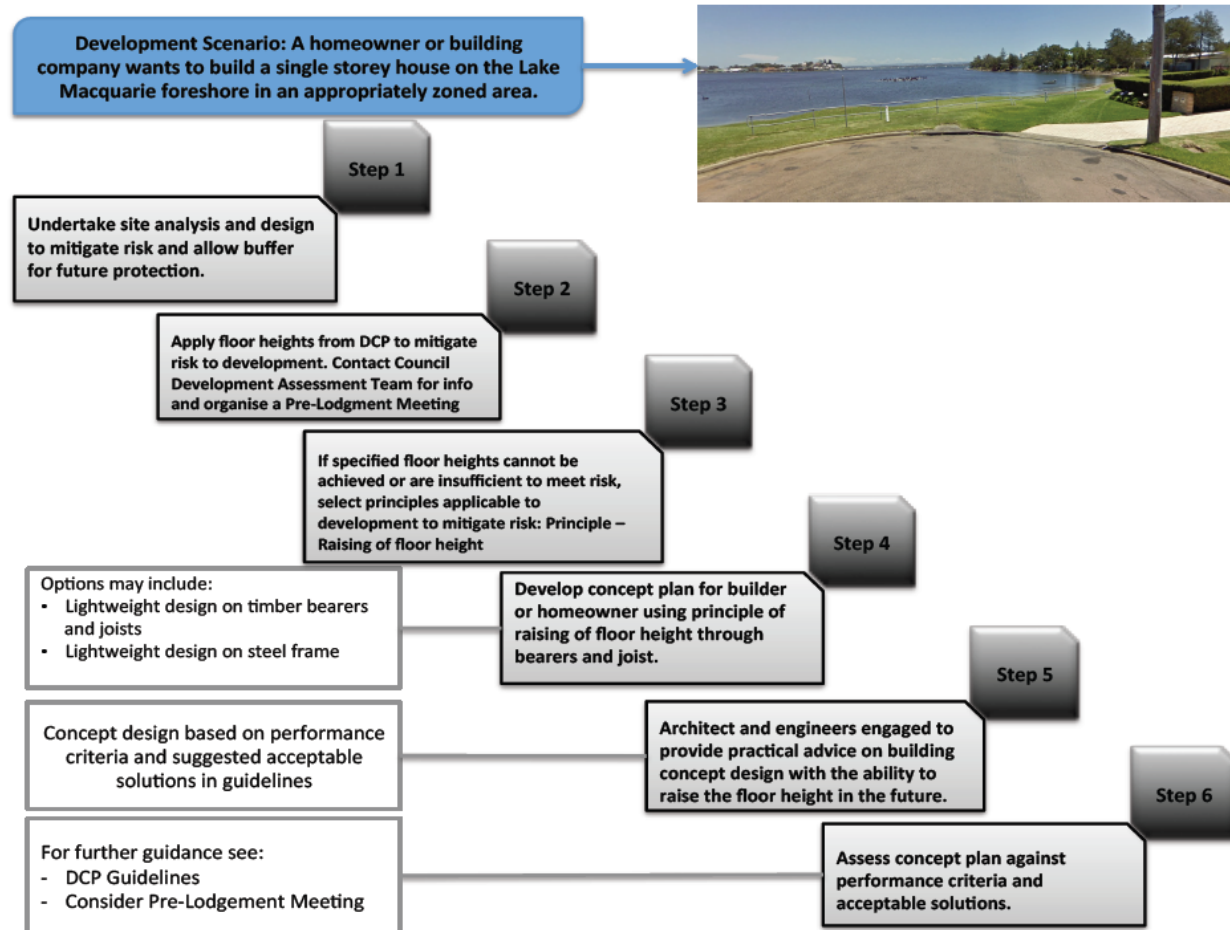


Designing a development using the principle of raising of floor height and site analysis and design

