The Report committee for Gibrán N. Lule-Hurtado

Certifies that this is the approved version of the following report:

Historic Preservation and Disaster Resilience:
Flooding in Santiago de Querétaro, Mexico

APPROVED BY

SUPERVISING COMMITTEE:

Supervisor: ______________________________________
Michael Holleran

____
Benjamín Ibarra-Sevilla

Historic Preservation and Disaster Resilience: Flooding in Santiago de Querétaro, Mexico

by

Gibrán N. Lule-Hurtado, B.A.

Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Community and Regional Planning

The University of Texas at Austin

May 2015

Acknowledgements

Heartfelt gratitude goes to Dr. Michael Holleran, to whom I owe my growing interest and much of my knowledge of historic preservation, a field flooding with opportunity. Michael's expertise, guidance, availability, and humor amount to more than I could have expected or requested from an adviser.

Dr. Benjamín Ibarra-Sevilla's guidance was key from the preliminary research in summer 2014 onward. Conversing with Benjamín led to the materialization of the topic and informed the research and interviews conducted in 2015. *Preservation for Whom?*—the best speaker series this side of the Rio Grande—is organized by Benjamín and further informed my research.

Many thanks to the contacts I encountered and interviewed in Santiago de Querétaro, especially Erandi Martínez of the Municipal Planning Institute who was kind enough to answer my many questions at length and point me to multiple additional sources, all with a beaming *queretana* smile. Thanks also to Israel Ruiz González and the CIA de Querétaro, for explaining and granting me access to the many technical documents and tools used for flood risk analysis in the Valley and State of Querétaro.

The School of Architecture's Travel Scholarship afforded me the ability to stay in Querétaro for six weeks and conduct the first round of research for this report. My friends, family, and colleagues allowed me to rail *ad infinitum* regarding my research and offered advice and reading suggestions that would prove important.

Historic Preservation and Disaster Resilience:
Flooding in Santiago de Querétaro, Mexico

by

Gibrán Lule-Hurtado, M.S. C.R.P.

The University of Texas at Austin, 2015

SUPERVISOR: Michael Holleran

Santiago de Querétaro is a UNESCO World Heritage City in central Mexico experiencing exacerbating rates of flooding in its historic center due to increased uphill urbanization overwhelming the aging drainage infrastructure. Historic districts are important economic drivers and shrines of heritage that should be considered when planning for disaster resiliency. This Report explores flood mitigation considerations for historic structures and districts, identifying those best suited for Querétaro and can be implemented at the parcel, district, or public administrative levels.

Contents

Figures

Tables

Chapter 1: Introduction

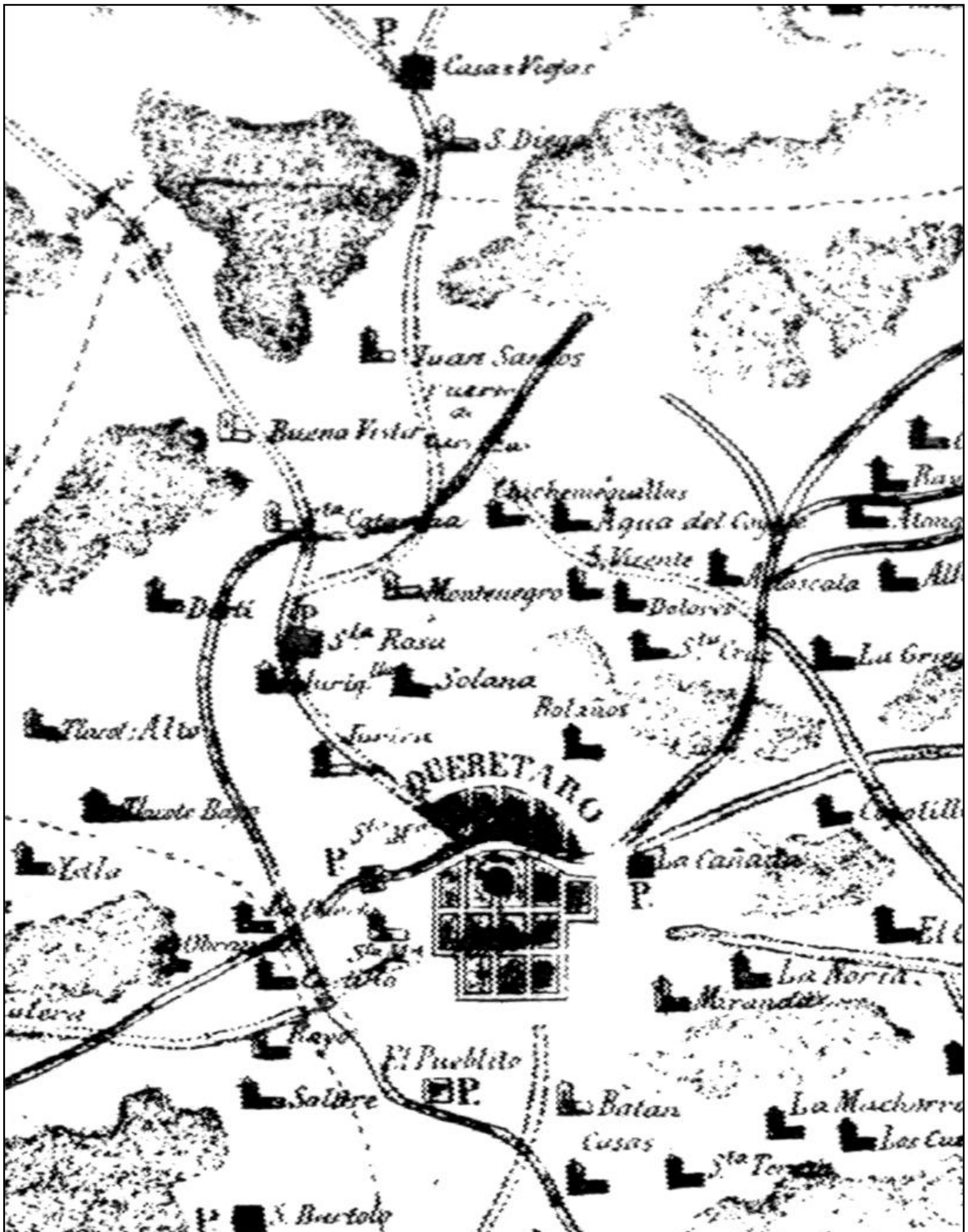


Figure 1-1: Colonial Map of Querétaro, 1840 (Source: Querétaro Rescate Patrimonial)

According to Mexico's latest census, the Santiago de Querétaro metropolitan area has a population of 1,097,025, and current estimates are in the 1,500,000 range. Its GDP per capita, at MXN$184,000, is among the highest in the country. The city's industrial growth has largely occurred within the last fifty years, when industrial zones began being established along the road to San Juan del Río. The population grew accordingly, effectively tripling from 1970 (at 112,900) to 1990 (385,503) and almost tripling once more from 1990 to 2010 (1,097,025) (Censo de Población 2010). Currently, the industrial and service sector continue to grow and attract international firms, accounting for the 7.2% economic growth rate.

Despite its remarkable growth, Querétaro has attempted to preserve its character and five-century heritage. Querétaro's historic center includes numerous buildings and monuments from Mexico's colonial era and was declared a UNESCO Cultural World Heritage Site in 1996. Its importance in colonial Mexico was in part due to its advantageous location along the *Camino Real de Tierra Adentro* ("Royal Inland Road"), a colonial road leading from Mexico City to the silver and gold mines of inland New Spain that also served as a trade route for central and northern cities (Gobierno 1985, p. 20). The same geographically strategic location—two hundred miles from Mexico City, along the Mexico-Irapuato Industrial Corridor, and along the main route to Northern Mexico and the United States—has driven its current impressive growth.

Figure 1-2: Location of the City of Santiago de Querétaro and Querétaro State within Mexico

In colonial Mexico, the city reached its apex of wealth and construction during the eighteenth century, when it became the third most important city in New Spain, after Mexico and Puebla. This growth warranted the construction of the majestic aqueduct stretching 1.28 kilometers northeast from the historical center. Hundreds of ornate structures, including homes, churches, hospitals, entertainment venues, and government offices were erected during this time. Many in the baroque style and employing the famed pink stone of Querétaro (Gobierno 1985, p. 30-32).

The city center was declared a national Historical Monument Zone in 1981 (under the 1972 Federal Law on Archaeological, Artistic, and Historical Monument Zones), affording it some protection and federal level preservation management and funding. Local regulatory conservation measures have been more recent. In 1991 the state legislature passed the Law for the Protection of the Historical Heritage of the State of Querétaro. In 1995, the municipal council delineated a conservation boundary around the oldest parts of the city, the Conservation Zone of the Historical Center and the Traditional Quarters of Querétaro; a management plan for this zone was completed by the municipal government in 2005 (Municipio 2006, Vol. I, p. 2).

Through INAH, the National Institute of Anthropology and History, the federal government is responsible of overseeing the application of the 1972 Law on Archaeological, Artistic, and Historical Monument Zones. The state and municipality exert control over settlement and growth patterns through statutory instruments. The municipality has run programs to encourage public participation in preservation since 1994. Furthermore, the World Heritage proposal brief puts the number of private foundations working for the conservation of the historic center at over a dozen.

FLOODING

The city sits at the edge of the central Mexican "Bajío" basin region and is surrounded on three sides by hills. As the city has continued to grow and expand into these hills, impervious cover is increased and water that would ordinarily percolate into the surrounding areas now flows downhill into the urban core. The 2005 Historic Center Management Plan notes the risk and flooding due to blocked flows in the center, but not due to increased impervious cover in the surrounding topography. The

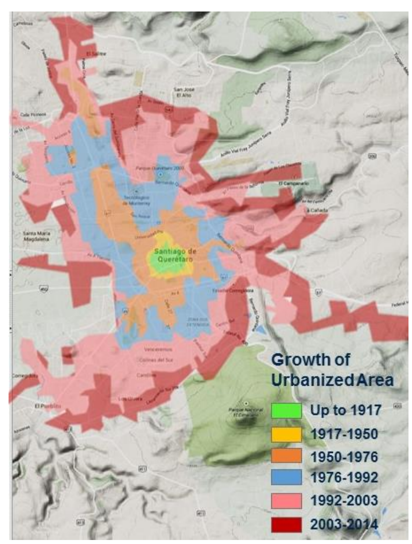


Figure 1-3: Urban Growth

proposed solution is clearing of water flow paths and construction of 2.5km of stormwater drainage infrastructure. Increasing incidence and severity of floods have caused the governor's committee on urbanization, consisting of representatives from the four municipalities in the conurbation—Querétaro, Corregidora, El Marqués and Huimilpan—, to address the issue. In 2009 they generated flood mitigation guidelines, the *Plan Maestro Fluvial de Zona Metropolitana* (see Chapter 8), which the municipality administrations had to then officially adopt. The municipalities of El Marqués and Huimilpan adopted the plan officially, the municipalities of Querétaro and Corregidora have not.

This report will provide information on the built environment and population of Querétaro's Historic Center, as well as the hydrology of the area and the larger basin of the Valley of Querétaro. It will attempt to identify areas in the Historic Center susceptible to flooding using rainfall-runoff models and present current flood mitigation approaches in the city. It will conclude with flood mitigation recommendations to be considered by agencies responsible for the preservation of the Historic Center and the protection of its population.

Figure 1-4: Flooding on Ezequiel Montes St, 2014

Figure 1-5: Flooding on Universidad Av, 2014

(Source: Evalúan daños)

Chapter 2: Historic Center

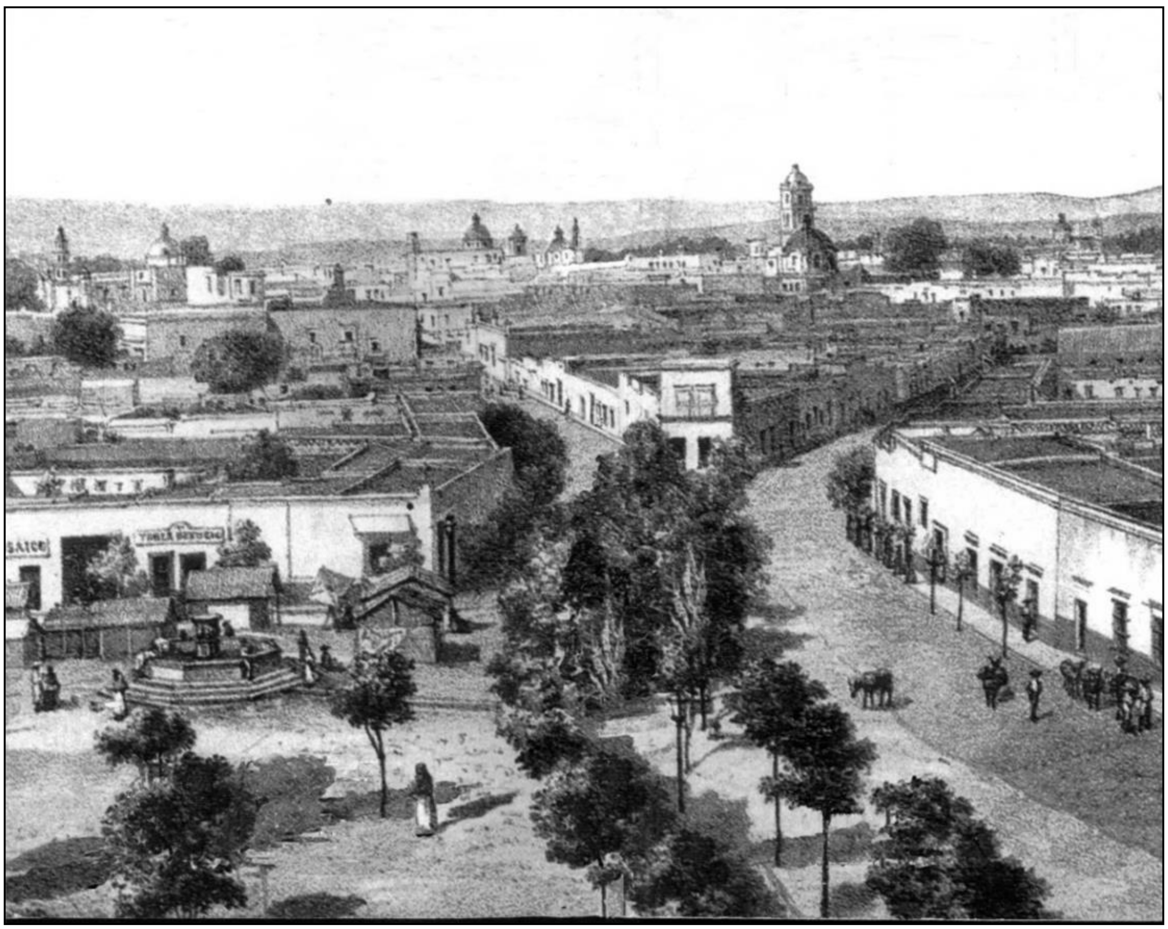


Figure 2-1: Late 1800s Lithograph
Source: Querétaro Rescate Patrimonial

The area that is now Querétaro was occupied by Mesoamerican civilizations, including Otomí and Chichimec, as far back as 200 C.E. The City of Querétaro was founded on July 25, 1531 under a Spanish-Otomí alliance. As such, the town was originally divided into two sectors: one Spanish and one Otomí. This original setup is evident to this day in the urban form: the blocks on the west of the Historic Center, originally inhabited by Spaniards, are larger and rectilinear, while those on the east, originally inhabited by Otomí, are narrower and more curvilinear (see Figure 2-2; Municipio 2006, Vol. I, p. 18). Many buildings in the core of the Historic Center date to the sixteenth, seventeenth, and eighteenth centuries (see Figure 2-3).

