Deltares

Rapid Flood Hazard Assessment of IDP Camps in Dikwa, Borno State, Nigeria

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Summary

Flooding has become a critical and recurrent challenge for Internally Displaced Persons (IDP) camps in Dikwa Local Government Area (LGA), Borno State, Nigeria, exacerbating the vulnerability of displaced populations and highlighting the urgent need for effective flood risk mitigation measures. The devastating floods of 2022 displaced over 2.4 million people nationwide, damaging thousands of shelters and leaving vulnerable populations exposed to significant risks. Recognizing the persistent nature of these challenges, the International Organization for Migration (IOM) commissioned Deltares to conduct a Rapid Flood Hazard Assessment to evaluate the current flood risks and explore solutions to enhance the resilience of IDP camps in Dikwa.

This study aimed to assess the effectiveness of existing drainage channels, model flood hazards under various rainfall scenarios, and propose actionable interventions to mitigate flood risks. The assessment included comprehensive data collection, including rainfall records, digital elevation models, and field surveys of drainage systems and historical flood marks. Advanced hydrological and hydraulic modeling tools, such as Delft3D FM, were used to simulate flood scenarios for return periods of 2, 10, 25, and 100 years. The analysis compared conditions without drainage, with existing drainage, and with proposed drainage designs, focusing on 17 IDP camps across the study area.

The results revealed that most camps are highly vulnerable to flooding due to their location on low-lying, flood-prone land, inadequate or absent drainage infrastructure, and the use of lightweight shelters susceptible to water damage. Camps such as 1000 Camp and Agric IDP Camp exhibited significant flood exposure, with negligible mitigation provided by existing drainage systems. The modeling demonstrated that while current drainage infrastructure offered minimal improvements, the implementation of proposed improved drainage can substantially reduce flood risks, increasing the number of shelters classified as "Not Flooded" and decreasing the number of high-risk zones. For example, the proposed designs showed marked improvements in flood mitigation for extreme events, such as the 100-year return period.

Based on these findings, the study recommends that IOM and other agencies prioritize investments in improve drainage systems, including expanding coverage, ensuring adequate sizing, and maintaining channels to prevent blockages. In high-risk camps where drainage alone cannot mitigate risks, relocation to safer areas should be considered, with careful site selection to avoid transferring vulnerabilities. Integrating drainage considerations into camp layout planning is strongly recommended. Planners can utilize the interactive dashboard developed by this study, empowering them to make informed decisions and implement evidence-based interventions.

This assessment highlights the critical role of effective drainage systems in mitigating flood risks and improving living conditions in IDP camps. By addressing vulnerabilities and scaling up flood risk reduction efforts, humanitarian agencies and local authorities can enhance the safety and resilience of displaced populations in Dikwa and contribute to long-term disaster preparedness elsewhere in the region.

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1 Background

In 2022, severe flooding in Nigeria affected over 4.4 million people, of whom 2.4 million people were displaced and resulting in over 660 fatalities. Internal Displaced Person (IDP) camps in Borno State were particularly hard hit. The International Organisation for Migration (IOM) carried out an impact assessment under the Displacement Tracking Matrix (DTM) program from June to August. Determining that 4,989 shelters were damaged, leaving 8,181 households in urgent need of shelter. On July 22, 2024, flash floods caused by heavy rainfall severely damaged camps in Dikwa and Mafa LGAs, including Fulatari, GGSS, and Masarmari camps. In total, 265 shelters were damaged, affecting 4,444 individuals, including 600 women, 491 men, and 1,460 children.

Due to the frequent occurrence of damaging floods, IOM commissioned Deltares to develop flood hazard models based on various rainfall scenarios for selected existing IDP campsite. The models consider existing drainage channels and propose potential new drainage channels to contribute to flood risk reduction within the camps. The objective is to evaluate the effectiveness and impact of drainage channels as a measure to mitigate flood risks to tents and buildings in Dikwa Local Government Area.

In the following sections, we present information on previously flood-affected locations, field data collected by the IOM WASH team on existing drainage channels, an overview of the flood model development process, and the outputs of the flood model. These outputs include flood hazard maps illustrating the extent and depth of flooding under various rainfall scenarios. Finally, we introduce an interactive dashboard to view the flood model for selected campsites, enabling users the ability to explore flood scenarios without existing drainage, with existing drainage, and the potential impact on buildings and camps when a proposed drainage channel is implemented. Ultimately, the findings and tools from this study aim to guide evidence-based planning and implementation of flood mitigation measures in IDP campsites. By identifying the most effective drainage solutions, IOM seeks to enhance the resilience of vulnerable populations to flooding, protect essential infrastructure, and ensure safer living conditions for displaced persons in flood-prone areas.

1.1 Previous Flood Events Impacts

As outlined in the background and rationale section, the Dikwa Local Government Area is frequently affected by flooding. During the period of carrying out this research study, the region once again experienced flooding, impacting several campsites in the area. The images below, captured by the IOM team after the flood event, underscore the urgent need for flood adaptation measures and mitigation efforts in this region.

Figure 1: Fulatari Camp flooded - 22nd July 2024

Flood-affected campsites highlight the critical need to understand the concept of vulnerability and its relationship to flood hazards. While excessive or extreme rainfall is a key driver of flooding, it does not always lead to a flood disaster. A flood disaster, defined as a severe and unexpected inundation of water within a displacement site or temporary settlement, disrupts living conditions, compromises safety, and damages shelters, infrastructure, and essential services. It also exacerbates the vulnerability of already displaced populations.

Vulnerability, on the other hand, refers to the degree to which an internally displaced persons (IDP) campsite is exposed and susceptible to harm from external hazards such as floods. This susceptibility is shaped by physical, social, economic, and environmental factors that reduce the site's ability to prepare for, withstand, and recover from such events.

Figure 2: Kilagaru camp in Dikwa flooded on 06th August 2024. Note the collapsed mud walls and non-durable construction.

Several factors contribute to the vulnerability of campsites to flooding (Figure 2):

- **Lightweight Shelter Materials:** Tents and shelters are constructed using materials that lack the durability to withstand severe weather or prolonged exposure to floodwaters.

- **Location on Flood-Prone Land:** Campsite established in low-lying or flood-prone areas due to the scarcity of safer alternatives or land constraints.

- **Inadequate Drainage Systems:** The absence or insufficiency of drainage channels around camp tents allows water to pool, exacerbating the impact of flooding.

These factors amplify the risks posed by flooding and increase the likelihood of a flood event escalating into a disaster. Understanding and addressing these vulnerabilities are essential for improving the resilience of IDP campsites and reducing the devastating impacts of floods.

1.2 Selected Campsite in Dikwa LGA

The study focuses on the existing IDP Campsites in Dikwa LGA in Borno State, a region heavily affected by Boko Haram insurgency, climate change, and environmental challenges. Dikwa has a tropical dry climate with a rainy season from June to September and a dry season from October to May. It serves as a hub for internally displaced persons, hosting several camps supported by humanitarian organizations. Seasonal flooding in these camps poses significant challenges, including shelter damage, water contamination, and disruption of essential services, worsening conditions for displaced individuals. At the start of the project, IOM Nigeria's WASH department in Maiduguri provided a list of IDP campsites for flood modeling analysis.

The study examines 17 IDP campsite in Dikwa, the table below includes the names of these camps along with additional details, such as the estimated total number of structures (with digital footprints available for at least 80% of locations, though some have none). It also lists the estimated camp populations, based on the latest Displacement Tracking Matrix data.

Table 1: list of campsites in Dikwa and total number of available building footprint as source from OSM Buildings database

S/N	Campsite Name	Area size (m^2)	Population	Number of building/camp tent
1	1000 Camp	216,705	6,549	1,416
2	Agric IDP Camp	20,110	6,349	197
3	Alhaji Bashir Camp	52,120	4,260	358
4	Bulabulin Primary School	14,851	2,945	109
5	Fulatari	253,968	9,369	1,137
6	Kamchiji Camp	11,447	3,089	150
7	Klagaru Camp	42,439	5,527	370
8	Masamari Camp	149,761	8,428	881
9	Masamari_ext	90,017	Not available	345
10	Ministry of Works Camp	22,062	1,044	217
11	Mohammed Kyari	45,736	3,540	291
12	Motor Park Camp	99,204	3.191	408
13	New Mohammed Kyari Camp	81,677	3,540	331
14	Reception Camp	10,512	414	Not available
15	Sangaya Camp	45,554	8,180	310
16	Shehuri Modu Kasa Camp	109,634	6,649	960
17	Shuwari	303,175	3,778	1234

