FLASH FLOOD MODELLING FOR SELECTED AREA IN RIYADH CITY

Husam Abdullah Al Shawi

Abstract

Due to uncontrolled urban expansion and increased rainfall events in the desert regions of Saudi Arabia, effects of frequent flash flooding have become greater on infrastructures and human life in recent years. With the availability of high resolution datasets, detailed Terrain information resulting from frequent on going aerial survey, it is promising for modeling and analyzing flash flood in urban areas more accurately using such higher precision data derived from LIDAR.

The purpose of this Master's Project was to evaluate and compared low and high resolution elevation in use for assess effects on identification of flooding risk potential areas in Saudi Arabia using Um Qaser Areas in Riyadh as study area. The paper presents literature review carried, methodology, results achieved and there comparison, discussion, limitations and future research areas.

The processing successfully resulted in identifying an increase of about50% in water accumulation points of 59 quantity using LIDAR terrain data in comparison to processed Satellite ASTER 30m Elevation data of 26 quantity. Processing LIDAR based terrain data also resulted in generation of hyrdro network information in better detail then satellite DEM.

More future work needs to be carried out to integrate cadastral information to the DTM processing of LIDAR for higher accurate water flow network generation leading to better modelling.

Introduction

Urban flooding has become a major threat during the recent years due to frequently increased environmental hazards. Flash flooding causes some life losses, infrastructure damages, and spread of diseases. Assessing and managing the effects is a significant challenge specially in a rapid developing urban city such as Riyadh which currently seeing great development and economic activities and major Metro Rail, Financial economic districts and new residential district projects leading to increase in population density.

Geographical Information System (GIS), Remote Sensing imagery and datasuch as Light Detection and Ranging (LIDAR), and

Digital Elevation Model (DEM) are been used for modeling urban flooding in several parts of the world (Ghazali and Kamsin, 2008).DEM has been used primarily to define the water surface flow networks in flooded areas including pathways and temporary ponds, sinkholes … etc.

Objective and Justification

This study seeks to show how the integration of Remote Sensing and GIS would help in modeling the flash flood impact in Riyadh region using datasets available from newer technologies such as LIDAR.

Flash flooding in Riyadh occurs as a consequence of excessive rapid rainfall, which has increased recently, possibly because of climate fluctuations and lack of well thought out spatial development practices and planning. These extreme natural events have become a source of great loss to property and lives in the last 5 years or so especially in Riyadh City and surrounding areas.

The main aim of this study is to determine the effectiveness of LIDAR based elevation data in comparison to satellite derived DEM by visualizing and comparing the Hydro Network and accumulated risk areas from the two processing, and it focuses on:

1. Generating hydro drainage network and identify water accumulation points.
2. Identifying flash flood risk using LIDAR and satellite platforms in a comparative manner.
3. Visualization of the study area with flood risk areas in 3D.

Methodology

Idea is to study and analyze the selected region/area in Riyadh city's catchment areas characteristics, drainage network and flood simulation which will assist in analyzing the impact on the selected area, all these data processed using ERDAS Imagine for Remote Sensing processing and data preparation of DEM, 3D data from LIDAR, where ESRI ArcHydro used for modeling processes. Rainfall data obtained fromThe General Authority of Meteorology and Environmental Protection. The outcomes of this study will support and improve the daily activities of all relevant agencies such Municipality, ADA, Civil Defense … etc.

Process involved High resolution DEM generation and pre-processing from a previously conducted Riyadh Aerial Imagery, LIDAR Survey in 2011-2012 by ArRiyadh Development Authority

(ADA). This would be the key input for ArcHydro and other tools for flood hazard mapping, water flow generation etc. As well as 3D visualization along with Aerial and Satellite Imagery with flood inundation in the study area.

DEMs are characterized by different precision and accuracy. On the one hand, the spatial resolution of low-cost DEMs from satellite imagery, such as ASTER and SRTM, is rather coarse (around 30 to 90m). On the other hand, the LIDAR technique is able to produce high-resolution DEMs (at around 1m) (A. Md Ali et al, 2015).

As a comparitve study, DEM derived from ASTER sensor etc. lower resolution previous/existing data sources was also processed side by side to access the accuracy and detail of the results in relation to the LIDAR derived datasets output. This study is needed similar to (A. Md Ali et al, 2015) to determine whether the quality and accuracy of the DEM is more important than the resolution and precision of the DEM.

The final stage involved 3D visualization of the flooded areas using ArcGIS and ERDAS softwares as well as production of flood map of the area.

LITERATURE REVIEW

Review and summary of various literatures that is studied in relation to flood hazards and assessment, methods, modern tools, technologies and data requirements for using remote sensingز and GIS to produce flood hazard maps and other visual representation of floods such as 3D views.

There has been numerous studies over the years in many countries to carry our mapping of flash floods, for example in United States (Mastin, 2009), China (Liang et al., 2011), Egypt (El Bastawesy et al., 2009; Ghoneim et al., 2002), Saudi Arabia (Saud, 2010; Dawod et al., 2011), India (Bhatt et al., 2010) and Ghana (Forkuo, 2011).

Flash Floods and Hazards

Flooding is the process of water overflowing onto land surface area that are usually dry, they can happen during heavy rains or when rivers overflow due to heavy waters, or when dams and/or levees break etc.

Flash flooding is a heavy onset of water on land area in very short amount of time and occurs rapidly, generally within one hour of rainfall, and sometimes accompanied by landslides, mud flows, ridge collapse, damage to buildings, and fatalities (Hapuarachchi et al., 2011). Flood extents and depth are usually considered the most important flood parameters, especially when it comes to mapping flood hazards [9] (Mugisha, 2015).

Flooding in Riyadh occurs as a consequence of excessive rapid rainfall, which has increased recently over a few year, possibly because of climate fluctuations since start of this decade,normal regional land cover, topography and geological soil formations andhas often affected urbaninfrastructure as well human life due reasons such as lack of well thought out spatial development practices and planning as well construction activities taking place at the time. These extreme natural events have now become a source of great loss to property and lives in the last 10 years or so especially in Riyadh City and surrounding areas.Flood extents and depth are usually considered the most important flood parameters, especially when it comes to mapping flood hazards (Mugisha, 2015).

