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Department of Landscape and Urban Planning



Landscape Planning master's degree program

Diploma Thesis

**Approaches to restoration and conservation of the urban
ravines in Puebla City, Mexico**

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Thesis title

Approaches to restoration and conservation of the urban ravines in the City of Puebla, Mexico

Objectives of thesis

This thesis aims to suggest the first theoretical and practical guide for restoring the urban ravines in Puebla City.

Methodology

The theoretical part will cover legislation related to the urban ravines in other countries, the issue of soil erosion, and the environmental, social, and economic information about Puebla City referring to the ravines.

Based on available GIS data (points shapefile of ravines) and orthophotographs, a new polygon shapefile and database of urban ravines in Puebla City will be created.

According to the review of ravine management from other countries, a set of guidelines will be suggested for managing urban ravines in Puebla City.

The proposed extent of the thesis

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Keywords

soil erosion control, ravines, water regime, soil loss

Recommended information sources

- Gutierrez, P. V. et al. 2019. The ravines of Puebla City, Mexico. An untapped resource in a metropolis with a deficit of green areas. Redalyc.
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- Morgan, R. C. P. 2005. Soil Erosion and Conservation (third edition), Blackwell Publishing, Oxford, UK, 304 pp.
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A handwritten signature in black ink, appearing to be 'Alfonso Sánchez', written in a cursive style.

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Abstract

This thesis addresses the urban ravines situation in Puebla City to propose guidelines for its restoration and conservation. The theoretical phase is composed of an extensive review of the legislation in Puebla City and the legislation and management programs of the Mexican States of Mexico City, Morelos, and Jalisco. Also, a literature review covered the conditions in Puebla City, the previous studies and articles that directly and indirectly addressed the issues in the urban ravines, and the Toronto Ravine Strategy. Additionally, a set of maps is created from existing spatial data to characterize the ravine system in Puebla Municipality.

All the information mentioned was organized and processed to achieve two objectives. First, create a shapefile layer representing the urban ravines in Puebla City using available spatial data with ArcGIS Pro 3.0.2 and supported by Google Earth Web. Second, to propose guidelines for their restoration and conservation.

Keywords: urban ravines, restoration, spatial data, management

Abstrakt

Tato práce se zabývá situací městských roklí ve městě Puebla a navrhuje způsoby jejich obnovy a zachování. Teoretickou část tvoří rozsáhlý přehled legislativy města Puebla a souhrn legislativy a správních programů mexických států Mexico City, Morelos a Jalisco. Další součástí práce je literární rešerše dokumentů týkajících se podmínek ve městě Puebla, souhrn předchozích studií a článků, které se přímo i nepřímo zabývaly problematikou městských roklí, a dále pak přehled torontské strategie pro městské rokly (Toronto's Ravine Strategy). Z existujících prostorových dat byla vytvořena sada map, které charakterizují systém roklí ve městě Puebla.

Všechny uvedené informace byly uspořádány a zpracovány tak, aby bylo dosaženo dvou cílů. Prvním cílem bylo vytvořit vrstvu představující městské rokly ve městě Puebla s využitím dostupných prostorových dat v programu ArcGIS Pro 3.0.2 a s podporou aplikace Google Earth Web. Druhým cílem pak bylo navrhnout postupy pro obnovu a zachování městských roklí.

Klíčová slova: městské rokly, obnova, prostorová data, správa

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List of acronyms translated from Spanish to English.

CONABIO

Spanish: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad

English: National Commission for the Knowledge and Use of Biodiversity

CONAPO

Spanish: Comisión Nacional de Población

English: National Commission of Population

IMTA

Spanish: Instituto Mexicano de Tecnología del Agua

English: National Institute of Water Technology

INECC

Spanish: Instituto Nacional de Ecología y Cambio Climático

English: National Institute of Ecology and Climate Change

INEGI

Spanish: Instituto Nacional de Estadística, Geografía e Informática

English: National Institute of Statistics, Geography, and Informatics

PAOT

Spanish: Procuraduría Ambiental y del Ordenamiento Territorial de la Ciudad de México.

English: Mexico City Environmental and Land Management Attorney's Office

SIAMEP

Spanish: Sistema de Información Ambiental del Estado de Puebla

English: Environmental Information System of Puebla State

SMADSOT

Spanish: Secretaría de Medio Ambiente, Desarrollo Sustentable y Ordenamiento Territorial

English: Secretary of Environment, Sustainable Development and Planning

UACM

Spanish: Universidad Autónoma de la Ciudad de México

English: Autonomous University of Mexico City

UNAM

Spanish: Universidad Nacional Autónoma de México

English: National Autonomous University of Mexico

1.0 Introduction

The environmental sector in Mexico has been facing several political and administrative changes in recent years, which are revealing the need to establish a common vision to manage certain natural spaces.

Within this framework, many natural spaces that were ignored before are being revalorized. However, the current conditions of many of those spaces are demanding significant investments, addressing socio-environmental problems, and many other factors in a single issue.

The impacts made on these spaces are mostly from human activities, especially if they are inside an urban area. This is the case of the ravines in Puebla City, which are recognized as urban ravines due to their location and the impacts affecting them.

The urban ravines in Puebla City are functioning nowadays as disposal sites, for wastewater, solid waste, construction debris, and domestic garbage. The common vision about the ravines for many inhabitants is that those spaces are synonyms of pollution, bad odors, are dangerous, and are not compatible with recreational activities.

It has been like this for at least 40 years, considering the experiences of my family members who shared personally that there was one time when these spaces were used to play and spend time.

Now, my personal experience in the Czech Republic showed me an example of how those times could be, with accessible and functional areas with water flows and living organisms living their cycles.

Those experiences are the motivation of this thesis that aims to propose guidelines for the restoration and conservation of the urban ravines in Puebla City. The literature review includes an extensive review of the local legislation together with the legislation and management programs of other Mexican states was made to identify how the authorities perceive the urban ravines.

Additionally, relevant information about Puebla City and the few valuable studies and articles that addressed the issues with the urban ravines in Puebla City were considered together with the Toronto Ravine Strategy. Besides, several maps

where created with the available spatial data from INEGI to identify the ecological features of the ravine system in the whole municipality,

Considering the information above, a shapefile layer was created using ArcGIS Pro 3.0.2, Google Earth Web, together with the personal knowledge as citizen of Puebla City. The layer was created to know the extension of the urban ravines and support the proposal of guidelines for their restoration and conservation. Hereunder, are more details about the process.

2.0 Aim of the thesis

This thesis aims to suggest guidelines for the restoration and conservation of the urban ravines in Puebla City.

The first objective is to create a new polygon shapefile of the urban ravines in Puebla City, based on available GIS data (points shapefile of ravines), satellite imagery, and other helpful shapefiles.

The second objective is to suggest guidelines for restoring and conserving the urban ravines based on the studies conducted in Puebla City, the management experiences from other Mexican states (Mexico City, Morelos, and Jalisco), the Toronto Ravine Strategy, and the GIS data generated.

3.0 Methodology

Using spatial data from Mexican official sources together with the software ArcGIS Pro 3.0.2 and Google Earth Web version, a polygon shapefile representing the urban ravines in Puebla City was created to calculate their extension and support the guidelines for their restoration and conservation.

The suggestion of guidelines was made following a process that made possible the identification of four main aspects from the information reviewed. They were adapted to the Puebla City context and classified as: legal guidelines, guidelines for stakeholders and transparency, environmental guidelines, and guidelines for social engagement and cultural development.

4.0 Literature review

4.1 What is meant by a ravine in the national and local legislation?

The concept of a *ravine* in Mexico has some slight differences according to the different approaches needed or the territory of study. Even so, a conception of this word can be found in the updated *Geomorphological Dictionary* made by [Jose Lugo Hubp \(2011\)](#) and published by the university UNAM, one of the most recognized institutions in Latin America. The definition states:

“Ravine¹: Negative linear shape of relief, narrow, with steep slopes, often branching towards the headwaters. In length, it reaches some kilometers, and in width and depth, some tens of meters. They are generally formed in incoherent or easily eroded rocks, such as loess, pyroclastic deposits, and conglomerates, by seasonal runoff of rain and snow water. (...)” (p. 44)

The description above shows a detailed understanding of what a *ravine* is; however, this approach has a clear meaning for scientific and academic purposes.

Due to the objectives that this thesis pursues, another approach was necessary to start understanding the situation of the ravines in Puebla City. That approach was the legal conception, an important factor to consider since environmental law regarding the protection of the natural resources in Mexico has a historical background dating back to 1917, the year of the declaration of the first natural protected area, which corresponds to a national park named “*Desierto de los Leones*” ([Anglés Hernández et al., p.30](#)).

At this point, it is necessary to mention that Mexican law is a system based on the *Kelsen pyramid of law*, which represents graphically the hierarchy of the legislation and how they are related ([López, 2014, p.1](#)) as it is shown in the Figure 1.



Figure 1: Kelsen pyramid for the Mexican legislation: Source: Made with information from López (2014)

¹ Original text in Spanish states: Barranco, m. forma lineal negativa del relieve, estrecha, con laderas abruptas, con frecuencia se ramifica hacia la cabecera. En longitud llega a alcanzar algunos kilómetros, y en anchura y profundidad. Los barrancos se forman generalmente en rocas incoherentes o fácilmente erosionables, como los loess, depósitos piroclásticos y conglomerados, por escurrimiento de temporada de las aguas pluviales y nivales.

Considering the above hierarchy and the fact that all actions or projects related to the environment in Mexico are subject to law, a review of environmental laws, governmental strategies, or assessments that may describe or mention the ravines, was pertinent. The review also had the intention of finding the possible actions, regulations, prohibitions, authorizations, or measures that are considering the ravines somehow. The documents reviewed pertain to the three levels of the Mexican government (national, state, and municipal), which apply to Puebla City.

In total, there were 14 documents revised:

- Five Federal Environmental laws:
 1. [General Law of Ecological Balance and Environmental Protection \(1988\)](#)
 2. [National Water Law \(1992\)](#)
 3. [General Law for the Prevention and Integral Management of Waste \(2003\)](#)
 4. [General Law of Sustainable Forestry Development \(2018\)](#)
 5. [General Law of Climate Change \(2012\)](#)
- Four Puebla State Environmental laws:
 1. [Law for Natural Environment Protection and Sustainable Development of the State of Puebla \(2002\)](#)
 2. [Law for the Prevention and Integral Management of Urban Solid and Special Handling Waste of the State of Puebla \(2006\)](#)
 3. [Water Law for the State of Puebla \(2012\)](#)
 4. [Law for Urban Planning and Development of the State of Puebla \(2017\)](#)
- Two Puebla State strategies:
 1. [State Strategy for Climate Change 2021-2030, issued by the Secretary of Environment, Sustainable Development and, Planning of the State of Puebla \(2021\)](#)
 2. [Strategy for conservation and sustainable use of biodiversity of the State of Puebla \(2013\)](#)
- One State Plan:
 1. [State Plan for Development 2019-2024 \(2019\)](#)
- One State Assessment (document supported by the state government)
 1. [Biodiversity in Puebla: State Assessment \(2011\)](#)
- One Municipal Plan of Development and 1 Municipal assessment
 1. [Municipal Plan for Development 2021-2024 \(2021\)](#)

The Table 1 hereunder shows a summary of the results, including the name of the documents consulted, the publication year, its hierarchy (national, state, or municipal), and an extract of the paragraph where a strategy, plan, or action is applied to the ravines. In some cases, no mention of ravines was found.

Table 1: Legislation reviewed to find strategies, plans or actions related to the ravines in Puebla City

Document	Year	Hierarchy	Strategy/Plan/Action related to ravines
General Law of Ecological Balance and Environmental Protection	1988	Federal	No mention of ravines
National Water Law	1992	Federal	No mention of ravines
General Law for the Prevention and Integral Management of Waste	2003	Federal	(1) Article 100, 1 st prohibition: "Dumping waste in public space, vacant lots, glens, ravines, drainage, and sewage pipelines (..) and non-authorized sites by related legislation. (2) In the same way, prohibit the disposal of tires in vacant lots, ravines, glens, sewage pipelines, water bodies, and subterranean cavities" (p.34)
General Law of Sustainable Forestry Development	2018	Federal	No mention of ravines
General Law of Climate Change	2012	Federal	No mention of ravines
Law for Natural Environment Protection and Sustainable Development of the State of Puebla	2002	State	(1) Article 1: "establishing buffer zones between soils destined for conservation, urban, industrial zones, human settlements, the federal zone of ravines, dam reservoirs, and river slopes" (p.14)
Law for the Prevention and Integral Management of Urban Solid and Special Handling Waste of the State of Puebla	2006	State	(1) Article 39: "Deposit or throw any type of waste on roads, public spaces, brownfields, ravines, glens (...) is prohibited" (p.36)
Water Law for the State of Puebla	2012	State	No mention of ravines
Law for Urban Planning and Development of the State of Puebla	2017	State	(1) Article 111: "No authority may grant licenses, feasibilities, permissions, or any other authorization related to the foundation and/or creation of human settlements on the rights of electrical, communications, and hydraulic communications, as well as risk zones corresponding to rivers and ravines" (p.82-83)
State Strategy for Climate Change 2021-2030, issued by the Secretary of Environment, Sustainable Development and, Planning of the State of Puebla	2021	State	No mention of ravines
Strategy for conservation and sustainable use of biodiversity of the State of Puebla	2013	State	No mention of ravines
State Plan for Development 2019-2024	2019	State	No mention of ravines
Biodiversity in Puebla: State Assessment	2011	State	No mention of ravines

Table 1: Legislation reviewed to find strategies, plans or actions related to the ravines in Puebla City

Document	Year	Hierarchy	Strategy/Plan/Action related to ravines
Municipal Plan for Development 2021-2024	2021	Municipal	<p>(1) "In addition to the previous information, the main issues as deficiencies in urban mobility, informal commerce, (...) the pollution of ravines, and the lack of green areas in the city" (p.48).</p> <p>(2) "Respecting the environmental issues, it was exposed the main issue of the deficiency of waste collection service, as it generates waste incineration at brownfields or lands and the pollution of water runoff and ravines" (p.51)</p> <p>(3) "the problem of deforestation by clandestine logging and forestry plagues, the use of ravines as urban solid waste, construction waste sites, and the excessive waste from local festivities" (p.52)</p> <p>(4) Nonetheless, there is still an important volume of waste on roads, wastelands, and ravines, generating pollution at sites like Alseseca and Atoyac Rivers" (p.144)</p> <p>(5) "Propose strategies to recover the ravines and the micro watersheds in the municipality"(p.170)</p> <p>(6) "Conduct clean-up days at municipal markets, housing units, and ravines, promoting civic engagement." (p.172)</p>

The legislation reviewed showed that at the national level only one law explicitly mentions the word *ravine*, which is the [General Law for the Prevention and Integral Management of Waste \(2003\)](#) and is limited to applying prohibitions to waste dumping. The other laws do not mention the ravines, nonetheless, the interpretation of some definitions might implicitly include the ravines, for instance, the definition of environment that is stated in the explicitly [General Law of Ecological Balance and Environmental Protection \(1988\)](#), which states the following (next page).

“Article 3°. Environment²: The set of natural and artificial elements or induced by the human that make possible the existence and development of human beings and other living organisms that are interacting within a determined space-time” (p.2)

On the other hand, the legislation for the state level revealed that three laws mention the ravines explicitly, which are:

- [Law for Natural Environment Protection and Sustainable Development of the State of Puebla \(2002\)](#): Mentioning the creation of buffer zones in strategic zones, including the ravines, indicating that they are under federal jurisdiction.
- [Law for the Prevention and Integral Management of Urban Solid and Special Handling Waste of the State of Puebla \(2006\)](#): Prohibits the disposal of waste of any type in different zones, where ravines are mentioned.
- [Law for Urban Planning and Development of the State of Puebla \(2017\)](#): Where the ravines are indicated as risk zones, therefore, no grant of licenses, feasibility studies, permissions, or other kinds of authorizations should be done for the creation of human settlements.

Finally, the municipal review showed the most mentions of the ravines in the document [Municipal Plan for Development 2021-2024](#), which is a document that describes the guidelines of development the city will follow either for the economy, society, or environment, among other areas, during the period of administration of the ongoing government, which is 6 years until the next political elections.

The current plan of development, in summary, recognizes and identifies some problems affecting the ravines located in Puebla City, for instance, the pollution, the pressure from urban development, or the lack of an effective waste collection system. It is also aware that proposals to recover the ravines are needed as they are part of the micro watersheds that are supplying the city. This first revision, shows that even though the concept of a *ravine* is used, there is not an official definition addressed in all hierarchies. Additionally, no management programs were found, either from the Puebla State, Puebla Municipality, Puebla City, governmental institutions, or academic groups.

² Original text in Spanish states: Ambiente - El conjunto de elementos naturales y artificiales o inducidos por el hombre que hacen posible la existencia y desarrollo de los seres humanos y demás organismos vivos que interactúan en un espacio y tiempo determinados

4.2 Legislation and management of ravines in other states of Mexico.

Due to the results found previously, the review was extended to other Mexican states too. The intention was to find possible examples outside Puebla City, Mexico where other states might be applying some laws, strategies, plans or management programs specially for the ravines in their territories. The research revealed four states of the country that have laws or management programs directed to their ravines. A list of those documents is shown below.

- Mexico City
 1. Legislation:
 - [Environmental Law for Land Protection in Mexico City \(2000\).](#)
 2. Assessments made by local authorities:
 - [Irregular settlements and environmental risk at the ravines of "Cuajimalpa de Morelos" Delegation, Federal District \(2010\).](#)
 - [Risk Zones and Environmental Vulnerability at the ravines of "Álvaro Obregón" Delegation, Federal District \(2010\).](#)
 3. Assessments made by tender from local authorities:
 - [Assessment: Technical diagnostics to determine environmental disturbances conditions at the ravines of the Federal District \(2010\).](#)
- Mexico State
 1. Environmental Impact Assessments:
 - [Environmental Impact Assessment for the executive project about the sanitation of the ravines and creeks at "Huixquilucan" Municipality, Mexico State \(2012\).](#)
- Morelos State
 1. Management Plans
 - [Integral plan for the sustainable management of the northwestern ravines of the State of Morelos \(2012\).](#)
 - [Integral management plan for the ravines system in northwestern of Morelos \(2018\).](#)
- Jalisco State
 1. Management Program
 - [Technical Justification Study and Management Program: Ravines of "Santiago" and "Verde" Rivers \(2018\).](#)

The Table 2 on the next page, shows a summary of the results, where there are extracts and descriptions of the articles from the Mexico City environmental law where the word *ravine* is mentioned. The Table 3 includes a brief description of the management programs or assessments from the other states.

Table 2: Mexico's City Law including the ravines in its content.

State	Document	Year	Strategy/Plan/Action or Objective related to ravines
Mexico City	Environmental Law for Land Protection in Mexico City	2000	<p>(1) Article 3: "Establishing intermediate buffer zones between agricultural zones, the federal zone of ravines, wetlands, dam reservoirs, water bodies, and channels" (p.3).</p> <p>(2) Article 5: "Ravine: A geographic depression that, due to its topographic and geological conditions, is presented as a crevice, and serves as a refuge for wildlife, a channel for natural runoff from rivers, streams, and rainfall, and is important area for the hydrological and biogeochemical cycle" (p.6).</p> <p>(3) Article 5: "Ecological land use planning: compulsory environmental regulation (...) realization of activities for soil conservation and integrated ravines to urban development programs". (p.11).</p> <p>(4) Article 10: "Delegations should allocate a percentage of annual funds to guarantee the maintenance, protection, preservation, and monitoring of green areas and ravines within their delimitation" (p.26).</p> <p>(5) Article 10: "Delegations that do not have at least 9 square meters of green area per inhabitant should increase it to reach that objective with alternatives to creating new green areas as green roofs, ravines, the removal of unnecessary asphalt in esplanades, and pathways, vertical green areas, and planters in secondary streets" (p. 26-27).</p> <p>(6) Article 46: Related to activities that need authorization. Ravines are included in this article if they are affected by activities that may affect vegetation and surface runoff soils (p.42).</p> <p>(7) Article 58: Related to payment of rights for real state or office construction projects, where there is additional payment if the construction or maintenance activities are next to ravines and other environmentally valuable areas (AVA) (p.52).</p> <p>(8) Article 85: Related to criteria that must be followed for the protection, restoration, and preservation of environmentally valuable areas, where ravines are mentioned and their watercourses and ephemeral or permanent cannot be modified permanently (p.69).</p> <p>(9) Article 88 bis 1: Is about prohibited activities in specific areas, where ravines are included. The activities are construction of any kind, change of land use, extraction of vegetation or soil by non-authorized entities, or deposit of construction debris. (p.75).</p> <p>(10) Article 90 bis: About areas of environmental value categories that belong to Mexico City administration, where urban forests and ravines are included. (p.77).</p> <p>(11) Article 90 bis 3: About areas of environmental value, where ravines are included. Also, it is mentioned that the competent secretary should elaborate an environmental diagnostic.</p>

Table 3: Management Programs and Assessments for the ravines in other Mexican States

State	Document	Year	Description about the document
Mexico City	Irregular settlements and environmental risk at the ravines of "Cuajimalpa de Morelos" Delegation, Federal District	2010	This document evaluates the conditions at one of the delegations in Mexico City, providing information that includes issue descriptions, information gathered from other studies, on-site analysis, and complaints related to the ravines. It also includes a methodology for cartography using satellite imagery (<i>QuickBird 2007-2008</i>) and the software ArcMap 9.3.
Mexico City	Risk Zones and Environmental Vulnerability at the ravines of "Álvaro Obregón" Delegation, Federal District	2010	Document intended to provide information for decision-making processes related to the risk zones and environmental vulnerability at the ravines of the "Álvaro Obregón" Delegation. It recognizes the degradation of the ravines.
Mexico City	Assessment: Technical diagnostics to determine environmental disturbances conditions at the ravines of the Federal District	2010	Document that makes a diagnosis about the severity of the disturbances at 3 ravines, where an ecological characterization is made including the soil, geology, climate, flora, and fauna. It also identifies and links local regulations about land tenure and planning that apply in those ravines. Finally, reports from on-site analysis include together with picture evidence, cartography made in Google Earth, and graphs.
Mexico State	Environmental Impact Assessment for the executive project about the sanitation of the ravines and creeks at Huixquilucan Municipality, Mexico State	2012	The assessment is carried out for a hydraulic project located in the ravines of the "Huixquilucan" Municipality, that was planned to construct more than 60,000 km of collectors and sub-collectors. Contains several maps about the project, a comprehensive description, environmental forecasts, and a proposal of alternatives for mitigating the impacts.
Morelos State	Integral plan for the sustainable management of the northwestern ravines of the State of Morelos	2012	A document made by the institute IMTA. It aims to be an instrument for the sustainable development of the ravines in the northwestern area of Morelos State. Identifies all the ravines located in the northwestern area of Morelos State and provides an ecological characterization of each one; general information about the state; related legislation and an environmental diagnosis that leads to the description of priority areas.
Morelos State	Integral management plan for the ravines system in northwestern of Morelos	2018	A document that included the participation of society, academic members, non-governmental organizations, activists, and government stakeholders. Despite the integral plan made by the institute IMTA, this document makes a general diagnosis and characterization of the ravines but identifies more issues and challenges and based on those, provides strategic guidelines and recommended actions.
Jalisco State	Technical Justification Study and Management Program, Ravines of "Santiago" and "Verde" Rivers.	2018	A document supported by the state government of Jalisco, it aims to preserve, restore, and boost the natural attributes of the area. Includes a report with remarkable cartography and different types of zoning about the ravines of "Río Santiago" and "Río Verde" made with the digital elevation model (DEM) of the area. Also, there is an internal regulation composed of articles that aim to establish the basic structure and functioning of the area.

