# Risk Analysis of Urban Water Infrastructure Systems in Cauayan City

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*Abstract*—**The City of Cauayan Isabela is known as one of the first smart cities and leading agro-industrial centers in the Philippines. Since the center of the economy is in urban areas like Cauayan City, there is a tendency for people and businesses to converge when development and activity take place, with that, a risk analysis was done to analyze hazards for urban water infrastructures in the City of Cauayan. This paper includes an Inventory of the existing urban water infrastructure, with the aid of Geographic Information system Software and gathered data, maps were generated for flood hazards with 5, 25, and 100 yr. return period, liquefaction, ground shaking, and drought of urban water infrastructures. These maps were generated to help the people of Cauayan City, Isabela. The main goal of the paper is to assess the potential prone areas where water infrastructures are located, and monitor areas that are suitable for building such water infrastructures. Problems encountered by the people in utilizing urban water infrastructure can be able to minimize by proper installation of water infrastructures in suitable places which can help the people of the city in water utilization. Since Storm water can cause wide flooding in low elevated areas, to utilize the storm water and to address such problems, an urban water infrastructure with decision support systems intervention can be able to help the city in times of scarcity of water. In addition, the analysis can be used by the local government of the city for proper planning and to project the extent of the hazards.**

***Keywords—Water infrastructure; risk analysis; geographic information systems; decision support systems; storm water***

## I. Introduction

Urban places like Cauayan City in the province of Isabela have a growing population which is a sign that the water demand will increase in future years. Building water infrastructures in places that are prone to hazards like flood, drought, liquefaction, and ground shaking will cause trouble in water utilization which leads to limited sources of water. Thoroughly hazards like flood, drought, liquefaction, and ground shaking will affect the growing economy of the City, and to mitigate the effects of future hazards, a risk analysis can able to help people to assess the areas where water infrastructures can be installed and for proper planning.

Risk analysis is the process of identifying and assessing potential issues that could negatively impact important business initiatives and operations [1]. This process is utilized in mitigating or reducing certain risks. When performing a risk analysis, adverse events are taken into account, caused by either natural phenomenon, such as severe storms, earthquakes, or floods, or undesirable occurrences brought about by intentional or unintentional human activities. In addition, the process of a risk analysis helps determine the potential harm from these occurrences, as well as the probability of its occurrences [2].

One of the most frequent types of natural disasters is floods, occurring when an overflow of water submerges land that is usually dry [3]. Floods brought by heavy rainfall can result in a wide range of devastation of critical public health infrastructure, damage of personal property, agricultural sector, and loss of life. From 1998-2017, 2 (two) billion people worldwide were affected by floods [4]. The most vulnerable to floods were the people who live in floodplains or non-resistant buildings, places that are not aware of flooding hazards, or lack warning systems. In this case, a flood risk assessment (FRA) can be done, reviewing the development of documents for its proposal form to consider the possibility of flooding from rivers or groundwater, surface water from sewer sources, estuaries, or even the coast, It must also consider the community and whether a flood risk exists with the development risk to adjacent areas.

Historically, saturated soils have been primarily linked to liquefaction in soils. Unsaturated soils may also be prone to liquefaction in the presence of seismic activity. The consequences of not prioritizing unsaturated soils that are close to saturation as the first rule for liquefaction assessment can be dangerous and disastrous.

Ground shaking is the second main risk for earthquakes due to rapid ground acceleration [5]. There are various levels of ground shaking in one region depending on aspects like topography, type of bedrock, and location and orientation of the fault rupture, all of these have an impact on how seismic waves travel through the ground. Suppose an earthquake is strong enough to cause significant damage to established structures, and sloped terrain may become unstable temporarily or permanently. In a wider extent of earthquakes, districts can be completely destroyed by the effects of ground shaking.

In the natural climate cycle, a drought is a protracted dry period that can happen anywhere. The lack of precipitation makes it a disaster with a slow onset that causes in a shortage of water. Drought can seriously affect agriculture, health, energy, economies, and the environment [6] . Drought affects an estimated 55 million people worldwide every year, and they are the greatest threat to livestock and crops almost everywhere in the world [7]. Due to drought, the livelihood of individuals is at high risk of disease, death risks are increased and mass migration is fueled. In addition, 40% of the world's population suffers from water scarcity [8], and as a result, the probability of 700 million people being uprooted due to droughts is high by 2030 [7]. On the other hand, regions that are already dry are becoming drier due to rising temperatures brought on by climate change, and wet areas getting wetter. This means that as temperature rises in arid areas, water evaporates more quickly, increasing the possibility of drought or extending the period of drought. Approximately 80-90% of all reported disasters caused by natural calamities over the last ten years have been devastated by floods, drought, tropical cyclones, heat waves, and extreme weather [7].

## II. Related Works

The identification of locations susceptible to floods and flash floods is an important component of risk management. Floods are natural risk occurrences that vary in severity and cause considerable economic and human losses. They are caused by the interaction of various distinct anthropogenic and natural variables that are particular to a place and have varied impacts on the formation of these events [9]. Around one billion individuals live in flood-prone regions, and floods are regarded as one of the world's most damaging dangers. Under anticipated climate change scenarios, the risks of extreme hydrological events and floods are especially expected to be high and to rise over time [10].

Flash floods are one of the most severe natural disasters, threatening human lives and property in many countries around the world [11] [12]. Floods destroy a large number of people and animals and create catastrophic financial and property damages. They have massive socioeconomic consequences, infrastructural devastation, and environmental disturbance [13]. One of the solutions to solve this is through flood suitability and flood hazard maps that would be useful in assisting local governments, national and international organizations with flood disaster risk reduction and flood shelter design and building [14].