Figure 2-2: Initial Settlement and First Roads (in black)
(Source: *Querétaro Rescate Patrimonial, 1985,* based on 1760 Sketch by Ignacio de las Casas*)*

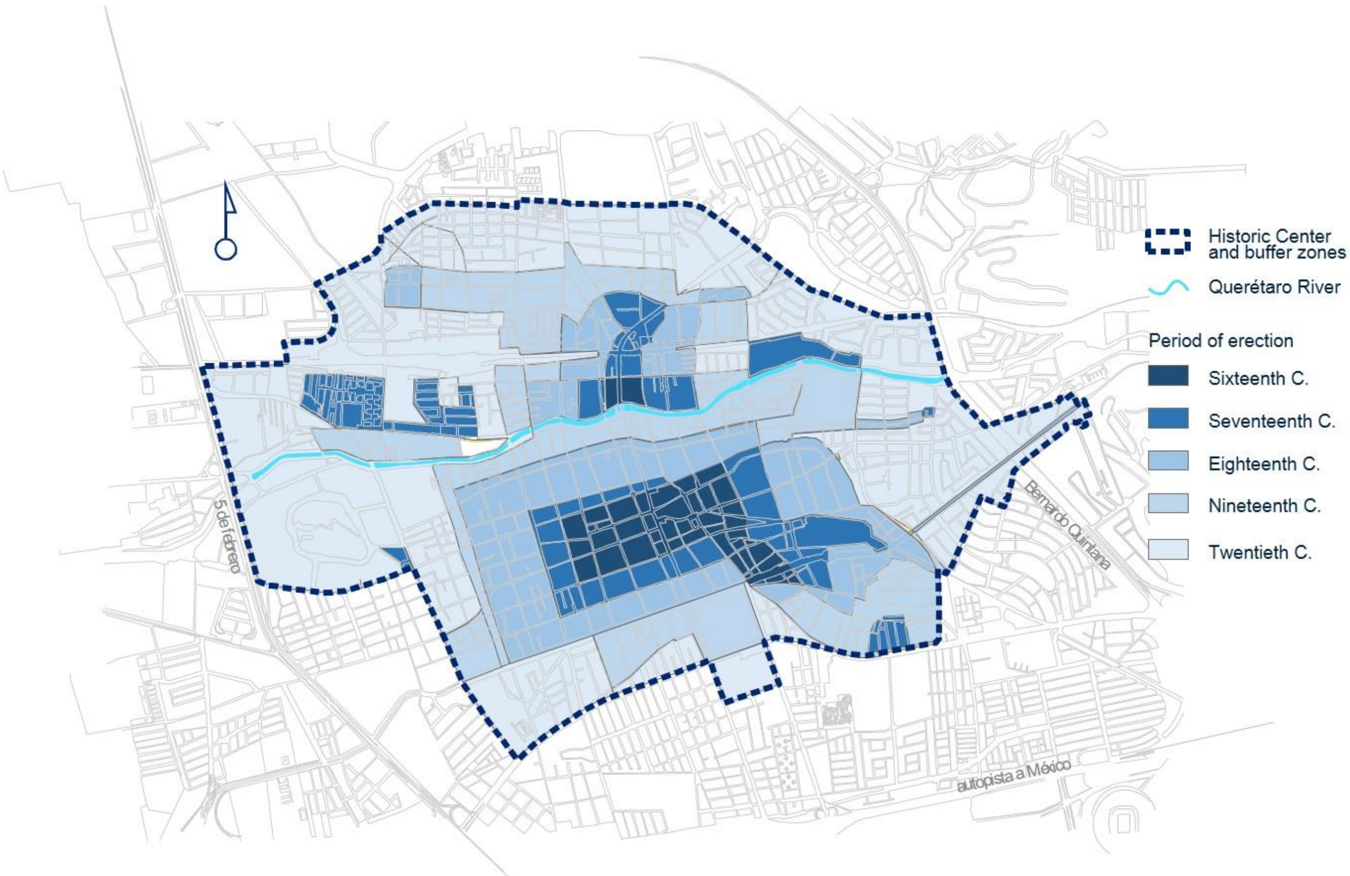


Figure 2-3: Period of Erection, by Block
(Source: Municipio 2006)

The Historic Center of Querétaro was declared a historic monument zone by presidential decree in March of 1981. This recognition granted it protected status under the 1972 Federal Law on Archaeological, Artistic, and Historical Monument Zones. The inscription identified the city as a unique and important testimony of the nation's social and political history. It further identified it as one of most exceptional urban models in the country due to the "incorporation of European and indigenous elements in its architectural monuments" and urban form (Declaratoria Ejecutiva 1981, p. 2). Under the 1972 Law, preservation, restoration, and recuperation of monuments forming part of the nation's built and cultural heritage are deemed of high public value. (Municipio 2006, Vol II, p. 5)

The decree identified a primary conservation zone and surrounding buffer zones to ensure the preservation of the built heritage (See Figure 2-4: 1981 Decreed Historic Area and Buffer Zones). The primary conservation zone encompasses the oldest portions of the rectilinear Spanish sector and the winding roads of the indigenous section of the city, along with the *Alameda* public park and the seventeenth-century aqueduct, all south of the Querétaro River. The oldest blocks of the Traditional *Barrios* north of the river were also included. The buffer zones included the *Cerro de las Campanas*, a hill to the west of the urban center, known as the home to the Autonomous University of Querétaro and the place of execution of Emperor Maximilian. The buffer zones extending east from the center frame the historic aqueduct up to its source (Municipio, 2006, Vol. I, p.9).

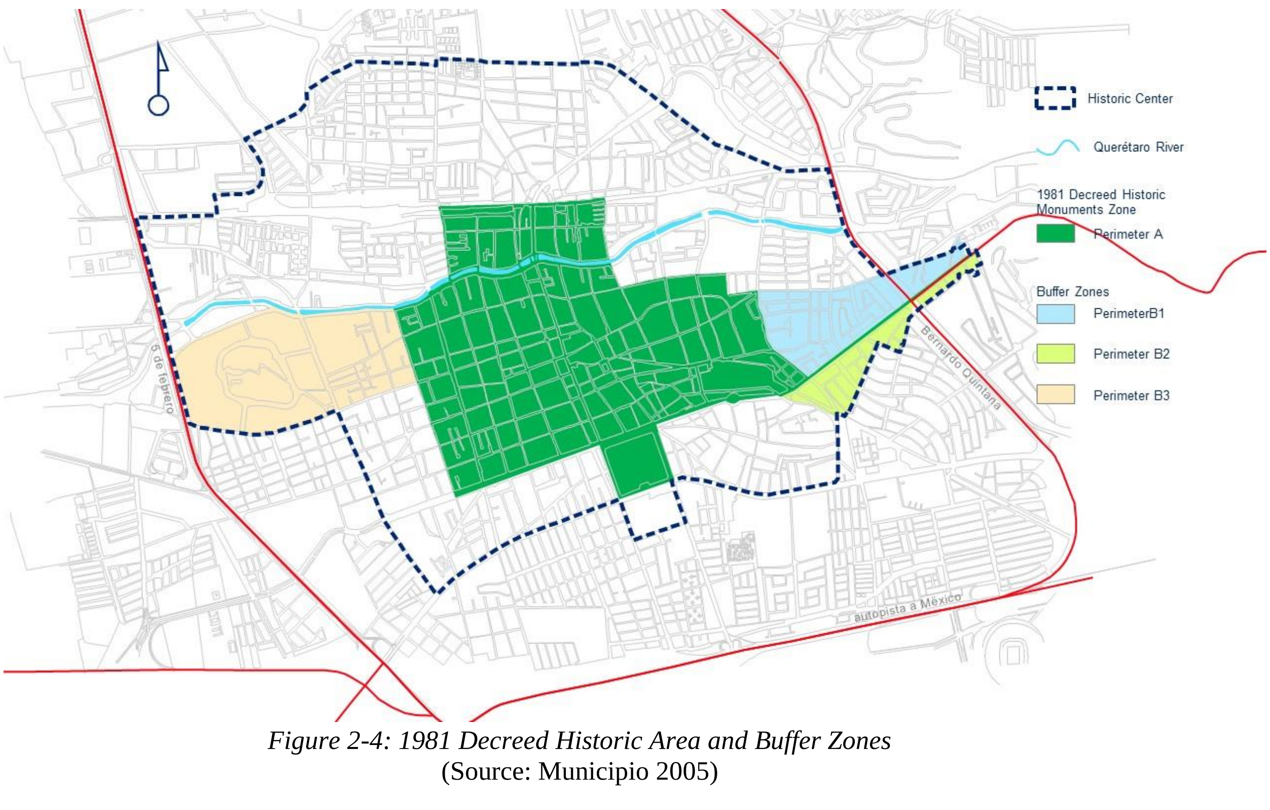


Figure 2-4: 1981 Decreed Historic Area and Buffer Zones
(Source: Municipio 2005)

The World Heritage nomination spans four square kilometers, covering 203 blocks in the historic center. It stretches northeast to envelop the aqueduct and included over 1,400 designated historical buildings in 1996. World Heritage recognition expanded the preserved area to include the Traditional Quarters north of the river and southeast of the city center (see Figure 2-5). The number of buildings designated historical by INAH has since increased to over 1,700. The vast majority of parcels in the Historic Center (over 99%) are privately held (see Table 2-1; Municipio 2005, Vol. I, p. 79).

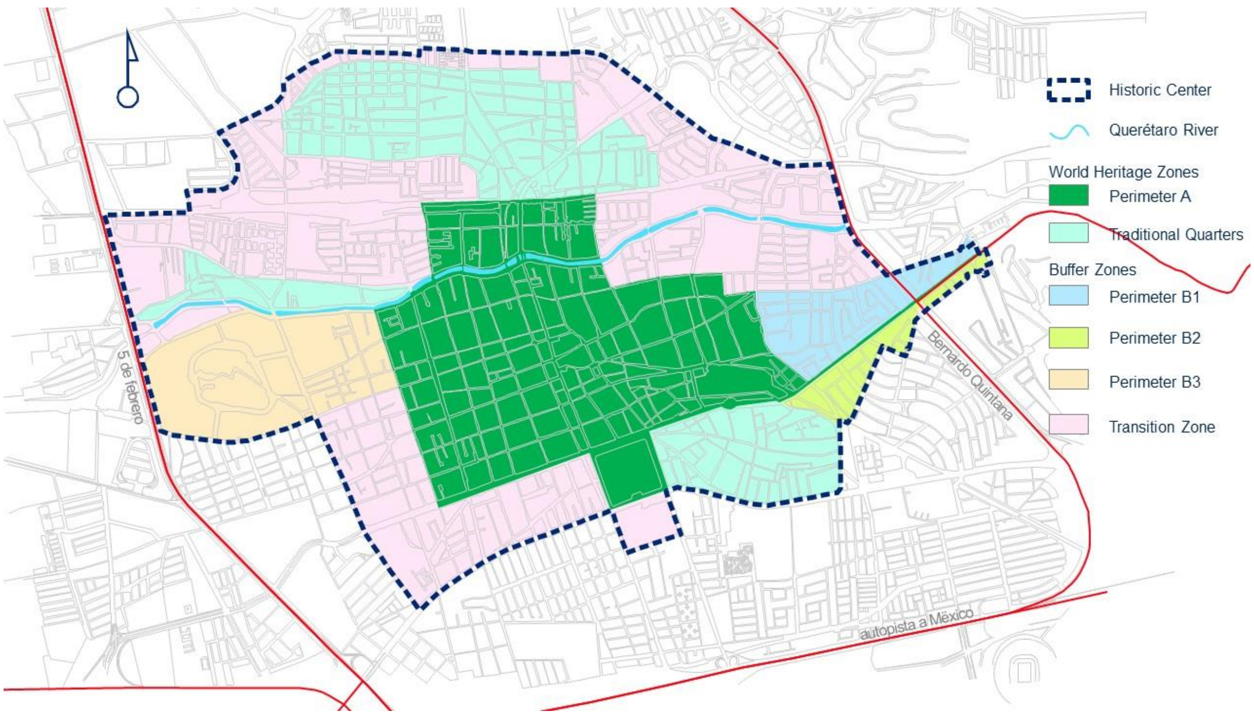


Figure 2-5: World Heritage Proposal Zones and Buffers

Table 2-1: Land Holders in the Historic Center

Type of Holder	Parcels	
	Number	Percentage
Private	19,525	99.01
Municipal	13	0.07
State	111	0.56
Federal	72	0.37
TOTAL	19,721	100.0

Source: Municipio 2005

The management plan proposal identifies historical building loss as a concern. Two designated buildings were demolished or altered to the point of losing designation in the decade of 1990 to 2000, an average rate of 0.2 buildings lost per year. From 2000 to 2006, the rate of loss jumped dramatically to 2.3 buildings per year—with fourteen buildings deemed lost in those six years (Municipio, 2006, Vol. I, pp. 147-150).

URBAN FEATURES OF PERIMETER A – *HISTORIC MONUMENTS ZONE*

Perimeter A encircles the largest concentration of historic structures in the city. Changing institutional and residential uses show the evolution of the city. The eastern half keeps the layout set in the sixteenth century by indigenous inhabitants of the city, although these residents were expelled from the city in the seventeenth century, their homes replaced by Spanish-style buildings.

Most blocks are rectangular or trapezoidal with parcels between 500 and 2,000 square meters. Many buildings exhibit neoclassical and baroque features in stone, while some have smooth facades. Preservation of facades, the urban form, and public spaces is good, but many properties exhibit signs of interior deterioration (Municipio 2006, Vol. I, p. 40)

Homes in Zone A were constructed using long-lasting materials. Adobe and stone walls are common, plastered with lime. Most rooves are flat, constructed with traverse beams and brick. Pink quarry stone (*cantera*) is commonly found on doorways, windows, and pillars.

Residential Typologies

In addition to institutional buildings, architectural surveys by INAH and Construcciones JAVE (in 1999 and 2000) have identified the following eight housing typologies in the Historic Center (Images from INAH, 1987 and JAVE 2000).

Type One: Arcaded two-story homes in the core of the Historic Center. These homes allowed for conducting commercial activities on the ground floor.

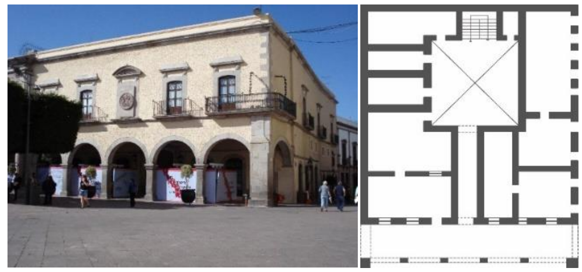


Figure 2-6: Type One Home and Floorplan

Type Two: Single-story homes with uncentered doorway. Consist of two rows of room, one of which leads into a long interior courtyard.

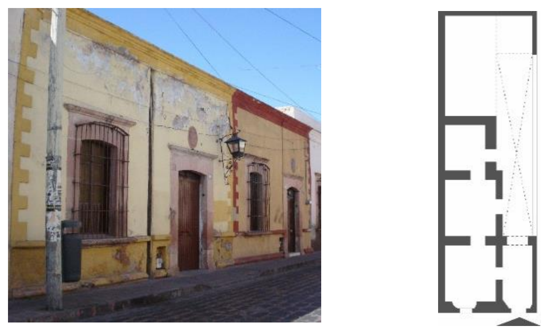


Figure 2-7: Type Two Home and Floorplan

Type Three: Single-story homes with central doorway. These homes consist of three rows of rooms, the central row includes an interior courtyard.

Figure 2-8: Type Three Home and Floorplan

Type Four: These homes have one row of rooms with a courtyard and kitchen towards the rear of the home.

Figure 2-9: Type Four Home and Floorplan

Type Five: Homes with one row of rooms on two stories. Usually kitchen, bathroom and courtyard on ground floor, with bedrooms on second story.