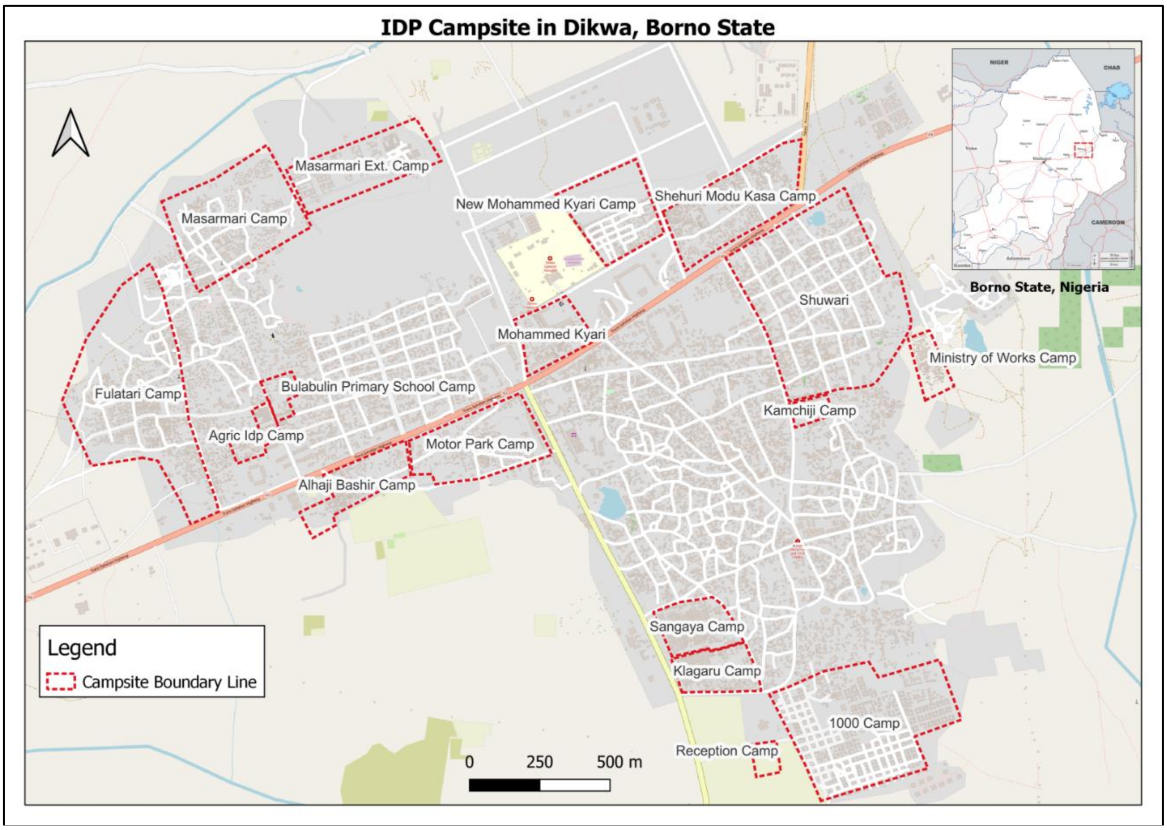


Figure 3: IDP Campsite in Dikwa LGA (Source: IOM Nigeria)

1.3 Field Data Collection

The assessment required a large range of data to characterise the camps and the flooding hazard. The following table details the data required to assess the flood hazard.

No	Data	Description	Source
1	Historical Rainfall data	The historical rainfall information stands as a crucial dataset required for both hydrological analysis and hydraulic modeling. This data is instrumental in statistically computing return periods and serves as input for pluvial flood modeling. Two different sources of rainfall data were considered in this analysis: hourly global satellite-based data (ERA5) and daily local measurements from collected from the meteorological station located at Maiduguri Airport. Both datasets were used in an extreme value analysis to derive the design rainfall events. The advantage of using ERA5 data is that it is hourly, enabling the construction of a design rainfall event based with an hourly timestep. However, such a global precipitation product is known to underestimate local peaks in rainfall, which is indeed confirmed by a	▪ Global data (ERA5) ▪ Local rainfall data obtain from the nearest airport (complemented with CHIRPS)

No	Data	Description	Source
		comparison with the local rainfall collected data. Therefore, the local data from Maiduguri forms the basis for the extreme value analysis. A generalized extreme value distribution is fitted in this data, resulting in a relationship between rainfall intensity, rainfall duration and the frequency of the event (IDF curve). Using these IDF curves, four rainfall events are derived for 2, 10, 25, and 100 years return period with a duration of 48 hours. In the final step, the hourly ERA5 data is used to transform the Maiduguri-based rainfall events from a daily to hourly timestep while retaining the total rainfall depth and event duration.	
2	Digital Elevation Model	The accuracy of pluvial flood modeling is directly influenced by the quality of the Digital Elevation Model (DEM) used. For this study, a detailed digital terrain model was not available for the Dikwa region. Therefore, Copernicus DEM (2022) was used to obtain the elevation data at **30-meter** resolution.	• Corpenicus DEM
3	Land Use/Cover	Land use data plays a vital role in hydraulic modeling. A highly detailed land use map that delineates various land use patterns, such as buildings, bare land, and vegetation, within the camps and their surroundings, is essential.	• ESA Worldcover
4	Soil Data	The soil type significantly influences the rate of infiltration, making a highly detailed soil map covering the study area an essential dataset for hydraulic modeling.	• Soil Grid 2020
5	Campsite boundary shapefile	Geospatial shapefile data outlining the boundaries of the campsite within Dikwa	• IOM Nigeria
6	Shelter footprint data	The geospatial polygon shapefile of the camp tents [footprint] is crucial for calculating and estimating the potential risk of tent based on the different flood return periods. There was an unavailability of shelter footprint data from the IDP campsites in Dikwa, which posed a challenge for this study. To address this, we leveraged the Humanitarian OpenStreetMap Team (HOTOSM) platform to digitize the shelter	• Humanitarian OpenStreetMap Team (HOT). Retrieved from https://www.hotosm.org

No	Data	Description	Source
		footprints within the camps. This digitized data provided the necessary spatial information on the distribution and structure of shelters, which was used as a critical input for our analysis.	
7	Drainage Channel data (see Figure 4)	To collect data on the existing man-made drainage channels and natural flow path within each campsite, the data collector team capture the geolocation points for each drainage feature. Using the KoBoToolbox survey form, enumerators recorded the geolocation points for each drainage channel, capturing them from one point to the next along the channel's length. These individual geolocation points were then digitized into a line file, which was subsequently incorporated into the model as part of the 1D flood modeling process. This approach ensured accurate representation of the drainage network for modeling and analysis.	• Field Data collection using Digital Survey Tool
8	Flood Marks - historical flood data (See Figure 5)	We also collected data on flood marks, including the maximum height of water during flooding (e.g., Foot Level, Knee Level, Waist Level, Shoulder Level), the date of flooding at specific locations, and the geolocation of flood points where the floodwaters became stagnant. This information was crucial for understanding the extent and behaviour of flood events within the camp.	• Field Data collection using Digital Survey Tool
9	Rainfall frequency	We gathered critical information on rainfall patterns and their relationship to flooding within the camp. Household heads were asked about experiences with rainfall frequency, specifically how many rainy seasons they had witnessed since arriving at the camp. To understand the impact of extreme weather, we inquired about the year they experienced particularly heavy rainfall and when it occurred. We also sought to identify the months when flooding is most prevalent in the camp, helping us correlate rainfall periods with flood events. Further, we asked whether the rainfall was continuous throughout the day or occurred in short, intense bursts.	• Field Data collection using Digital Survey Tool

No	Data	Description	Source
		This helped us determine the duration and intensity of rainfall that contributes to flooding. By asking, "How many hours or days of rainfall are typically required to cause flooding?", we were able to link specific rainfall thresholds to flood occurrence, providing valuable data for modeling flood events.	

To collect additional data a survey was implemented using KoBoToolbox, an open-source, user-friendly platform widely recognized for its applications in humanitarian action, development, environmental protection, peacebuilding, and human rights efforts. KoBoToolbox was chosen for its ease of use, offline functionality and integrated geolocation (GPS) support. To ensure data accuracy and consistency, a team of trained enumerators from the International Organization for Migration (IOM) conducted the data collection. The enumerators received virtual training sessions by one of the experts in Deltares to familiarize them with the purpose of the survey and the specifics of each question. Following this preparation, they visited the camps and interviewed selected household heads to gather the required data effectively.