On the other hand, liquefaction is a soil behavior in which strength is reduced and arises due to an increase in pore pressure during earthquake ground shaking on saturated soil [15].One of the most prevalent seismic consequences that frequently leads to major structure damage during earthquakes is soil liquefaction. Various locations of the world have previously reported liquefaction-induced ground and structure damage in loose, saturated sands and other granular soils [16].

Mapping broad territories for earthquake-induced soil liquefaction danger may appear to be an oxymoron, given that soil liquefaction is a spatially highly limited phenomena in and of itself [17]. In a recent study, they developed combined velocity and fault model that paved the way for further research into seismic segmentation, ground shaking, and rupture modeling [18]. Following the current national earthquake hazard models, the a newly constructed seismogenic source model was established in a paper which includes completely harmonized and cross-border seismogenic sources [19]. In addition, a seismic hazard analysis was also done based from the geologic and geomorphic data [20]. In this study, it includes current and future challenges. Another study was conducted to develop a region-specific soli behavior type index corrections for evaluating liquefaction hazards [21].

Drought is also considered for assessment in this study. Drought catastrophes endanger agricultural productivity and are projected to worsen as a result of global climate change [22]. Drought analysis was studied that resulted in the identification of key dry periods based on the analyzed drought features, as well as the development of geographic maps of magnitude, length, and intensity for each index for each dry period [23]. Authors have also identified that the standardized precipitation index is used to estimate the drought hazard (SPI) while drought susceptibility is assessed using a variety of indicators, including meteorological conditions, soil characteristics, and irrigation factors [24]. Several models for drought hazards were established like novel hybridized models [25] and MODIS-based Evaporative Stress Index (ESI) and ROC Analysis [26] that offer the spatial resolution required to evaluate regional drought hazard assessment and small-scale agriculture area.

## III. Materials and Methods

### A. Flood Hazard

Techniques for assessing the risk of flooding are based on a variety of factors, including meteorological, hydrological, and socioeconomic factors. There are 4 (four) significant phases that are involved in the assessment of flood risk, which include describing the location, estimating the amount of danger, and evaluation of sensitivity and risk as well as intensity. A base map of Cauayan City was obtained from the Local Government Unit of Cauayan, also, secondary data from LiDAR Distribution for Archiving was requested, Using Quantum GIS, this data was processed to determine the extent of flooding. LiDAR flood data includes 5, 25, and 100-yr return periods.

### B. Liquefaction and Ground Shaking Hazard

A base map of Cauayan City was obtained from the Local Government Unit of Cauayan City, also, Secondary data from GEORISK.PH was requested regarding liquefaction and ground shaking, using quantum GIS, this data was processed to determine the extent of liquefaction and ground shaking within the vicinity of Cauayan City.

### C. Drought Hazard

A widely used measure for describing precipitation is the standard precipitation index (SPI) using a variety of timescales for meteorological drought. The SPI is closely related to soil moisture on short time periods, while on longer time scales, it can be related to groundwater and reservoir storage. Regional comparisons of the SPI can be made with climates that differ significantly. It calculates observed precipitation using a consistent scale. Deviation from a chosen probability distribution function represents the raw data on precipitation. Typically, raw precipitation data are fitted to a Pearson type III distribution and then transformed into a normal distribution. SPI values can be interpreted as the number of standard deviations associated with the observed anomaly that deviates from the long-term average. The SPI can be generated using monthly input data for various time periods ranging from 1 to 36 months.

Rainfall data from PAG-ASA were gathered and served as input to compute the SPI of consecutive months which was analyzed through QGIS. This open-source software was used to analyze and generate a drought hazard map of different existing water infrastructures of Poblacion Cauayan City, Isabela. Existing water infrastructures are: water elevated infrastructures, drainage networks, flood control, and irrigation infrastructures. The principle of the Standardized Precipitation Index was used to analyze and generate maps that include 1, 3, 6, 9 and 12-month SPI through Interpolation. This method requires precipitation data then a calculation of the SPI values out of rainfall data gathered from PAG-ASA was performed to categorize the current level of drought occurring in the City.

## IV. Results and Discussion

### A. Flood Hazard

Flood Hazard data from the LiDAR portal for archiving and distribution was gathered. The local government could use the created map for the Cauayan City government for proper land use planning in flood-prone cones and to identify places at high risk of disaster and manage disaster risk, such as effective and immediate evacuation plans and flooding.

A flood Hazard map with a 5, 25, and 100-year return period was created. Based on the 5-year Flood Hazard Map (see Fig. 1) the Analysis shows that the different Existing water Infrastructures were Classified as Low hazard and Medium Hazard(See Appendix Summary Table for Flood Hazard Map 5-year return period) While on the 25-year Flood Hazard Map (see Fig. 2) the analysis revealed that among the water Infrastructures 9 are classified as medium Hazard, 3 are high risk and the rest are Low Hazard (see Appendix Summary Table for Flood Hazard Map ,25-year return period) and for the 100-year flood hazard Map (see Fig. 3) the analysis shows that among the water Infrastructures, 12 are classified as Medium Hazard, 4 are high risk and the rest of the water infrastructures were low hazard (See Appendix Summary Table for Flood Hazard Map 100-year return period).

### B. Liquefaction and Ground Shaking Hazard

The assessment was based on the geology and seismic source zone, historical reports of liquefaction, geomorphology, hydrology, and preliminary data from the microtremor survey is used to confirm the type of underlying materials. A semi-detailed map has been developed that can be utilized for land use, emergency response, and mitigation planning but shouldn't be utilized for site-specific evaluation. In addition, no construction is prohibited by liquefaction and ground shaking hazard maps, buildings, and construction in places prone to liquefaction and ground shaking are still possible for as long as the appropriate engineering factors are considered.

