Sustainable Urban Community Development: A case study of flood design in Snoqualmie, WA, USA

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Abstract

Sustainable Urban Community Development: A case study of flood design in Snoqualmie, WA, USA

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Flooding is an important issue in Snoqualmie. Floods occur almost every five years. They are caused by multiple factors: massive precipitation in winter, melting snow in spring, and Snoqualmie River's convergence upstream of Snoqualmie city.

Flood management in Snoqualmie is complicated because of two main reasons: historic buildings in downtown area and the National Flood Insurance Program (NFIP). For example, since the National Flood Insurance Program requires house owners who own houses in the 100-year flood zone to pay high insurance fees, they reduce house owners' budgets to elevate endangered houses.

This thesis explores effective ways to manage flooding impact from an urban design perspective. It tries to consider what viewpoints engineers lack, such as design aesthetic and integrity. Through comprehensive analysis and diverse flood management research, this thesis proposes flood-proofing designs and strategies for Snoqualmie.

Flood-proofing is of particular interest because we live in a flood-threatened world. Urban areas are often more susceptible to the damage caused by flooding due to high population densities and inadequate infrastructure design. Climate change in recent history

has also significantly changed precipitation patterns and increased the chance of flooding in many regions. This thesis intends to find suitable flood-proofing designs and strategies for Snoqualmie, which can be applied to other places around the world.

Past studies focus on climate change and the effect of human development on flooding issues. They propose that a good flood management strategy is to live with floods and be resilient to damages (e.g. wet flood-proofing, dry flood-proofing, and house-elevating). Natural systems, such as vegetation, soils, floodplains, and wetlands are better ways to maintain water balance and mitigate flooding. Urban development should be sustainable and less harmful to natural systems.

This thesis proposes sustainable and flood-resilient development methods. Two main methods are presented: restoring floodplain habitats by removing structures/setback levees, and constructing detention pounds/bio-swales. Both methods combine open spaces with flood management infrastructure designs.

In the historic downtown area, both wet flood-proofing and dry flood-proofing methods are applicable. Box barriers or sandbags are applicable around the area. Buildings can use flood-proofing materials to withstand floods and facilitate easy clean up. Buildings can also use backflow devices on sewer drains.

This thesis proposes comprehensive flood management design after analyzing historic maps, zoning maps, flood hazard data, and hydrological data. The research presented here makes substantial use of Geographic Information Systems (GIS) to analyze sites' current conditions, such as development patterns maps and zonings maps. It also forecasts future potential development areas by considering the surrounding ecosystem.

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Chapter 1 Introduction

1. A. Thesis Statement

Natural hazards have historically posed a threat to our daily lives. Urban areas are often more susceptible to damage caused by natural hazards due to high population densities and poor infrastructure design. In recent years, climate change has been attributed to induce increasingly more common extreme weather events, and the resulting disasters can quickly destroy any efforts made in urban development. Thus, we need cities to be more sustainable in order to face hazards.

The purpose of this study from the perspective of urban design is to propose and think of strategies for effectively preventing or reducing the impact of potential flood hazards due to rainfall and snowmelt. An urban design perspective attempts to consider specifically the viewpoints engineers lack, such as aesthetic and integrity. Thus, while engineers mainly focus on quantifying how structures can handle floods and the degree to which they are affected by them, they often fail to focus on the relation to community.

This research is focused on finding a relationship between flooding and the urban environment, flooding and drainage, and further connections to other factors possibly related to flooding. Since this research focuses on sustainable urban community development, especially flooding, a couple initial questions can be raised: “What is an effective way to prevent or reduce losses from flooding due to rainfall and snowmelt?” and “How can we effectively utilize local resources for flood management?"

By exploring answers to these questions, we will propose flood management designs compatible with sustainable development in Snoqualmie. This thesis can serve as useful information to local developers and governments to aid sustainable development in flood areas.

According to the 1987 United Nation Brundtland report[1], "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In this research, we further define this to entail resilient designs for a better future and reducing the impact of hazards and the risk of hazards. From the book "Resilience Practice", [2] a key aspect of resilient design is that it expresses a community's capacity to adapt to change while retaining its essential identity and integrity. Flood design in Snoqualmie can be an example for sustainable development. It can help the community to utilize local resources to protect against flooding and mitigate damage when it occurs.

1. B. Flood overview and Strategies

As defined by the US Federal Emergency Management Agency (FEMA),[3] a flood is "A general and temporary condition of partial or complete inundation of normally dry land area or of two or more properties from:

• Overflow of inland or tidal waters;

• Unusual and rapid accumulation or runoff of surface waters from any source;

• Mudflow; or

• Collapse or subsidence of land along the shore of a lake or similar body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels that result in a flood as defined above."

[1] Our Common Future, Chapter 2: Towards Sustainable Development.(1987)), Retrieved from URL:http://www.un-documents.net/ocf-02.htm. Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6QDdrbBjs)

[2] Walker, B., & Salt, D. (2012). *Resilience Practice*. : Island Press, USA. P3.

[3] Flood definition, FEMA, (2014/March), Retrieved from URL: http://www.fema.gov/national-flood-insurance-program/definitions. Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6QDe90jqi)

The first step in devising any flood management strategy is to understand floods, how they form, and the different types of flooding. Only by doing so can we achieve a better flood management strategy.

Flood Sources:

The most common sources of flooding are heavy rains, spring thaw and tropical storms:

1. Heavy rains: When rains become too heavy or last too long, rainwater becomes a significant problem. A sudden and large amount of rainwater during a short period of time can cause flash floods. If the rainwater cannot soak into the ground or the local drainage system is insufficient, the runoff can run thorough the street, damaging infrastructure and buildings.

2. Spring Thaw: As spring arrives and progresses, moisture trapped in the ground as ice or snow during the winter begins to melt. As it melts, the large amounts of water can result in overflowing of rivers and lakes.

3. Tropical Storms: Storms can bring strong winds, heavy rain and cause flooding to coastal areas, up to a hundred miles inland.

Flood Types:

There are many different types of flooding, and are generally classified as River Floods, Coastal Floods, Pluvial Floods and Urban Floods.

1. River Floods: River floods occur when river flows exceed the capacity of river channels and spill out to nearby low-lying areas. They may occur due to large amounts of water from rainfall, snowmelt and tropical storms. They may also result from the collapse of land along river. Flood durations for these types are strongly dependent on the amount of water, and can be long or short.

2. Coastal Floods: Coastal floods result from tidal surges caused by storms or tsunamis. In a storm event, heavy rains and strong winds cause seawater to rise inland. This may happen very quickly in just a few hours. Coastal floods are most frequently caused by storms. On the other hand, coastal floods caused by tsunamis are less frequent, but still can be severe.

3. Pluvial Floods: Pluvial floods are caused by rainfall or snowmelt that is not absorbed into the ground and where the runoff accumulates quickly. These floods are usually caused by local weather events, for example, storms bringing large amounts of rain. These floods can happen anywhere, regardless of distance to a river or coast.

4. Urban Floods: Urban floods usually arise from a combination of different causes in an urban environment. They can be caused by rivers, storms and other infrastructure failures. When a large amount of water cannot be handled by the drainage system, it inundates the urban area. The level of flood impact is influenced by the impermeable materials in urban structures and the area's ability to control runoff.

Flood Management Strategies:

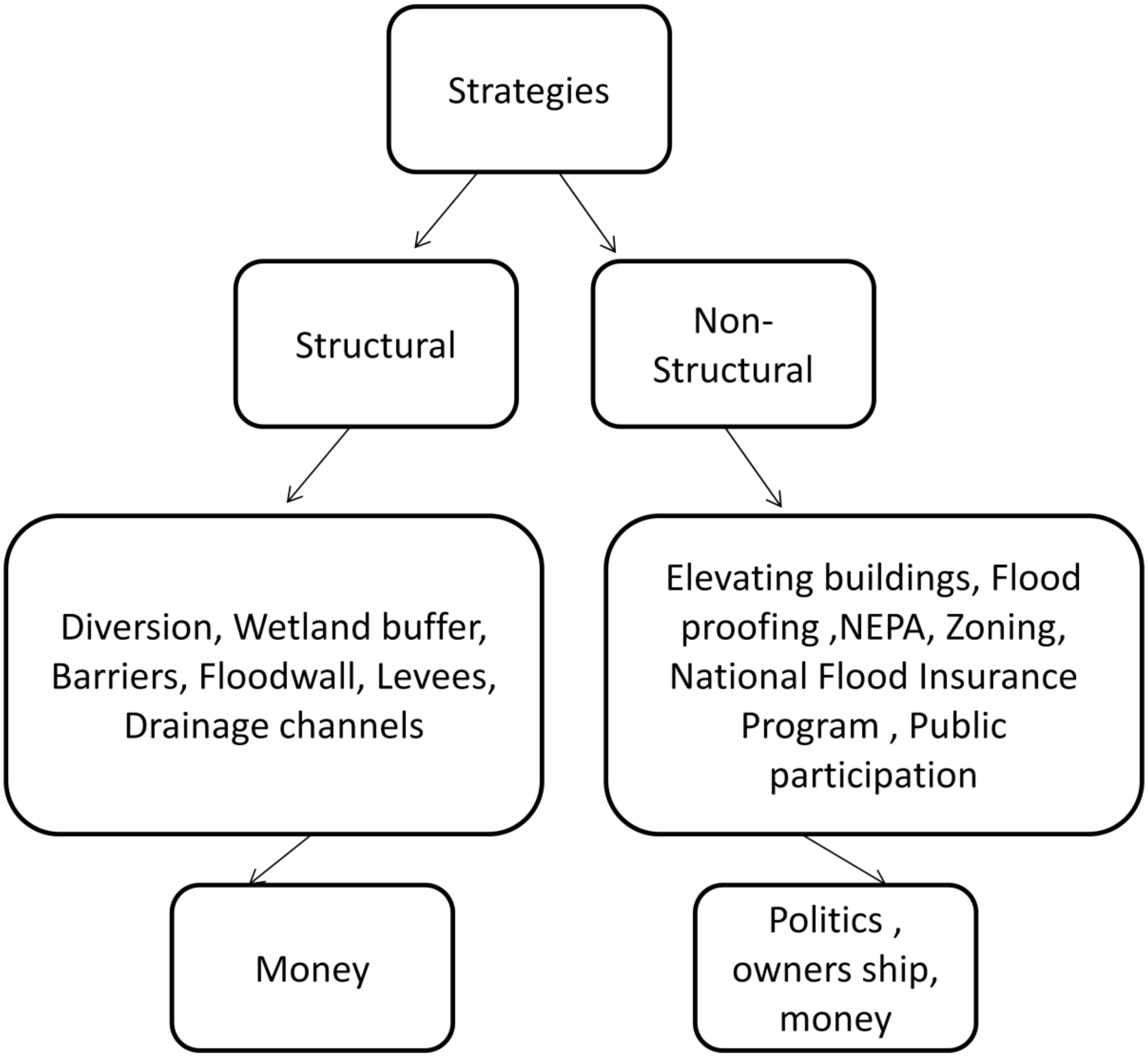


Figure1. Strategies classification. Created by Pin-hao Huang. (2014, May 23).

Flood management strategies can be divided into Structural and Non-Structural strategies:

Structural strategies address flooding with physical measures, and may involve substantial engineering and technical design. Common examples of structural strategies include levees and flood walls. They control floods by decreasing the flow or depth of flooding, but in some cases are unable to handle increasing flood levels. In these circumstances, these flood management measures may be rendered useless or be severely compromised.

The Non-Structural strategies try to reduce the flood impact for each individual building. The strategies will deal with the flood in law or policy or, for example, establishing land use policies and regulations to prevent overdevelopment. These measures will also focus in engineering flood management structures. They often promote advance flood forecasting and preparation. Aside from preparedness, these measures may also try to reduce the recovery time when a flooding event does occur. These measures usually are less costly and easier to implement than structural strategies. The drawbacks to these non-structural strategies are that they can often be hampered by politics and bureaucracy as they may involve many stakeholders.

Modern methods may take a holistic environmental approach and try to create sustainable environments which are resilient to any future flooding. They not only restore an ecosystem's ability to manage runoff, but may also further increase its ability to do so. Thus, they often employ both Structural strategies and Non-Structural strategies.

Here we discuss common strategies in terms of capability – small, medium and large.

Small: Green Roofs

1. Green Roofs: Green roofs are vegetated systems installed on rooftops that absorb rainwater. There are different types like single layer systems with soil, and multi layers systems. Installations should consider various factors like roof size and slope.

Medium: Rain Garden, Retention Pond, Structural Soil Cells, Vegetated Swale, Flood proofing for Buildings, Porous Pavement

1. Rain Garden: A shallow depression that can capture runoff and storm water from roofs, roads and other areas around a building. A rain garden is usually filled with several feet of soil and planted with native vegetation that can withstand wet or dry conditions.

2. Retention Pond: Usually an artificial lake surrounded by vegetation. Storm water is typically channeled to the retention pond, which allows large amounts of water to enter.

3. Structural Soil Cells: A linear water management method, usually consisting of trees in a small soil area with containers. These methods are often used in linear areas with limited space.

4. Vegetated Swale: A vegetated runoff channel with native grasses, shrubs and trees. The vegetated swale can convey water in a slow velocity, some of which will be absorbed into the ground.

5. Floodproofing for Buildings: Floodprofing for buildings can be divided into dry floodproofing and wet floodproofing. Both types of measures involve modifying buildings to prevent flood waters or reducing flood damage.

6. Porous Pavement: This is a pavement usually covering sidewalks, roads or parking lots. It replaces the original urban impervious pavement on roads and can reduce runoff by promoting ground absorption.

Large: Buffer Area, Flood barriers - Levee or Flood wall, Elevated Buildings, Relocate Buildings

1. Buffer Area: A buffer area preserves the natural environment and provides a space for flood water to accumulate. It is a setback established by local zoning and is defined as a regulated area.

2. Flood barriers - Levee or Flood wall: These are barriers that can prevent flood water from entering into urban areas.

3. Elevated Buildings: As buildings are elevated several feet and higher off the ground, it becomes harder for flood waters to enter.

4. Relocate Buildings: Buildings in flood prone coastal or river areas can be relocated to other locations not prone to flooding.

1. C. Background of Snoqualmie and issues

The City of Snoqualmie was established in 1903 and is located approximately 25 miles to the east of Seattle, WA. The downtown area is situated next to the Snoqualmie River and is a historic district. The city was a lumber mill town and has served as a transportation hub for those crossing the Cascade Mountain Range by wagon, rail and motorized vehicle. Now, people come to visit the historic downtown and the nearby Snoqualmie Falls. Snoqualmie has a historical record of regular floods.

Figure2. Snoqualmie Fall. Shot by Pin-hao Huang (2014, May 23).

Figure3. Snoqualmie Downtown. Shot by Pin-hao Huang (2014, May 23).

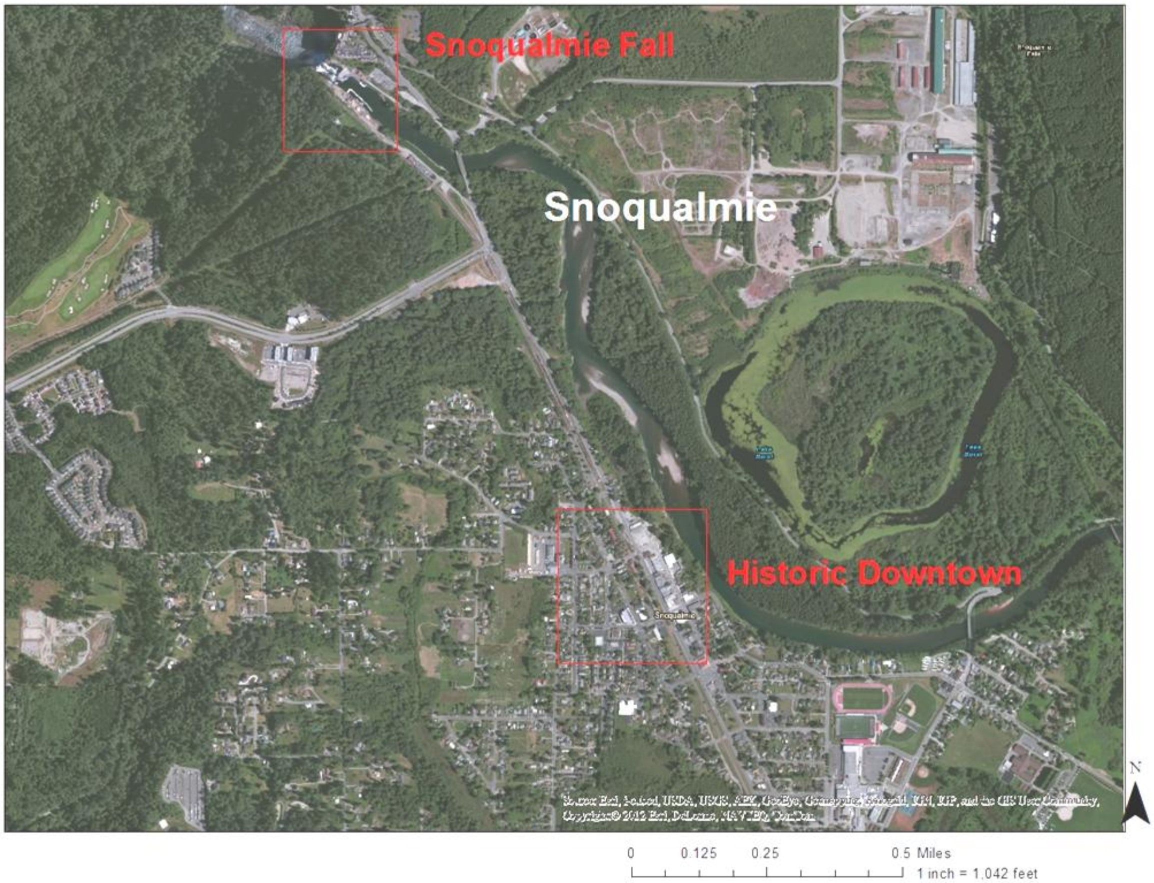


Figure4. Snoqualmie Map. Created by Pin-hao Huang. (2014, May 23).

Flood in Snoqualmie:

Here, we discuss floods in Snoqualmie in greater detail[4]– Timing, Frequency, Severity, Issues

1. Timing:

Flooding usually occurs in the winter season. It is slow and gradual, and there is plenty of time for residents to prepare. Flooding usually lasts one or two days.

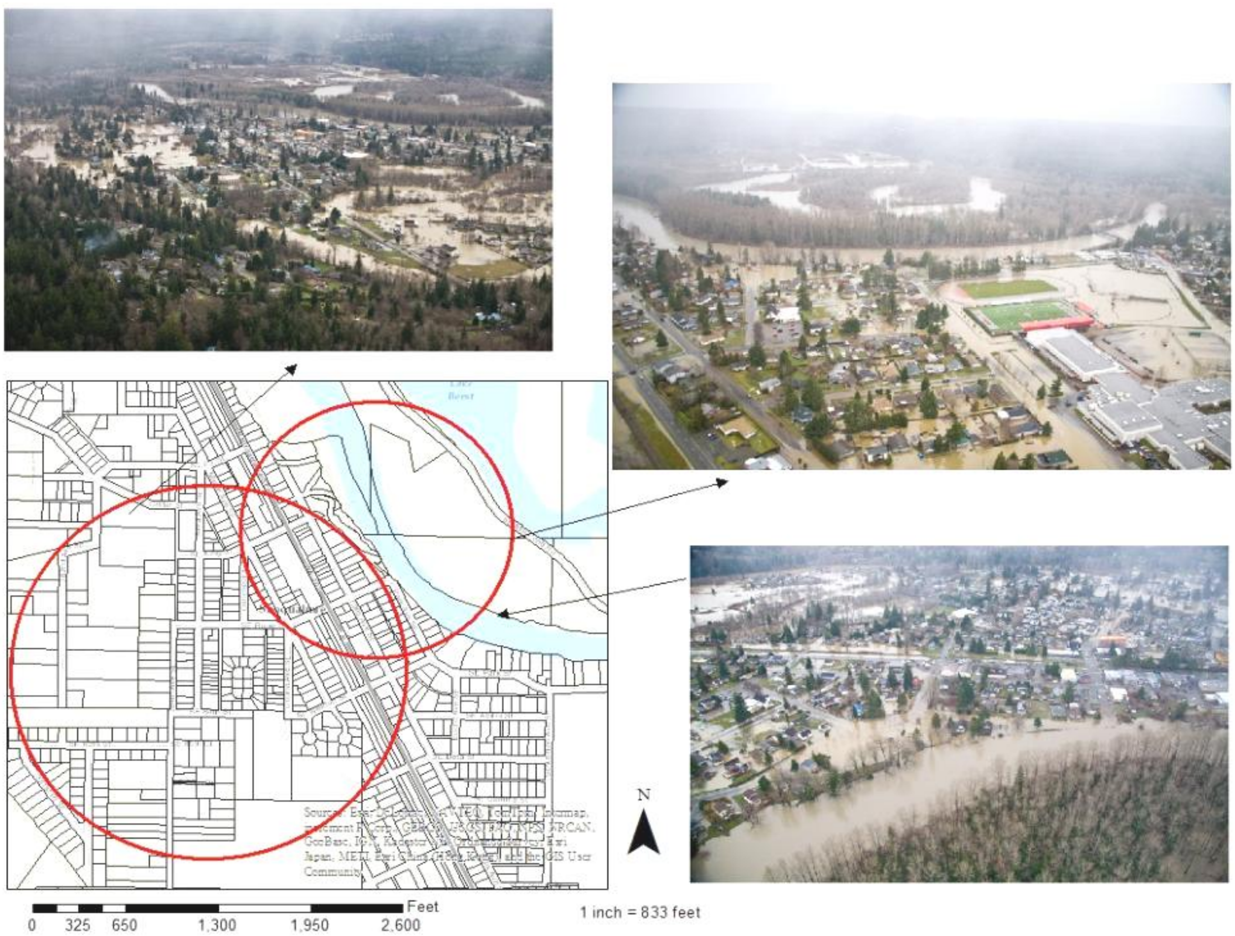
2. Frequency:

[4] Bob Freitag, Susan Bolton, Frank Westerlund, Julie Clark.2009. *Floodplain Management: A New Approach for a New Era*. Island Press.