From the tables above, it is evident that Mexico City has made more progress in relation to the protection of its ravines. The [Environmental Law for Land Protection in Mexico City \(2000\)](#) provides several articles indicating measures, responsibilities, prohibitions, and even a description of what the city considers a ravine. It recognizes the potential of the ravines to serve as wildlife habitats and the environmental services that benefit the city, as can be seen in the description included in that law.

Article 5° - Ravines³: A geographic depression that, due to its topographic and geological conditions, appears as crevices and serves as a refuge for wildlife, a channel for the natural runoff of rivers, streams, and rainfall, and constitutes an important area for the hydrological and biogeochemical cycle (p.6)

It is also remarkable that, there is a legal category whose translation to English is "Areas of Environmental Value", written as "AVA" by its acronym in Spanish. This category is defined by the abovementioned law as follows:

Article 5° - Areas of Environmental Value⁴: The green areas whose its original landscape was modified by anthropogenic activities and require to be restored or preserved, considering that they are keeping certain biophysical and aesthetic features that are contributing to the environmental quality of the city (p.5)

Considering the information above, it should be mentioned that Mexico City has a website from the PAOT Attorney's Office called [Ravines of Mexico City \(consulted in November 2022\)](#), dedicated to disseminating information related to its ravines. It explains what is considered a ravine in Mexico City, the recognition of 44 ravines (and the potential to recognize about 100 areas as ravines), the information about 27 ravines considered Areas of Environmental Value (with the possibility to download the decree made), and that around 12 ravines are subject to management programs (not available to visualize).

Nonetheless, according to the local press ([Villavicencio, 2017](#)), the management plan for the ravines that Mexico City was about to present is incomplete and delayed. This can be evidenced by the finding of another website from the PAOT

³ Original text in Spanish states: Depresión geográfica que por sus condiciones topográficas y geológicas se presentan como hendiduras y sirven de refugio de vida silvestre, de cauce de los escurrimientos naturales de ríos, riachuelos y precipitaciones pluviales, que constituyen zonas importantes del ciclo hidrológico.

⁴ Original text in Spanish states: Áreas de valor ambiental: Las áreas verdes en donde los ambientes originales han sido modificados por las actividades antropogénicas y que requieren ser restauradas o preservadas en función de que aún mantienen ciertas características biofísicas y escénicas, las cuales les permiten contribuir a mantener la calidad ambiental de la ciudad.

Attorney's Office which is title is [Program for the Conservation and Sustainable Management of the Ravines of Mexico City](#) (consulted in November 2022). This website provides information about the objectives of that program according to the Mexico City strategy to manage and preserve critical natural resources. Also, mentions the goals that are planned to be achieved, which are the making of a diagnostic of the ravines in Mexico City, creating a legal framework, creating a strategy for their protection and restoration, identifying priority areas, and integrating an information system.

On the other hand, official documents for public knowledge were found. The first one is called [Workshop Memories: Urban Ravines: Solutions to environmental Issues and Financial Options \(2007\)](#) which it can be described as an output document from a workshop organized by the institute INECC and the university UACM. The document informs about a funding proposal for environmental amelioration of the ravines. The assistance was provided to about 150 people and included the participation as speakers of government stakeholders, academic members, and civil organizations that work for the ecological restoration of ravines.

The second document is called [Urban ravines in the southwest of Mexico City, Areas of Environmental Value 2006-2012](#). This document was addressed to the public and explains the efforts made by the Environmental Secretary of Mexico City, through different studies and forums, to evidence the importance of the urban ravines for the sustainability of the territory.

In the case of Morelos State, the most significant results were the management programs for the ravines located in the northwest area. It is interesting to point out that one document was produced by a decentralized public organization, whereas the other was made by an academic community from the university "El Colegio de Morelos".

Both documents provide evidence that there are important ravines in the northwest area of Morelos State and that their preservation and sustainable management motivate different entities to participate in creating such documents.

Finally, for Jalisco state there was one document that is also a management program and additionally a technical justification study, which provides a strong cartography work in the first chapters to present the data, the location of the ravines, and their ecological characteristics.

4.3 Previous scientific and academic research about the ravines in Puebla City.

The legal approach above showed that only Mexico City, the State of Jalisco, and the State of Morelos are making positive progress regarding the ecological conservation of their ravines with clear concepts, management measures, and management programs.

In the case of Puebla State and Puebla City, there is a kind of perception about what constitutes a *ravine* at all hierarchies (national, state, and municipal). However, there is not yet a clear consensus yet or a formal definition within the legislation reviewed.

Even so, the impacts affecting the ravines in the city are well-known by the authorities, for instance, the [Municipal Plan of Development 2021-2024](#) identifies the pollution issues and is aware of the need to clean the ravines and improve their status. Consequently, there are prohibitions or restrictions that are mentioned in that document, intended to stop its degradation.

Here is where the scientific approaches are crucial since no management programs or government diagnoses were found to have an estimation of how well preserved the ravines are in Puebla City.

Research online on scientific databases and scientific journals was made and returned six publications that describe and analyze the urban ravines issue in Puebla City from different focuses. The Table 4 below shows a summary.

Table 4: The studies, assessments and articles related to the ravines in Puebla City

Authors	Year	Publication Title
Gutiérrez Pacheco, Victor & Silva Gómez, Sonia Emilia	2017	The ravines: Change of epistemic framework and its revaluation
Gutiérrez Pacheco, Victor; Silva Gómez, Sonia Emilia; Chaves Bravo, Edith; et. al.	2018	The Ravines of Puebla City, Mexico: An untapped resource in a metropolis with a deficit of green areas
Gutiérrez Pacheco, Victor & Silva Gómez, Sonia Emilia	2019	Anthropic environmental degradation of El Conde and Malinalli ravines from Puebla city, Mexico
Gutiérrez Pacheco, Victor & Silva Gómez, Sonia Emilia	2020	The Puebla City's ravines
Gutiérrez Pacheco, Victor; Silva Gómez, Sonia Emilia & Varela Olguin, Laura Leonor	2021	Oak forest flora (<i>Quercus: Fagaceae</i>) of two ravines of Puebla city, Mexico
Gutiérrez Pacheco, Victor.	2021	Socio-environmental assessment of two ravines of Puebla City

These results were the only ones found for Puebla City ravines, so they represent a pioneering effort coming from the scientific sector to address the issue.

The publications shown above are distinguishable in their scope. Three of them are exploring and setting up a wide overview of the urban ravines in the city, from its epistemological conception to the main anthropogenic impacts, the role of the local government and the private sector, and the negative social consequences (publications from the years 2017, 2018, and 2020).

Meanwhile, the other three publications from 2019 and 2021, are focused on two ravines known as "El Conde" and "Malinalli". The assessments executed on those ravines were more technical and had site-specific objectives. In summary, those publications exposed the main impacts and their sources, showed the results of vegetation data surveying, and carried out analysis through the application of the Margalef and Pielou indices, known tools for applied ecology, to calculate species richness and species evenness, respectively. Then the results were compared to see the ecological performance of both ravines, as the "El Conde" ravine is under high human stress compared to the "Malinalli" ravine, which has less.

Lastly, the socio-environmental assessment (2021) proposed a new index to evaluate the status of the ravines, denominated "Index of Ecosystem Status of Ravines" (IEEB by its acronym in Spanish), which was based on the OECD (Organization for Economic Cooperation and Development) methodologies, specifically the PER method (Pressure, Status, and Answer, by its acronym in Spanish), and other existing models to evaluate the status of riparian forests and lentic water bodies. Also, this publication considered the wellness perception of the population living in the ravines, and some proposals were made to serve as a basis for future management programs.

Due to the valuable work done on those publications, their findings and key elements were considered for this thesis, as they represent the first effort to aim for the amelioration of the ravines in Puebla City.

5.0 Puebla City overview

Puebla Municipality is in the central-western part of the State of Puebla, with an altitude between 1800 and 4400 meters above sea level, and 563.4 km² of extension, representing 1.55% of the state territory (Municipal Plan for Development, 2021, p.33). Puebla City is the municipal seat and the capital of the state.

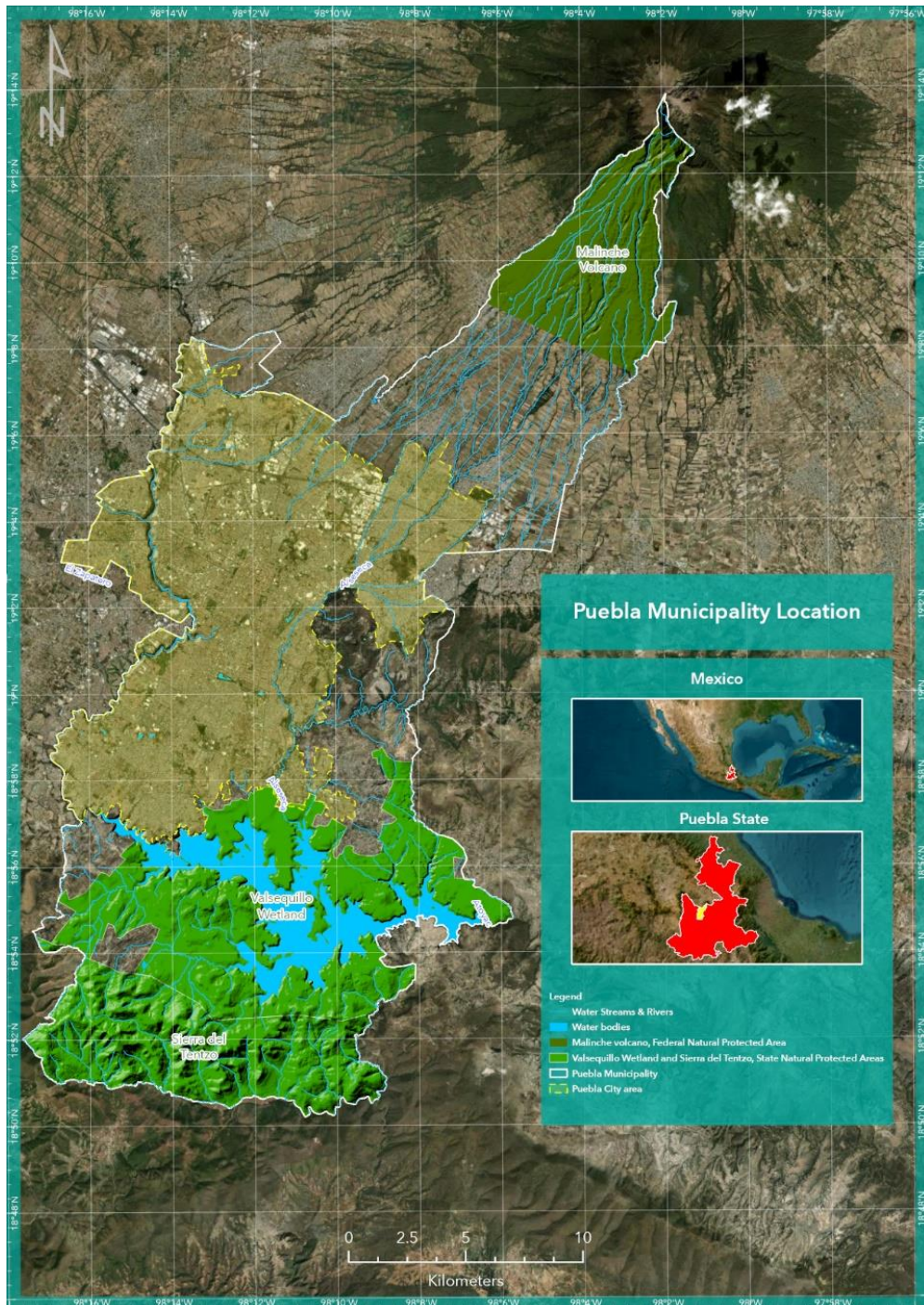


Figure 2: Map of Puebla City location. Source: Made with information from INEGI.

5.1 Population and urban growth

According to the [Municipal Plan for Development \(2021, p.33\)](#), the municipality is facing a transitioning population period due to the intensity of urbanization. Since four decades ago, the demographic trend has been going down very slowly, mainly in the child population. On the other hand, the young and productive population has an increasing tendency, as does the elderly population.

The same document mentions that between the years 1980 and 2020, the population increased from 835,759 inhabitants to 1,692,181 inhabitants, representing a duplicative growth in 40 years. Nonetheless the growth rate between 1980 and 1990 was around 2.3%, and between 2010 and 2020, the growth rate was 0.9%.

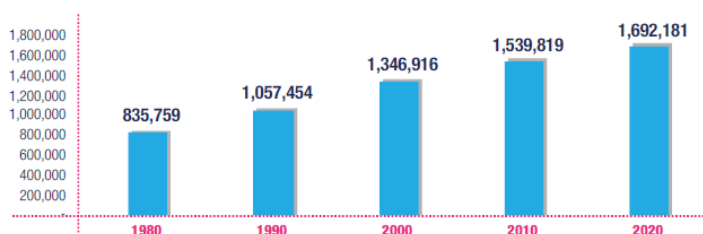


Figure 3: Population growth between 1980 - 2020 period. Source: [Municipal Plan of Development 2021-2024](#)

Additionally, it is mentioned that the population structure of the municipality is composed of 52.2% females and 47.6% males. In addition, the young population is concentrated in an age range between 15 and 29 years old.

Related to the urban growth, due to the demographic density of Puebla Municipality, the economic activities, the services that concentrate in its territory, the urban equipment, and its strategic location that serves as the connection between the center and the southeast area of the country; it constitutes the metropolitan area of Puebla-Tlaxcala, with 19 municipalities from Puebla State and 20 from Tlaxcala State ([Municipal Plan for Development, 2021, p.36](#))

The [Municipal Plan for Development \(2021, p. 39-44\)](#) places emphasis on the horizontal and dispersed urban growth tendency of Puebla City and the region, a consequence of the residential development projects, and irregular human settlements, especially in the surrounding areas. Those factors are causing several problems, like mobility issues (increasing traveling times and costs from the residential areas to job places), affectations on life quality, limited access to public

services and infrastructure, low-quality public transportation, limited access to adequate housing for low-income sectors, and a low amount of public spaces oriented to recreation. Additionally, there is a special mention of the several human settlements that are happening in natural protected areas or risk areas because, in 2020, around 4.5% of the settlements were in geological faults and fractures, 12.4% were in slope instability areas, and 9.3% were in high-risk flooding areas.

Finally, [Gutiérrez Pacheco et. al. \(2018, p.3\)](#) mention that inside the city, the available spaces for green areas are no longer available, since the buildings and constructed spaces are dominant. This idea was also supported by [Gante & Rodríguez \(2009, p.6\)](#), who mentioned that the number of lands without any kind of construction is not enough to satisfy the current deficit of green areas, gardens, or parks.

In addition, there is high pressure on the municipality's ecosystems since the urban area has been extending onto agricultural lands and the remnants of the oak forests that are present in the surroundings [Gutiérrez Pacheco et. al. \(2018\)](#).

5.2 Economy

According to the [Municipal Plan for Development \(2021, p.65-68\)](#) in 2020, the State of Puebla contributed to the Mexican GDP with 3.2%, occupying the 11th place in the country. This is possible due to the tertiary economic sector, which is the most important in the municipality, where 70.6% of the economically active population participates. It is formed by activities related to commerce, services such as hotels, restaurants, transportation, professional services, banking, and international organizations, among others.

Special mention should go to the tourist sector since Puebla City is an important spot for material and immaterial cultural heritage, meaning it is an important factor for economic development. For instance, the Historical Center has been listed since 1987 on the World Heritage Sites UNESCO list; the Palafoxian Library has been registered on the Memory of the World list since 2005; the General Archive of Puebla Municipality has been listed as the Memory of the World from Latin America and the Caribbean since 2015, and Puebla City has been included in the Creative Cities UNESCO network since 2015.

The same document indicates that the secondary economic sector concentrates 27% of the economically active population and is related to the manufacturing, construction, extractive, and electrical industries. Of those industries, manufacturing is the dominant one due to the automotive industry, which stimulates the local economy (the Volkswagen factory provides employment directly and indirectly in the municipality).

5.3 Environmental issues & Climate Change

Among the most severe environmental issues in the region and the municipality, according to the [Municipal Plan for Development \(2021, p.39\)](#), water pollution requires urgent attention, since the following bodies of water have severe pollution:

- Atoyac River (chemical, heavy metals, and organic pollution)
- Alseseca River (chemical and heavy metals pollution)
- San Francisco River (chemical and organic pollution)
- Ametlapanapa River
- Zapatero River
- Valsequillo Reservoir (chemical and organic pollution [overpopulation of water lilies due to eutrophication])

The pollution is a consequence of wastewater discharging across the regional watershed, the limited infrastructure for water treatment, and the lack of legal tools to regulate the industry's emissions and discharges.

Another problem identified by the same document is related to pollution of the air, which has been progressive and proportional to the increase of vehicles circulating in the municipality. For instance, it is mentioned that during the year 2016, Puebla City registered up to 30 days of bad-quality air, due to the number of suspended particles and up to 32 days due to the concentration of ozone (O₃), both derived from fossil fuel burning (p.140).

Regarding the federally protected natural areas, the document abovementioned mentions that there are disturbances affecting their integrity, such as illegal logging for carbon and timber production in the National Park of Malinche (the area that belongs to the inactive volcano), urban sprawl affecting the State Park of Valsequillo Wetland, and livestock activities in the State Reserve "Sierra del Tentzo".

The quantitative analysis made in that document, with data from INEGI (2018) shows that between the years 1984 - 2018, there was a loss of 25.2% of forest coverage in the municipality. In the same way, the number of forests in good conservation status in the same period changed from 27% to 15.8%. The same situation exists for the protected natural areas under municipality jurisdiction, for instance, the zone called "La Calera" is facing an intense urban sprawl that has been fragmenting the natural landscape. On the other hand, the urban park "Tlapacoyan" is facing legal instability, which leaves an open door for land uses incompatible with ecological conservation (p.141).

Regarding urban waste, the [Municipal Plan for Development \(2021, p.144\)](#) indicates that there is a progressively increasing volume, due to population growth and consumption habits. The document indicates, with information taken from INEGI (2013) and the Cleaning Service Operator Organism (2021), that between 2013 and 2019, the urban solid waste increased from 1,300 to 1,700 tons per day in the municipality, representing a 30% increase, as well as the pressure on the local landfill and the cleaning operating services. Also, it is mentioned that an important volume of urban solid waste is dumped on roads, wastelands, and ravines.

Related to the coverage of green urban areas, according to the [Municipal Inventory of Green Areas \(2016, p.43\)](#) there are 4.4 square meters available in the municipality, which also considers vegetated open public spaces under state management. The [Municipal Plan for Development \(2021, p.45\)](#) considers this amount very low compared to international averages that can reach up to 15 square meters.

Finally, the climate change factor is also considered in the [Municipal Plan for Development \(2021, p.144\)](#), where it is mentioned that the current energy model need to be changed to minimize greenhouse gas emissions. It cited information from the Climate Action Plan of Puebla Municipality (2013) that around 71.3% of greenhouse emissions belong to the energy sector, while 74.4% correspond to the transportation subsector, either public or private.

5.4 Expected scenarios.

Data from [CONAPO \(2015\)](#) indicates that the population is expected to increase by around 170,000 inhabitants by the year 2030, with the same growth rate of 0.9% as

the period of 2010 and 2020. This also represents an increase in the elderly adult population due to the increase in life expectancy.

Respecting the climate change scenarios, the [Institute of Atmospheric Sciences and Climate Change \(2021\)](#) from the university UNAM, provides information related to the temperature increase using data from the Intergovernmental Panel on Climate Change (IPCC from the UN). There are several scenarios calculated, but the following Table 5 shows those with the highest temperature possible.

Table 5: Climate change scenarios delimited for Puebla City

Scenario	Period	T° Increase
RCP 4.5 (Monthly increase of maximum extreme T°)	2021-2040	1.2°
RCP 8.5(Monthly increase of maximum extreme T°)	2021-2040	1.4°
RCP 4.5(Monthly increase of maximum extreme T°)	2041-2060	1.8°
RCP 8.5(Monthly increase of maximum extreme T°)	2041-2060	2.6°
RCP 4.5 (Monthly increase of maximum extreme T°)	2081-2100	2.2°
RCP 8.5(Monthly increase of maximum extreme T°)	2081-2100	4.8°-5°

5.5 Ecological characterization of Puebla Municipality ravine system

The ravines in Puebla Municipality Valley, are described by [Gutiérrez Pacheco & Silva Gómez-a \(2020, p. 5\)](#) as crevices created by the volcanic activity (associated with the tectonic activity), the action of million-years of water erosion, and the settlement of living organisms, and are composed by a wide variety of geological features of many kilometers of longitude, without any known specific data of that extension ([Gutiérrez Pacheco & Silva Gómez-b, 2019, p.3](#)).

However, it is known that the ravines present different physiographic features, from low to steep slopes of 90° of inclination, and this variety allows for different temperatures and humidities compared to the surroundings, indicating the existence of a different microclimate inside them. The presence of vegetation plays a crucial role in this dynamic ([Rivas, 2001, as cited in Gutiérrez Pacheco et. al., 2018, p.5](#)).

The ravines in Mexico and Puebla Municipality, are identified by toponyms (names) resulting from the interaction of the variety of languages and dialects from the so-called *Old World* and *New World*, mostly Nahuatl, Mayan, and Spanish ([León-Portilla, 2020, p.2](#)). Considering this reference, the INEGI's website provides

information about the names of different geographic elements of Mexico in the so-called [“Register of Continental, Island, and Undersea Geographical Names for Statistical and Geographical Purposes \(2022\)”](#), which is available in a CSV file.

