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USE OF GIS FOR THE DESIGN AND PLANNING OF INFRASTRUCTURE

Abdul Razzaq Ghumman
Dean, Faculty of Civil and Environmental Engineering,
University of Engineering and Technology, Taxila, Pakistan.
email: abdulrazzaq@uettaxila.edu.pk, Ph: 0092-51-9047601
Ishtiaq Hassan
Research Scholar, Civil Engineering Department,
University of Engineering and Technology, Taxila, Pakistan.

Abstract

The use of Geographical Information System (GIS), as a decision support tool is increasing in all fields of Civil Engineering in Pakistan. This study demonstrates the usefulness of GIS as a spatio-temporal analysis technique for the design and planning of infrastructure.

For the development of any area, planning and design of Infrastructure components like roads, potable water supply system, disposal of sanitary sewage and storm drainage has gained much importance. Planning and design of these components requires topographic surveys, which consume much time before the start of planning especially. By the application of Geographical Information Systems, planning; and design may be carried out in a very short space of time by super-imposing that planning on survey sheets prepared by the Surveying authority and the same was done in this study.

Satellite image was used to study the various geographic realities of the area and master planning was done by making water supply zones, defining sewerage disposal paths and storm drainage galleries that naturally exist within the site. Hence, maps having various layers of roads, water supply, sewerage and drainage were prepared and superimposed on satellite imagery using GIS, to bring as much geographical information as possible for investigation of all the related problems. On the basis of these plans, by super-imposing survey or topographic sheets to correlate elevations with planning, required results were obtained.

Keywords: Design and planning, GIS, infrastructure, spatio-temporal analysis technique.

INTRODUCTION

In Pakistan the trend of town development is increasing day by day to meet the requirements of housing. Master planning, road networks, water supply network, sewerage and drainage systems form an important part of town development. Till today, planning of these infrastructure components is being done on survey and topographic sheets. All this process is time consuming especially in case of large and inaccessible hilly town developments. First of all survey is initiated which takes weeks and even months for its completion and is then finally submitted to the designer. So by using GIS, at least planning could be initiated within a short time by using satellite image(s) of high resolution and quality, obtained from various organizations.

In Pakistan, GIS based planning is still not under common use because of certain financial constraints and ignorance of GIS techniques on the part of planners and designers. However, sewerage system of one of the provincial capitals, Quetta, having various functional faults, was analyzed, re-planned and re-designed by using maps having various layers of houses, streets, and exiting system [NESPAK 2004]. Similarly, various irrigation (canals) projects in Punjab are also based on GIS planning [NESPAK 2005]. In other countries, GIS is being used extensively for Infrastructure planning & other Civil Engineering applications. In Saudi Arabia Infrastructure Planning of 97 cities of 12 regions was done using GIS [Cabuk *et al*. 2004]. Mesaieed Industrial City (MIC) management used GIS for planning of Sewer Infrastructure of MIC, Qatar [Varma 2005]. Canada and USA are also using GIS in infrastructure and public health [Maclachlan *et al*. 2004] engineering to study problems and define solutions. In USA, Geographic Information System (GIS) and empirical data were used for analyzing spatial water consumption patterns with the objective of prioritizing water conservation areas within the City of Seattle, Washington (USA). Municipalities have relied upon this analysis of large-scale consumption patterns to evaluate management options [Forster and Beattie 1979, Martin *et al*. 1994, Gracia *et al*. 2001]. In Canada, a GIS based 3D Hydrodynamic Pollutant Transport simulation model was prepared for the Development of fourth generation Water Resources using GIS applications [Tsanis and Boyle 2005-6]. In India, GIS Based Distributed Model for Soil Erosion and Rate of Sediment Outflow from Catchments [Jain *et al*. 2005-6] has been developed and applied to data from several catchments. There are so many other examples of GIS application all over the World which, however, these few examples describe wide range of GIS application and its growing importance in developed and developing countries.

Geographical Information Systems (GIS) have become a valuable tool [Maclachlan *et al*. 2004] in an expanding variety of environments including business applications, market analysis, urban planning, government health care and relevant university coursework [Cabuk *et al*. 2004].

Different definitions of GIS have been described by Ozemoy *et al*. [1981] and Burrough [1986], Parker [1988], Demers [2000], Clark [2001].