Flooding in Snoqualmie occurs often - almost every five years. The most recent cases of flooding occurred in 2009, 2006, 1995, and 1990.

3. Severity:

Flood waters can reach a height of several feet in the City of Snoqualmie, and usually one or two feet in the historic downtown. Figure 5 shows the severity for the Snoqualmie flood in January 8, 2009.



January 8, 2009

Figure5. 2009 Snoqualmie Flood Created by Pin-hao Huang (2014, May 23).

4. Issues:

First, flood damage to buildings in the historic downtown is chronic, but even slight flood waters can have substantial consequences for business operations. The cost to repair and the time spent on cleanup delays businesses from opening. Also, old buildings are often harder to cleanup due to the building materials and the design of the buildings. Moreover, National Flood Insurance Program (NFIP) requires house owners who own houses in the flood zone to pay higher insurance fees, thereby reducing house owners' budgets to elevate houses or to change house materials to flood resistant materials. Thus, the time to recovery is important; meeting NFIP requirements and proper design planning can help recovery.

Second, flood damage to utilities varies by type and location. Damage is usually chronic because floodwaters rise slowly and velocities are relatively low in Snoqualmie. However, the main problem for utilities is debris transported by floodwaters that strikes poles, wires, and utilities such as electrical substations that are located at or near ground level. Natural gas utilities may also prevent local businesses from operating if water enters the system and impacts gas flow.

Third, sediment accumulates in storm water conveyance systems. During flood events, large amounts of river water are backed up at Snoqualmie Falls, gradually flow out of the river channel, and inundate the city. This flood water brings a significant amount of sediment, which is deposited in storm water catch basins. As the sediment builds up and reduces the capacity of the storm water catch basins, subsequent large rain events can more easily cause additional flooding problems. These floodwaters may in turn flow to new areas, causing more problems. In order to avoid this situation, the city of Snoqualmie employs vacuum cleaning trucks to clean out sediment after a flood event, which can be costly.

Chapter 2 Comparative Cases Analysis

2. A. Overview

Flood management methods can be divided into three categories: large scale, medium scale, and small scale.

Large scale:

Taking a broad approach can reduce the impact of flooding as a whole. This can include, for example, modifying the river with dams, adding conveyance channels, and dredging. The installation of retention ponds also helps to deal with overflowing river water. Another large scale flood management mechanism is to restore wetland or floodplains to act as buffer space for the river. Large scale methods using multiple measures to tackle flood management can be highly effective, but also costly.

Medium scale:

This scale focuses on parks and some smaller strategies. For example, the construction of sustainable flood control parks can help catch rainwater runoff.

Small scale:

Small scale flood management methods often operate at the street level and smaller. Wet floodproofing, dry floodproofing, building elevation, and installing backflow prevention devices on sewer drains all fall in the category of small scale flood management. Also included in the small scale category are swales, porous pavement and structural soil cells. Temporary flood barriers such as free-standing barriers (e.g., box barriers) and sand bags can also be effective low cost small scale measures. Permanent barriers such as floodgates and walls built around houses are other small scale measures.

2. B. Comparative Cases Analysis

Japan Super Levee Project

There are several ways to modify a river with dams. One particularly well known example is the Japan Super Levee. In this case, an original levee was modified and augmented with additional functions.

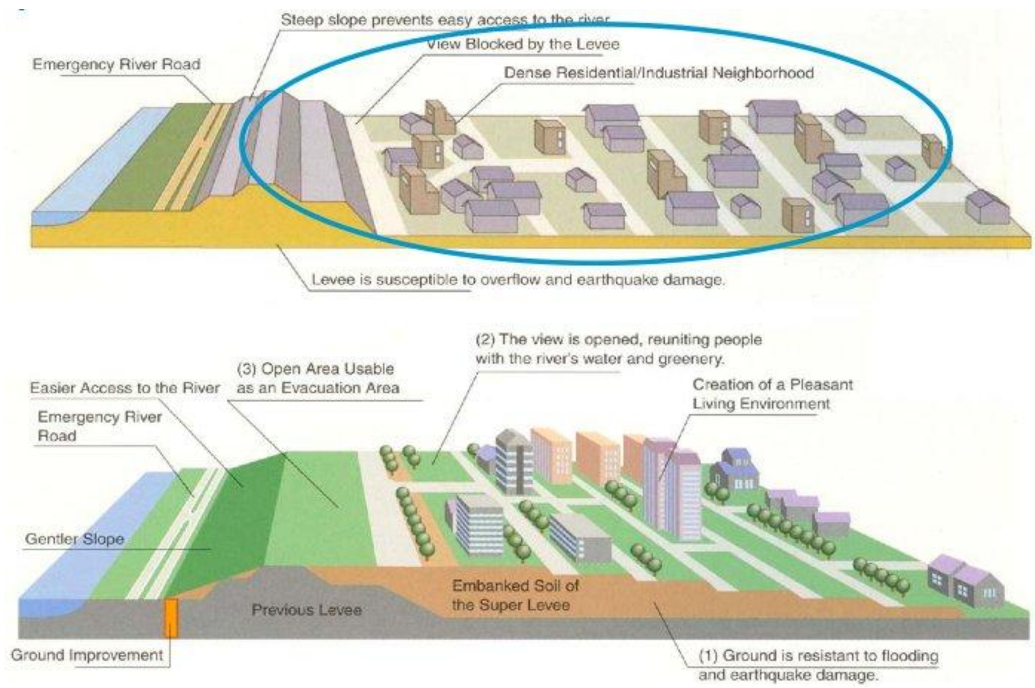


Figure6. Tokyo Super levee .Retrieved from URL: http://www.seacityresearchnet.com/archives/1145. Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PnGPk0VR)


Figure7. Tokyo Super levee .Retrieved from URL: http://www.seacityresearchnet.com/archives/1145. Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PnGPk0VR)

The Japan Super Levee is a large scale project in the Tokyo Metropolitan Area built along the Arakawa and Tama rivers in Tokyo, Japan from 1985-present. The project was designed by the Planning Section, River Department, Bureau of Construction, and the Tokyo Metropolitan Government. The length is around 14.5km with an underground reservoir, a tunnel (length: 4.5km; internal diameter: 12.5m) with the capacity to hold 540,000 m^3 of flood water. The cost of the project has reached 100 billion JPY (2009). With the original super levee project abandoned by the national budget system in 2010, the scale of super levees project has been narrowed to certain low-lying areas or densely built-up areas in large cities.

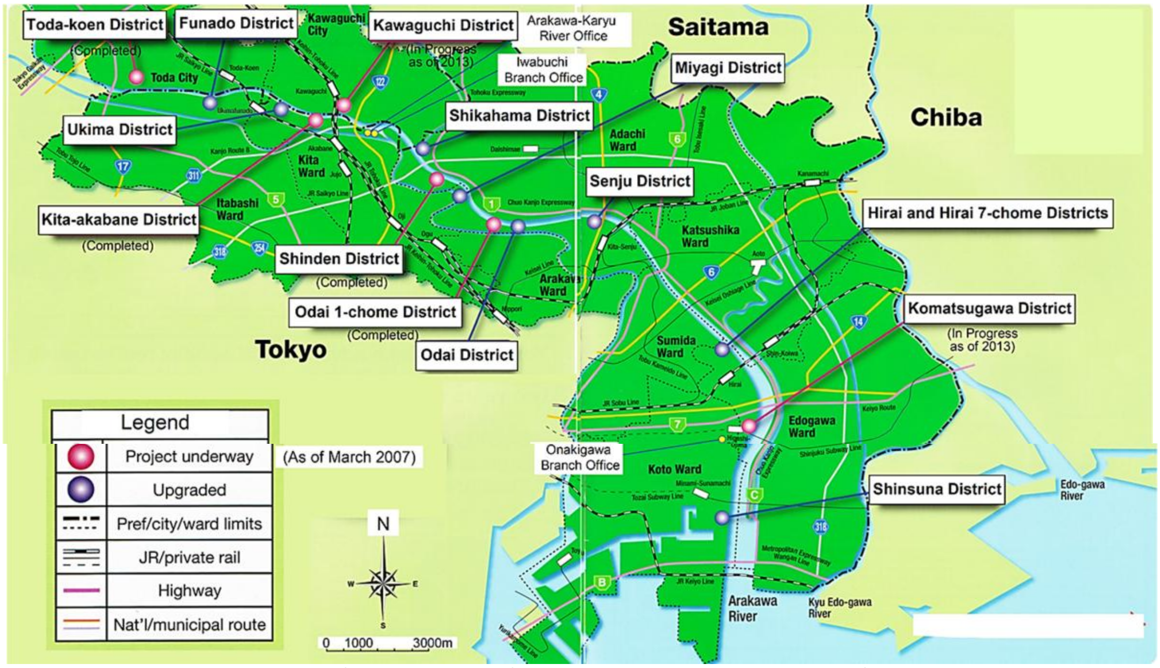


Figure8. Tokyo Super levee .Retrieved from URL: http://icfr2013.ex.ac.uk/papers/A1_Nakamura.pdf. Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PnHXjjRD)

The eastern part of Tokyo area has many low-lying lands, most of which are below sea level. Thus, these areas are vulnerable to flood damage. The super levee project was proposed as a solution to the area's flood vulnerability in the 1980s. It is a wide levee with a gradual inward slope combined with urban redevelopment projects. The average height of the super levee is 10 meters high by 300 meters wide, and it extends into residential areas, effectively raising the level of the surrounding area higher than the level of the river. ; Some of the raised land is treated as a designated evacuation area.

The super levee project is a multifunction project for the urban cities. It serves the triple functions of recreation, flood- management and housing. It aims to be sustainable because it allows more room for the river to flood. The idea of elevating the land near a flood zone in the project is a possible strategy can be applied in Snoqualmie. However, there are some problems: They are not sustainable enough because the concrete made riverbank impedes the growth for wildlife and it cannot create river habitat. They are significant costly, and the possibility that its effectiveness may be reduced due to climate change because the sea level rise can make the flooding worse. These projects are much more suitable for high population densities and urbanized areas; in contrast, Snoqualmie has a low population density and smaller urbanized area. There are some historic buildings in the downtown area and residents enjoy a rural lifestyle. Building these super levees will require urban development, thereby changing the natural environment and influencing wildlife habitats.

Figure9.Tokyo Super Levee .Retrieved from URL: http://www.seacityresearchnet.com/archives/1145. Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PnGPk0VR)

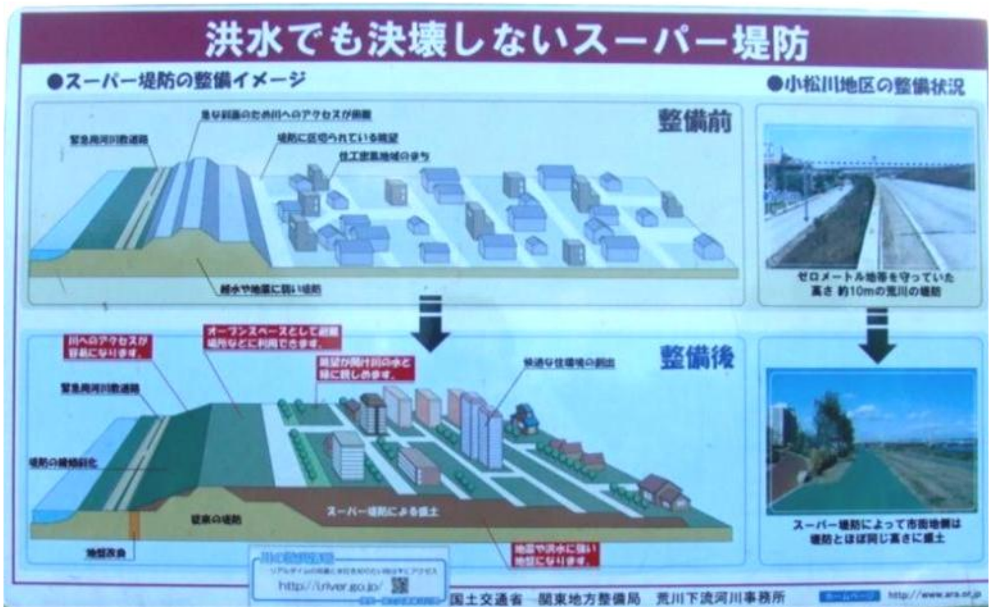


Figure10. Tokyo Super Levee .Retrieved from URL: http://blog.japantimes.co.jp/yen-for-living/tag/flood-control/ .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PnHhdHbi)

Seattle High Point Project

Retention ponds are a well known flood management method. There are many variations to the retention pond, but here we take the Seattle High Point Project as an example.

Figure11. Seattle High Point Retention Pond .Retrieved from URL: http://www.uswateralliance.org/2010/11/01/driving-political-change-on-green-infrastructure/ .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PrgkIa4i)

The Seattle High Point Project combined medium and small scale management methods. This project is located at High Point in the west of Seattle, began in 2003, and was completed in 2009. The primary design is to control runoff and rainwater by establishing porous surfaces and swales. Runoff is reduced and filtered, then runs into the retention pond. High Point accounts for ten percent of runoff into Longfellow Creek. According to records, the system has successfully prevented local flooding since its completion. The use of porous pavement on streets and sidewalks retains some runoff and absorbs rainwater into the ground. The swales along the streets and sidewalks are usually six feet wide and one foot deep with grass and gravels which can also help retain water and absorb it into the earth. Finally, the gradual slopes direct the remaining runoff towards the retention pond. The retention pond controls the water entry and exit. The water in the retention pond will be filtered, then released into the creek. In other words, it will reduce water emission impact to the creek habitat. The High Point project utilizes vegetation and other materials as natural filtration to reduce rainwater runoff.

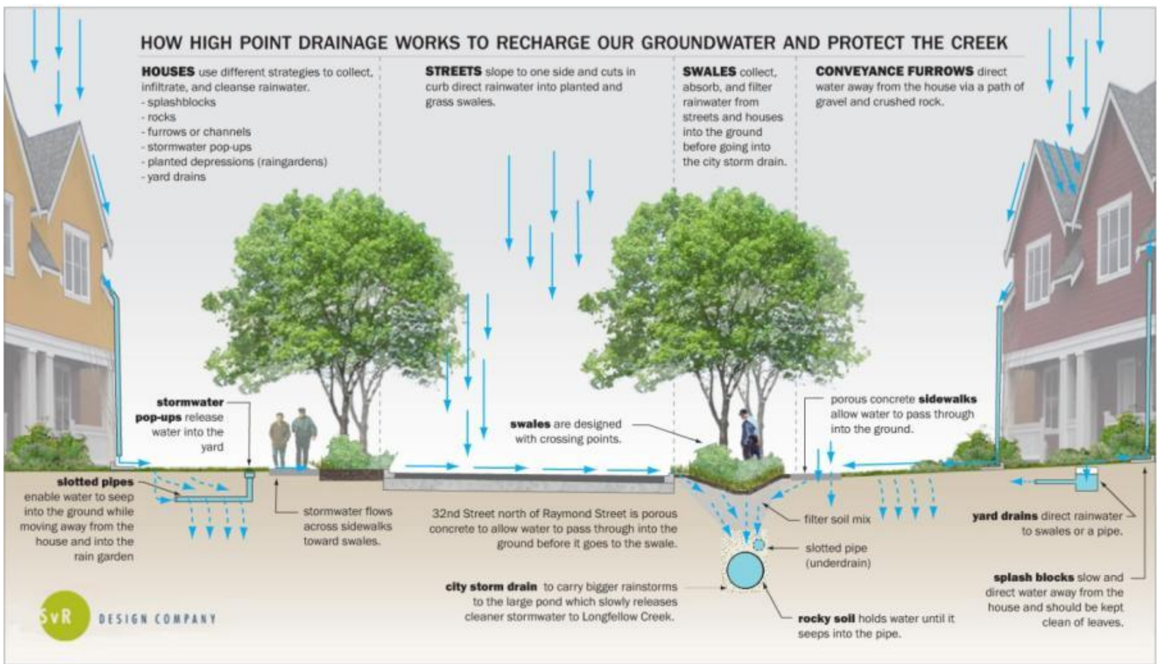


Figure12. Drainage Diagram .Seattle High Point Community.2014-06-09.Retrieved from URL: http://bettercities.net/images/14862/drainage-diagram .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PzUlexxN)

The Seattle High Point Project effectively reduces rainwater runoff, and the idea of installing a series of swales, porous surface roads, and a large retention pond can be applied to Snoqualmie to reduce the rainwater runoff back to the Snoqualmie River. However, it cannot effectively reduce the river flooding as it may not be able to absorb the volume of water typical in Snoqualmie river flood events.

Figure13. Swales in Seattle High Point .Shot by Doug J. Scot Retrieved from URL: http://pedshed.net/blog/wp-content/uploads/2010/05/HighPoint_Swale_and_Park.jpg .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PtWK8zoM)

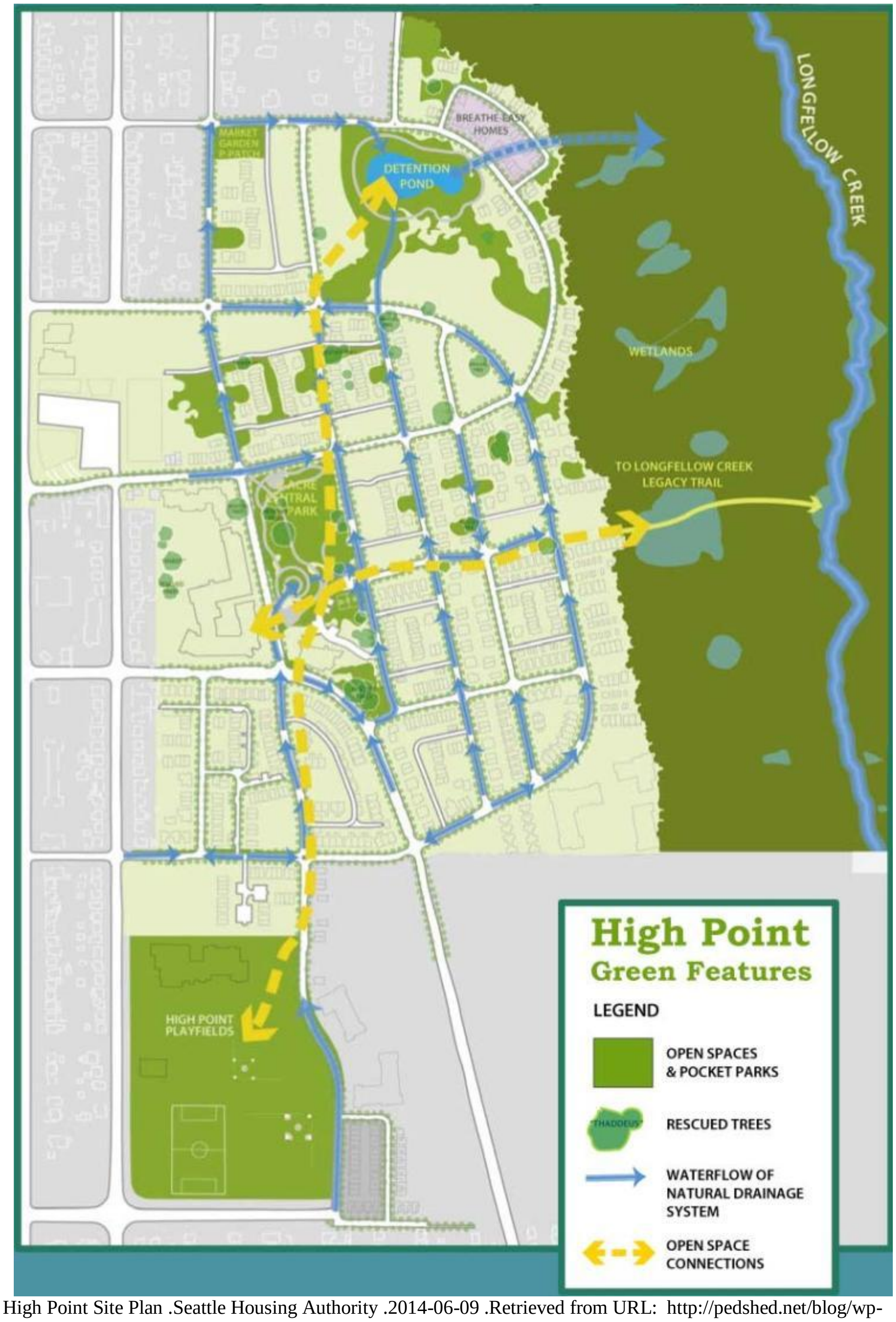


Figure14. High Point Site Plan .Seattle Housing Authority .2014-06-09 .Retrieved from URL: http://pedshed.net/blog/wp-content/uploads/2010/05/High_Point_Plan.jpg .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6QD4502Fn)

Green River Project and Large Wooden Debris

The usage of large wooden debris in a stream is also one effective way to reduce flood damage. The following project is a large scale project called the "Green River Project". Unlike the Japan super levee, the Green River project can not only mitigate flood impact but also create habitats for wildlife. The Green River in Washington State has caused several flood events in recent history. Several levees have been built to protect against flooding, but have become out of date and are no longer as effective. Therefore, the City of Kent began the Green River Levee Improvement Program. The improvement project uses large wooden debris in the stream to restore the habitat and reduce the river flow speed in order to decrease the erosion rate of the river line. The project also involves planting native trees and shrubs, whose roots help stabilize the riverbank soil.