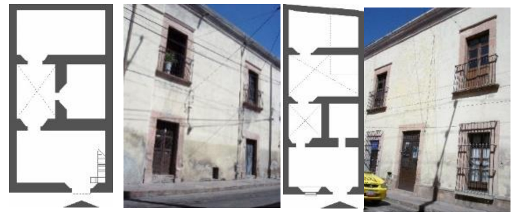


Figure 2-10: Type Four Home and Floorplan

Type Six: Two-level homes with two rows of rooms. It is common to find businesses on the ground floor, often with one or two courtyards.

Figure 2-11: Type Four Home and Floorplan

Type Seven: These homes have two levels and three rows of rooms, with a central doorway. Commonly run businesses on the ground floor and have multiple courtyards.

Figure 2-12: Type Five Home and Floorplan

Type Eight: These homes do not fit into any of the above typologies. They might be taller than two stories or on strangely shaped parcels.

Figure 2-13: Type Five Home and Floorplan

Table 2-2: Percentage of Contributing Structures by Typology

Tipology	Percentage of Total
1	0.65
2	46.78
3	22.95
4	12.53
5	1.09
6	2.24
7	2.03
8	11.73

Source: *Catálogo Nacional de Monumentos Históricos Inmuebles del Estado de Querétaro*, INAH 1990.

URBAN FEATURES OF *TRADITIONAL QUARTERS*

Expelled from the central city in the seventeenth century, the indigenous population moved to what is now the Traditional Quarters surrounding the core of the Historic Center, once more establishing curvilinear and form-following street networks and large marketplaces. These quarters were established along existing roads leading north and east from the city.

These areas, not originally protected under the 1981 decree, have suffered significant alterations to the original structures and are now largely heterogeneous in appearance—hosting both historic and newly constructed buildings. The railroad line that now cuts through the northern Traditional Quarters has interrupted the connectivity therein and adversely impacted the historic character and nodal quality of the San Sebastián *Barrio* (Municipio 2005, Vol. I, p. 132).

The Traditional Quarters are representative of historic architecture and have been placed in the secondary (buffer) conservation perimeter due to their sometimes altered forms. Their streets and many remaining historic properties retain significant cultural and contextual value for the city (Gobierno 1985, p 50).

URBAN FEATURES OF PERIMETER B – *BUFFER ZONES* – AND *TRANSITION ZONE*

The Buffer Zones (Perimeter B) and Transition Zone, as defined in the early nineties for World Heritage nomination, were formerly agricultural areas and haciendas which have largely developed in the twentieth century. They include newer nodes of social, cultural, and commercial activities. This Zone includes the Autonomous University of Querétaro, the Querétaro Institute of Technology, hospitals, and shopping areas.

Although close to Zone A, many of the properties in this zone, which includes industrial facilities which have fallen into disuse, are unaesthetic. This is also the case along Zaragoza Avenue, which delineates most of Zone A's southern border (Municipio 2005, Vol. I, p. 132).

The 2005 Urban Management Plan for the Historic Monument zone and Traditional Quarters Zone identifies some strategies to protect and preserve the area, including physical interventions and normative instruments such as transfer of development rights It identifies the key institutions responsible for the upkeep of the historic center as: INAH and the Secretariat for Social Development at the federal level; Governance Secretariat, Urban Development and Public Works Secretariat, and the Planning and Finances Secretariat at the state level; the municipal government and the municipal planning institute at the local level. (Municipio 2006, Vol. III, p. 8; *ibid*, Vol. IV, p. 21).

Chapter 3: Population

The Historic Center of Querétaro is a very active urban core home to 84,000 residents. The population continues to increase and is projected to reach nearly 90,000 by 2025 (See *Table 3-1*). The most densely populated areas of the core are the Traditional Quarters (See Figure 3-1). The area is still home to many government offices for the municipality and state, as well as small and medium businesses (Municipio 2006; Vol. III, p. 16-18; *ibid*, Vol. III, p. 34).

Table 3-1: Past and Projected Population for the Historic Center, by Perimeter

Year	Perimeter A	Perimeter B (Buffer)	Transition Zone	Traditional Quarters	Total Population
1995	17,890	14,356	16,789	29,345	78,380
2010	17,450	14,720	19,743	32,066	83,979
2015 (projected)	17,209	13,976	20,939	32,598	84,722
2025 (projected)	17,113	12,698	24,524	35,214	89,549

Source:Censo de Poblacion

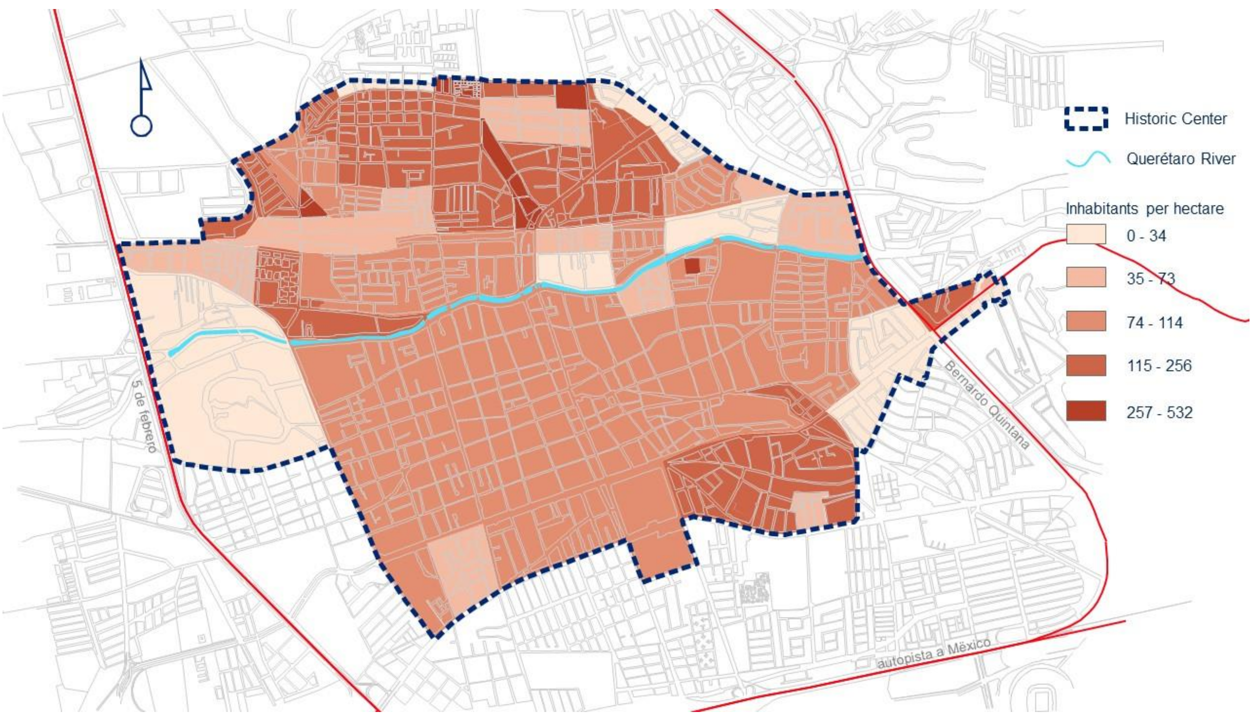


Figure 3-1: Population Density
(Source: Municipio 2006)

The area continues to function as a center of commerce for the local population. There are over four thousands retail shops, more than two thousand providers of services, and 269 known light industrial or manufacturing businesses (See Table 3-2 through Table 3-4)

Table 3-2: Commercial Businesses in the Historic Center

Business	Number
Grocery/Foodstuffs	1,122
Crafts	82
Butcher Shop	95
Electronics	161
Pharmacy	63
Office supplies	130
Clothing store	466
Shoe store	120
Other	*1809*
Total	4,048

Source: Municipio 2005

Table 3-3: Service Industry Businesses in the Historic Center

Service	Number
Private school or tutoring services	112
Consulting	170
Doctor or Clinic	234
Restaurant	110
Firm	251
Beauty Shop	182
Mechanic Shop	174
Other	*922*
Total	**2,155**

Source: Municipio 2005

Table 3-4: Light Industrial and Fabrication Businesses in the Historic Center

Light Industrial/Fabrication/Food Production	Number
Bakery	36
Welding and metalworks	27
Furniture repair	18
Printing and binding	78
Lathing	17
Tortilla production	36
Other	57
Total	**269**

Source: Municipio 2005

When considering the effects of flooding on the historic center, it's important to include the population and its sources of income. Flooding in the area would not only be damaging to the physical irreplaceable structures, but also displace residents, adversely affect the thousands of businesses, and negatively impact the tourism industry which has become a large part of the city's economy.

Chapter 4: Topography and Hydrology

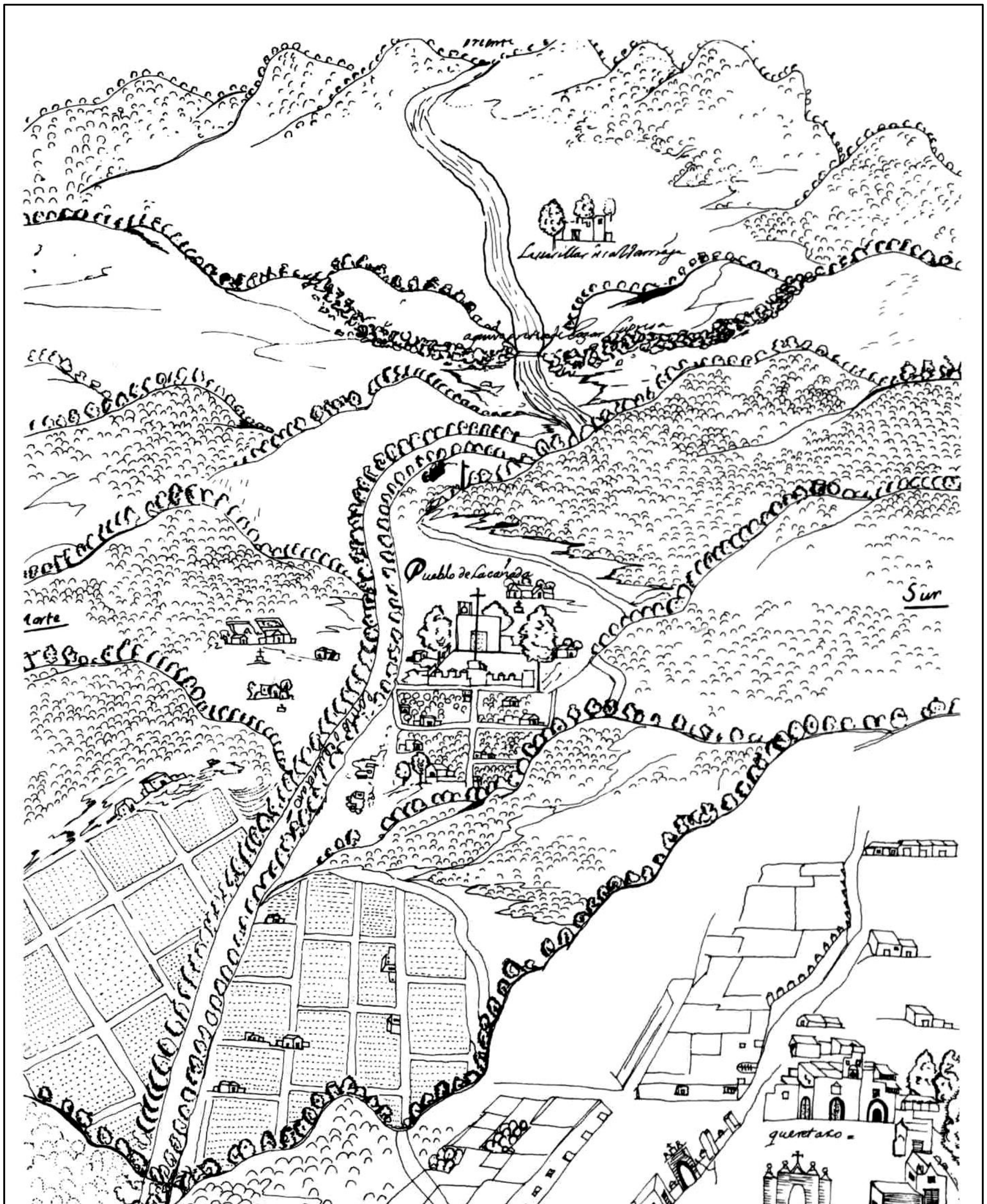


Figure 4-1: Sketch of the City of Querétaro (facing east), 1620
(Source: Querétaro rescate patrimonial)

Santiago de Querétaro lies in the lowest part of the State—the Valley of Querétaro—at 1,820 meters above sea level. The immediate surroundings of the metropolitan area are large hills rising to 3,000 meters above sea level to the northeast and southeast. The area directly to the west of the urban area rises more gently and forms the basin of the Querétaro River. The valley drains exclusively to the west, into the larger Bajío basin region of central Mexico (See Figure 4-4).

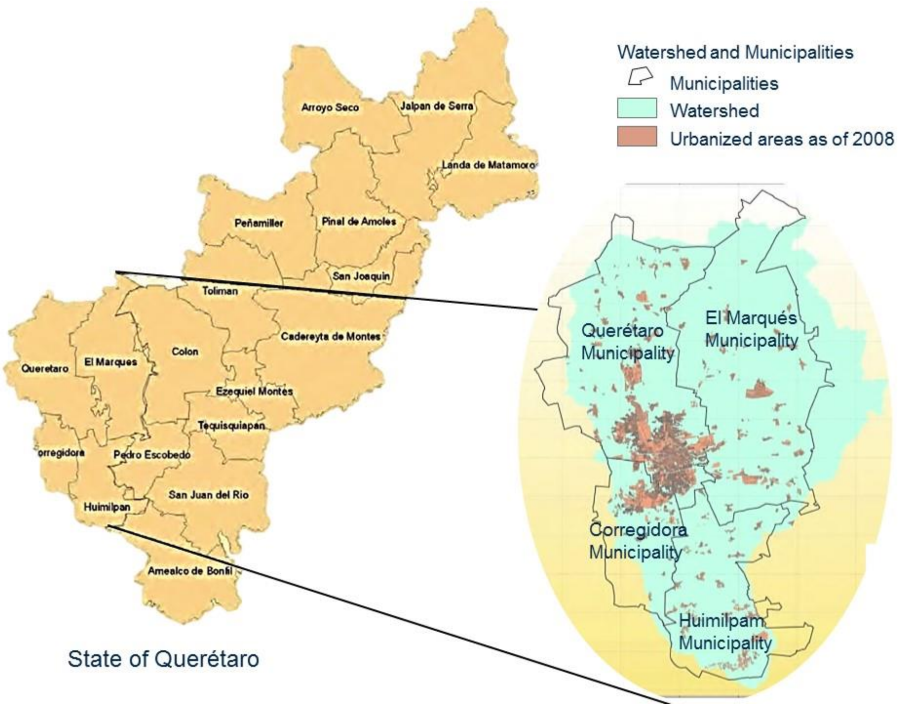


Figure 4-2:Watershed of the Study Area (Source: Plan Pluvial)

The large Cimatario National Park (See Figure 4-3) serves as a protected green area and watershed divide. The area most affecting flooding in the Historic Center is that to the east, the basin of the Querétaro River.

