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GIS-Based Identification and Mitigation of Waterlogging-Prone Areas Using Terrain, Watershed and Infiltration Analysis

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Abstract: Waterlogging is a common surface-water management problem in areas where topography, drainage patterns, and soil infiltration characteristics interact. This study investigates the spatial characteristics of a selected study area using an integrated Geographic Information System (GIS) and terrain-modelling approach. Elevation data were analyzed using QGrid, Surfer 13, and QGIS to generate two-dimensional contour maps, three-dimensional terrain representations, and surface-elevation maps. Contour and terrain analysis were further used to identify high-elevation zones, depressions, and potential areas of surface-water accumulation. Watershed delineation was carried out to understand the contributing catchment and the natural movement of surface runoff within the study area. To complement the spatial analysis, field infiltration tests were conducted at six locations selected according to different contour elevations. The measured infiltration rates varied considerably, ranging from 0.5 to 6.0 in/hr, indicating substantial spatial variation in the soil's infiltration capacity. The results demonstrate that elevation alone does not adequately explain the potential occurrence of waterlogging; rather, the interaction between terrain characteristics, drainage/catchment patterns, surface depressions, and soil infiltration properties needs to be considered. The integrated analysis provides a spatial basis for identifying potential waterlogging-prone zones and selecting appropriate locations for future stormwater drainage, infiltration, and water-management interventions. The study demonstrates the usefulness of combining GIS-based terrain analysis with field-based soil infiltration assessment for site-specific waterlogging assessment and preliminary civil engineering planning.

Keywords: Geographic Information System (GIS); Terrain Analysis; Watershed Delineation; Contour Mapping; Waterlogging Assessment; Soil Infiltration; Digital Terrain Modelling; Surface Runoff; Water Management.

INTRODUCTION: The terrain of a site is an important first step in addressing surface-water and drainage-related problems. Small variations in ground elevation can influence the direction of runoff, the formation of local depressions, and the accumulation of water during rainfall. In university campus and its surrounding developed areas, where buildings, roads, open spaces, and other infrastructure modify the natural surface, understanding these spatial variations becomes particularly important. Geographic Information System (GIS) provides a practical way to study such terrain characteristics by combining elevation data, spatial analysis, and field observations within a common framework. This study therefore presents a GIS-based methodology for terrain analysis and preliminary assessment of surface-water behaviour in a university campus and its nearby surrounding area. The study primarily uses elevation data derived from the Shuttle Radar Topography Mission (SRTM) as the basis for terrain representation and contour generation. The elevation information was processed and examined using QGrid, Surfer 13, and QGIS, with each platform contributing to different stages of the analysis. Two-dimensional contour maps and three-dimensional terrain representations were generated to visualize the variation in ground levels across the study area. Further analysis using Surfer 13 was carried out to represent the terrain surface and identify prominent peaks and depressions, while watershed delineation was performed to understand the contributing catchment and natural surface-water pathways. QGIS was subsequently used for GIS-based spatial representation and contour analysis, allowing the terrain information to be examined in relation to the campus and surrounding area.

The GIS investigation was supported by field-based observations and infiltration testing at selected locations representing different contour elevations. Six infiltration-test points were surveyed to examine variations in the soil's ability to absorb water at different locations within the study area. The resulting information was considered together with the contour pattern, terrain characteristics, watershed boundaries, and identified depressions to develop a more complete understanding of the factors associated with potential water accumulation. By bringing together remotely derived elevation data, terrain modelling, GIS analysis, and field investigation, the study establishes a practical methodology for identifying critical locations and provides a foundation for subsequent civil engineering measures related to drainage, infiltration, and sustainable surface-water management.

LITERATURE REVIEW:

I. This study used GIS as an effective tool for analysing terrain, elevation, slope, drainage patterns, and spatial variations related to surface-water movement.