Flood Hazard Assessment

Flood hazard assessment involving creating and maintaining relevant flood information, flood maps for an area is important in policy formulation and its implementation for flood management initiatives

One of the first steps to do so is to review the flooding history for the selected area. But this may not always be available or be relevant since flash flooding is a varying and highly uncertain phenomena in terms of prediction for future location and strength as well the regular Landover changes in urban areas overtime (Bellos, 2012).Overcoming these problems can involve the use of statistical and modelling tools to calculate the hazards in a hypothetical scenario and there are various parameters that can be used to denote such flood hazards (Mugisha, 2015). These may include flood extents, water depth, flow velocity, duration, warning time and the rate at which the water rises (Alkema, 2007).

When dealing with current and recent floods the use of remote sensing technologies and satellite imagery is very helpful in flood extents determination (Mugisha, 2015).The modelling approach helps to understand the flood hazard and serve as a tool are also useful in understanding the effect of mitigation measures (Bhattacharya, 2010). These models are available in many types nowadays, from simple 1D models to complex 2D models, taking flow direction into account (Prachansri,2007).

Flood Modeling Approaches

According to Fura, 2013 flood models are simplified representation of realties and that they are instruments used to mimic and provide insight of process or phenomenon such as flow of water in channels, urban expansion etc. Although simplified yet they still are powerful tools to simulate and predict the implication of certain actions in the future (Couclelis, 2005).

Different types of flood models exist (Pender and Neelz, 2007) reviewed some of existing 1D and 2D flood models. These models have the same principle of conservation of mass, momentum and energy (Horritt and Bates, 2002).

If water is confined in a channel, it is best simulated as an unsteady 1D flow model (Verwey, Stelling S. 2006). This 1D model defines flood only in terms of discharge and water level as a function of space and time (Mugisha, 2015). This approach has limitations of simulating floods in the overland, this situation causes a shift from 1D to 2D model that simulates flood in the overland (Horritt and Bates, 2002). 2D flood model predict flood inundation based on 2D shallow water equation (Mignot et al., 2006).

Various approaches have been created as part of research and development activities around the world to integrate both 1D and 2D approaches to produce effective hydrodynamic models of flood plain (Mugisha, 2015) such as SOBEK (Alkema, 2007) SWI-2D (Finaud-Guyot et al., 2011), LISFLOOD and TELEMAC-2D (Horritt& Bates, 2002), and OPENLISEM (De Roo et al., 1996).

Remote Sensing and GIS Technologies for Flood Mapping

Rapid development of GIS technology and remote sensing techniques, availability and production of high resolution DEM using high resolutions stereo-paired imagery as newer technologies such as LIDAR as well as advancements in integrating GIS with hydrological modelling, flood prediction with distributed models tends to be more advantageous and competent by linking GIS with hydrological modelling (F. De Smedt et al., 2004).According to American Society of Photogrammetry and Remote Sensing (ASPRS) Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena (National Research Council, 2007). Outputs created from photogrammetric process may include Digital Elevation Models; Orthophoto imagery; 2D maps and 3D Feature datasets.

Digital elevation model (DEM) is the most important input of the hydrological modeling to get Flood maps. The precision of watershed calculation is directly dependent on the scale and precision of topographic maps (Elkhrachy, 2015). Availability of high-resolution stereo pair imagery and tremendous advancements in Photogrammetric softwares and process have yield in high-resolution DEM generation from these types of remotely sensed datasets. For example: using ERDAS IMAGINE Photogrammetric system capabilities such as Automatic Digital Terrain Modelling and extraction to generate higher resolution Points cloud similar to imagery resolution yielding in high resolution DEMs.In addition, greater availability of LIDAR data for DEM generation via Aerial Surveys in much higher resolutions than the ones derived from satellite stereo images have also produced much higher detailed elevation models very beneficial for targeted study area flooding studies.

There has been numerous studies over the years in many countries to carry out mapping of flash floods, for example in United States (Mastin, 2009), China (Liang et al., 2011), Egypt (El Bastawesy et al., 2009; Ghoneim et al., 2002), Saudi Arabia (Saud, 2010; Dawod et al., 2011), India (Bhatt et al., 2010) and Ghana (Forkuo, 2011).

Light Detection And Ranging (LIDAR)

Airborne Laser Scanning (ALS) technology is one of the highly accurate methods of collecting large volume; georeferenced 3D data (Weed, 2000; Shan, Toth, 2008).LIDAR is an active remote sensing technology that uses a laser to measure distances to target points. Because it generates its own energy, LIDAR survey can be conducted anytime of day or night, and in some slightly cloudy or hazy conditions (National Research Council, 2007).Using ALS, we collect “point cloud” datawith three coordinates: X, Y and Z representing: latitude, longitude and height above sea level.These data contain additional information such as intensity and number of return (Korzeniowska and Łacka, 2011).To obtain a Digital Elevation Model (DEM), 3D buildings, power lines or various types of objects represented in the “point cloud”, high-quality classification of “point cloud” data is needed (Wang, Tseng, 2010).Most of this software tools offer scripts and algorithms for “point cloud” data classification to land cover classes, bare earth extraction, generating Digital Surface Models (DSMs) and generating DEMs from points classified as bare earth (Fernandez et. al., 2007).