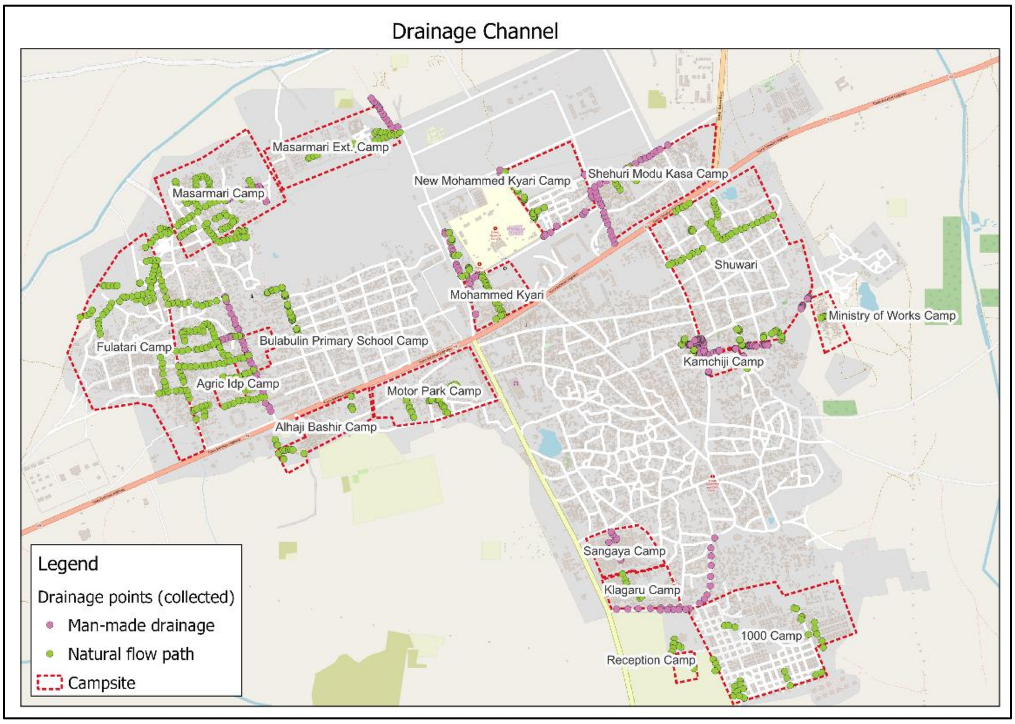


Figure 4: Mapped drainage points, both man-made and natural flow paths

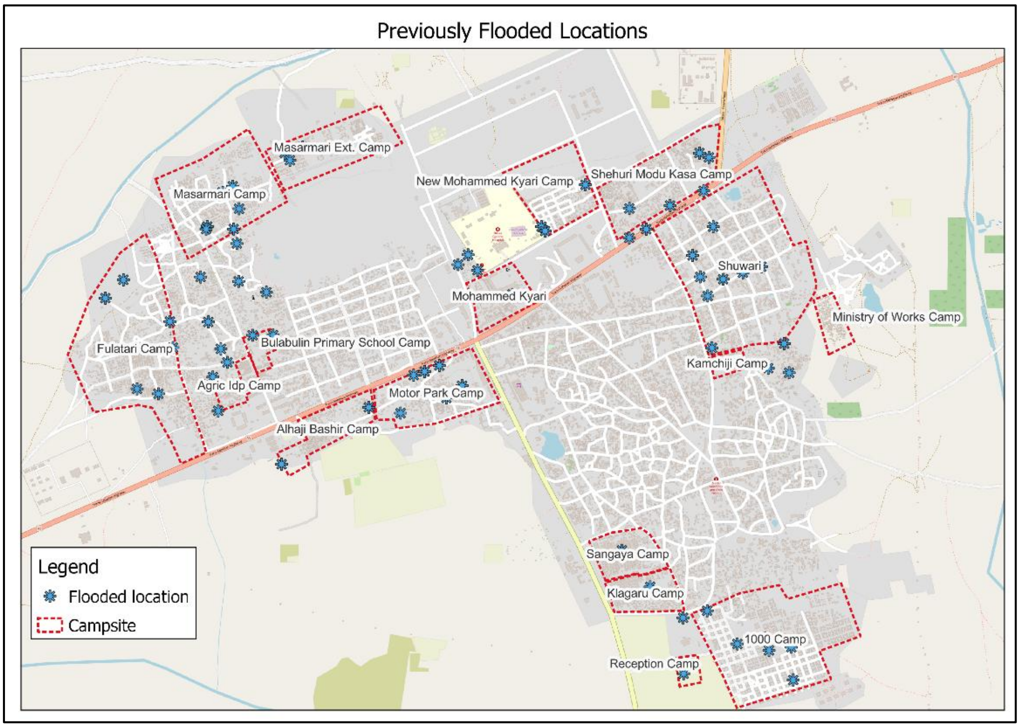


Figure 5: Mapped points of previously flooded locations

2 Model Development

The approach for this project involves multiple phases, starting with data collection and processing, followed by hydrological analysis, which includes rainfall event design. This is then integrated with the hydraulic modeling process and existing drainage channels (using standard width and height which is a width of 0.5 meters and a depth of 1.0 meters). The flood scenario analysis was conducted using Deltares modeling tools (Delft3D FM 1D2D). Delft3D-FM is able to simulate coupled 1D-2D processes. This means that a two-dimensional flood event can be simulated, capturing the spatial heterogeneity of the surroundings, with the inclusion of existing drainage channels as 1-dimensional elements. It furthermore supports the rain-on-grid simulation method to determine surface water runoff over the terrain. To estimate evaporation and infiltration, a hydrological Wflow model was used. The resolution of a Delft3D-FM model is flexible as it supports the use of flexible-mesh models, and it is typically constrained to the resolution of the available elevation data. The final flood hazard maps were then used to assess the impact on buildings and determine their flood depth and risk levels. The last phase focuses on developing an interactive dashboard that consolidates all the flood model scenarios.

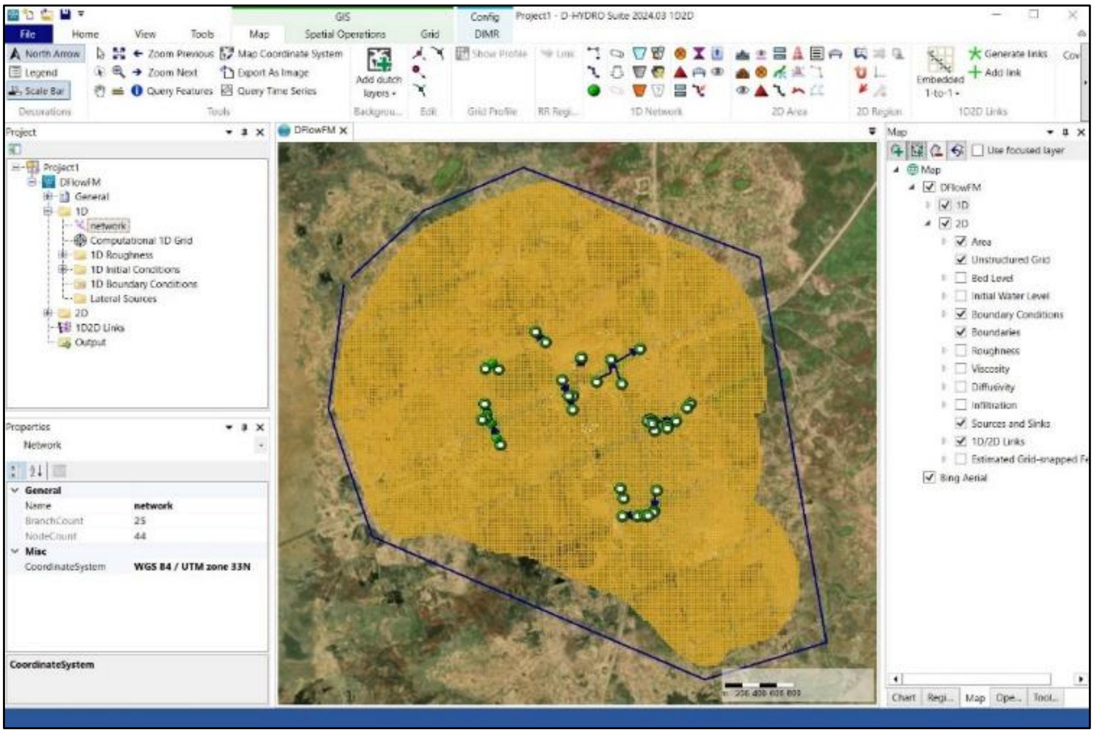


Figure 6: Delft3D FM of Model development Interface

3 Result: Flood Hazard Maps

The flood modeling results are presented as flood depth maps, generated based on the rainfall inputs used in the model. These maps, with a resolution corresponding to the 30-meter cell size of the digital terrain model (DTM), depict the extent and depth of flooding across the study area. The results are shown for different return periods, ranging from the relatively mild 2-year event to the more significant 10-year event, and culminating in the extreme 100-year flood scenario. These maps visually represent flood behaviour across various return periods, highlighting both the extent of inundation and the corresponding flood depths. Additionally, the maps indicate existing drainage channels, represented in pink (on the right).

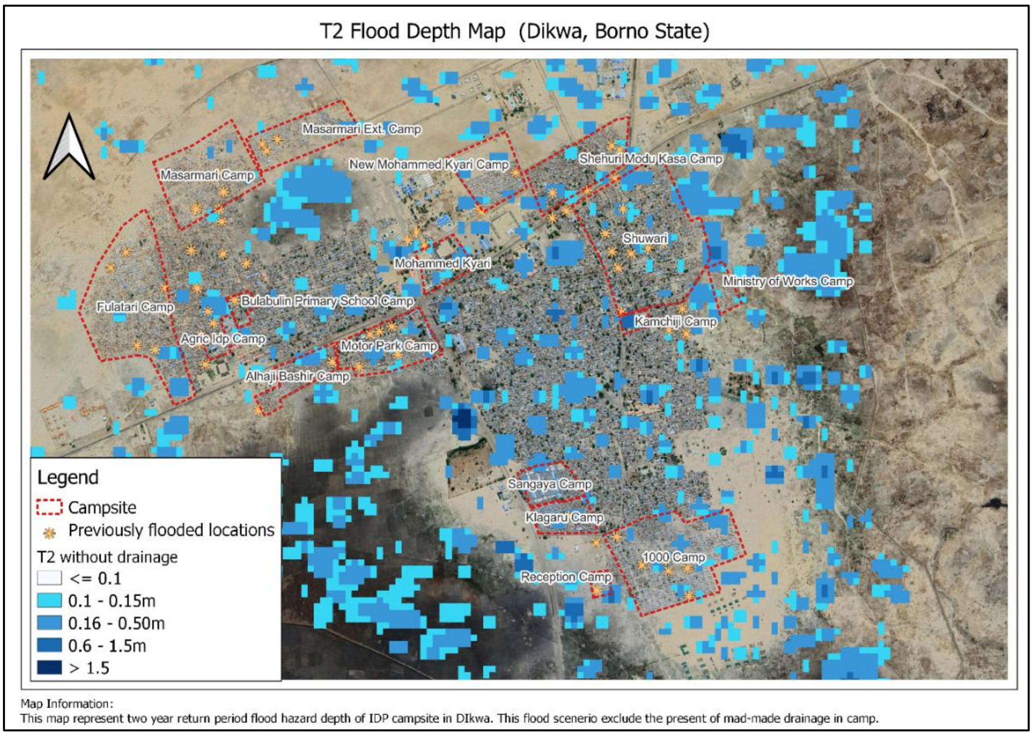


Figure 7 Flood depth and extent map for a 2-year return period (no drainage channel scenario)