II. SRTM-based Digital Elevation Models (DEMs) have been widely used for generating contours, terrain models, watershed boundaries, and drainage characteristics where detailed elevation data are required.

III. DEM-based contour and terrain analysis helps in identifying high-elevation areas, low-lying zones, natural slopes, and local depressions that influence surface runoff and water accumulation.

IV. GIS-based watershed delineation has been successfully applied to determine contributing catchments and understand the natural direction and concentration of surface runoff.

V. Three-dimensional terrain modelling provides improved visualization of elevation variations and helps in interpreting peaks, depressions, and potential water-accumulation zones within a study area.

VI. Previous waterlogging studies indicate that water accumulation is generally influenced by the combined effects of topography, runoff concentration, drainage conditions, surface depressions, and soil characteristics rather than elevation alone.

VII. Field infiltration testing is an important complementary approach to GIS-based terrain analysis because variations in soil infiltration capacity influence the amount of rainfall or runoff that can enter the ground.

VIII. Integrating spatial terrain information with field-based infiltration measurements provides a more reliable assessment of potential waterlogging-prone areas than using topographic information alone.

IX. The combined analysis of contours, watershed characteristics, peaks and depressions, and infiltration behaviour can assist in locating critical zones and selecting appropriate drainage, infiltration, and water-management interventions.

STUDY AREA DESCRIPTION:



FIG 1: LOCATION POINTS ON GOOGLE EARTH

a) Geographic Location of corner points

1. FRONT UNI CORNER –

Latitude:~ 32° 3'41.92"N , Longitude: ~ 75°26'14.71"E

2. AGRICULTURE WING –

Latitude:~ 32° 4'0.11"N, Longitude: ~ 75°26'34.84"E

3. **CAMPUS ENDING –**

Latitude:~ 32° 3'39.19"N, Longitude: ~ 75°26'57.51"E

4. **ROAD CROSSING–**

Latitude:~ 32° 3'27.52"N Longitude: ~ 75°26'33.35"E

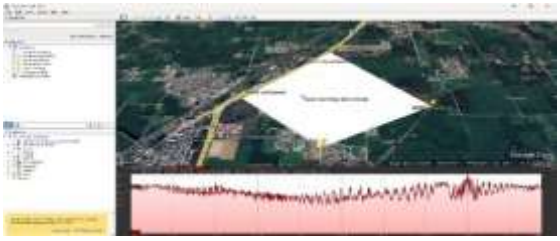
b) Area description

SARDAR BEANT SINGH STATE UNIVERSITY GURDASPUR, PUNJAB and its nearby area is the location of study. Four corner points are marked according to its location on GOOGLE EARTH PRO. Using GIS based software, the contour 2D & 3D maps, peaks & depressions map and watershed maps are made, so we used three GIS SOFTWARES for making contour maps of the same location for cross checking and accuracy . GIS and Digital Elevation Models provide effective tools for terrain, contour, watershed, and surface-water analysis, particularly where ground-based measurements are difficult due to buildings, vegetation, roads, and other obstacles. In the present study, Quickgrid ,Surfer 13, and QGIS are integrated with SRTM-derived elevation data to analyse contours, terrain, peaks, depressions, and watershed characteristics. Field infiltration tests are also incorporated to assess variations in soil water-absorption capacity, while the predominantly clayey and relatively low-permeability soil may contribute to water accumulation. The integrated analysis helps identify potential waterlogging-prone areas and provides a scientific basis for developing practical engineering solutions for the identified waterlogging problem.