Based on the Liquefaction Hazard Map (see Fig. 4) the Analysis shows that the different Existing water Infrastructures were Classified as Low Susceptible, Not Susceptible, and Moderate Susceptible. Among the Water Infrastructures, 14 are Low Susceptible, 1 – is Moderate Susceptible, and 16 water infrastructures are not Susceptible (see the Appendix Summary Table for Liquefaction Map). In Addition, based on the Ground Shaking Hazard Map (see Fig. 5) based on the revealed analysis it shows that the different Existing water Infrastructures were Classified as Destructive Ground Shaking, labeled as PEIS* Intensity Vll (see Appendix Summary Table for Ground Shaking Hazard Map).

### C. Drought Hazard

According to the generated 1-month SPI Map (see Fig. 6), among the existing water infrastructures in the different barangays of Poblacion it reflects that it is categorized as near normal which ranges from 0.99 to -0.99 (see Appendix Summary Table of water infrastructures for 1-month SPI Drought Map). The 1-month SPI map depicts a map showing the 30-day period's usual precipitation percentage. However, the generated SPI represents monthly precipitation more accurately because the distribution has been made normal. Based on the generated 3-month SPI map (see Fig. 7) it reflects that all water infrastructures at Poblacion are categorized as near normal which ranges from 0.99 to -0.99. In addition, it appears that some of the barangays were categorized as moderately dry ranging from -1.0 to -1.49 which includes barangay Gappal, Dianao, Manaoag, Linglingay and Buyon (see Appendix Summary Table of water infrastructures for 3-month SPI Drought Map). The 3-month SPI offers a comparison between the precipitation over a certain three-month period and the sum of the 3-month totals of precipitation for each of the years included in the historical records. For the 6-month SPI drought map (see Fig. 8) it reflects that 22 barangays were categorized as moderately dry ranges from -1.0 to -1.49 which includes barangays where water infrastructures located and the rest of barangays in the City were categorized as near normal ranges from 0.99 to -0.99 (see Appendix Summary Table of water infrastructures for 6-month SPI Drought Map). A six-month SPI compares the rainfall for that time frame with the corresponding six-month period over the historical data and can be very effective in showing the precipitation over distinct seasons, While on the generated 9-month SPI map (see Fig. 9), it reflects that existing water infrastructures within the vicinity of Poblacion area of the City were categorized as near normal ranges from 0.99 to -0.99 but based on the map generated (see Fig. 9) there are 9 barangays categorized as moderately dry ranges from -1.0 to -1.49 (See Appendix Summary Table of water infrastructures for 9-month SPI Drought Map). The 9-month SPI shows inter-seasonal precipitation patterns over a medium-term duration, typically, it takes a season or longer for a drought to emerge.

The SPI value below -1.5 for these periods is a good sign that dryness has a major effect on agriculture and might also be having an impact on other sectors. For the 12-month SPI map (see Fig. 10), it also reflects that existing water infrastructures within the Poblacion area were considered as near normal ranges from 0.99 to -0.99 while 17 barangays were categorized as moderately dry ranges from -1.0 to -1.49 (see Appendix Summary Table of water infrastructures for 12-month SPI Drought Map). Long-term precipitation trends are reflected in the SPI at these timescales. A comparison of the precipitation over 12 consecutive months is referred to as a 12-month SPI which is reported in the same 12 months in a row in every previous year for which data is available. Due to the fact that these timeframes represent the sum of potentially shorter timelines, higher or lower than usual, the longer the SPIs typically converge to zero unless a noticeable dry or wet tendency is present.

TABLE I. APPENDIX SUMMARY TABLE FOR 5-YR FLOOD HAZARD

| Appendix Summary Table of Water Infrastructures for 5-yr Flood Hazard Map | |
|---|---|
| Location | Degree of risk/susceptibility |
| District 1 | Low susceptibility |
| District 2 | Low susceptibility |
| District 3 | Low susceptibility |
| San Fermin | medium susceptibility |
| Tagaran | Low susceptibility |
| Cabaruan | Low susceptibility |
| Alicaocao | medium susceptibility |
| Turayong | Low susceptibility |
| Minante l | Low susceptibility |
| Minante ll | Low susceptibility |
| Marabulig l | Low susceptibility |
| Marabulig ll | Low susceptibility |
| Sillawit | Low susceptibility |
| Alinam | Low susceptibility |
| Nungnungan l | Low susceptibility |
| Nungnunganll | Low susceptibility |
| Culalabat | Low susceptibility |
| Guayabal | Low susceptibility |
| Baringin norte | Low susceptibility |
| Buena suerte | Low susceptibility |
| Rizal | Low susceptibility |
| Baringin Sur | Low susceptibility |
| Dabburab | Low susceptibility |
| San antonio | Low susceptibility |
| Amobocan | Low susceptibility |
| San francisco | Low susceptibility |
| Santa luciana | Low susceptibility |
| San isidro | Low susceptibility |
| Naganacan | Low susceptibility |
| Pinoma | Low susceptibility |
| Nagrumbuan | Low susceptibility |
| Labinab | Low susceptibility |

Based on the revealed risk analysis with 5-year return period shown in Table I that among thirty-two (32) existing water infrastructures, thirty (30) water infrastructure are low susceptibility in flood hazard while two (2) water infrastructures labeled as medium susceptibility on flood hazard.

