Inter-American Development Bank

2011

ANNEX 08 ISSUES OF FLOOD MITIGATION AND DRAINAGE

PADECO i.E.

CONTENTS

4. **UNDERSTANDING FLOOD RISK VULENRABILITY AND CONSEQUENCES**
    a. a key step in managing the impacts of flooding

5. **POLICY CONTEXT AND RESPONSABILITIES**
    a. National policy
    b. responsabilities

II
THE MASTER PLAN AND FLOOD RISK MITIGATION

6. **INTEGRATING THE MASTER PLAN FOR BELIZE CITY DOWNTOWN WITH FLOOD RISK MITIGATION:** a flood compatible strategic master-plan of Belize City downtown

    a. Flood risk assessment
        i. Flood risk zones
    b. A flood compatible Land use planning
        i. The collet canal key investment project
    c. Control: reducing the risk
        i. Tidal and Fluvial sources of flood risk
        ii. Pluvial Flood Sources and Flooding from Sewers
        iii. ecoinfrastructures to reduce the probability and severity of floods
        iv. Key investment project that combines flood protection, drainage, landscape, open space and urban development
            1. Riverside promenade acting as new flood defense
            2. The multifunctional neighborhood and the river
            3. The case of Collet canal development area

7. **MITIGATION**
    a. Safety
    b. Resistant built-heritage
        i. key investment and Demonstration projects
            1. A water-retention area with houses raised above the floodplain, exploiting a site which would otherwise be uninhabitable.
    c. Planning and Design of Resistant Infrastructure
        i. key investment projects
            1. design a flood defense for an strategic piece of infrastructure
    d. public realm and landscape
    e. combining a hierarchy of mitigation measures
        i. Key investment project: dynamic water living

III
STORM WATER MANAGEMENT IN A WATER RESPONSIVE BELIZE CITY

8. NATURAL FLOOD DEFENSES FOR INCREASING THE QUALITY OF LIFE

a. A vision for a water responsive Belize City

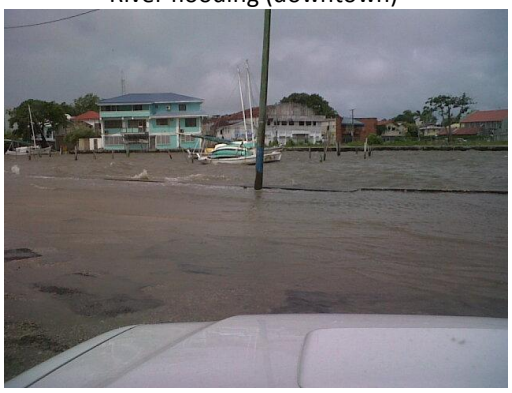
FLOOD RISK IN BELIZE CITY

Summary

Belize City is a waterfront city, located in low areas (a low-lying city with some 70,000 inhabitants) near the Belize river mouth, where it meets the Caribbean coast. It is exposed and severely affected by floods from the sea, the river as well as floods caused by direct extreme rainfall (figure 1) and poor drainage, due to the form of its settlement pattern and spatial structure.

Figure 1: River flooding (downtown)

River flooding (downtown)



Ocean flooding (downtown)

Ocean flooding (downtown)

Source: Carlos Betancourth, PADECO/iE

The exposure to flooding can escalate due to land subsidence (does the land progressively sinks below the sea?) or climate-related changes of rainfalls, flood incidence, and sea level rise. As a consequence of these phenomena daily flooding during ebb and flow is a common occurrence, and inundations of a few centimeters to decimeters (in the streets) are common. This may cause severe disturbance to the residents of and visitors to the city, and disrupts not only economic development significantly but also may lead to retreat of new economic activities and companies from Belize City urban areas most exposed to flooding. It can be concluded that the risks of flooding at Belize City are acute, and need utmost attention.

A poor country and city like Belize and Belize City cannot absorb repeated disaster costs[1]. Belize City with a fast growing urban population in these hazard prone areas will incur larger costs to pay for the damage and losses caused by floods and that might occur with increasing frequency. It is only through incorporating risk into urban development master planning (and not just through and only strategies of flood defense) as the city can start to reduce this exposure. Given this exposure to the risks of flooding; it is important that the country and the city have public investment budgets that include risk-criteria. Moreover, the international lending community has yet to fully recognize that if global, sustained and equitable development is to be achieved, then disaster reduction, climate change adaptation and poverty eradication must shape future urban development master plans. It is important that the master plan for Belize City downtown proposes risk sensitive urban development strategies. Now is the turning point for concrete action to manage disaster and climate risk. An important goal therefore is to protect lives and development investments. Risk reduction's inclusion in the urban development master plans for Belize City, especially in hazard zones, should be an informed choice. An integrated approach to urban development master planning in Belize City is needed to help reduce the impacts of natural hazards and the risk of flooding. It is to this that we now turn.

Strategies of flood defense

A standard response to the risk of flooding: a polder system INVESTMENT PROJECT

The exposure to these risks of flooding should be formulated with more precision and it should be discussed openly with the relevant stakeholders. On the basis of these discussions, ideas should be presented to address the risks of flooding in Belize City. So far the ideas include the following:

1. Belize City-a low lying delta city-, is severely affected by floods from the sea, the river as well as floods caused by direct extreme rainfall (figure 1). **The polder concept** is initially identified and proposed as a feasible way to alleviate the flood and drainage problems in the urban areas of Belize City.

2. It is important to develop a strategy that describes this polder system as a viable adaptation scheme to resolve the current problems with flood and inundation in Belize City. Applied in the Netherlands (and elsewhere) for centuries, a well managed polder can reduce (if not eliminate) flood- and drainage-related impacts. A polder is an area, surrounded by a closed ring of flood protection elements (dykes and dams) to separate the water regime inside the polder area from the water regime outside. The water table inside the polder is controlled by tidal gates and/or pumping stations (figure 2).

3. Yet realization of a polder system on itself is not sufficient: the responsibility for operation and

[1] In the wake of Hurricane Mitch in 1998, Honduras' President, Carlos Roberto Flores said damages totaling US$6 billion had destroyed 50 years of progress. Following the Indus River floods in Pakistan, the provincial Punjabi Authority allocated most of the development budget to disaster response with little likelihood of replenishment. Essentially, these losses nullify investments made by poorer countries to achieve the Millennium Development Goals. Indeed, the costs of disasters are challenging the very basis of investments. The earthquake in Haiti completely devastated one of the world's poorest countries. The Pakistan floods disrupted economic growth, agricultural production, and cost around US$12 billion. The Great East Japan Earthquake in March 2011 caused at least US$300 billion in damage; floods in Australia in 2010 cost US$10 billion; while an earthquake in the same year in New Zealand cost upward of US$5.5 billion

maintenance should be arranged as well, by means of establishment of a **Polder Authority** (institutional process);

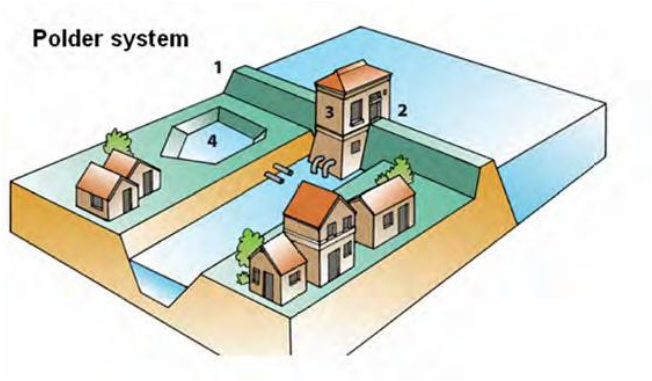
   a. This should include the creation of social, managerial and legal support for the polder system and Polder authority

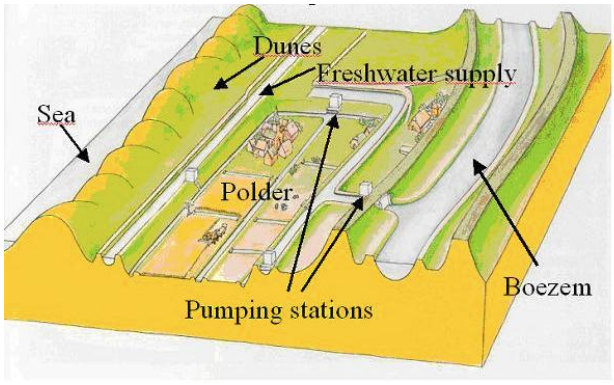
4. In order to verify the possibilities of the realization of such a polder system including the Polder Authority it is proposed to define a Pilot Polder key investment project in a specific area within the limits of Belize City

5. It may not be necessary to establish a single Polder Authority, it could well be imbedded in existing municipal departments such as a technical department;

6. the realization of such a polder may need a bottom-up approach
   a. The citizens of Belize City must actively participate and decide to take responsibility of maintenance of the existing polder elements (figure 2).

Figure 2: The polder concept





1. Closed dyke-ring,
2. Dam, to close the river. The dam is part of the dyke-ring
3. Pumping station, to discharge the rainfall and to control the water level inside the polder
4. Retention basin

These preliminary ideas should be further elaborated and described in a polder system project plan. This should be a document that describes the project plan for the realization of the pilot polder and the establishment of a Polder Authority. Due to time and resource constraints this will not be included in this document; a separate effort will be required for this.

To Strategies of flood risk management

An Alternative to the standard response: a flood control project that uses ecosystem services (ecosystem management as a vital component for disaster risk reduction)

This key investment project plan should take into consideration that the polder system that gets rid of undesired water by pumping it off is also at risk of becoming a victim of its own success as ground levels subside, sea levels rise and prolonged periods of drought become more common[2].

We don't know if there is a system of levees around the Belize river delta and Halouver creek (to control floodwaters and to create farm and urban land out of tule marshes and mangrove forests and wetlands). Nor we know if many of those levees are old, decrepit and leaking and if there is a chance of a catastrophic levee failure in the Belize delta in the next years. This needs to be investigated. Whatever the answers to these questions, levees cannot be, the only line of defense against floods. As the world warms (greenhouse gas-driven atmospheric warming), the air becomes warmer and warmer air holds more water vapor, which can trigger more intense deluges. Levees will be under a lot more pressure as the world gets warmer and floods may get more intense. This will prompt greater adoption of natural flood defenses.

Key investment Belize City river living defenses project: Adopting natural flood defenses: the case of the Belize river and the Halouver creek

It is thus important to **reactivate the flood plain.** There are important limitations[3] in the long-term strategy of hemming in the rivers with levees and dams, then pushing farms and towns up against the river walls. The potential high flooding of the rivers around Belize City in combination with the growing awareness of global climate change may make the public and respective authorities realize that flood protection cannot continue to be maintained by endlessly increasing the height of levees and dikes. Instead, more room should be given to the river (the World Bank *extension plan for Belize City* wants to reduce that space!) in order to allow it to discharge more water at a lower water level. Levees ought to be the last line of defense. The natural river defenses should come first.

[2] For centuries, the Dutch waged a stunningly successful war against water, building levees and using windmills to pump the lowlands dry and give their citizens "droge voeten," or dry feet. Vast tracts of land have been won back from the wet: More than 60 percent of the population lives at or below sea level. But the country has been gradually sinking inside its giant defenses and is crossed by increasingly tempestuous rivers rampaging seaward behind ever-bigger dikes. The threat of devastating flooding in 1993 and 1995 — caused by wet weather and snowmelt — and an ominous mix of demographic and climate changes, including the promise of heavier winter rains, suggested disaster lay ahead. Hence a 21st-century government vision for sustainable water management, which involves lowering dikes in some areas and moving them back, inviting the rivers to flood, and creating space for them to do so safely.

[3] A rising Mississippi River has forced hundreds of residents from their homes in a surge of rainwater and snowmelt that has been predicted to break records dating to 1927. Recently, the Army Corps of Engineers pulled a trick it had not been forced to use in nearly 75 years: **It blew open a two-mile run of a Missouri levee**, sacrificing about 130,000 acres of farmland and 100 homes to save the town of Cairo, Ill

This may entail that the city and the government begin buying up homes and farms and relocate residents to restore flood plains and wetlands. It may also entail moving levees back from the water's edge.