Generating DEM is one of the most important issues in various fields of science especiallythe Flood Modelling using surfaces and morphological modeling (Weed, 2000; Rayburg et. al., 2009). During the last decade, several new methods to generate DEMs with high 3D positional accuracy have appeared. Recent research carried out on ALS has shown that it is one of the best solutions to generate DEMs for large areas in short time (Korzeniowska and Łacka, 2011).GIS Hydrographical Tools: ArcHydro, HEC-RAS

Hydrological flood modelling and flood data management tools are now readily available to assist domain experts in analysis, modelling and management of flood modelling data and studies with greater decision support capabilities and accuracy. Tools available such as ArcHydro and HEC-RAS integrated with ArcGIS platform provide easy access to algorithms and workflows needed to process surface elevation data to produce the necessary features for flow direction and accumulation for water in the relevant study area. Tools such as HEC-RAS and HEC-GeoRAS (ArcGIS Integrated) help develop Flood inundation maps

Arc Hydro is a geospatial and temporal data model for water resources management and analysis, a tool jointly developed by ESRI and Center for Research in Water Resources (CRWR) of University of Texas a collaboration called GIS and Water Resources Consortium (David R. Maidment, 2002), involving representatives from industry, government and academia. The purpose of Arc Hydro is enable the analysis to define, process Surface water hydrology and hydrography, it is not full-fledged analysis and simulation tool in itself but integrates other research and algorithm in flood modelling, simulation to exchange and process and manage the data in way to achieve the desired results. ArcHydro is used in extracting characteristics of the watershed, such as stream network and catchment, delineation is essential for hydrological analysis and water resource management in GIS (Zhang et al. 2013). The foundation of these hydrologic models lies on how to obtain hydrologic and topographic parameters, i.e. watershed characteristics, from Digital Elevation Models (DEMs) (Ames et al. 2009; Jenson 1991; Lacroix et al. 2002).

Another popular and widely used tool for flood extent and depth assessment is HEC-RAS and HEC-HMS from US Army Corps of Engineers. HEC-RAS is a Hydrologic Modeling System designed to describe the physical properties of streams and rivers, and to route flows through them. Given the discharge computed by HEC-HMS or by other means, HEC-RAS computes the resulting water surface elevation.Using another program called HEC-GeoRAS,the elevations can then be mapped in ArcGIS to form a flood inundation map (Djokic and Maidment, 2012). HEC-RAS is a 1-D model that can simulate both steady and unsteady flow conditions (A. Md Ali et al, 2015)

Analytical Hierarchical Process

The Analytic Hierarchy Process (AHP), developed by Saaty (1977, 1980), and is a widely used multi-criteria decision support method and tool that is considered most popular in many fields, including natural resource management (Mendoza and Sprouse, 1989, Murray and Gadow 1991, Kangas 1992, Rauscher et al., 2000, Reynolds, 2001, Vacik and Lexer, 2001 and Ananda and Herath, 2003). AHP is a mathematical theory of value, reason, and judgment, based on ratio scales for the analysis of multiple-criteria decision-making problems (Saaty, 2001).

STUDY AREA and PROCEDURES

This chapter deals with background, location and details of the study area as well as the methodology and processes for flash flood mapping in the study area. The second part deals with the data collection and pre-processing that is carried out before actual data modeling and the tools and processing are used.

Study area located in the Southeast region of Riyadh the capital city of Saudi Arabia. As per ArRiyadh Development Authority (ADA), total developed area in Riyadh city was 1297 sq. km (ADA, 2013) and the area allocated for urban development is expected to be close to 3115sq. km. by the year 2029 (Medstar Review, 2009). The city consists of 209 districts and comprises of 13 municipalities including the Riyadh governorate.

Riyadh is a multi-cultural city with 65% Saudi and 35% non-Saudi population and has been rapidly expanding. Climate of the city: hot dry summer and cool winter with humidity in the air. Rainfall has been typically ranging from 85mm to 116m (Al Saleh, 1997; Alyamani and Sen, 1992; Subyani, 2004), but in the recent past weather patterns have changed locally, regionally as well as globally resulting in heavy downpours lasting from hours to days more frequently year on year causing high volume run-off (ADA, 2013).

The selected study area isUm Qaseras shown in figure 1 and 2. It was selected due to its topography which is of interest due to varying elevations as well as wadiand low lying areas and surrounded by heavy built-up urban area that can be directly and greatly affected by any heavy flashing in the region.

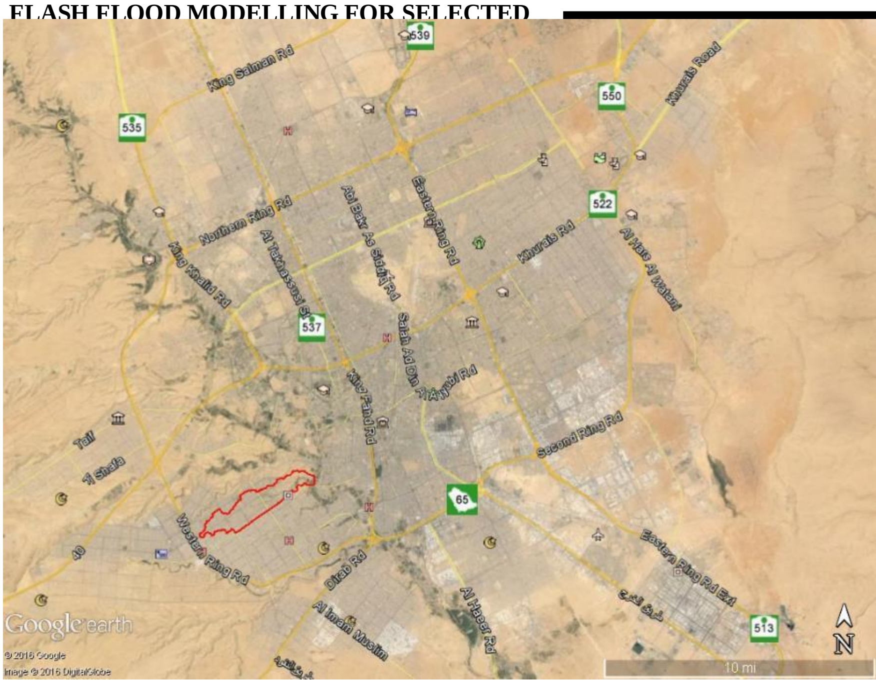

Figure 2.1: Riyadh City, Saudi Arabia Capital, Red Highlighted region is the Study Area. Source: Google Earth/Maps– http://maps.google.com

Figure 2.2: Zoomed in view of Um Qaser study area, vector shapefileoverlaid on top of Google Earth Image, Source: Google Earth/Maps – http://maps.google.com

STUDY FINDINGS

One of the outcomes of this study was the production of several maps that indicate some aspects of flash flood risk as well review and visualize hydro network and study area as normal GIS cartographic map as well 3D visualization. This chapter illustrates the various outputs developed during the previous processing as cartographic outputs with legend information for both LIDAR based as well as Satellite information based processing

Flood Risk Potential Maps (LIDAR)

The maps in this section are the results of LIDAR elevation data processing carried out as demonstrated in the previous section. The maps illustrate the modelled direction of water flow in the study area as shown in figures 4.1 as well identified catchments and longest path of water flow as well as areas that are at risk of greater water accumulation mainly derived from identified drainage points in the catchments of the study area.