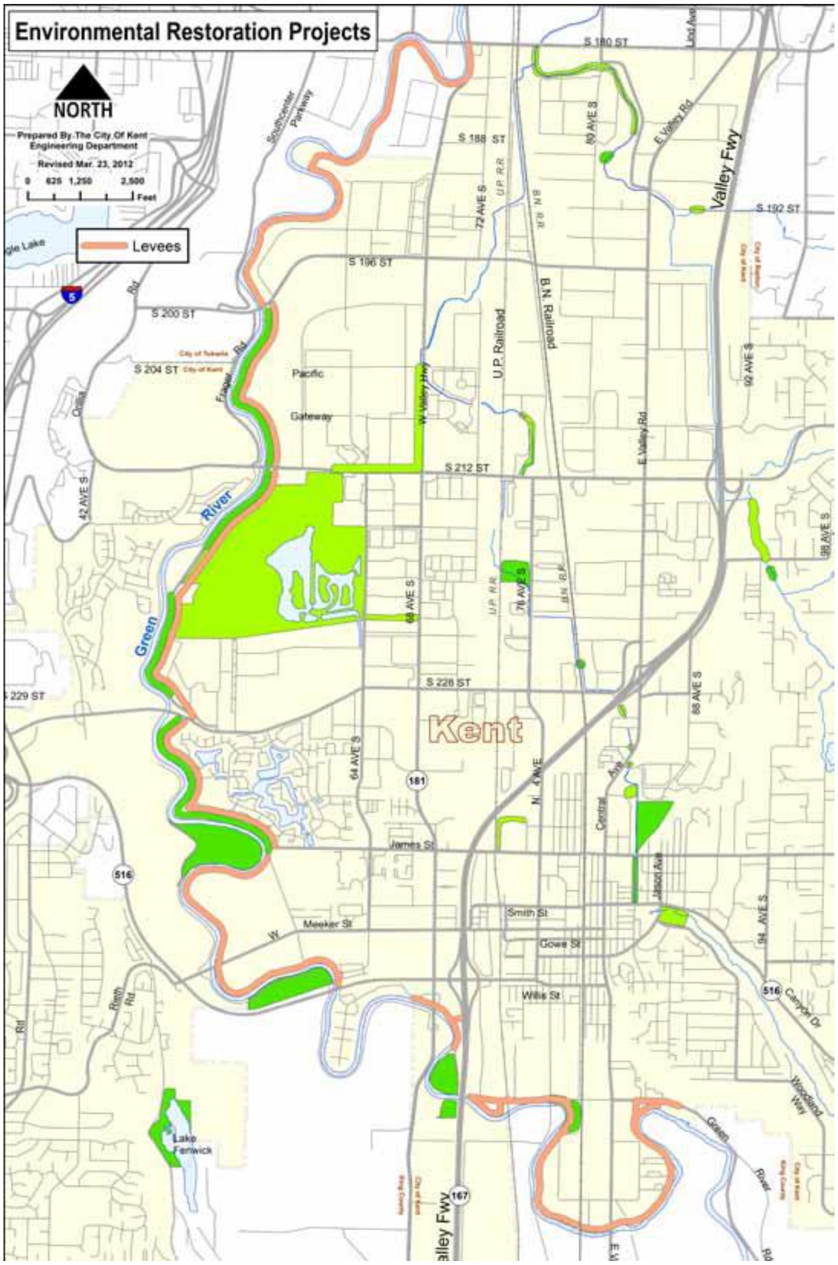


Figure 15.Project Location .Adapted from "GREEN RIVER PROJECTS" by City of Kent, 27 April 2012, p02–06,

Figure16. Boeing Levee, Adapted from “GREEN RIVER PROJECTS” by City of Kent, 27 April 2012, p006

Figure17.LWD .Thinkbluemarin.(2013/Nov) .Retrieved from URL: http://thinkbluemarin.files.wordpress.com/2013/11/woody-debris-structures-lagunitas-creek.jpg .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PtWe3V6E)

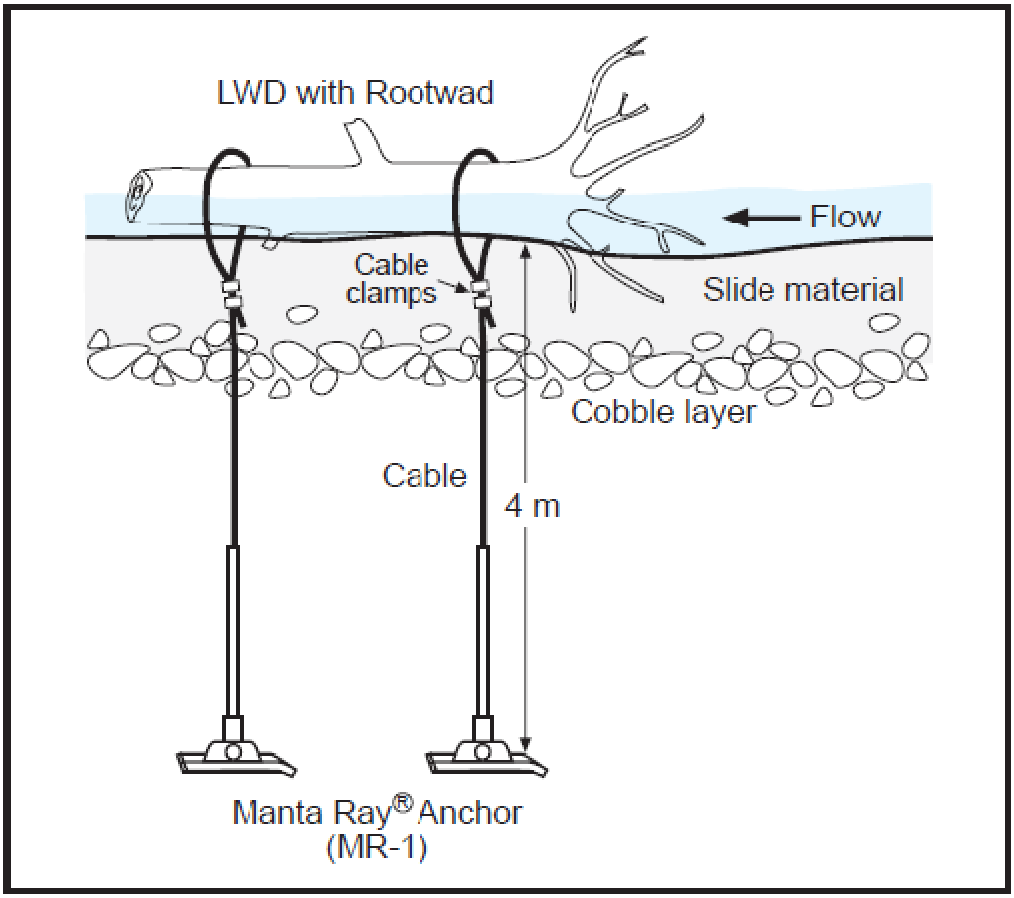


Figure18. This diagram demonstrates the snug installation of the cables and clamping to avoid sharp bends. The Manta Ray™ Anchor was used to anchor the LWD against floatation and horizontal sliding caused by flowing river water. Adapted from "A Large Woody Debris Anchoring System for Sites with Limited Access" by Rick Rodman

The large wooden debris serves as a flood alleviation mechanism. Pieces of dead wood larger than 0.1 m in diameter and 1.0 m in length are placed into streams with or without along the scour area. (See figure19) The placement of large wooden debris can hold back flood waters and raise the river's water storage capacity. This is a cost-effective method; the cost can be low depending on the site location and condition. However, the large wooden debris should be carefully considered before commencing work, as improper installation can increase erosion, bank failure, and flooding potential. Loosened anchors can also be a safety hazard.

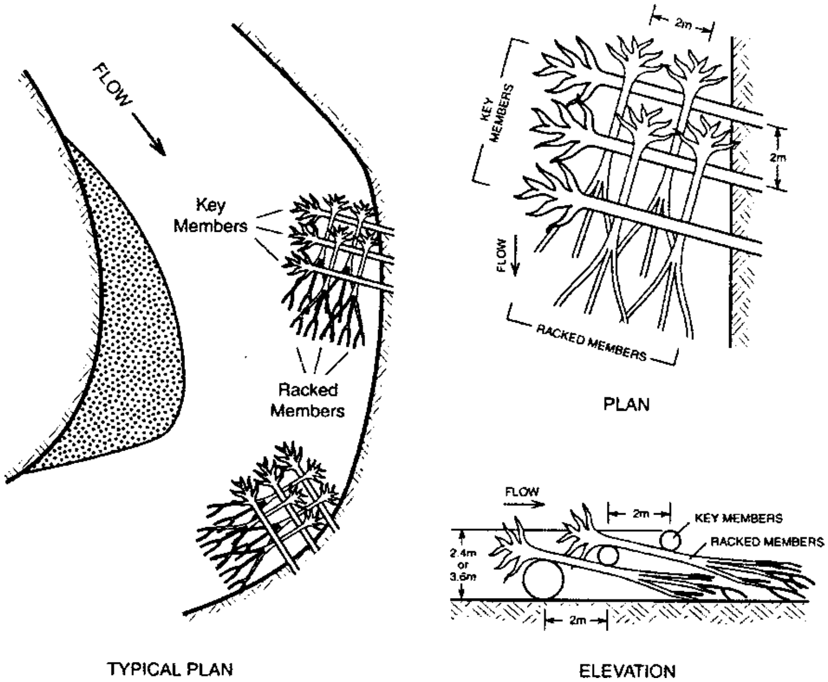


Figure 19.Large Woody Debris Placement, Adapted from "Large Woody Debris Structures for Sand-Bed Channels" by F. Douglas Shields Jr., M.ASCE; Nathalie Morin; and Charles M. Cooper,2004,p02

Park systems for flood management:

The Emerald Necklace in the Boston area is a large and medium scale project started in 1980s, which consists of different units of flood management methods and covers a 1,200 acre chain of nine parks linked by parkways and waterways.

Figure 20 .Emerald Necklace .2014-06-09 .Retrieved from URL: http://www.emeraldnecklace.org/park-overview/park-map/ .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6QD4fSRSC)

The Emerald Necklace project uses several flood channels and ponds to reduce the impact of flooding; For instance, it can reduce the chance of river water overflow and serve as a flood buffer.

Muddy River in the Emerald Necklace has added shrubs and trees along the river to prevent erosion. There are also ponds and flood channels to reduce flood damage. If floodwater overflows, there are also overflow conduits to manage the situation. This improvement project is still under construction. Once the project is completed, flood damage will be reduced and it can lower the flood influence to the downstream Charles River.

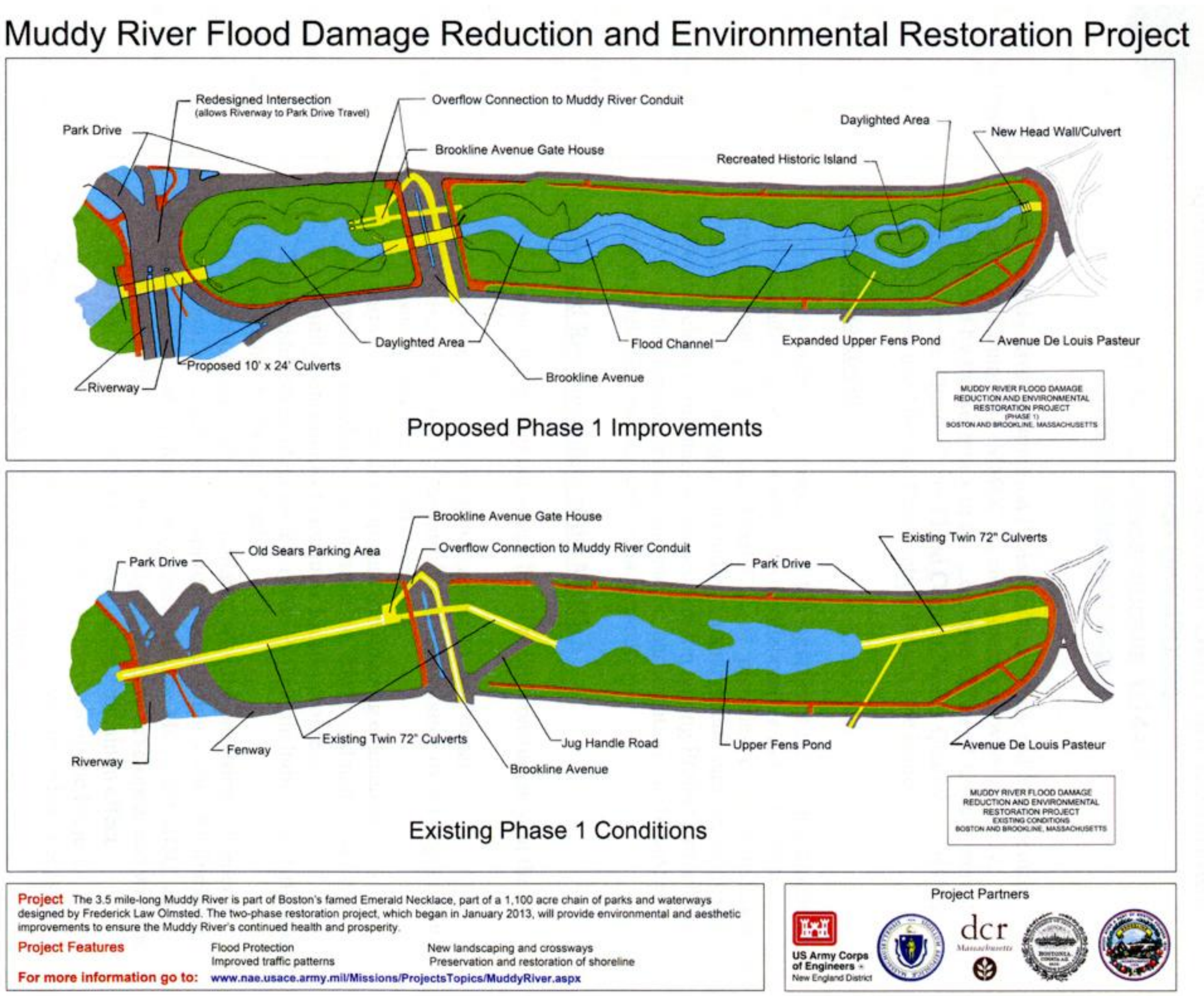


Figure21. Muddy River Restoration Project in Emerald Necklace. (2014/March) .Retrieved from URL: http://www.muddyrivermmoc.org/ .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PtXdrwh6)

The project utilizes river sediments and dredges them to restore the original depth and width of the river; it is a viable strategy to increase the river water capacity for Snoqualmie.

Elevated house

The elevated house is a popular flood management strategy. Here we consider the elevated houses in the Lower 9th Ward community of New Orleans as an example. There are several hurricane-resistant elevated houses built by the Make It Right Foundation. All of these houses are certified LEED Platinum.

Figure22. A hurricane-resistant home going up in the Lower 9th Ward community in New Orleans .Brad Pitt's Make It Right Foundation. (2014/March) .Retrieved from URL: http://kathyprice.typepad.com/dispatch_from_new_orleans/lower_ninth_ward/ .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PtXqC2wX)

This is an effective method to prevent flood water from entering into houses and is suitable for Snoqualmie. The disadvantages are cost and that it cannot stop flood waters from entering into houses in extreme flood events.

Barrier:

Many homes in Vicksburg are situated along the Yazoo River, a tributary of the overflowing Mississippi River, and their owners have surrounded themselves with tons of earth and sand. These houses can be considered as extreme alternative ways to flood management design. The main problem is that the barriers are useless if the flood waters exceed the height of the barrier.

Figure23. Extreme barrier in Vicksburg Retrieved from URL: http://www.dailymail.co.uk/news/article-1388660/Mississippi-River-flooding-Residents-build-homemade-dams-saves-houses.html .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PtXxsoEi)

Another example is the usage of box barriers. The municipality of Zwijndrecht in the Netherlands placed 90 box barriers as a defense against flooding during the storms of 5 and 6 December, 2013. Similar to the extreme barrier in Vicksburg, box barriers require time and money for installation.

Figure24.Box barriers in Netherlands .Retrieved from URL: http://www.boxbarrier.com/about-us/news/item19 .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6Plw3t8Wu)

Technique	Cost	Net flood management	100 yr flood management	Runoff volume reduction	Maintenance	Habitat Establishment
River Channel modification	M	H	H	×	M	M
Spillway	M	M	M	×	M	×
Retention Pond	M	H	M	H	M	M
Infiltration Basin	L	M	L	M	L	M
Large Woody Debris	L	M	L	×	M	M
Swale	L	M	L	M	L	M
Pervious Pavement	M	L	L	L	L	×
Wetland	M	H	M	H	L	H
Elevated House	H	H	H	×	M	×
Elevated River Bank	H	H	H	×	M	×
Green Roof	L	L	L	M	L	×
WetFloodproofing	M	M	M	×	M	×
DryFloodproofing	M	M	L	×	M	×
Barrier	H	M	M	×	H	×

H=High, M=Medium, L= Low, × = No Function

Figure25.Analysis Chart .(March. ,2014) Created by Pin-hao Huang.

The above chart is the evaluation form of different flood management methods from the cases previously mentioned. Low cost and high net flood management strategies are chosen first, followed by low cost and moderate net flood management methods. The rest are chosen in a similar manner.

From this chart, possible strategies for Snoqualmie are river channel modification, retention pond, infiltration basin, large woody debris, swale, pervious pavement, elevated house, green roof, wet flood proofing, and dry floodproofing. Cost and net flood management will be the first consideration.

Chapter 3 Intervention

3. A. Site Analysis

Large Scale Analysis

Snoqualmie is approximately 25 miles east of Seattle. The city is close to highway I-90, within the Snoqualmie River Watershed, and in the upper Snoqualmie Valley.