The Collet Canal as part of the Belize river´s natural flood defenses

It also entails abandoning steep levees and straight deep concrete channels in favor of gently sloped green spaces. This is the strategy to be applied to the case of the Collet canal: transforming it from a **straight deep concrete channel (geometry that drives floodwaters downriver fast and high) in favor of gently sloped green space.** The transformation proposed for collet canal (from a concrete channel to a sloped green space; see Figure 9b) is part of a larger strategy to adopt natural flood defenses and reactivate the river flood plain.

Here there is an opportunity to design **a Belize City living river project**. Confronted with a plan to turn the downtown collet canal (and possibly the riverbank) into a concrete channel with parking lots, it is important- from the perspective of adopting natural flood defenses - to restore and transform collet canal into a sloped green space and wet-land park. This project could be extended to the riverbanks. This strategy (give the river more space to flood safely) will be intended to help the river cope with a lot more water than it does now. It will involve **key investment projects** such as:

- Re-locating and moving the levees inland
- pulling levees inland makes the flood plain wider;
- deepening riverbeds, and lowering the flood plains
- excavating the flood plain will allow them to hold more water;
- adding a higher water channel
- designed to reroute overflow away from the river. Some water may be routed to lake beds for temporary storage; and
- permanently turning land back into flood plain and mangrove wetlands.
- It will include projects for replacing floodwalls and levees with terraced marshes, wider mangrove wetland barriers, and restored riparian zones; and
- For converting lands around the city into marshes, mangrove wetlands and mudflats.

Such project will reduce or eliminate flood-related human and economic casualties: property damage; cleanup costs; community disruption; unemployment; lost business revenue and the need for flood insurance. By taking a cross-sectoral planning approach the project will also create an economic renaissance, instigating the development of luxury hotels, offices and housing along the river which, today, is viewed as a blighted area. The benefits of this project may include: stimulus to private development investment in downtown Belize City; improvement of Belize city citizens' health with access to trails and recreation areas along the river; improved water quality, creating urban mangrove wetlands, enhancing and restoring urban wildlife habitats.

The restoration of the historical river floodplains will lead to the integration of trails and green and blue areas in Greater Belize (the bourdon canal, the river and creek fronts, the coastal front, the krumman lagoon, etc) which will revitalize Belize City´s downtown (see figure 3). Within this plan, water, housing, nature, agriculture, recreation and other features go hand in hand. At

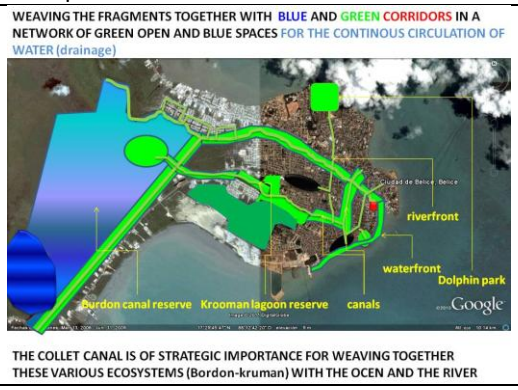
completion, the project will protect people and residential-commercial units from flooding catastrophe.

This project will represent a non-traditional flood management approach that seeks to combine flood protection with wetland restoration and reconnection of the Belize river to its historic floodplain. In addition to mitigating flood losses, this project will place a revitalized, healthy river as the centerpiece of Belize City. Many Belizeans will then be able to take advantage of the resources the river has to offer, including fishing, boating, walking and cycling along river trails, bird watching, and scenic dining.

The Belize city River flood protection project would engender strong support largely because it will address multiple interests and goals in a simultaneous manner. The project would not rely on any single approach, such as raising levees or moving all structures out of harm's way, but would combine multiple strategies in a way that makes optimal use of engineering and ecology, so as provide flood protection while restoring important ecosystems.

Figure 3: The canals in Belize-city have a great potential to become part of a **seamless green-blue network at various spatial scales** (Bordon canal reserve-Belize river-Halouver creek-sea front, etc) well integrated with adjacent urban developments

Bourdon canal nature reserve



The nature reserve enters the city

Water, housing, nature, agriculture, recreation and other features go hand in hand.

Adopting natural flood defenses: the case of coastal defenses

Adaptation to climate change is becoming an increasingly important part of the development agenda. Protecting mangrove forests, wetlands, coastal habitats, and other natural ecosystems can provide social, economic, and environmental benefits, both directly through more sustainable management of biological resources and indirectly through protection of ecosystem services. Natural ecosystems maintain the full range of goods and ecosystem services, including natural resources such as water, timber, and fisheries on which human livelihoods depend; these services are especially important to the most vulnerable sectors of society. Protected areas, and the natural habitats within them, can protect watersheds and regulate the flow and quality of water, prevent soil erosion, influence rainfall regimes and local climate, conserve renewable harvestable resources and genetic reservoirs, and protect breeding stocks, natural pollinators, and seed dispersers, which maintain ecosystem health.

Most efforts designed to reduce the effects of floods have focused on such structural measures as the construction of dams or embankments (see above, polders, levees, etc). In response to climate change, the country and the city are likely to invest in more hard and grey infrastructure for coastal defenses and flood control to reduce the vulnerability of its human settlements to climate change. This large-scale flood control projects may not be economically suitable for a country, like Belize, since they may increase the country's debt significantly for little economic return. It is therefore important to search for alternatives to standard responses to the risk of flooding.

Coastal mangrove forests and wetlands, or other natural habitats play an important role in protecting high-quality water supplies. Similarly, these natural ecosystems can reduce vulnerability to natural hazards and extreme climatic events and complement, or substitute for, more expensive infrastructure investments to protect the coastal and riverine settlements of Belize City. Floodplain forests and **coastal mangroves forests and wetlands** provide storm protection and coastal defenses and serve as safety barriers against natural hazards such as floods, hurricanes, and tsunamis, while wetlands filter pollutants and serve as water recharge areas and as nurseries for local fisheries. Traditional engineered solutions often work against these ecosystems, particularly when they aim to constrain regular ecological cycles, such as annual river flooding and coastal erosion, and could further threaten ecosystem services if the construction of dams, seawalls and flood canals leads to habitat loss.

What Belize City needs are coastal (and river. See above) flood control projects that utilize the natural storage and recharge properties of critical mangrove forests and wetlands by integrating them into living with floods and creating more space for the river (see above) strategies that incorporate forest protected areas and riparian corridors (the interface between the river and the land). These simple and effective solutions protect both communities and natural capital. It is therefore fundamental to design a project to conserve and protect this very important environmental heritage of natural habitats and ecosystem services, thereby contributing to effective mitigation and adaptation strategies.

Floodplain forests and coastal mangroves act as safety barriers against natural hazards such as floods and hurricanes, while natural mangrove wetlands filter pollutants and serve as nurseries for local fisheries. Maintenance or restoration of the historical mangroves heritage and wet-landscapes can offer increased protection of coastal areas to sea level rise and extreme weather events. Restoration of degraded mangroves in the river delta in Belize City could improve management of coastal forests, improving coastal protection and safeguarding important nursery grounds for local fisheries. The rehabilitation of upland forests and of wetlands can help regulate flow in the Belize

river watershed, thereby moderating floods from heavy rain and ameliorating water quality. Strengthening protection of cave systems and natural forests can safeguard important aquifers and freshwater supplies.

Natural flood defenses for improving the quality of life

This alternative Flood Protection Program and projects above will incorporate and harness natural habitats (to reduce vulnerability) into flood defenses and provided a low-cost solution as an alternative to costly infrastructure, with the added benefit of high biodiversity gains. This will be combined with a long term strategic initiative to:

transform the city´s utilitarian drains, canals and lagoons into vibrant, aesthetically pleasing and clean flowing streams, rivers and lakes (See below, section 9) bring people closer to the water so that they will cherish and take ownership create a seamless blue-green network well integrated with the adjacent urban developments.

Introduction: key concepts

The Increased Risk of Flooding in Belize City

Flood risk is a challenge that is becoming increasingly relevant for a number of reasons. Climate change is predicted to cause sea levels to rise and more extreme weather patterns (increased rainfall in the wet season), which in turn will cause greater risk of tidal flooding, inland flooding from the rivers and surface water run-off. The pressure for new housing and current policies that prioritize the opening of new lands (such as those along chatumal street expansion; but, see also *Expansion plan proposal* by the World Bank), much of which is already at risk of flooding, may well mean more new development within the floodplain and flood prone areas within the city. Increasing urbanization is reducing the amount of natural soak-away available and straining existing drainage infrastructure. People and properties in Belize City that are not within currently recognized and defined floodplains are also increasingly at risk of flooding, usually from surface water.

Types and the Sources of Flooding in Belize City (figure 4)

People tend to underestimate the power of floods: six inches of fast-moving water can knock you down; two feet of water can float most cars away. Floods kill people (what is the average number of people that die per year in Belize city as result of floods?) and cause property damages (how many millions annually?). Different types of flooding present different forms and degrees of danger to people, property and the environment, due to varying depth, velocity, duration, rate of onset and other hazards associated with flooding. With climate change, the frequency, pattern and severity of flooding are expected to change, becoming more uncertain and more damaging. Flooding in Belize city maybe increasing in frequency and severity.

There are essentially two major causes of flooding: coastal and inland flooding. This may include: (i) floods caused by high water level outside the city (in the rivers and in the ocean), and (ii) inundation caused by heavy rainfall. These types of floods maybe amplified first, by land subsidence, because the coastal (and river?) areas may be progressively subsiding below sea water level, and second, because the discharge of the rainfall is blocked by:

1. the expansion of paved areas in the city, such as the expansion of paved areas planned for collet canal! (the city´s surface gets more and more sealed by the need of car parking), and
2. the negligence of maintenance and clogging of the existing drainage infrastructure (such as the canals and collet canal in particular),
3. both of which may increase the inundation.

Notice that addressing the issue of flooding and of drainage at Collet canal is of strategic importance. It is therefore fundamental that the master plan proposes a strategy in this regard (see above, T*he Collet canal as part of the Belize river´s natural flood defenses*)

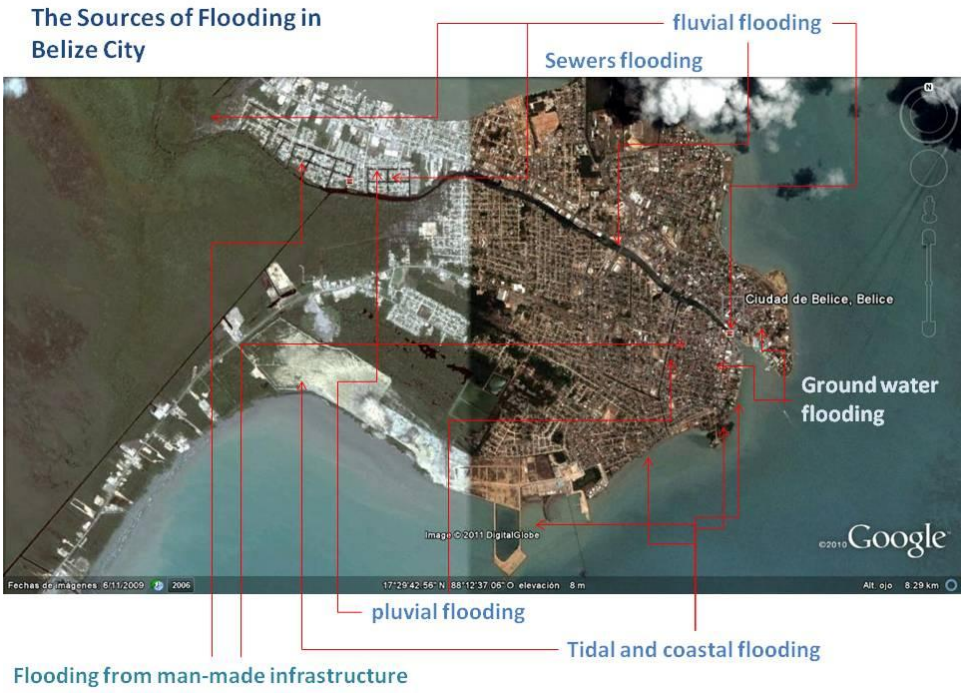
There may be at least six more or less recognized sources of flooding at work in Belize City:

Tidal and coastal Flooding

Both sea and river defenses may be overtopped or breached by a combination of low pressure weather systems and peak high tides (higher sea levels than normal), largely as a result of storm surges/hurricanes resulting in the sea overflowing onto the land (figure 1 above). Storms with high wind speeds cause tall and powerful waves and low pressure fronts cause sea levels to rise above normal levels. High tide levels may vary through the lunar and solar cycle and when superimposed upon other tidal variations exceptionally high tides may result. Coastal flooding in Belize City (which is caused by higher sea levels than normal, largely as a result of storm surges, resulting in the sea overflowing onto the land (figure 1)) maybe influenced by the following factors, which may work in combination:

- high tide level,
- Storm surges caused by low barometric pressure exacerbated by high winds (the highest surges can develop from hurricanes); and
- Wave action which is dependent on wind speed and direction, local topography and exposure.
- The other cause of tidal flood in Belize City maybe land subsidence. We don't know what the present land elevation of Belize City is, nor do we know what the land subsidence rate is per year (cm/year). We may speculate and suggest that that the city may progressively be sinking (or not) below the sea.