METHODOLOGY:

The survey methodology adopted in this study was based on GIS-based software and virtual data collection using software. This study area was first identified, and coordinate points were selected. Geographic coordinates (latitude, longitude) along with the corresponding elevation values were extracted for each observation points using Terrain Elevation Tool available in Google Earth Pro. The collected data is processed into the software (TCX converter and GPS visualizer) and then after creating a CSV file, the points were organized in Microsoft Excel to create a structured spatial database suitable for further processing. The dataset was then imported into QGrid software, similarly where interpolation techniques were applied to generate continuous terrain surface model. Based on interpolated surface contour lines representing equal elevation intervals were produced for terrain analysis. This methodology enabled efficient identification of elevation variations, slope characteristics, and low-lying zones potentially susceptible to water stagnation, while minimizing the need for conventional field surveying methods. Similarly, we created contour maps using QGIS and Surfer 13 for cross-checking and more accuracy.

a) Selection of site from GOOGLE EARTH



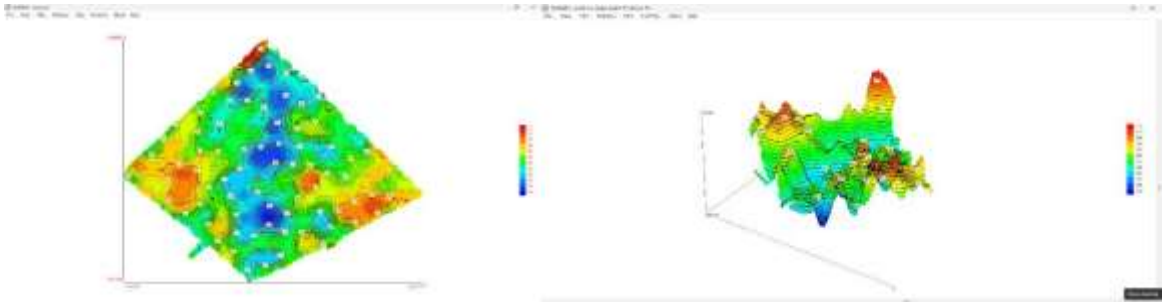
b) Using TCX converter and GPS visualize



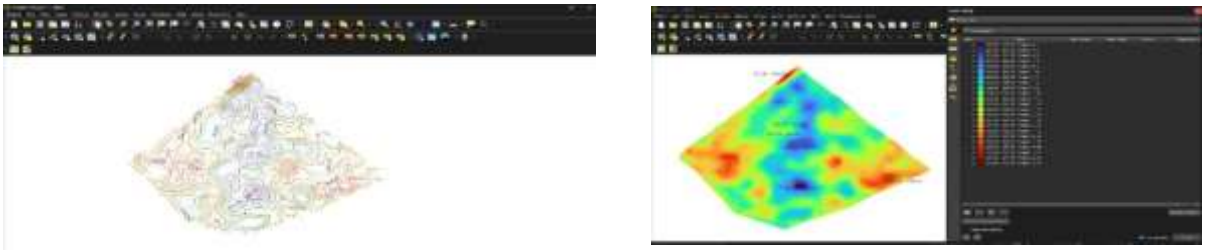
c) Extraction of data points from Microsoft EXCEL

latitude	longitude	elevation
32.06086306	75.44822312	267
32.06083004	75.44818324	267
32.06081997	75.44819289	267.056
32.0608009	75.44811873	267.173
32.06081177	75.44812726	267.142
32.0608488	75.44815995	267.023
32.06088031	75.44818152	267
32.0609045	75.44823083	267
32.0609312	75.44825486	267
32.06097015	75.4482385	267
32.06096275	75.44820767	267
32.06094817	75.44818434	267
32.06091025	75.44813713	267.073
32.06089022	75.44812896	267.108
32.06087101	75.4480872	267.216
32.06083726	75.44808065	267.305
32.06081825	75.44804836	267.426
32.06079195	75.44802868	267.515
32.06077298	75.44800139	267.631
32.06075393	75.44899911	267.747
32.06073073	75.44896766	267.716
32.06070701	75.44895234	267.620
32.06065279	75.44903313	267.481
32.06062398	75.44806357	267.326