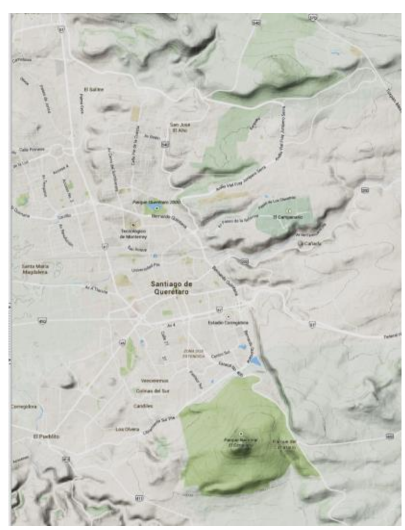


Figure 4-3: Surrounding Topography (Source: Google Maps)

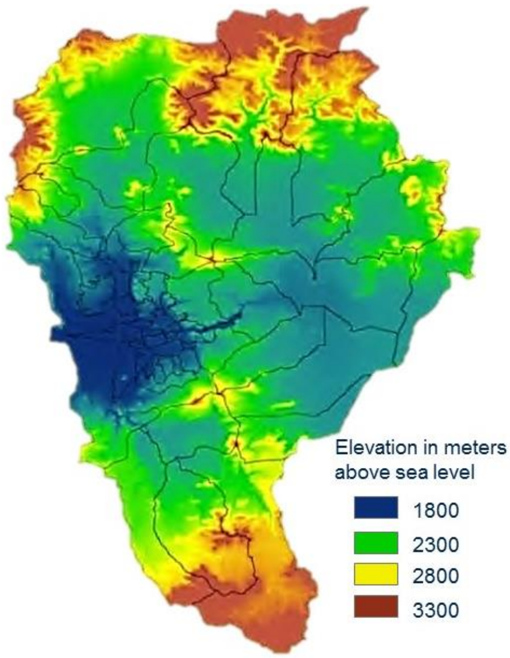


Figure 4-4: Elevation of Western Querétaro State (Source: IMPLAN Querétaro)

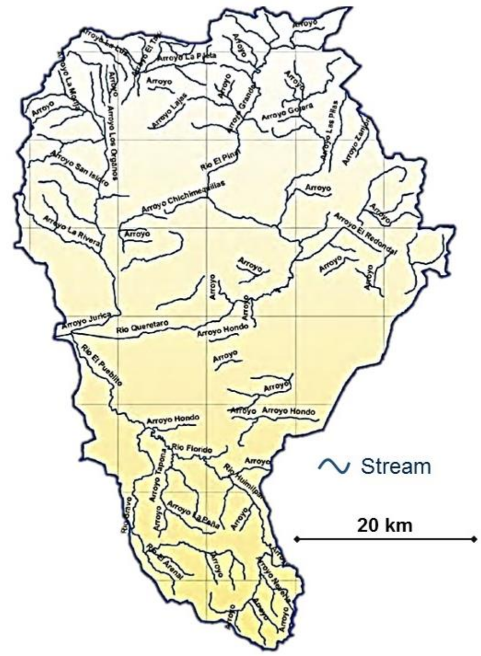


Figure 4-5: Watershed Hydrology (Source: Plan Pluvial)

QUERÉTARO RIVER

The Querétaro River begins on Zamorano Hill in Colón Municipality (northeast) and travels 25.5 kilometers through El Marqués Municipality and the Historic Center. It flows into the Lerma River system at Las Adjuntas, near the border with Guanajuato state. The River's significant tributaries are the Arenal and Cimatario drainage channels, as well as the El Pueblito River. These three flow into the Querétaro River at points downstream from the city center. The Arenal and Cimatario drainage channels are streams which have been hardscaped and engineered to divert stormwater into the River and away from flood-prone areas in the center and south of the city (Facultad 2009, p. 15).

The segment of the Querétaro River flowing through the urban area has also been channeled and cobbled in an attempt to improve flow, and control shifting (See Figure 4-6). In the Historic Center, Universidad Avenue follows the trace of the river on either side; the banks of the river in this area have been landscaped into a linear park (See Figure 4-7 and Figure 4-8)

Figure 4-6: Hardscaped Portion of Querétaro River

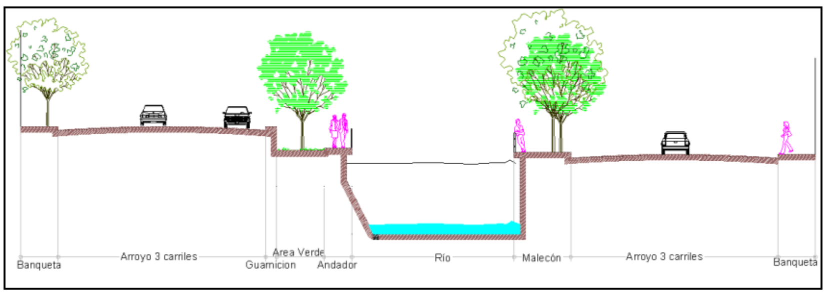


Figure 4-7: Cross Section of River at Ignacio Altamirano St.

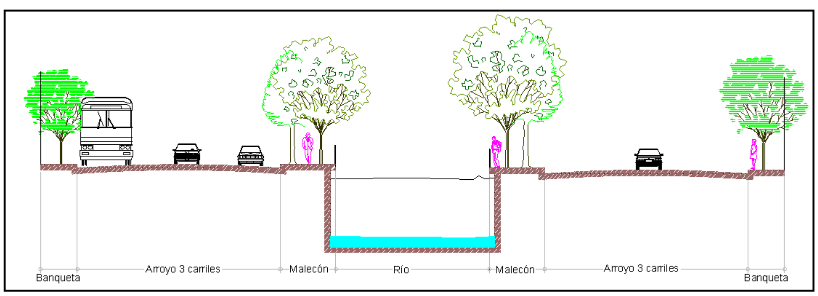


Figure 4-8: Cross Section of River at Corregidora St.

The river serves as the primary drainage for the central area of the city. Water in the south is diverted along the Cimatario drainage channel, running parallel to the Querétaro River to prevent overflows of the River in the urban area, it flows into the River at the Military Zone downstream from the urban core (Facultad 2009, p. 181).

Dams and Retention Berms

The 2008-2015 Stormwater Plan for the city identifies many dams and retention berms in the basin of the Querétaro River, upstream from the city. These have been built up over the centuries for water retention for agriculture and flood prevention. The plan identifies seventeen dams and thirty-five retention berms or weirs (*bordos*) (Facultad 2009, p. 81) .

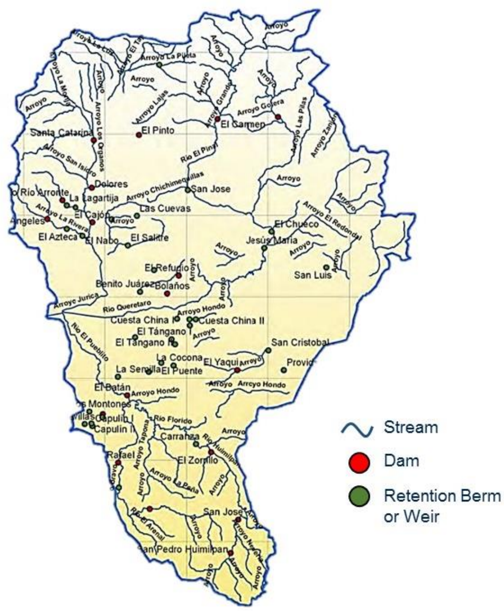


Figure 4-9: Dams, Berms and Weirs in the Watershed
(Source: Plan Pluvial, 2009)

CURRENT DRAINAGE NETWORK

As is the case in most of the city, the drainage network in the Historic Center is a combined system carrying both wastewater and stormwater to a water treatment facility near the River's intersection with Ezequiel Montes Street (Facultad 2009, pp. 156-157). This combined system presents the risk of overflowing and spilling both sewage and pluvial flows onto the street network (*ibid*, p. 184). Figure 4-11 identifies points where overflows have occurred, six of them in the Historic Center. Figure 4-12 shows that the vast majority of the drainage infrastructure in Perimeter A is over fifty years old.

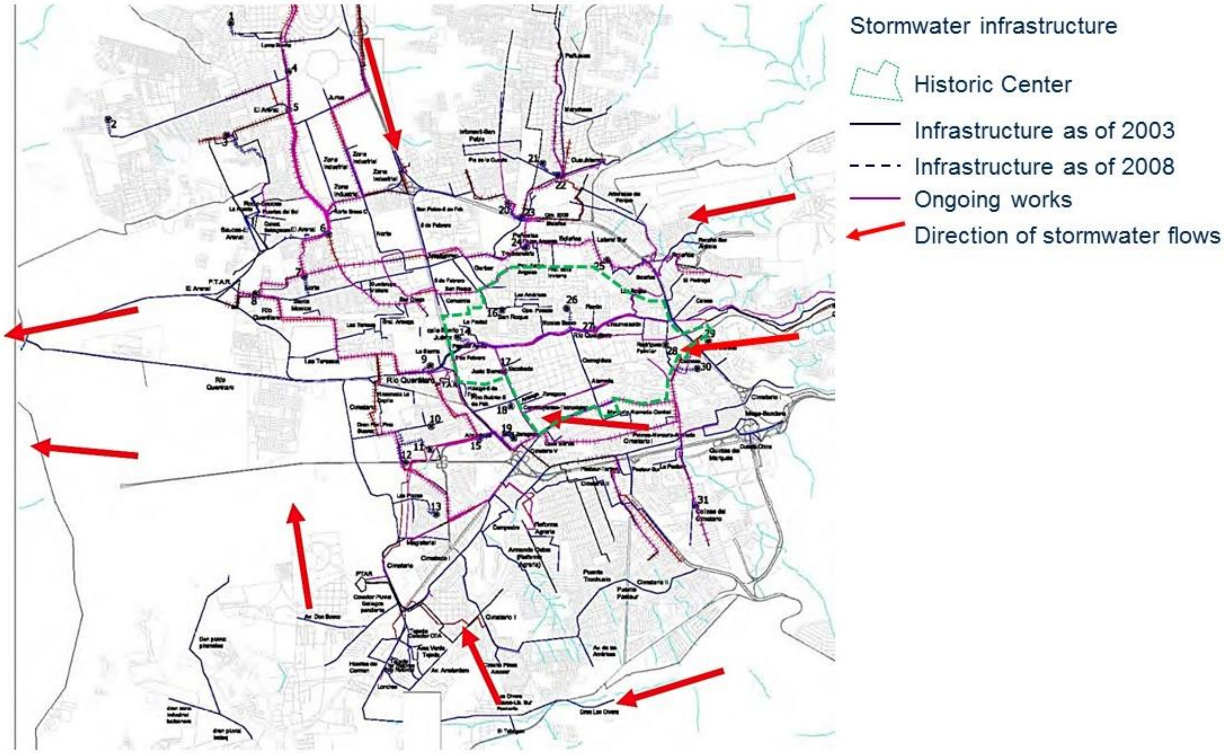


Figure 4-10: Urban Drainage Infrastructure for the Metropolitan Area
Source: Plan Pluvial, 2009

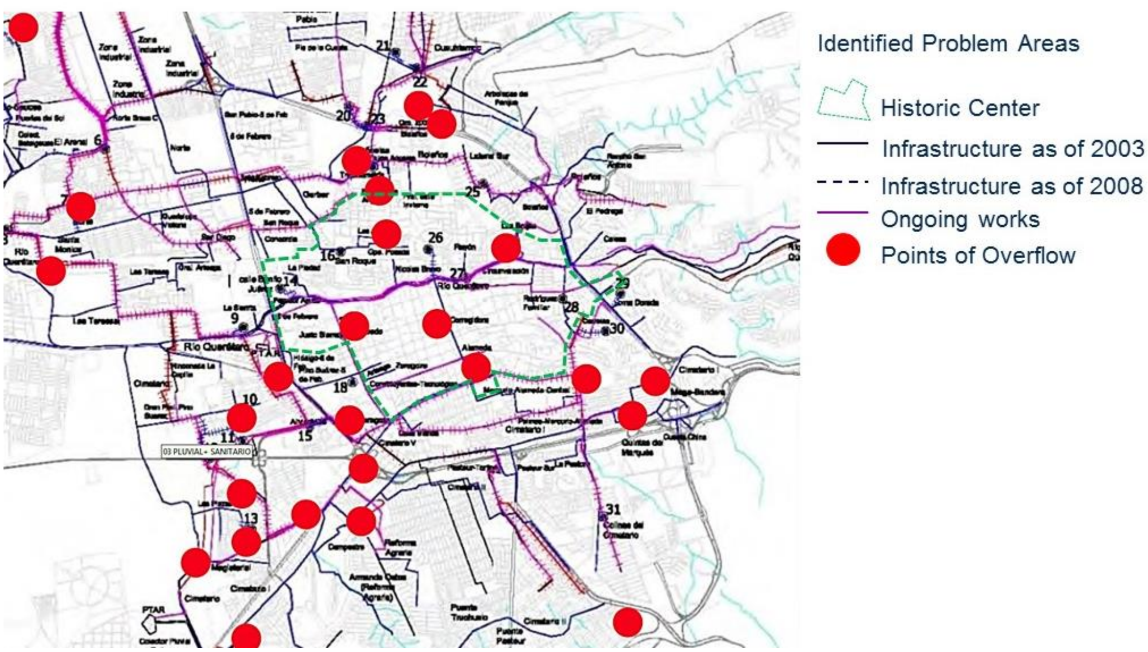


Figure 4-11: Points of Drainage System Overflows
(Source: Plan Pluvial, 2009, p. 188)

It is important to keep this problem in mind, as the generation wastewater is projected to increase proportionally with population in the area, most significantly in the Traditional Quarters and Transition Zone. Using 2006 as a baseline, wastewater generation in the Zone of Transition will increase by twelve liters per second by 2025 and nine liters per second in the Traditional Quarters (Municipio 2006, Vol. II, p. 26). In total, wastewater generation is projected to increase by twenty-five liters per second, a fifteen percent increase (See Table 4-1).

Table 4-1: Projected Wastewater Generation for Historic Center (liters/second)

Year	Perimeter A	Perimeter B	Transition Zone	Traditional Quarters	Total
2006	35.20	30.43	36.89	61.67	164.19
2015	36.68	29.48	41.20	64.14	171.5
2025	42.57	29.75	48.25	69.29	189.86

Source: Construcciones JAVE, S.A. de C. V.

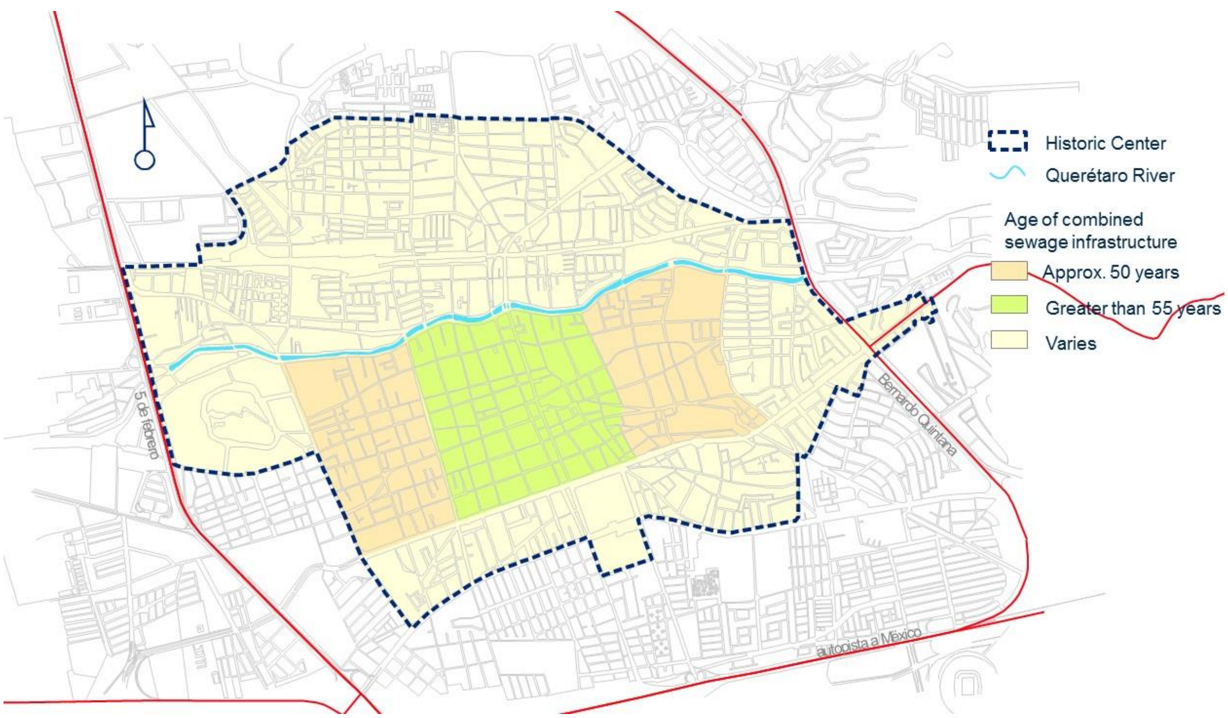


Figure 4-12: Age of Wastewater/Stormwater Drainage Infrastructure
(Source: Municipio 2006)

GEOLOGY

Geologically, the Historic Center is composed mostly of soft alluvial soil—namely clays and vertisol. These fertile soils led to the settlement of the area for farming. The drying of these soils is a major concern, as clay and vertisol greatly compact when dry and can pose problems for buildings erected thereon. Some areas of basalt extrusions exist in the west, southeast, and north of the Historic Center (See Figure 4-13).