This file contains, among other information, the geographic coordinates of the ravines in the country, which were transformed into a shapefile point layer in the GIS software ArcGIS Pro 3.0.2 to create a map delimiting the location of the ravines in Puebla Municipality. The register abovementioned highlights that it does not represent the official location of the geographic elements but is intended to name those elements and provide an approximation of their location. It was made with residents and authorities without any official classification. In Puebla Municipality, according to the attribute table of the software mentioned, there are 82 ravines, and the map layout is shown on the next page 35.

Finally, it is necessary to point out that the ecological characterization of the ravines in Puebla Municipality was made considering the methodologies and scopes from the management programs of Morelos ([Integral plan for the sustainable management of the northwestern ravines of the State of Morelos, 2012](#) & [Integral management plan for the ravines system in northwestern of Morelos, 2018](#)) and Jalisco State ([Technical Justification Study and Management Program: Ravines of “Santiago” and “Verde” Rivers, 2018](#)). Additionally, the ecological characterization made by [Guerra Martinez \(2012\)](#) on the “Tarango” Ravine in Mexico City was considered.

Those documents provided information about which ecological features of a ravine are typically described and how. This information was valuable since it was possible to compare the features considered between management programs from different institutions and one example from the academic sector. The comparison allowed to identify the features that must be included for an ecological characterization of the ravine system of Puebla Municipality to obtain a first insight about the conditions in the surroundings.

As a result, the features considered for this Chapter were relief (including physiography and landforms), flora, fauna, the water regime, climate, and soil & land use. The following pages show the information related to those features taken from different literature and spatial data that led to the creation of the map layouts shown in the next pages, using the software ArcGIS 3.0.2.

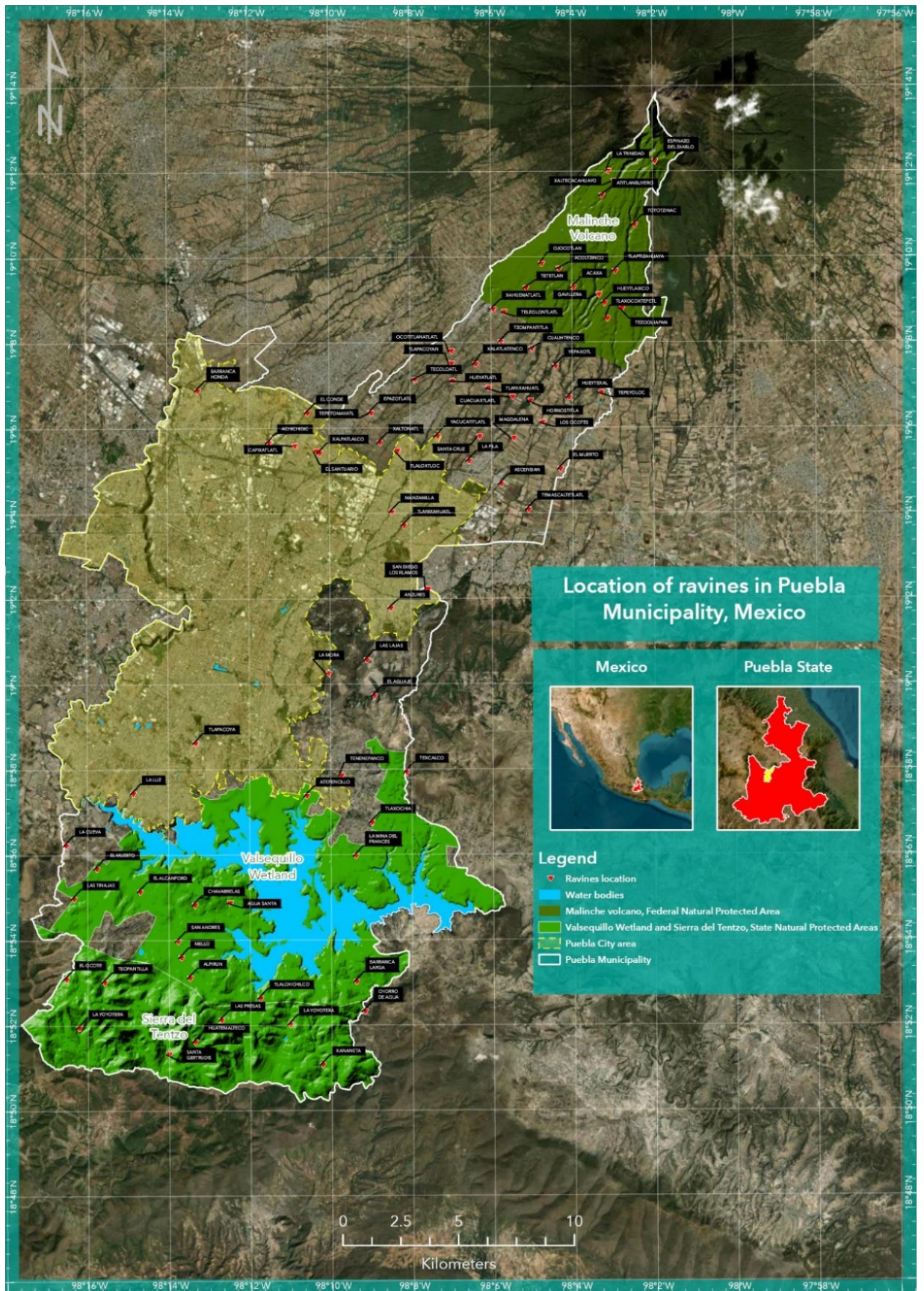


Figure 4: Map showing the location of ravines in Puebla Municipality. Source: INEGI.

5.5.1 Relief

Puebla Municipality is settled over lands of volcanic origin and configured by the magma, stone material, and ashes spread by the volcanoes around, which are "Popocatepetl", "Iztaccihuatl", "Citlaltepētāl" and "Malinche" [Gutiérrez Pacheco & Silva Gómez-c \(2017, p.2\)](#). Also, it is located in the so-called "Mexican Volcanic Belt", a physiographic province that crosses the country along 14 states, and contains the majority of geographical peaks relevant for Mexico and Latin America ([INEGI, 2010](#); [De la Torre, 2003](#)).

The spatial data (scale 1:1,000,000, year 2001) obtained from [INEGI's Continental Relief Geoportal](#) and subsequently processed in ArcGIS Pro 3.0.2 revealed that there are physiographic sub-provinces identified in the municipality called "Lakes and Volcanoes of Anahuac", which covers most of the area, and "Southern Mountain Range of Puebla", which has a very small area in the southwest direction. Additionally, the spatial data contained information about the landforms in the municipality, where six types were found: alluvial plain and rolling hills, plain with rocky or cemented hills, rocky or cemented ground plain, volcanic mountain range with stratovolcanoes, volcanic mountain range with steep slopes, and volcanic mountain range with steep slopes and hills.

The layouts representing the physiographic sub-provinces the landforms in the municipality are shown on the pages 39 and 40.

5.5.2 Flora

The ancient forests in Puebla Municipality were formed mostly by oak trees (*Quercus*), which are also the most diverse in the region, providing support for other flora species, generating tree leaves that enrich the soil, producing acorns that are a food source for birds and mammals, and providing refuge for amphibians, reptiles, and invertebrates. Also, it is possible to find ferns, mosses, lichens, and epiphytes in their trunks. The forests that were once occupying the territory of the current city, have their remnants precisely in the ravines of the municipality ([Gutiérrez Pacheco & Silva Gómez-c, 2017, p. 3](#)).

In the case of the ravines, the study made by [Gutiérrez Pacheco et. al. \(2021\)](#) provides detailed information about the vegetation found in two ravines called "El Conde" and "Malinalli" which are allocating remnants of *Quercus Fagaceae* forests. The tree inventories carried out in both revealed a richness of 105 species, 81

genera and 40 families in total, including endemic and exotic species, as well as 2 endangered species. The most representative genera and species belonged to *Commelinaceae*, *Poaceae*, *Convolvulaceae*, *Asparagaceae*, *Fagaceae*, *Fabaceae*, and *Asteraceae*. The study strengthens the hypothesis that these kinds of remnants may be similar in the whole ravine system of Puebla municipality.

The oak tree or *Quercus* are very common in Mexico, especially in areas with temperate and semi-humid climates. This richness is because Mexico possesses around 150 species of *Quercus*, ranking as the most diverse country in the world with this genus of trees. Besides, these trees are commonly found in the country, sharing a niche with *Pinus* trees, resulting in mixed forests. This kind of forest is dominant in the Mexican Volcanic Belt and has been impacted by human activities from a long time ago, since humans are occupying attractive areas for agricultural development that is mostly seasonal (Rzedowski, 2006, p.274-276).

5.5.3 Fauna

Regarding the fauna in the ravines of Puebla Municipality, no specific studies were found to describe its dynamics or richness. However, there is knowledge about the species that are present in Puebla State, due to scattered observations made by academic institutions and governmental entities.

Thus, information from the [SIAMEP Geoportal](#) of the state government was used and processed in the software ArcGIS Pro 3.0.2. The spatial data available revealed information from different sources about the different faunal observations made in the municipality in different years.

The information indicated observations of reptiles (183), fish (31), mammals (221), invertebrates (2400), birds (10758), and amphibians (145). At the same time, includes information that shows the species scientific name, coordinates, status (critically endangered or of least concern), endemism or invasive species, among other useful data of national importance.

The layout representing the faunal observations is shown on the page 41.

5.5.4 Water regime

According to [Gutiérrez Pacheco et. al. \(2018, p.5\)](#) a ravine is an ecosystem that is part of a hydraulic system associated with a micro-watershed, and it can be related to a bigger ravine or be associated with different runoff units that are forming a

micro-watershed. Using the spatial data from [INEGI's Hydrography Geoportal](#) (scale 1: 50,000, year 2021) and processed with ArcGIS Pro 3.0.2, it was possible to visualize that most of the ravines are containing intermittent water streams that are flowing to the main rivers of the municipality (Atoyac and Alseseca Rivers) and to the Valsequillo Reservoir.

The layout representing the faunal observations is shown on the page 42.

5.5.5 Climate

About the climate [INEGI \(2010\)](#) mentions that Puebla Municipality ranges in temperature from 10° to 16° with 400-900 mm of precipitation. The type of climate is predominantly temperate sub-humid, with rains during the summer that reach 48.6% humidity. Meanwhile, the other 2 types of climates are semi-cold and sub-humid and cold, which were identified in the Malinche volcano area using the spatial data (scale 1:1,000,000, year 2008) from the institution abovementioned.

[INEGI's Climate Geoportal](#) was used to get data from Puebla Municipality and was used together with the point shapefile of the ravines. The layout representing the climate units is shown on page 43.

5.5.6 Soil & Land Uses

The data about soil was taken from the spatial data of [INEGI's Edaphology Geoportal](#) at 1:1,000,000 scale (year 2005), meanwhile the land use data in the municipality was taken from the spatial data of [INEGI's Vegetation and Land Use Geoportal](#), at 1:1,000,000 scale (year 2005) and 1:250,000 scale (year 2022), respectively.

The soil types identified were Andosol, Cambisol, Phaeozem, Fluvisol, Litosol, and Rendzina. On the other hand, the land use information is accompanied by the type of vegetation that is present in the municipality. Strictly, the main land uses found were urban and agricultural (which is classified as annual and semi-permanent irrigation or annual-seasonal irrigation). Meanwhile, the vegetation identified corresponds to oak, pine, and oyamel forests, cultivated forests, high mountain meadows, secondary shrubby and arboreal vegetation, and some areas with removed vegetation. According to the spatial data, most of the ravines follow a path through annual-seasonal agricultural and urban lands. The layouts representing the soil, and vegetation & land uses are shown on the pages 44 and 45 respectively.

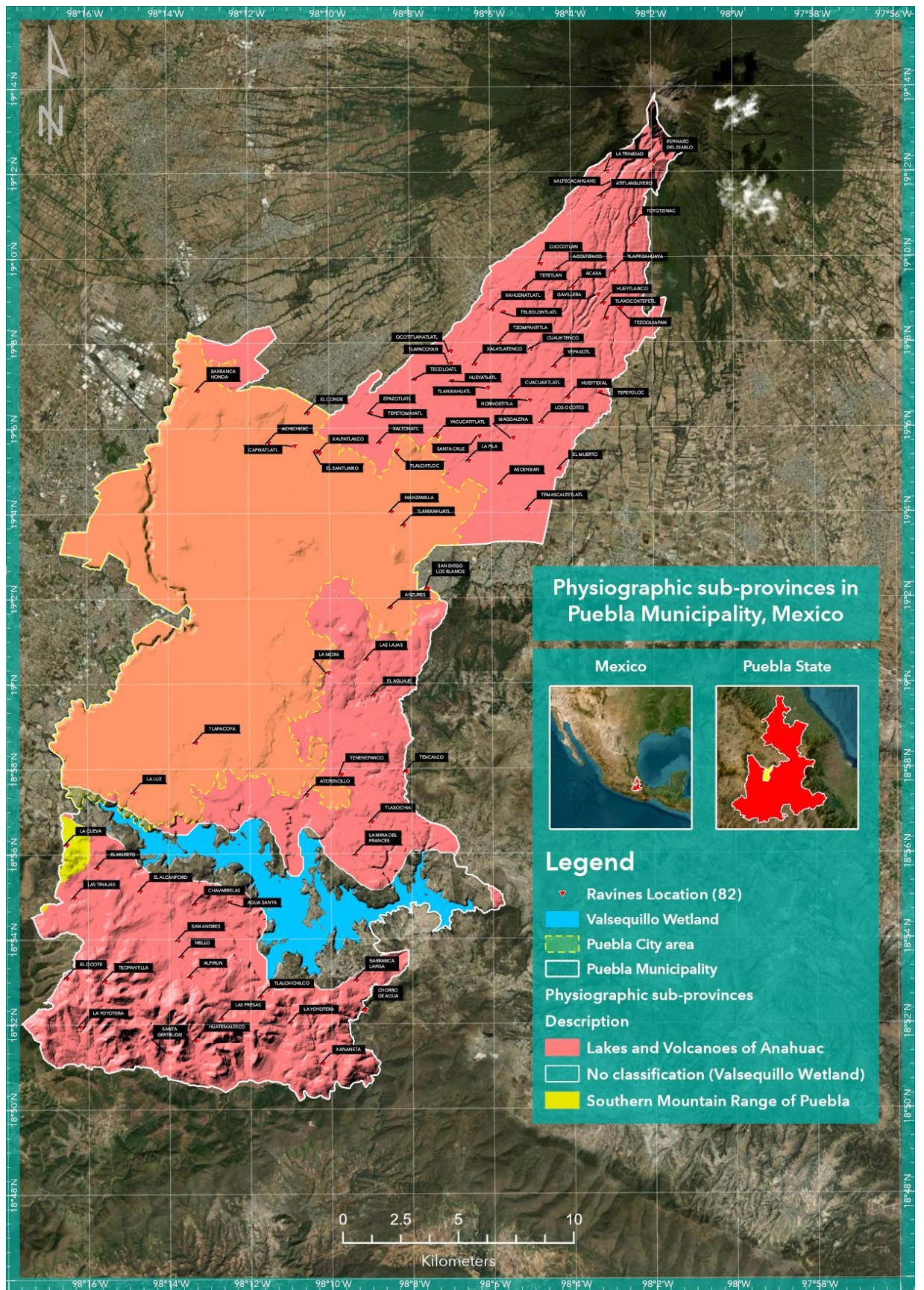


Figure 5: Map representing the physiographic sub-provinces in Puebla Municipality together with the location of the ravines. Source: INEGI.

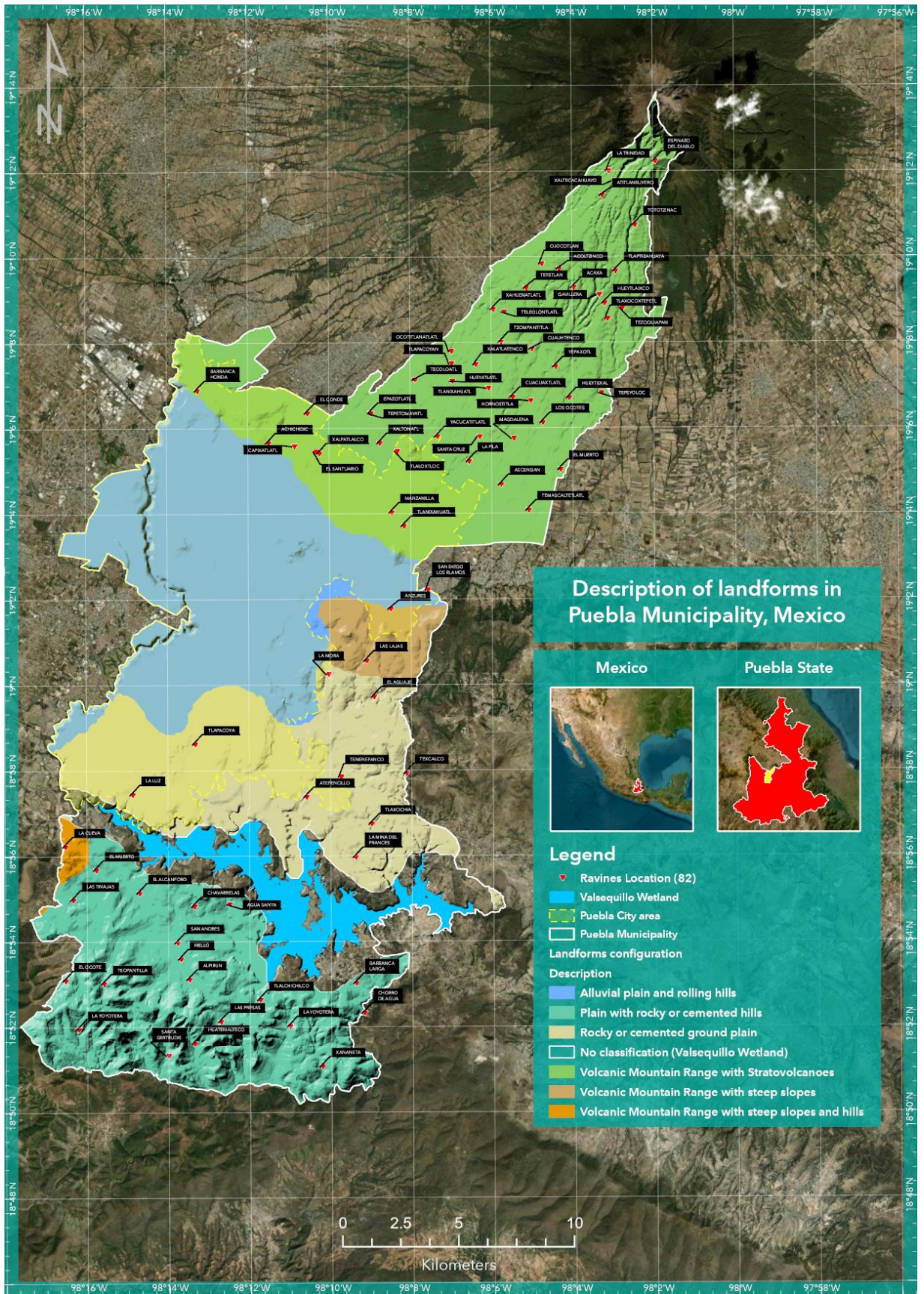


Figure 6: Map representing the description of landforms in Puebla Municipality together with the location of the ravines. Source: INEGI.

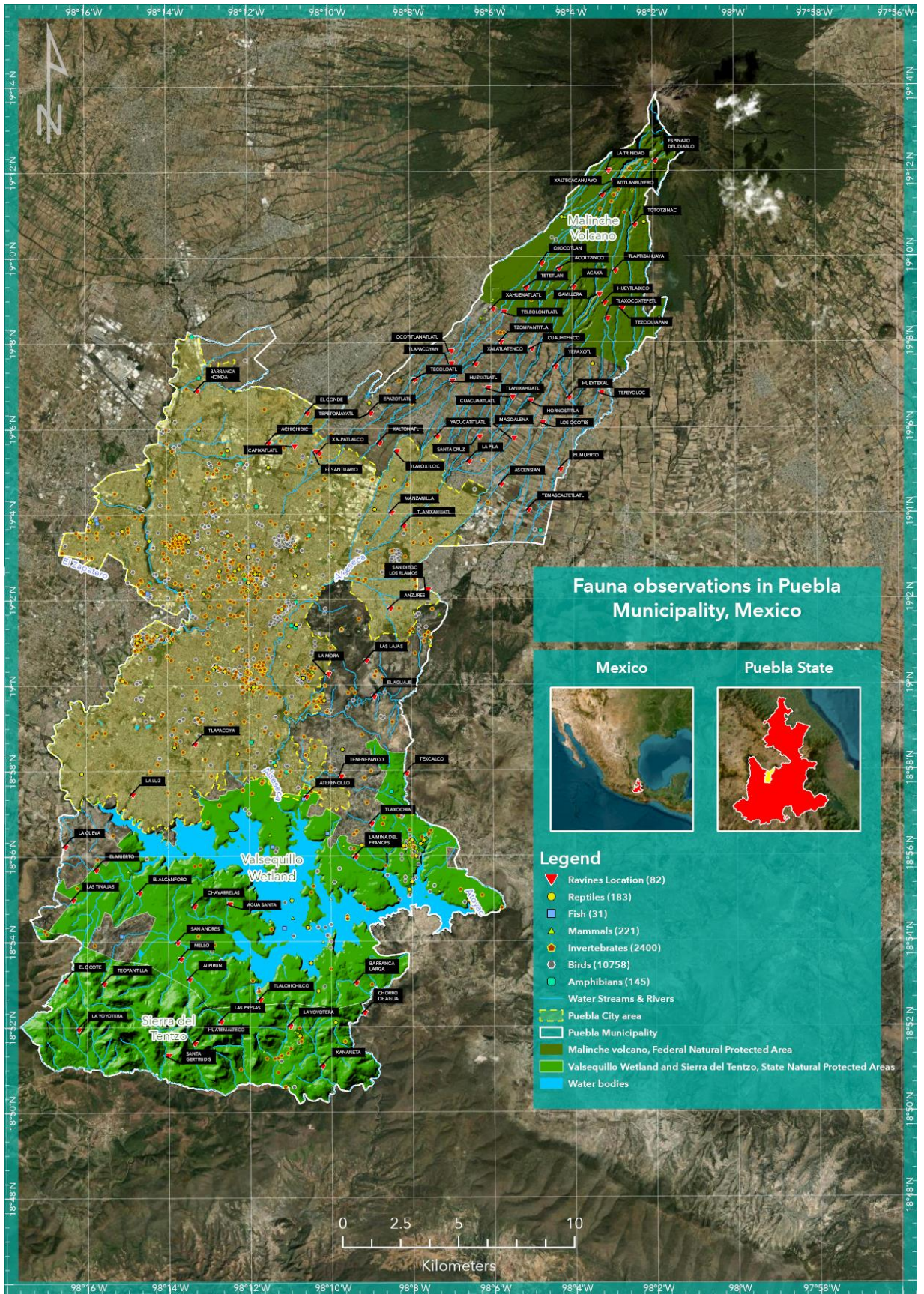


Figure 7: Map representing fauna observations in Puebla Municipality together with the location of the ravines. Source: INEGI.