Resilient housing principles being applied to this case study	<ol style="list-style-type: none"> <i>Site analysis and design:</i> The principle of site analysis and design is based on the premise that the predicted flood and sea level rise risk can be treated by optimising the position of the building on the site; and/or design and construction of appropriate protection works. Site analysis and design is applied to all resilient housing development. <i>Raising of floor height:</i> The principle of raising the floor height is based on the premise that the building floor level can be raised above the predicted flood and sea level risk point.
Development type	<p>Suited to a range of development types but the most practical development type would be detached or semi-detached single storey dwellings. Three alternative construction solutions are considered as acceptable solutions to raising of floor height:</p> <ul style="list-style-type: none"> • bearer and joist construction on piers and/or piles; • increasing the height of concrete slab foundation; • floatable foundations. <p>It is envisaged that the most practical solution to Principle 3 is to build bearer and joist construction on piers and/or piles due to the expected ease in raising the floor height and the ability to easily reconnect services.</p>
Site attributes	The site will be located on the Lake Macquarie foreshore and will be at risk from flooding, tidal inundation and rising groundwater as a result of rising sea levels.
Key resources	<ul style="list-style-type: none"> • Lake Macquarie Waterway Flood Study (to determine risk based on location) • Development Guidelines for Resilient Housing for Lake Macquarie (to understand background and obtain performance criteria and suggested acceptable solutions)
Risk management	The principle of the ability to raise the floor height in future is about allowing development to occur at the same floor level as other buildings and connect to existing services while the risk level is acceptable, but incorporating the ability to raise the floor height when the flooding risk becomes unacceptable.
Functional implications	Functional implications include using lightweight building materials to allow for ease of raising, with foundations designed specifically to withstand water saturation. Consideration must be given to access points and service connection, once the building is raised and jacking and lifting points on the building.

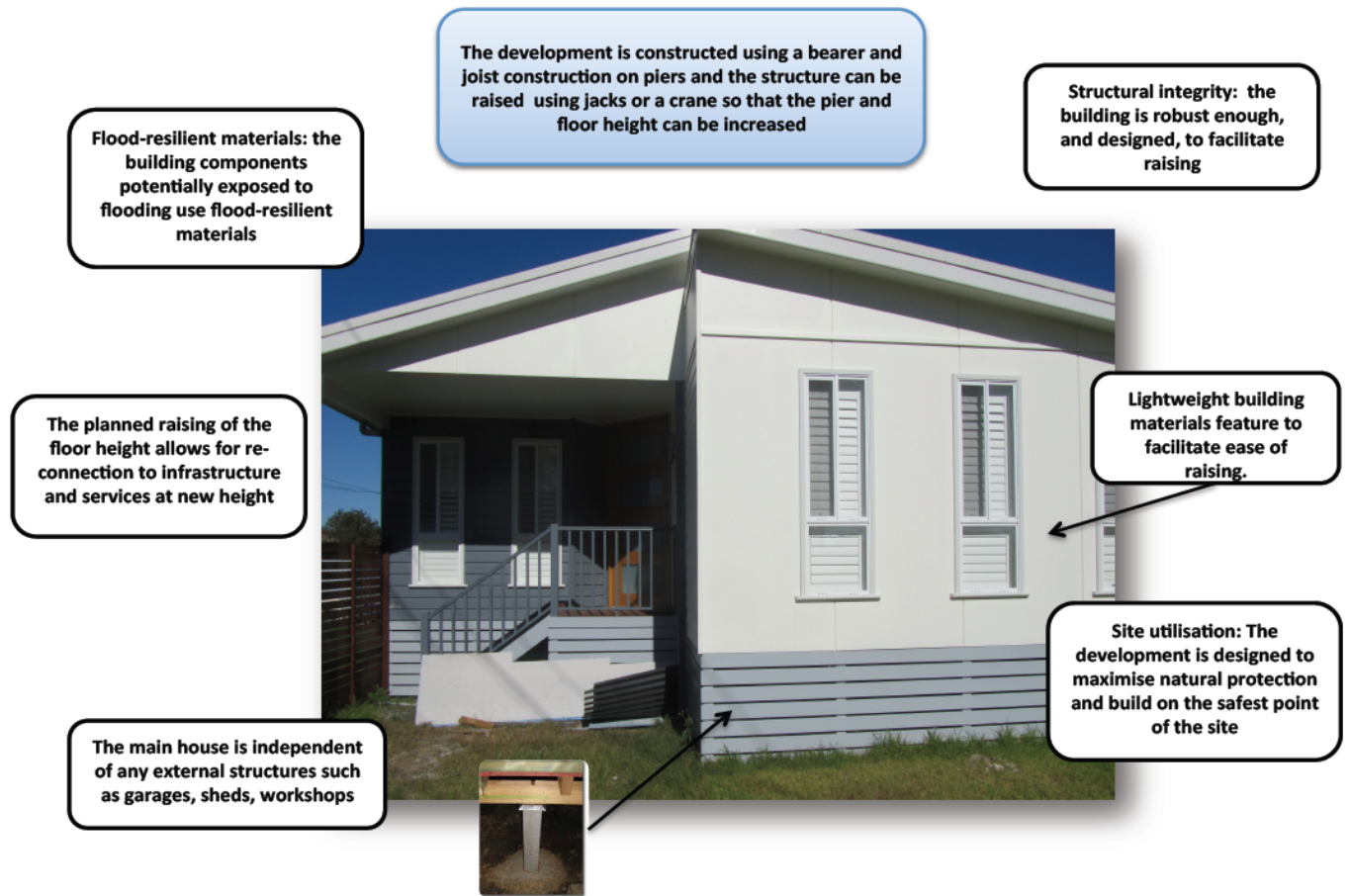
Development scenario using the guidelines

The diagram below provides an overview of a process you might follow if building a single storey detached dwelling in a risk area on the lake foreshore.