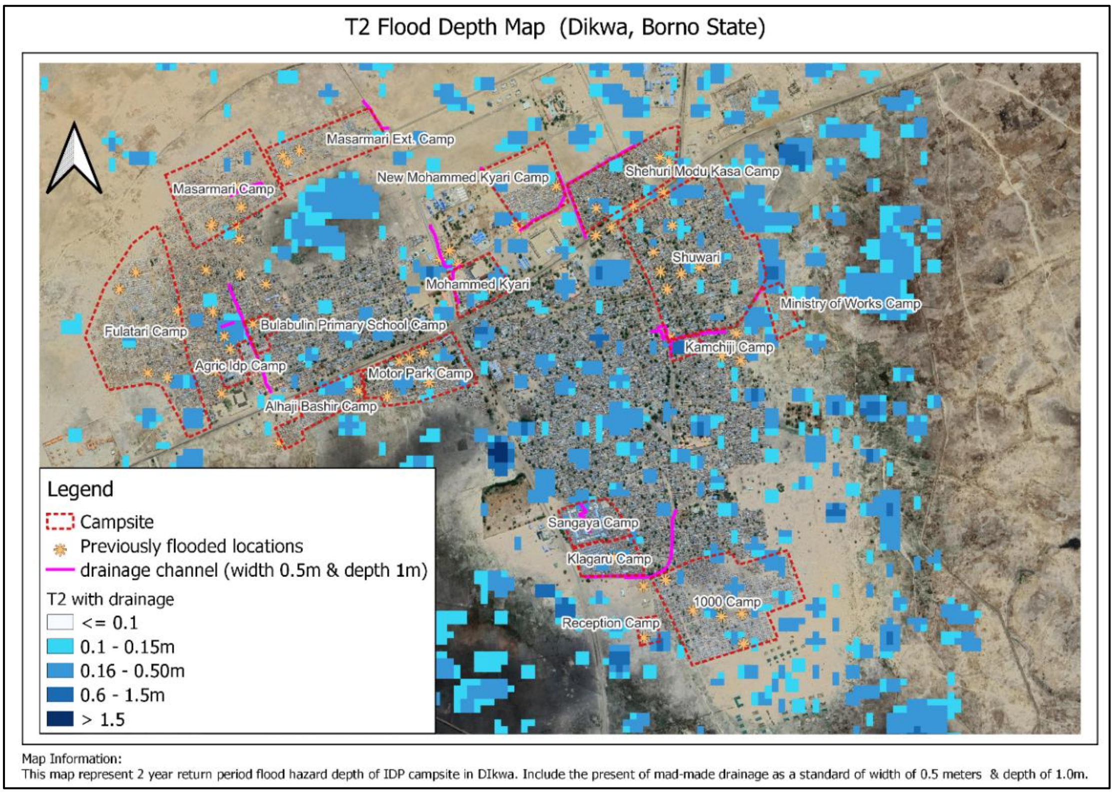


Figure 8 Flood depth and extent map for a 2-year return period (drainage channel of 0.5m width and 1.0m depth scenario)

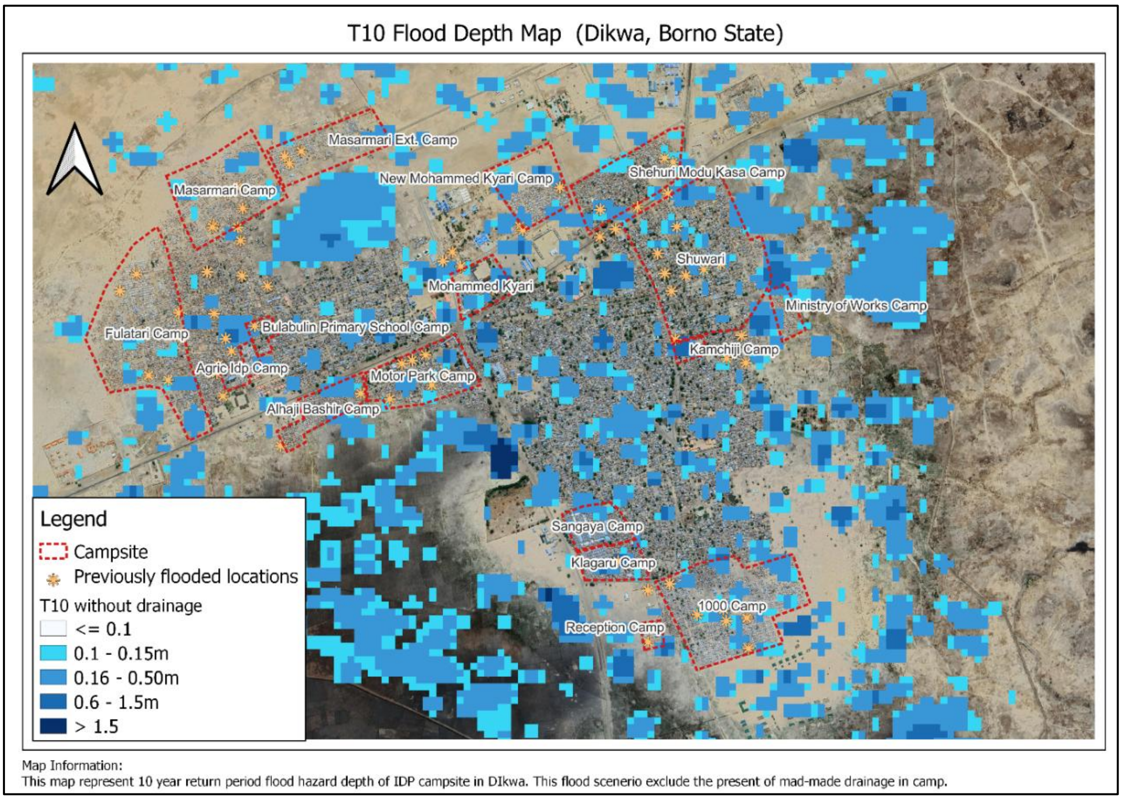


Figure 9 Flood depth and extent map for a 10-year return period (no drainage channel scenario)

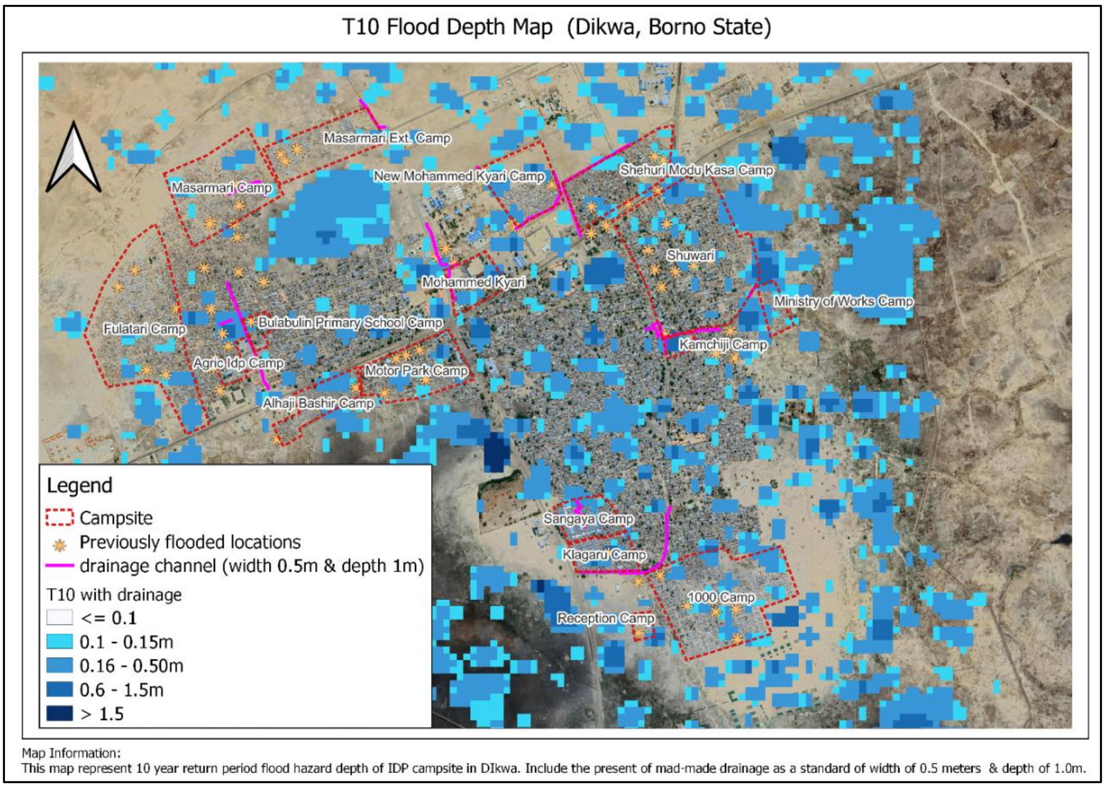


Figure 10 Flood depth and extent map for a 10-year return period (drainage channel of 0.5m width and 1.0m depth scenario)