SITE DESCRIPTION AND SCOPE

For study purpose, a familiar and an accessible site of sector H-12 of Islamabad Capital was selected.

National University of Sciences and Technology (NUST) is developing its new campus in sector H-12 Islamabad. The campus shall accommodate nearly thirty six (36) institutes affiliated with it along with hostel and residential accommodations. Client's requirements for various building requirements were underlined in their PC1 already approved from the governing authorities. Fig. 1 shows location of sector H-12 on Islamabad plan.

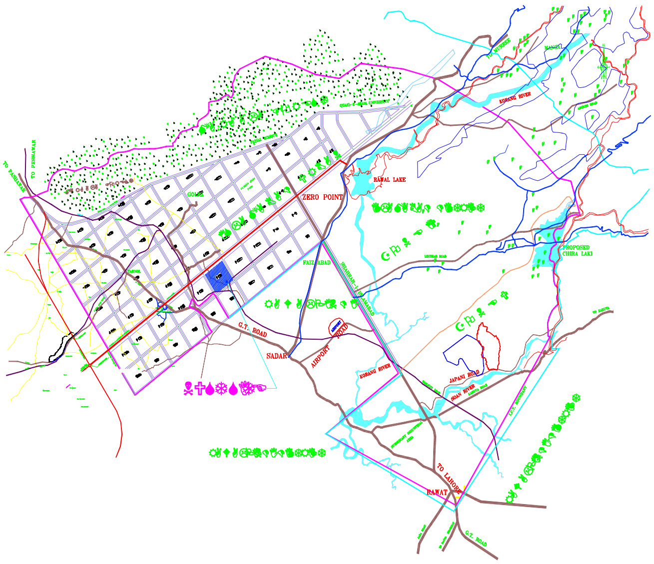

Fig. 1: Location Plan of Sector H-12 (NUST site).

The scope of services includes:

- To analyze owner's (client's) requirements to arrive at a suitable decision pertaining to layout, concepts, space requirements, inter-relationship and arrangements.
- Preparation of land use and zoning plan.
- Preparation of Master Plan showing location of various buildings and facilities with room for future expansion, road layouts, and proposals for site development infrastructure, utilities, services and landscaping etc.

MATERIALS AND METHODS

MASTER PLAN AND ROADS

Following considerations have been made which will be helpful for making arrangements while placing the buildings:

Main Access Road

There is an active solid waste dump point of CDA on Northern boundary of the campus that has heavy deposits of solid waste. In addition, this Northern belt is high rocky type obstructing direct view of entire NUST sector from the Kashmir Highway. So, it is not possible rather unadvisable to take direct access for the campus from the Kashmir Highway at its right angle. The most appropriate point for main access road is the North-West corner of sector H-12 where roundabout-1 is marked. Here a sector road has to be constructed by CDA. This will ultimately get linked with the Kashmir Highway. Fig. 2 describes planning of access road by highlighting these ground realities.