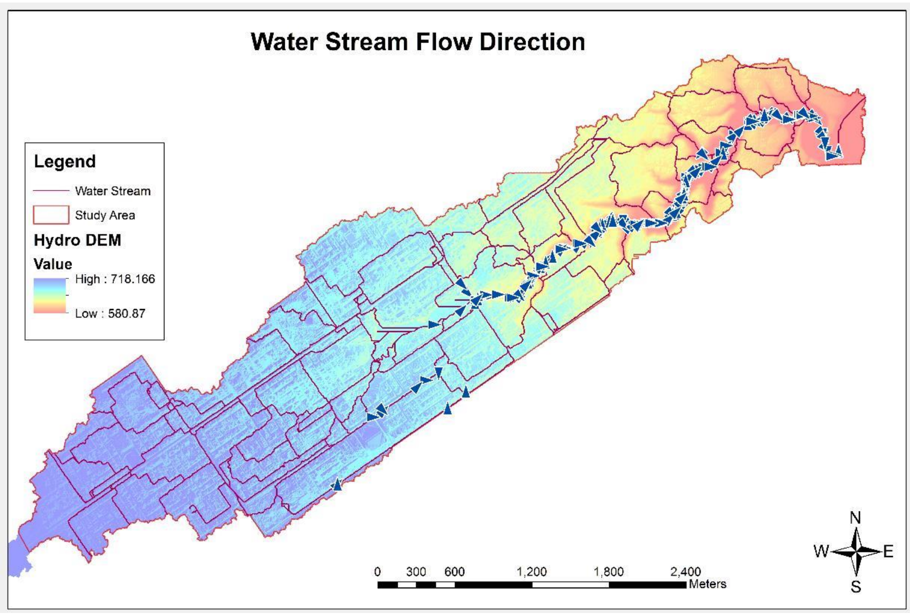

Figure 3.1: Water Stream Flow Direction Map

The map in figure 4.2 and 4.3 illustrates the flow of water streams generated via DEM processing as well modeled direction from high elevation 718mto low elevation areas till 580 m. Color classification highlights the difference in ground DEM evelation.

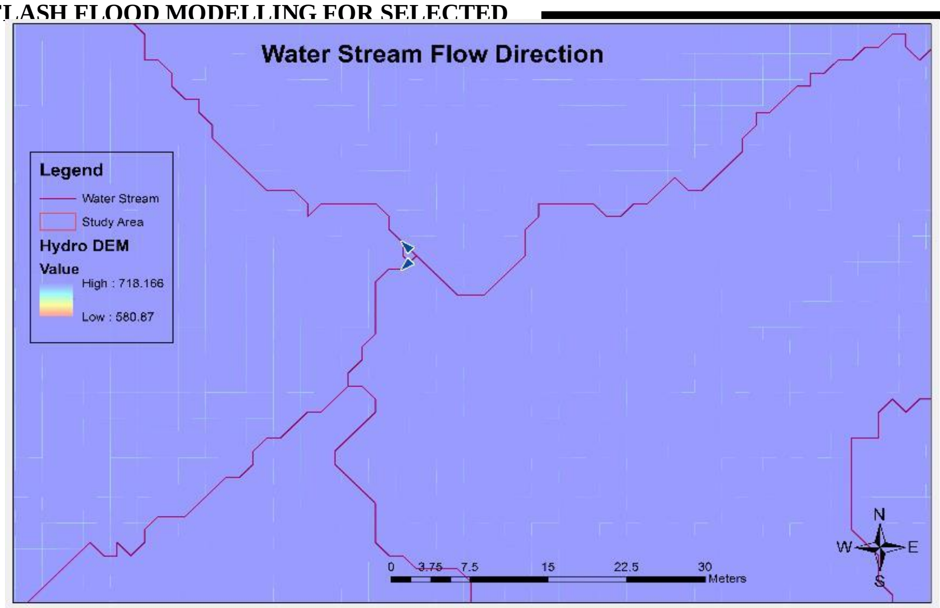

Figure 3.2: Water Stream Flow Direction Focused Map 1

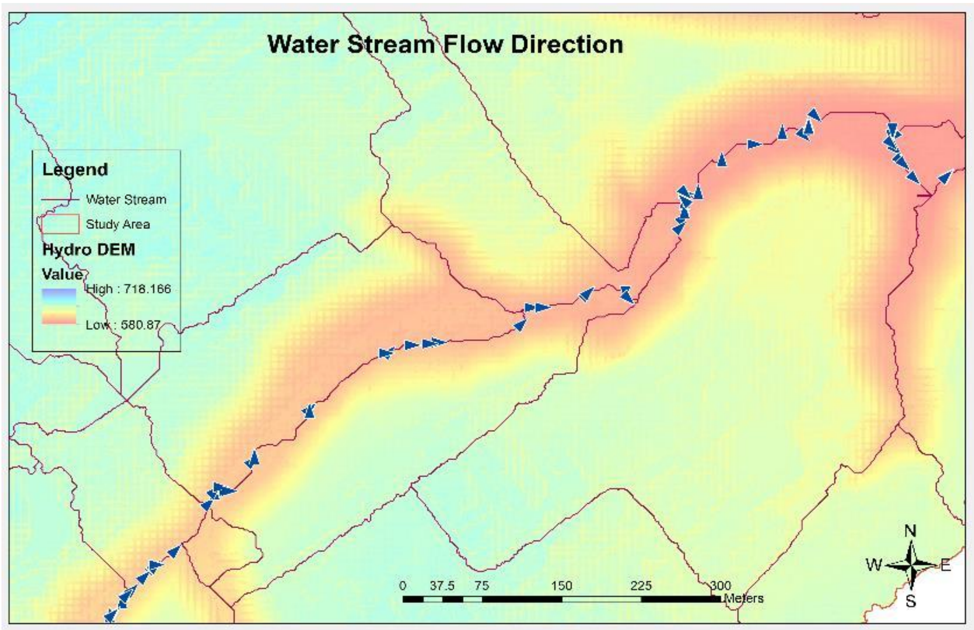

Figure 3.3: Water Stream Flow Direction Focused Map 2

Catchment areas identified via ArcHydro tool was 59 areas classified as critical to further watershed, drainage and hydro network processing as shown in figure 4.4.