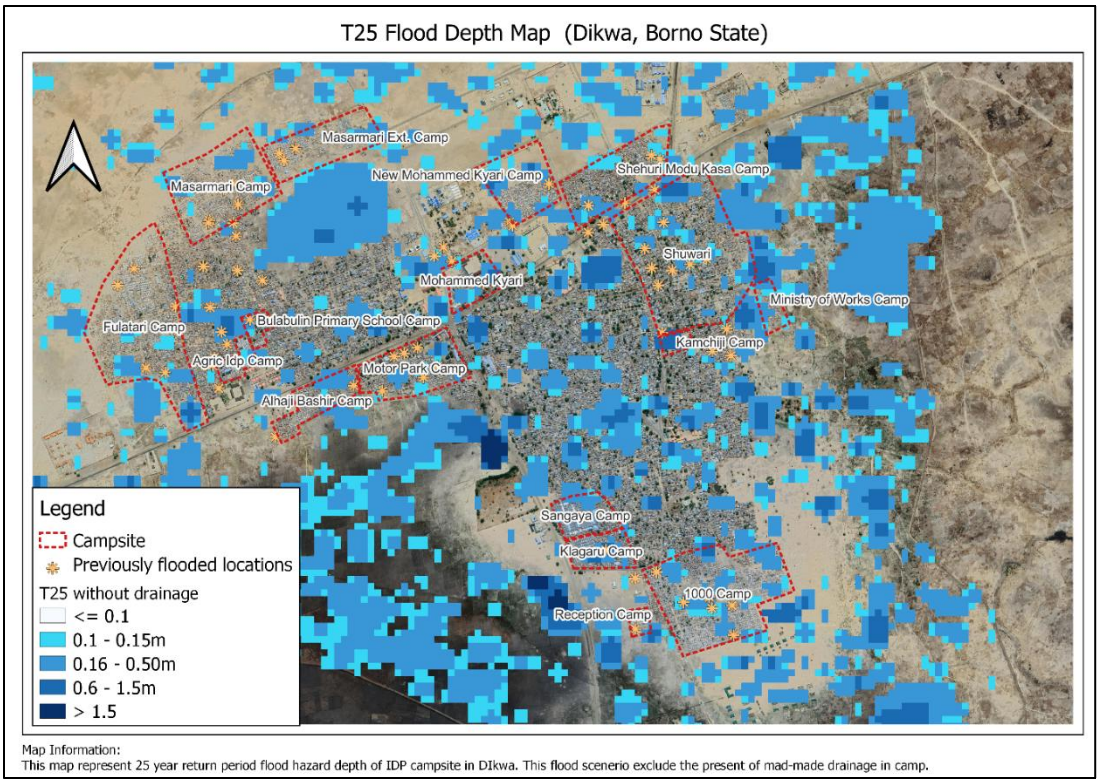


Figure 11 Flood depth and extent map for a 25-year return period (no drainage channel scenario)

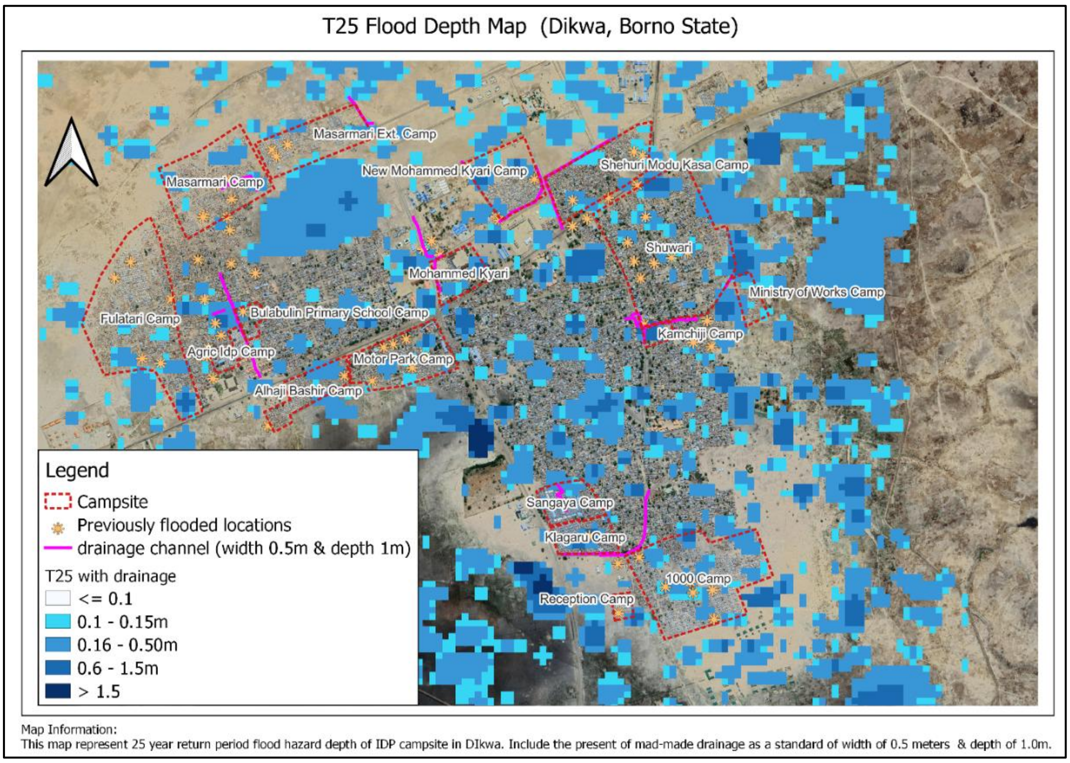


Figure 12 Flood depth and extent map for a 25-year return period (drainage channel of 0.5m width and 1.0m depth scenario)

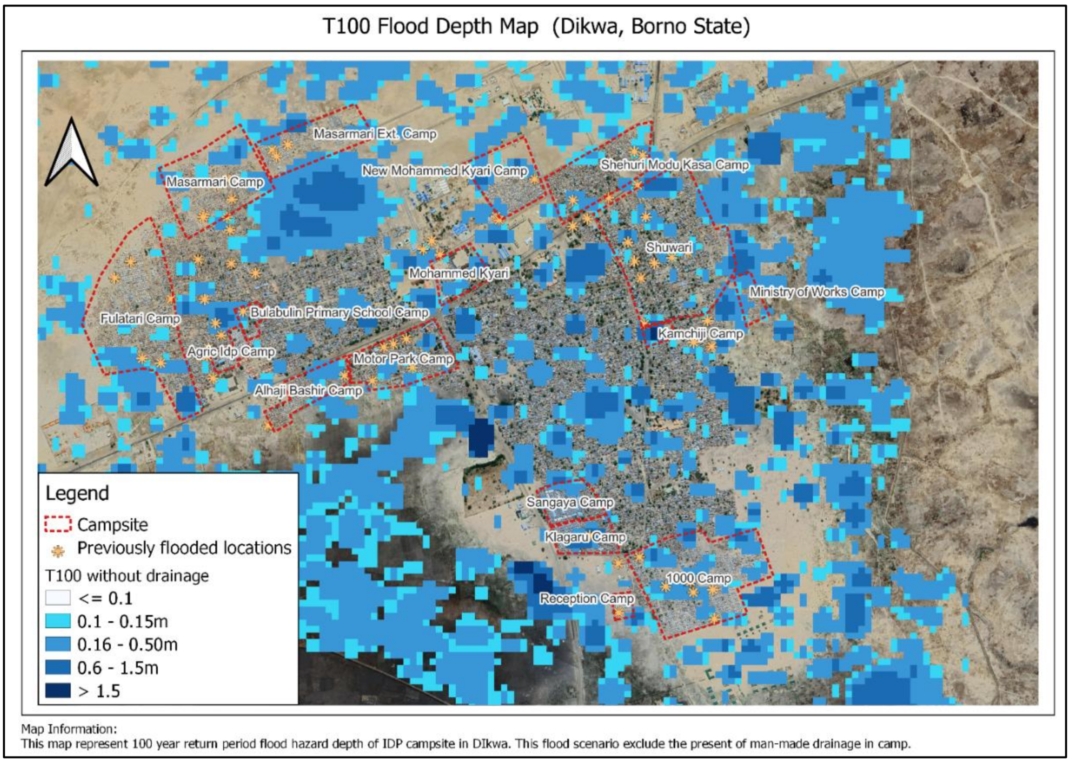


Figure 13 Flood depth and extent map for a 100-year return period (no drainage channel scenario)

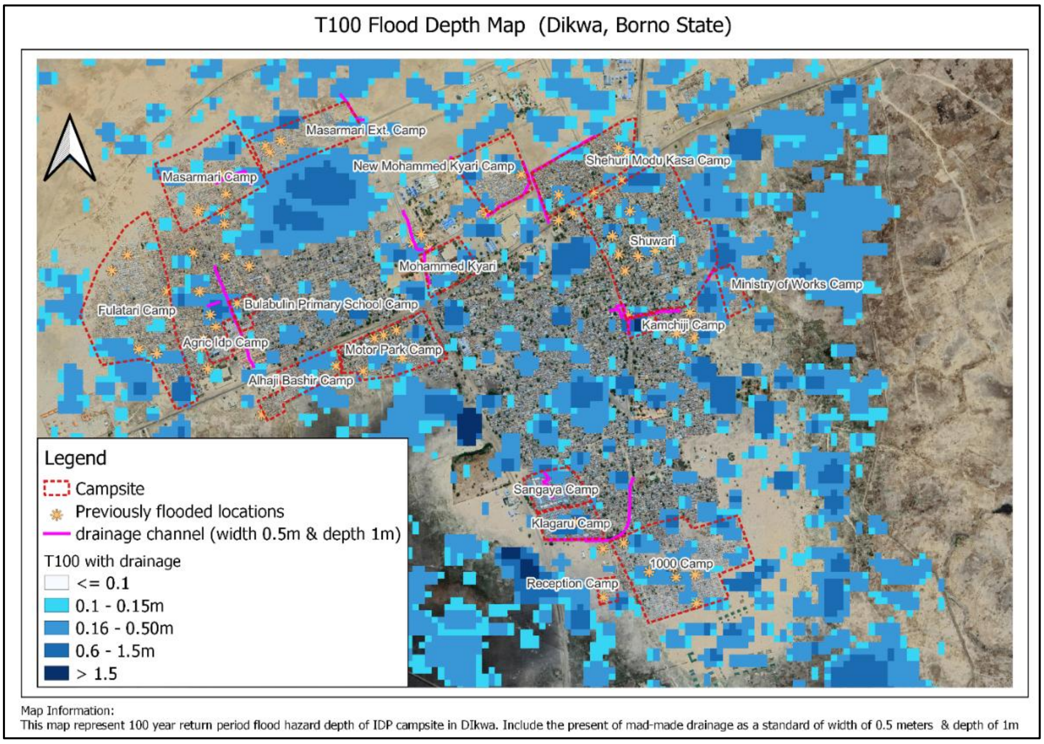


Figure 14 Flood depth and extent map for a 100-year return period (drainage channel of 0.5m width and 1.0m depth scenario)

The maps above show that the more extreme, less frequent rainstorms result in greater inundation, significantly impacting most of the IDP campsites. In the following section, we show the interactive dashboard analysis, focusing on the campsites most affected by flooding. Additionally, we assess the risks posed to buildings within each camp.