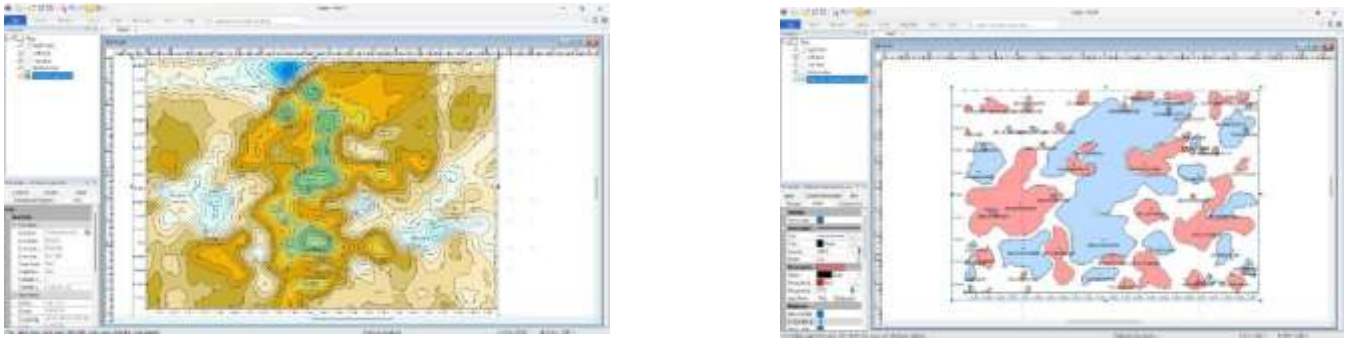
d) Creating 2D & 3D CONTOUR MAP of the location on QUICKGRID

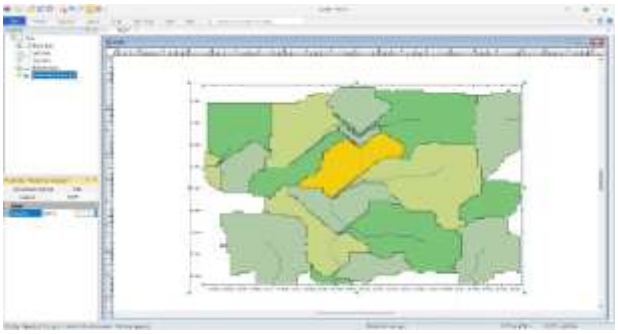


e) Creating CONTOUR MAP of the location on QGIS



f) Creating CONTOUR MAP, PEAKS & DEPRESSIONS MAP and WATERSHED MAP of the location on SURFER 13





g) SITE SURVEY & TESTING: INFILTRATION TEST



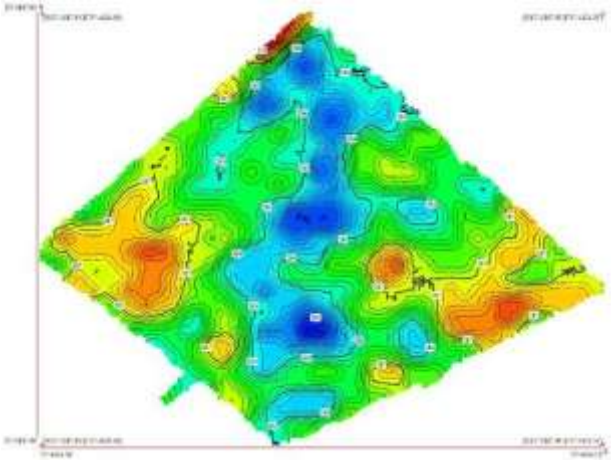
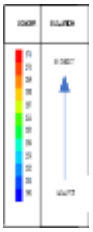


Point	Elevation (m)	Infiltration rate (in/hr)	LATITUDE	LONGITUDE	Interpretation
P1	270	6.0	32.06650°N	75.44328°E	Very high infiltration
P2	269	3.5	32.06094°N	75.44064°E	High infiltration
P3	267	2.0	32.06366°N	75.44072°E	Moderate infiltration
P4	265	0.5	32.06115°N	75.44435°E	Very low infiltration
P5	264	5.0	32.06612°N	75.44498°E	High infiltration
P6	261	1.0	32.05868°N	75.44345°E	Low infiltration