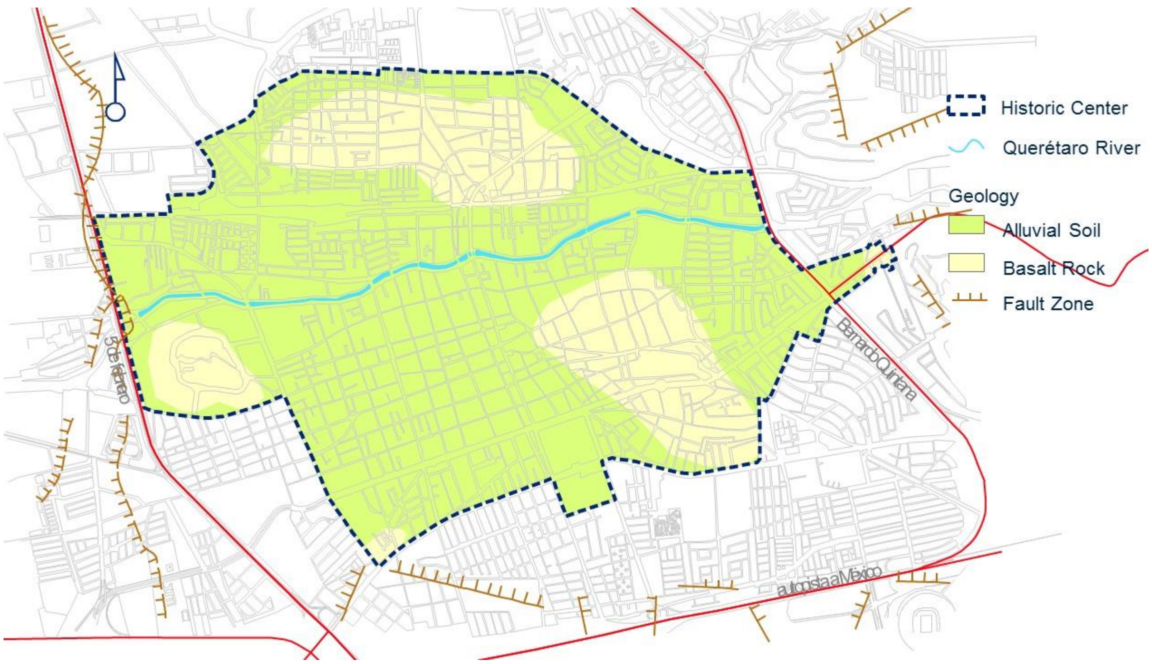


Figure 4-13: Geology of the Historic Center
(Source: Municipio 2006)

Most heavy rain occurs in the wet summer season. Table 4-2 shows yearly recorded precipitation in millimeters from 1974-1999 and the total rainfall in millimeters for the wettest month in each year.

Table 4-2: Yearly Recorded Precipitation from 1974-1999

Year	Wettest month (mm)	Total annual (mm)
1974	132.8	406.7
1975	157.7	580.1
1976	322.0	731.4
1977	96.6	488.0
1978	148.4	464.2
1979	87.2	274.1
1980	139.2	561.7
1981	155.2	687.5
1982	127.1	426.5
1983	222.6	544.7
1984	181.1	461.8
1985	222.9	698.8
1986	248.7	903.5
1987	124.9	436.8
1988	221.2	579.8
1989	125.6	353.7
1990	180.7	525.6
1991	254.9	633.6
1992	160.5	806.5
1993	143.6	449.2
1994	99.8	452.6
1995	115.0	609.2
1996	195.9	453.0
1997	67.7	440.5
1998	253.0	789.6
1999	151.9	369.1

Source: CNA, 2002

.

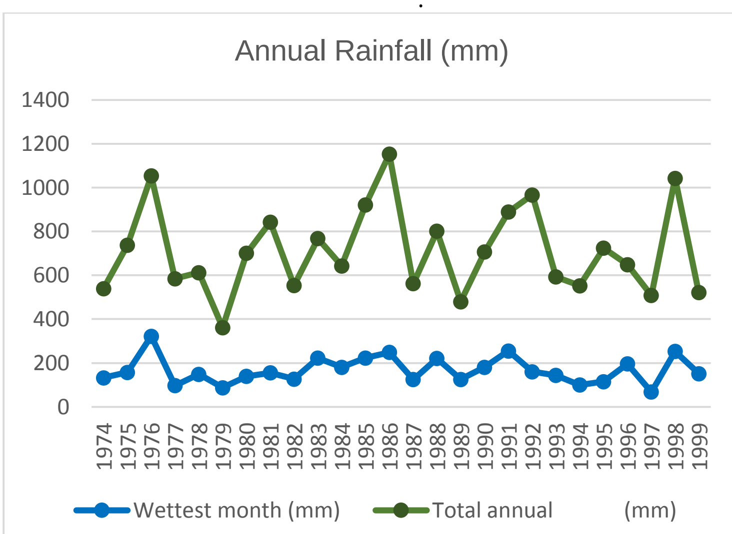


Figure 4-14: Annual Rainfall 1974-1999
(Source: CNA, 2002)

Chapter 5: Flood Risk

As the city continues to rapidly grow, it is important to evaluate flood risk and identify areas of danger. The city continues to expand into the higher areas as official state and municipal policy have discouraged westbound growth, fearing it would lead to the establishment of new residents and taxpaying businesses in nearby Guanajuato State. The *Plan Maestro Pluvial de Zona Metropolitana* (Stormwater Master Plan for the Metropolitan Area) warns about increasing urbanization and loss of impervious cover in the areas north, west, and south of the city (Facultad 2009, pp. 150-153). Urbanization to the south is of least concern to flooding, as the large Cimatario National Park (See Figure 4-3) serves as a protected green area and watershed divide. The urbanization most directly impacting the Historic Center is that to the west, in the basin of the Querétaro River. This loss of impervious cover puts more strain on the already flooding stream that bisects the Historic Center (*ibid*).

FLOODING HISTORY

It is common for some flooding to occur in the city during the rainy summer season. Two serious flood events have occurred in the past fifteen years: summer of 2003 and August of 2014.

The 2003 floods put the city at a standstill due to the many kilometers of untraversable roads. One rain event that summer event dropped 100 millimeters (3.94 inches) of precipitation in the span of only one hour, greatly overwhelming the existing stormwater system. The result was flooded roads, homes and fields, mostly in the western part of the city (see Figure 5-1) (Martínez, 2015).

The flooding affected several areas of the Historic Center, primarily the southwest portion of Zone A and the western portion of the Traditional Quarters. Flooding in the city continued throughout the summer and warranted the issuance of a national disaster declaration. The National Water Commission (CONAGUA) issued a report stating that the flooding was mostly a result of inordinate precipitation and not inadequate infrastructure.

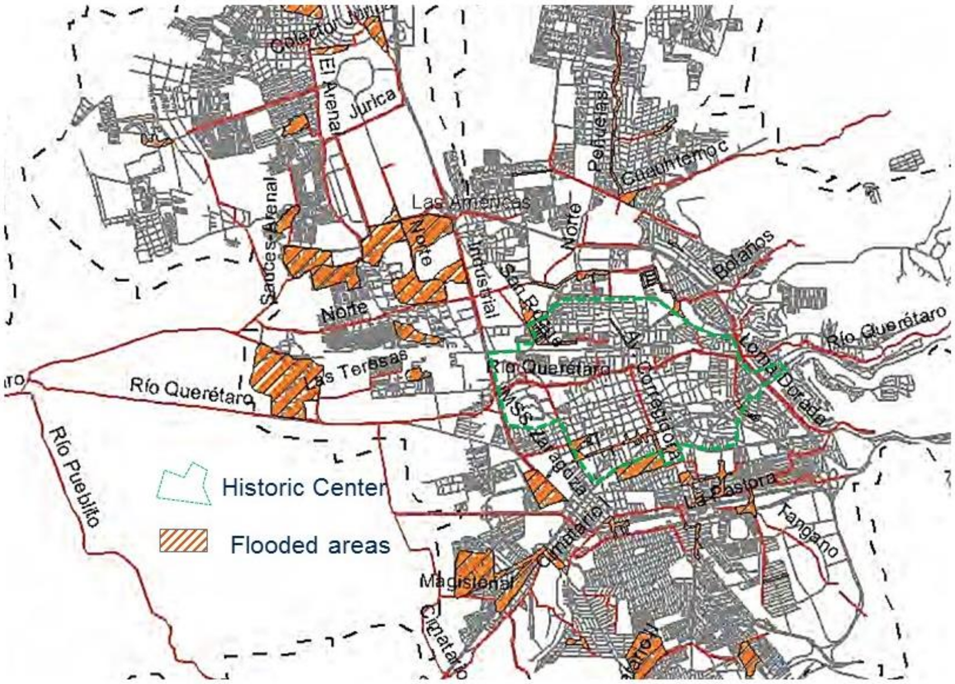


Figure 5-1: Areas Flooded in Summer 2003.
Source: Protección Civil del Municipio de Querétaro

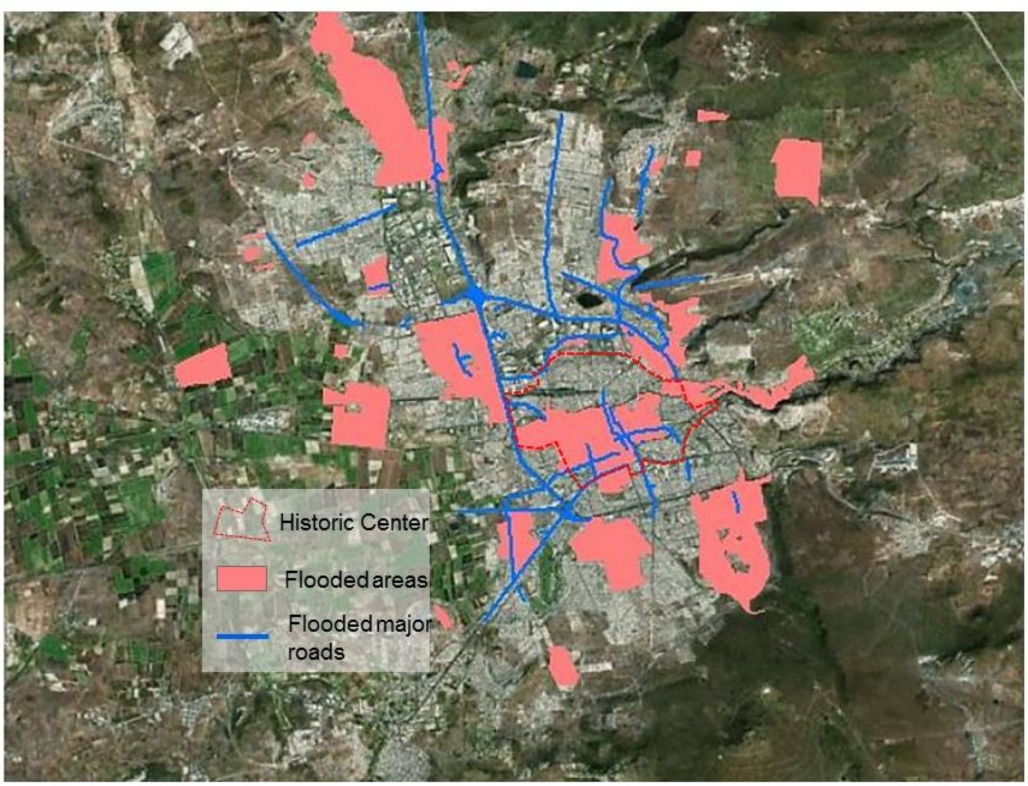


Figure 5-2: Areas Experiencing Flooding during August 19, 2014 Flood
(Source: Torres & Benítez 2014)

The 2014 flood affected some of the same flood-prone areas in the west as the 2003 flood. However, the central and eastern parts of the city also suffered flooding (See Figure 5-2). The Historic Center recorded 51 millimeters of rain during this storm event and was temporarily cut off from the city due to the flooding of most connecting roads (Evalúan daños, p. 1).

The Historic Center Management Plan, using information acquired from the State Water Commission (CEA) has identified twelve areas of potential flooding. These include the intersections of Zaragoza Street with Juarez, Allende, Guerrero, Ocampo, Tecnologico, and Corregidora Streets. The entirety of the portion of the Querétaro River running through the downtown is identified as a risk area. Four other intersections: Esmeralda at Maestu, Los Arcos at Capuchinas, Felipe Angeles at Epigmenio Gonzalez and Psicometría at Trigonometría are listed as points at risk of flooding (Municipio 2006, Vol. III, p. 32).

Figure 5-3: Areas at Risk of Flooding
Source: Plan Parcial, 2005

MODELING FLOODS

The State Water Commission (CEA) and Center for Water Research of Querétaro (CIAQ) have developed flood models based on land cover and stream network analysis. These models use the curve number (CN) model developed by the US Soil Conservation Service (now Natural Resources Conservation Service). This method classifies land cover and predicts runoff quantities based on the *curve number* an index of absorption capacity and runoff potential of different types of land cover (Facultad 2009, p.146).

Using existing data and collecting information through fieldwork, CIAQ generated a land cover inventory for the basin of the Valley of Querétaro, which became the study area for the Stormwater Plan. The four broad categories are Land Covers A, B, C, and D. Land Cover A includes sandy soils and high absorption areas. These areas are unlikely to produce much runoff and have basic infiltration rates of eight to twelve millimeters per hour. Category B includes more consolidated soils with above average absorption. Basic infiltration rates for Category B range from four to eight millimeters per hour. Category C are land uses with moderately high potential to produce runoff. This includes clay soils and groundcover with basic infiltration rates between one and four millimeters per hour. Lastly, Category D includes heavy compact soils and paved over areas; these are land uses that are highly likely to produce runoff, with basic infiltration rates of under one millimeter per hour (Soil Conservation Service 1989, pp. 20-35).

There has been substantial pressure to urbanize into the north and west of the Valley of Querétaro, first following gentle slopes and now climbing into the hills. This has seriously affected the zones of percolation in the surrounding slopes and river basins, causing more and more water to runoff into the urban core. The upstream Querétaro River basin, a high infiltration zone as recently as the 1980s now includes highly impervious urban and industrial land uses (Facultad 2009, p. 140).