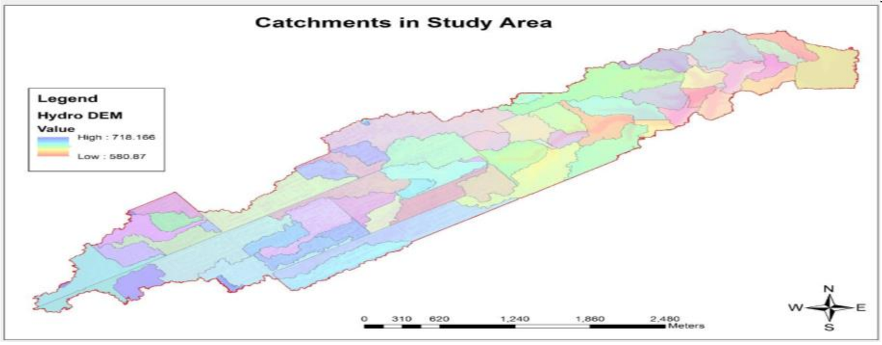

Figure 3.4: LIDAR Catchment Areas Map

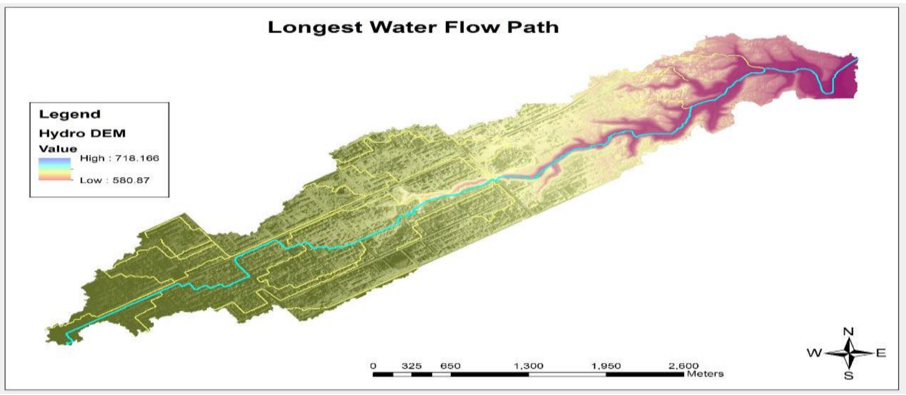

Figure 3.5: LIDAR: Longest Water Flow Path Map

The above figure illustrates the longest flow path of water across the study area generated from catchment area and water flow direction processing, identifies the long single water stream flow from the highest to the lowest elevation in the area with a length of above 10 KM.

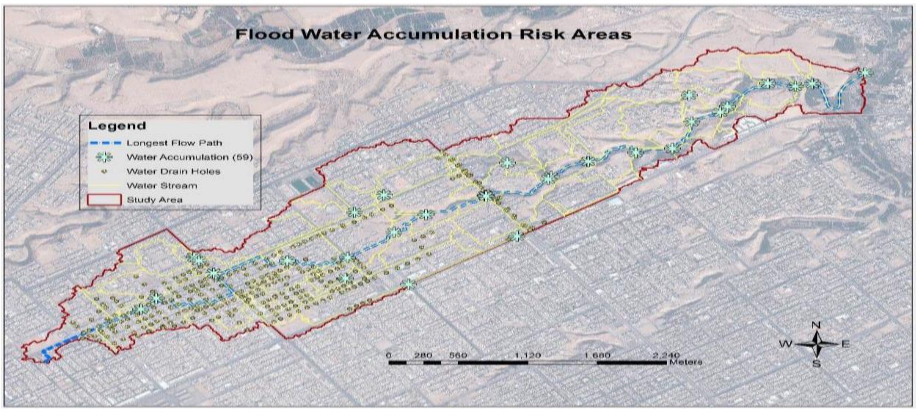

Figure 3.6: LIDAR Water Accumulation/Risk Areas Map

Main water accumulation risk areas map, identifying the potential areas to focus for water accumulation due to flash floods, derived from drainage areas calculation during catchment area, water flow direction, water streams and elevation information crossing of different catchments. Total selected points was 59 out of 236 points in the generated Hydro Junctions focused on the potential sink area points. The map data in figure 4.6 illustrates the points overlaid on top of water manholes information along with longest water flow as well satellite Image of the study area.

Flood Risk Potential Maps (ASTER 30m DEM)

The maps in this section are the results of ASTER DEM elevation data processing carried out as demonstrated in the previous section. The maps illustrate the modeled direction of water flow in the study area as well identified catchments and longest path of water flow as well as areas that are at risk of greater water accumulation mainly derived from identified drainage points in the catchments of the study area all similar to LIDAR based data processing, using the same tools and processing techniques in ERDAS, ArcGIS and ArcHydro etc. resulting in map and attributes output used in accessing the quality and quantity of resulting information.