TABLE II. APPENDIX SUMMARY TABLE FOR 25-YR FLOOD HAZARD

| Appendix Summary Table of Water Infrastructures for 25-yr Flood Hazard Map | |
|---|---|
| Location | Degree of risk/susceptibility |
| District 1 | Low susceptibility |
| District 2 | Low susceptibility |
| District 3 | Low susceptibility |
| San Fermin | medium susceptibility |
| Tagaran | Low susceptibility |
| Cabaruan | High susceptibility |
| Alicaocao | medium susceptibility |
| Turayong | Low susceptibility |
| Minante l | Medium susceptibility |
| Minante ll | Low susceptibility |
| Marabulig l | Medium susceptibility |
| Marabulig ll | Medium susceptibility |
| Sillawit | Medium susceptibility |
| Alinam | Medium susceptibility |
| Nungnungan l | Medium susceptibility |
| Nungnunganll | Medium susceptibility |
| Culalabat | Low susceptibility |
| Guayabal | Low susceptibility |
| Baringin norte | Low susceptibility |
| Buena suerte | Low susceptibility |
| Rizal | Low susceptibility |
| Baringin Sur | High susceptibility |
| Dabburab | Low susceptibility |
| San antonio | Low susceptibility |
| Amobocan | Low susceptibility |
| San francisco | Low susceptibility |
| Santa luciana | Low susceptibility |
| San isidro | Low susceptibility |
| Naganacan | Low susceptibility |
| Pinoma | Low susceptibility |
| Nagrumbuan | Low susceptibility |
| Labinab | High susceptibility |

Based on the revealed risk analysis with 25-year return period shown in Table II that among thirty-two (32) existing water infrastructures, twenty (20) water infrastructure are low susceptibility in flood hazard and nine (9) medium susceptibility while three (3) water infrastructures labeled as high susceptibility on flood hazard.

TABLE III. APPENDIX SUMMARY TABLE FOR 100-YR FLOOD HAZARD

| Appendix Summary Table of Water Infrastructures for 100-yr Flood Hazard Map | |
|---|---|
| Location | Degree of risk/susceptibility |
| District 1 | Low susceptibility |
| District 2 | Low susceptibility |
| District 3 | Low susceptibility |
| San Fermin | medium susceptibility |
| Tagaran | Low susceptibility |
| Cabaruan | High susceptibility |
| Alicaocao | High susceptibility |
| Turayong | High susceptibility |
| Minante l | Medium susceptibility |
| Minante ll | Medium susceptibility |
| Marabulig l | Medium susceptibility |
| Marabulig ll | Medium susceptibility |
| Sillawit | Medium susceptibility |
| Alinam | Medium susceptibility |
| Nungnungan l | Medium susceptibility |
| Nungnunganll | Medium susceptibility |
| Culalabat | Low susceptibility |
| Guayabal | Low susceptibility |
| Baringin norte | Medium susceptibility |
| Buena suerte | Low susceptibility |
| Rizal | Low susceptibility |
| Baringin Sur | High susceptibility |
| Dabburab | Low susceptibility |
| San antonio | Medium susceptibility |
| Amobocan | Low susceptibility |
| San francisco | Low susceptibility |
| Santa luciana | Low susceptibility |
| San isidro | Low susceptibility |
| Naganacan | Medium susceptibility |
| Pinoma | Medium susceptibility |
| Nagrumbuan | Low susceptibility |
| Labinab | High susceptibility |

Based on the revealed risk analysis with 100-year return period shown in Table III that among thirty-two (32) existing water infrastructures, fourteen (14) water infrastructure are low susceptibility in flood hazard and thirteen (13) medium susceptibility while five (5) water infrastructures labeled as high susceptibility on flood hazard.

TABLE IV. APPENDIX SUMMARY TABLE OF EXISTING WATER INFRASTRUCTURE OF CAUAYAN CITY FOR LIQUEFACTION MAP

| Appendix Summary Table of flood control, irrigation and Drainage infrastructures for Liquefaction Map | |
|---|---|
| Location | Degree of risk/susceptibility |
| San fermin | Low susceptibility |
| labinab | Low susceptibility |
| District l | Low susceptibility |
| Marabulig l | Low susceptibility |
| Marabulig ll | Low susceptibility |
| Minante l | Low susceptibility |
| Minante ll | Low susceptibility |
| Nagrumbuan | Low susceptibility |
| Pinoma | Low susceptibility |
| Nungnungan l | Low susceptibility |
| Nungnungan ll | Low susceptibility |
| Naganacan | Low susceptibility |
| Alinam | Low susceptibility |
| Sillawit | Low susceptibility |
| San Isidro | Low susceptibility & Moderate susceptibility |
| Santa Lucia | Low susceptibility |
| San francisco | Low susceptibility & Moderate susceptibility |
| Amobocan | Low susceptibility & Moderate susceptibility |
| San Antonio | Low susceptibility & Moderate susceptibility |
| Dabburab | Moderate susceptibility |
| Baringin Sur | Moderate susceptibility |
| Rizal | Moderate susceptibility |
| Buena Suerte | Low susceptibility & Moderate susceptibility |
| District lll | Not Susceptible |
| Baringin Norte | Moderate susceptibility |
| Guayabal | Moderate susceptibility |
| Culalabat | Moderate susceptibility |
| Turayong | Not Susceptible |
| Cabaruan | Not Susceptible |
| Tagaran | Not Susceptible |
| Alicaocao | Not Susceptible |

Based on the revealed liquefaction risk analysis shown in Table IV that twenty (20) barangays where water infrastructures were installed are classified as low susceptible in liquefaction hazard and six (6) barangays were moderate susceptibility while five (5) barangays were in the influence of both low and moderate susceptibility on liquefaction hazard.