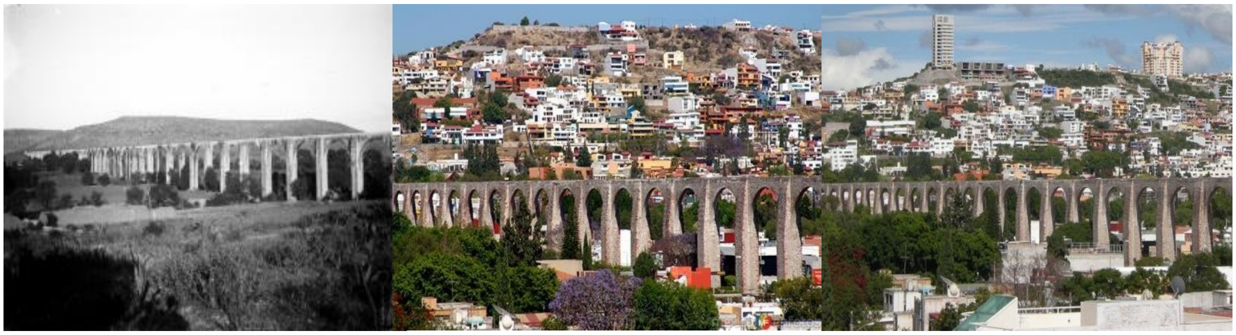


Figure 5-4: Development into the Eastern Hills, 1920-2014
(Sources: Fototeca Nacional INAH, Hogares Reunión, SerTourista)

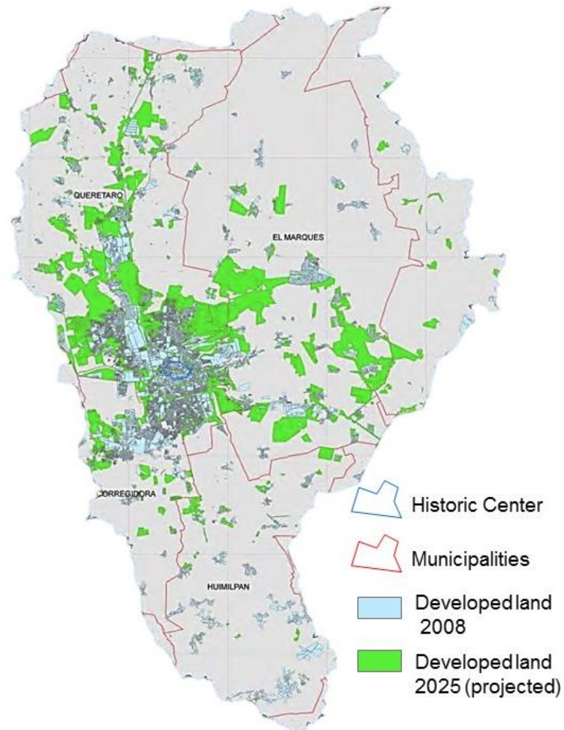


Figure 5-5: Current Urbanized Area and Projected Growth
(Source: Facultad 2009)

The municipality commissioned a metropolitan urban growth analysis through the year 2025 for use in the Partial Development Plans adopted in 2005 and the Rainwater Plan of 2009. The projection accounts for growth in the Municipalities of Querétaro, Corregidora, Huimilpan, and El Marqués. Figure 5-5 shows the projected growth of the urban area within the Lerma River's basin within Querétaro State, as well as the political boundaries of the four municipalities in the metropolitan area.

The basin has become the study area for the Stormwater Plan, which has published the curve number analysis maps for the southeast of the state. Figure 5-6 shows curve number values for the microbasins in the valley. Red and orange indicate low infiltration and areas of high runoff, whereas green and yellow indicate percolation zones with low runoff. It is apparent that the urban area is the most impermeable due to land uses and will grow in all directions by 2025. Growth to the west will further overload the Querétaro River due to increased runoff and pose a problem downstream in the Historic Center (Facultad 2009, pp. 151-170).

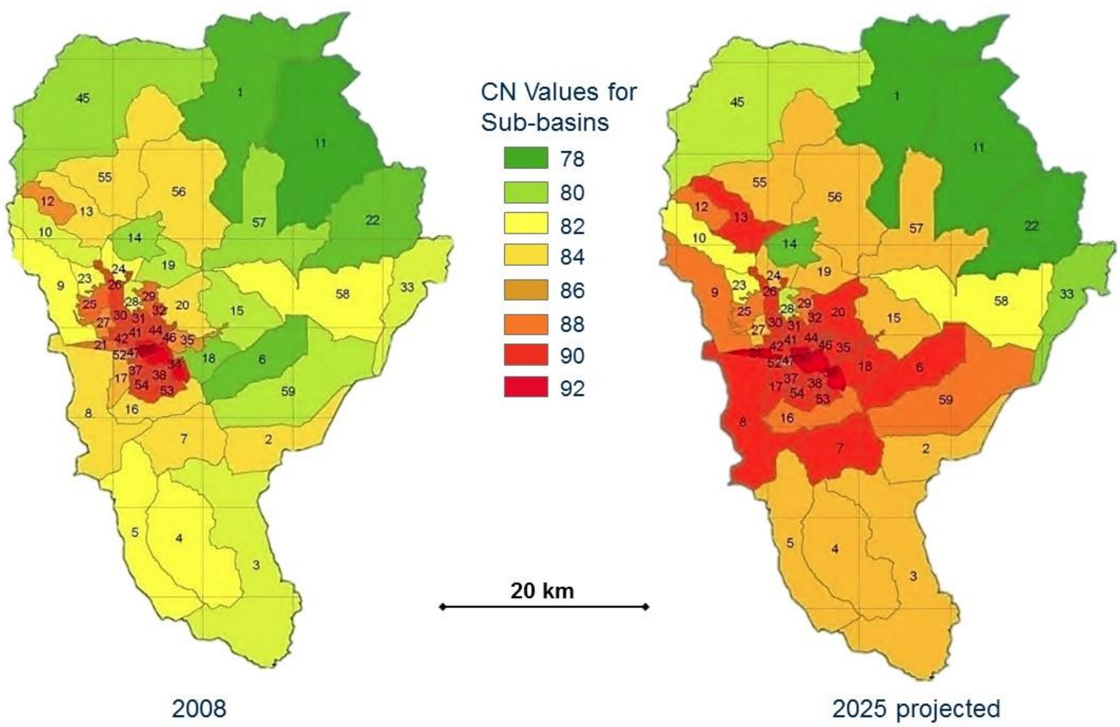
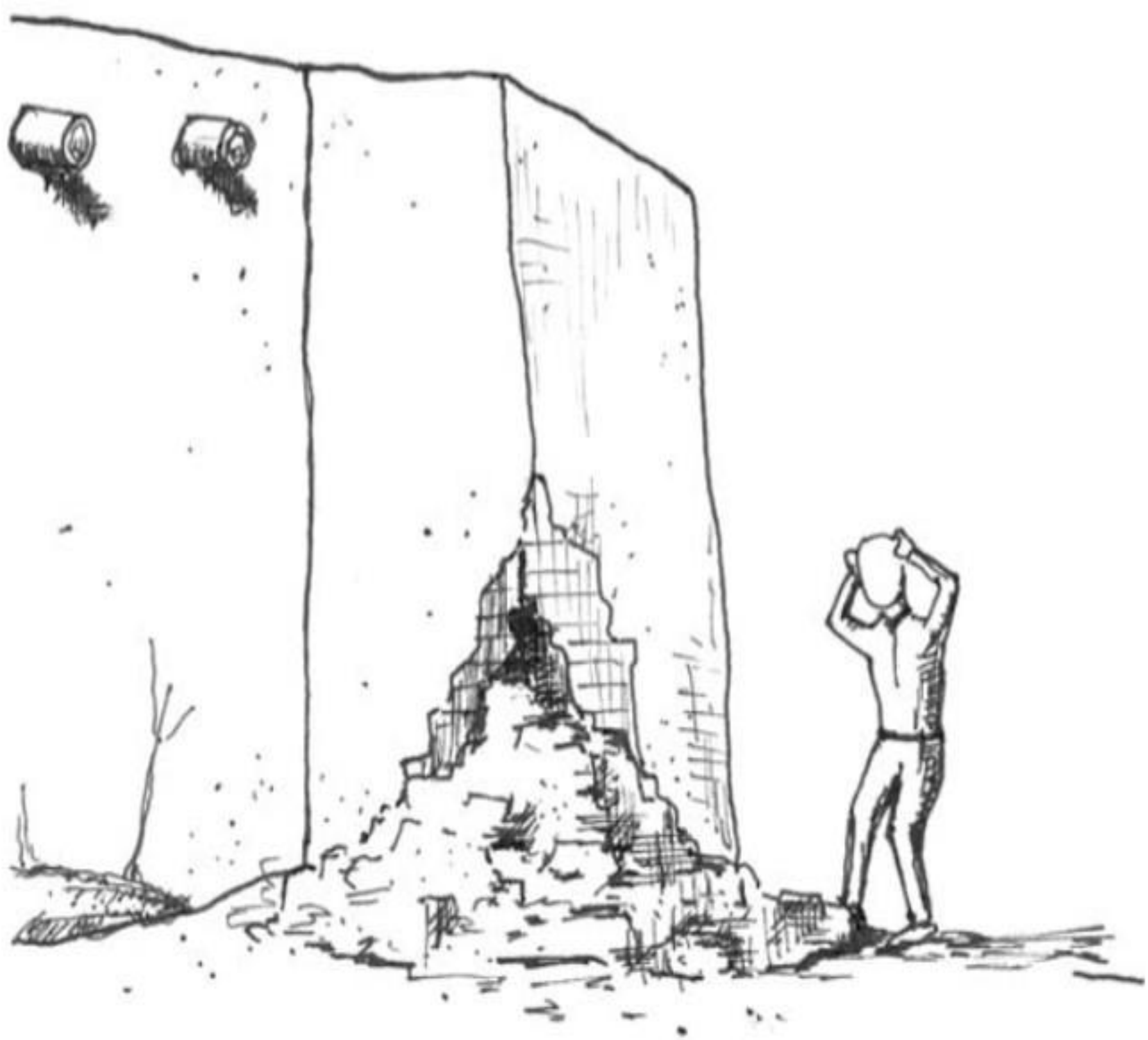


Figure 5-6: Curve Number Values for Southeast Querétaro State

Software-modeled disaster scenarios can provide valuable information informing policy and allowing authorities to identify areas at risk. The state and municipal planning institute have partnered with the Querétaro Water Research Center (CIAQ) to generate pluvial and fluvial flood scenarios using the Soil Conservation's Service CN method and the US Army Corps of Engineers' Hydrologic Engineering Center River Analysis System (HEC-RAS) (Ruiz González, 2015).

The Water Research Center is in the process of updating flood models using the latest trends of urbanization in the metropolitan area. Their new models and flood scenarios will inform planning policy at the municipal and state level, as a new stormwater management plan is slated to be adopted in summer of 2015 (*ibid*).

Chapter 6: Floods and Historic Adobe Structures



(Image source: Cornerstones 2008)

Flooding can significantly damage any building and can have especially damaging effects on historic properties. Common inundation damage to historic homes' structures and items includes collapsed wall, cracked foundations, compromised structural integrity, cracked plaster, unleveled floors, loss of items and interior finishes, rot, rust, and spalling (Cornerstones 2008; Martínez, 2015).

As the buildings of Querétaro's historic center were erected at a time when flood levels were significantly lower, they face a growing threat of flood and its resultant damage. Due to this serious risk, it is important to not only look for infrastructure solutions, but also evaluate the potential damage to heritage zone structures and consider mitigation methods that have worked elsewhere, ultimately allowing for the implementation of effective mitigation strategies at the district level.

According to the Management Plan, the vast majority of contributing structures in the historic center are buildings with adobe walls—sometimes incorporating stone—plastered with mud and lime (Municipio 2006, Vol. I, p. 132). Walls are composed of layers of adobe bricks (sundried blocks of earth) laid over a stone foundation and held together by mud or lime mortar and wooden bond beams. Many are protected from running water by concrete curtains on the exterior base of the wall and invariably finished with layers of mud and lime plaster (See Figure 6-2) (Martínez, 2015).

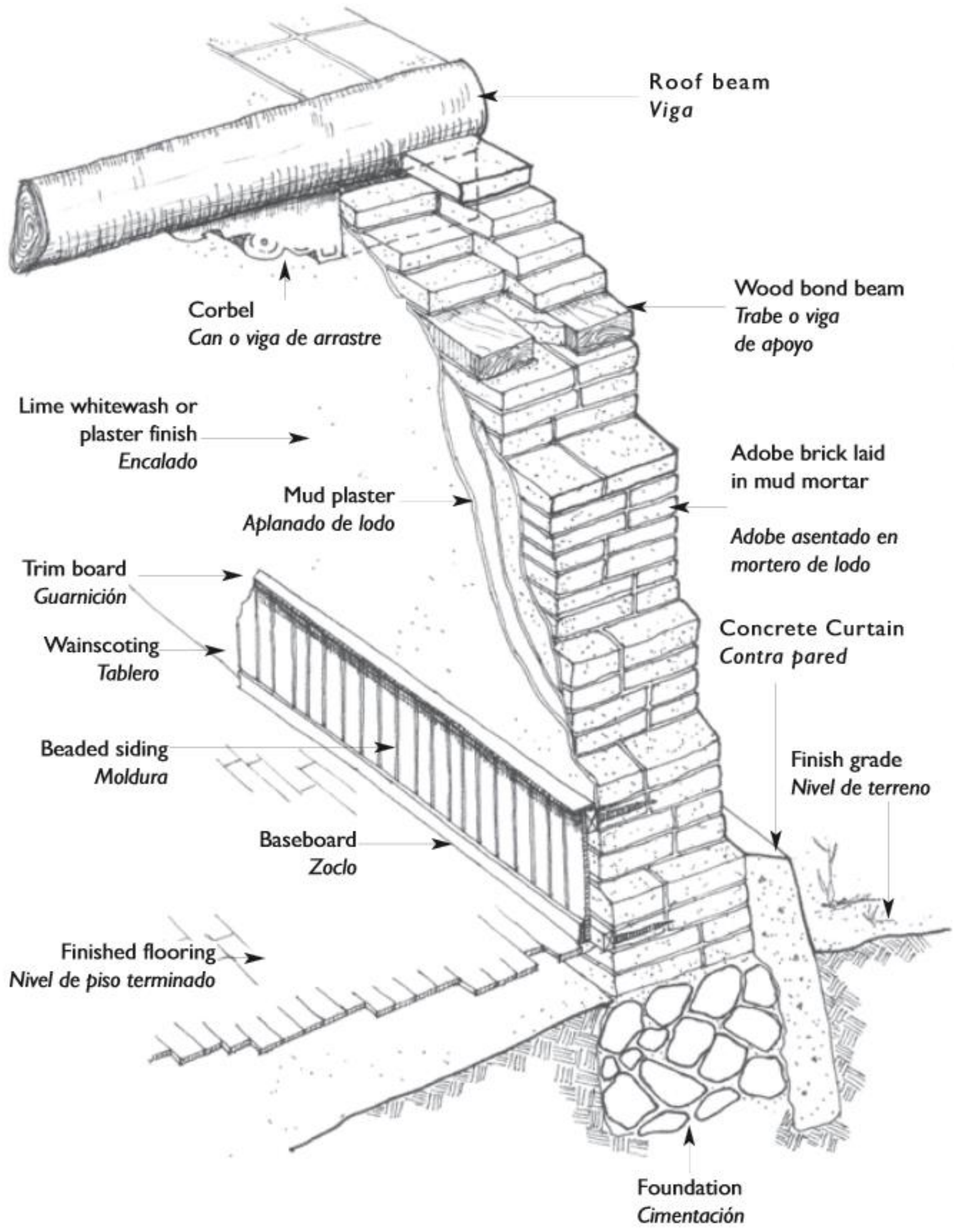


Figure 6-1: Elements of Adobe Wall Construction
(Source: Cornerstone, 2008)

Adobe is durable when well-maintained but, as its main ingredient is earth, can weather and collapse when uncared for. Furthermore, it is particularly susceptible to flooding. If exposed to running water, adobe walls are quickly eroded, compromising the structural integrity of the entire building. Long-term submergence causes the adobe to swell and become weaker as it absorbs the water (San Bartolomé, Cabrera, & Huaynate, 2012). Vertical strain on adobe doubles only after about ten hours (600 minutes) of initial submergence, making it apparently resistant to short-term first-time floods. Cycles of wetting and drying, however, cause the material to lose integrity as its earthen blocks swell, shrink, and break apart. Day's laboratory tests on adobe showed vertical strain on a sample piece of the material was sixfold after being submerged for seven days and left to dry. The sample disintegrated after only ten minutes of subsequent submergence (Day 1993, pp. 165-168; See Figure 6-2)

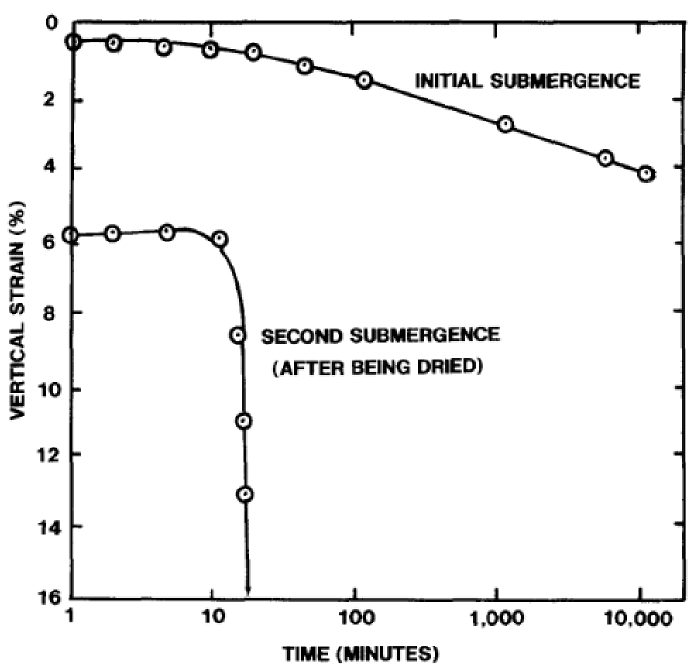


Figure 6-2: Vertical Strain on Submerged Adobe
(Source: Day 1993)

Because the interior of the walls swells as moisture is gained, the exterior layers of plaster often bulge and crack. This process exacerbates the rate of absorption—and thus the structural integrity—, as greater quantities of water seep into the wall through these cracks (San Bartolomé, Cabrera, & Huaynate, 2012). Figure 6-3 and Figure 6-4 below show common visible damage due to moisture and swelling.