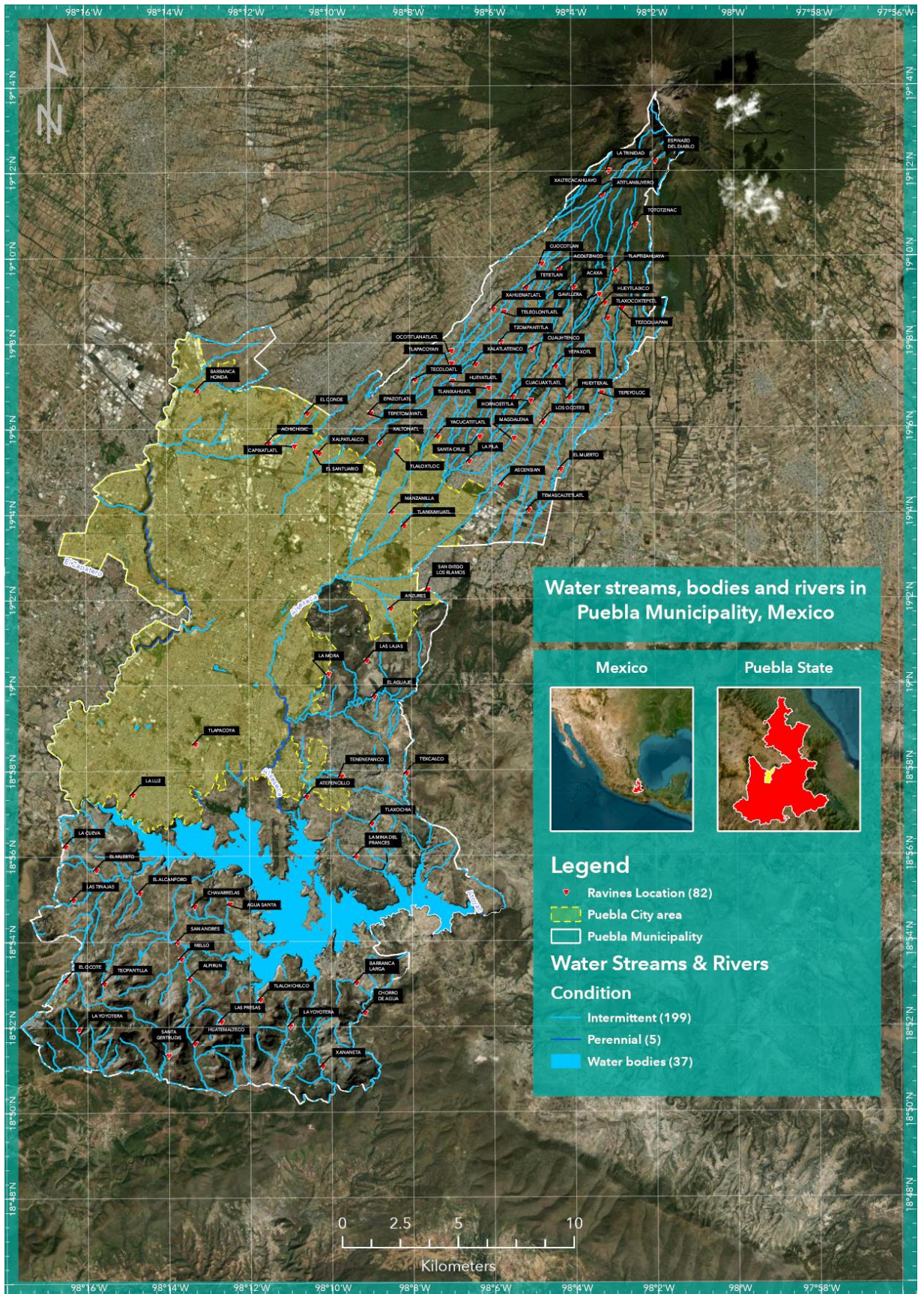


Figure 8: Map representing the water streams, bodies, and rivers in Puebla Municipality together with the location of the ravines. Source: INEGI.

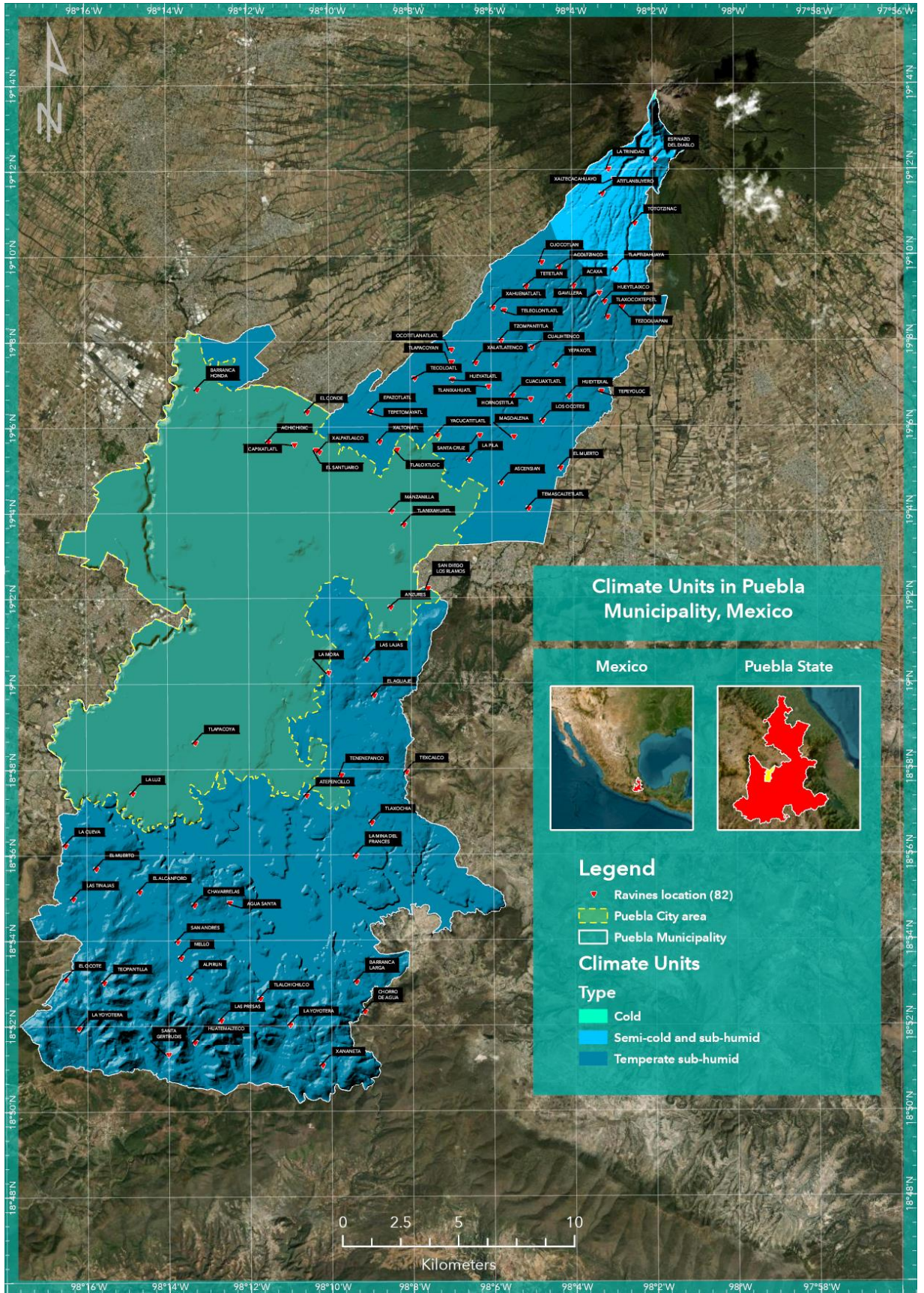


Figure 9: Map representing the climate units in Puebla Municipality together with the location of the ravines. Source: INEGI.

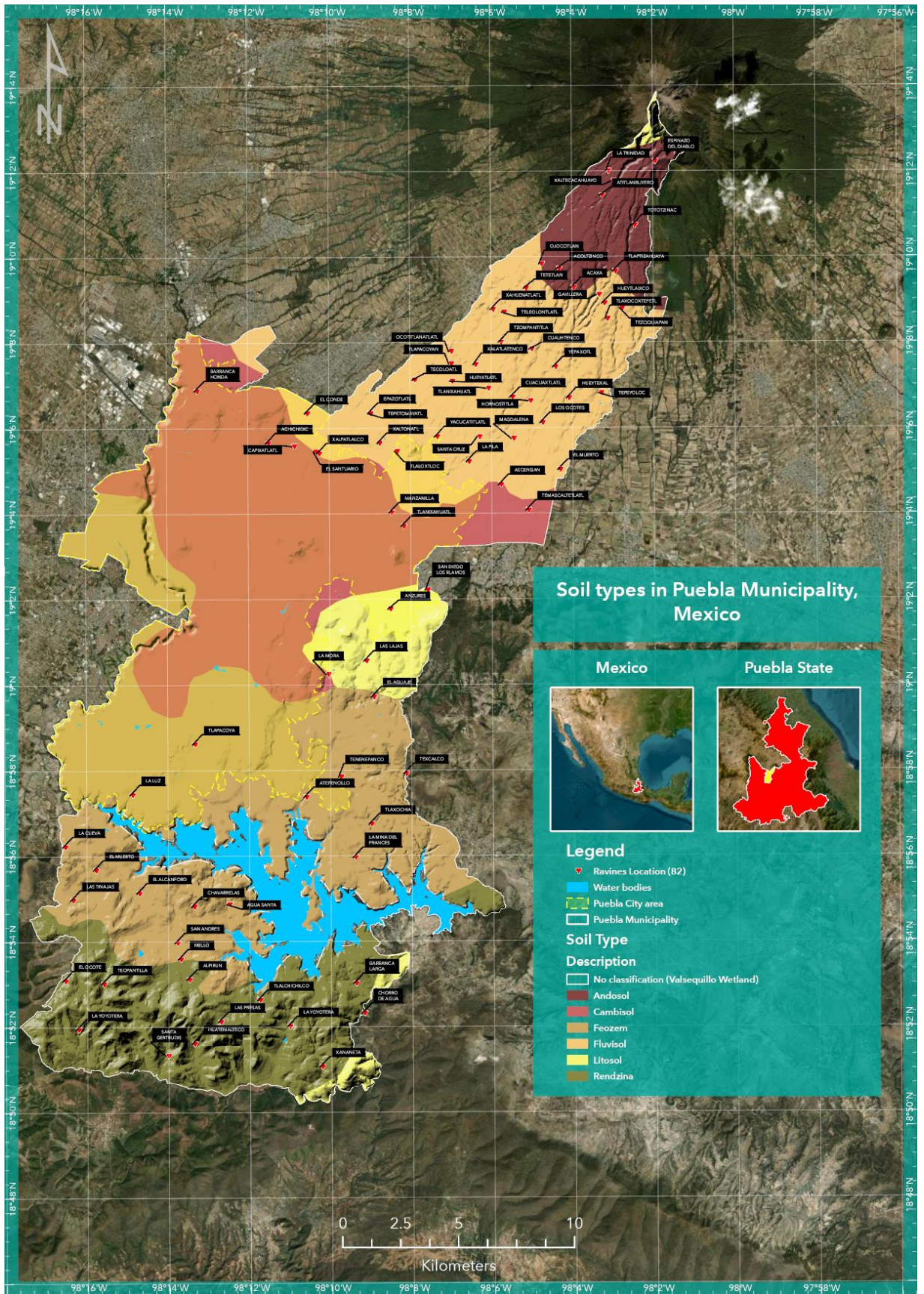


Figure 10: Map representing the soil types in Puebla Municipality together with the location of the ravines. Source: INEGI.

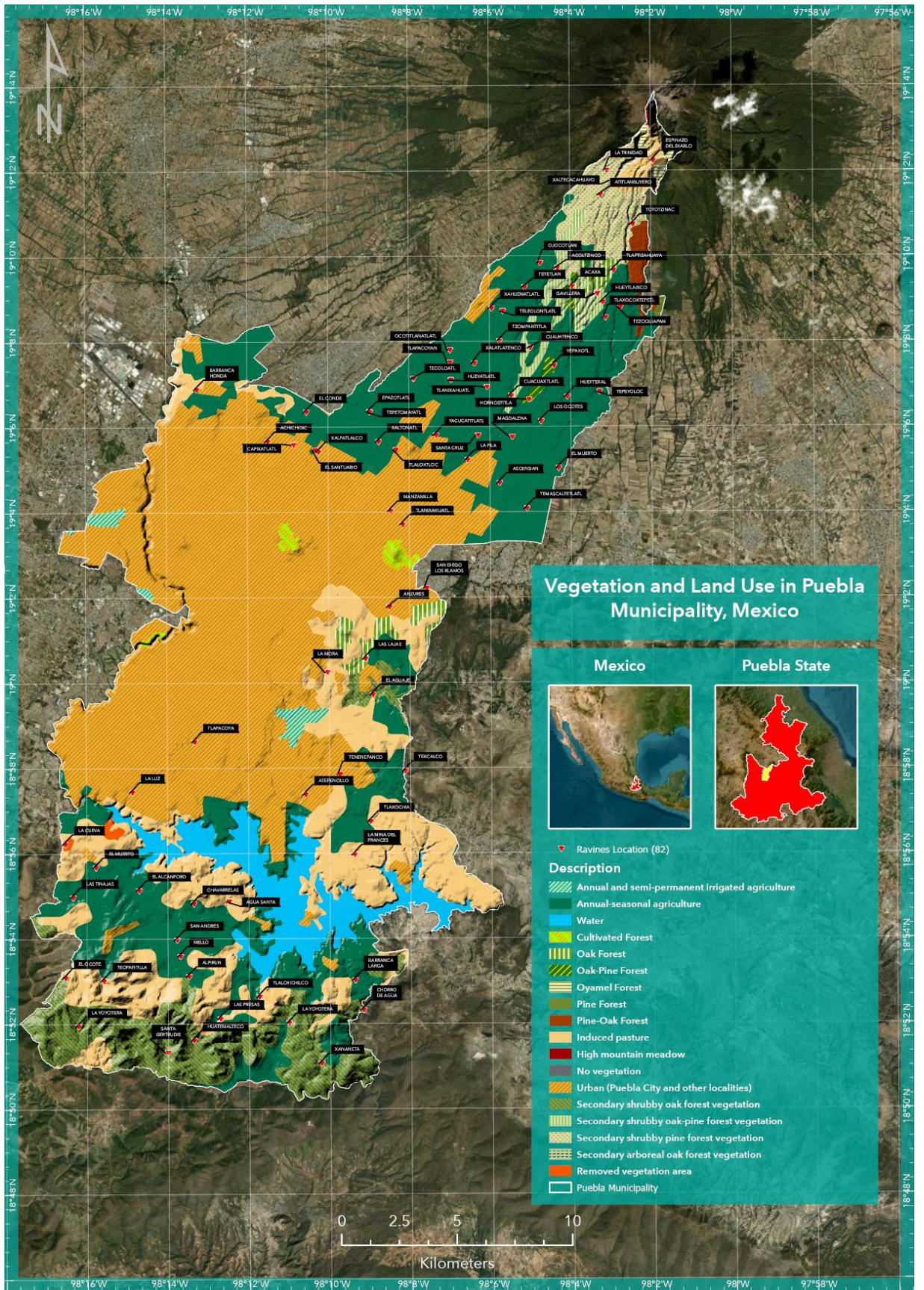


Figure 11: Map representing the vegetation and land uses in Puebla Municipality together with the location of ravines. Source: INEGI

6.0 Issues and challenges related to urban ravines in Puebla City

According to [Gutiérrez Pacheco et. al. \(2018, p.4\)](#), there is no diagnosis available or made for the urban ravines of Puebla City by academic groups or local authorities. For a long time, the ravines inside and outside the city were seen as places with no utilities, due to their physiographic features that made agricultural activities or construction projects difficult.

For instance, some testimonials collected by [Gutiérrez Pacheco & Silva Gómez-a \(2020, p.3\)](#) testify that in the past (not specified year, but according to the age of the interviewed people, more than 65 years ago) the ravines "Xaltonac" and "Xaltipan" were places with abundant vegetation and fresh water, until the 1990s where both ravines were filled with construction debris and solid waste. Other testimonials testify to the same situation for the ravine so-called "Xalpatlac", which was filled in the 1980s decade following the same process on an initiative of the local authorities.

Such practices carried out since then, confirm the statement made by [Gutiérrez Pacheco & Silva Gómez-c \(2017, p.1\)](#), who mention that the ravines were seen for a long time as an obstacle to urban development, and consequently, some of them were piped or filled.

Moreover, the urban ravines that were not piped or filled, are facing several impacts, where [Gutiérrez Pacheco & Silva Gómez-b \(2019, p.3\)](#) identify wastewater discharges of domestic and industrial origin, garbage, and irregular human settlements in the following ravines: "Alseseca", "Los Alamos", "Manzanilla", "San Antonio", "San Diego", "Guadalupe" and "El Conde", all of them located inside the city of Puebla and close to industrial parks.

The impacts identified, especially at the ravine "El Conde", show that they are not happening exclusively in those locations but rather are an example of the issues along the whole ravine system in Puebla City ([Gutiérrez Pacheco & Silva Gómez-b, 2019, p.11](#)).

6.1 The poverty and urban sprawl phenomenon

According with [López \(2005, as cited in Gutiérrez Pacheco et. al., 2018, p.4\)](#) due to the need of profit and speculation, the low-income society sectors had found relative easiness to get housing without governmental regulations (such as

construction licenses, taxes, or payment of rights), creating a phenomenon denominated “urbanization of poverty model”, which is characterized by the following aspects:

- Basic services deficit
- Informal housing
- Economic vulnerability to natural disasters and environmental issues
- Growing inequality inside the cities



Picture 2: Gabion wall at zone “25 Zona Militar” in Puebla City. Source: Self-made picture



Picture 1: Another view of the ravine at “25 Zona Militar” in Puebla City. Source: Self-made picture

This phenomenon has been playing an important role in the whole country, increasing the gap between low-income and high-income societies, and contributing to the inequality problem. Puebla City is not apart from this phenomenon, and it is very often visible in the urban ravines, where low-income and other vulnerable groups are living.

6.2 Industry practices and water pollution

It is known that the ravines are being affected by the discharge of greywater and sewage water, due to the current water treatment plants that are discharging them without following the quality criteria of the current national and local laws, such as the number of suspended solids, oils, biochemical oxygen demand, or fecal coliforms. In addition, the current sewer system is in rudimentary condition, and its destination is also the ravines (Pérez Castresana, 2019).

However, the ravines in Puebla City are part of the water pollution problem and, moreover, the starting point of this chain. Some ravines are naturally connected to

the main rivers, which are the Alseseca River (coming from the inactive volcano Malinche) that receives water discharges from an industrial park called "Puebla 2000" whereas the Atoyac River (originated by the snowmelt and runoff from Iztaccíhuatl volcano) receives water discharges from the industrial park called "5 de Mayo", which presents serious pollution that is 8 times above the National Water Commission (CONAGUA by its acronym in Spanish) standards (Gutiérrez Pacheco & Silva Gómez-a, 2020, p.4; Bonilla y Fernández *et. al.*, 2007, p.2; Morales García *et. al.* 2016, p.2)

This problem dates to the year 1960, when industrial and municipal water started to be discharged on the Atoyac River on a minor scale. Since then, the Valsequillo reservoir has been concentrating pollutants due to its connection with the Atoyac and Alseseca Rivers, generating, among other problems, a severe eutrophication issue that is leading to a highly dense population of water lily (Domínguez Mariani *et. al.*, 2002, p.3; García Laug, 2016). This reservoir functions as the main water supply for Puebla municipality and its surroundings, especially to irrigate corn, sugarcane, potato, beans, chili, alfalfa, coffee, and tomato crops (Morales García *et. al.* 2016, p.2)

Different kinds of industries are contributing to the pollution of water with heavy metals, such as the chemical, metal-mechanic, tannery, pharmaceutical, or automotive industries. Metals like cadmium (Cd), nickel (Ni), lead (Pb), iron (Fe), chromium (Cr), copper (Cu), and zinc (Zn) have been found in the water streams inside the ravines "Guadalupe", "El Conde, and "San Antonio", which are located near the industrial parks "5 de mayo" and "Puebla 2000". Some of these metals are close to the allowed limits under Mexican legislation, while others are well above those limits, representing a threat to different biological communities. (Bonilla y Fernández, 2007; Morales García *et. al.* 2016, p.13)

On the other hand, recent studies have been considering the potential impact of microplastics, which have been found in the Atoyac River and are coming from the urban-industrial corridor of the city (Shruti, V.C. *et. al.*, 2019), where some of the ravines previously studied for heavy metal concentrations are located. There is also evidence of fibers from the textile industry, pharmaceutical components such as Triclosan, Naproxen, and Diclofenac, as well as pesticides and other biocides coming from agricultural activities that are present on the Atoyac River and are associated with human health risks (Mora *et. al.*, 2021).

Finally, another fact that worsens the water management is related to the water treatment plants in the whole Puebla state, as only 35 of the 278 plants are functioning and fulfilling the legal requirements due to the high operation costs (Camacho, 2013 as cited in Bonilla y Fernández et. al., 2013, p. 3) . From these 35 plants, there are 5 that are within Puebla municipality and are operating at 60% of capacity, until 2012. (Bonilla y Fernández et.al., 2013, p.3)



Picture 4: Ravine located at zone "Amalucan" in Puebla City. Source: Self-made picture.



Picture 3: Ravine located at zone "3 Cruces" in Puebla City. Source: Self-made picture



Picture 5: Ravine located at zone "Margarita" in Puebla City, known for its bad odor. Source: Self-made picture.

6.3 Solid waste pollution

Puebla City has a problem dealing with solid waste along its streets, public spaces, and other areas that, even with the existence of monetary penalties, is still affecting the urban landscape. For instance, the historical center constantly faces deficient waste collection in the main avenues (Machado, 2022; Nuñez, 2021), despite being a UNESCO World Heritage Site. The statistics given by the Institute for Municipal Management, Administration, and Liaison (IGAVIM by its acronym in Spanish, 2020) indicate that Puebla State generates around 5,991 tons of urban waste daily, ranking 6th in the country. From this amount of urban waste, in Puebla City, the recycling performance reaches up to 34,827 kilograms per month, meaning less

than 1% of the total amount generated in the state. In addition, the landfills approved by the local and federal authorities, are close to finishing their life cycle. Puebla City's landfill, called "El Chiltepeque" reached 70% of its capacity, and the estimations suggest that it has only 8 years left in its lifespan. (López, 2021).