TABLE V. APPENDIX SUMMARY TABLE OF EXISTING WATER INFRASTRUCTURE OF CAUAYAN CITY GROUND SHAKING MAP

| Appendix Summary Table of Existing Water Infrastructures for Liquefaction Map | |
|---|---|
| Location | Degree of risk/susceptibility |
| San fermin | PEIS* Intensity Vll: Destructive Ground Shaking |
| labinab | PEIS* Intensity Vll: Destructive Ground Shaking |
| District l | PEIS* Intensity Vll: Destructive Ground Shaking |
| Marabulig l | PEIS* Intensity Vll: Destructive Ground Shaking |
| Marabulig ll | PEIS* Intensity Vll: Destructive Ground Shaking |
| Minante l | PEIS* Intensity Vll: Destructive Ground Shaking |
| Minante ll | PEIS* Intensity Vll: Destructive Ground Shaking |
| Nagrumbuan | PEIS* Intensity Vll: Destructive Ground Shaking |
| Pinoma | PEIS* Intensity Vll: Destructive Ground Shaking |
| Nungnungan l | PEIS* Intensity Vll: Destructive Ground Shaking |
| Nungnungan ll | PEIS* Intensity Vll: Destructive Ground Shaking |
| Naganacan | PEIS* Intensity Vll: Destructive Ground Shaking |
| Alinam | PEIS* Intensity Vll: Destructive Ground Shaking |
| Sillawit | PEIS* Intensity Vll: Destructive Ground Shaking |
| San Isidro | PEIS* Intensity Vll: Destructive Ground Shaking |
| Santa Lucia | PEIS* Intensity Vll: Destructive Ground Shaking |
| San francisco | PEIS* Intensity Vll: Destructive Ground Shaking |
| Amobocan | PEIS* Intensity Vll: Destructive Ground Shaking |
| San Antonio | PEIS* Intensity Vll: Destructive Ground Shaking |
| Dabburab | PEIS* Intensity Vll: Destructive Ground Shaking |
| Baringin Sur | PEIS* Intensity Vll: Destructive Ground Shaking |
| Rizal | PEIS* Intensity Vll: Destructive Ground Shaking |
| Buena Suerte | PEIS* Intensity Vll: Destructive Ground Shaking |
| District lll | PEIS* Intensity Vll: Destructive Ground Shaking |
| Baringin Norte | PEIS* Intensity Vll: Destructive Ground Shaking |
| Guayabal | PEIS* Intensity Vll: Destructive Ground Shaking |
| Culalabat | PEIS* Intensity Vll: Destructive Ground Shaking |
| Turayong | PEIS* Intensity Vll: Destructive Ground Shaking |
| Cabaruan | PEIS* Intensity Vll: Destructive Ground Shaking |
| Tagaran | PEIS* Intensity Vll: Destructive Ground Shaking |
| Alicaocao | PEIS* Intensity Vll: Destructive Ground Shaking |

Based on the revealed ground shaking risk analysis shown in Table V, all barangays mentioned were classified as PEIS* Intensity Vll: Destructive Ground Shaking.

TABLE VI. APPENDIX SUMMARY TABLE FOR 1-MONTH SPI MAP

| Appendix Summary Table of flood control, irrigation and Drainage infrastructures for 1-month SPI Drought Map | |
|---|---|
| Location | Description/Value |
| San fermin | near normal |
| labinab | near normal |
| District l | near normal |
| Marabulig l | near normal |
| Marabulig ll | near normal |
| Minante l | near normal |
| Minante ll | near normal |
| Nagrumbuan | near normal |
| Pinoma | near normal |
| Nungnungan l | near normal |
| Nungnungan ll | near normal |
| Naganacan | near normal |
| Alinam | near normal |
| Sillawit | near normal |
| San Isidro | near normal |
| Santa Lucia | near normal |
| San francisco | near normal |
| Amobocan | near normal |
| San Antonio | near normal |
| Dabburab | near normal |
| Baringin Sur | near normal |
| Rizal | near normal |
| Buena Suerte | near normal |
| District lll | near normal |
| Baringin Norte | near normal |
| Guayabal | near normal |
| Culalabat | near normal |
| Turayong | near normal |
| Cabaruan | near normal |
| Tagaran | near normal |
| Alicaocao | near normal |

Based on the revealed 1-month SPI drought risk analysis shown in Table VI that all barangays mentioned were classified as near normal for drought hazard.

TABLE VII. APPENDIX SUMMARY TABLE FOR 3-MONTH SPI MAP

| Appendix Summary Table of flood control, irrigation and Drainage infrastructures for 3-month SPI Drought Map | |
|---|---|
| Location | Description/Value |
| San fermin | near normal |
| labinab | near normal |
| District l | near normal |
| Marabulig l | near normal |
| Marabulig ll | near normal |
| Minante l | near normal |
| Minante ll | near normal |
| Nagrumbuan | near normal |
| Pinoma | near normal |
| Nungnungan l | near normal |
| Nungnungan ll | near normal |
| Naganacan | near normal |
| Alinam | near normal |
| Sillawit | near normal |
| San Isidro | near normal |
| Santa Lucia | near normal |
| San francisco | near normal |
| Amobocan | near normal |
| San Antonio | near normal |
| Dabburab | near normal |
| Baringin Sur | near normal |
| Rizal | near normal |
| Buena Suerte | near normal |
| District lll | near normal |
| Baringin Norte | near normal |
| Guayabal | near normal |
| Culalabat | near normal |
| Turayong | near normal |
| Cabaruan | near normal |
| Tagaran | near normal |
| Alicaocao | near normal |
| Gappal | Moderately Dry |
| Dianao | Moderately Dry |
| Manaoag | Moderately Dry |
| Buyon | Moderately Dry |
| Linglingay | Moderately Dry |

Based on the revealed 3-month SPI drought risk analysis shown in Table VII that thirty-one (31) barangays where water infrastructures were installed are classified as near normal in drought hazard and five (5) barangays were classified as moderately dry on drought hazard.