Figure 4: the sources of flooding in Belize City



The onset of flooding from the sea and tidal river maybe sudden and the extreme forces driving it may present a significant danger to life. It is often possible to forecast this type of flooding with reasonable accuracy, due to the predictability of the tide and track-ability of low pressure systems. The duration of this type of flooding is also limited by the cycle of the tides where efficient drainage is available.

Inland flooding which is caused by prolonged and/or intense rainfall. Inland flooding can include a number of different types:

Fluvial and river Flooding

Fluvial flooding may occur in the floodplains of the Belize-river when the capacity of water courses is exceeded as a result of rainfall (figure 1). Blockages of water courses and flood channels may also lead to rising water levels (excess water spills out from the river, creek and channels onto adjacent low-lying areas (the floodplain)). River defenses may then be overtopped due to increased water levels.

The onset may be quite slow with steadily rising water levels. However, flash flooding can occur and is far more immediate. Flooding from the river, maybe predicted with good accuracy. However flash floods from sudden downpours challenge the capability of detection and forecasting systems. Water over about 250mm in depth may carry debris particularly in urban locations. Even travelling at low speeds this can make it extremely hazardous to people caught in it.

Ground Water

Low lying areas sitting over aquifers may periodically flood as ground water levels rise (this may be the case of the historical downtown area, where aquifers thrive. This still needs more research). Groundwater flooding occurs when the level of water stored in the ground rises as a result of prolonged rainfall to meet the ground surface and flows out over it, i.e. when the capacity of the underground reservoir is exceeded.

This type of flooding is often seasonal and therefore can be forecasted with good accuracy. It is often slow in its onset. Groundwater flooding tends to be very local and results from interactions of site-specific factors such as tidal variations. While water level may rise slowly, it may be in place for extended periods of time. Hence, such flooding may often result in significant damage to property rather than be a potential risk to life.

Pluvial Flooding

Surface water flooding is caused by **rainwater run-off** from urban (and rural) land with low absorbency. Increased intensity of development in urban areas has given rise to land with a larger proportion of non-permeable surfaces, a problem often exacerbated by the overloaded and out-dated drainage infrastructure that characterizes Belize City. These circumstances, combined with intense rainfall, can give rise to localized flooding. The expansion of paved areas such as those planned for collet canal! will exacerbate this kind of flooding.[4]

This sort of flooding is caused by quite localized weather conditions and it is very difficult to forecast. Its onset can also be very rapid, and the level of flooding very severe. In Belize City often much of the flooding experienced is not directly caused by the river or the sea alone, but by surface water. Large volumes of rainfall saturate the ground and intense rainfall cause both urban and rural areas to flood. Two important subsets of pluvial flooding include: overland and drainage systems flooding

Overland flow

Overland flow occurs when the amount of rainfall exceeds the infiltration capacity of the ground to absorb it. This excess water flows overland, ponding in natural hollows and low lying areas or behind obstructions. This occurs as a rapid response to intense rainfall and eventually enters a piped or natural drainage system (this can often be seen in the Belama area)

Flooding from artificial drainage systems

Flooding from artificial drainage systems results when flow entering a system, such as an urban storm water drainage system, exceeds its discharge capacity and the system becomes blocked, and / or cannot discharge due to a high water level in the receiving watercourse. This mostly occurs as a rapid response to intense rainfall. Together with overland flow, it is often known as pluvial

[4] The South Side Poverty Alleviation Project: Phase 2 Infrastructure Works (under Ministry of Works), should be evaluated from this perspective

flooding. Flooding arising from a lack of capacity in the urban drainage network is becoming an important source of flood risk in Belize City.

Key investment project: the management of urban storm-water (the role of collet canal)

Thus an important component of the strategy for flood protection project must be the management of urban storm-water.

For this we will-in line with the alternative natural Flood Protection Program above (*a Flood control project that uses ecosystem services*)-, propose to recover and re-use in Collet canal natural systems which retain and treat storm-water on site before allowing the water to naturally flow into the receiving watercourse (the ocean?). At the same time, these features will form ecological habitats that benefit from the proximity to water sources as well. In addition, the resulting "*naturalized*" collet canal environments will be conducive for social and recreational activities. This will create new spaces for the community to engage in nature and get closer to water, and meets the larger objective for people to learn to value and cherish water as well as do their part to care for it and keep it clean.

Flooding from Sewers

Flooding from sewers can occur where there are combined storm and foul sewers and their capacity is exceeded due to large amounts of surface water run-off in a short time. Poor cleaning and maintenance can lead to blockages that can also cause local flooding. This is a common occurrence in Belize City. This type of flooding is hard to predict, has significant sanitary consequences for those affected, and can occur very rapidly.

Estuarial flooding

Estuarial flooding may occur due to a combination of tidal and fluvial flows, i.e. the interaction between the Belize river and the sea (at the mouth of the river in the very downtown of Belize City), with tidal levels being dominant in most cases. A combination of high flow in the river and a high tide will prevent water flowing out to sea tending to increase water levels inland, which may flood over the river banks. This is the case of the area around the Belize river mouth where it meets the sea

Flooding from Man-made Infrastructure

Flooding can also arise from the failure of man-made infrastructure designed to store or carry water (e.g. the breach of a dam, a leaking canal, or a burst water main), or to protect an area against flooding (e.g. breach of a flood defense, failure of a flap valve or pumping station or blockage of a pipe or culvert). Because of the sudden onset, the impacts of this form of flooding can be severe and where appropriate should be assessed

Coastal erosion

Coastal erosion of both the foreshore and the shoreline itself is intimately linked with coastal flooding. The loss of natural coastal defenses such as the mangrove forest and wetlands, and sand dunes (non-existent in Belize City coastal areas), due to erosion (or mechanical removal of sand) can increase the risk of flooding in coastal areas. Coastal erosion should therefore be considered in the coastal areas of Belize City within the urban planning process for Belize City.

Possible investment project: recreating sand dunes and beaches for costal defense and recreation

It is important to notice in this regard that a key investment project for the coastal part of the collet canal includes a multifunctional infrastructure that includes the creation of a beach and sand dunes at the Yabra neighborhood for coastal defense and for recreation

New urban development and flood risk

In addition, increases in flood risk as a result of new urban developments in Belize City may be caused by:

- Urban development upstream
    - by restricting the capacity and conveyance function of the Belize river and Halouver creek watercourses and floodplain system;
        - this may be the case of ongoing developments along the river (in areas along the northern highway, in areas near the airport, Belama, etc)
- Urban development downstream
    - by decreasing the volume available for flood storage on the floodplain, altering flow routes on the floodplain, which can increase the flow discharged to downstream locations (this is the case of the Belize river and Halouver creek as they cross through Belize City downtown); and
    - by increasing run-off due to changes in land management and introducing surfaces with reduced permeability, such as roads, roofs and car parks (this is the case of the plans to transform collet canal into parking space for cars).

The impacts of Flooding

The effects of flooding from the sources outlined above are felt by various receptors. These include, people, buildings, infrastructures, agriculture, open recreational spaces and the natural world and its ecosystem services. In extreme cases flooding may cause a loss of life. However, the social and emotional costs from flooding can also be significant and are often widespread and indiscriminate in flooded areas. These costs include: displacement from homes, the loss of personal valuables and the ongoing fear and insecurity caused by the experience. Potable water supplies may be lost or contaminated in a flood and this can have immediate health effects upon people and animals. The economy can also be severely affected by flooding. Businesses may lose stock, patronage, data and productivity, and disruption to utilities and transport infrastructure can have knock-on effects to a wider area. Tourism, farming and livestock can equally be affected. The built environment and the historical heritage may be damaged or destroyed as a result of flooding with high repair costs and long periods required for reinstatement. The public realm is often badly affected through damage and the deposit of potentially large quantities of debris. Land contamination may also be transported

and spread during flooding. Vital infrastructure may also be damaged or disrupted. Electricity and gas supplies can be interrupted to individual properties but also to wider communities if sub-stations and transformers themselves are flooded (see below, the case of the substation located right at the edge of the river). Road links, canals etc. may be blocked causing disruption to the wider transport network, and accessibility severely disrupted for local inhabitants, especially amongst those considered most vulnerable. A knock-on effect of the loss of electricity experienced in floods is the loss of communications networks. Telephones, radios, televisions and the internet are all increasingly reliant upon mains power and without a robust means of conveying information to householders, rescue and clean up operations may be hampered.

Factors which Determine the Effects of Flooding

The level of predictability: this affects the timing, accuracy and communication of warnings given before a flood.

The rate of onset of the flood: how quickly the water arrives and the speed at which it rises will govern the opportunity for people to prepare and respond effectively for a flood.

The speed and depth of the water: this dictates the level of exposure of people and property to a flood. It is difficult to stand or wade through even relatively shallow water that is moving. Flood water often carries debris, including trees, and water over 1m in depth can carry objects the size of cars. Fast flowing water can apply devastating *forcé* to property and other receptors.

The duration of the flood: this is another important factor in determining the extent of its impact, particularly on individuals and affected communities.

Understanding Flood risk, vulnerability and consequences

A key step in managing the impacts of flooding

Understanding flood risk is a key step in managing the impacts of flooding. Two factors should be considered when assessing flood risk. Flood risk is a combination of the likelihood of flooding[5] and the potential consequences that it might have upon the various receptors in its path.[6] The probability of a flood is normally expressed as a likely return period for a certain depth of flood water. In a recognized floodplain it is possible to estimate from records the likely level of a one in 20 year flood, a one in 100 year event, a one in 200 year flood and a one in 1,000 year event. These are the most commonly used design frequencies. Climate change is now also accepted as a factor which will increase the level and frequency of flooding in the future and an

[5] Likelihood of flooding is normally defined as the percentage probability of a flood of a given magnitude or severity occurring or being exceeded in any given year. For example, a 1% probability indicates the severity of a flood that is expected to be exceeded on average once in 100 years, i.e. it has a 1 in 100 (1%) chance of occurring in any one year

[6] Consequences of flooding depend on the hazards associated with the flooding (e.g. depth of water, speed of flow, rate of onset, duration, waveaction effects, water quality), and the vulnerability of people, property and the environment potentially affected by a flood (e.g. the age profile of the population, the type of development, presence and reliability of mitigation measures etc).

allowance for this should also be made. One should expect The Ministry of the Environment (the land reserves and the coastal management authority) to hold data on river and coastal flooding and develop models for predicting risk as well as supply information, including the probability and height of flood waters.