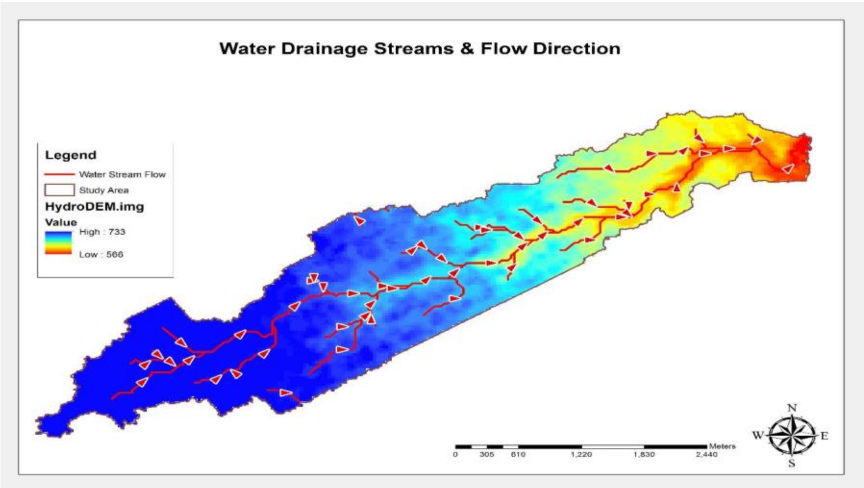

Figure 3.7: Satellite: Water Drainage Streams and Flow Direction Map

The above figure illustrates the Generated water streams in the drainage area and directions of water flow.

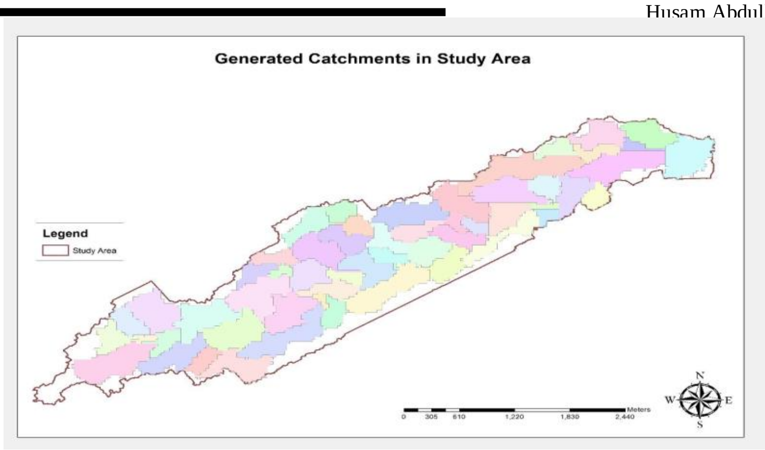

Figure 3.8: Satellite Catchment Areas Map

The above figure identified the catchment areas using ASTER 30m DEM in 56 quantity. Generated via ArcHydro catchment area processing tool.

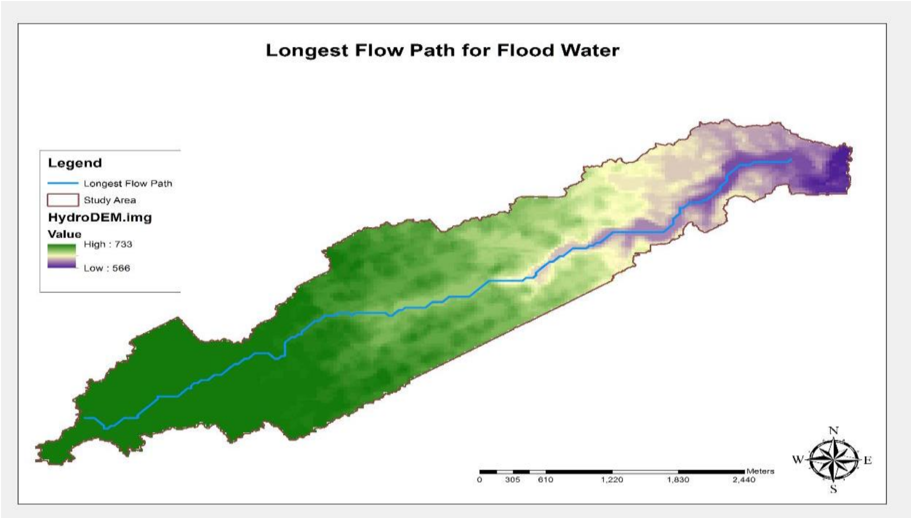

Figure 3.9:Satellite Longest Flow Path Map

Above figure illustrates the longest flow path calculated similar to LIDAR processing. Flow path length of around 7.7km that is 3km less than the length derived from LIDAR DEM.

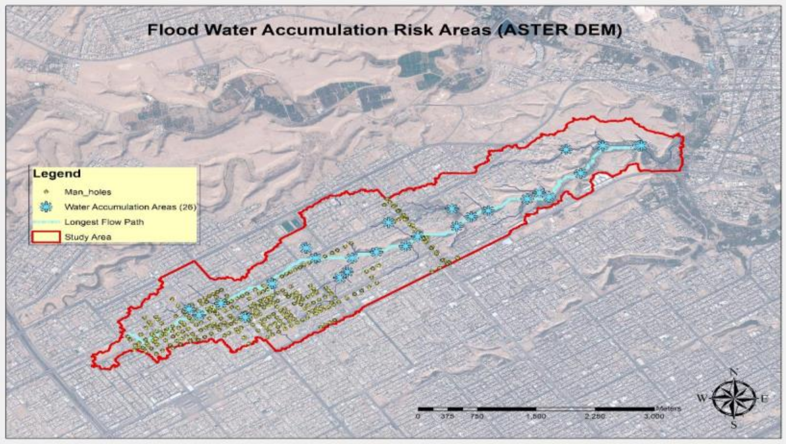

Figure 3.10: Satellite: Water Accumulation Risk Areas Map

Above figure illustrates the water accumulation risk areas identified as 26 potential areas where water may collect due to lower depressed elevation in the points identified in the Hydro Junction processing.

Simulation Flood Risk view of affected area.

The 3D view built via simulating water level in the study area along with DEM elevation of LIDAR DEM dataset and overlaying along with satellite imagery as well as water streams and accumulation risk points and municipal drainage water manholes, the other 2 views of the same area with zoomed inset views in greater imagery detail of the simulated affects if the water level rises in the area.