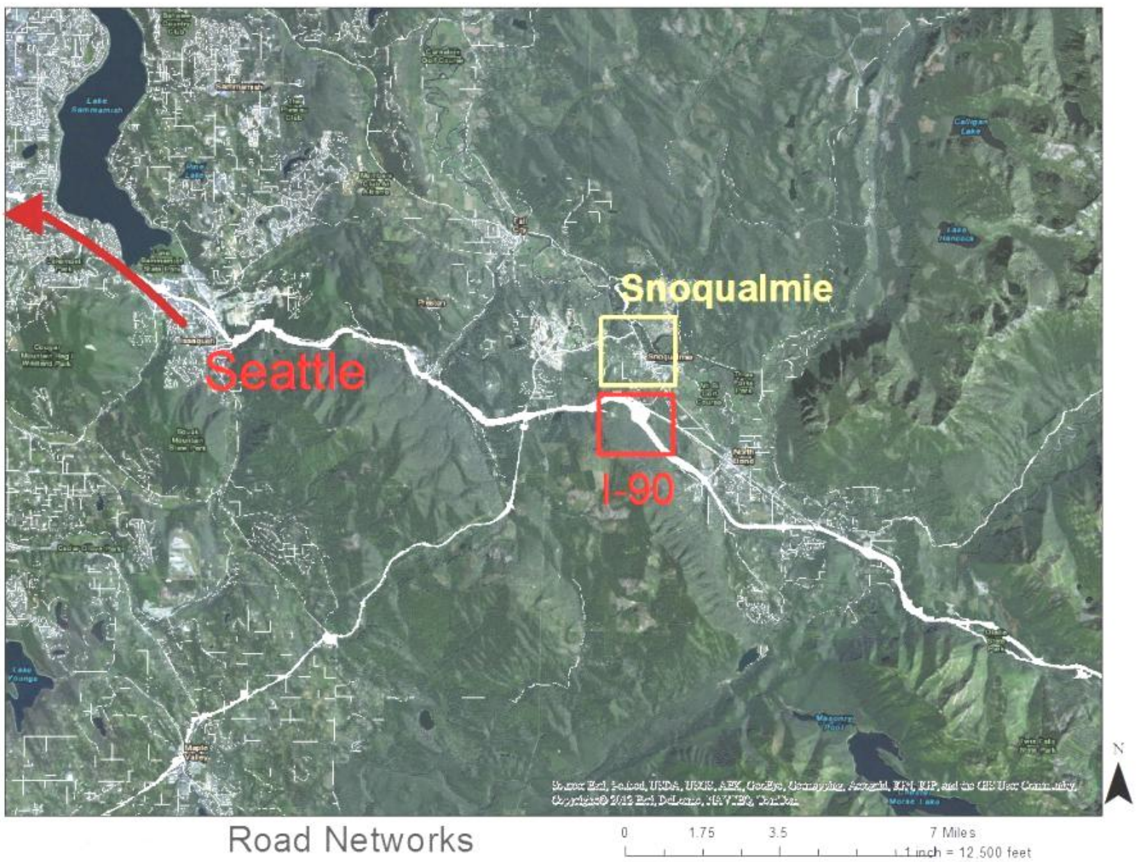


Figure26.Context map (March.2014).Created by Pin-hao, Huang.

The Snoqualmie River watershed is the largest watershed in King County, and is 75% forested. The tributaries of the Snoqualmie River- North, Middle, and South Forks converge in the upper Snoqualmie Valley. Hence, the Snoqualmie River in this region is easily inundated in the rainy season. When flood events happen, the City of Snoqualmie is greatly impacted by Kimball Creek and Snoqualmie River. River channel migration and inundation are very common during flood events in this region. The cities of Snoqualmie and North Bend in the upper Snoqualmie Valley have suffered from flood issues for a long time. Therefore, flood management strategies should first consider the whole upper Snoqualmie Valley. With proper sustainable flood reduction methods upstream of Snoqualmie River, flood damage can be effectively reduced. The best way to solve flooding issues is to deal with the source of flooding. The North, Middle, and South Forks are the Snoqualmie tributaries that have the greatest effect on flood levels. Therefore, a series of flood management methods distributed along these tributaries can significantly reduce the impact of flooding on the city of Snoqualmie.

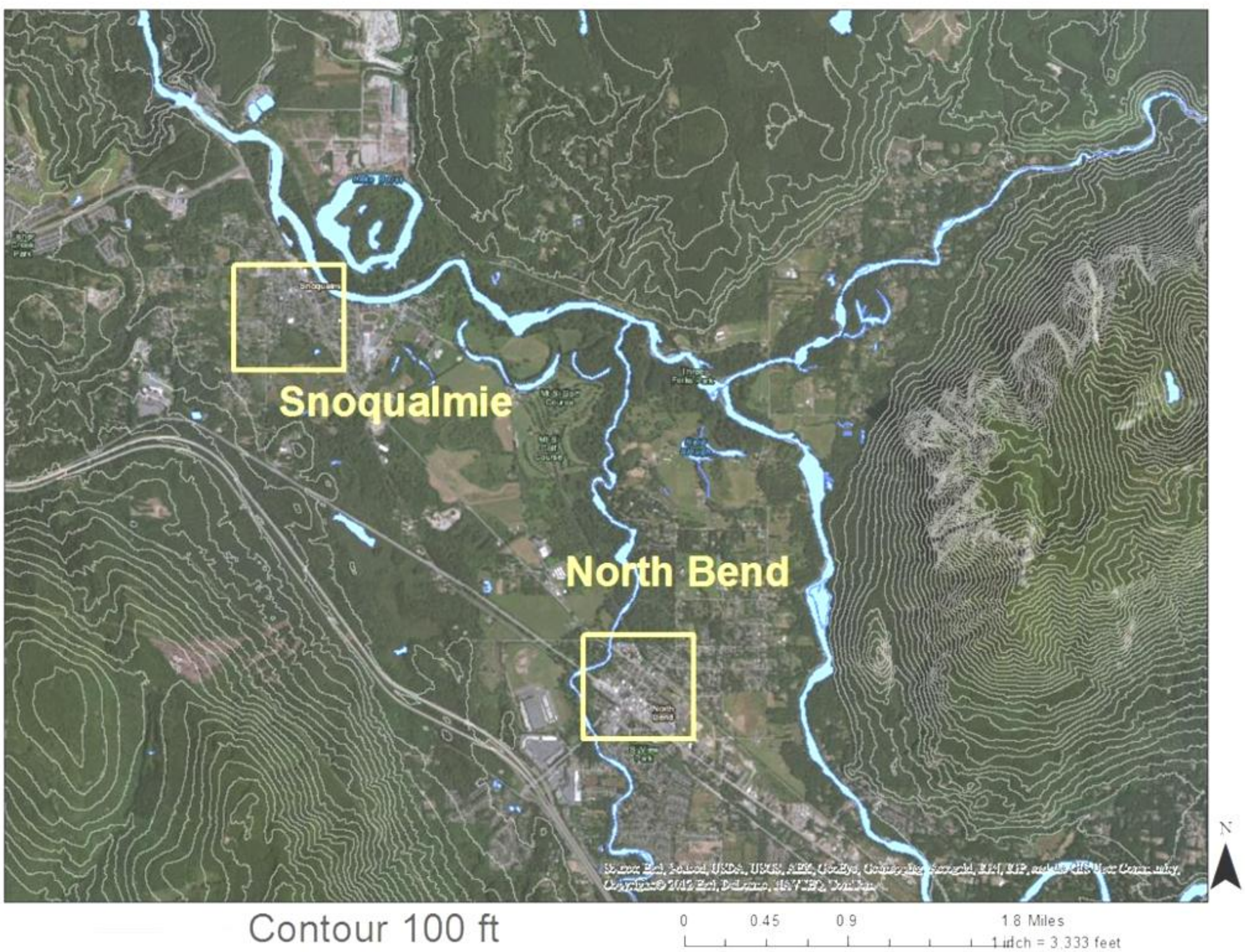


Figure27. Contour 100ft map (March2014) Created by Pin-hao Huang.

Overall, terrain is gradually higher toward the southeast, with mountains in excess of 2000 ft in elevation around the southwest and the southeast sides of Snoqualmie. Therefore, large scale flood management design should focus on the watershed management to the southeast of Snoqualmie, planting more vegetation along riverine areas and adding large woody debris in streams, which can reduce erosion and support a sustainable environment. The average elevation of Snoqualmie is 427 ft (130 m) and the elevation of the river channel is 403.5 ft (123m). In other words, the elevation difference between Snoqualmie and the river is 23.5 ft. Flood management methods should consider the capacity of the Snoqualmie River and account for the elevation difference between the river and the city, which can help inform what flood management infrastructures should be installed

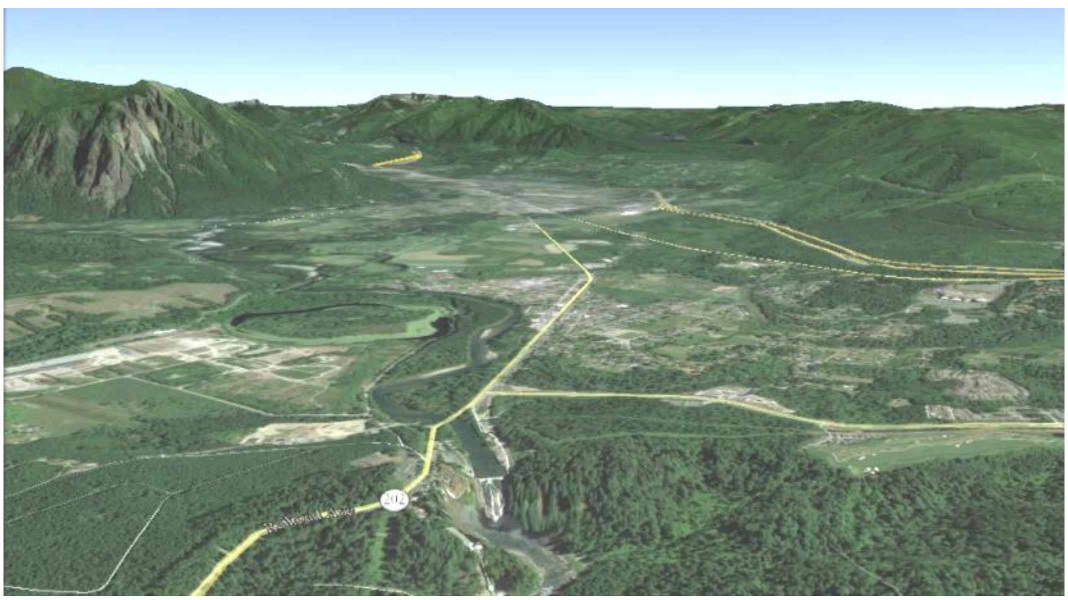


Figure28. Looking from the Northwest at Snoqualmie River. Adapted from Google Earth by Pin-hao, Huang (March.2014).

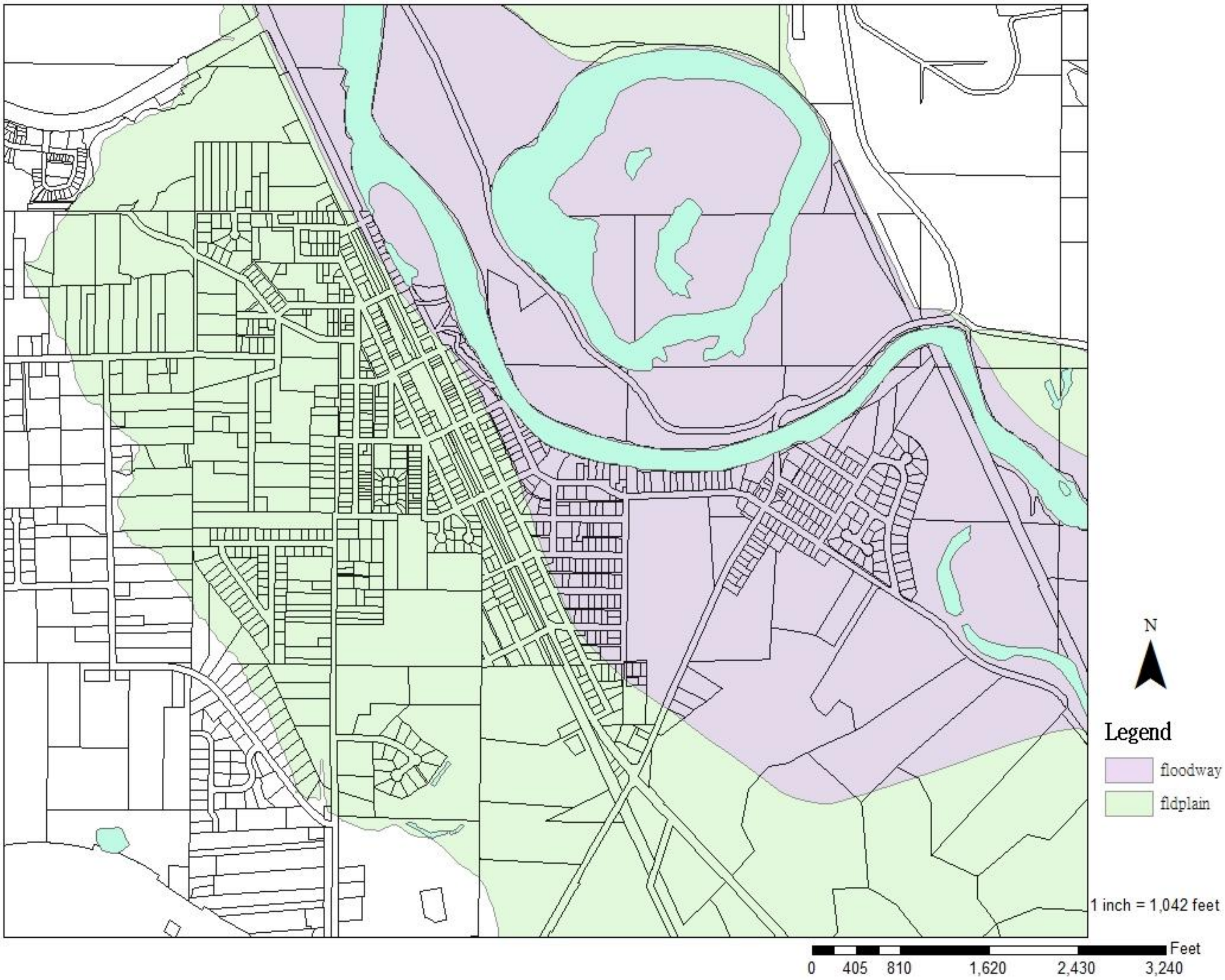


Figure29. Floodplain map Created by Pin-hao, Huang (March.2014).

Another important fact about Snoqualmie is that it lies in the floodplain of the Snoqualmie River and Kimball Creek. The entire downtown area of Snoqualmie is in the hundred year floodplain, and the historic downtown area is even located within the floodway. [5] Base flood elevation for downtown is 422 feet, so flood management measures

[5]FEMA .(2014) "A floodway is the channel of the river or other watercourse, and those floodplain portions, which must be reserved to discharge base floodwaters without cumulatively increasing water surface elevation by more than one foot".

need to consider the flood elevation. These factors should be carefully considered when devising proper flood management strategies for Snoqualmie.

As mentioned earlier, the most effective way to reduce flood impact is by addressing flooding at the source. It is helpful to use existing geographic features by retrofitting them with a series of flood management strategies along the riverway.

Figure30.Oxbow ponds along Snoqualmie River. Created by Pin-hao,Huang.(March.2014).

One group of geographic features we can use are the oxbow ponds. There are a number of oxbow ponds along Snoqualmie River (see figure30) which can be utilized as retention ponds to help manage floodwaters. Oxbow ponds are formed by the meandering of a river. Over time, soil bank erosion causes the river to cut through the bank and form bodies of water. Over time, oxbows become isolated from the river as sedimentation buildup blocks the river-proximal ends of the oxbow pond. (See figure31)

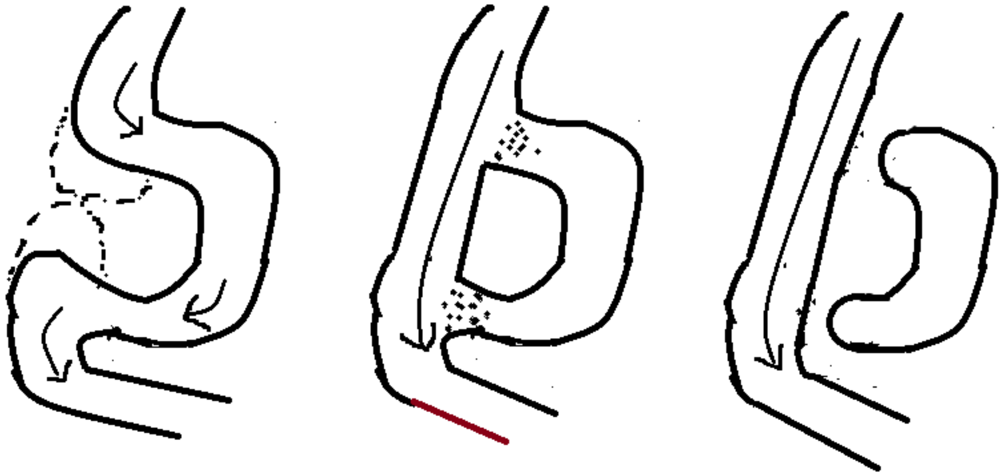


Figure31. Oxbow ponds formation.Drawn by Pin-hao, Huang.(March.2014).

Figure32. Proposed River retrofit place Created by Pin-hao, Huang. (March2014).

Another strategy is to modify the river channel. Particularly windy areas of the river are highly susceptible to rapid erosion. Strategic placement of large woody debris in these areas can substantially reduce erosion and increase the river's water capacity. Planting trees along the riverine area can also protect the river bank from erosion. In Figure 32, the red squares show where these can be placed.


Figure33. Current woody debris in Snoqualmie River .Shot by Pin-hao, Huang. (March2014).

Figure34. Current erosion in Snoqualmie River bank at Sandy Cove Park . Shot by Pin-hao, Huang. (March2014).

To understand where we can establish flood management infrastructure, it is important to consult zoning maps. The 2012 zoning map shows many open spaces which that can be utilized as flood management systems without encroaching on private property.

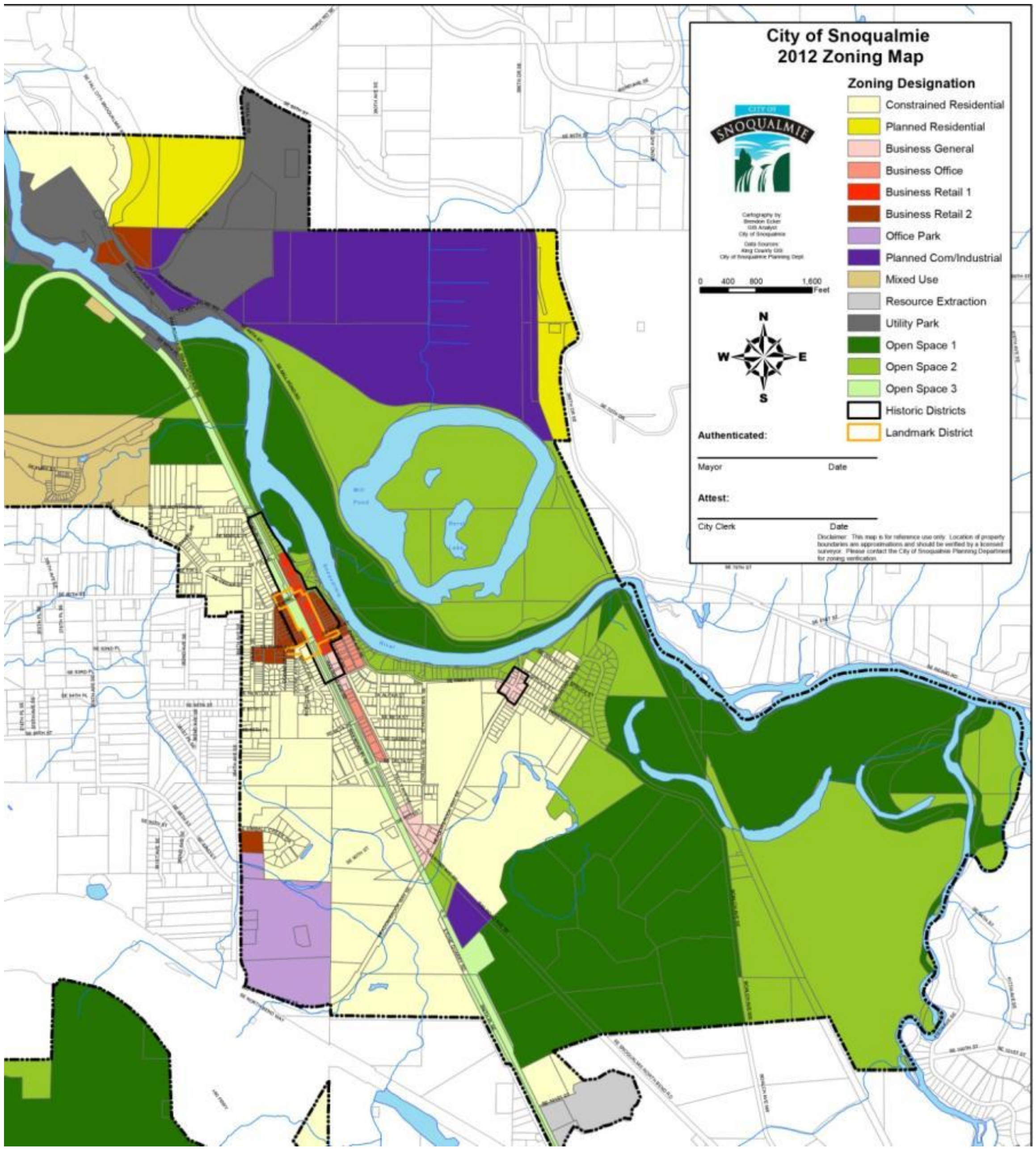


Figure35. Current Zoning map, Adapted from City of Snoqualmie 2012Zoning Map by Pin-hao, Huang. (March2014).