The potential consequences that a flood might have depend upon the vulnerability of the receptor. For example, a housing complex would be more vulnerable than a retail unit. Clearly residents being cared for in a nursing home are significantly more vulnerable to the effect of a flood than visitors to an outdoor sports facility or recreational park. Certain building uses such as hospitals, police and fire stations and other emergency services can be considered more vulnerable than others because of their importance to disaster relief and recovery. Equally, infrastructure items such as water supply and mains electricity are also more critical than others due to the far reaching consequences of their failure on health, and social and economic activities. Risk is a product of probability and consequence, it is for example possible to reduce the probability of a flood with new defenses but still increase the overall risk by placing vulnerable receptors behind the defenses thereby increasing the potential consequences

Policy Context and Responsibilities

National Policy

National policy must ensure that

- flood risk is considered as an integral factor in the planning process and master plan of Belize city (as well as other coastal cities in the country).
- To prioritize new development away from areas of flood risk
- To stop inappropriate development taking place in areas at risk
- To make sure that new development takes climate change into consideration
- To ensure new development does not increase the risk of flooding elsewhere

National policy should compel local authorities to assess the risk of flooding by carrying out city wide strategic flood risk assessments. National policy must require national (and local) authorities to carry out a test when allocating land (This applies to the land reserves authority particularly in relation to the *extension plan for Belize City* (see component 1 and *Urban development scenarios for Belize City*)). The test will be intended to encourage authorities to consider land at risk of flooding for development only if there are no other suitable locations. Such test would also require the authority to demonstrate that the sustainable benefits in allocating development on land at risk of flooding outweigh the costs and that appropriate measures have been taken to address flood risk. Once land has been allocated for development, any planning application submitted must be supported by a site specific flood risk assessment. This must quantify the extent of any flood risk and then demonstrate that proposals: (i) fully mitigate the risk of flooding (ii) do not place occupants at greater risk (iii) do not increase the risk of flooding to neighbouring areas. This should be of particular interest to the **land reserves authority** particularly in relation to the *extension plan* for Belize City and the settlement of lands around the new Chatumal extension (see component 1 and *Urban development scenarios for Belize City*))

Responsibilities

It is important to identify the various actors and stakeholders that may be responsible for flood risk management (ministry of environment, land reserves authority, property owners, water companies and sewerage, ministry of public works, ministry of housing, and urban development, insurance companies, etc).

II
THE MASTER PLAN AND FLOOD RISK MITIGATION

6
Integrating the master plan for Belize City downtown with Flood Risk Mitigation: a flood compatible strategic master-plan of Belize City downtown

There are a number of potential challenges to the master plan for Belize City that arise from possible flood risk control and mitigation measures. It is essential that the risk of flooding is recognized as a key constraint and the drivers of the risk as potential opportunities from the outset. For the master plan to respond to these challenges we propose a sequential, multidisciplinary and integrated approach that starts with:

1. an assessment of the risk (*assessment*) that
    a. prioritizes spatial planning (multiple land use planning (see key input 5)) to avoid placing new development in risk areas or at least substitute vulnerable uses wherever possible.
2. considers strategies to minimize the probability and severity of a flood (*control*), followed by
3. a review of strategies to minimize the potential consequences of a flood on occupants and properties (*mitigation*).
4. Finally proposals are re-assessed (*re-assessment*) to check their impact upon future occupants' safety, neighbouring areas, wildlife and ecology.

The design process is iterative, with the potential and type of flooding understood first, proposals then developed, their impact assessed and if necessary alterations and revisions considered. Due to time and resource limitations (the assessment of risk and hydraulic modelling of flood events in many circumstances requires the input of specialist consultants (and a multi-disciplinary approach) using sophisticated software. The design of flood defenses, barriers and underground drainage systems requires civil and structural engineering expertise) we will not be able to develop this process in any detail. In what follows I will just simple illustrate some of its main components, but this will require a separated effort

6a
Flood Risk Assessment

Flood risk zones

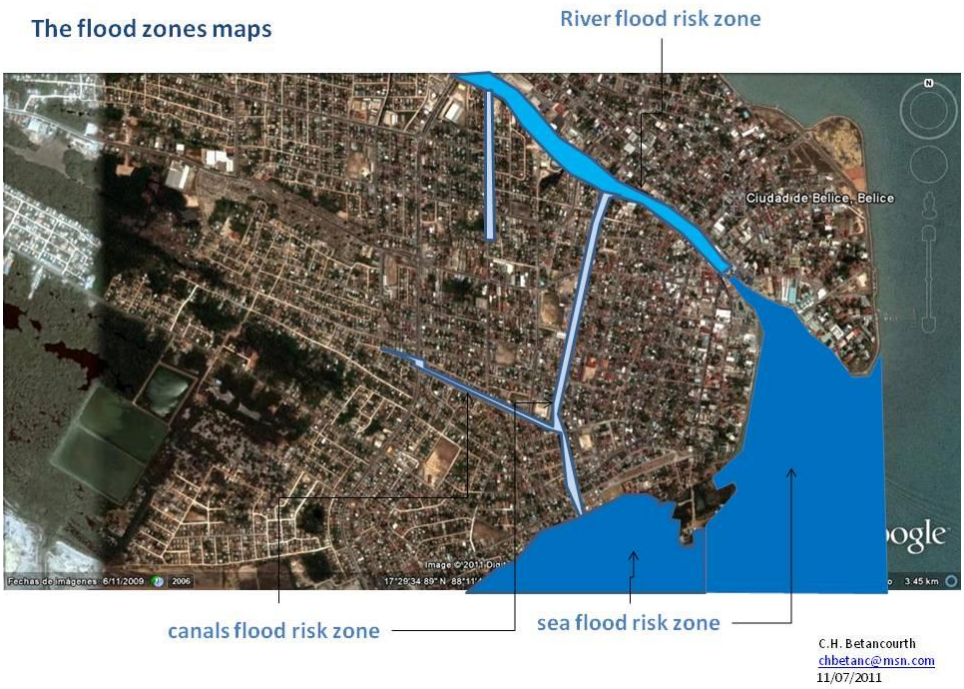
It is possible to make a very basic appraisal of the potential that an area (and a site) has to the different sources of flood risk (see above) by simply looking at the context and topography within which the land is set.[7]

A site adjacent to **the Caribbean sea** and or within **the Belize river valley** is obviously at potential risk from these sources. Sites in the vicinity of man-made infrastructure such **Belize City canals** may also be at risk. This is particularly the case of what we have referred to as the development area conformed by the river, collet canal and the ocean front (figure 5).

The key investment project for the Collet canal development area (as well as the master plan) should define (in flood risk maps and based upon the annual probability of flooding) the extend of each of the flood risk zones for each one of these sources of flood risk (river-canal-ocean). This will allow us to assess whether a particular property is within a recognized flood zone. Such Flood risk preliminary appraisal and assessments aim to identify, quantify and communicate to decision makers and other stakeholders the risk of flooding to land, property and people.

[7] This still needs to be supported by Information made available in the form of city-wide and strategic flood risk assessments prepared by the local authority and the national government. In addition, the assessment of flood risk requires a thorough understanding of the sources of flood water (e.g. high sea levels, intense or prolonged rainfall leading to run-off and increased flow in rivers and sewers), the people and assets affected by flooding (the receptors) and the pathways by which the flood water reaches those receptors (e.g. river channels, river and coastal floodplains, drains, sewers and overland flow). This in turn requires the elaboration of a cause-path-receiver model, to assess and inform the management of environmental and flood risks (figure 6)

Figure 5: the flood risk zone map of Belize city downtown



The purpose is to provide sufficient information to determine whether particular actions (such as proposed development, the construction of a flood protection scheme or the installation of a flood warning scheme) can be undertaken without causing an increase in risk elsewhere and adequately reduced risk at the site. The flood risk zones maps essential purpose is to indicate the main areas where flooding needs to be considered in decisions on land use and land management (figure 5).

An **important investment project** is to undertake a flood risk assessment of sites around the three main sources of risk flooding in the collet development area (river-canal-sea). Figure 5 illustrates this in a very intuitive and speculative fashion.

Figure 7 shows the hypotetically extent of areas of high, medium and low risk across the current area of Collet canal. The source and type of flooding is identified as primarily fluvial. Further work may be done such as a flood hazard assessment if appropriate to determine the level of hazard as a function of water speed and depth across the area, water quality and duration. The assessment will also estimate the current capacity of the area to store flood water in the event of a flood, allowing for the footprint of existing buildings and structures within the flooded areas. Similar flood risk assessments should be done for the other areas in the other two flood zones in collet canal, namely the canals and the ocean (see figure 5 above).

In addition, a flood risk assessment for the historical environment of downtown should be done. A very preliminary observation identifies the historical environment in downtown as one in which the overtopping and breaching of the existing defenses (the wall from the mouth of the river until the house of culture) would be the prime risks that requires consideration in the conservation of the built heritage (see figure 1)

Figure 6: the cause-path-receiver model

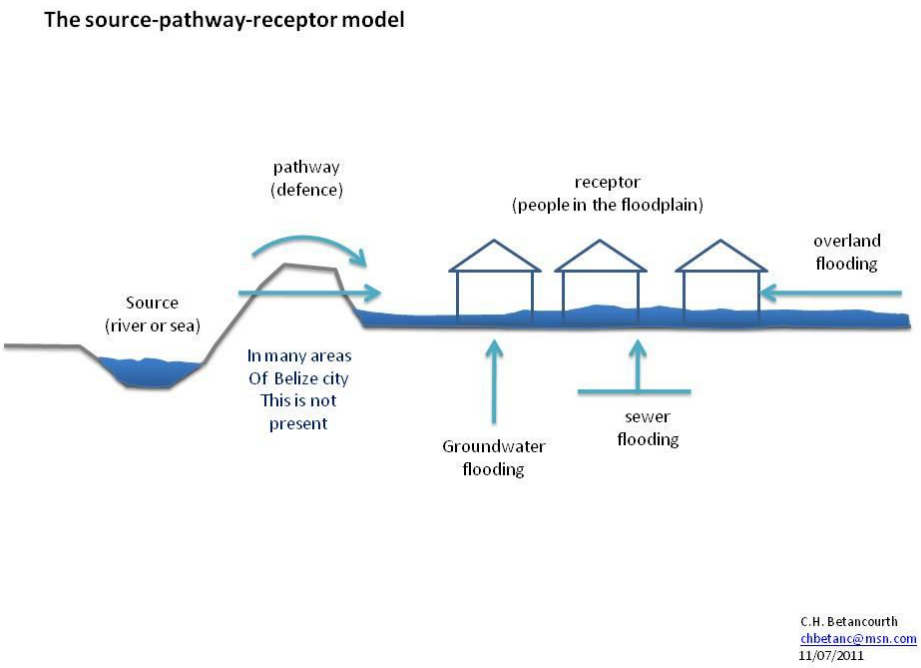


Figure 7: the theoretically extent of areas of high, medium and low risk across the current sites along the river front in the collet canal development area

the theoretically extent of areas of high, medium and low risk across the current sites along the river front in the collet canal development area

C.H. Betancourth
chbetanc@msn.com
11/07/2011

These preliminary assessments of flood risks within the river floodplain, the sea, and the canals **will be used to inform a flood compatible strategic master-plan for Belize City downtown.**

6b
A flood compatible multiple Land use planning

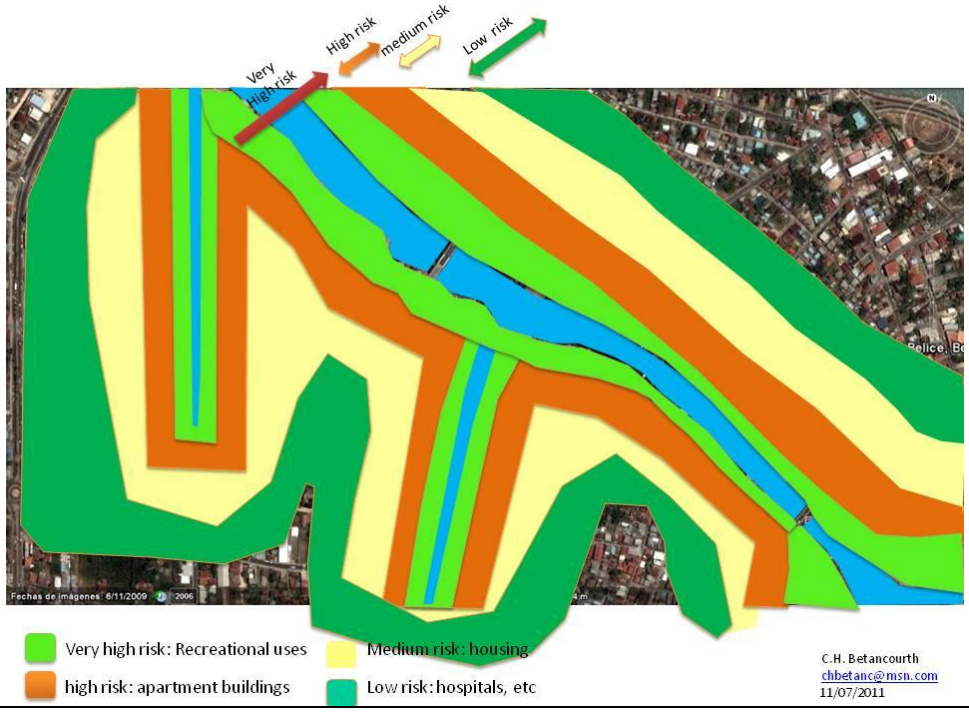
The master plan will need to indicate compatible land uses for each of the flood zone levels (figures 5, 7). A classification of vulnerability will have to be produced as well so as a proposal to locate the most vulnerable categories of land use in the areas of least flood risk and vice versa. Only the most robust use categories may be appropriate for areas of high flood risk.