At this point, the urban ravines in Puebla are playing an important role as "waste containers". According to Ibararán Viniegra (as cited in Vera [local press], 2022), 30% of the waste that is not collected goes to the ravines, an amount that reached up to 141 tons in 2021. For the following year, according to the local authorities (Puebla Municipal Government, 2022), during the cleaning period of 5 ravines between May 10th and May 23rd, around 4,050 tons of urban solid waste were collected.

The kinds of urban solid waste that can be found in the urban ravines are furniture, wheels, green waste, fridges, mattresses, and clothes, among any other kind of waste. Some places have such a severe degree of solid waste pollution that the cleaning machinery cannot operate correctly (Puebla's Municipal Civil Protection Department, as cited in Cuapa [local press], 2022). On the other hand, the industrial sector in Puebla Municipality also generates solid waste with a high content of toxic substances that are thrown into the ravines and the water bodies along the city, despite the existence of municipal systems of waste collection (Gutiérrez Pacheco & Silva Gómez-b, 2019).

Finally, it is important to mention that the clandestine disposal of construction debris is also contributing to the pollution of the ravines, which is a growing trend due to real estate projects. Conflicts are being generated between the society that is living near the ravines and the people who are throwing the debris, which have been accused of aggressive behavior that threatens the society's safety (García, 2022).



Picture 6: Panoramic view of a ravine located near the zone "25 Zona Militar". Solid waste pollution is very common. Source: Self-made picture.

6.4 Natural disaster risks

There is another significant issue related to the urban ravines in Puebla City that is related to the risks some of them represent. The best official source to describe the issue comes from the local authorities, who manage and publish a document called "Risks and Hazards Atlas" (by its translation in Spanish), which is applied by federal requirements. In fact, each state of Mexico and its municipalities are obligated to develop the document and keep updating the information.

To understand the role of this document in Puebla Municipality, the last update is named "[Risks and Hazards Atlas, 2021](#)", and it provides information about how Puebla Municipality defines the document itself. The definition states:

"Risks Atlas is defined by Municipal Civil Protection authorities as: Updated geographic information system that allows the identification of risks to which the vital services, strategic systems, people and its goods, and the surroundings (art. 380, fracc. V)" (p.10).

Also, for the case of Puebla Municipality the general objective is defined as follows:

"Generate a territorial planning instrument directed to identify the hazard, vulnerability, and risk, understanding the last one as a continuous process of socio-territorial consolidation defined by the interaction between the economic activities coming from social actors in the municipality together with the geophysical context on which is located developing its natural processes" (p.10)

Once the definition and role of the document were described, it was possible to mention the findings related to the urban ravines registered there. The review revealed that there was an inspection of different flooding zones where some urban ravines were identified as important spots with recurrent flooding.

On the other hand, it recognizes the pollution of water in the Atoyac River and points to the ravine "El Conde" as an important source since it allocates several discharging points of wastewater. Also, it is mentioned that solid waste pollution is an issue that increases the risk of flooding. Additionally, the document indicates that there were settlements located in the ravines, in zones of high flooding risks, mentioning important flooding events from the past that support the statement.

Due to those findings, the document proposes the continuous cleaning and desludging of the urban ravines to prevent the flooding risk. Also, propose campaigns directed at the society to sensibilize and promote a culture of ecology.

Other proposals include improving the alert system, impeding settlements in high-risk areas, and restricting construction projects that are expanding the city in areas where the land use is not compatible with the terrain.

The actions proposed to address the flooding issues were made at the watershed level, recognizing a “high watershed” coming from the volcano “Malinche” and a “low watershed” that belongs to the city. It mentions the need to consider reforestation, soil amelioration, and water preservation for the “high watershed”. Meanwhile for the watershed in the city propose preventive actions mainly in the riverbeds of the Atoyac and Alseseca rivers.



Picture 7: Ravine with unstable slopes. Source: Risks and Hazards Atlas, 2021 of Puebla City.

Ditches, living barriers, stone dams, gabion check dams, and dams with geobags are included in the actions proposed to contain the flooding and improve the permeability of the soil.

7.0 Management of ravines in other cities

In the search for examples around the world where ravines are an important feature in the urban landscape that need attention and support, the [Toronto Ravine Strategy \(2017\)](#) from Canada appears to be a unique example of its kind.

The document of the strategy provides a definition of what ravines are coming from the [Ravine and Natural Feature Protection Bylaw \(2008\)](#), which considers the ravines as protected areas. The definition is states:

A. "A discernible landform with a minimum two-meter change in grade between the highest and lowest points of elevation that may have vegetation cover and that has or once had water flowing through, adjacent to, or standing on, for some period of the year".

B. "Contiguous buffer areas, areas of tree canopy and environmentally significant areas that contribute to the ecological function of a ravine".

Interestingly, the definition is divided into 2 categories, where 1 is considering something more than the landform features and the other mentions the term "environmentally significant areas", which can be interpreted as a legal entity for the local environmental legislation.

On the other hand, the strategy document mentions that the City of Toronto possess one of the largest networks of ravines in the world (more than 300 kilometers, according to the [strategy website](#)), carrying water and wildlife through a dense urban area, so the ravines are considered part of the green infrastructure. The purpose of the Ravine Strategy is divided into 5 points, which are the following:

1. Establish the principles to guide decision-making in ravines.
2. Help prioritize future management efforts based on a set of consistent criteria.
3. Chart a course for future communications, engagement, and balanced use with Torontonians in their ravine system.
4. Improve co-ordination between management agencies, including external stakeholder groups.
5. Ensure that all management decisions are made with a long-term view that transcends short-term interests.

Moreover, it is composed of 5 guiding principles that were developed with public consultation, interest groups, staff, and key stakeholders. The following picture shows the principles.



Figure 12: Guiding principles of the Toronto Ravine Strategy. Source: City of Toronto [website](#)

Each principle includes concrete actions; only some of them are highlighted hereunder.

Actions related to the principle “Protect”:

- Develop and implement management plans for what the strategy denominate as “Environmental Significant Areas (ESAs)”.
- Ensure high quality planning, design, construction, and maintenance of the ravines by continuing to develop and implement best practices for capital projects and on-going maintenance of infrastructure and natural ecosystems, including trail accessibility, dumping and litter, and invasive species management.
- Assess the potential of climate change impacts on the ravine system, including impacts to natural systems, existing and proposed infrastructure.

Actions related to the principle “Invest”:

- Execute an ecosystem services analysis for greenspace in Toronto, including both the market and non-market value provided by green infrastructure and associated ecosystem services in the ravine system, like flood protection, pollution removal, erosion control, recreation, and wildlife habitat.
- Identify ten “Priority Investment Areas” based on the Ravine Strategy framework and undertake studies and develop plans to implement improvements in those areas.

Actions related to the principle “Connect”:

- Review existing trails and access points and develop an implementation plan to address gaps in the system and connections to trails that run east west and to trail systems in adjacent municipalities.
- Provide opportunities to honor and share stories of special and historic spaces and ways of relating to the natural environment within the ravines collaborating with Indigenous communities, the City of Toronto, and other entities.

Actions related to the principle “Partner”:

- Create partnership opportunities and capacity to expand the Community Stewardship Program to include additional sites. Also, identify candidate sites.
- Establish a framework to support further opportunities to engage volunteer groups in ravine stewardship.

Actions related to the principle “Celebrate”:

- Create a campaign and events to engage the society, including children and other diverse communities to celebrate the ravines and foster its appreciation and understanding with a “Ravine Day.”
- Develop outreach plans to specific groups such as park users, property owners adjacent to ravines, pet owners and underserved communities. Communicate good stewardship practices for uses and activities in ravines to avoid adverse impacts in habitats and if possible, restore or enhance natural areas.
- Develop a communication strategy to promote the ravines as a natural asset and key identity element of the City of Toronto with the help of key stakeholders.

The map presented on the next page is included in the [Toronto Ravine Strategy \(2017\)](#) and shows the ravine system in the City of Toronto. It is important to point out that there are other elements, such as the so-called “Environmentally Significant Areas” or the “Greenbelt Protected Countryside” that are shown in the map.

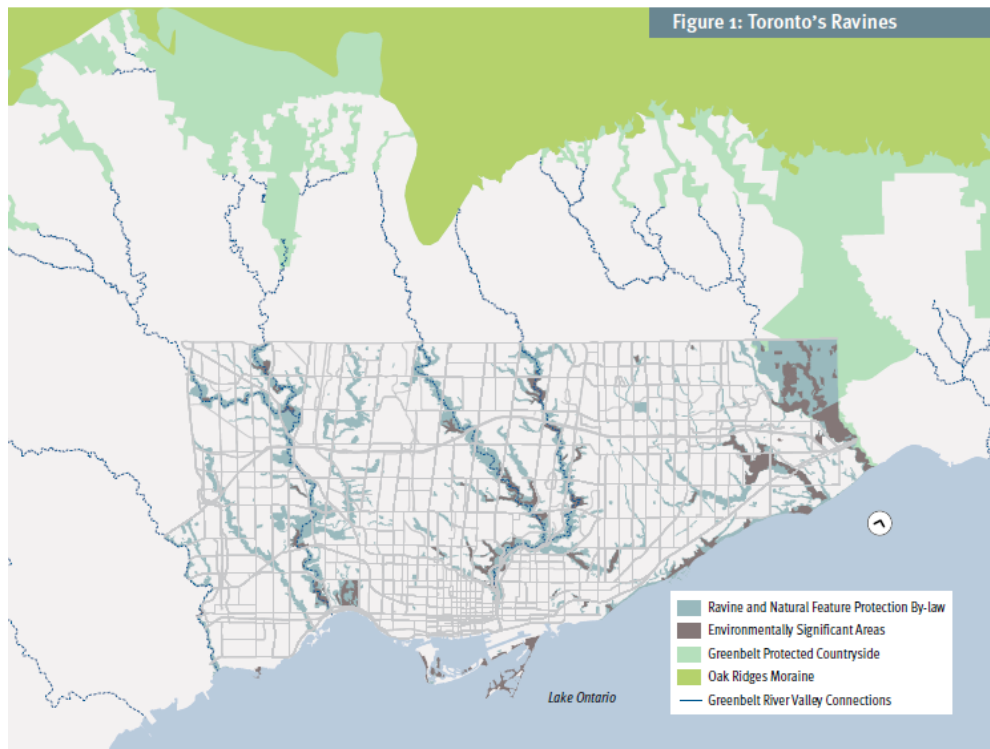


Figure 13: Ravine System in Toronto with other strategic elements. Source: City of Toronto [website](#)

The map above becomes more relevant when the Ravine Strategy mentions that residents may not be aware of the ravine system in their daily lives, due to the bridges in the roads that can create the perception of a “flat” city.

Despite this perception, it is recognized that the ravines are holding remnants of the ancient natural spaces and therefore, are vital for biodiversity, providing habitat for wildlife and functioning as corridors for migrating birds. Additionally, it mentions their function to catch and filter storm water for larger watershed systems and their importance as urban greenspaces essential for the health of the residents and to make a more livable city.

On the other hand, it mentions that the ravines contain “grey infrastructure”, which corresponds to roads, bridges, sewer lines, and other utilities critical to the function of the whole city.

Regarding the protection of ravines at a legal scale, the Toronto Ravine Strategy mentions 3 main measures, which are shown in the picture on the next page.



Figure 14: How Toronto's ravines are protected. Made with information from Toronto Ravine Strategy (2017)

Those measures are intended to protect the ravines from degradation, either from the removal of trees, changes in the steepness, or lack of management, and are applied to both public and private properties. Also, the development is often restricted to compatible recreational or cultural facilities that will mitigate the impacts generated.

Finally, the [Toronto Ravine Strategy \(2017\)](#) is fully integrated into the official plan of the city and other strategies, which include, for instance, the Pollinator Strategy, Cycling Network Plan, and Erosion and Hazard Mitigation Plan. The following picture is provided by the website for the strategy and illustrates the integration.

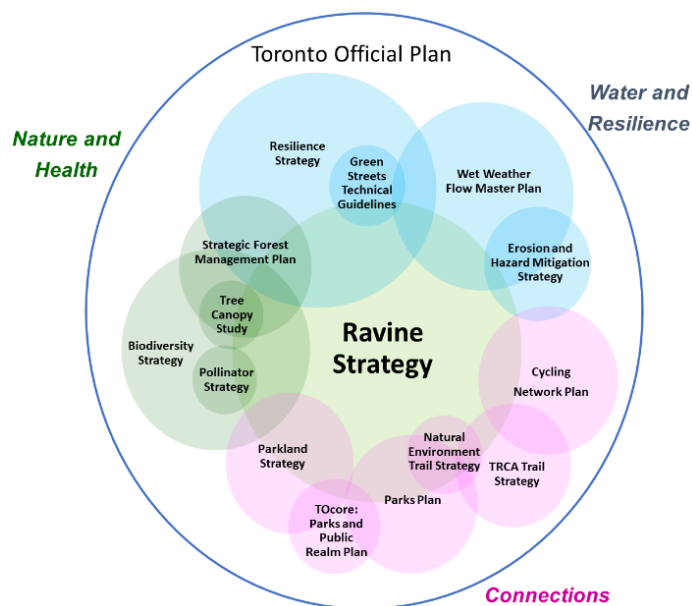


Figure 15: Toronto Ravine strategy aligned with the official plans of the city. Source: City of Toronto, Toronto Ravine Strategy

In general, the [Toronto Ravine Strategy \(2017\)](#) provides a strong framework for the protection of the ravine system in the city with short- and long-term actions. The document highlights that the strategy is the first phase of an ongoing management process that will guide city policies, activities, developments, and investments that may impact the ravines, which are crucial to the future of the City of Toronto.

Regarding the inclusion of other cities around the world, the literature research made on different databases and online search engines did not return numerous results about the management of ravines in urban areas. In fact, most results lead the research to the Toronto Ravine Strategy, which seems to have had a considerable impact and dissemination in the field.

The other results, for instance, were leading to studies made on agro-ecosystem ravine lands ([Kumar, 2020](#); [Pande, 2021](#)) or to studies or articles about natural conservation without mention of ravines specifically.

For those reasons, the inclusion of the [Toronto Ravine Strategy \(2017\)](#) was considered the most adequate to review due to its parallelisms with the Mexico City experience and the object of study of the present work.

8.0 Benefits of ecological restoration of ravines in urban areas.

Considering that Puebla City has a lack of green, that its urban ravines are preserving remnants of ancient oak forests (Gutiérrez Pacheco *et. al.*, 2021), and the information from the [Toronto Ravine Strategy \(2017\)](#) reviewed in the last Chapter, it became pertinent to explore the possible benefits of their ecological restoration. The research of information included the terms “urban green spaces”, since the concept of “restoration of ravines” did not show numerous results, and the urban ravines, due to their condition, can be considered as green spaces.

Under that category, the World Health Organization has a document called [Urban green spaces and health. A review of evidence \(2016\)](#) describes several factors by which urban green spaces influence public health positively through several potential mechanisms and proven evidence, according to numerous authors.

Within the potential mechanisms, the document mentions the following: improved air quality, enhanced physical activity, stress reduction, greater social cohesion, engagement with nature, relaxation, anthropogenic noise buffering, production of natural sounds, reduction of the urban heat island effect, and optimized exposure to sunlight and improved sleep. Meanwhile, the proven evidence about the benefits of green spaces on health includes improved mental health and cognitive function, reduced cardiovascular morbidity, a reduced prevalence of type 2 diabetes, improved pregnancy outcomes, and reduced mortality.

Other authors, denominate as cultural ecosystem services to the intangible features that a greenspace provides to its users, such as aesthetic appreciation, relaxation, and physical activity, since they can help the users feel more attached to them and, increasing the visitation frequency (Oviedo *et. al.*, 2022).

Another benefit coming from urban green spaces is mentioned by [Nowak *et. al.* \(2006\)](#) which is also connected to the improvement of air quality. The urban trees can intercept particles blown by the wind, retaining them on the surface, and cause their resuspension into the atmosphere, where the particles can be cleaned by rain or directed to the ground together with the plant's leaves and twigs. The authors point out that by increasing the urban tree canopy cover, a greater percentage of air can be improved.

On the other hand, the ravines, as a component of the natural landscape, had been recognized as important refuges for a variety of organisms, such as *Orchidaceae* in

south-eastern Mexico. Due to factors like elevation, orientation, slope, and the inaccessibility of the ravines, the orchids richness is influenced positively (Damon *et. al.* 2015).

Additionally, there are benefits recognized as environmental services by the cities reviewed in the previous Chapters. For instance, the [Environmental Law for Land Protection in Mexico City \(2000\)](#) defines environmental services as follows:

“Environmental Services⁵: Those derived from ecosystems or its elements which values and benefits are economic, ecologic, or socio-cultural and affect the protection and amelioration of the environment, facilitating a better life quality for the society and justify the need to develop actions to promote the preservation, recovery and rational use of those elements relevant to generate these services and beneficiate the present and future generations” (p.14)

The City of Toronto, through the [Toronto Ravine Strategy \(2017\)](#) recognizes several benefits derived from the protection of the urban ravines, such as support for health and well-being, support for biodiversity, provision of critical ecosystem services, mitigation of climate change effects, support for the local economy through tourism or the allocation of important infrastructure.

Finally, the document [Irregular settlements and environmental risk at the ravines of “Cuajimalpa de Morelos” Delegation, Federal District \(2010\)](#) describes that the ravines in Mexico City are providing services to the people who are living near them and the society in general through a different approach, since it describes the benefits of the ravines as benefits coming from forested areas.

For instance, the benefits mentioned are the regulation of the hydrological cycle, erosion and sedimentation control, reduction of salinity in the soil, preservation of aquatic habitats, conservation of biodiversity categorized as genetic diversity, species diversity, and ecosystem diversity, and finally the carbon sequestration made by forests.

The information abovementioned comes from different approaches that can be applied to the urban ravines since they are remnants of the native ecosystem ([Gutiérrez Pacheco et. al., 2021](#))

⁵ Original text in Spanish states: Aquellos derivados de los ecosistemas o sus elementos cuyos valores o beneficios son económicos, ecológicos o socioculturales y que inciden directamente en la protección y mejoramiento del medio ambiente, propiciando una mejor calidad de vida de los habitantes y que justifican la necesidad de desarrollar acciones para promover la preservación de estos servicios en beneficio de las generaciones presentes y futuras.

9.0 Methodology

The methodology to create the shapefile polygon representing the urban ravines in Puebla City was done considering the following documents:

- Jalisco State management program [“Technical Justification Study and Management Program: Ravines of “Santiago” and “Verde” Rivers \(2018\)”](#)
- Mexico City
 - [“Irregular settlements and environmental risk at the ravines of “Cuajimalpa de Morelos” Delegation, Federal District \(2010\)”](#).
 - [“Risk Zones and Environmental Vulnerability at the ravines of “Álvaro Obregón” Delegation, Federal District \(2010\)”](#).
 - [“Assessment: Technical diagnostics to determine environmental disturbances conditions at the ravines of the Federal District \(2010\)”](#)

Those documents, despite not explaining the process used to delineate the ravines of their areas of study, provided pictures and maps which that allowed one to infer which GIS tools, layers, and criteria were used.

On the other hand, the methodology followed for the proposal of guidelines, was made by analyzing the structure of the management programs and assessments, from the Mexican States, the Toronto Ravine Strategy and identifying the main topics they cover. Additionally, the studies, assessments and articles made for Puebla City urban ravines and the GIS data generated were considered to address the main issues and challenges.

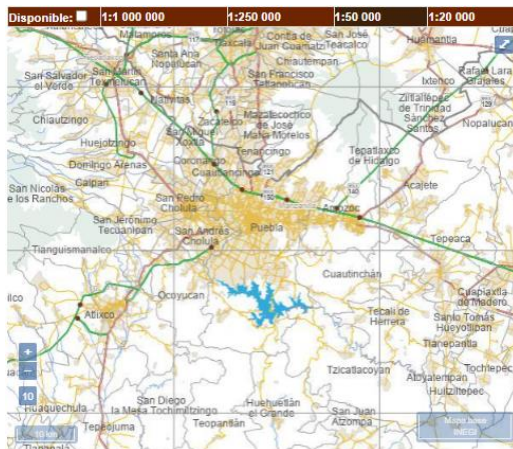
9.1 Delimitation of Puebla City urban ravines

To create and delimitate the shapefile polygon of the urban ravines in Puebla City, different spatial data sets were prepared and processed in the software ArcGIS Pro 3.0.2.

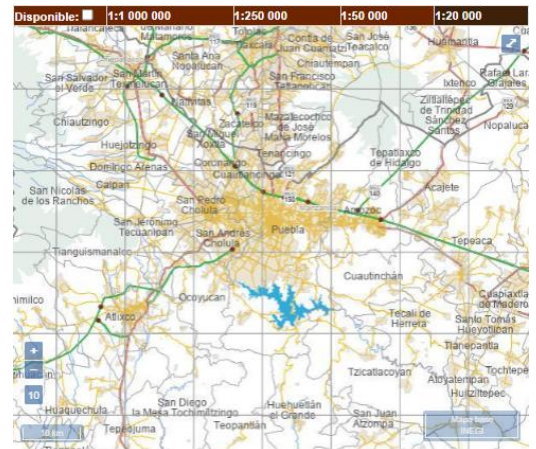
First, topographic data for Puebla Municipality was obtained from [INEGI's topographic geoportal](#), which divides the country in a grid of different sizes depending on the scale selected, which can be 1:1000000; 1:250000; 1:50000 or 1:20000. Each square of the grid is selectable and allows for the download of spatial data in shapefile format.

The last two scales were compared and showed minimum differences, so the data from scale 1:50000 was elected to be processed since there were fewer data sets

to manipulate. The grid of 1:20000 scale covers approximately 7-8 squares of the Puebla Municipality area, while the grid of 1:50000 does the same with two bigger squares.