4 Flood Risk Categorisation

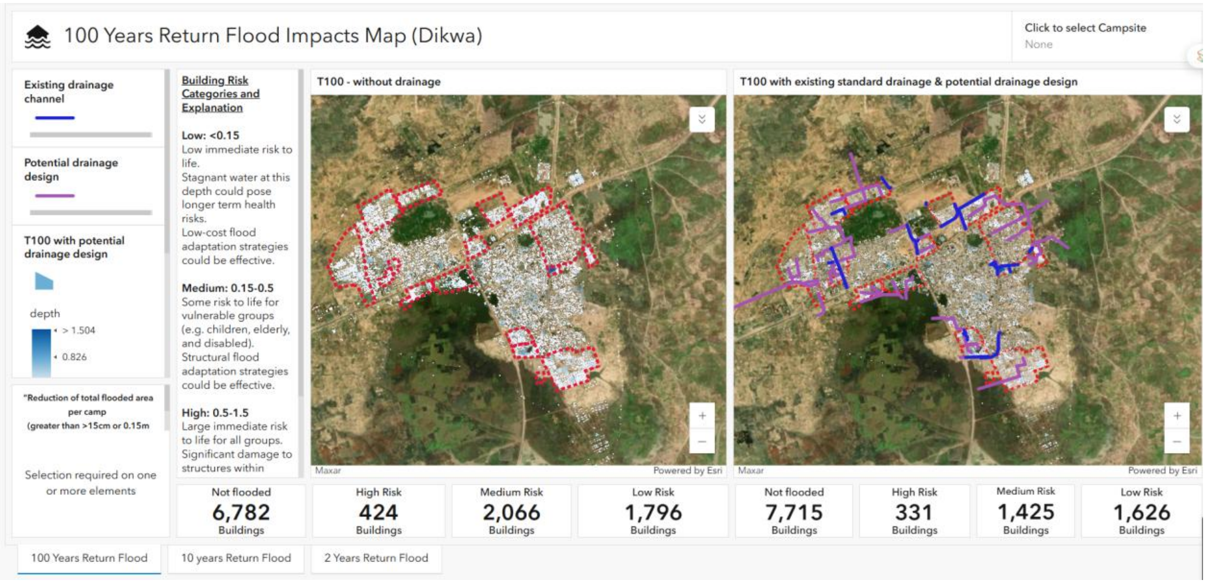
In the following interactive dashboard, we illustrate the impact of flooding on buildings by categorizing flood depth in relation to its effects on the structures. The dashboard highlights the impact of extreme flooding on buildings. Based on existing literature and research studies, the flood risk is classified into three levels: Very High, Medium, and Low. The table below provides a detailed explanation of each risk category, the corresponding flood depth, and the potential impact on buildings at each risk level.

Table 2: Risk Categories and impact based on flood depth

Risk Category	Flood Depth (meters)	Description of impact
Low	<0.15m	Low immediate risk to life. Stagnant water at this depth could pose longer term health risks. Low-cost flood adaptation strategies can be effective.
Medium	0.15 -0.5m	Some risk to life for vulnerable groups (e.g. children, elderly, and disabled). Structural flood adaptation strategies could be effective
High	0.5 - 1.5m	Large immediately risk to life for all groups. Significant damage to structure within camp.

4.1 Dashboard of Building-Level Flood Depth and Risk Categorization for 2, 10, and 100-Year Return Periods under No Drainage and Existing/Potential Drainage Scenarios

The dashboard provides a comprehensive analysis of building-level flood depth and associated risk categorization for various return periods under two scenarios: no drainage and existing/potential drainage. The "no drainage" scenario evaluates flood depths and risks in the absence of effective drainage systems, highlighting vulnerabilities and areas most prone to inundation. Conversely, the "existing/potential drainage" scenario incorporates the impact of current or planned drainage infrastructure, showcasing its effectiveness in mitigating flood depths and risks across different return periods.



Click to view live dashboard

4.2 Exposure Result

Number of exposed buildings at 2 years return Period
The bar chart below provides an overview of the number of buildings categorized by their risk levels under two years return period scenarios, including no drainage, existing drainage, and the proposed drainage design.

Figure 15: 2 years exposed building risk

Number of exposed buildings at 10 years return Period

The bar chart below provides an overview of the number of buildings categorized by their risk levels under 10 years return period scenarios, including no drainage, existing drainage, and the proposed drainage design.

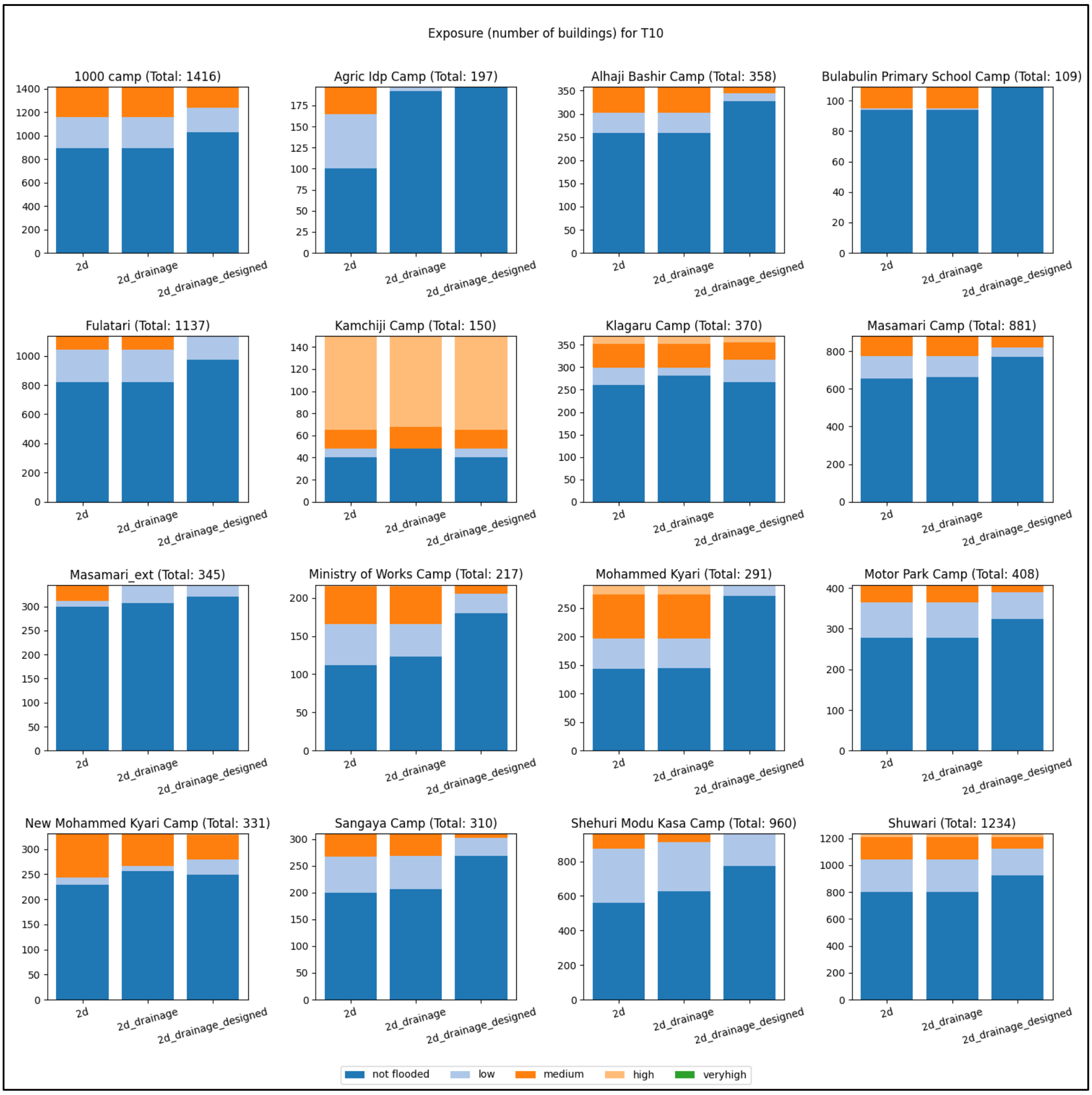


Figure 16: 10 years exposed building risk

Number of exposed buildings at 25 years return Period
The bar chart below provides an overview of the number of buildings categorized by their risk levels under 25 years return period scenarios, including no drainage, existing drainage, and the proposed drainage design.