Design features and considerations

Each principle in the resilient housing guidelines has a set of performance criteria that must be met to ensure that the development is built to standards that incorporate safety, amenity and adaptability and flexibility. The performance criteria are design features and considerations.



Appendix G – Case Study: Multi-residential housing designed with redundancy



Lake Macquarie foreshore areas offer picturesque backdrops to work, live and play and are highly sought after parcels of land. Development on this low-lying land is at risk from increased flood and tidal inundation and in this high-growth region there is a trend towards development intensification around the lake.

Managing risk - Development Guidelines for Resilient Housing for Lake Macquarie

To help manage this risk Lake Macquarie City Council (LMCC) has produced Development Guidelines for Resilient Housing for Lake Macquarie. Resilient housing, based on adaptability and flexibility, allows for buildings to respond to changing uses and hazards over time. The guidelines include principles for building resilient housing, along with a set of performance criteria and suggested acceptable solutions, and are designed to guide the industry, homeowners and LMCC staff on how best to plan for the future and develop resilient housing.

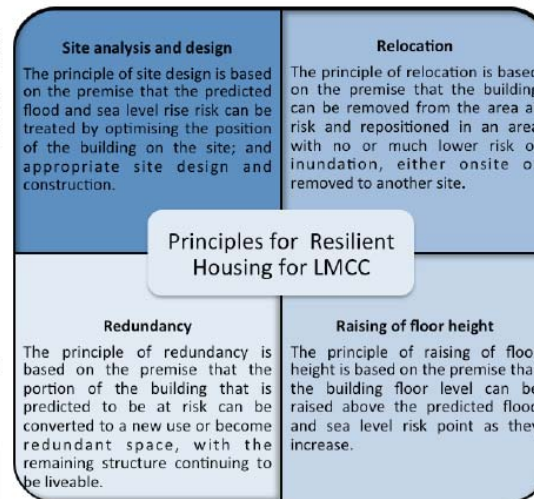
The Principles

The principles for Resilient Housing in Lake Macquarie are:

1. Site analysis and design (common to all resilient housing development)
2. Relocation
3. Raising of floor height
4. Redundancy

All resilient housing developments must use the principle of site analysis and design and then select other principle/s as appropriate to the site and/or desired house

This case study provides a summary and example of resilient housing using the principle of redundancy including key design features, risk management and further resources.