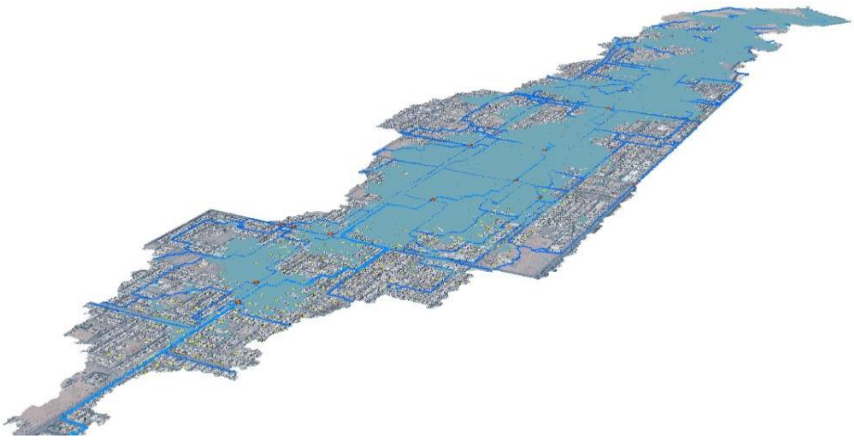

Figure 3.11: 3D Flood Risk Map

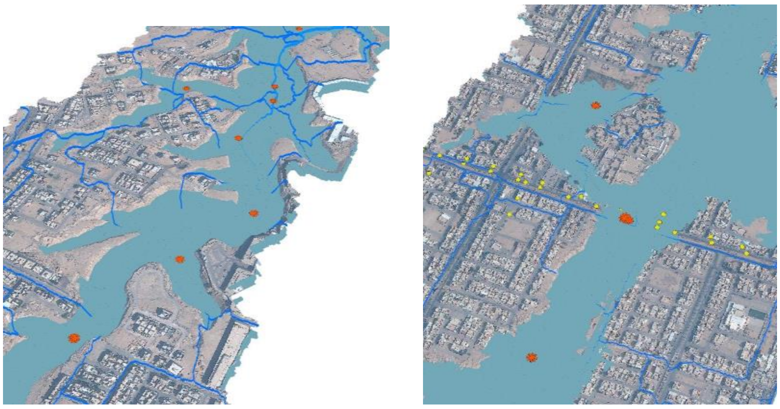

Figure 3.12: 3D Flood Risk Areas Zoomed Map

Summary

Hydrological data processing was carried on both Digital Terrain Models from two different sources, one from an aerial survey project that generated LIDAR data using the relevant laser scanning sensors and the other dataset was acquired from NASAS's ASTER sensor downloaded from USGS website. The ASTER GDEM v2 (Global Digital Elevation Dataset) was downloaded from https://earthexplorer.usgs.gov/ website as GeoTiff using the location information of the study area. The DEM having resolution of 30m was subset to the extents of study area using ERDAS Imagine software.

LIDAR data was available as LAS format of around 200 files in quality separately for both Ground and Non-Ground for the study area. The Ground Datasets were used, analyzed, issues with data resolved, missing, corrupt areas replaced with other free available lower resolution elevation data. The LIDAR datasets where processed and converted to Digital Elevation data using ERDAS IMAGINE software and subset of the study area was extracted from. After Terrain data processing a high resolution of 1.3 meters was achieved from these datasets.

Further Hydrological processing was carried using ArcHydro tools in ArcGIS Desktop 10.3 environment as illustrated in Data Processing section. The aim of the processing and data modelling was to generate drainage data, network of water streams that flow across the study area, generate catchment and watersheds and finally identify locations at risk of water accumulation during any rainfall induced flash flooding and overlay the data with other infrastructure GIS data to help determine potential affected areas and their surroundings. The main aim of the analysis and study is to determine the effectiveness of

LIDAR based elevation data in comparison to satellite derived DEM by visualizing and comparing the Hydro Network and accumulated risk areas from the two processing.

Comparison between LIDAR Terrain and ASTER Terrain

The sink filled two Hydro DEM resulted in water drainage lines after flow direction and flow accumulation processing, out as below:

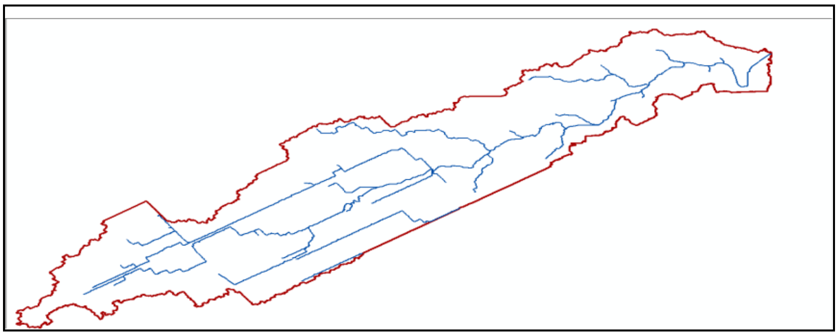

Figure 4.1 LIDAR Terrain Drainage Lines, Polylines -Count: 59

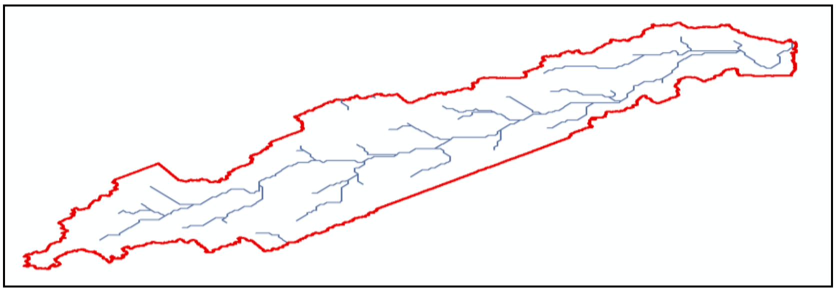

Figure 4.2 ASTER Terrain Drainage Lines, Polylines -Count: 56

The LIDAR derived Terrain's drainage lines look much more refined compared to ASTER based particularly in the lower elevation urban areas at the start of the study are in left portion. Comparatively in ASTER output the drainage lines jagged in flow and longer segments of connectivity, possibly due to wider pixel gaps that is lower resolution than LIDAR. Drainage Area for the both datasets per drainage line was also calculated. The overall drainage Polylines are more or less equal in quantity but LIDAR based appear more cleanly and following the terrain accurately. The generated drainage lines were based on the equal number catchment polygons produced in earlier steps.