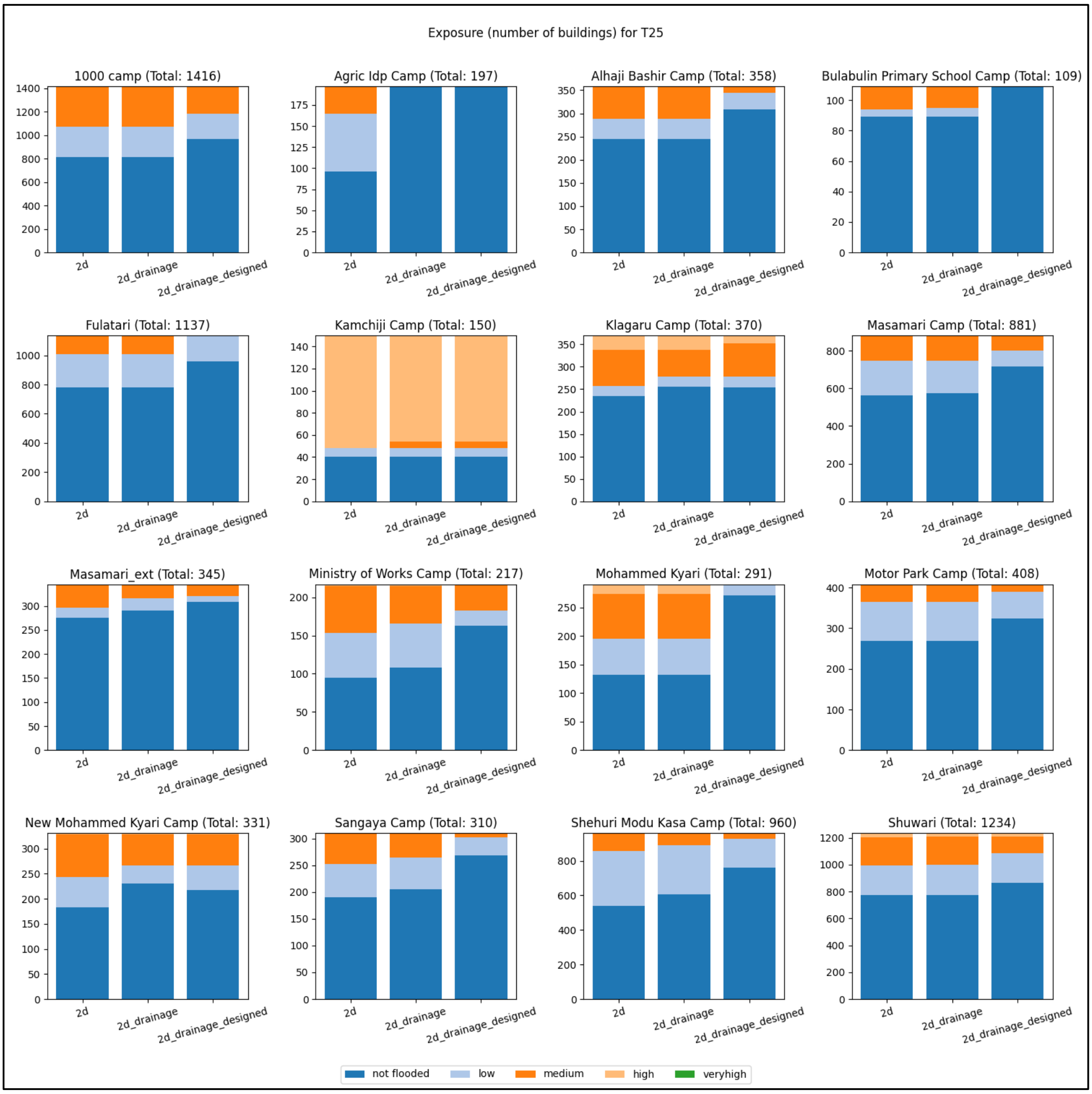


Figure 17: 25 years exposed building risk

Number of exposed buildings at 100 years return Period
The bar chart below provides an overview of the number of buildings categorized by their risk levels under 100 years return period scenarios, including no drainage, existing drainage, and the proposed drainage design.

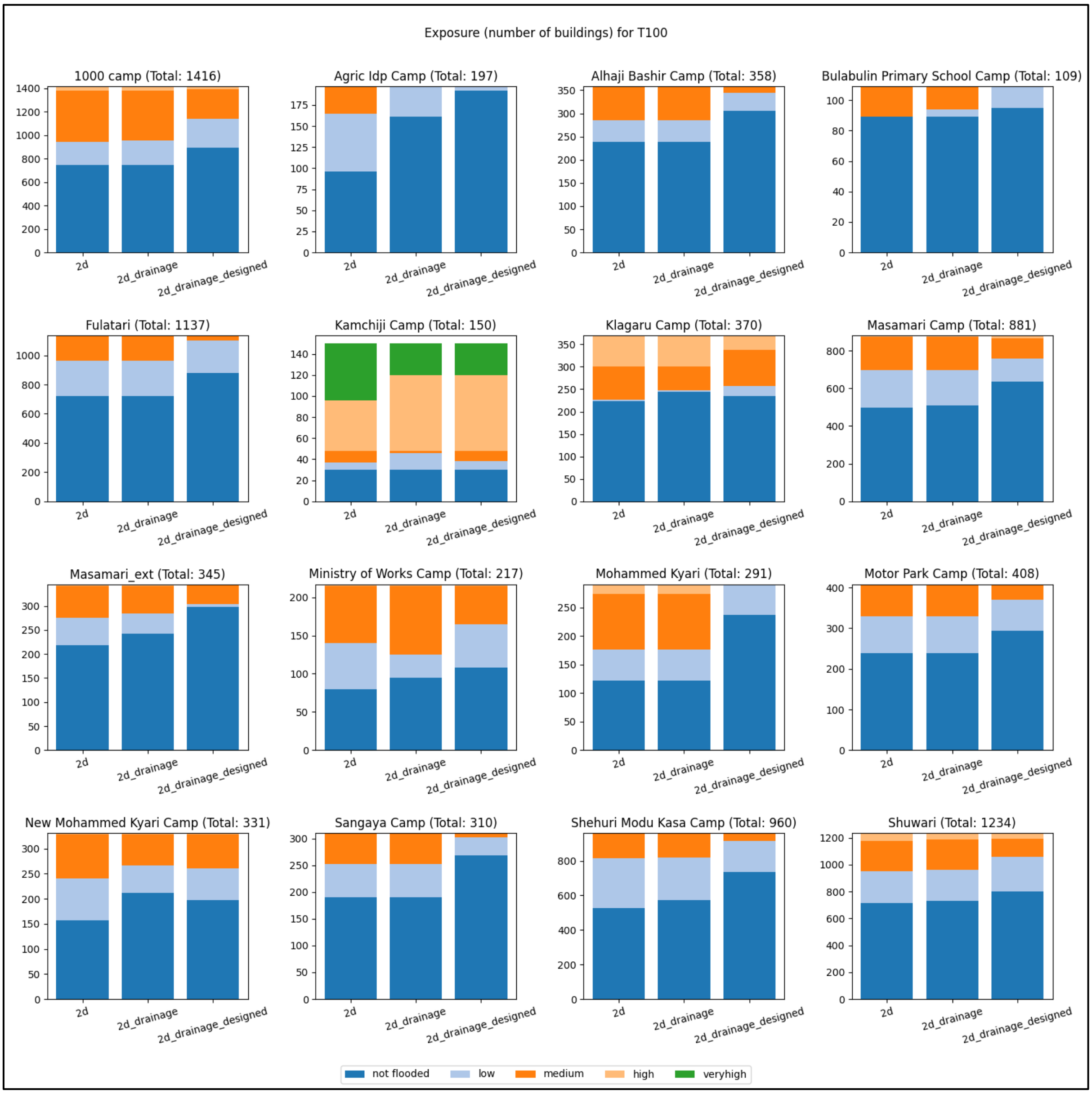


Figure 18: 100 years exposed building risk

4.2.1.1 Important information on Potential Drainage Design (2d_drainage designed)

The demonstration of the implementation of a possible drainage system designed has been derived by using the existing drainage, obtained during the field data collection, as the starting point, and interpreting the DEM data to find the most logical drainage paths. The objective was to drain flooding hotspots and local depression by connecting them to areas outside of the city. To make the drainage system consistent, a uniform slope is applied along all drainage branches which is determined by the elevation difference and the length of the drainage path."

We have also ensured that outflow location has been chosen based on capability of this location to absorb/infiltrate the flood volume.

5 Result Discussion and Recommendation

In this section, we provide a detailed explanation of the outcomes of the flood impact on buildings footprint for each camp under three scenarios: without drainage, with existing drainage, and with a proposed drainage design. The analysis evaluates the impact of these scenarios on building risk across different flood return periods. The results highlight how the absence of a drainage system exacerbates flood risks, while the existing drainage offers minimal improvement. However, the introduction of the proposed drainage design demonstrates a significant reduction in flood extent and risk to buildings. For further details and visual representations of these findings, please refer to the dashboard and bar chart above.

5.1.1 1000 Camp

The camp currently lacks an existing drainage system, which represents a significant issue given the observed risk of exposed buildings. Analysis of flood building exposure bar charts, and the dashboard confirms the absence of drainage infrastructure in the camp. This is evident from the negligible differences between the flood extent results for scenarios "without drainage" and "with existing drainage," as no drainage system is in place.
However, the analysis incorporating a proposed drainage design showed a notable reduction in flood extent. The bar chart illustrates a significant decrease, with a large portion of the previously flooded area now categorized as "Not Flooded," highlighting the substantial impact of the proposed drainage design.

5.1.2 Agric IDP Camp

The camp currently has a very limited drainage system, which poses a significant challenge given the extent of flooding observed. An analysis of the flood exposure bar chart and dashboard highlights the limited effectiveness of the existing drainage infrastructure. This is evident from the minimal differences in flood extent results between the "without drainage" and "with existing drainage" scenarios, underscoring the inadequacy of the current system. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement. The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.1.3 Alhaji Bashir Camp

The camp currently has a very limited drainage system, which poses a significant challenge given the extent of flooding observed. An analysis of the flood building exposure bar chart and dashboard highlights the limited effectiveness of the existing drainage infrastructure. This is evident from the minimal differences in flood extent results between the "without drainage" and "with existing drainage" scenarios, underscoring the inadequacy of the current system. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement. The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.1.4 Bulabulin Primary School

The camp currently lacks an existing drainage system, which represents a significant issue given the observed risk of exposed buildings. Analysis of flood building exposure, bar charts, and the dashboard confirms the absence of drainage infrastructure in the camp.