Medium Scales:

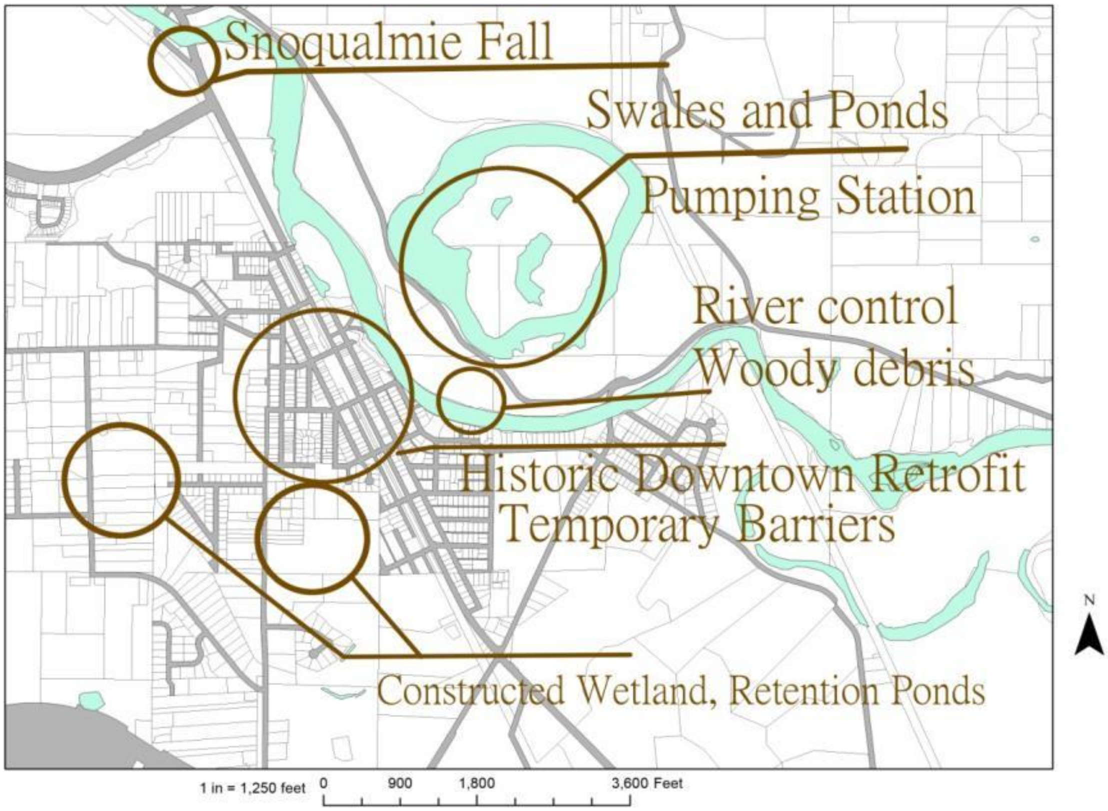


Figure36. Proposal for Snoqualmie .Created by Pin-hao Huang.(March2014).

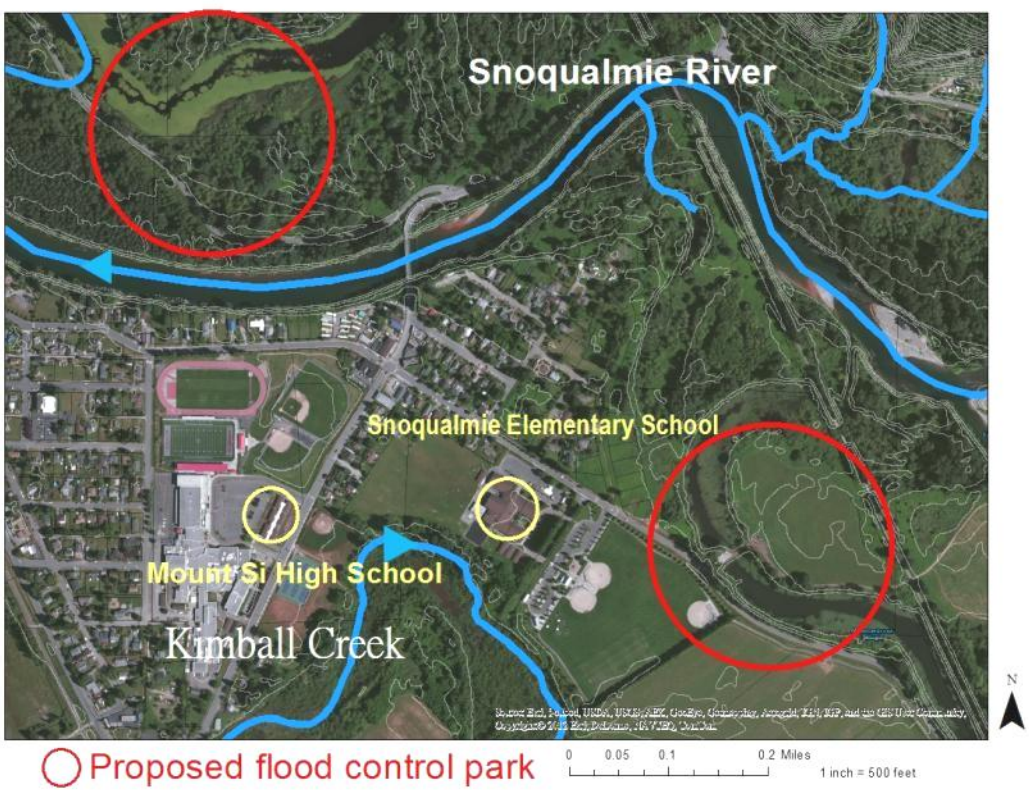


Figure37. Possible Flood Control Park Site along Snoqualmie River.. Created by Pin-hao,Huang.(March.2014).

Constructing retention ponds and strategic placement of large woody debris along the river is a promising low-cost strategy for flood management in Snoqualmie. There will be possible flood control parks with retention ponds or infiltration basins along Snoqualmie River (Figure 37) and in the southwest area of Snoqualmie close to Highway I-90 (See Figure 38&39).

The southwest area lacks vegetation and places to hold large amounts of rainwater and floodwater. It is an Urban Reserve Zone (UR) area for Snoqualmie, which reserves large tracts of land for possible future growth in Snoqualmie while still allowing reasonable interim property use. This area also contains many residential dwellings and the "St Joseph's School Of Issaquah" school called “St Joseph's School Os Issaquah”. The Kimball Creek passes through this area, along with numerous wetlands, and proper infrastructure can help significantly reduce the impact of Kimball Creek flooding on nearby residents. A park system with retention ponds here can serve the dual purposes of flood management and a recreation area for residents (See Figure40 for the GreenSpace Proposal)

Figure38.Possible Flood Control Park Site. Near Kimball Creek Created by Pin-hao,Huang.(March.2014).

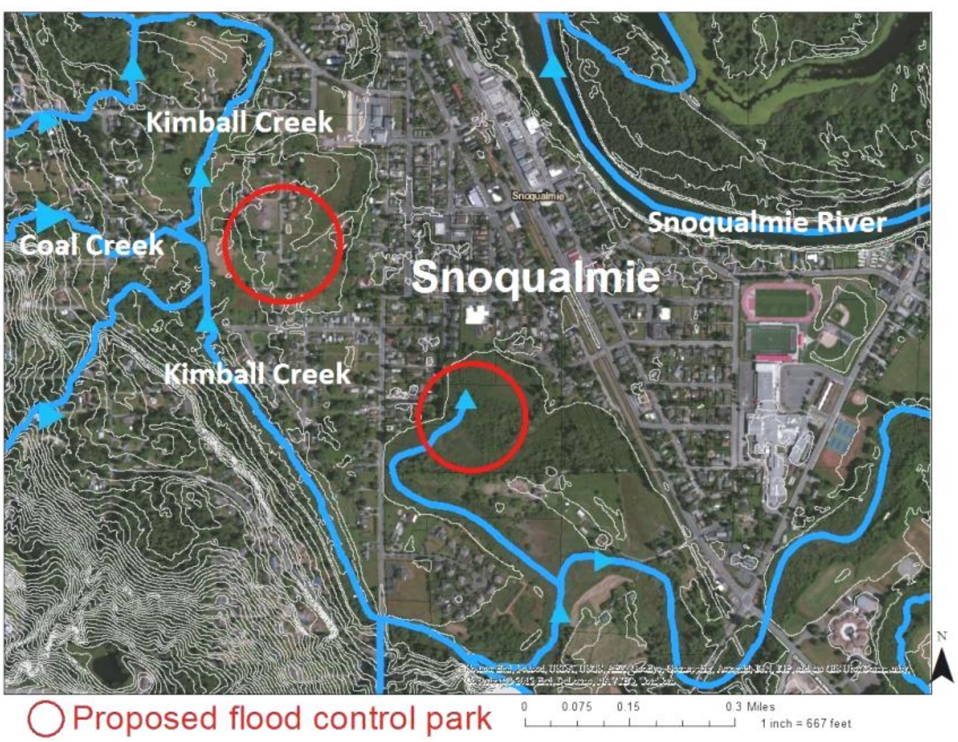


Figure39. Enlarge Possible Flood Control Park Site. Created by Pin-hao,Huang.(March.2014).

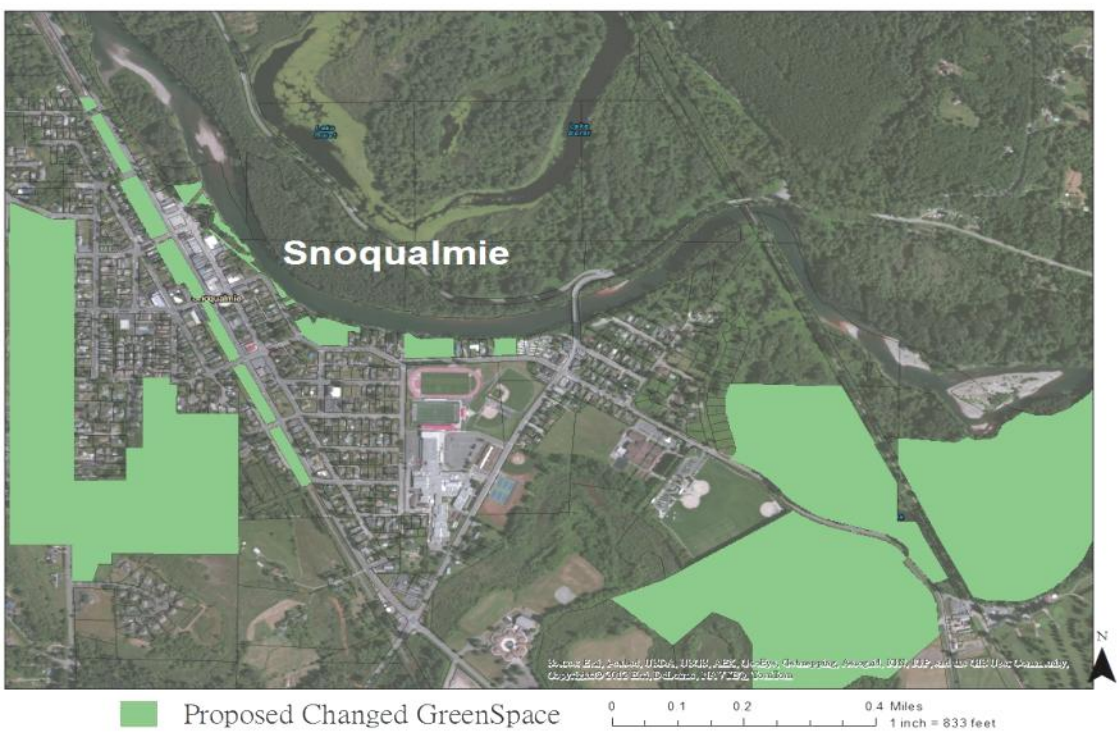


Figure40. GreenSpace To Change Created by Pin-hao,Huang.(March.2014)

Small scale:

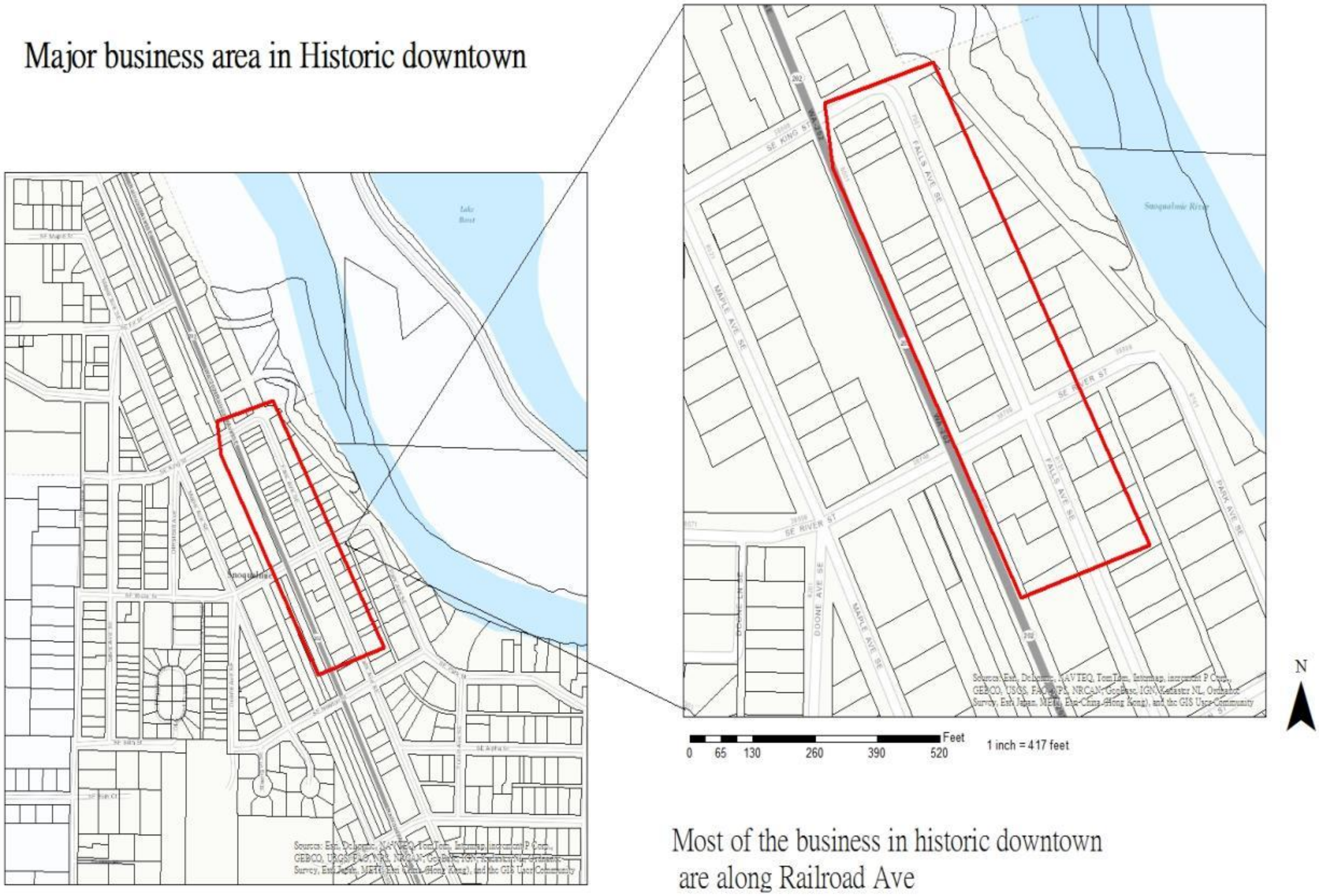


Figure41.Historic Downtown .Created by Pin-hao,Huang.(March.2014)

Businesses are clustered along Railroad Ave, and flood management methods should be focused in this area. Most of these buildings are not elevated. Location of storm water facilities should also be a consideration for flood management. Most of the storm water facilities are along roads and the business are protected by these facilities.

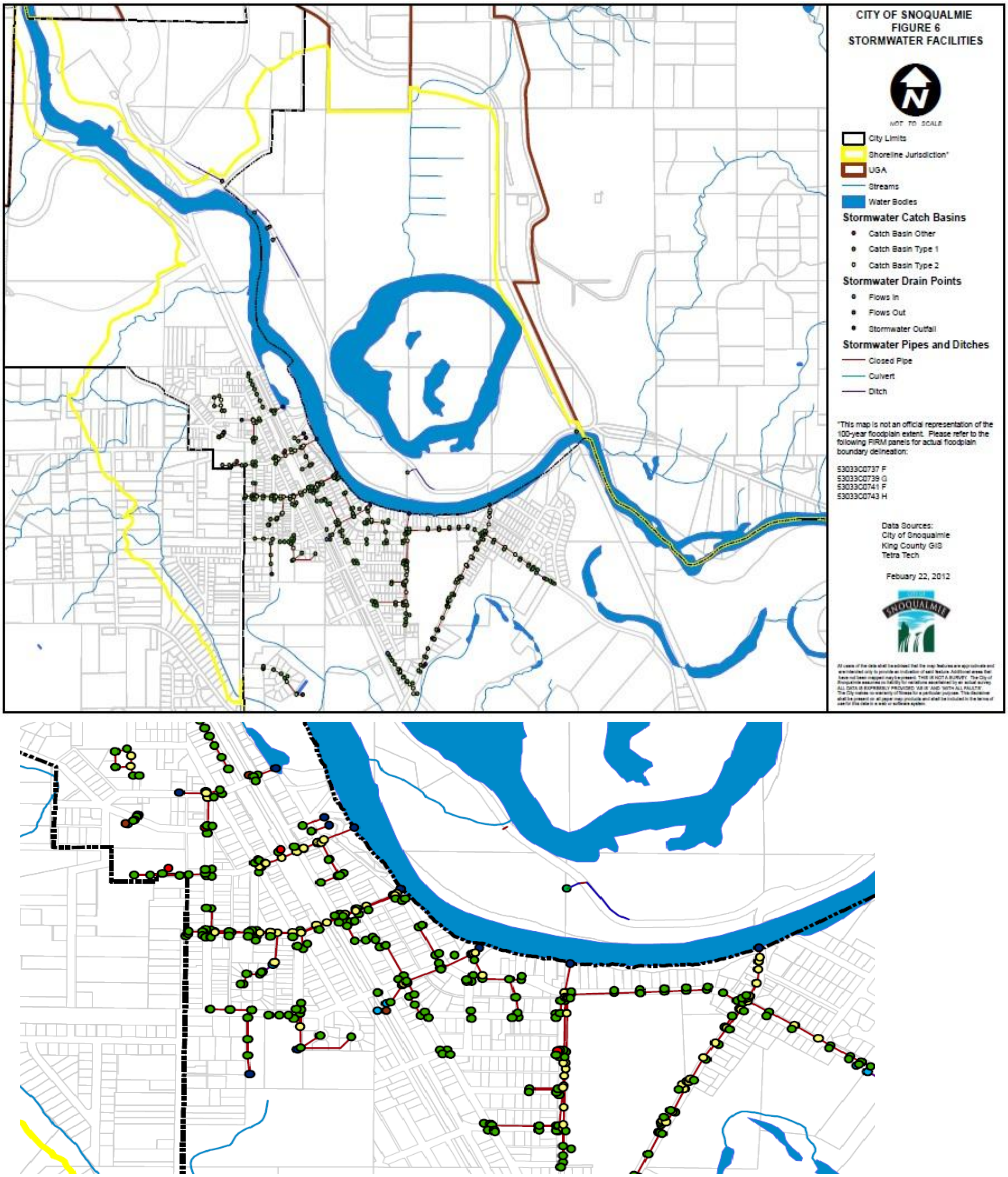


Figure42. Storm water Facilities Map Adapted from City of Snoqualmie Storm water Facilities Map 2012 (March.2014).

In order to reinforce the storm water facilities, we must first know where they are located before taking action. Depending on the scale of a flood, temporary flood barriers can be used and placed along these facilities. Temporary flood barriers are suitable in Snoqualmie, as they are often low cost and can be quickly and inexpensively deployed on streets, particularly the downtown area.