This is concludes that elevation itself do not causes the infiltration rate. Data actually shows that the relationship isn't monotonic—for example, 264 m has 5 in/hr while 265 m has only 0.5 in/hr. It demonstrates that soil infiltration characteristics need to be considered along with topography, rather than assuming that low elevation alone explains waterlogging

CONCLUSION:

a) Contour map of the location

The study successfully integrated rainfall data, soil infiltration testing, terrain analysis, and GIS-based spatial processing to assess waterlogging conditions within the university campus. Field infiltration tests were conducted at selected locations to evaluate the soil's water infiltration behaviour and its influence on surface runoff and water accumulation.

GIS-based elevation, contour, slope, and terrain maps were prepared to identify variations in ground levels, natural flow paths, and potential runoff-accumulation zones. The integration of these maps with rainfall and soil infiltration characteristics enabled the identification of areas more susceptible to waterlogging. The study demonstrates that combining field-based soil investigation with GIS-based spatial analysis provides a practical approach for understanding campus drainage conditions and supporting the planning of suitable stormwater management and drainage interventions.

Zone	Infiltration condition	Problems identified	Recommended engineering solution
Zone 1 – 270 m	6 in/hr	Water can infiltrate rapidly; accumulation is less likely if runoff if reaches this area naturally.	Recharge/infiltration zone – rain garden, recharge pit, infiltration trench or recharge well
Zone 2 – 269 m	3.5 in/hr	Good infiltration, but surface runoff may still accumula if it receives flow from higher areas	Permeable drainage/recharge system – infiltration trench with shallow swale or permeable pavement
Zone 3 – 267 m	2 in/hr	Moderate infiltration; prolonged ponding may occur during intense rainfall	Combination system – shallow surface drain/swale leading toward an infiltration trench or recharge structure
Zone 4 – 265 m	0.5 in/hr	Critical low-infiltration zone; high possibility of prolonged water stagnation	lined/open drain or underground stormwater pipe connected to a suitable outlet; raised/graded surface may also be considered
Zone 5 – 264 m	5 in/hr	High infiltration makes the location suitable for receiving runoff provided it is not already a natural depression with excessive inflow	Detention/recharge zone – recharge pit, infiltration basin, rain garden or detention–infiltration system
Zone 6 – 261 m	1 in/hr	Low infiltration and potentially lower terrain can result in accumulation from upstream runoff	Drainage + controlled discharge – graded drain/channel directing water toward an appropriate outlet, with detention or recharge structure

RESULTS:

I. The terrain analysis using QGrid, QGIS, and Surfer 13 showed clear spatial variation in ground elevation across the study area.

II. Contour and terrain maps identified distinct higher and lower elevation zones, along with local peaks and depressions.

III. Watershed analysis identified natural runoff pathways and areas receiving surface flow from surrounding higher elevations.

IV. The combination of low-lying areas, depressions, and converging runoff pathways indicated locations with greater potential for water accumulation and waterlogging.

V. Infiltration testing at six selected locations showed considerable spatial variation, with infiltration rates ranging from 0.5 to 6.0 in/hr.

VI. The highest infiltration rates were recorded at 270 m (6 in/hr) and 264 m (5 in/hr), indicating comparatively better infiltration conditions.

VII. The lowest infiltration rates were recorded at 265 m (0.5 in/hr) and 261 m (1 in/hr), making these locations important for further drainage assessment, particularly where they coincide with runoff-converging or depressed areas.

VIII. The integrated results of elevation, contours, watershed characteristics, depressions, and infiltration capacity were used to classify critical locations and provide a basis for developing site-specific engineering solutions for drainage and waterlogging management.

7.REFERENCES

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