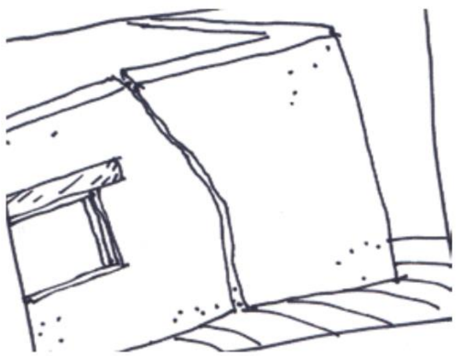


Figure 6-3: Vertical Crack due to Moisture
(Source: Cornerstone, 2008

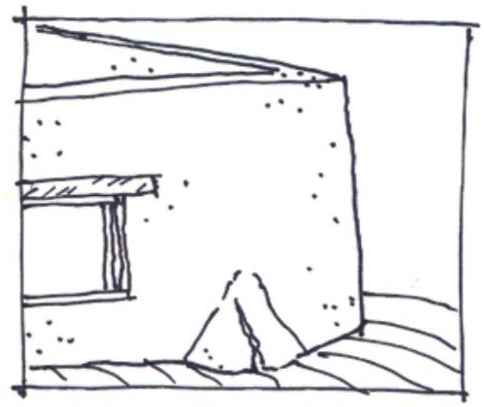


Figure 6-4: Base Bulging and Cracking due to Swelling
(Source: Cornerstone, 2008)

The adobe structures of Querétaro have remained intact so far, but it is useful to consider cases in which such structures have been affected to appropriately plan for a disaster resilient heritage zone. Cuzco, Peru has a significant inventory of adobe structures, plastered and unplastered, many of which were affected by flooding in 2010 and 2013 (Goshen College, 2010). Figure 6-5 shows a near complete collapse of a whitewashed unplastered wall after the 2008 floods outside of Cuzco. Figure 6-6 shows serious damage suffered by a plastered two-story adobe residence. The cracks in the plaster from swelling and unleveling are evident in the first and second stories. Figure 6-7 shows partially collapsed adobe homes as a result of soil and wall erosion during flooding. Figure 6-8 shows a partially collapsed wall in Cusco. Also evident is the loss of protective plaster and whitewash near the foundation of several buildings, attributable to water erosion and cracking due to swelling.

Figure 6-5: Home Affected by 2010 Cusco Floods
(Source: Goshen College 2010)

Figure 6-7: Home Affected by 2010 Cusco Floods
(Source: Goshen College 2010)

Figure 6-6: Homes Affected by 2013 Cusco Flood
(Source: Cuatro casas 2013)

Figure 6-8: Homes Affected by 2013 Cusco Flood
(Source: Cuatro casas 2013)

Chapter 7: Approaches to Mitigating Flood Effects on Built Heritage

(Image Source: Apoyemos a nuestros hermanos)

As evidenced by the Peruvian floods, Querétaro is by no means alone in dealing with flooding and having to respond to its effects on vulnerable historic structures. There are many cases and strategies from which to learn and hopefully evade serious damage in the heritage zone. This chapter will explore flood damage mitigation strategies for historic structures. Those most applicable to the case of Querétaro's Historic Center—as well as a broader set of best practices to ameliorate the flooding at the watershed level—can be found in Chapter 9: Flood Mitigation Recommendations.

While vacating flood-prone areas is presented as an option in multiple cases, the Historic Center's immense value as a cultural resource, high population density, and high property values make buyouts and demolitions a highly unlikely strategy. Such alterations are likely to also alter the city's status a UNESCO World Heritage Site.

Another severe solution unlikely to be effected is the relocation of buildings away from the flood risk area, as seen in many cases with historic buildings in United States' floodplains. This option would be ineffective due to the sheer amount of buildings in the flood risk area and the unavailability of space to relocate said structures. The building materials—adobe on rock foundations—would make the endeavor arduous and prohibitively expensive. These two options aside, there are many small- and large-scale changes that can be made to improve the zone's structures' resilience to flood events.

NON-INVASIVE INTERVENTIONS

Positive Drainage

Sloping the surrounding grounds away from building will drain water away from the walls and keep the building significantly drier. The slope can be gentle and should interfere minimally with the structure (FEMA 2008, p.10).

Elevation of Utilities

Raising electrical outlets, transformers, telephone lines and mechanical equipment reduces the risk of damage and electrical shorts caused by flooding (Martínez, 2015).

Raising Historical Items

Placing valuable historic furniture and other movable items in the second story or highest room on the ground floor keeps them safer in the event of a flood (FEMA 2008, p.11).

Flood-Resistant Materials

When repairs or rehabilitation is needed, sensible flood-resistant materials, such as brick or concrete block, should be considered, especially on ground levels and in low areas of the structure. Much care should be taken when selecting material as to not adversely affect the historicity of the structure (*ibid*).

Evaluation of Inventory

Historic district management bodies can keep track of flood preparedness and assess risk of properties. For adobe properties, assessment should include stability of materials and imperviousness of plaster.

Plastering

Keeping plaster solid greatly improves the performance of adobe in floods, as it is the wall's defense against erosion and direct absorption (San Bartolomé, Cabrera, & Huaynate, 2012).

Small floodwalls

Low-rise walls around window wells or low-lying homes can be built to prevent water intake. Similarly, door thresholds can be raised to prevent flooding in some events. Some material options for this permanent mitigation strategy are brick, poured concrete, and concrete blocks. These structures should be securely fastened to a footing to prevent undercutting and seepage. Again, care is required in design and selection of materials to adhere to character of building.

Insurance

Property owners should be encouraged to invest in insurance covering flood damage. This should facilitate rehabilitation in the event of a damaging flood event and ensure that sufficient funds are available to make repairs faithful to the building's history and character.

Temporary Protection

In the event of a flood, property owners and administrative bodies place temporary barriers such as sand bags or flood shields in openings to keep water outside buildings. Important historic items should be moved, when possible, to higher areas in the home. The success of a temporary mitigation approach depends on the level of planning by the administrative body and homeowners; residents should be aware of the low openings in their home that should be blocked off in the event of a flood and governments should have enough flood shields or sand bags to fill said openings. Monitoring should be constant and warnings given well ahead of time (FEMA 2008, p. 11).

EXTENSIVE INTERVENTIONS

Elevation

Elevation is a more suitable option to consider in Querétaro, as space is too rare and dear for relocation. Keeping buildings *in situ* would also be more adequate for a World Heritage Site. There are two types of elevation to consider: raising the entire building, an exorbitant cost for larger buildings, and raising just the interior, an option which can be considered for buildings with high ceilings and large windows. The town of Bellhaven, North Carolina, United States successfully elevated several brick buildings in its historic district and is proceeding to raise more out of the Pungo River's floodplain. Elevating the buildings saved the town $1.3 million in costs after a subsequent flood (FEMA, 2008, p. 15).

Reinforced Plastering

The Pontificia Universidad Católica de Perú in Lima has found, through materials engineering experimentation, that adobe walls often fail when adobe swells and ruptures the mud and lime plaster, allowing more water to enter and further swell and weaken the wall. One well-performing tested solution was applying the plaster over an eight-gauge wire mesh attached to the adobe wall. The mesh was nailed into lower part of the wall and then plastered over, achieving the appearance of a standard plastered adobe wall. Due to the structural reinforcement, plaster remains solid and keeps adobe dryer for much longer (San Bartolomé, Cabrera, & Huaynate, 2012). A similarly crack-free plaster can be achieved by mixing with fiberglass, but solid adherence to the adobe is not guaranteed as with the mesh.

Dry Floodproofing

This approach makes the lower portion of a building impermeable, keeping all water out of the structure and interior during a flood event. Existing building materials are replaced with flood resistant ones, or an impermeable membrane is added. Temporary floodshields are placed at remaining openings, such as doors and windows, when a flood event occurs (See Figure 7-1). Dry floodproofing can be unobtrusive and avoid disturbing a building's façade, but walls often requires interior reinforcements to withstand hydrostatic force during a flood. Membrane dry floodproofing has been used successfully in brick buildings in the historic district of Darling, Wisconsin, United States after the 1993 flood in that area (FEMA, 2008, p. 17)

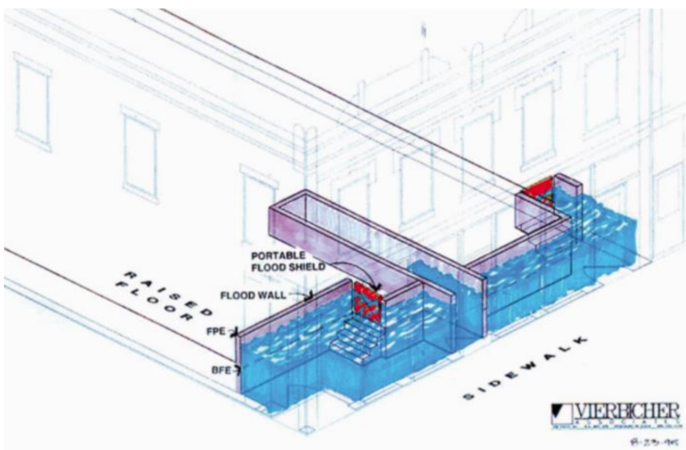
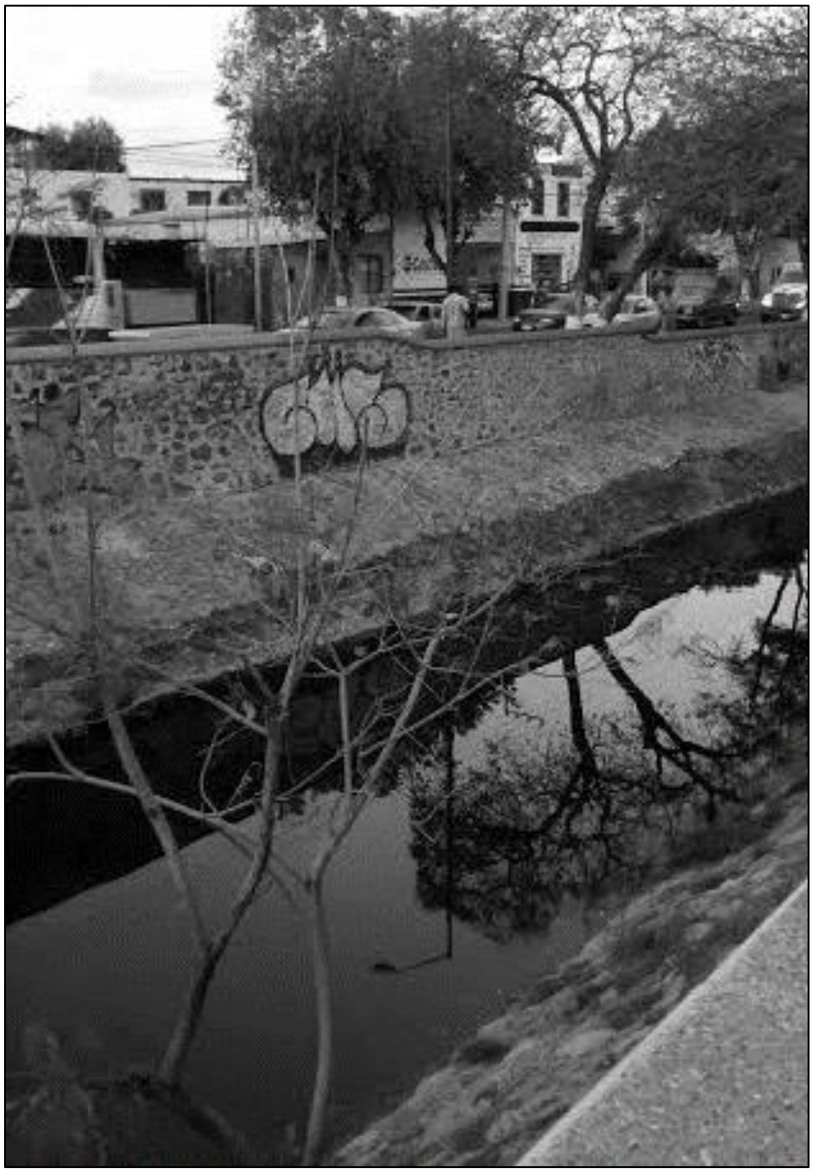


Figure 7-1: Dry Floodproofing (Source: FEMA 2008)

Wet Floodproofing

This method uses flood-resistant materials to make a structure able to withstand flooding while allowing the floodwater to enter the building. Wet floodproofing decreases the chance of hydrostatic forces damaging walls. In order for wet dryproofing to be effective in adobe structures, the inferior portion of walls would have to be replaced with flood-resistant materials or perfectly covered with a membrane protecting the walls but not the home's interior from infiltration (FEMA 2008, pp. 16-17).

Chapter 8: Current Flood Mitigation Approaches in Querétaro



Recently proposed flood mitigation efforts have come from the state and municipal governments. The state has generated new flood preparation guidelines indicating what municipalities should be doing and assigning tasks. The municipality, in the Partial Plan and Stormwater Plan, has identified several infrastructure projects and policies it deems necessary for the prevention of future flooding in the urban core of the city.

One of the primary recommendations set forth in the Partial Plan is the replacement of all infrastructure older than fifty years old in the Historic Center. This would replace the vast majority of drainage infrastructure in Perimeter A, 14.2 kilometers in total. This recommendation points out that renewing this infrastructure might lead to drier soil conditions, as current infrastructure is likely failing and seeping in multiple points. This would mean having to constantly monitor buildings for stability after drainage infrastructure replacement, as the vertisol soils react strongly to wetness and dryness, possibly adversely impacting the above structures (Municipio 2006, Vol III, p. 28).

The Partial Plan further suggests managing stormwater flows in the Historic Center through the construction of 2.5 kilometers of additional underground drainage flowing into the Querétaro River (Municipio 2006, Vol III, p . 33).