That is, land use categories may be ranked in order of their vulnerability. Categorized in this way they will be set against low, medium, high and very high levels of flood risk to form a land use ready matrix to assist in the selection of compatible uses (see *key input 5* to the master plan. See also figure 8 below).

The idea is to make efficient use of land at risk of river-canal-ocean flooding by matching a mix of uses with the levels of risk. Vulnerable uses may be stacked over robust uses to create active frontages and a positive public realm at street level. New outdoor amenity space, areas of biodiversity, and new recreational uses can be created within areas of higher flood risk. This is the idea of the collet canal (including the river and ocean front) as a linear park.

The matrix will relate flood risk vulnerability, land use and flood zone compatibility (See figure 8 for a preliminary illustration)

Figure 8: The matrix relates flood risk vulnerability and flood zone compatibility



The illustration shows how robust recreational uses maybe located in the most hazardous part of the area adjacent to the water courses (river-creek-canal-ocean), whilst land levels could be adjusted to create low risk areas (say for homes with very vulnerable occupants). In adjusting the topography of the area care maybe taken to retain at least the same level of storage capacity of flood water as the initial assessment identified. Ideally this capacity should be increased. In the area of high risk apartment buildings with control and mitigation maybe proposed and in the area of medium flood risk housing with mitigation.

The Collet canal key investment project

The Collet canal area in particular provides an opportunity to provide a significant landscape and public open space that provides both visual amenity and plays an active role in **surface water management** and bio-diversity and urban habitat recreation (see section III below).

This public open space will be revitalized to provide maximum benefit to all residents from the surrounding area and the city at large. The canal space will be used to incorporate amenity space as well as sustainable drainage, flood attenuation, habitat creation and a close integration with the urban development for the area. Strong visual connections and natural surveillance will be coupled

with regular access points to ensure that the landscaped space is both accessible and safe to use. The overall quality of the environment will stem from a diversity of treatments that provide wildlife habitat without compromising the usability of the space for leisure and recreation.

Sustainable design will be embodied as a concept throughout the scheme for collet canal. The landscape whilst acting as a green lung for the entire development area and for the city; also has a vital role to play in the water management strategy of the area and of the city (See section III below).

Run-off from hard surfaces will be directed into surface swales via petrol and oil interceptors that provide filtration and removal of suspended solids. Ponds provide space for the attenuation of rainwater run-off during peak storm events and provide a contribution to the amenity space. The ponds also provide a more significant storage capacity for attenuation of rainfall during peak storm events and make a positive contribution to the amenity and ecological value of the area. In addition to providing habitat for wildlife this also provides filtration and final polishing of rainwater run-off quality prior to discharge off-site (figure 9k below). The area will also provide flood attenuation to the Belize River basin and the construction of a flood alleviation basin in the northern corner of the site (closed to the fish market) will ensure that the new housing developments will not be at risk. This area also provides an opportunity to use wetland and marginal plant species to further enhance the biodiversity of the site.

Control: Reducing the Risk

Having attempted to avoid placing vulnerable uses in hazardous areas the next step is to reduce the probability and severity of a flood to any parts of the city in general and the Collet development area in particular, still at risk. The control measures most appropriate will depend largely upon the source of flood risk.

Tidal and Fluvial sources of flood risk

Tidal and fluvial flooding can be controlled with costal defenses, river walls, barriers and barrages (see ***a polder system project plan***, in *Summary* above). These measures provide a primary defense against the risk. There will, however, remain a **residual risk** of a breach or failure of the primary defense; moreover these defenses can still be overcome by a severe flood (this is the case with the sea wall along the south side; see figure 1 above).

In order to control this risk it will be necessary to raise the level of habitable accommodation above the design flood level and provide safe access. It may be possible to adjust land levels in such a way as to protect some areas whilst providing flood storage capacity in other areas. On a larger scale making additional space for water within the overall Belize river catchment areas may contribute to a reduction in overall level of flood risk. It may be possible to justify ‘reclaiming’ land in one area by providing compensatory flood storage elsewhere in the catchment area (see, ***a Flood control project that uses ecosystem services,*** in *Summary* above)

Pluvial Flood Sources and Flooding from Sewers

The risk of flooding from rainwater run-off and exceedance of drainage capacity can be reduced by an eco-infrastructure integrated with the building and landscape revitalization of the Collet canal. This will help control run-off generated by the area along collet canal and also manage run-off from adjacent land. This eco-infrastructure system is composed of green live roofs, rainwater harvesting systems and permeable paving through to networks of swales, filter beds and detention ponds (figure 9k). Rainwater harvesting can be incorporated into this eco-infrastructure to help reduce volumes of water entering the storm water system (see section III).

Opportunities

- Integrate river and coastal flood defenses with new areas of public realm such as Belize river-side walkways, cycle routes and pocket parks
- Design defenses to promote biodiversity and create wildlife corridors
- Provide additional flood storage capacity by creating new wetland areas
- Maximize visual and physical connections to the river, coasts, wetlands etc. to increase the amenity and commercial value of new developments
- Enhance the public and private realm with high quality robust landscape designs which promote water conservation and surface water management
- Integrate the above eco-infrastructures with systems for the rapid retreat of flood waters. The eco-infrastructure can be linked to areas of flood alleviation that improve the quality and quantity of rainwater run-off discharged into surface water or sewer networks. There must be synergy between the ecoinfrastructure primarily designed to manage surface water (section III) and the removal of pluvial flood water. Flood alleviation networks built into the ecoinfrastructure design can help absorb the impact of tidal or fluvial surges during peak storm events.

Eco-infrastructures to reduce the probability and severity of floods

The illustrative scheme above (figure 8) suggests that the contours of the area must be adjusted to provide additional flood storage in the recreational area next to the river and Halouver creek.

Many areas at risk from tidal and fluvial flooding in Belize City seem to have traditionally turned their back on the river and the ocean, choosing to put up impermeable flood defenses that only exacerbate the problem (such as the sea wall along the South side).
It is important to design a key investment project that re-links the river to tidal/fluvial expansion zones and sets development back from the edge to create opportunities for the expansion of the flood zones, and create more opportunities for greater biodiversity and amenity value along the Belize river floodplains (figure 9a).

Living accommodation in the apartment buildings zone (figure 8) would be raised above the design flood level and they would be orientated to take advantage of views towards the river and the canal. To control surface water run-off and provide a route for flood waters to retreat, a system of drainage corridors in the form of swales planted with trees will be proposed. These lead to water detention ponds that will in turn slowly discharge back into the river-canal-ocean system. Green roofs, permeable surfaces to parking areas and access drives will support this eco-infrastructure figure 9k) . All these devices and components of the eco-infrastructure will slow down the passage of rainwater towards the river/ocean thereby helping to control flooding on site

Key investment project that combines flood protection, drainage, landscape, open-space and urban development

We could pick up any site next to the Belize River, the Collet canal or the ocean (see key inputs 5, and 2: *the basic cell of the master plan*. See also figure 9e-9h below). We will first determine the flow zone type according to figure 7, 8 above. Some areas (like the area along the coast from the mouth of the river until the house of culture) may be "protected" by a flood defense wall that isolates the inland areas from the ocean or from the river (figure 1). The master plan will integrate a range of control and mitigation proposals into the urban, architectural and landscape proposals.

Riverside promenade acting as new flood defense

For instance, where there is a wall defense (along the river from the moving bridge to the house of culture), it will be replaced by a new terraced flood defense which opens up the river/ocean/canal frontage to the public with a new landscaped promenade and also creates a new river/ocean/canal bank rich in estuarine flora and fauna (See figure 9a, 9b. See also key input 5). This is a **key investment proyect to be considered as part of the feasibility studies.**

Figure 9a: **Riverside promenade acting as new flood defense**

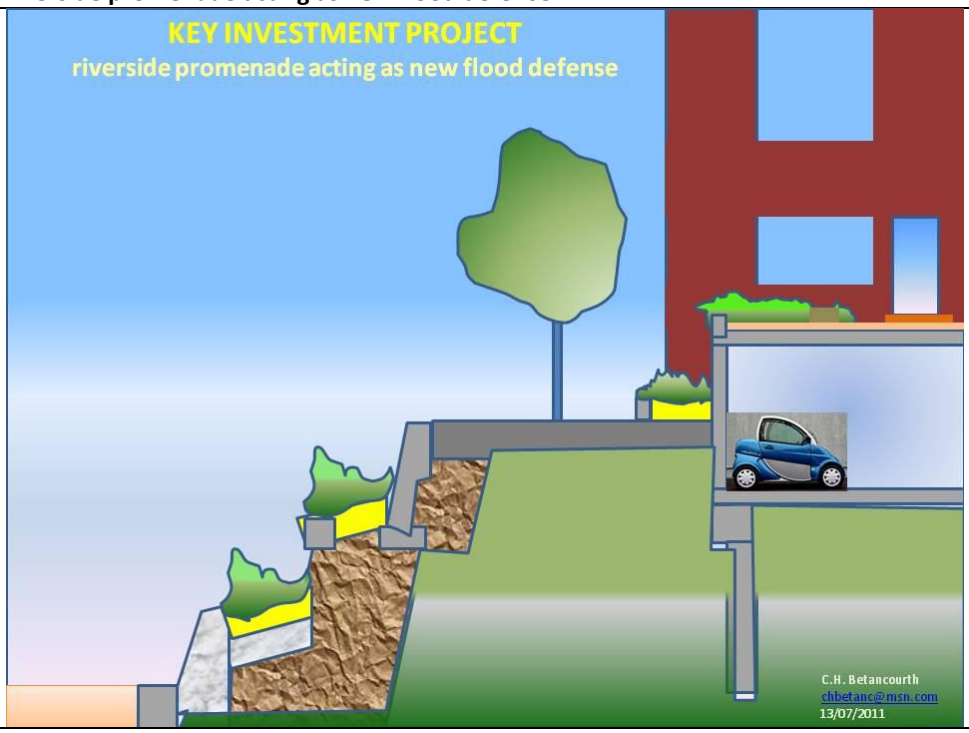


Figure 9b: **experiencing collet canal**

multifunctional ecoinfrastructures and Multi-functional landscapes

Multifunctional neighborhoods and the river

New access to the river/ocean would allow the various neighborhoods around these sources of flood risk (river-ocean-canal) to be re-organized as sustainable multifunctional neighborhoods (see figures 9e-9h. See also key input 5 and 2) around a series of cuts through that run from the interior of the neighborhood through to the river/ocean, a feature which also maximizes the benefit of the riverside/ocean setting (figures 9c, 9d).