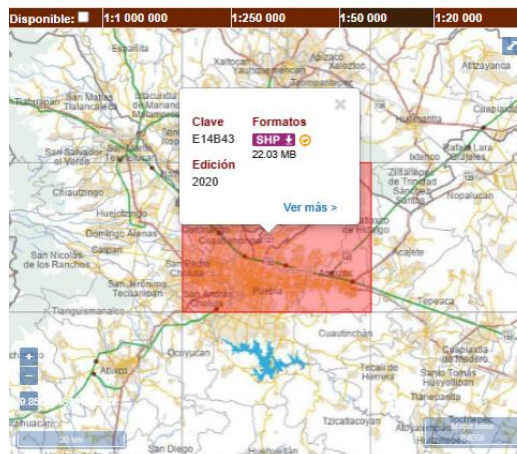


Picture 9: Grid of 1:50000 scale. Divides the area in several big sampling squares. Source: INEGI's Topographic Geoportal

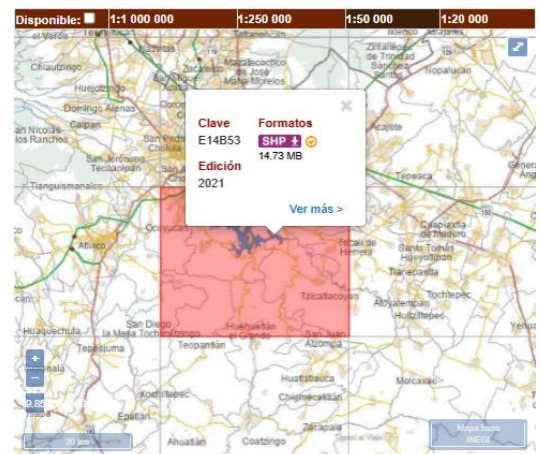


Picture 8: Grid of 1:20000 scale. Divides the area in several small sampling squares. Source: INEGI's Topographic Geoportal

From the grid of 1:50000 scale, the squares labeled with the codes "E14B43, year 2020" and "E14B53 year 2021" were selected to download spatial data. The selection of data is shown in the next pictures.



Picture 11: Sampling square with the code "E14B43" covering the north area of Puebla. Source: INEGI's Topographic Geoportal.



Picture 10: Sampling square with the code "E14B53" covering the north area of Puebla. Source: INEGI's Topographic Geoportal

From the downloaded data, the shapefile polygons representing the localities were processed with the tool "Selection by attributes" in ArcGIS Pro 3.0.2 to select only the polygon corresponding to Puebla City. Also, the shapefile lines representing the water streams were chosen, since the information in the literature review indicated that most of the ravines in Puebla Municipality are holding water streams.

Due to the division of the topographic data of Puebla Municipality into 2 sampling areas, it was necessary to use the tool "Merge" from ArcGIS Pro software to get one single layer of Puebla City and the water streams.

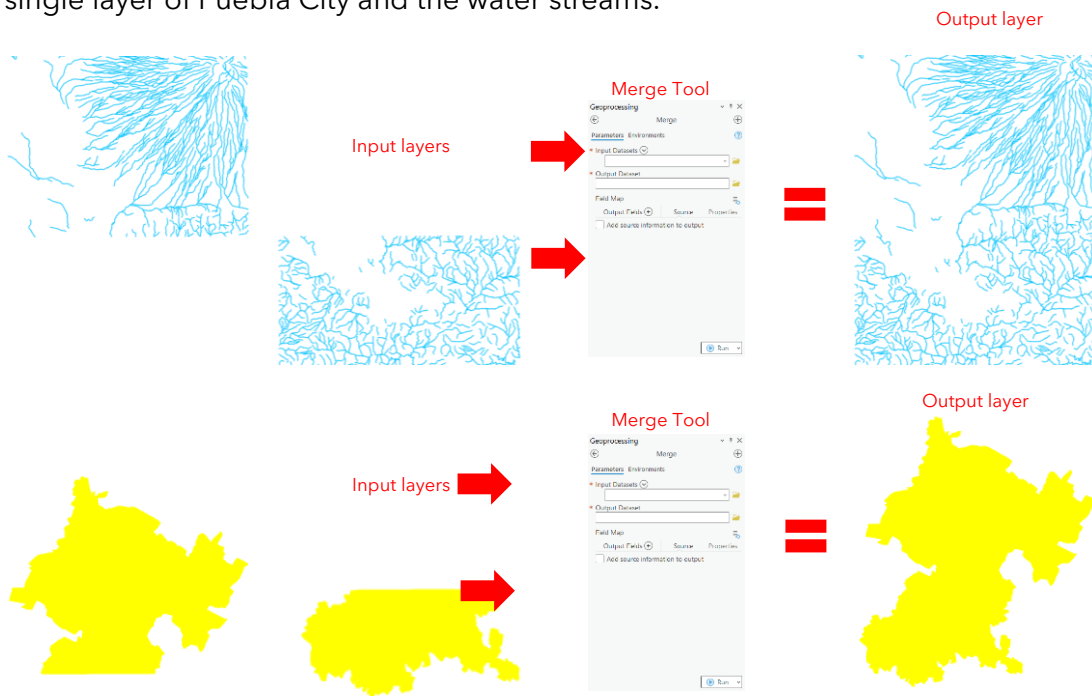


Figure 16: Topographic data of water streams and localities polygon which were processed with the tool "Merge" to obtain a single layer of each one. Source: Self-made.

The resulting layers were used for the next step, which included the use of the tool "Pairwise Clip" to delimitate the water streams that belong to the Puebla City polygon, as can be seen in the following figure.

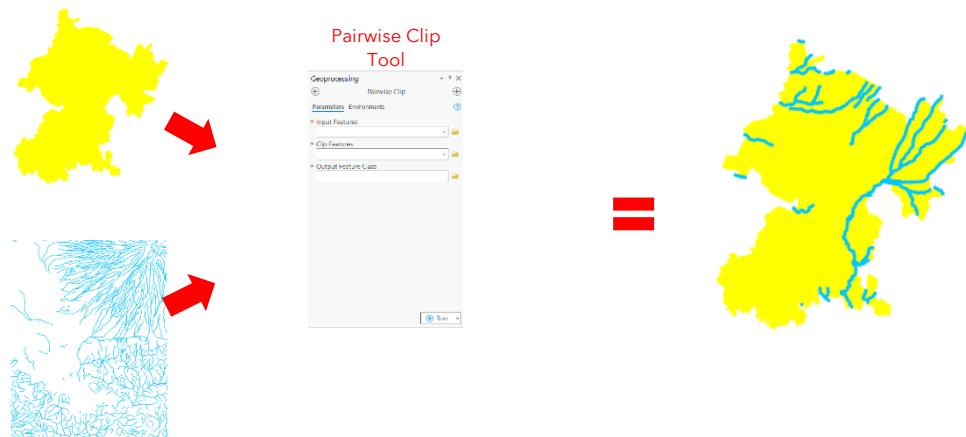


Figure 17: Topographic data of water streams which were processed with the tool "Pairwise Clip" and polygon of Puebla City. Source: Self-made.

On the other hand, the shapefile point layer, which was obtained from the "Register of Continental, Island and Undersea Geographical Names for Statistical and Geographical Purposes (2022)" and contains the location of the ravines in Puebla

Municipality (mentioned in the ecological characterization Chapter), was used again.

The purpose was to delineate the location of the urban ravines using the shapefile polygon of Puebla City. In this case, the tool "Select by location" helped to achieve the task, selecting the criteria "Within" which indicates the tool should search for spatial information of one layer contained within the area of another layer.

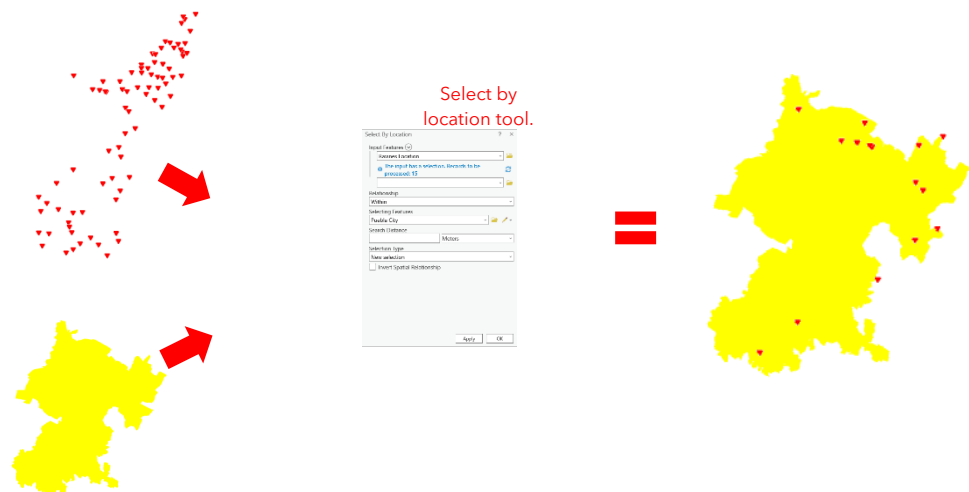


Figure 18: Topographic data of water streams which were processed with the tool "Pairwise Clip" and polygon of Puebla City. Source: Self-made.

Additionally, the spatial data about the territorial boundaries was required to distinguish between Puebla Municipality and Puebla City. Again, the INEGI's website was consulted, specifically the [Geostatistical Framework geoportal](#) which allows to download the national, state, and municipal boundaries of Mexico. The figure below shows the polygon of Puebla Municipality.



Figure 19: Polygon representing Puebla Municipality shape. Source: INEGI Geostatistical Framework. Source: Self-made.

Finally, the satellite imagery called "World Imagery" from the base maps of ArcGIS Pro 3.0.2 was used. According to the metadata of that layer, it provides 1 meter or

less resolution for many parts of the world, thanks to the companies ESRI, Maxar Technologies, Earthstar Geographics, and the GIS User Community. Those features were considered enough to draw the ravines with the software.

The figure below shows the satellite imagery that was delineated for Puebla Municipality to illustrate its usefulness.



Figure 20: Satellite imagery from ArcGIS Pro 3.0.2 basemap delimited with the Puebla Municipality polygon. Source: Self-made.

Once the processing of the layers was done, there were 5 resulting layers set up to create the polygon of the urban ravines in Puebla City. The layers were aligned to the projected coordinate system "WGS 1984 UTM, Zone 14N" which is used in Puebla State by official institutions. The figure below illustrates and summarizes the layers used together to achieve that goal.

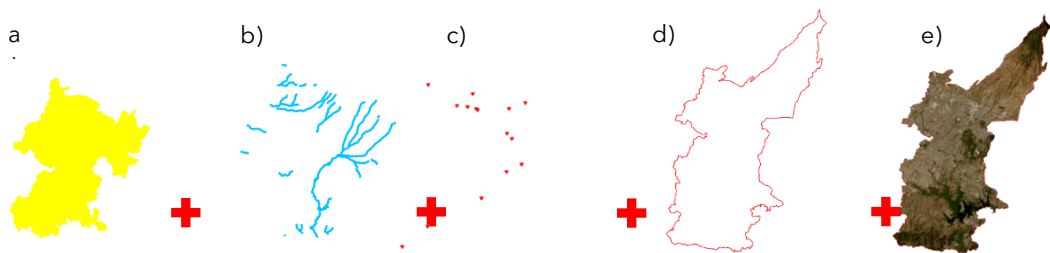


Figure 21: Layers used to draw the polygon of urban ravines where a) is Puebla City polygon, b) the water streams, c) the urban ravines location, d) Puebla Municipality boundary and e) the satellite imagery from ArcGIS Pro 3.0.2 base map "World Imagery". Source: Self-made

It is important to mention that during the drawing of the urban ravines, there were some challenges that forced the process to add a new tool to achieve the creation of an accurate shapefile polygon. Those challenges were related to 3 aspects that are shown in the figure on the next page.

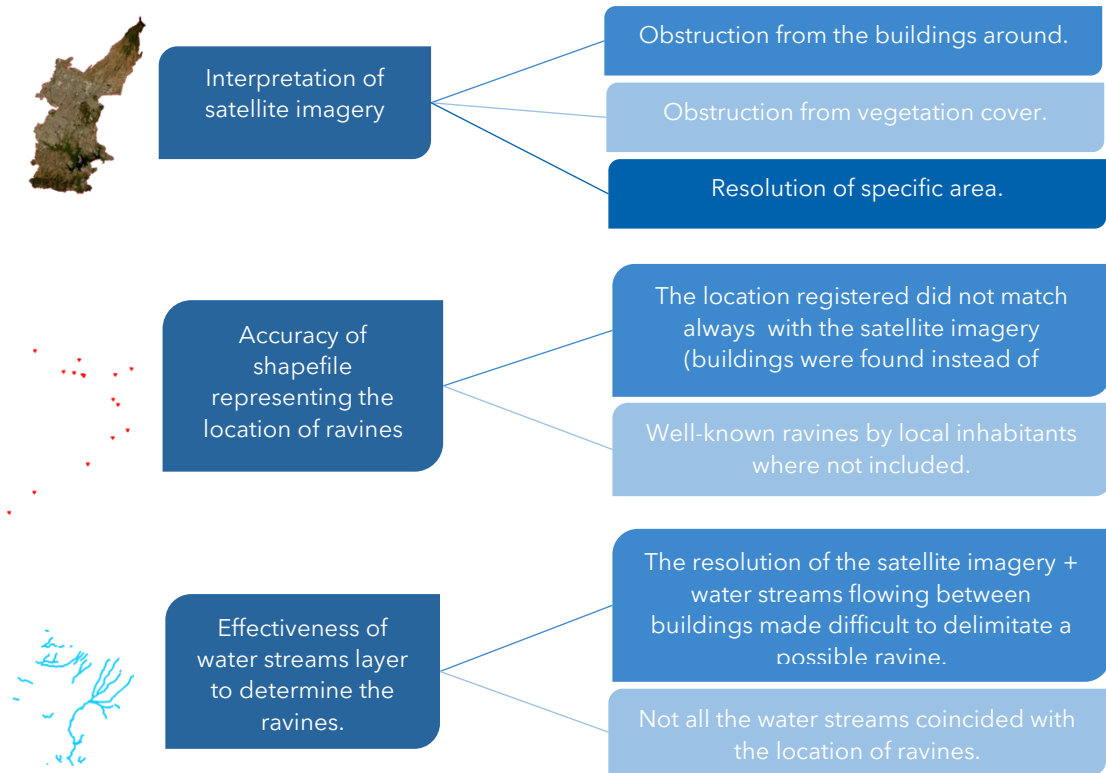


Figure 22: Challenges found during the drawing process of the urban ravines in Puebla City.
Source: Self-made.

Due to those challenges, it was necessary to resort to [Google Earth Web](#) (version 9.183.0.1), which has a powerful 3D visualization of most areas of the world and provides access to the well-known tool "Street View". Basically, was used to better visualize the areas that were challenging on the satellite imagery from ArcGIS Pro 3.0.2, intercalating between the 3D visualization, which allows to see the landform, and the "Street View" tool. The pictures below provide an example.



Picture 12: Screenshot of Google Earth Web satellite imagery.



Picture 13: Screenshot of ArcGIS Pro 3.0.2 satellite imagery from base map "World Imagery"



Picture 14: Screenshot of the tool "Street View" from Google Earth Web revealing a cemented ravine.



Picture 15: Screenshot of the 3D visualization of the buildings and relief from Google Earth Web. The tool allowed to identify areas that were not possible only with ArcGIS Pro 3.0.2 satellite imagery.

Once those challenges were solved, it was pertinent to summarize the criteria followed to draw the urban ravines, which are explained in the following figure.

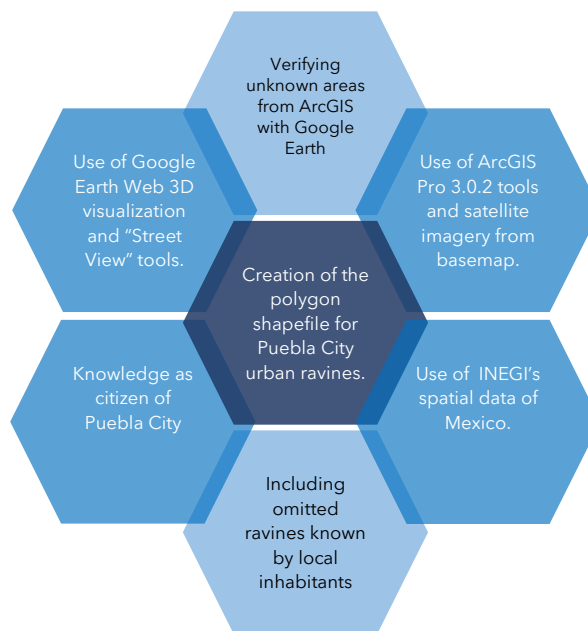


Figure 23: Matrix representing the criteria and tools used to draw the polygon of urban ravines in Puebla City. Source: Self-made.

Once the ravines were drawn, to calculate the area, it was necessary to create a new column in the attribute table of the polygon shapefile, which was called "Area_ha", defined with the following parameters:

- Data type: Float (since many areas are small it is convenient to see the values with decimals)

- Number format: Numeric (4 decimal places)
- Precision: Not defined
- Scale: Not defined
- Length: Not defined

Then, the tool from the attribute table “Calculate Geometry” was used with the following parameters.

- Field: Area_ha
- Property: Area
- Area Unit: Hectares
- Coordinate System: WGS 1984 UTM, Zone 14N (Same as layer)

The same process was repeated to obtain a result in square kilometers, another measurement used in the country. Then, the tool “Statistics” was used to see the total sum of the areas in the drawn ravines.

9.2 The process to propose guidelines for the restoration and conservation of Puebla City urban ravines.

The literature review provided significant information to consider from the Mexican States of Morelos, Jalisco, Mexico City, and Mexico State, the Toronto Ravine Strategy, the studies made about the issues on the ravines in Puebla City, and the findings about the benefits of restoring them. This information was set up as it is explained hereunder to provide a useful framework to propose guidelines for the urban ravines in Puebla City.

The situation of the Mexican States of Morelos and Jalisco showed that the few management programs existing are isolated applications supported by the local authorities or made by other organizations, while the legal framework does not stand out to propose alternatives but rather follows the existing framework, which has some loopholes.

The local press indicated that the Mexico City program, despite being the state with the most developed legal framework, is not complete. This was proven personally by the fact that much of the information is not easily accessible, for example, the 12 management programs that were not found online or the incomplete website talking about the “Program for the Conservation and Sustainable Management of the Ravines of Mexico City”. Those experiences, far from being unhelpful, are

providing key elements to consider for Puebla City in identifying the elements that are obstructing coordinated and effective efforts.

Regarding the Toronto Ravine Strategy, it was found to be a valuable reference for a city that considers its ravines crucial areas for ecological stability, providing a clear strategy with defined targets and a consistent legal framework. Due to its content, it was considered a useful basis to get important insights into structuring the guidelines.

On the other hand, the studies made in Puebla City by the authors Gutierrez Pacheco, Silva Gómez, *et. al.* together with related studies found in the literature review, provide the main framework to direct the guidelines to address the main issues and challenges regarding the urban ravines.

Finally, the GIS data generated during the ecological characterization and the polygon shapefile representing the urban ravines provide useful perspectives and new approaches that the guidelines

With these considerations, the figure on the next page shows the framework followed to propose the guidelines for restoration and conservation of the urban ravines in Puebla City.

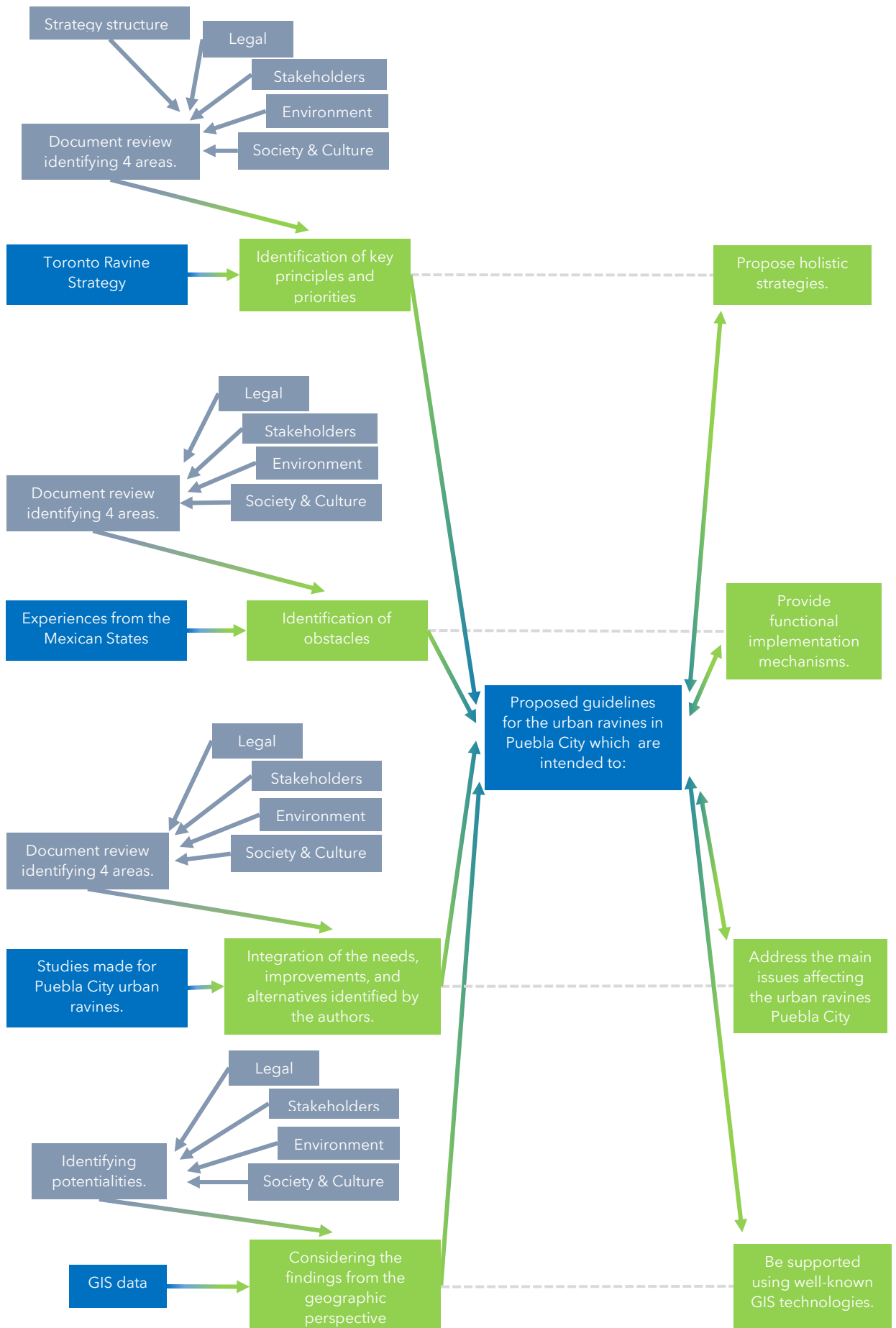


Figure 24: Diagram summarizing the criteria considered to suggest guidelines for the urban ravines in Puebla City. Source: Self-made.

10.0 Results

10.1 The identified urban ravines in Puebla City

The final shapefile polygon was included in the map layout shown below.