Figure43. Historic Downtown Created by Pin-hao,Huang.(March.2014)

Trees lining streets can be converted to weirs or retrofitted with structural soil cells. Structural soil cells can be transformed into swales and absorb floodwater or rainwater. However, the number of existing structural soil cells is small. If Snoqualmie can build more swales or structural soil cells, then more water can be absorbed into the ground. The current sidewalk is concrete, and can be changed to porous pavement to aid water absorption. Sidewalk width should also be considered during any retrofit; the current width is between 4ft to 16 ft depending on the location.

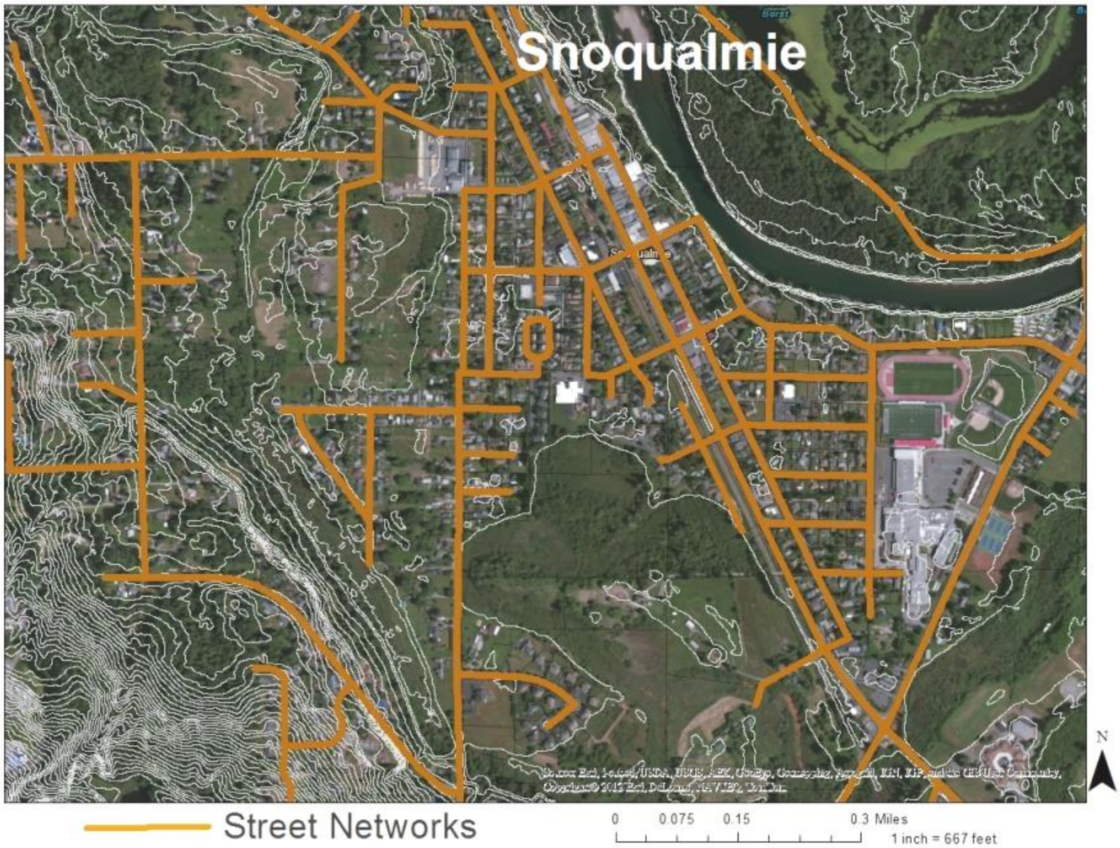


Figure44. Street Networks. Created by Pin-hao,Huang.(March.2014)

Figure45. Current street in Snoqualmie Downtown. Shot by Pin-hao, Huang. (March.2014)

Figure46. Current structural soil cells in Snoqualmie. Shot by Pin-hao, Huang. (March.2014)

Parking lots in Snoqualmie (See Figure 48) are typically concrete, and are poorly suited for controlling rainwater runoff. Replacing the concrete with porous pavement will significantly improve the ability of parking lots to help control runoff and promote ground absorption of runoff rather than channeling it into the river. (See Figure47) Porous pavement parking lots can be further combined with swales alongside streets to reduce runoff.

Figure47. Porous Paving .Retrieved from URL: http://www.pinterest.com/pin/2533343513997462/ .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6QD92RrHP)

Figure48. Parking lot in Snoqualmie .Created by Pin-hao, Huang. (March.2014)

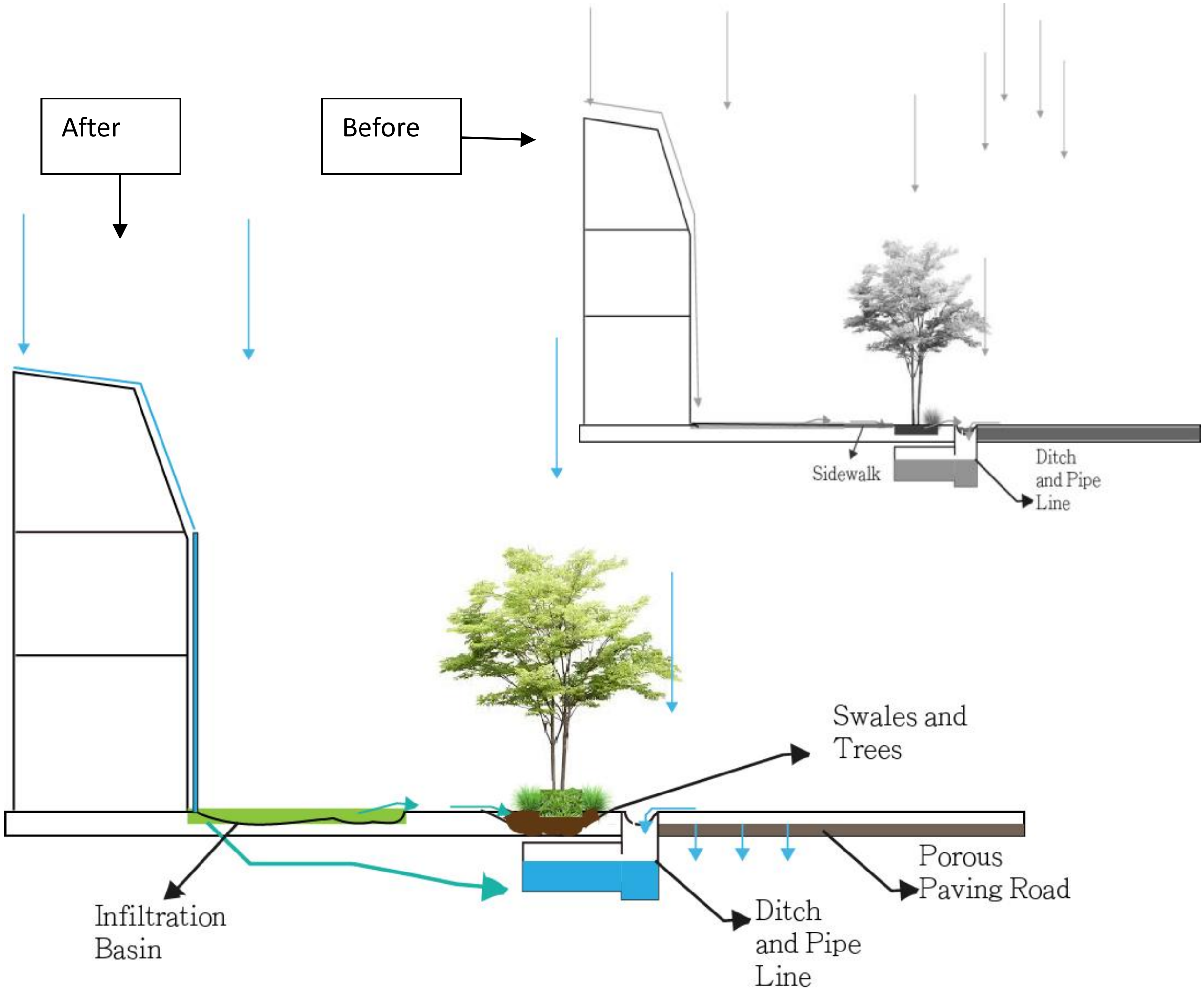


Figure49, Illustration for Street Runoff management System .Created by Pin-hao Huang. (March.2014)

Existing roadways are insufficient in managing rain or floodwater runoff. A large amount of runoff will flow into ditch systems during heavy rainfall. Most houses in Snoqualmie have front yards, which can potentially be used as infiltration basins to reduce runoff. Rainwater from rooftops can also be absorbed into infiltration basins. Individual infiltration basins can be integrated with swales and a porous pavement street system. If an infiltration basin reaches capacity, then the excess water can overflow to the swale followed by the ditch. These methods combined will result in a much improved ability to manage runoff than the original street drainage system.

Figure50.Elevated houses along Snoqualmie River. Shot by Pin-hao,Huang.(March.2014).

Elevated buildings are highly effective at protecting against floods in Snoqualmie as they directly raise a house out of harm's way. Floodwaters will typically not enter elevated buildings, and the area under the buildings can be used for parking and storage. Over 200 houses in Snoqualmie are already elevated, and can be used as examples for small scale flood design.(See Figure50.) However, elevated buildings should also be combined with other strategies to protect against the problem of heavy debris loading, which can be prohibitively expensive. Using Google Street View, a number of elevated buildings in Snoqualmie were identified. (See Figure51)

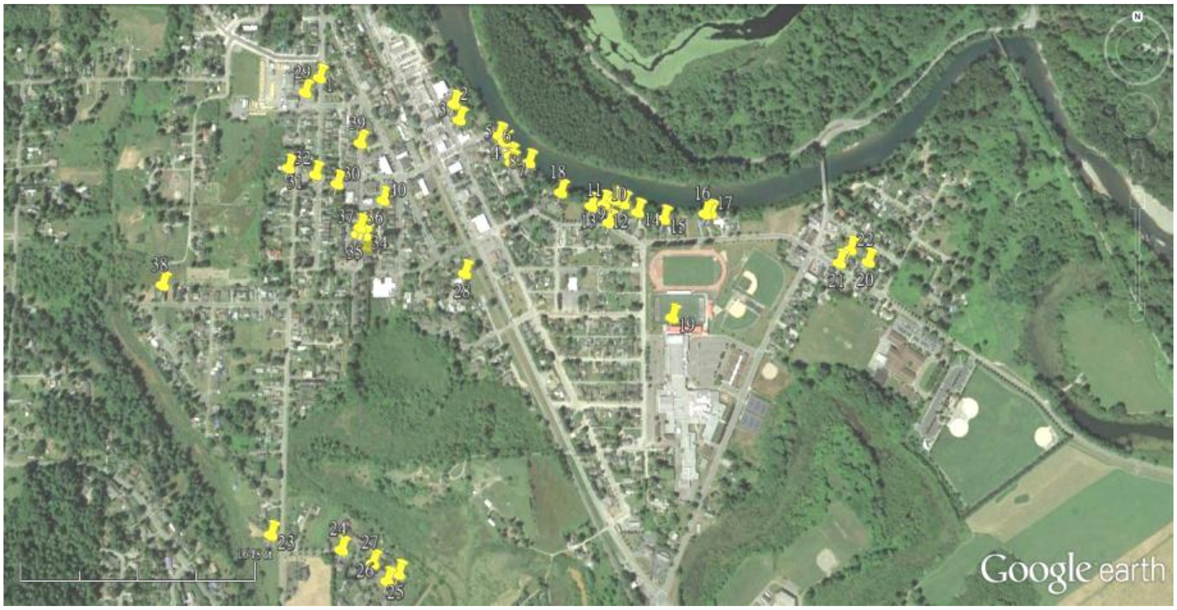


Figure51. Elevated buildings in Snoqualmie .Created by Pin-hao Huang. (March.2014)

Wet floodproofing is also an effective strategy since it directly improves the ability of a building to accommodate a flood event. The materials make the building durable to flooding and easier to clean silt and other waterborne debris away. The main disadvantages of wet floodproofing are that significant advance warning is required so that stored items can be removed; the cost of construction and maintenance; and that it is not suitable for high velocity flows or heavy debris flood events. Moreover, for residential structures, it will not reduce NFIP premiums or help meet base flood elevation requirements.

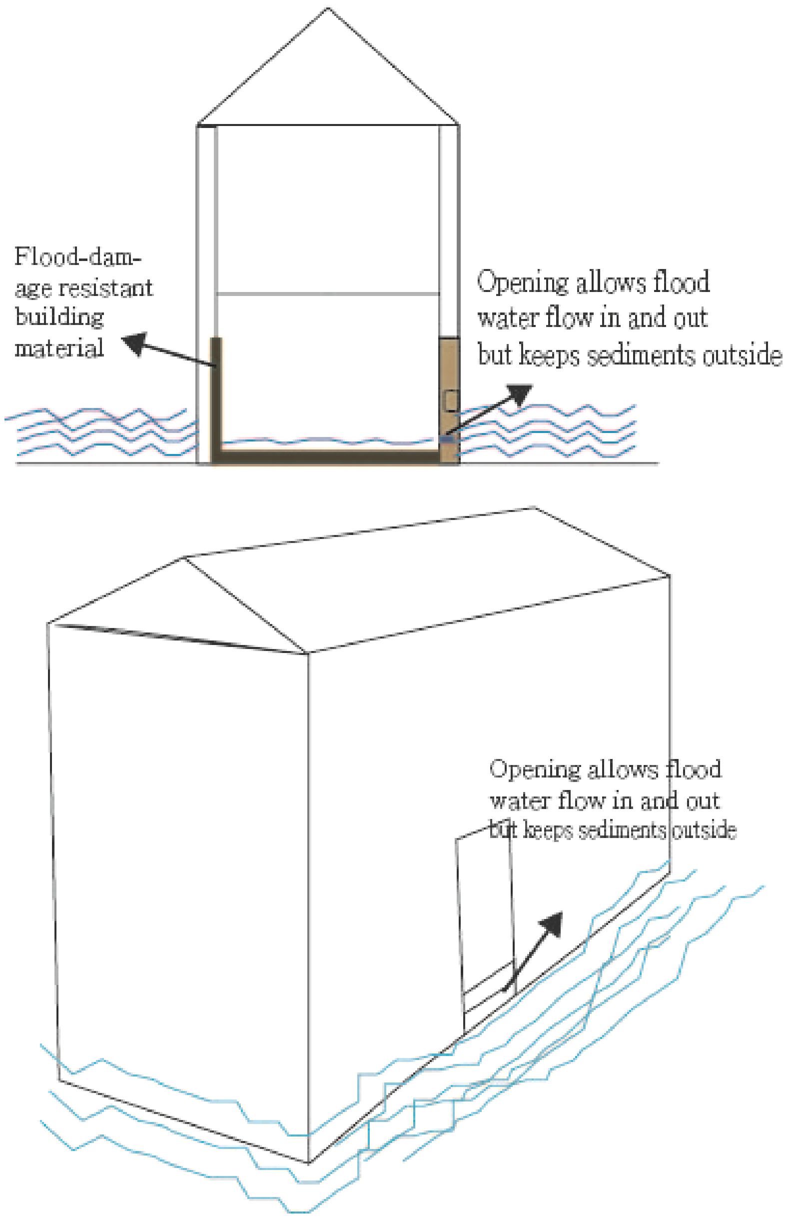


Figure52.WetFloodproofing Created by Pin-hao, Huang. (March2014).

Dry floodproofing is also an option, and is effective in preventing flood damage to a building interior by preventing water from entering the building. It has some benefits with meeting NFIP requirements and in reducing premiums for non residential structures. However, it can also be expensive and the extra space required around the exterior of a building may impede walkways or other areas around the building. Furthermore, it is not suitable for high velocity flows or heavy debris flood events.

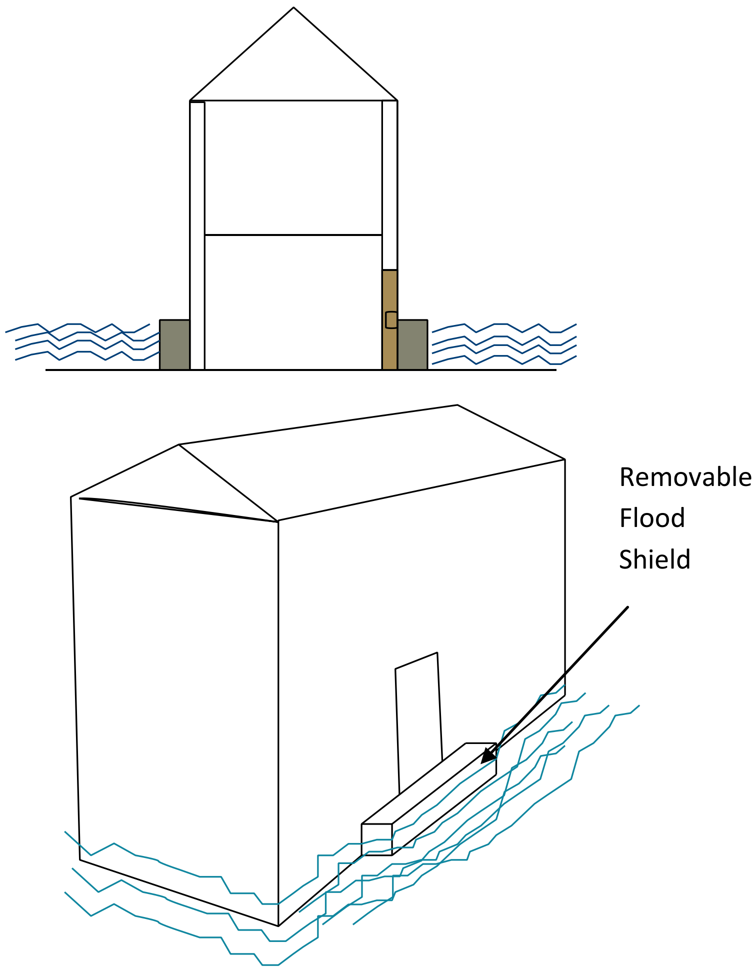
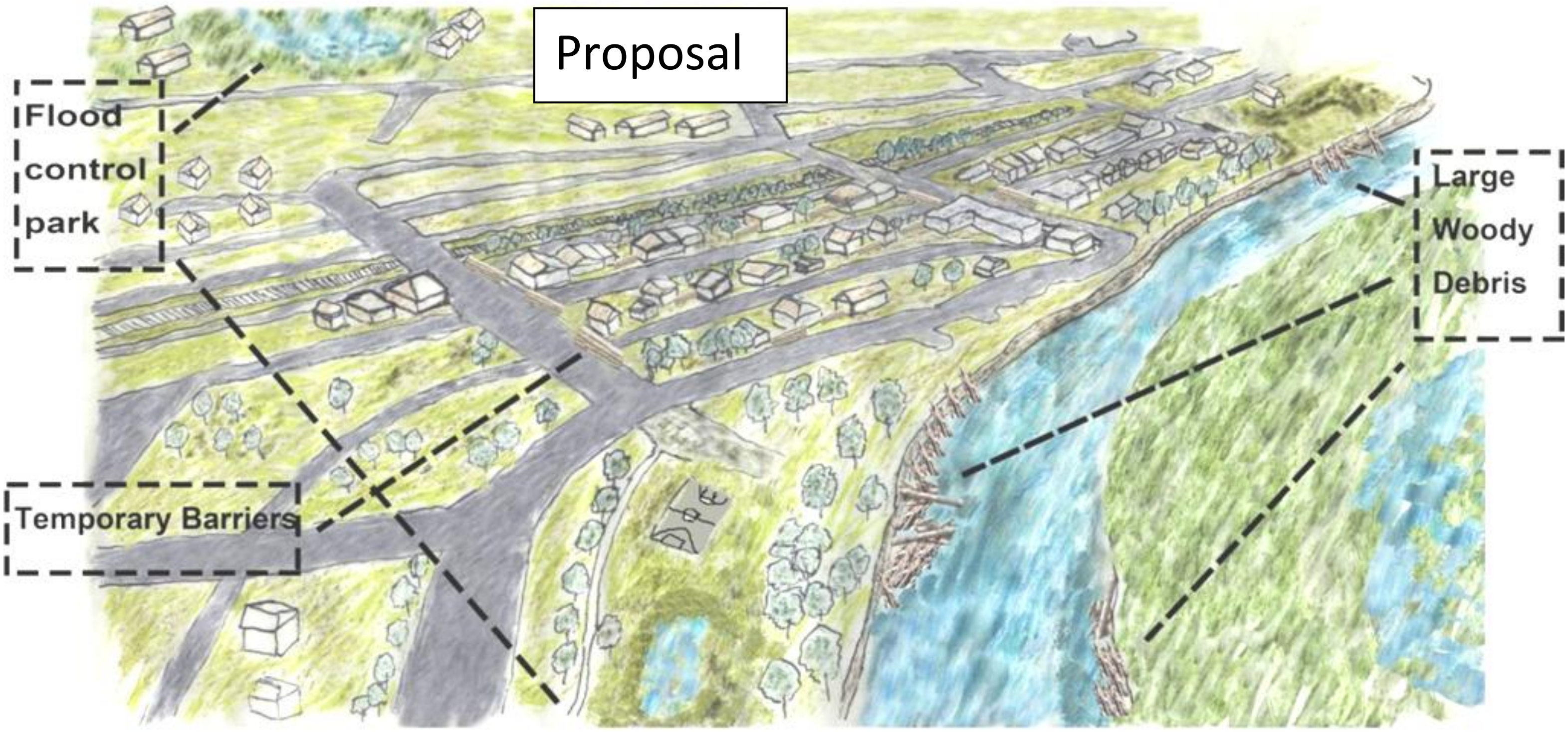


Figure53. Dry Flood proofing Created by Pin-hao, Huang. (March2014).