TABLE VIII. APPENDIX SUMMARY TABLE FOR 6-MONTH SPI MAP

| Appendix Summary Table of flood control, irrigation and Drainage infrastructures for 6-month SPI Drought Map | |
|---|---|
| Location | Description/Value |
| San fermin | near normal |
| labinab | near normal |
| District l | near normal |
| Marabulig l | near normal |
| Marabulig ll | near normal |
| Minante l | near normal |
| Minante ll | near normal |
| Nagrumbuan | near normal |
| Pinoma | near normal |
| Nungnungan l | near normal |
| Nungnungan ll | near normal |
| Naganacan | near normal |
| Alinam | near normal |
| Sillawit | near normal |
| San Isidro | near normal |
| Santa Lucia | near normal |
| San francisco | near normal |
| Amobocan | near normal |
| San Antonio | near normal |
| Dabburab | near normal |
| Baringin Sur | near normal |
| Rizal | near normal |
| Buena Suerte | near normal |
| District lll | near normal |
| Baringin Norte | near normal |
| Guayabal | near normal |
| Culalabat | near normal |
| Turayong | near normal |
| Cabaruan | near normal |
| Tagaran | Moderately dry |
| Alicaocao | near normal |
| District l | Moderately dry |
| Mabantad | Moderately dry |

| | |
|---|---|
| Carabatan Chica &Grande | Moderately dry |
| Gagabutan | Moderately dry |
| Nagcampegan | Moderately dry |
| Catalina | Moderately dry |
| Carabatan bacarena | Moderately dry |
| Carabatan punta | Moderately dry |

Based on the revealed 6-month SPI drought risk analysis shown in Table VIII that thirty (30) barangays where water infrastructures were installed are classified as near normal in drought hazard while nine (9) barangays were classified as moderately dry on drought hazard.

TABLE IX. APPENDIX SUMMARY TABLE FOR 9-MONTH SPI MAP

| Appendix Summary Table of flood control, irrigation and Drainage infrastructures for 9-month SPI Drought Map | |
|---|---|
| Location | Description/Value |
| San fermin | near normal |
| labinab | near normal |
| District l | near normal |
| Marabulig l | near normal |
| Marabulig ll | near normal |
| Minante l | near normal |
| Minante ll | near normal |
| Nagrumbuan | near normal |
| Pinoma | near normal |
| Nungnungan l | near normal |
| Nungnungan ll | near normal |
| Naganacan | near normal |
| Alinam | near normal |
| Sillawit | near normal |
| San Isidro | near normal |
| Santa Lucia | near normal |
| San francisco | near normal |
| Amobocan | near normal |
| San Antonio | near normal |
| Dabburab | near normal |
| Baringin Sur | near normal |
| Rizal | near normal |
| Buena Suerte | near normal |
| District lll | near normal |
| Baringin Norte | near normal |
| Guayabal | near normal |
| Culalabat | near normal |
| Turayong | near normal |
| Cabaruan | near normal |
| Parts of Tagaran | Moderately dry |
| Alicaocao | near normal |
| Mabantad | Moderately dry |
| Carabatan chica and grande | Moderately dry |
| Carabatan punta | Moderately dry |
| Carabatan bacarena | Moderately dry |
| Nagcampagan | Moderately dry |
| Parts of Villa luna | Moderately dry |
| Parts of Union | Moderately dry |
| Parts of San luis | Moderately dry |

Based on the revealed 9-month SPI drought risk analysis shown in Table IX that thirty (30) barangays where water infrastructures were installed are classified as near normal in drought hazard and the rest of the barangays that are mentioned were classified as moderately dry on drought hazard.

TABLE X. APPENDIX SUMMARY TABLE FOR 12-MONTH SPI MAP

| Appendix Summary Table of flood control, irrigation and Drainage infrastructures for 12-month SPI Drought Map | |
|---|---|
| Location | Description/Value |
| San fermin | near normal |
| labinab | near normal |
| District l | near normal |
| Marabulig l | near normal |
| Marabulig ll | near normal |
| Minante l | near normal |
| Minante ll | near normal |
| Nagrumbuan | near normal |
| Pinoma | near normal |
| Nungnungan l | near normal |
| Nungnungan ll | near normal |
| Naganacan | near normal |
| Alinam | near normal |
| Sillawit | near normal |
| San Isidro | near normal |
| Santa Lucia | near normal |
| San francisco | near normal |
| Amobocan | near normal |
| San Antonio | near normal |
| Dabburab | near normal |

| | |
|---|---|
| Baringin Sur | near normal |
| Rizal | near normal |
| Buena Suerte | near normal |
| District lll | near normal |
| Baringin Norte | near normal |
| Guayabal | near normal |
| Culalabat | near normal |
| Turayong | near normal |
| Cabaruan | near normal |
| Parts of Tagaran | Moderately dry |
| Alicaocao | near normal |
| Mabantad | Moderately dry |
| Nagcampagan | Moderately dry |
| Carabatan Chica | Moderately dry |
| Carabatan Grande | Moderately dry |
| Parts of Catalina | Moderately dry |
| Carabatan Bacareno & Punta | Moderately dry |
| Parts of Villa luna | Moderately dry |
| Parts of Union | Moderately dry |
| parts of San luis | Moderately dry |
| Parts of Gappal | Moderately dry |
| Manaoag | Moderately dry |
| Linglingay | Moderately dry |
| Parts of Buyon | Moderately dry |
| Parts of Dianao | Moderately dry |
| Parts of Rogus | Moderately dry |

Based on the revealed 12-month SPI drought risk analysis shown in Table X that twenty-nine (29) barangays where water infrastructures were installed are classified as near normal in drought hazard and sixteen (16) barangays that are mentioned were classified as moderately dry on drought hazard.