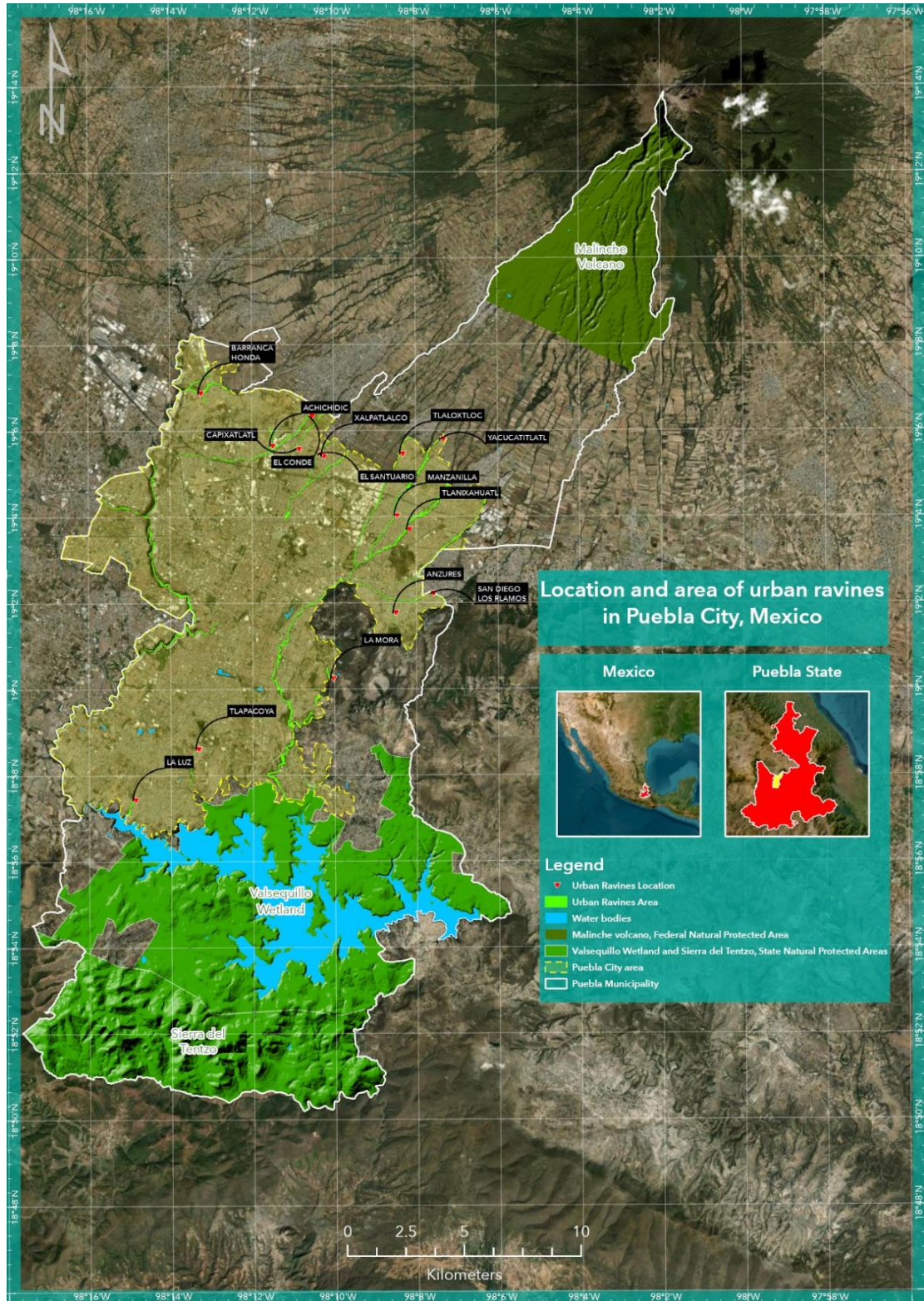


Figure 25: Map showing the urban ravines in Puebla City. Source: Made with spatial data from INEGI, ArcGIS Pro 3.0.2 and Google Earth Web.

The attribute table of the point shapefile representing the location of the ravines, which was delimited with the tool "Select by location" in the software ArcGIS Pro 3.0.2 returned 15 elements corresponding to the urban ravines in Puebla City. Following the methodologies from Jalisco State and Morelos State, the following Table 6 presents the UTM and geographic coordinates:

Table 6: Names and coordinates of the identified urban ravines in Puebla City. Source: Made with information from INEGI and ArcGIS Pro 3.0.2

Ravine name	UTM X	UTM Y	Latitude	Longitude
LA LUZ	579072.9636029367	2096259.3747832186	18° 57' 25.89601637" N	098° 14' 56.11598769" W
TLAPACOYA	581767.8571217733	2098448.205448468	18° 58' 36.72501945" N	098° 13' 23.64101538" W
ACHICHIDIC	584918.1302019279	2111444.475022451	19° 05' 39.06300713" N	098° 11' 33.87097846" W
CAPIXATLATL	586046.7860318946	2111320.5764285894	19° 05' 34.86197328" N	098° 10' 55.26801231" W
XALPATLALCO	587120.2938767395	2111010.0242228643	19° 05' 24.59499482" N	098° 10' 18.58301538" W
EL SANTUARIO	586981.2143997666	2111091.901199194	19° 05' 27.27998559" N	098° 10' 23.32897846" W
BARRANCA HONDA	581847.2850082872	2113694.9112241	19° 06' 52.72698251" N	098° 13' 18.61397538" W
EL CONDE	586597.2262360139	2112731.52597589	19° 06' 20.67900713" N	098° 10' 36.20501538" W
TLALOXTLOC	590481.3269613478	2111115.456384013	19° 05' 27.49797944" N	098° 08' 23.55398769" W
MANZANILLA	590245.0184367155	2108465.6521779257	19° 04' 01.33297636" N	098° 08' 32.08399385" W
TLANIXAHUATL	590773.7957341477	2107885.400337584	19° 03' 42.37199790" N	098° 08' 14.08997538" W
YACUCATITLATL	592213.1852302346	2111754.9697495373	19° 05' 48.02301944" N	098° 07' 24.18201231" W
LA MORA	587533.269628053	2101487.682387106	19° 00' 14.74997329" N	098° 10' 05.99497846" W
ANZURES	590202.2925951043	2104316.401248602	19° 01' 46.35701329" N	098° 08' 34.23900923" W
SAN DIEGO LOS ALAMOS	591809.3199504773	2105136.71614134	19° 02' 12.78599790" N	098° 07' 39.12899077" W

Nonetheless, it is important to know that those ravines belong to the data coming from the [Register of Continental, Island, and Undersea Geographical Names for Statistical and Geographical Purposes \(2022\)](#), which, as previously mentioned does not represent the official location of the ravines but was made with information from local authorities and inhabitants of each zone surveyed.

This was considered during the drawing process, and it was possible to see that the ravines identified in the previously mentioned register were connected to other ravines not registered. Since there was no reference to its extension, the adjacent ravines that were not registered were included in the drawing process since they are part of a stream system that connects several ravines. This was confirmed by the shapefile of water streams that helped to solve this problem together with the satellite imagery from ArcGIS Pro 3.0.2, Google Earth Web, and the personal

experience as citizen of Puebla City. The following figure shows the ravines no registered that were added (shown in color red).

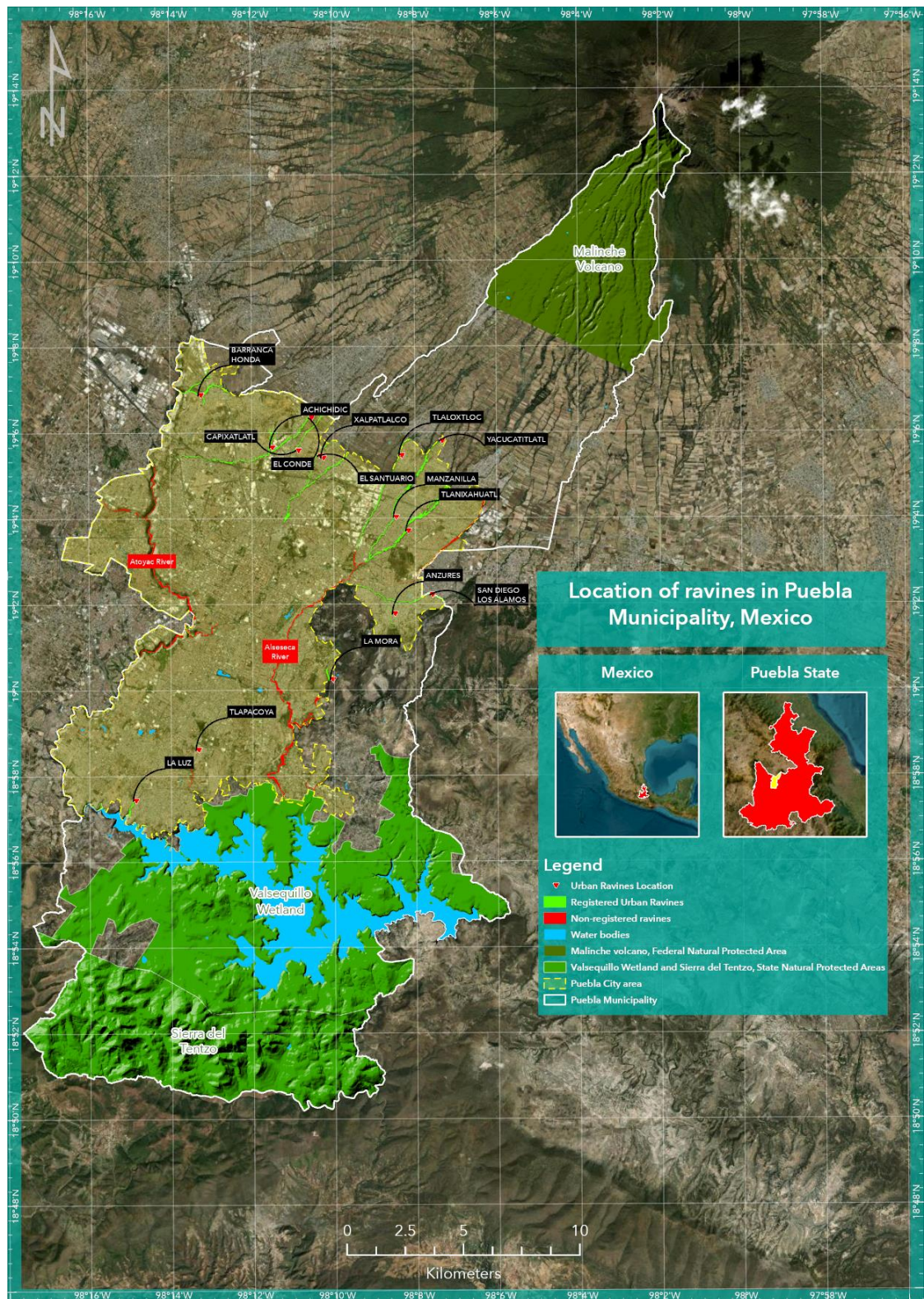


Figure 26: Map showing the ravines which were not registered and were added to the main map. Source: Made with spatial data from INEGI, ArcGIS Pro 3.0.2 and Google Earth Web.

The urban ravines added are the areas that belong to the Alseseca and Atoyac Rivers, which are connected to other urban ravines.

On the other hand, to answer the question about the extension of the urban ravines, the tool "Calculate Geometry" from ArcGIS software used to calculate the area (set up in hectares) returned a value of 390.8 ha.

10.2 The proposed guidelines for the restoration and conservation of the urban ravines in Puebla City

The figure 24 shown in Chapter 8.2 summarizes the process to propose the guidelines. However, the process involved the identification of key elements, which were categorized into 4 aspects. For the [Toronto Ravine Strategy \(2017\)](#), the key elements found are described in Table 7 below:

Table 7: Main aspects identified in the Toronto Ravine Strategy. Source: Toronto Ravine Strategy.

Document	Aspect	Significant aspects
Toronto Ravine Strategy	Strategy structure	Purposes: <ul style="list-style-type: none"> • Establish the principles to guide decision-making in ravines. • Help prioritize future management efforts based on a set of consistent criteria. • Chart a course for future communications, engagements, and balanced use with Torontonians in their ravine system. • Improve coordination between management agencies and other external stakeholders. • Ensure all decisions are made with long-term view that transcends short-view interests. 5 guiding principles: Protect, Invest, Connect, Partner and Celebrate.
	Stakeholders and transparency	The government, Aboriginal Communities, City Planners, Transportation sector, Toronto Water authority, Economic Development and Culture authority, Parks, Forestry and Recreation authority, Institutions, Landowners and public, Community and Environmental groups.
	Environmental (Actions, measures, strategies)	Short and long-term actions. Ravines are considered as green spaces and natural heritage system. The extension of ravines is known (more than 300 km) 20 actions distributed among the 5 guiding principles
	Society and culture	Through campaigns, seasonal events, art installations, including children and diverse communities. Also developing plans to specific groups like park users, property owners, pet owners or other communities.
	Legal	Ravines are protected under the Ravine and Natural Feature Protection Bylaw. Establish a ravine as "landform with a minimum of two-meter change in grade between the highest and lowest points of elevation". Also, consider as ravines the buffer areas, areas of tree canopy, and environmentally significant areas contributing to the function of a ravine. "Environmental Significant Areas" or ESAs .

Regarding the experiences from the Mexican States of Mexico City, Morelos, and Jalisco, as it was mentioned before, the purpose was to identify the aspects that were obstructing progress to execute effective and coordinated efforts to protect their ravines. The Environmental Impact Assessment from Mexico State was not included since it is oriented toward a project. Only describes measures to downscale the impacts, so it cannot be considered an integral management program. The document review of each city allowed for the identification of the following obstacles described in Table 8 and Table 9.

Table 8: Obstacles identified in the law and management programs from Mexico City. Source: Self-made with the documents mentioned. .

City	Aspect	Obstacles identified
Mexico City	Legal	There are loopholes between the law and the actions. The Environmental Law for Land Protection states that <i>all ravines</i> are "Areas of Environmental Value" but the website " Ravines of Mexico City " indicates that there are 27 of 44 officially recognized ravines declared under that category through decrees.
	Stakeholders and transparency	<p>The local press revealed that the Mexico City management plan for the ravines that the local authorities were about to present was incomplete and delayed This was demanded by other governmental institutions related to environmental protection. This situation gives a clue about the low level of coordination between the local authorities and the federal authorities.</p> <p>The websites mentioned in Chapter 3.2 are just providing general information about the ravines. There are links to non-working websites, not all the documentation mentioned is available and the information is not updated. Therefore, it is difficult to track the progress of the city regarding the ravines.</p> <p>The website "Program for the Conservation and Sustainable Management of the Ravines of Mexico City" mentions that there is an ongoing process to develop the program. Nonetheless, there is no official document, year of reference, or other references. The website belongs to the government but it seems incomplete.</p>
	Environmental (Actions, measures, strategies)	The documents reviewed and the websites consulted, which were mentioned in Chapter 3.2 show that there are diagnoses made for some of the ravines in Mexico City. Those diagnoses are identifying the issues, but the environmental proposals are mostly limited to mentioning which environmental features and legal frameworks should be considered for the next steps.
	Society and Culture	<p>There were no cultural approaches found in the documents reviewed and the websites consulted.</p> <p>The document "Workshop memories: Urban Ravines: solutions to environmental issues and financial options (2007)" mentioned in Chapter 3.2, indicates that there are civil organizations working for the restoration of the ravines, but they are not identified.</p> <p>The website Ravines of Mexico City is providing information to make reports to the authorities about any illegal or suspicious activity in the ravines. Nonetheless, there is no other mechanism to engage the society identified in this website, which is oriented toward public knowledge.</p>

Table 9: Obstacles identified in the management programs from the Mexican States of Morelos and Jalisco.

City	Aspect	Obstacles identified
Morelos State	Legal	The documents " Integral plan for the sustainable management of the northwestern ravines of the State of Morelos (2012) " and " Integral management plan for the ravines system in northwestern of Morelos (2018) " were made by two different entities (public decentralized organization and university respectively). The legal mechanisms to apply them are not clear.
	Stakeholders and transparency	Not defined explicitly in the document " Integral plan for the sustainable management of the northwestern ravines of the State of Morelos (2012) " It only identifies the legal framework applicable and the related strategies and programs. The main stakeholders would be the local authorities, the private sector, and the society. No obstacles were identified in the document " Integral management plan for the ravines system in northwestern of Morelos (2018) ". Stakeholders are listed explicitly.
	Environmental (Actions, measures, strategies)	No obstacles were identified for the document " Integral plan for the sustainable management of the northwestern ravines of the State of Morelos (2012) " There are concrete actions for each ravine. No obstacles were identified for the document " Integral management plan for the ravines system in northwestern of Morelos (2018) " There are concrete actions for the ravines in general.
	Society and Culture	No obstacles were identified for the document " Integral plan for the sustainable management of the northwestern ravines of the State of Morelos (2012) ". There are actions intended to promote civil engagement. No obstacles were identified for the document " Integral management plan for the ravines system in northwestern of Morelos (2018) ". There are actions intended to promote civil engagement.
Jalisco State	Legal	No obstacles were identified, since the document " Technical Justification Study and Management Program, Ravines of "Santiago" and "Verde" Rivers (2015) " indicates the program is in accordance with the Federal and State law.
	Stakeholders and transparency	No obstacles were identified, since the document " Technical Justification Study and Management Program, Ravines of "Santiago" and "Verde" Rivers (2015) " indicates provides a diagram of the stakeholders.
	Environmental (Actions, measures, strategies)	The document " Technical Justification Study and Management Program, Ravines of "Santiago" and "Verde" Rivers (2015) " mention are actions but more details are needed.
	Society and culture	There were no cultural approaches found in the document " Technical Justification Study and Management Program, Ravines of "Santiago" and "Verde" Rivers (2015) ". Only mentions public consultation as a federal law requirement, but the document indicates the procedure should be done by local authorities.

Regarding the studies made in Puebla City about the urban ravines, the needs, improvements, and alternatives that the authors identified are described in the Table 10 on the next page.

Table 10: Needs, improvements or alternatives proposed by the authors of the studies, assessments, and articles for Puebla City ravines. Source: Made with the reference below indicated.

City	Aspect	Needs, improvements or alternatives
Puebla City	Legal	<p>Change the paradigm regarding the ravines (Gutiérrez Pacheco & Silva Gómez-c, 2017).</p> <p>Considerate the ravines as a complex system that is part of the city metabolism (Gutiérrez Pacheco & Silva Gómez-c, 2017).</p> <p>Management should guide the decree of the urban ravines as federal protected areas (ANP by its acronym in Spanish) (Gutiérrez Pacheco et. al., 2018).</p> <p>State government should take the initiative, despite of the indifference of the Federal authorities (Gutiérrez Pacheco et. al., 2018).</p>
	Stakeholders and transparency	<p>Change the paradigm regarding the ravines (Gutiérrez Pacheco & Silva Gómez-c, 2017).</p> <p>Considerate the ravines as a complex system that is part of the city metabolism (Gutiérrez Pacheco & Silva Gómez-c, 2017).</p>
	Environmental (Actions, measures, strategies)	<p>Considerate the ravines as a complex system that is part of the city metabolism (Gutiérrez Pacheco & Silva Gómez-c, 2017).</p> <p>Conservation measures are needed to ensure the conservation of the remnants of oak forests (Gutiérrez Pacheco et. al., 2021).</p> <p>Extend studies to all living organisms that are present in the urban ravines (Gutiérrez Pacheco et. al., 2021).</p> <p>Extend the environmental studies to all the ravines in Puebla City (Gutiérrez Pacheco et. al., 2021).</p> <p>Conservate the environmental services that the urban ravines are providing to the city (Gutiérrez Pacheco et. al., 2021).</p> <p>Interdisciplinary approaches to know the complexity of the current situation (Gutiérrez Pacheco et. al., 2018)</p> <p>The studies should provide information for decision-making processes (Gutiérrez Pacheco et. al., 2018).</p>
	Society and culture	<p>Change the paradigm regarding the ravines (Gutiérrez Pacheco & Silva Gómez-c, 2017).</p> <p>Considerate the ravines as a complex system that is part of the city metabolism (Gutiérrez Pacheco & Silva Gómez-c, 2017).</p> <p>Disseminate information about the benefits of restoring and conservating the urban ravines to Puebla City society (Gutiérrez Pacheco et. al., 2021).</p> <p>Promote connection and identity between the society and the urban ravines (Gutiérrez Pacheco et. al., 2021).</p> <p>Promote interest to academic sector (Gutiérrez Pacheco et. al., 2018)</p> <p>Considerate an approach to the wellness from the society to the urban ravines (Gutiérrez Pacheco & Silva Gómez-a, 2020)</p>

Finally, regarding the GIS data generated in Chapter 4.5 (the characterization) and the polygon shapefile representing the urban ravines in Puebla City, the findings were used to generate the following considerations for the guidelines. The results are shown in Table 11.

Table 11: Considerations made from the GIS Data from the ecological characterization of the Chapter 4.5 and the polygon shapefile representing the urban ravines in Puebla City.

City	Aspect	Considerations from GIS Data
GIS Data	Legal	When creating a legal framework, it is necessary to use GIS tools to delineate and identify properly the ravines.
	Stakeholders and transparency	Open spatial data will help for transparency. This is an ongoing practice at all levels of Mexican government.
	Environmental (Actions, measures, strategies)	<p>Establish an official method to delineate the urban ravines.</p> <p>There is spatial data that provides information about the flora, fauna, soil types or land uses. Specific data is needed for the urban ravines, coming from on-site analysis.</p> <p>Locating the sources of pollution can support decision-making processes.</p> <p>Critical to know the situation of the ravines in the municipality since the urban ravines are only a part of the whole system.</p>
	Society and culture	The ravines are identified by names which allowed the creation of a point shapefile from official institutions (INEGI). There is potential to create a connection and identity between the society and the urban ravines if this feature is exploited.

Once all the aspects and key elements from the Toronto Ravine Strategy, the experiences from the Mexican States, the studies and articles made about Puebla City urban ravines, and the GIS data were combined, it was possible to propose guidelines that were classified by their area of application.

The guidelines are exposed on the next page, presented as circular diagrams that are structured as follows.

- The center of the circle represents the main category of the guideline.
- The external arcs represent the subcategories of the guideline.
- The inner polygons represent the proposals belonging to the subcategories.



Figure 27: Proposed legal guidelines for the urban ravines in Puebla City. Source: Self-made.



Figure 28: Proposed guidelines for stakeholders and transparency practices for the urban ravines in Puebla City. Source: Self-made.