This is evident from the negligible differences between the flood extent results for scenarios "without drainage" and "with existing drainage," as no drainage system is in place.
However, the analysis incorporating a proposed drainage design showed a notable reduction in flood extent. The bar chart illustrates a significant decrease, with a large portion of the previously flooded area now categorized as "Not Flooded," highlighting the substantial impact of the proposed drainage design.

5.1.5 Fulatari Camp

The camp currently lacks an existing drainage system, which represents a significant issue given the observed risk of exposed buildings. Analysis of flood building exposure bar charts, and the dashboard confirms the absence of drainage infrastructure in the camp. This is evident from the negligible differences between the flood extent results for scenarios "without drainage" and "with existing drainage," as no drainage system is in place.
However, the analysis incorporating a proposed drainage design showed a notable reduction in flood extent. The bar chart illustrates a significant decrease, with a large portion of the previously flooded area now categorized as "Not Flooded," highlighting the substantial impact of the proposed drainage design.

5.1.6 Kamchiji Camp

The camp has a limited existing drainage system that runs along its boundary. Flood modeling results reveal an increase in the number of buildings classified as "Not Flooded" when the existing drainage system was incorporated. Additionally, there was a rise in the number of buildings categorized as having medium risk and a corresponding decline in high-risk buildings. Due to the area's elevation, incorporating a potential drainage design was challenging in the modeling process. However, this limitation might differ in real-on ground implementation. Despite these challenges, the current drainage design does not achieve a substantial reduction in the number of flood-affected buildings. Nonetheless, the limited potential drainage design did show improvements, reducing the number of buildings at risk compared to the scenario without any drainage system. Investigating the on-ground implementation in the camp will be a good idea.

5.1.7 Klagaru Camp

The camp's existing drainage system, though limited and running along its boundary, had a measurable impact on flood modeling results. Incorporating this drainage system into the analysis led to an increase in the number of buildings classified as "Not Flooded," along with a rise in medium-risk buildings and a decline in those at high risk. For the 100-year return period, the drainage design demonstrated the greatest effectiveness, with a significant increase in non-flooded buildings and a substantial shift toward medium risk. However, the results indicate that the drainage design is less effective for the 2-year return floods. This variation suggests that the drainage system's performance may depend heavily on flood intensity and return periods. Additionally, the current drainage design is based on existing elevation data used for modeling, which may limit its accuracy. A more refined, ground-truth-based drainage design could potentially yield better results and further reduce flood risks in the camp.

5.1.8 Masamari Camp

The camp currently has a very limited drainage system, which poses a significant challenge given the extent of flooding observed. An analysis of the flood exposure bar chart and dashboard highlights the limited effectiveness of the existing drainage infrastructure. This is evident from the minimal differences in flood extent results between the "without drainage" and "with existing drainage" scenarios, underscoring the inadequacy of the current system. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement. The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.1.9 Masamari Ext

The camp currently lacks existing drainage system, which represents a significant issue given the observed flood extent. Analysis of flood exposure bar chart and dashboard confirm the absence of drainage infrastructure in the camp. This is evident from the negligible differences between the flood extent results for scenarios "without drainage" and "with existing drainage," as no drainage system is in place. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement. The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.1.10 Ministry of Work Camp

The camp currently lacks a functional drainage system, which presents a significant challenge given the observed flood extent. Analysis of the flood exposure bar chart and dashboard confirms the absence of drainage infrastructure, as evidenced by the minimal differences between the flood extent results for the "without drainage" and "with existing drainage" scenarios. However, drainage from a neighbouring campsite contributed to a reduction in flooding within this camp, leading to an increase in the number of buildings classified as "Not Flooded" compared to scenarios without drainage in the modeling. The analysis incorporating a proposed drainage design demonstrated even more substantial improvements. The bar chart indicates a significant rise in the number of buildings categorized as "Not Flooded" and a corresponding decline in buildings classified as low risk. These findings highlight the critical role a well-designed drainage system could play in mitigating flooding within the camp, effectively reducing both flood extent and associated risk levels.

5.1.11 Mohammed Kyari

The camp currently has a very limited drainage system, which poses a significant challenge given the extent of flooding observed. An analysis of the flood exposure bar chart and dashboard highlights the limited effectiveness of the existing drainage infrastructure. This is evident from the minimal differences in flood extent results between the "without drainage" and "with existing drainage" scenarios, underscoring the inadequacy of the current system. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement. The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.1.12 Motor Park Camp

The camp currently lacks existing drainage system, which represents a significant issue given the observed flood extents. Analysis of flood exposure barchart and dashboard confirms the absence of drainage infrastructure in the camp. This is evident from the negligible differences between the flood extent results for scenarios "without drainage" and "with existing drainage," as no drainage system is in place. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement. The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.1.13 New Mohammed Kyari

The camp's existing drainage system, though limited and running along its boundary, had a noticeable impact on flood modeling results. Incorporating this drainage system into the analysis led to an increase in the number of buildings classified as "Not Flooded," along with a rise in medium-risk buildings and a decrease in those at high risk. However, due to the terrain and land use characteristics of the area, which is primarily wetland, the results show that implementing a designed drainage system could lead to increased flooding within the camp. In such a scenario, the best course of action may be to either maintain the existing drainage system or consider relocating residents, as the potential for significant flood damage, especially in extreme events such as a 100-year return flood, would be high.

5.1.14 Sangaya Camp

The camp's existing drainage system, although limited and running along its boundary, had a noticeable impact on flood modeling results. When this drainage system was included in the analysis, there was an increase in the number of buildings classified as "Not Flooded," along with a rise in medium-risk buildings and a decrease in those at high risk. In contrast, the analysis incorporating a proposed drainage design showed even greater improvements. The results indicated a further increase in the number of buildings categorized as "Not Flooded," alongside a decline in the number of buildings classified as low risk. These findings highlight the significant potential of a well-designed drainage system to reduce flood extent and risk, demonstrating its key role in mitigating flooding within the camp.

5.1.15 Shehuri Modu Kasa Camp

The camp currently lacks existing drainage system, which represents a significant issue given the observed flood extent. Analysis of flood exposure bar chart and dashboard confirms the absence of drainage infrastructure in the camp. This is evident from the negligible differences between the flood extent results for scenarios "without drainage" and "with existing drainage," as no drainage system is in place. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement. The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.1.16 Shuwari

The camp currently lacks existing drainage system, which represents a significant issue given the observed flood extent. Analysis of flood exposure barchart and dashboard confirms the absence of drainage infrastructure in the camp. This is evident from the negligible differences between the flood extent results for scenarios "without drainage" and "with existing drainage," as no drainage system is in place. In contrast, the analysis incorporating a proposed drainage design demonstrated a notable improvement.

The bar chart reveals an increase in the number of buildings classified as "Not Flooded" and a decline in buildings categorized as low risk. These findings underscore the substantial impact that a well-designed drainage system could have in mitigating flooding within the camp, significantly reducing both flood extent and risk level.

5.2 Recommendation

Improve Existing Drainage Management: In all camps studied the existing drainage infrastructure was highlighted as an exacerbating factor. For the existing camps it is recommended to focus investments on improving the existing infrastructure so that it covers the entirety of the camp, is properly sized and interconnected to convey stormwater to the nearest natural river. Adequate maintenance must also be carried out prior to each rainy season to prevent the channels and culverts becoming filled in with sediment and solid waste.

Consider Relocation in High-Risk Areas: For camps that remain highly vulnerable to flooding, especially during extreme flood events, relocation of buildings, shelters and people may be the only viable solution to reduce long-term flood risks and prevent loss of life and property. When selecting a new location (or expanding and existing camp for the relocated assets and people) the chosen site, layout and drainage infrastructure must consider the current flood hazard for that location, as well as the flood hazard considering the new camp infrastructure that may worsen the flooding situation.

6 Conclusion

The flood modeling analysis conducted for Dikwa LGA, focusing on selected IDP camps, emphasizes the critical role of drainage systems in mitigating flood risks. While a limited drainage infrastructure exists in a few camps, with drainage systems running along the camp's boundaries, these measures have shown a measurable impact in reducing flood extent. This is reflected in the increase in buildings classified as "Not Flooded" and a shift from high-risk to medium-risk categories for some camps, as discussed in the results and discussion section.
However, the current drainage infrastructure is insufficient to fully address flood risks, particularly during extreme events such as those with a 100-year return period. Further analysis incorporating a proposed drainage design demonstrated significant improvements in flood mitigation. The proposed system led to a notable reduction in flood extent, with a substantial increase in buildings classified as "Not Flooded" and a decrease in low-risk buildings. These findings highlight the potential of a well-designed drainage system to significantly reduce both flood depth and the number of buildings at risk, particularly in extreme flood return period scenarios.

This project has demonstrated the impact of different rainfall scenarios on camp shelters and buildings, highlighting the critical importance of having standardized drainage channels in camps. Often, existing drainage systems are blocked, exacerbating flood risks. The results of this study provide an evidence-based tool to support decision-making, enhancing the understanding of flood-related disasters in these camps. Furthermore, the findings can guide future campsite planning and development in Dikwa, Borno State, Nigeria.

The project had been carried out by Deltares (Netherland) and IOM WASH team (Nigeria)
Deltares
An independent research institute (based in Netherland in the field of water, soil and subsurface. www.deltare.nl
IOM
Intergovernmental organization from the United Nations that provides services and advice concerning migration to governments and migrants, including internally displaced persons, refugees, and migrant workers.

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