3. B. Design Proposal for different scale



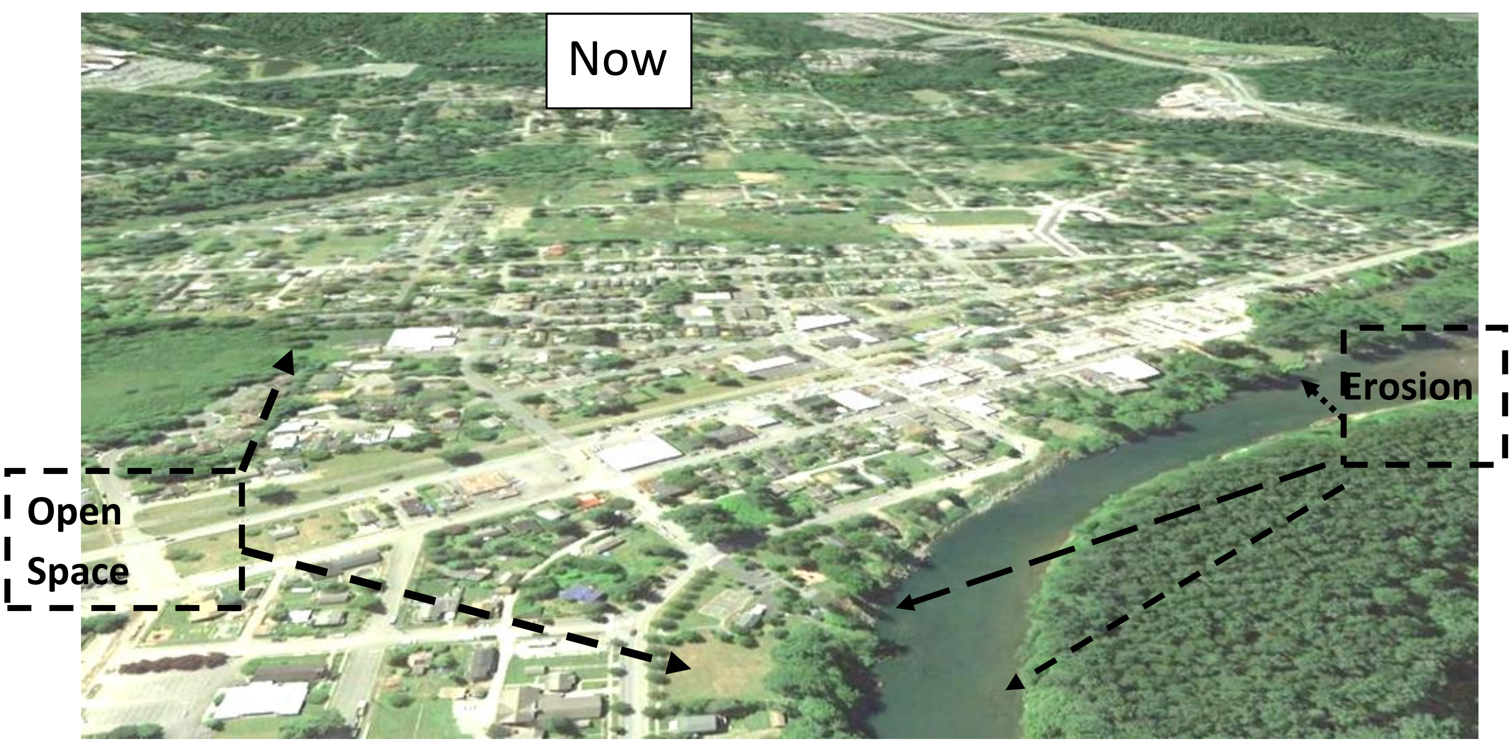


Figure54 .Proposal and Now Demonstration. Created by Pin-hao Huang (March.2014)

Large scale:

The river channel will be lined with large woody debris to protect the river bank from erosion and provide a habitat for native plants and animals

Figure55. River Channel retrofit location map Created by Pin-hao, Huang (March 2014)

Figure56 below shows the location of large woody debris placements for area A and area B

Figure56. River Channel retrofit Demonstration. Created by Pin-hao, Huang (March 2014)

Oxbow ponds:

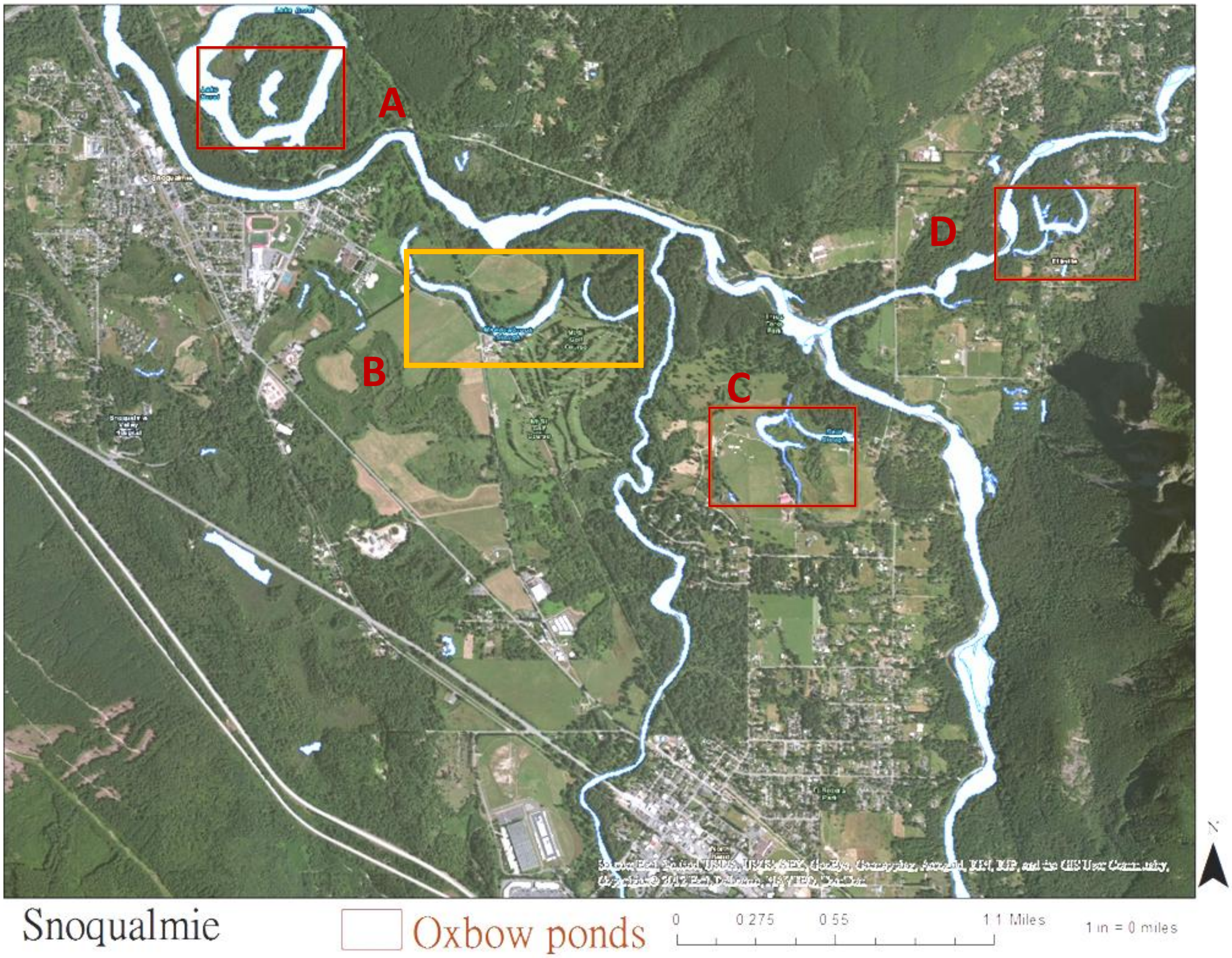


Figure57. Oxbow ponds retrofit location map. Created by Pin-hao, Huang.(May2014)

The different oxbows ponds will be transformed into flood control parks, which can increase the flood water capacity for Snoqualmie. In this research, we use Oxbow pond B as an example. (See inside Figure57 with yellow outline)

Flood Control Park:

Four areas will contain flood-control parks and we use the area C as example. (See Figure58 with red outline) Area C contains Oxbow Pond B and the Three Fork Park, which can be transformed to a flood control park.

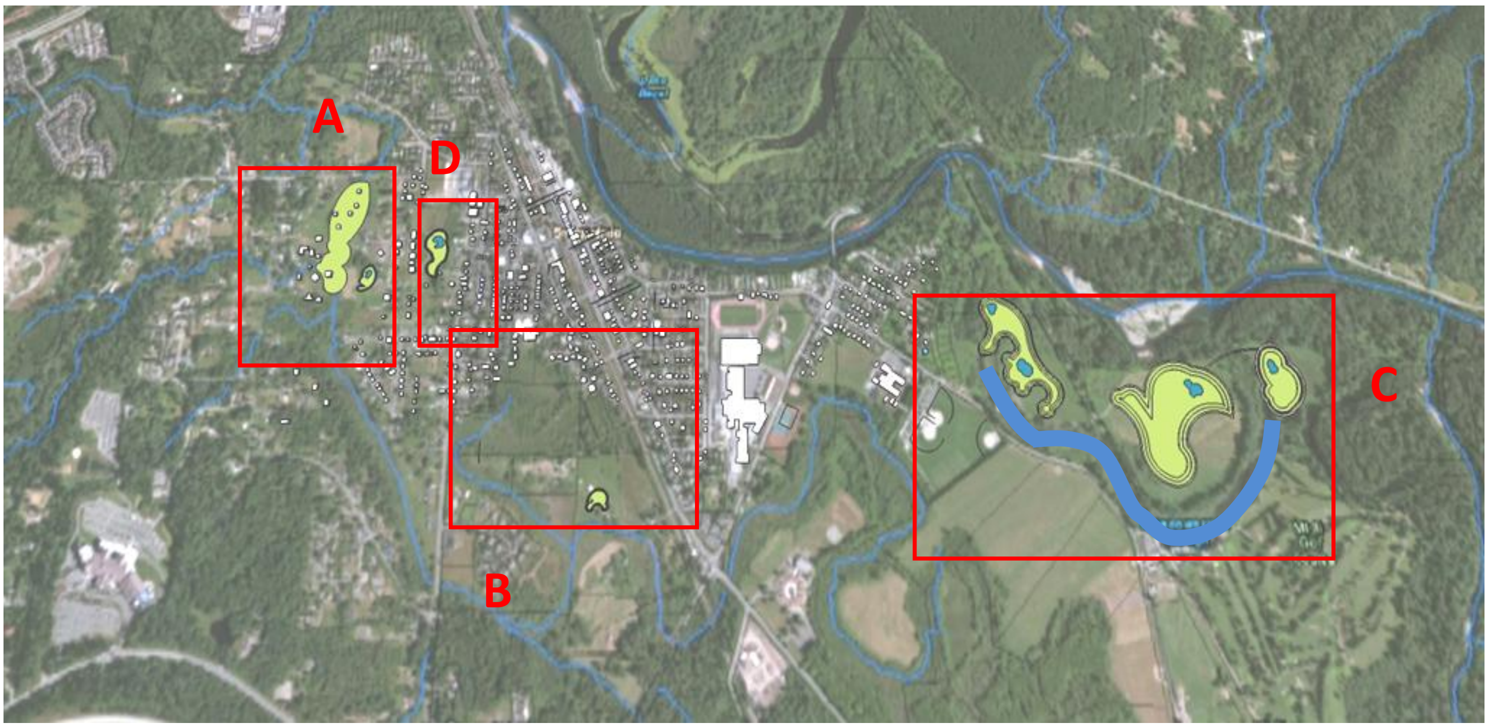


Figure58. Flood control park location map. Created by Pin-hao Huang. (May2014)

Overview:

Figure59. Three fork Park. Retrieved from URL: http://freethoughtblogs.com/entequilaesverdad/2014/04/15/mount-si-and-the-three-rivers/ .Accessed: 2014-06-09. (Archived by WebCite® at http://www.webcitation.org/6PtYKqQ16)

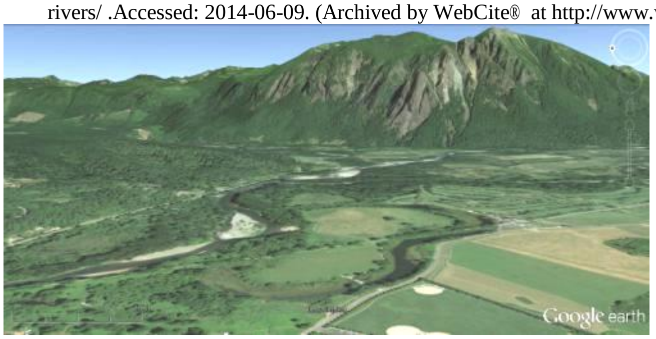


Figure60. Figure61. Current bird eye views .Adapted from Google Earth by Pin-hao Huang. (March2014).

Design:

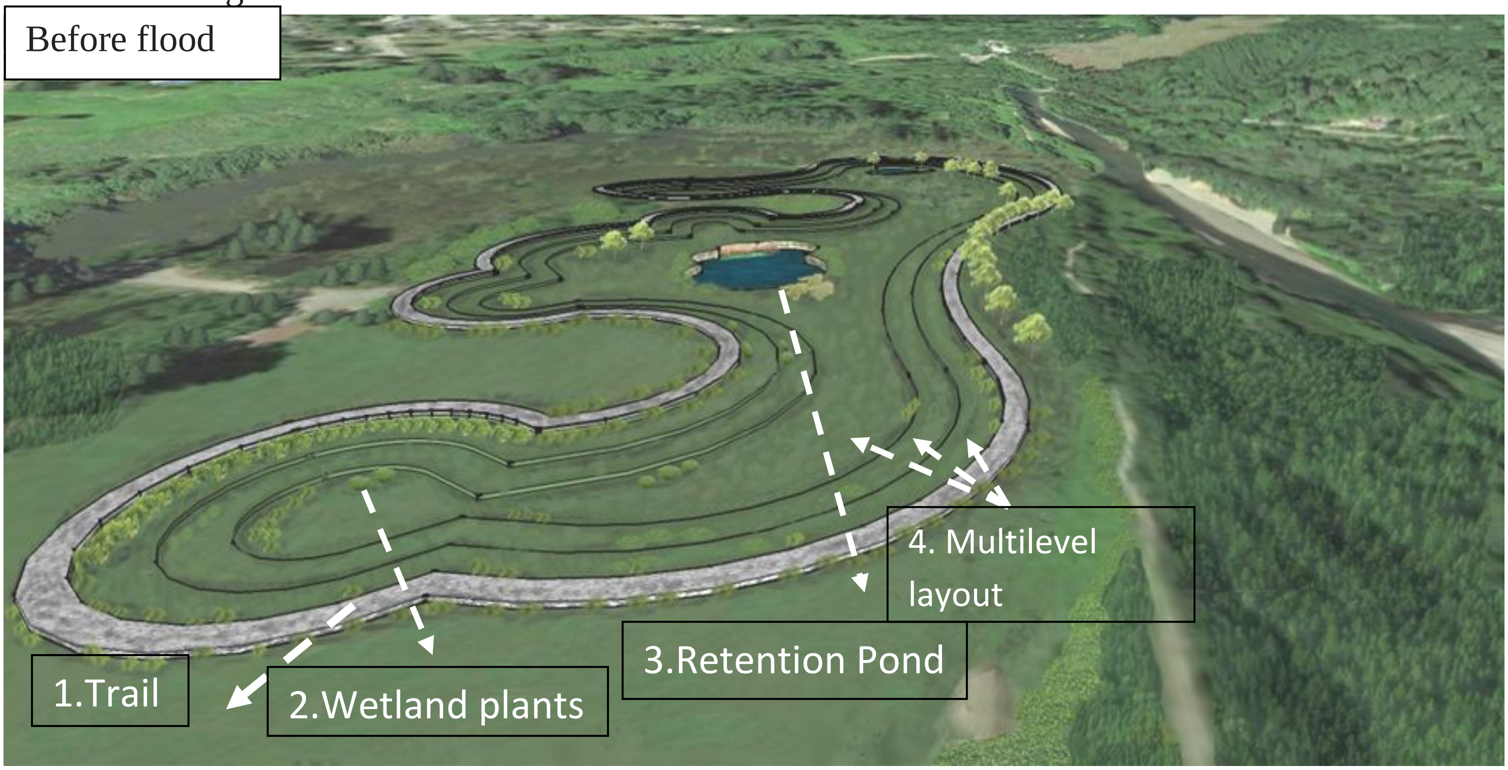


Figure62.Design Demonstration Created by Pin-hao Huang (May2014)

1.Trail: Provides a recreation function and a walkable path during flood events. 2. Wetland plants: Increases capacity to absorb runoff. 3. Retention Pond: Contains floodwater and runoff .4. Multilevel layout: Increased capacity for flood water.