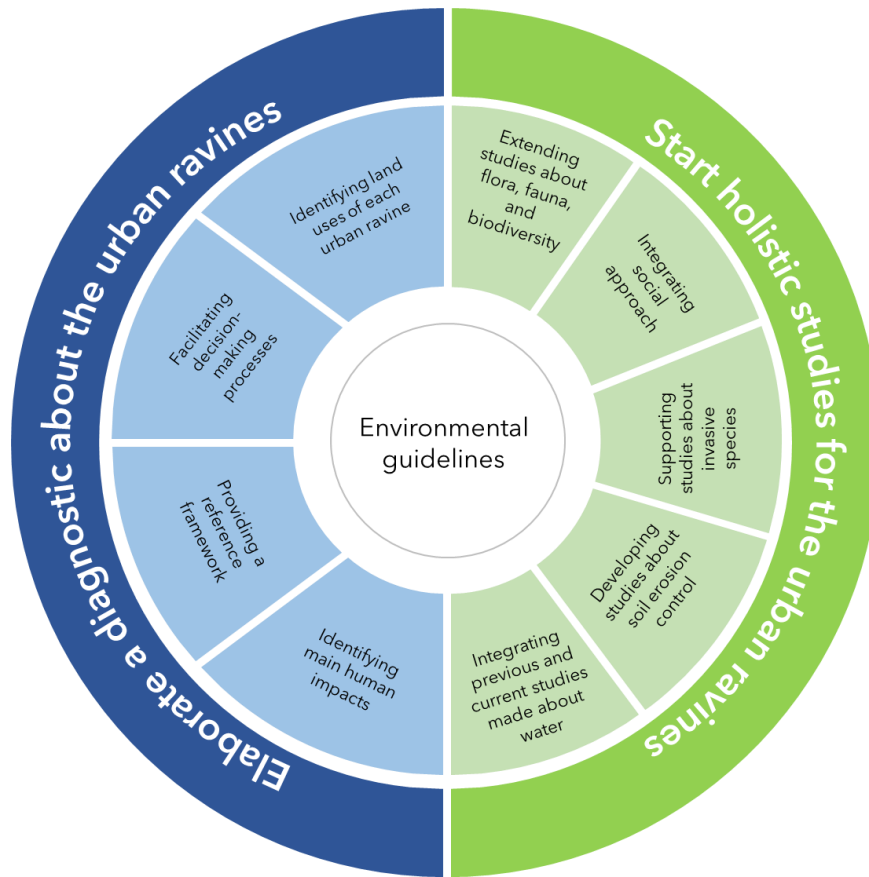


Figure 29: Proposed environmental guidelines for the urban ravines in Puebla City. Source: Self-made.

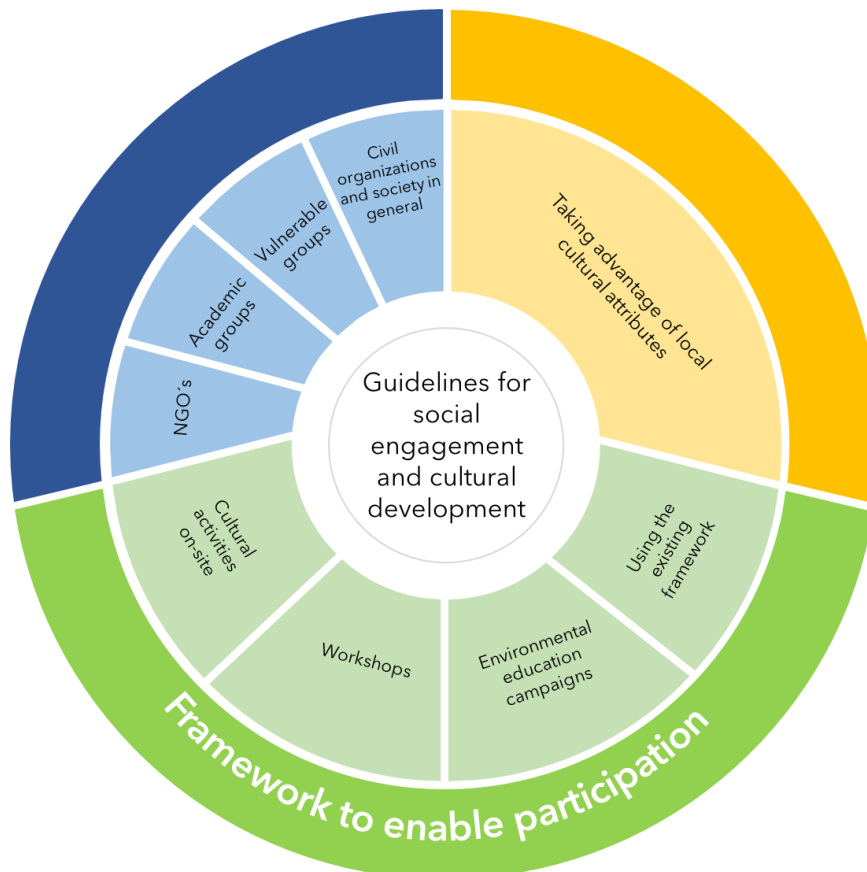


Figure 30: Proposed guidelines for social engagement and cultural development related to the urban ravines in Puebla City. Source: Self-made.

11.0 Discussion

11.1 Regarding the legal guidelines

The Chapters 3 and 3.1, which made a review of what is a ravine and the legislation related at all levels of government, revealed that Mexico City has more legal developments for the ravines in its territory, compared with the other Mexican states. Furthermore, Chapters 6 and 9.2 revealed that the Toronto Ravine Strategy has a defined legal framework for the ravines, which are connected to other strategic areas of the city. Looking at the stakeholders involved, made it possible to see the scope of this strategy, involving natural protection, transportation, economic development, and the inclusion of aboriginal communities, just to mention a few examples.

With these considerations, it was possible to identify important legal and strategic similarities between Mexico City and Toronto City, despite being in different countries. Those similarities are described below:

- A definition of what is a ravine is included in the legislation. Mexico City includes the definition in the "[Environmental Law for Land Protection](#)", whereas Toronto City has the "[Ravine and Natural Feature Protection Bylaw](#)."
- The creation of a legal entity where the ravines can be included, depending on its features. For Mexico City, this entity is called "Areas of Environmental Value" and for Toronto City, is "Environmentally Significant Areas".
- Both cities, in their laws, contemplate that any activity or modification that may change the ravines or their features, requires authorization.
- Both cities recognize that ravines are part of the green infrastructure. Mexico City in the "[Environmental Law for Land Protection](#)" and Toronto City in its [Ravine Strategy \(2017\)](#).

These similarities led us to consider that in cities where ravines are an element of the urban landscape and the city metabolism, the establishment of a legal framework is needed. Subsequently, the proposed guidelines belonging to the group "*Include the ravines within a legal category*" came from the identification of these similarities.

The only proposed guideline, which in fact comes from a difference between both cities, is related to the measure of the ravines. The [Toronto Ravine Strategy \(2017\)](#), at least on its website, provides a measure of the whole ravine system, which is more than 300 km, whereas the Mexico City legislation or the website "[Ravines of Mexico City](#)" do not provide this information. Including a measure in the legislation or decrees about the extension of relevant areas is a typical practice in Mexico, for instance, where it is used in the decrees of protected natural areas.

For these reasons, proposing an official measure about the extension of the ravines in Puebla seems plausible and necessary.

On the other hand, the proposed guidelines belonging to the group "*Create a legal strategy to make way for management programs*" were made considering the [Toronto Ravine Strategy \(2017\)](#) structure, which exposes some points that were not found within the revised Mexican documents. Hereunder are described those points:

- The document mentions that the strategy is the first phase of an ongoing management process that will guide policies, activities, investment, or any other aspect related to its ravines (p. 63).
- Propose to see the ravines as a whole system (p. 63).
- It proposes management decisions with long-term views transcending short-term interests (p. 1)
- Within the long-term actions, the creation and implementation of management plans will take no more than 10 years (p. 1). According to the [Toronto Ravine Strategy website](#), there was an adoption by the City Council in January 2020 of the "Ravine Implementation Report", which outlines the recommendations and actions for the next 10 years.

Those points establish clearly that a strategy is needed before taking actions and developing management programs. This strategy is even setting a baseline for a decade, probably considering the complexity of restoring and protecting the ravines in the city, involving several stakeholders and interests related to the ravines.

On the contrary, the experiences of the Mexican States revealed that there is not a clear or common strategy, but instead the application of management programs

comes directly from the interpretation and application of the law at all levels of government.

This might be appropriate for other sectors, but the evidence found reveals that a change or alternative is needed, especially in cities with ravines. For instance, in Morelos state 2 management programs were found with no information about which one is officially applied, or in the case of Mexico City where not all ravines have been studied and the process seems lengthy, no common strategy was found and it is not fulfilling the deadlines.

Therefore, Puebla City can use those experiences, from Toronto City and the other Mexican states, to build from scratch the legal requirements that can allow the creation of a local strategy adapted to the local context and needs, with completion times according to the complexity of the issues and the investments that the stakeholders are willing to make.

These ambitions may be difficult to realize due to the current political instability that Mexico is facing, which is particularly significant in the environmental context. On the other hand, addressing the urban ravine situation under this scope, can bring benefits to current and future governmental administrations if the benefits are well analyzed and communicated to strategic actors.

11.2 About the guidelines for stakeholders and transparency practices.

Regarding the sub-category "Identify key stakeholders", the [Toronto Ravine Strategy \(2017\)](#) and the management program from Jalisco State, had a significant influence on the proposal.

One of the guiding principles is called "Partner", where the document of the strategy describes the involved city agencies and other interested parties in the management of the ravines. This information made evident that restoration and conservation of the ravines are tasks that imply an important role from authorities. However, the strategy showed that goals cannot be dependent on one actor due to the complexity of the issues to be addressed. This is especially true in Puebla City, where the issues related to the urban ravines are requiring different approaches, investments, alliances, and the accurate identification of responsibilities.

On the other hand, the legislation review made in Chapter 3.2 allowed to identify that only Jalisco State had structured information about the stakeholders involved in its management program. On the contrary, Mexico City, despite having the tools to structure the information related to the stakeholders, does not make this very clear to the public and appears to be intended to describe the legal formalities. The same situation was seen regarding the identification of mechanisms that could allow cooperation between stakeholders, where Mexico City was noted for its setbacks.

With the information abovementioned, identifying the key stakeholders was considered a step that, despite being basic and somehow obvious, could significantly influence the success of the implementation of strategies, programs, and actions.

In the sub-category called "Prioritize decisions and actions", the Puebla City context and the [Toronto Ravine Strategy \(2017\)](#) were considered entirely. The Canadian strategy has a guiding principle called "Invest", which basically recognizes the economic benefits that the ravines in Toronto are providing, as well as the need to invest money in areas that require particular attention. However, the areas where those investments are planned are according to the Toronto City context.

At this point, the information from Chapter 5 helped to address the main issues of Puebla City, which were in general the human impacts derived from the practices of the industry sector, the solid waste pollution, the water pollution, and the poverty that has led vulnerable groups to settle down next to or inside some of the urban ravines.

Those problems seem urgent in Puebla City since they are negatively affecting the city metabolism, degrading the urban landscape, affecting the life quality of the people who are living in or near the urban ravines, and threatening the remnants of biodiversity.

For those reasons, investments are required to improve the general status of the urban ravines, always considering the limitations of the stakeholders, which in Mexico in general, are mostly related to limited budgets from the official institutions and local authorities. Yet, small steps with small investments can be done if the existing mechanisms allow it or if they are created for a common purpose, which in this case is the restoration and conservation of the urban ravines.

Finally, the sub-category called “Share information related” was proposed considering the examples from the States of Mexico and the Toronto Ravine Strategy, where in general some amount of information was found in all cases. Nonetheless, the goal is to reach the maximum level of transparency, with structured information available to the public in the form of documents, websites, references, or audiovisual material such as videos. Within those practices, the Toronto Ravine Strategy stood out enormously, with a dedicated website for public dissemination that shared the most important details about the strategy, a video available on YouTube, diagrams, the official documentation available to download, references to related information, and contact details.

Fortunately, both the state and the municipality have existing mechanisms for sharing open data online with the public, such as the website “[Open Data Mexico](#)” which is from the federal government, or the website “[Open Data - Puebla State government](#)” . Therefore, structuring, publishing, and disseminating open data related to the ravines using these channels could be the starting point.

11.3 Regarding the environmental guidelines

These guidelines are divided into 2 sub-categories: “Elaborate a diagnostic of the urban ravines” and “Start holistic studies about the urban ravines”, which are deeply interconnected.

In other words, to create a diagnostic about the urban ravines in Puebla City, studies on different topics are needed to provide an overview of their status. Considering this, decomposing the information that led to the creation of the sub-category “Start holistic studies about the urban ravines” is important.

First, Chapter 3.3 demonstrated that only 6 sources were found that address the issues of the urban ravines in Puebla City from different perspectives. Three of them were focused on 2 urban ravines (“El Conde” and “Malinalli”) and provided an approximation of the general situation. However, the authors pointed out that it is important to extend the studies to other urban ravines.

On the other hand, the data available allowed for only an approximation of the different features of the urban ravines. For instance, Chapter 4.5 was made with national data, but the scale of the information presents various limitations if the data is used for detailed studies, such as the extension of certain types of soil present in

the urban ravines, the flora and fauna present inside them, or measures about the slope, which might not be precise until on-site analysis could verify the real measures.

Meanwhile, Chapter 5 revealed that there are studies that are indirectly or directly mention the situation of the urban ravines and their role in Puebla City metabolism, especially regarding water and solid waste pollution.

Moreover, the documents reviewed in Chapter 3.2 revealed similarities in the analysis of the environmental factors, probably due to the need for alignment with the federal legislation. However, there was no integration or mention of other studies coming from academic or scientific sources. Therefore, there is a high probability of omitting key elements. Here is where the Toronto Ravine Strategy has made more progress since it is considering existing mechanisms and knowledge about the ravines, proposing partnerships with the Royal Ontario Museum, the Toronto Zoo, or the Ontario Science Centre.

Due to the findings explained above, for Puebla City, the proposal of holistic studies that integrated the information regarding the water and solid waste, addressed from a socio-environmental point of view the problem of the human settlements living in the ravines, and extended the studies for flora and fauna was necessary to cover the most important urgencies regarding the urban ravines.

Additionally, it was noticed that, for the Mexican States and the [Toronto Ravine Strategy \(2017\)](#), just a few mentions about soil erosion control were made in the documentation. It is not possible to define if those cities do not consider erosion as a strategic practice for the protection and conservation processes, but at least for Puebla City, the pictures taken on-site showed that it should be a priority. The strongest evidence is the construction of gabion walls in segments of the urban ravines where people are living, a technique known as a measure for erosion or slope instability.

Once these elements abovementioned have been detailed, the last sub-category, "Create a diagnostic about the urban ravines", settles down the basis for the role of making a diagnostic about the urban ravines, such as facilitating decision-making processes, providing a reference framework, and identifying the main human impacts. Those are tasks which can be possible with the integration of holistic studies.

Those holistic studies should include, for instance, the consideration of the whole ravine system, which starts in the volcano "Malinche" and passes through the agricultural and rural areas before finding its way through the city.

Finally, the elaboration of a diagnostic can facilitate the identification of different land uses in each ravine depending on the human impacts, severity of degradation, and conditions of the soil, among other criteria. Determining the land use of the urban ravines must be considered a critical step that will impact directly on the wellness of Puebla City's inhabitants and the conservation of biodiversity throughout the upcoming years and for future generations.

For instance, we can mention the segment of 21 hectares of the Atoyac River that implied the restoration of an area with ravines. It was possible due to the "MIRAtoyac" project started in 2011 which transformed into an urban park that segment, which was severely degraded by solid waste pollution. Since then, the park quickly became part of Puebla City's dynamism and is now a very visited area, despite some disadvantages like the low maintenance of the park equipment, the bad odor emitted by the Atoyac River, or the insecurity inside the park and the adjacent parks.

This example is probably the most recognized in the city regarding the restoration of a degraded urban area and can be used as a reference to decide the land use of the other urban ravines around Puebla City. Considering the lack of green areas in the city exposed by [Gutiérrez Pacheco et. al. \(2018\)](#) the urban ravines, independent of their features, can be integrated into the green infrastructure.

A quick analysis of this was made in ArcGIS Pro 3.0.2, inspired by [the World Health Organization \(2016\)](#), using available open data from Puebla Municipality to compare the area of the registered parks and gardens in the city against the calculated area of 390.8 ha from the generated shapefile polygon of the urban ravines. The parks and gardens were obtained from the shapefile "*Inventory of public recreational spaces, 2019*," obtained from the geoportal [SIGEM](#).

The results revealed there are 148.6 ha of parks and gardens in Puebla City, therefore, there is a big potential for the urban ravines to be used as green spaces that, depending on their status, might be adequate to allocate equipment for recreation.



Figure 31: On the left, Puebla City polygon with the shapefile of recreational public spaces. On the right, Puebla City polygon with the shapefile of the urban ravines created. Source: Self-made with ArcGIS Pro 3.0.2 and with spatial data from SIGEM.

11.4 Regarding the guidelines for social engagement and cultural development.

This last category was influenced by the [Toronto Ravine Strategy \(2017\)](#), whose guiding principle “Celebrate” describes the importance of supporting the recognition of the ravines through different actions. Additionally, the literature found about the urban ravines in Puebla City was the other influence for this category since it provided the context for the proposals and the authors described the needed changes in the relationship between the urban ravines and society.

The first sub-category “*Establish communication mechanisms*”, includes non-governmental organizations, academic groups, civil society and organizations, and vulnerable groups. Those are the expected targets in a common process of communication between the authorities and society with one exception: the vulnerable groups.

That sector is referring to the people who are living in the urban ravines in poverty conditions and were added to the proposal as a separate group since alternative or extra mechanisms of communication and coordination are needed. For instance, they require legal support and advisory services to regularize their living conditions by way of permits, authorizations, or any other formality, as well as support to be re-allocated to safer places.

On the other hand, the sub-category called *“Develop a sense of ownership”* considers the previous arguments from [Gutiérrez Pacheco & Silva Gómez-c, 2017](#) about the need to change the paradigm constructed nowadays about the urban ravines as places with no utility, dangerous, polluted and subsequently, an obstacle.

An approximation to this change may be found in the proper Mexican culture, which is a result of the combination of the cultures from the so-called “Old World” and “New World” since the conquest of America. That heritage is expressed, for example, in the way Mexican society refers to the different geographic elements around it. One good example can be found in the volcano “Popocatepetl” which is also known by the nickname “Don Goyo” due to the myths attached to the volcano. Both names are used widely in the whole country and prove the connection and appreciation that people have for the volcano.

This cultural feature is also seen in the ravines in Puebla Municipality because, according to the [Register of Continental, Island, and Undersea Geographical Names for Statistical and Geographical Purposes \(2022\)](#), the ravines are also holding names. However, this information is clearly not spread and attached to the society as the example of the volcano explained in the last paragraph showed. Still, the fact that the ravines are named is proof that at some point in the local history there were events or features relevant to the location that could be useful to explore.

This example might be just one of several that can be used to contribute to changing society’s perception about the ravines taking advantage of the rich Mexican cultural heritage.

Finally, the last sub-category called *“Framework to enable participation”* was proposed, thinking about the urban ravines (where possible) as spaces to bring people together to develop different activities on-site, such as cultural activities or workshops. Enabling these spaces opens the way for people to experience another use for the urban ravines, rather than as sites of waste disposal or an obstruction for urban development. Additionally, these spaces can be used for environmental education campaigns to promote the urban ravines in a different way or to expose the most severe issues that are affecting their conservation.

Also, enabling participation involves other kinds of engagement that could be facilitated by the authorities, such as registering directly from the society the complaints, needs, or even proposals related to the urban ravines. In fact, there is a mechanism like this that was recently implemented for general purposes in the city and is known as "[Martes Ciudadano](#)" which closest translation is "Citizen's Tuesday" and is a direct channel between the society and authorities. However, there are no indicators about the level of participation from society or the kinds of issues that can be addressed.

Having said that, due to the complexity of the issues related to the urban ravines, new and specific channels can be opened to enable the society's participation and achieve good coordination with the authorities.

12.0 Conclusions

This thesis made it possible to analyze and compare the issue of the urban ravines in Puebla City from different approaches and with different examples in Mexico and Canada. At the same time, it revealed that managing urban ravines is a practice that needs to be evaluated holistically.

The examples from the Mexican States and the City of Toronto prove that urban ravines have the potential to improve or worsen drastically the environment and the landscape of their surroundings. It is worth noting that, despite finding the Toronto Ravine Strategy to be the best example of a city acting on its ravines, other cities might be applying restoration and conservation measures to their ravines. Nonetheless, only a few cities were found to give an individual identity to the urban ravines, apart but not excluded from the natural landscape.

The evidence shown in this project indicates that in some cases, giving an identity to ravines located inside cities (legal, ecological, cultural) is nothing but necessary under a framework of city metabolism, since they can serve as channels where the cities can dump the outputs of their activities, or they can serve as buffer zones that can eventually cover the ecologic, health, economic, and climatic needs.

Recognizing the potential of these spaces can be a great opportunity for cities with those landforms to demonstrate that urban activities can coexist with the natural environment.

Regarding the Puebla City situation, the inexistence of management programs or legislation oriented to its urban ravines, provides a great chance to analyze and set up priorities to establish a strategy. Such a strategy could integrate the previous research, studies, and articles addressing the issues in Puebla City to respond to the identified needs and propose urgent actions. Also, we could integrate all the different stakeholders from the authorities at all levels of government, the society, the vulnerable groups, the private sector, and all the institutions that are taking part directly or indirectly in the Puebla City developments.

Since this thesis presented approaches that led to the formulation of initial guidelines, there is more progress to be made that might change the priorities. Those proposed guidelines are followed by numerous implications that were considered challenging but possible, since the city has made similar efforts in other areas. For instance, locating and establishing the official area of the urban ravines

can be done using information already surveyed for the Risks and Hazards Atlas of Puebla City, 2021.

It is also very important to balance progress with on-site work supported by technologies like GIS or remote sensing. According to the documents reviewed, this is probably the best way to produce accurate and helpful information and data for decision making processes.

Regarding the scope of this thesis, since it integrated a series of works done from Gutiérrez Pacheco *et.al.*, establishing synergies and defining the useful contributions made on each project could help arrange an important contact with Puebla City authorities, explaining the findings and proposing alternatives considering limitations of any kind.

The authorities of Puebla City have demonstrated interest and willingness to listen to the needs of the society with the implementation of "Citizen's Tuesday", so this could be the first and fastest channel to expose the concerns that are competing for all Puebla City inhabitants.

Despite the challenges that Puebla and the country are facing, the recognition of natural areas such as the urban ravines is more important than ever to leave the next generation a better city to live in and experience.

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