The processing involved heavy Drainage Area characterization for both the elevation datasets in order to produce Hydrojunction points and HydroEdges of water flow streams. The ArcHydro tools used to process this where in the Terrain Morphology section of the software. The purpose of this processing was to extract Hydro Points for water inlets, outlet and sink/storage/accumulation areas for the study area. The main aim was to then extract water accumulation points and compare the results of the two types of DEMs and do further watershed delineations using the selected points.

The Water Accumulation points identified after the processing for the two datasets as below:

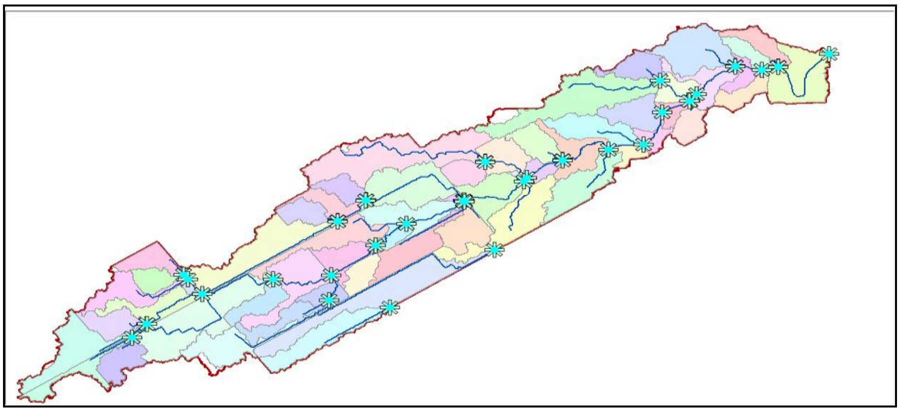

Figure 4.3 LIDAR Terrain – Water Accumulation Points – Count: 59

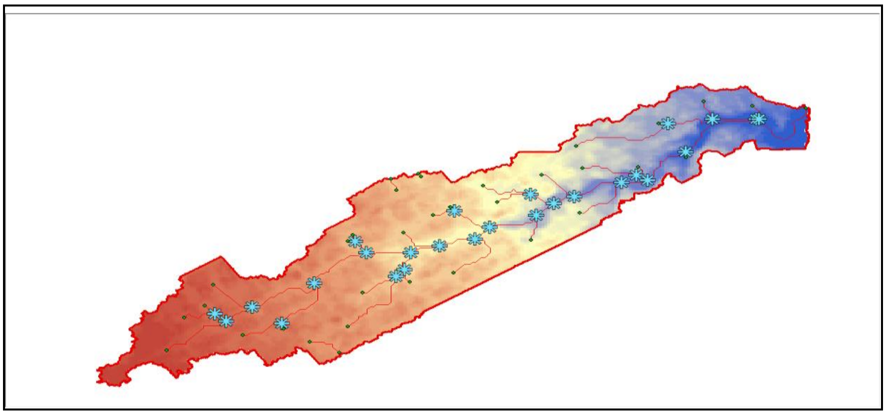

Figure 6.4 ASTER Terrain – Water Accumulation Points – Count: 26

The Water Accumulation points identified after the processing for the two datasets have a significantly marked difference seem the identification of Water risk accumulation points and this can only be attributed the high density Point cloud data of the LIDAR dataset's Terrain data model, an increase of almost 50% in accumulation points identifications.

Further comparing the proximity of the water retention areas to infrastructure water drainage manholes can be seen many missing areas prone to water risk do not have a nearby drainage manhole for storm water hence highlighting the need for such.

This analysis focused on the generating water accumulation areas and direction of water flow using both the resolutions of DEMs to help ascertain the capabilities of LIDAR dataset. It can be seen that LIDAR datasets producing high resolutions Terrain Models are ideal for dense focused urban areas for flood monitoring and analysis studies where lower resolutions DEM of 30m or high scale and wider coverage areas and/or semi/urban rural cities/towns.

Limitations and Future Research

As with any study, there certain limitations and future research methodologies that need to be carried forward for further research. This study focused on using and processing available Terrain data for water flood risk identification based on LIDAR and satellite platforms. Further processing, analysis and research needs to be carried out by acquiring geological datasets as well historical and current rainfall information of the study as well.

Geological Maps provided by Saudi Geological Survey was in Scanned format not GIS ready vector formats with attribution data to be on any use to this study. Also non availability of water flow height information from gages for previous years flooding as is the case with any river, lakes based analysis. Hence Analytical Hierarchical Processing had to be dropped from the plan to produce detailed area flood inundations maps.

The key limitation for nonuse of dedicated Flood Modelling software's such HEC-GeoRAS etc. ArcHyrdois primarily focused in generating watershed delineations for the study area and generating Hydro network information from DEM as well focused towards hilly and uneven terrain data unlike urban areas where there are more flatter less dramatic changes in terrain elevation. For this purpose, dedicated Urban focused commercial software such as MIKE, Tuflows or Flow-2D software should be trained upon.

With regard to LIDAR elevation data, one key aspect of data processing that needs to be integrated in future analysis in the integration of urban building into the DEM. The aim would be to integrate buildings into the DTM that can act as obstacles to the flow of flash flood rain water hence creating an accurate water flow path and identifying affected infrastructure. The needed data for this integration can acquired from LIDAR itself as it should contain non-ground information such as buildings, trees other overland objects as well as importantly from cadastral information of building blocks that can be acquired from relevant municipality. This type of heavy processing would require further research and study on the process and training and extensive processing to perform DTM corrections after burning in the building and other information such as bridges, underpasses etc. but would yield an accurate representation of water flow.

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