Through the Stormwater Plan, the municipality proposes revivifying the Querétaro River in the urban core. It proposes acquiring federal funds to conduct a study on integrated regeneration of the River and reestablishing the green areas beside it to maximize its ecosystem services. (Municipio 2006, Vol IV, p. 2).

Recently, the state government has announced an ongoing investment of 197 million pesos for implementation of the Stormwater Plan. This will include construction of a dam and a retaining berm, as well as river rehabilitation programs and a new drainage channel. (Mares 2015, p. 2).

The Stormwater Plan identified multiple areas in the urban core, including several blocks of the Historic Center as areas with medium flooding risk which require infrastructure improvements (See Figure 8-1). These infrastructure improvements would be addressed in phases II and III of the Stormwater Plan's implementation by replacing or widening existing stormwater drainage (See Figure 8-2; Facultad 2009, p. 191).

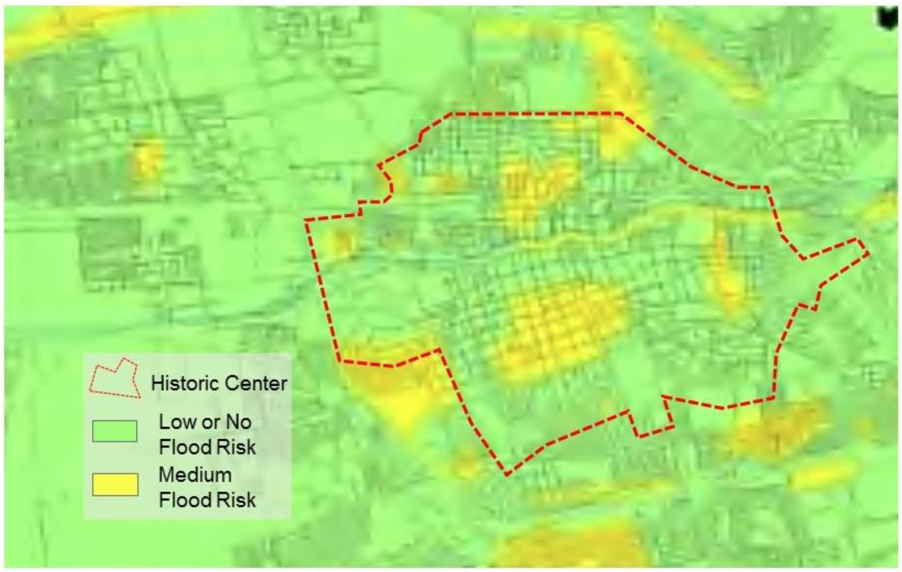


Figure 8-1: Areas with Medium Flood Risk Requiring Improvements

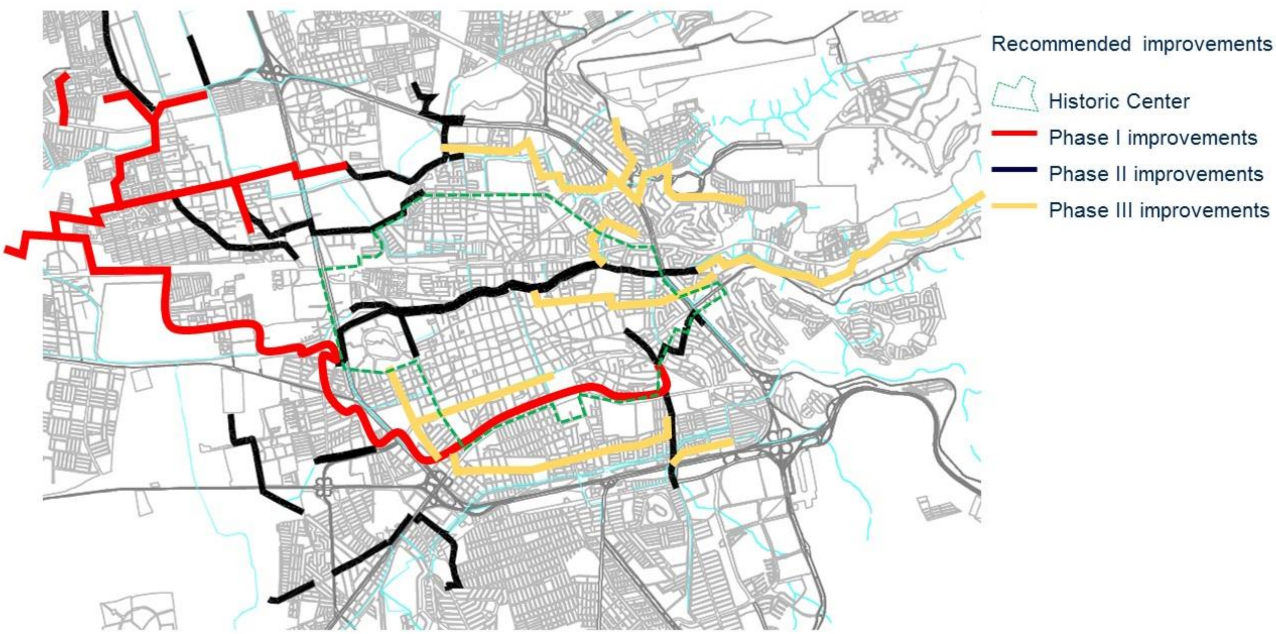


Figure 8-2: Improvements Proposed in Stormwater Management Plan
Source: Plan Maestro Pluvial, 2009

Chapter 9: Flood Mitigation Considerations for Querétaro

(Image source: Evalúan daños 2014)

The edifices in Querétaro's historic center were erected at a time when flood levels were significantly lower and are under ever-growing threat as impervious cover increases without the adequate corresponding infrastructure improvements being built. Residents of the entire metropolitan area are following the flooding problems closely through the media and experiencing it in person. Planners and preservationists should use this period of increased to institute the reforms and programs that will ensure the continued authentic existence of the heritage zone.

Considerations are organized into two broad categories: those to be implemented at the historic district level and those implemented at the municipal or metropolitan level. The former include addenda to the 2005 Management Plan, programs that can be carried out by the municipality's historic preservation department or residents themselves, flood-mitigating improvements to historic properties, and municipally installed infrastructure to benefit the district. The latter includes development regulation in the metropolitan area and large-scale stormwater drainage infrastructure projects.

HERITAGE ZONE CONSIDERATIONS

Historic Character Regulation

Flooding mitigation will ensure inventory survives to be appreciated and utilized by the next generation. In the management plan, explicitly permit property owners in the historic center to make modifications to buildings when done to increase disaster resilience. All physical modifications still must conform to the original character of the building. Institute an expedited review process for such cases.

Assessment and Rehabilitation

Establish commission at district level to periodically assess and monitor the condition of inventory in the heritage zone. These members can be municipal employees, preservation students, or volunteering residents. The team should especially note structural issues—such as cracked plaster, wall swelling, and negative incline—making properties more susceptible to damage from flooding. Provide assistance in finding qualified maintenance/rehabilitation person to resolve structural issues.

Training and Information

Establish monthly or bi-monthly courses and clinics to inform residents of historic center about risks from flooding and moisture and how to make easy repairs. Provide visual examples of common structural issues and what to look for.

Reinforced Plastering

Promote the use of wire-reinforced plaster on lower portions of walls. The low cost and simplicity of this strategy makes it affordable and widely available, while the limited intrusiveness allow the structure to retain its character and original wall structure. Homeowners can easily implement when having their home replastered.

Insurance

Encourage homeowners to acquire insurance policy with flood protection. Flood insurance allows for adequate maintenance of the historic property should it suffer reparable damage without the homeowner having to bear the cost burden of a historic rehabilitation.

Flood Plan

Develop a participatory flood action plan. Encourage neighbors with place for storage or sizeable rear courtyards to stow sandbags for fast distribution in case of a flood. Ensure residents know which openings in home are most risky and how to effectively block them using sandbags or flood barriers. Develop safe points for people to congregate in the event of a large flood.

Purchase of development rights

Continue purchase of development rights for historic center properties. Encourage spending of payment on flood mitigation or charge percentage fee to be spent on flood mitigation in the rights seller’s home or in the district as a whole.

Replacing drainage system

Make central drainage network more robust and divert downstream to avoid accumulation in the Querétaro River. Consider replacing aging combined sewer system in historic zone, but carefully evaluate and monitor buildings, as moist alluvial clays undergird historic center and would dry if new system does not allow for percolation into soil. Drying soil would compress, crack, and compromise the structural integrity and level floors of structures above.

MUNICIPAL AND METROPOLITAN CONSIDERATIONS

Integration into Hazards Planning

Incorporate historic property and cultural resource considerations into hazard mitigation planning. The historic center is important enough to warrant inclusion and special consideration, as its loss would severely affect the economic and social vitality of the city.

Impervious cover

Set limits on impervious cover in new developments, especially those uphill from urban core (north, east and south). Consider requiring developers to include pervious streets, parking lots, and driveways on new developments. Enforce generated stormwater diversion plan for new developments set forth in the 2008-2015 Stormwater Management Plan.

Growth restrictions in Querétaro River basin

At the metropolitan level, enact a system of transfer of development rights, similar to the one proposed for the historic center in the 2005 Management Plan, for the Querétaro River basin (Moreno Gómez, 2011, p. 5). Alternately, the municipalities—especially Querétaro municipality, the most affected—should consider purchase or purchase of development rights in the basin to prevent exacerbated flooding. Purchase-of-development-right land will continue to provide innumerable ecosystem services, while outright purchased hectares can be used by the purchasing municipality or municipalities to establish parkland or ecotourism.

Green infrastructure

Incorporate green infrastructure into rivers and streams of the area, allowing for swelling of rivers and adequate percolation zones. Sufficient infrastructure will mitigate risk of the streams bursting their banks in the urban core (Moreno Gómez, 2011, pp. 4-7).

Completion and reinforcement of diversion network

Complete Phases I-III of stormwater management infrastructure in the historic center (See Figure 8-2: Improvements Proposed in Stormwater Management Plan). Also complete and re-evaluate effectiveness of metropolitan stormwater diversion networks (See Figure 4-10: Urban Drainage Infrastructure for the Metropolitan Area). Reinforce drainage channels to prevent further ruptures and seepages (See Appendix A).

These considerations are by no means exhaustive and are the result of an initial exploration into the highly relevant and important matter of disaster resilience and historic preservation in Mexican World Heritage Sites. Preserving these places is not a task we can postpone indefinitely, as serious flood events are already becoming not only more frequent but more severe in this area of the Bajío. Our very ability to continue proudly bestowing unto upcoming generations our built heritage will directly depend on initiatives taken in the present.

Appendix A: Images from 2014 Flood

Figure A-1: Querétaro River
(Source: Noticias Querétaro)

Figure A-2: "El Arenal" Drainage Channel Overflowing
(Source: Evalúan daños)

Figure A-3: Ruptured Retention Wall on Río Querétaro
(Source: Torres & Benítez 2014)

Figure A-4: Ruptured Drainage Channel
(Source: Evalúan daños)

References

Apoyemos a nuestros hermanos en las inundaciones de Tabasco. (n.d.). Retrieved from Vecindad: http://blogvecindad.com/apoyemos-a-nuestros-hermanos-en-las-inundaciones-de-tabasco/

Atlas Naicional de Riesgos. (2014, December 10). Retrieved from Centro Nacional de Prevención de Desastres: www.atlasnacionalderiesgos.gob.mx/

Censo de Población y Vivienda. (2010). *INEGI*.

Cornerstones Community Partnerships. (2008). *How to Save Your Adobe Home in the Event of a Flood Disaster.*

Cuatro casas colapsadas y 30 afectadas por lluvias en Cusco. (2013, March 19). *La Prensa*. Retrieved from http://laprensa.peru.com/actualidad/noticia-cuatro-casas-colapsadas-y-30-afectadas-lluvias-cusco-4340

Day, R. W. (1993). Performance of historic adobe structure. *Journal of Performance of Constructed Facilities*, *7*(3), 164-169.

Evalúan daños en capital de Querétaro por inundaciones. (2014, August 19). *Diario Rotativo*.

Facultad de Ingenieria de la Universidad Autónoma de Querétaro. (2009). *Plan Maestro Pluvial de la Zona Metropolitana de Querétaro (2008-2025).* Querétaro, Qro.

FEMA. (2008). *Floodplain Management Bulletin: Historic Structures.*

García Ugarte, M. E. (1992). *Hacendados y rancheros queretanos: 1780–1920.* Consejo Nacional para la Cultura y las Artes.

Gobierno del Estado de Querétaro. (1985). *Querétaro Rescate Patrimonial.*

Gobierno del Estado de Querétaro. (2009). *Plan Querétaro 2010-2015.*

Goshen College. (2010). *Peru Study-Service Team.* Retrieved April 3, 2015, from https://www.goshen.edu/peru/2011/10/02/

Instituto Nacional de Antopología e Historia. (1987). *Catálogo Nacional Monumentos Históricos Inmuebles, Estado de Querétaro* (Vol. I).

Instituto Nacional de Antropología e Historia. (1987). *Catálogo Nacional Monumentos Históricos Inmuebles, Estado de Querétaro* (Vol. II).

Mares, P. (2015, March 6). Invertirán 183 mdp en obras para el 2015 en Querétaro. *ADN Informativo*. Retrieved from http://adninformativo.mx/invertiran-183-mdp-en-obras-para-el-2015-en-queretaro/

Martínez, E. (2015, January 15). Planner, Instituto Municipal de Planeación del Municipio de Querétaro. (G. Lule-Hurtado, Interviewer)

Moreno Gómez, A. (2011, November-December). Cómo evitar inundaciones en el estado de Querétaro. *Ingeniero Civil*, pp. 4-8.

Municipio de Querétaro. (2006). *Plan Parcial de Desarrollo Urbano de la Zona de Monumentos Urbanos y Barrios Tradicionales de la Ciudad de Santiago de Querétaro.*

Piperno, A., & Sierra, P. (2007, May). Estrategias desde el ordenamiento territorial para la prevención y mitigación de inundaciones. *Jornadas Internacionales sobre Gestión del Riesgo de Inundaciones y Deslizamientos de Laderas.*, 1-15.

Poder Ejecutivo de la República. (2003). *Declaratioria de Desastre - Inundaciones en Querétaro.*

Quantrill, M. (2007). *Space and Place in the Mexican Landscape.* College Station, Texas: Texas A&M University Press.

Ruiz González, I. (2015, January 16). Subdirector, Centro de Investigación del Agua de Querétaro. (G. Lule-Hurtado, Interviewer)

San Bartolomé, Á., Cabrera, D., & Huaynate, W. (2012). Experimental Study on Adobe With Long Term Water Exposure due to Floods. *12th Canadian Masonry Symposium*.

Soil Conservation Service. (1989). *Runoff Curve Number Computations.* US Department of Agriculture.

Torres, M., & Benítez, E. (2014). *Inundaciones del 19 de agosto.* Evaluación de Riesgos Naturales.

UNESCO World Heritage Committee. (1995). *World Heritage List Evaluation No. 792: The Historic Monuments Zone of Querétaro.*

Unidad Estatal de Protección Civil del Estado de Querétaro. (2013). *Plan Estatal Para la Atención de Fenómenos Meteorológicos.*

World Bank. (2011). *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century*.

Vita

Gibrán N. Lule-Hurtado was born in La Moncada, Guanajuato, Mexico. He obtained his Bachelor of Arts in Political Science and Global Politics from the University of Texas at Dallas and taught bilingual third and fourth grade in Irving, Texas for two years before enrolling at the University of Texas to pursue a Master of Science in Community and Regional Planning. His research and work interests include historic preservation in Mexico and Latin America (including the Southwest United States), disaster resilience, and community involvement in planning.

Permanent Address: El Gallo Nº 1
La Moncada, GTO
México
38720

gib.lule@gmail.com

This Professional Report was typed by the author.