Figure 9c: multifunctional neighborhood: **the river cuts through the neighborhood**

multifunctional ecoinfrastructures and Multi-functional landscapes

Figure 9d: multifunctional neighborhood: **the river cuts through the neighborhood**

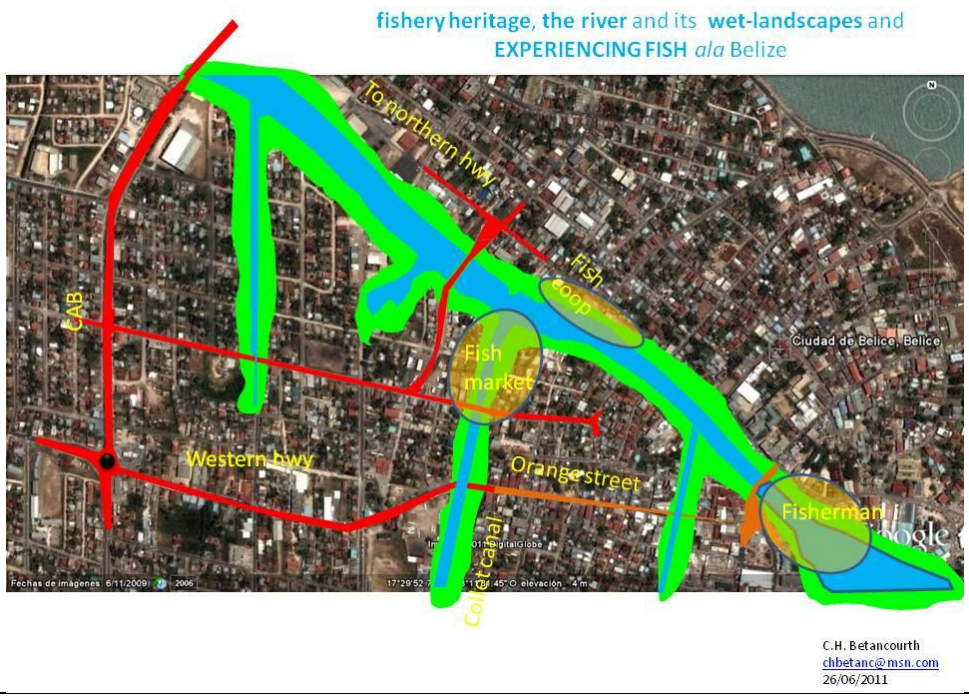
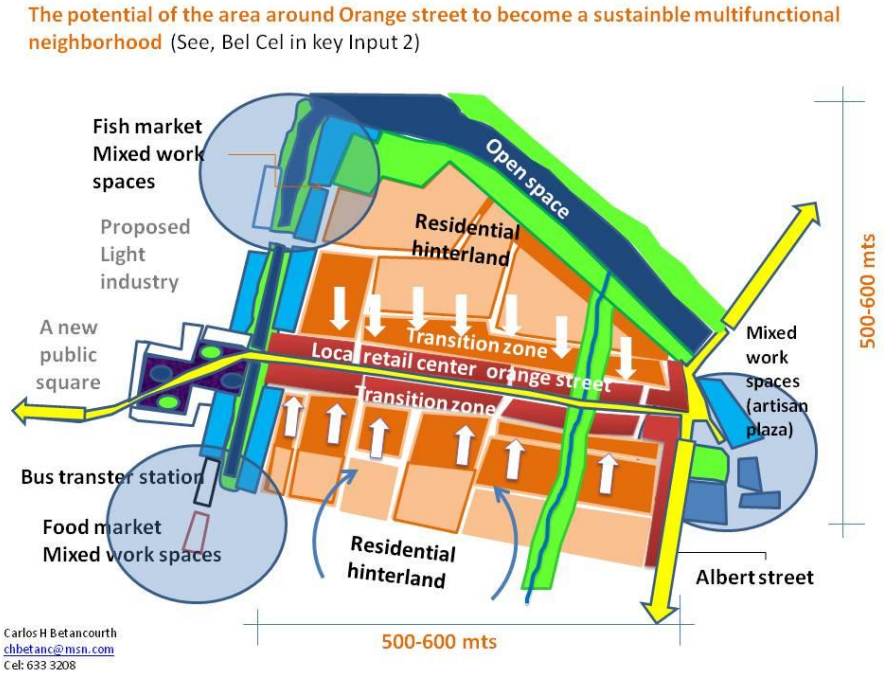
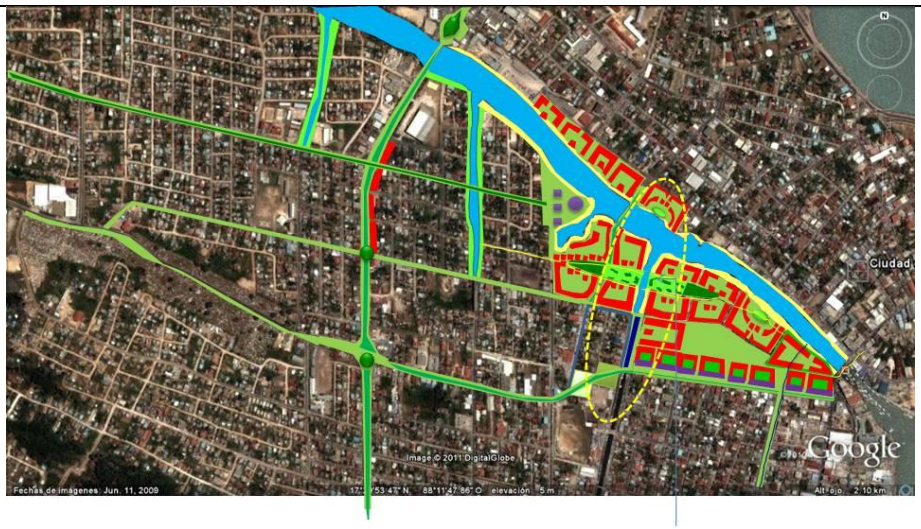


Figure 9e: **The 400-600 mts radious multifunctional neighborhood**



The neighborhood is organized around a series of cuts through **(in this case a section of Collet canal)** that run from the interior of the neighborhood through to the **RIVER**

Figure 9f: the fish market experience

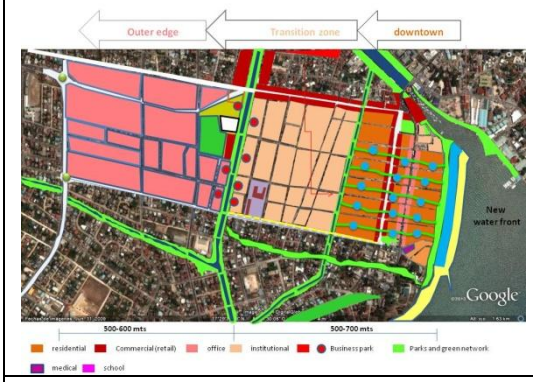


Experiencing fish in the river park
Through shops rstaurants and a
fish market

Carlos H Betancourth
chbetanc@msn.com
633 3208
07/06/2011

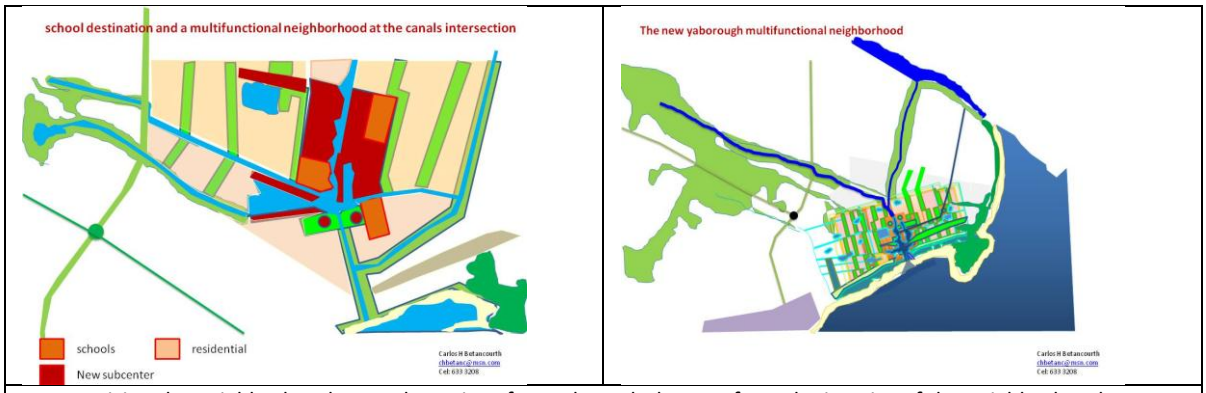
Re-organizing the neighborhood around a series of cuts through that run from the interior of the neighborhood through to the **RIVER** through to the **RIVER**

Figure 9g: experiencing collet canal



Re-organizing the neighborhood around a series of cuts through that run from the interior of the neighborhood through to the **OCEAN**

Figure 9h: experiencing collet canal



Re-organizing the neighborhood around a series of cuts through that run from the interior of the neighborhood through to the **CANAL**

The case of Collet canal development area

The Collet canal area in particular provides an opportunity to provide a significant landscape that provides both visual amenity and plays an active role in surface water management and bio-diversity. The space would be re-used to incorporate amenity space as well as sustainable drainage, flood attenuation, habitat creation and a close integration with the urban development of the entire area. The overall quality of the environment at the revitalized collet canal would stem from a diversity of treatments that provide urban wildlife habitat without compromising the usability of the space for leisure recreation and habitation.

Sustainable design would be embodied as a concept throughout the entire collet canal area. The landscape whilst acting as a green lung for the development area and for the entire city also has a vital role to play in the water management strategy for the area and the city.

With growing urbanization, the increase in hard landscaping, roads, driveways, parking facilities and roof areas would dramatically reduced the land's capacity for natural drainage. This growing urbanization, coupled with recent changes in rainfall patterns, means continuing growth in the volume of surface water runoff that traditional drainage systems have to handle. Traditional drainage systems may not be able to cope with the significant increase in peak volume flows.

Run-off from hard surfaces would be directed into the canals (functioning as surface swales) via petrol and oil interceptors (that provide filtration and removal of suspended solids). Ponds may provide space for the attenuation of rainwater run-off during peak storm events and provide a contribution to the amenity space. The ponds may provide storage capacity for attenuation of rainfall during peak storm events and make a positive contribution to the amenity and ecological value of the collet canal development area. The natural swales provide habitat for wildlife, filtration and final polishing of rainwater run-off quality prior to discharge (figures 9i, 9j, 9k). The collet canal will provide flood attenuation to the Belize River. The canal area also provides an opportunity to use wetland and marginal plant species to further enhance the biodiversity of the area.

The objective of this proposed surface water management strategy (which includes rainwater harvesting, swales, green roofs, basins, ponds and wetlands for surface water
run-off plus permeable pavements. See figures 7j, 7k) is to deal with surface water runoff as near to the source as practicable by attenuation and filtration.

At Collet canal surface water will be managed using green and living roofs, permeable paving with rain crate under-ground storage and a new green collet canal acting as a main multifunctional eco-infrastructure which reopens a historic and popular town walking and biking path (figure 7j, 7k). Residential accommodation will be stacked over more robust uses (figure 8 above). Active commercial uses will line the public spaces and ground with parking courts to the interior of each urban block (see figure 9l, and, key input 6).