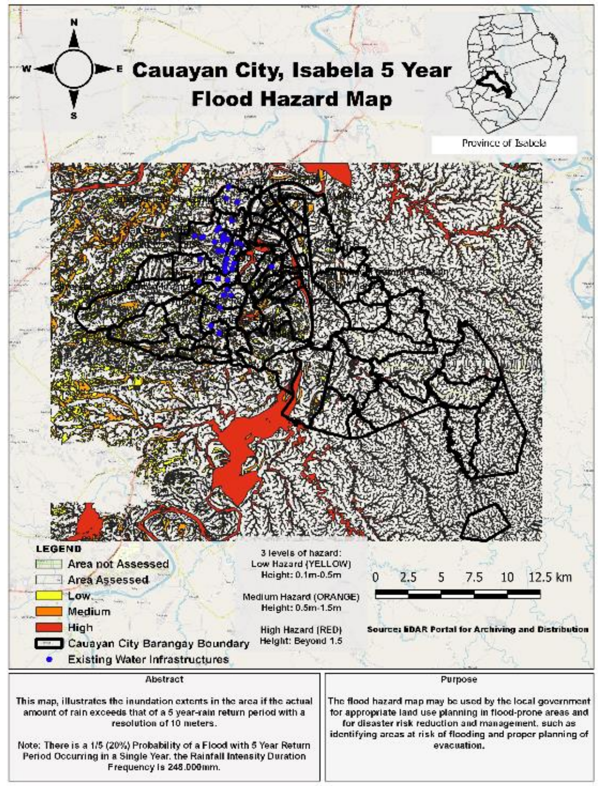


Fig. 1. 5-yr flood hazard map

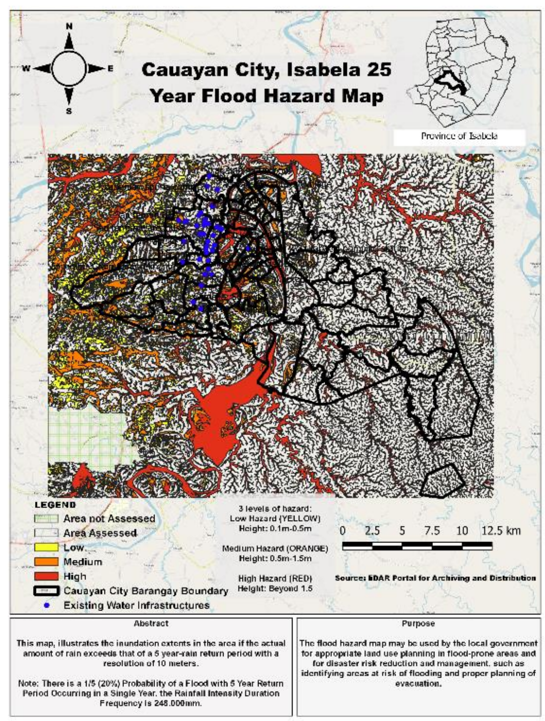


Fig. 2. 25-yr flood hazard map

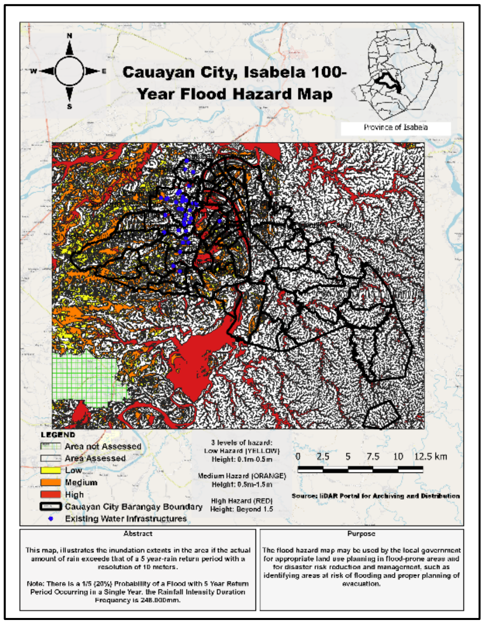


Fig. 3. 100-yr flood hazard map

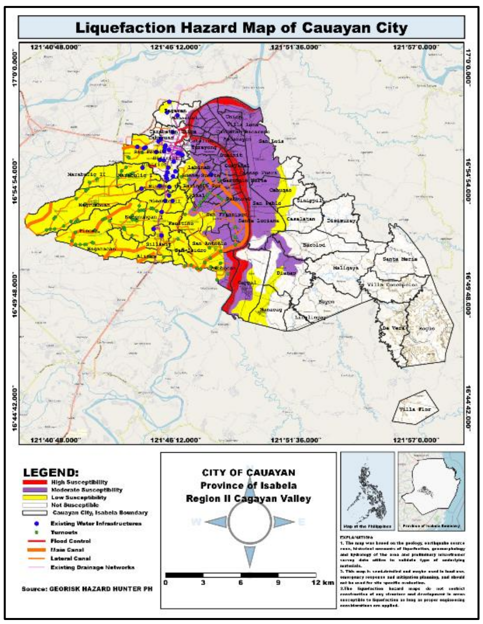


Fig. 4. Liquefaction hazard map

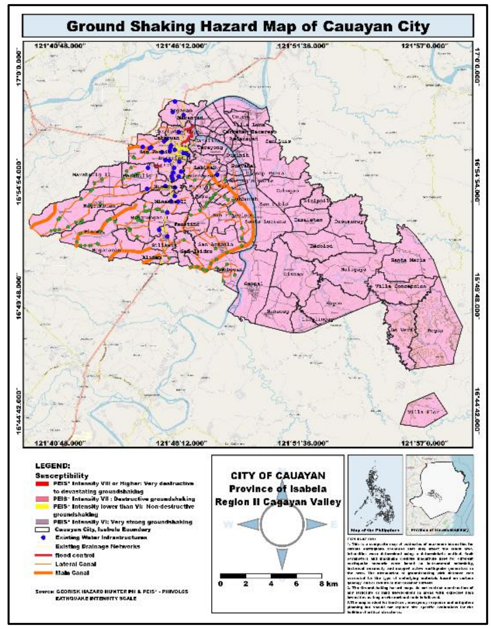


Fig. 5. Ground shaking hazard map

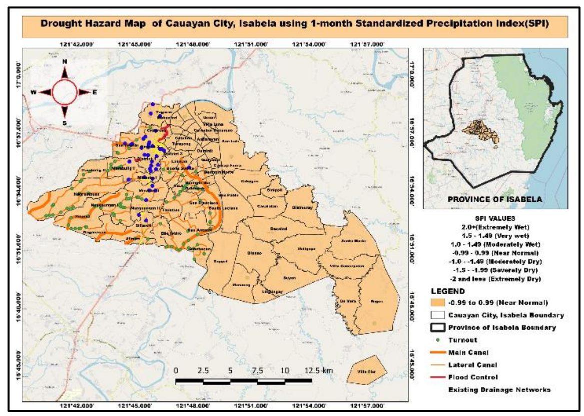


Fig. 6. 1-month SPI map of Cauayan city, Isabela

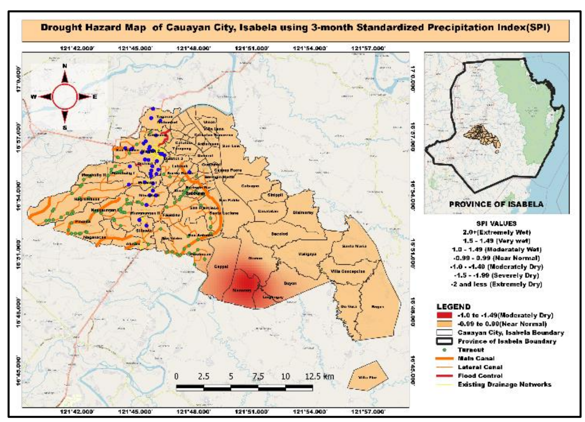


Fig. 7. 3-month SPI map of Cauayan city, Isabela

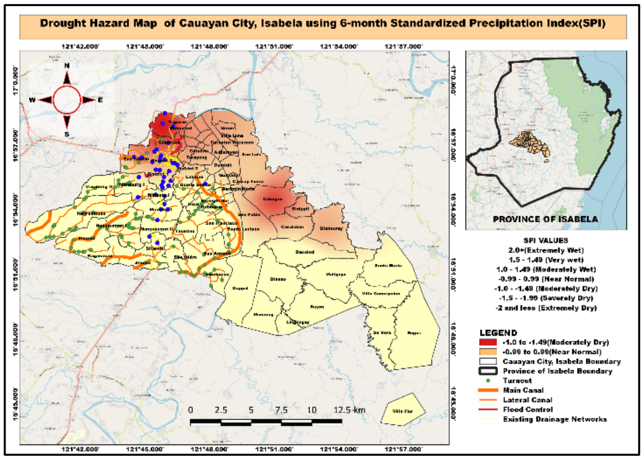


Fig. 8. 6-month SPI map of Cauayan city, Isabela

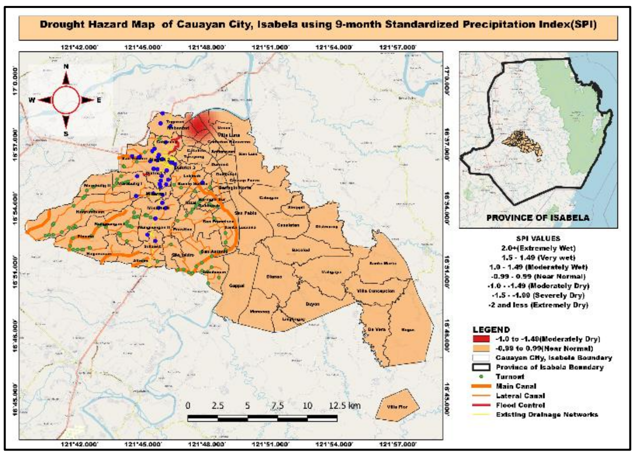


Fig. 9. 9-month SPI map of Cauayan city, Isabela

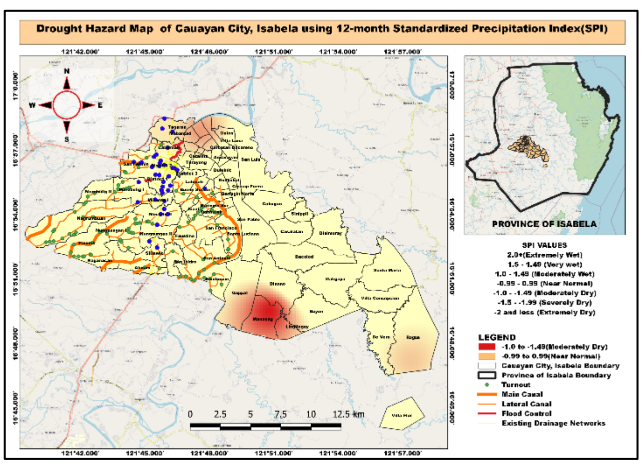


Fig. 10. 12-month SPI map of Cauayan city, Isabela

## V. Conclusion and Recommendations

Risk analysis was done to analyze and identify areas that are prone to different hazards such as flood, Liquefaction, ground shaking, and drought. Based on the flood analysis of existing urban water infrastructures it appears that these infrastructures were at high risk.

The local government would be able to use the generated hazard maps for identifying flood-prone areas and perform hazard risk reduction and management measures, such as establishing an effective evacuation strategy. In addition, liquefaction, ground shaking, and drought hazard maps also appear the potential areas that are prone to hazards.

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