Determining the requirement and context for using guidelines

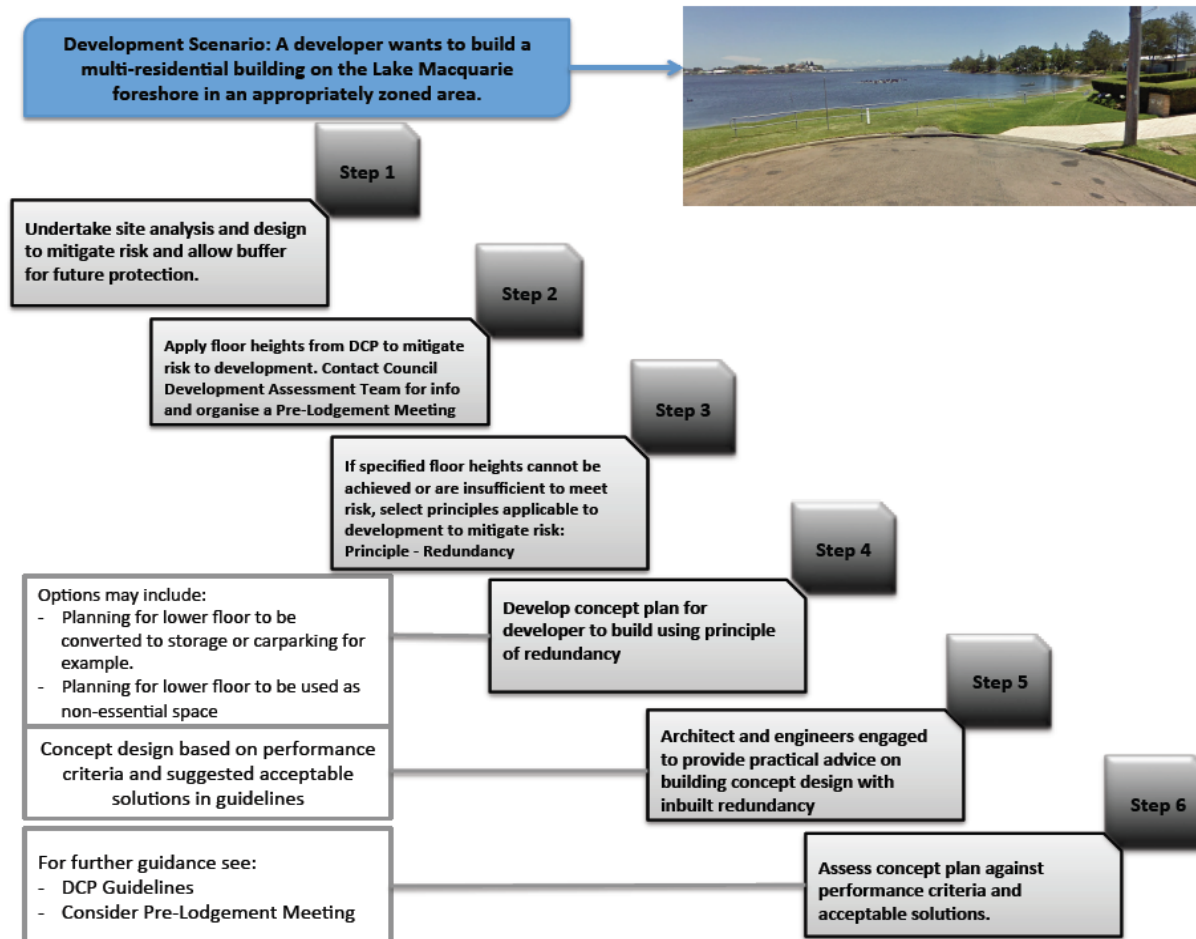


Designing a development using the principle of redundancy and site analysis and design

Resilient housing principles being applied to this case study	<ol style="list-style-type: none"> <i>Site analysis and design:</i> The principle of site analysis and design is based on the premise that the predicted flood and sea level rise risk can be treated by optimising the position of the building on the site; and/or design and construction of appropriate protection works. Site analysis and design must be applied to all resilient housing developments that trigger the guidelines. <i>Redundancy:</i> The principle of redundancy is based on the premise that the proportion of the building that is predicted to be at risk can be converted to redundant space and that the remaining structure can remain liveable and continue to be in accordance with LMCC's DCP.
Development type	Multi-residential attached dwelling or multi-storey detached residential dwelling.
Site attributes	The site will be located on the Lake Macquarie foreshore and will be at risk from flooding, tidal inundation and rising groundwater as a result of rising sea levels.
Key resources	<ul style="list-style-type: none"> Lake Macquarie Waterway Flood Study (to determine risk based on location) Development Guidelines for Resilient Housing for Lake Macquarie (to understand background and obtain performance criteria and suggested acceptable solutions) LMCC Development Control Plan (DCP) to determine floor height requirements for new development in areas vulnerable to lake flooding and sea level rise.
Risk management	Multi-residential unit blocks are a large investment and likely to be in use for 50 years and beyond. The building may have several owners making adaptations at a later point potentially difficult to negotiate and implement. Using the resilient housing guidelines and building a multi-residential unit development with the principle of redundancy increases the ability of the building to function if subjected to increased flood events, tidal inundation and/or rising groundwater.
Functional implications	A building designed with in-built redundancy will have an area that can be converted to a new use or made redundant, temporarily or permanently, when required. This means that the building must be able to function without relying on this space. The redundant space could be used for, or converted to, activities such as games and recreation area, indoor garden, storage, laundry and other domestic services or car parking. Access to upper levels must remain when the lower floor becomes redundant.

Development scenario using the guidelines

The diagram below provides an overview of a process you might follow if building a multi-residential unit block in a risk area on the lake foreshore.



Design features and considerations

Each principle in the resilient housing guidelines has a set of performance criteria that must be met to ensure that the development is built to standards that incorporate safety, amenity and adaptability and flexibility. The performance criteria are design features and considerations. These design features and considerations apply to single dwelling as well as the multi-residential building used in this case study.