Figure 9i: ALTERNATIVE STORMWATER MANAGEMENT IN BELIZE CITY DOWNTOWN

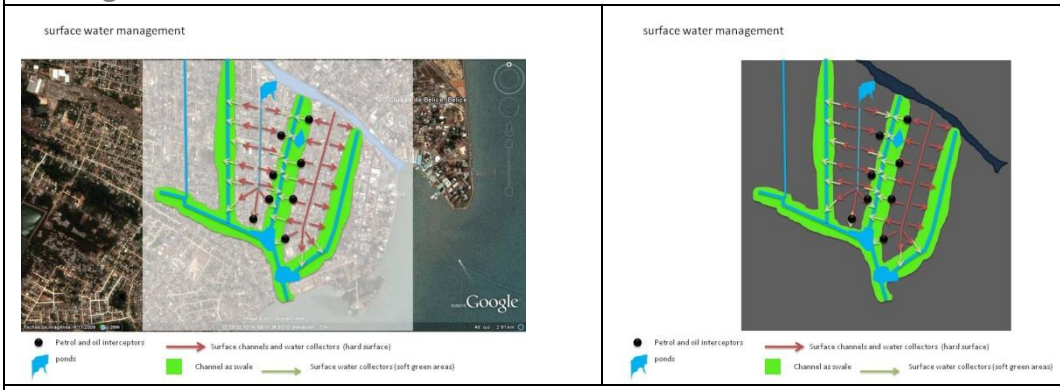


Figure 9j: ALTERNATIVE STORMWATER MANAGEMENT IN BELIZE CITY DOWNTOWN

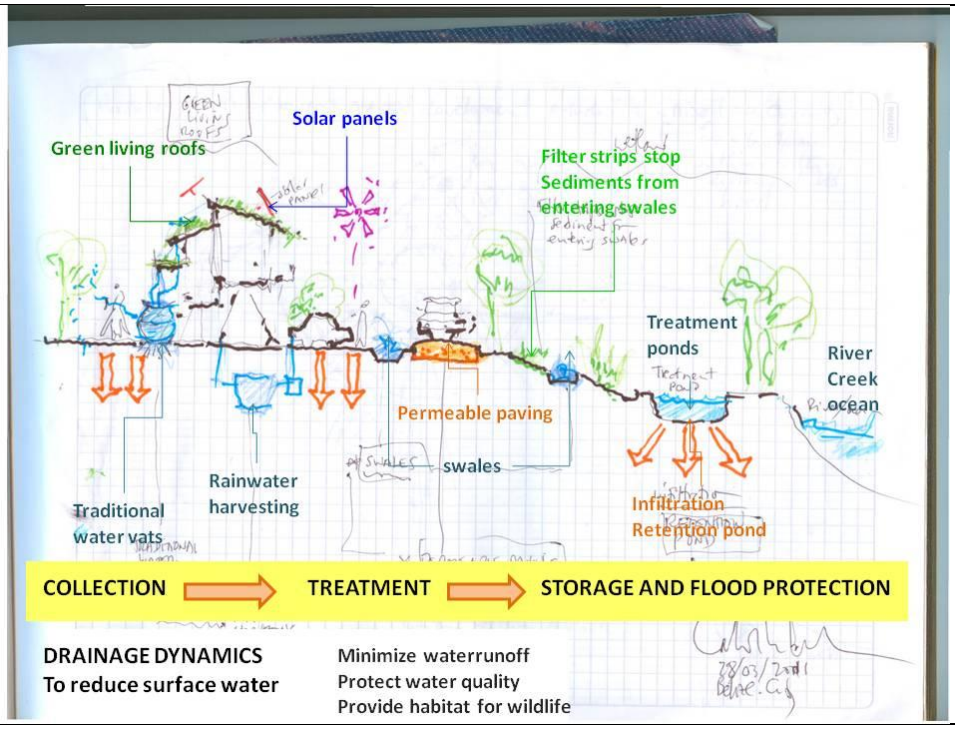


Figure 9k: ALTERNATIVE STORMWATER MANAGEMENT IN BELIZE CITY DOWNTOWN

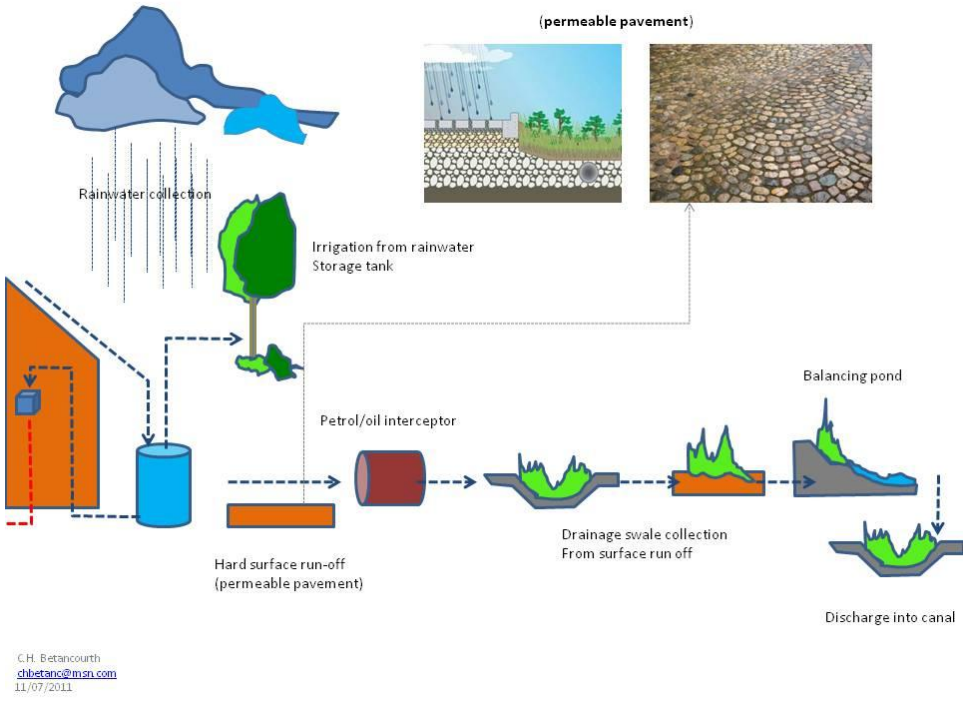
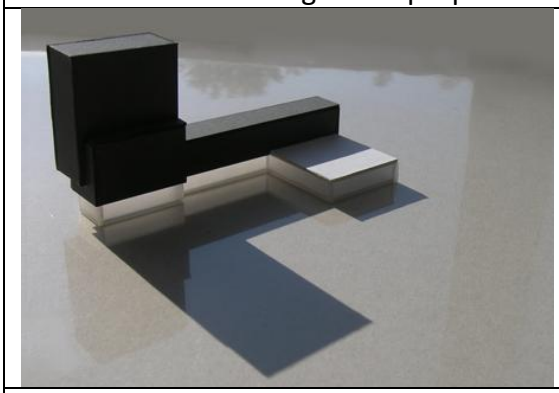
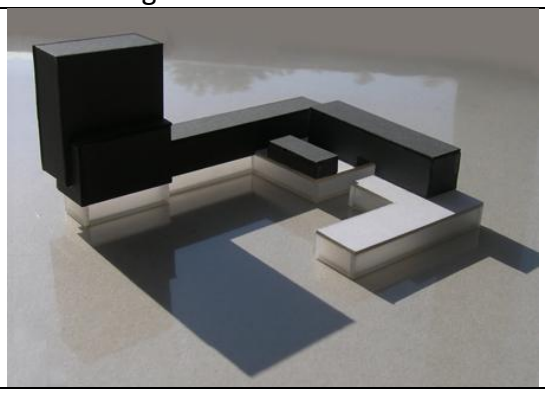
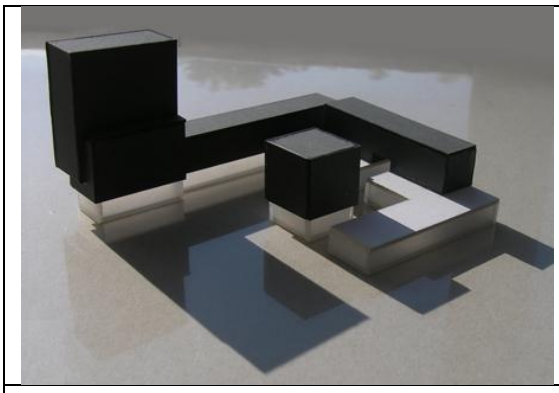
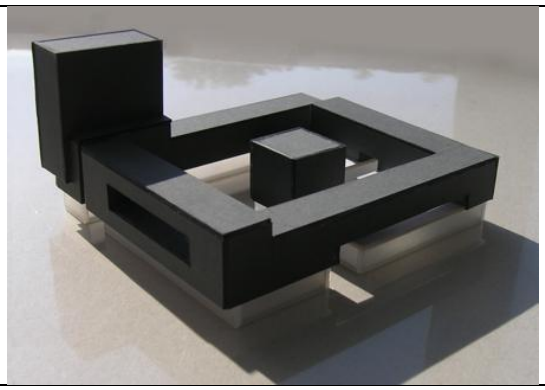


Figure 9l: proposed urban block along collet canal









Mitigation: Minimizing the Consequences

Having put in place measures to control the flood risk, the next step is to consider how proposals can minimize the potential consequences of a flood upon occupants, property, the public realm and the utilities infrastructure. Design flood risk levels are based upon historical data and modelling of complex hydraulic systems. At best they define an acceptably low risk of a certain flood event or worse happening. Obviously, however low that probability is, there is still a chance that a considerably worse flood will happen than that designed for. The consequences of climate change are as yet not fully understood. It is, however, generally accepted that warmer winters, drier summers and unseasonal and frequently extreme storm events will put even areas not normally prone to flooding increasingly at risk. Although allowances may be made for climate change in estimating the design flood height we are entering a period of greater uncertainty when it comes to predicting future events. Proposals for downtown Belize city and for the collet canal should therefore as far as possible plan for the worst case in order reduce the impact of a flood.

Safety

Clearly the most important consideration is the safety of people: residents, workers and visitors. **Safe escape routes** should be designed and **safe refuge areas** above the level of the flood for those that are unable to escape provided. Planning for the worst case a strategy for emergency access by rescue services in boats (or helicopters) should be designed into balconies, roof gardens or other suitable points. Flooding has a disproportionate impact upon vulnerable groups and these should be considered and planned for. Early warning systems and procedures must be put in place. Identify the relevant emergency responders and consult with them to agree viable plans at an early stage in the design process. Emergency supplies of potable water, heat, light, communications and temporary storage of sewage may also be required.

Resistant built-heritage

Property and internal fittings, particularly as they relate to the **built heritage**, should be designed to be resistant and/or resilient. These measures are particularly relevant to refurbishing existing properties and to the preservation of the built heritage, which are at risk of flooding (such as those in the South side of the city) and in some circumstances when developing properties in

areas of flood risk, such as those along the new chatumal extension and in the area for the extension plan (at this point, I don't know if design of resistant and resilient buildings is currently covered by the Building Regulations. If not they should be covered in future revisions). A resistant building would attempt to keep any water from entering property (this is not the case of most buildings along the river, the ocean and the canals. They are very often flooded). This is only viable if the potential flood water is less than about 600mm in depth. Above this the force exerted by the water is likely to cause structural failure and on balance it will be less damaging to allow the water to pass through the interior.

I don't know if the traditional construction used in Belize City is or is not inherently resistant or indeed resilient. This still needs serious consideration. To create properly resistant buildings, it is important to search for more inherently robust forms of construction which may be more appropriate. Creating acceptable access into a resistant structure presents a design challenge. Elevated access over the resilient threshold may be possible (the traditional stairs in Belize city that function as a semi-public space should be consider here) if it can be re-designed to comply with the principles of equal access to the disable.

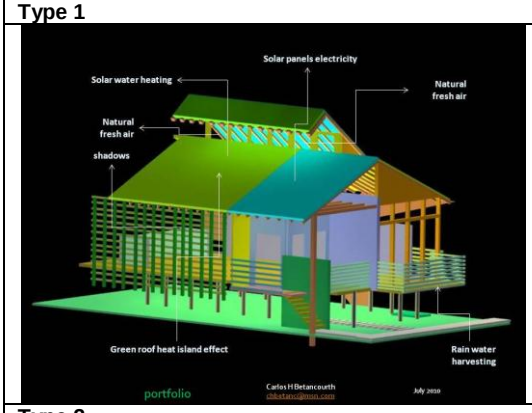
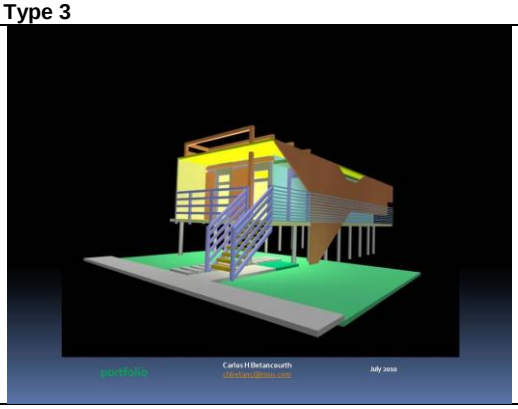
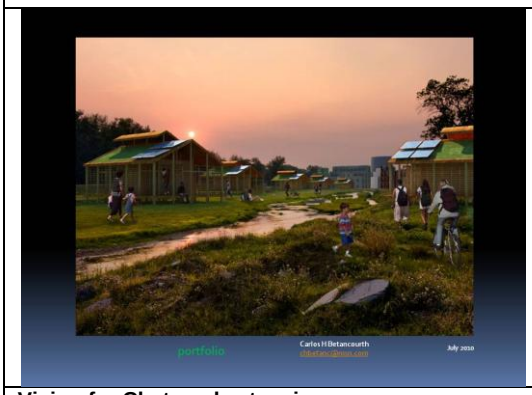
Taking a similar approach to the existing houses in *the London bridges area* around the Krumman lagoon (figure 12a), floating or amphibious houses could be developed that rise up on pontoons along mooring posts with rising flood water. These may fall into two basic categories: a hull type and a raft type. The hull type excludes water in the same way that a boat does and at a certain depth of water becomes buoyant. The raft type incorporates buoyancy into a deep supporting foundation slab. Access and servicing is via flexible walkways and connections.