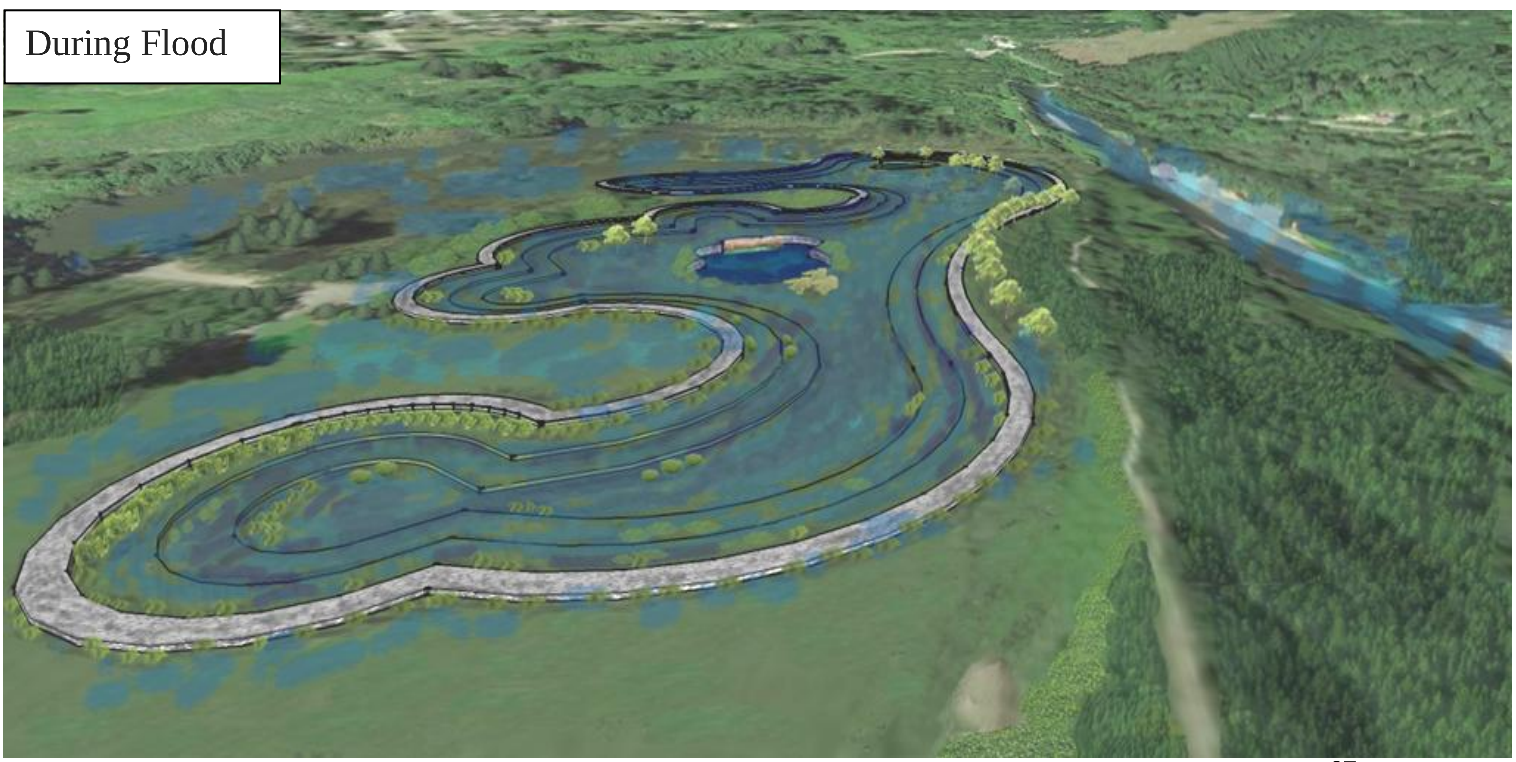


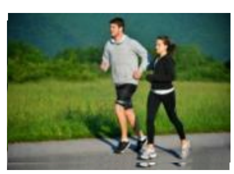
Figure63. Design Demonstration during Flood Created by Pin-hao Huang (May2014)

Figure64. Recreation Demonstration .Created by Pin-hao Huang (May2014)

The park can provide a recreation area, flood management mechanism, and ecological functions. Many recreational activities are possible in the park: 1.Kite flying 2.Jogging 3. Fishing 4.Dog walking 5.Picnic 6. Soccer

1

2



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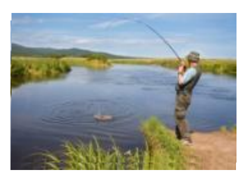

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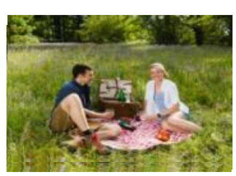

6

Small Scale:

Figure 65.Street flood con management location. Created by Pin-hao Huang (May2014)

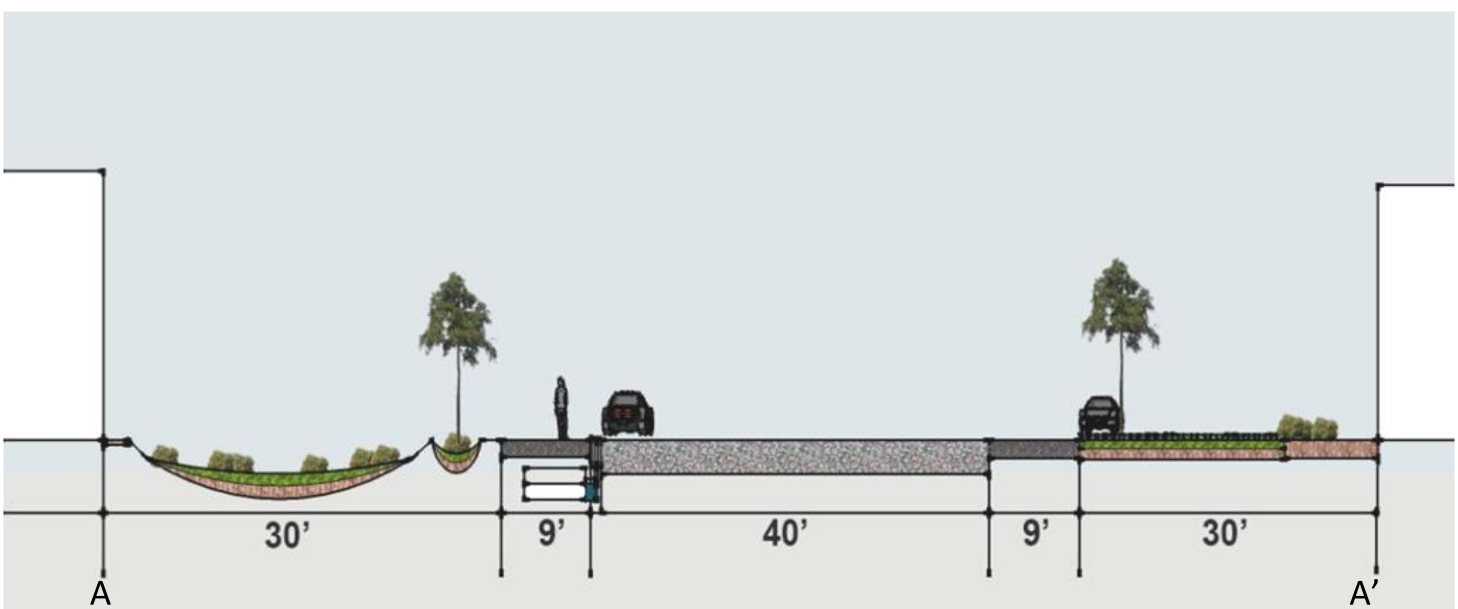

Figure66. Street section drawing. Created by Pin-hao Huang (May2014)

Figure67. Street flood management demonstration .Created by Pin-hao Huang (May 2014)

The street system will combine deep rain gardens with high water absorbent plants in residential front yards with bio swales along the sidewalks. The sidewalks, roads and nearby parking lots will be covered in permeable materials. The extra runoff and absorbed water will go into the drainage system underground. The large pipes in the drainage system will have a high capacity to manage runoff and floodwater.

Due to historic buildings and National Flood Insurance Program, it is hard to elevate houses in historic downtown. Thus, the cheaper flood management solution is to use barriers. A permanent flood wall can be built around part of the historic downtown, and prior to a large flood event, a small number of sandbags can be placed to protect buildings. Base flood elevation for here is 422 feet, and the streets around downtown are 423 feet to 425 feet. The barrier should be at least three to four feet height to cope with the 100-year flood. In addition, as floods enter, the water pressure will cause the water to pop out from the aquifer, so it is necessary to use the water pumps to extract water (See Figure68, 69)

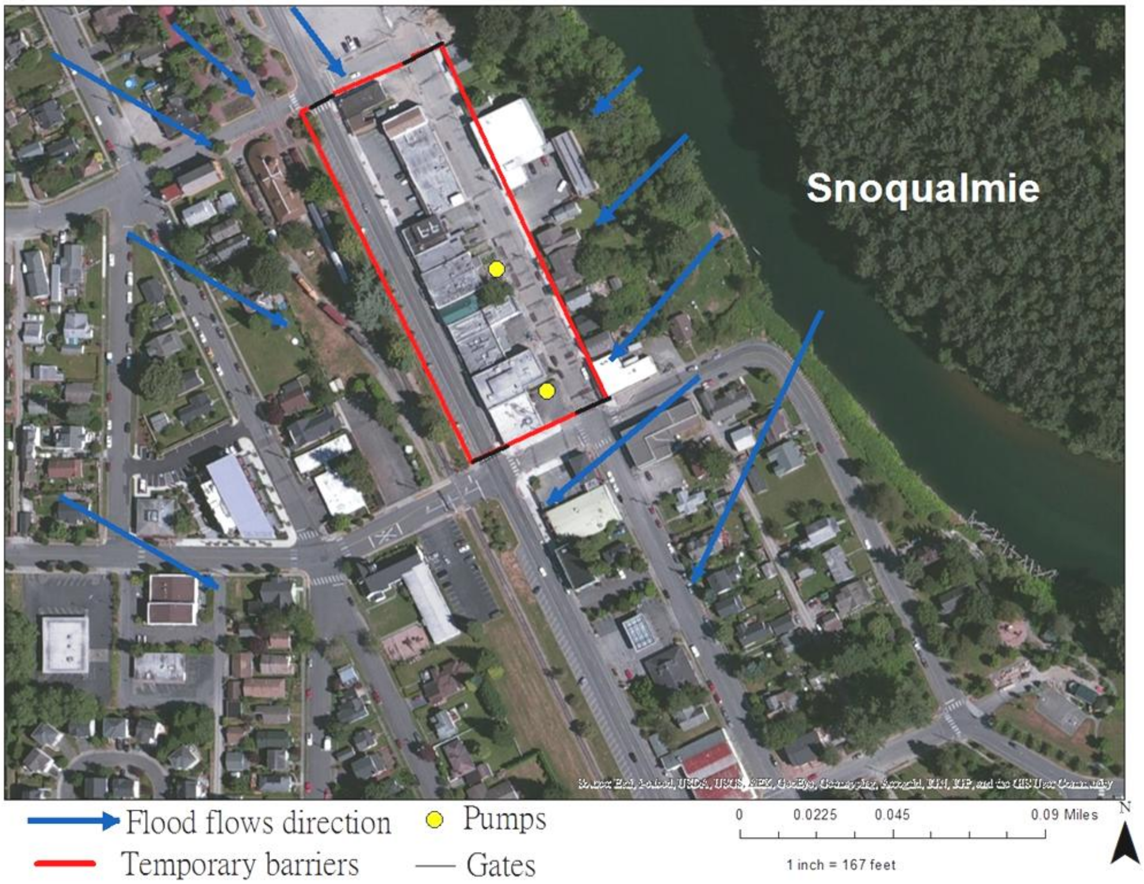

Figure68. Flood barriers location .Created by Pin-hao Huang(May2014)

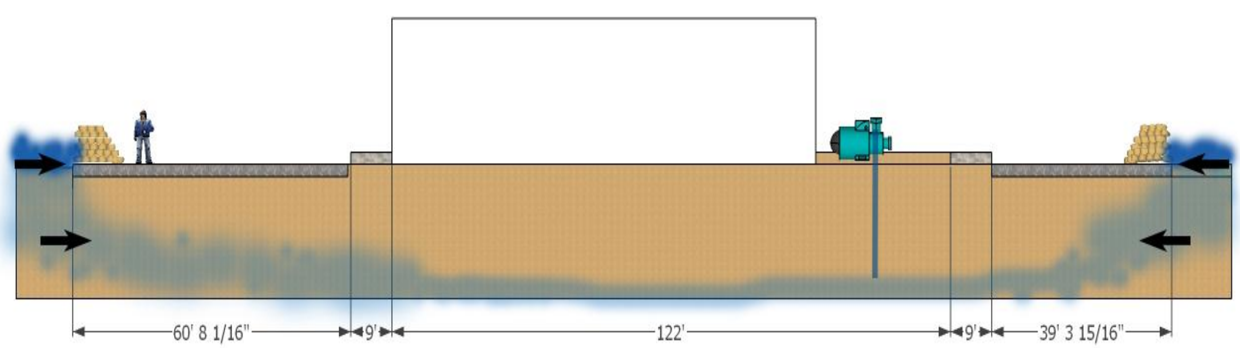

Figure69. Section drawing for flood barriers. Created by Pin-hao Huang (May2014)

In order to reduce the impact of flooding, houses in Snoqualmie should be elevated wherever feasible. Different types of elevated houses can be used in Snoqualmie and here we use the type in the Lower 9th Ward community, mentioned earlier in Chapter 2, as example. Though the individual house may still suffer flood damage in an extreme 500-year flood event, flood damage can be reduced by combining with other flood management systems mentioned earlier.

Figure70. Elevated house Demonstration. Created by Pin-hao Huang (May2014)

Building materials should also be changed to flood resistant materials, which can reduce the impact of flooding regardless of whether a house is elevated or not.

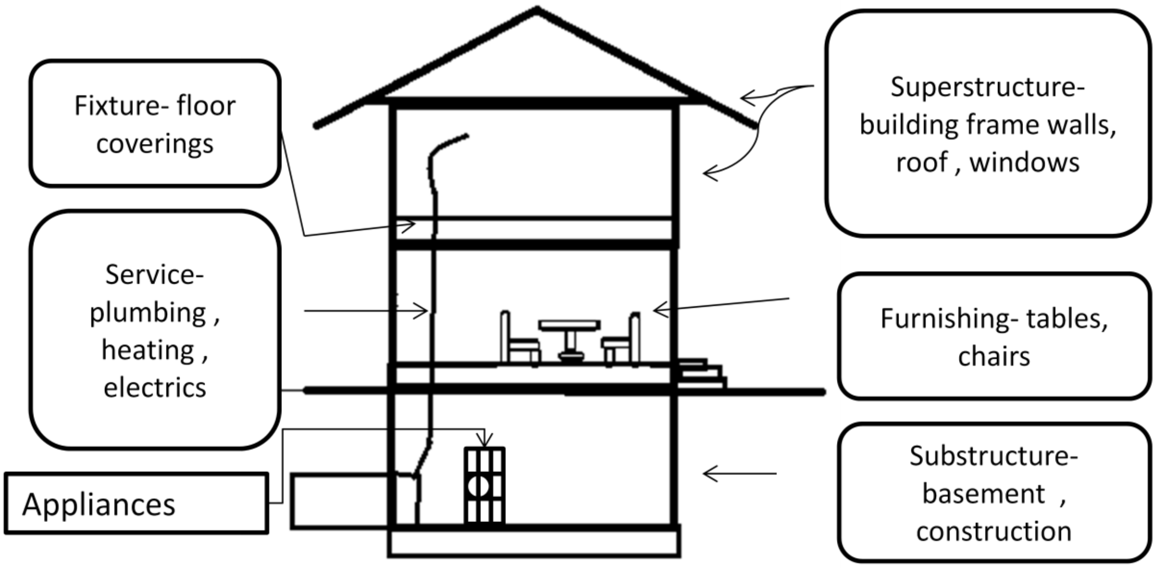

Figure71. House structure Section Drawing. Created by Pin-hao Huang (May 2014)

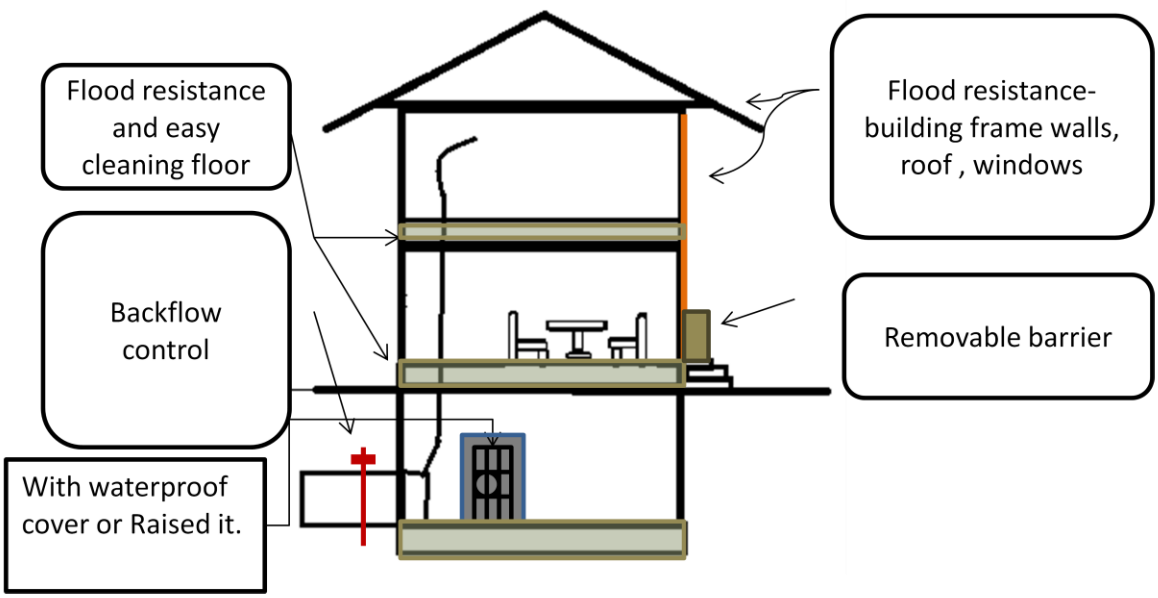

Figure72. Flood proofing for house. Created by Pin-hao Huang (May2014)

For the floodproofing barrier to the house door, there are many different types. Here, we suggest using the stainless steel type barrier; the following pictures are examples of these types of installations in historic downtown.

Figure73. Current downtown Shot by Pin-hao Huang (May2014)

Figure74 .Floodproofing door barrier .Created by Pin-hao Huang (May2014)

Chapter 4 Conclusion and. Recommendation

Due to climate change, there are more and more extreme weather events. In other words, flood frequency and extent are also increased. Flood management strategies should consider regional characteristics, integrity, and ability to cope with future extreme floods. Sustainable development methods should also be used to inform suitable strategies.

In this research, we studied strategies for flood management in flood prone regions of Snoqualmie from an urban design perspective, and proposed a flood management design consisting of a series of flood management methods. For instance, flood management is utilizing existing regional characteristics such as oxbow ponds to establish flood control parks, river channel retrofits and runoff managing rain gardens for street systems. The purpose of urban design is to consider the community, thus contributing to flood mitigation without destroying the community's character. Attempts were made to integrate engineering flood managements with design aesthetic. Hopefully the design proposed here can likewise be applied to other similar scenarios.

4. A. Conclusion

Snoqualmie is located in a hundred year floodplain, and flooding is inevitable. This design is based on the concept of sustainable development, environmentally friendly methods, and is able to deal with future extreme floods. Engineers often neglect to integrate flood management with aesthetic, and it is difficult for them to consider, as a whole, the Snoqualmie community's relation to water. Thus, as experts in urban design, we propose that multiple use amenities and engineering flood measures can be provided to Snoqualmie community after its regional characteristics are analyzed. Also, structures in downtown and residential can be changed to mitigate flood impacts. The design in this research proposes effective structural and non- structural measures to mitigate flooding risks by combining multiple flood management strategies at different scales. On one hand, the large scale and medium scale strategies are trying to reduce the flood impact. On the other hand, the small scale strategies are concerned with the historic buildings and the relation between community and flooding. In this research, we propose flood management strategies in five aspects: regional characteristics use, river channel retrofit, green street design, building renovation and flood management strategies for historic downtown.

1. Regional Characteristics Use:

There are many naturally occurring -Oxbow ponds in the upper Snoqualmie river valley, and using them to build a series of flood control parks will effectively reduce flood period times, peak rates of flood flows and also flood impact.

Building flood control parks with detention ponds along the river also creates spaces to vent floodwaters, and provides recreational functions during non-flood periods as well

2. River Channel Retrofit:

Placing large woody debris improves the riverbank resistance to erosion, and increases the local habitat.

3. Green Street Design:

Establishing rain garden with high water absorbent plants in residential front yards and bio swales along the sidewalk, and paving sidewalks and roads with permeable materials can effectively reduce runoff and lower the amount of runoff into the river and drainage system. They can relieve some of the burden on the river and drainage system.

4. Building Renovation:

Ideally, the houses throughout the region should be elevated. Even if not all of the houses in the whole area are elevated, flood damage and processing time can still be lowered by adding flood resistance and easily cleaned materials to the buildings.

5. Flood Management Strategies for Historic Downtown:

Since buildings in the historic downtown area are less likely to be elevated, one alternative is to build some temporary flood barriers, combined with the previously discussed flood management methods, to achieve the best management results in a flood event. Before a flood arrives, there are typically around two days within which to erect temporary flood barriers such as sandbags.

The establishment of temporary barriers may also turn out to be a community participation activity which can increase community cohesion for residents.

4. B. Recommendation

This study is about flood management strategies in Snoqualmie with an emphasis on sustainable future development. Hopefully, this study can be used by others as a reference to inform future flood management design.

This study refers to common flood management methods and some case studies; however, due to limited time and resources the resulting recommendation may be limited and incomplete. This recommendation lacks input from trained hydrologists or engineers, so the design will need further analyses for meteorology and hydrology. The capability of this recommendation for mitigating flood impact must be further analyzed by hydrologists and engineers. Moreover, as development increases and the natural environment changes, the proposed design may prove inadequate to handle new flooding situations.

This study is from the perspective of urban design, and considers an overall strategy and various flood management methods in its design aesthetic. There is no detailed capacity for flood mitigation and it needs practical engineering considerations and estimates.

Implementation of the flood management strategies discussed here will require further detailed analyses of meteorological, hydrological and topographic data. For example, how much rainfall in Snoqualmie and how much floodwater should the flood managements handle. At this stage, we highly recommend professional input from hydrologists and engineers. They will help to figure out the effective strategies and capacity for the flood management strategies. Furthermore, implementation of flood management strategies should consider population and growth trends. If there is too much population, the flood management strategies may prove to be inadequate.

The role of the urban designer is to propose flood management strategies which not only maintain the integrity for Snoqualmie but also add socially meaningful design components such as community engagement and identity. Urban designers have to consider what engineers cannot do and what can designers do. Engineers are dealing the flood structures and how much the structures can handle; they often neglect to look at how the residents can interact with flood management facilities. Urban designers can help the engineers to understand what strategies are suitable for residents while not changing the community's fundamental character. Urban designers can cooperate with hydrologists and other experts to think of better solutions for Snoqualmie. They also serve as a bridge between the community and the flood engineers.

The flood management strategies proposed in this study are mainly aimed at Snoqualmie and are tailored for the characteristics of this region such as oxbow ponds. Therefore, the study may have limited applicability to other regions. If flood management strategies in this thesis are to be adopted elsewhere, more comprehensive research that considers the characteristics of the target regions is needed.

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