Key investment and Demonstration **projects**

A water-retention area with houses raised above the floodplain, exploiting a site which would otherwise be uninhabitable (an important strategy in a city characterized by scarcity of land and resources)

It is important to design Demonstration projects located on waterfront/canal locations (river-canal-sea) or in wetlands and mangrove forests (London bridges, chatumal-street, Bourdon canal, etc) which maybe considered as areas designated for controlled flooding. This type of resistant design may only be appropriate for situations where there is no flow in flood waters and where debris will not be transported onto the site (see figures 10).

Figure 10: Stilt house

Type 1	**Type 1**
	
Type 2	**Type 3**
	
	
Vision for Chatumal extension	**Vision for Chatumal extension**

In this study, and based in a water-retention area (which could be along the river, the canal, the ocean, new chatumal and/or in the Bourdon area, the krumman lagoon), houses would be raised above the floodplain, exploiting a site which would otherwise be uninhabitable.

Planning and Design of Resistant Infrastructure

The infrastructure serving Belize city neighbourhoods should also be designed to be resistant or at least resilient to flooding. Main utility supply routes for power, data and water should, if possible, be run in the area of lowest flood risk. Paradoxically, there is a electrical station that sits next to the

river in downtown Belize city with no apparent flood protection at all. Any electrical sub-stations and transformers should also be placed in the area of least risk and/or should be protected by flood defense enclosures if necessary.

Key investment project: design flood defense for strategic piece of infrastructure

This should be a key investment project: to search for an alternative area with lower exposure to flood risk and/or to design a flood defense for this strategic piece of infrastructure. Such primary utility infrastructure would be run in the lowest risk areas or the electrical sub-station would be made resistant to flooding with a flood proof enclosure

Figure 11: **strategic infrastructure exposed to the risk of flooding**

A electrical station sits next to the river in downtown Belize city with no protection at all

Within buildings pump sets for water supplies should be raised above the design flood level along with electrical switch rooms, meter rooms, oil storage tanks, lift motor rooms and any other vulnerable plant. Sewerage systems in areas of flood risk should be fitted with non-return valves in order to prevent foul water backing up into properties.

Public Realm and Landscape

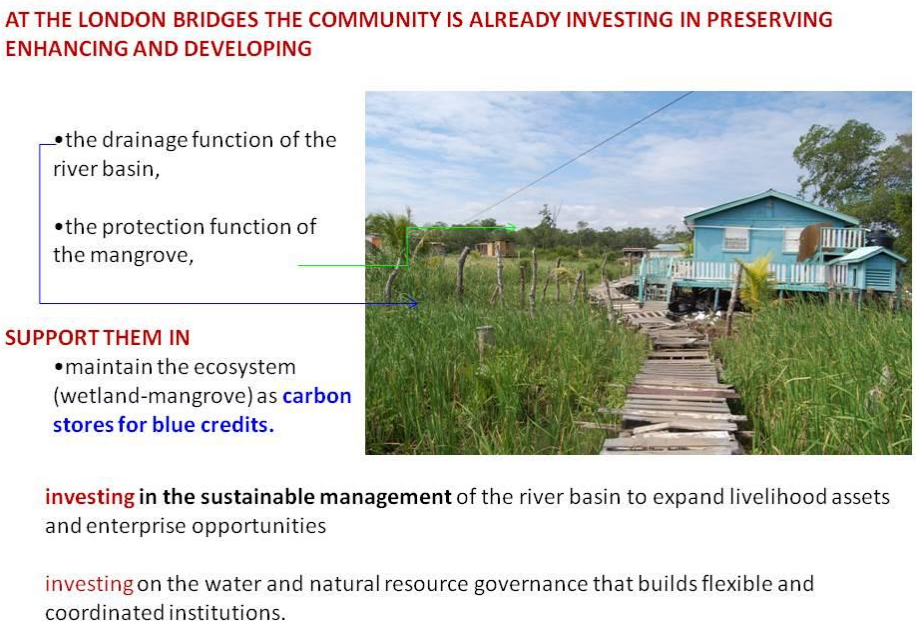
The public realm and landscapes too should be designed to withstand greater fluctuations in rainfall run-off and flooding. Native plants able to withstand periods of dry as well as wet, should be planted in or near canals and swales to prevent scouring and wash-out of surface drainage systems and to prevent debris from washing into and blocking storm water culverts.

Combining a Hierarchy of Mitigation Measures

The effective mitigation of flood risk is generally a combination of several different measures. A hierarchy of measures should successively reduce the impact of a series of worsening flood scenarios.

The first measure should be to raise accommodation levels above the flood level. This is a principle already at work in Belize City ´particularly in an area known as London Bridges (figure 12a).

Figure 12a: **the London bridges neighborhood**



If it is not possible to raise all the accommodation above the design flood level because it is necessary to provide level access to some parts of the building then these areas should be raised above the level of more frequent floods and designed to be resistant. Should resistant measures fail to exclude flood waters parts of the building below the worst case flood level should be designed to be sacrificial in terms of the use and function of the property. In addition they should be designed to be resilient in order to minimize the cost of any damage and to speed up recovery time. Within a building, whether commercial or residential, high-value fittings and essential functions should be located well above the flood level to give a degree of future proofing. Finally safe refuge and access for the emergency services should be incorporated into the design

Key investment project: dynamic water living

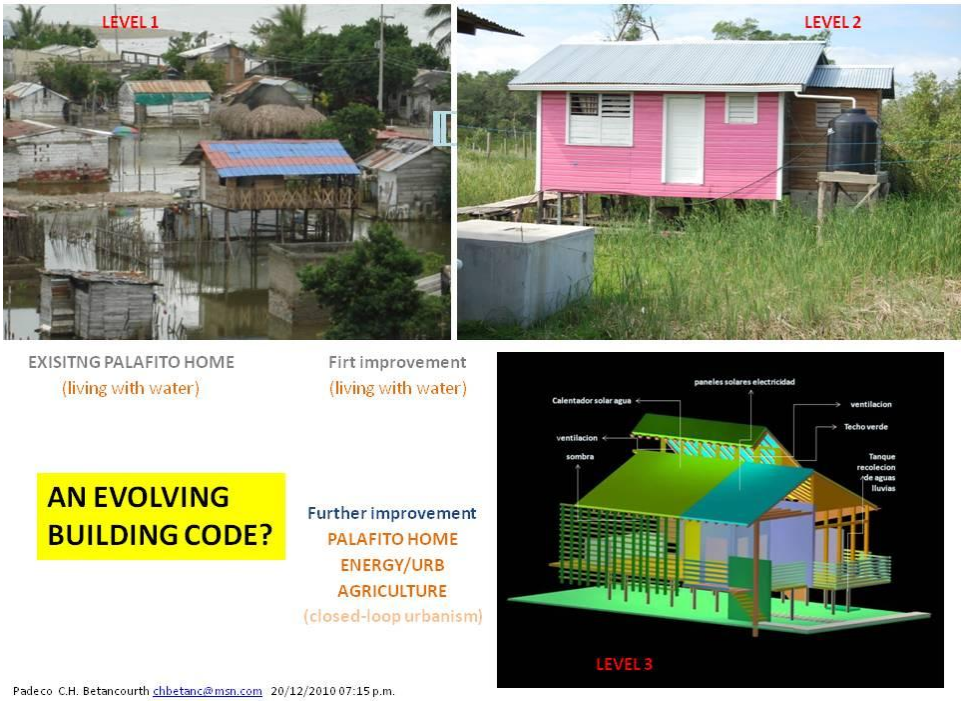
It is important to encourage innovative solutions to balance urban development needs in Belize City downtown with a response to increased flood risk. Houses need to be plan and designed so that they

could be built on the river floodplain, along the canal, on the waterfront, etc., and take the associated flood risk into account. It is important to ensure that that properties built on floodplains and flood prone areas in Belize City are planned and designed to mitigate the flood risk.

Concentrating on resilience, we could seek solutions by applying principles already at work in Belize City particularly in the London Bridges neighborhood (figure 12a). For most of the year the flood house may function as a typical house and only in a flood does it transform and a dynamic water living arrangement is adopted. Should water penetrate the ground floor occupants would relocate upstairs (12b, 12c).

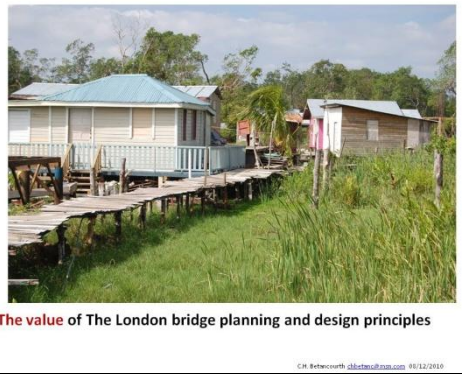
This demo and pilot project could be applied to the area around krumman lagoon (where the London bridges community is located at), the area around the new chatumal bridge extension, as well as the area around the Bourdon reserve (that has been proposed by the World Bank as the site for an extension plan for Belize City (see Component 1)). This will entail a transformation of one of these areas with an emphasis on water storage.

Figure 12b: **the London bridges neighborhood evolving into a neighborhood for dynamic water living**



The project will be based on the current trends of climate change and will give alternatives for water storage associated with different living conditions, climate and ecology. With this plan for the large-scale transformation of one of these development areas, water, housing, nature, agriculture, recreation and other features go hand in hand. The point of departure will be the principles at work in the London bridges (figure 12a, 12b) to be improved progressively through a design code (figure 12c)

Figure 12c: the evolution of London Bridges into a **dynamic water living community**



III
STORM WATER MANAGEMENT IN A WATER RESPONSIVE BELIZE CITY

Natural flood defenses for improving the quality of life

Once the risk of flooding has been managed (see sections I and II above), we may then be able to begin recreating Belize City as a city of blue and green gardens and networks

A vision for a water responsive Belize City

A shining river with landscaped Belize river and Halouver creek-banks; urban farmers, fishermen, and rowers paddling in the streams in their way to their market places along Collet canal; clean waterways and canals flowing into a picturesque Bourdon and Krumman lagoons, Halouver creek, river and ocean.

This (a water responsive Belize City concept) will be a dream dreamt again[8] and come true for Belize City in its near future, for the city and its citizen would have taken the challenge to protect the aquatic environments of its city´s urban areas, and transform the city into a beautiful experience of green landscapes and blue waters, wet-landscapes where people would love to live, work and play.

[8] One often hears the Belizeans says that not long ago they used to bathe in Collet canal

Realizing this vision will entail a long term strategic initiative and key investment projects

- to transform Belize city's utilitarian drains, canals, lagoons and waterways into beautiful and clean continuously flowing streams, rivers, lagoons, canals and coastal waters.
- To bring Belizeans closer to the water so that they will cherish it again and take ownership
- To create a seamless blue-green network well integrated with the adjacent urban developments (see figure 3 above)
- By integrating the streams, rivers, lagoons and canals with the parks and gardens in a holistic way, new pretty community spaces can be created. These spaces will be bustling with life and activity and transform the Belize City into a vibrant City of Gardens and Water, of wetlandscapes

Water is an essential resource, and the problem of wáter shortages is likely to worsen in the near future. Designing for resilience to the impacts of climate change, particularly ensuring secure water supplies and the protection of water environments, is an emerging challenge as the growing urban communities of Belize and of Belize city seek to minimize their impact on already stressed water resources. Thus the above vision and dream will also be a quest for a sustainable urban environment that involves development that neither depletes natural resources nor degrades the health and amenity of its land and water environments. A holistic and integrated water management approach to protect water resources and ensure a sustainable water supply thus becomes crucial.

In this last section we will propose a holistic approach to the management of urban storm-water (the main source of pluvial flooding. See above), to begin transition Belize city to a water responsive city (It should be noted that other parts of the urban water network such as water supply catchments, sewage management, demand management etc., are also important but are not covered by this document)[9].

It is also important that the city builds a diversified and sustainable water supply from various sources. For this water supply to remain sustainable, the community needs to play a part to conserve water and keep the waters clean.

Having developed this comprehensive water infrastructure to meet Belize city's growing water needs, the next step forward is to tap on these blue spaces to enhance the city's living environment. This will be the subject matter of this last section

[9] It is important to integrate urban planning with the management, protection and conservation of the urban water cycle that ensures that urban water management is responsive to natural hydrological and ecological processes.