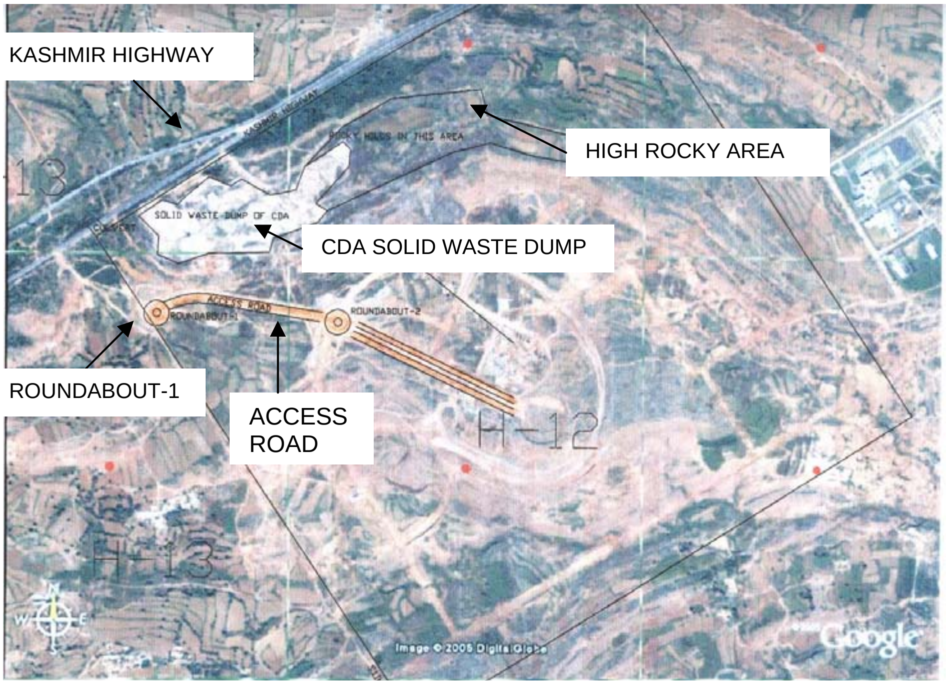

Fig. 2: Planning Access Road.

Location and Alignment of Road Network

The network of roads linking all other specified areas affectively have been planned in such a manner that almost balanced (equal) areas are fed by each road and their alignment, at the same time, involves less earthwork (cut & fill). Refer Fig. 3 for clear vision.

Location of NUST Headquarter

The NUST Headquarter is placed almost in the center of H-12 sector (acting as a nucleus) where the highest ridge exists. Refer Fig. 3 for clear vision.

Location of Institutes

Institutes are located around the NUST Headquarter so that academic area has close link with the administration of the campus as shown in Fig. 4.

Location of Hostels and Residences

Hostels were located in sub-sectors H-12/1 and H-12/4 where undisturbed entry points could be made available from the city centers. However, these areas shall be linked to the academic area through a suitable network of roads inside the campus as shown in Fig. 4.

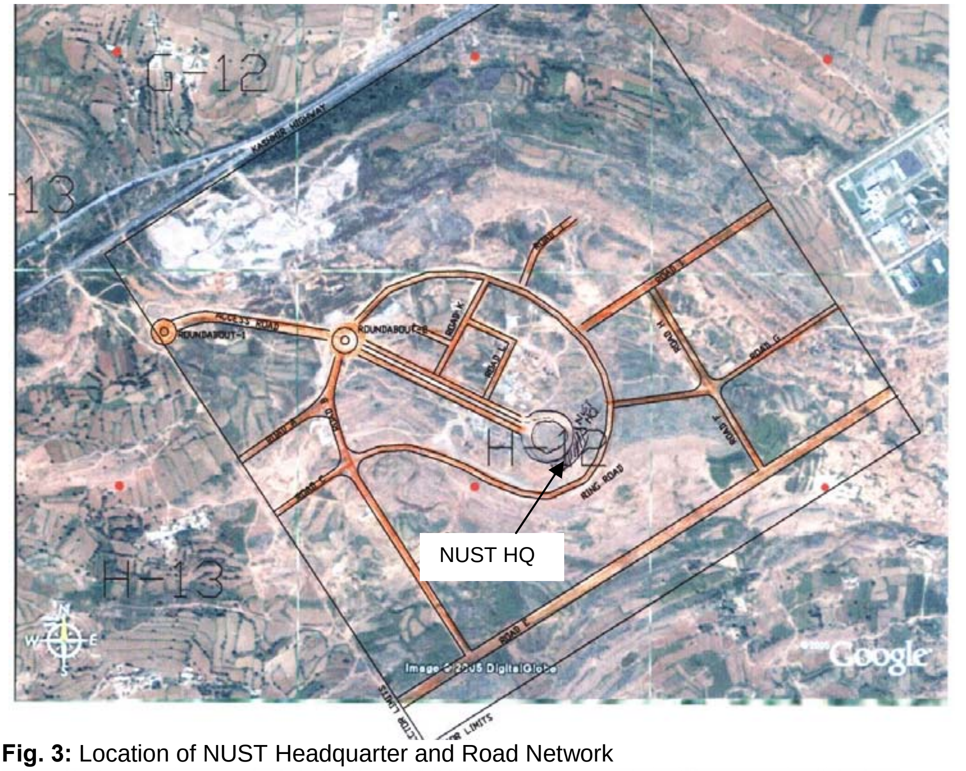

Fig. 3: Location of NUST Headquarter and Road Network

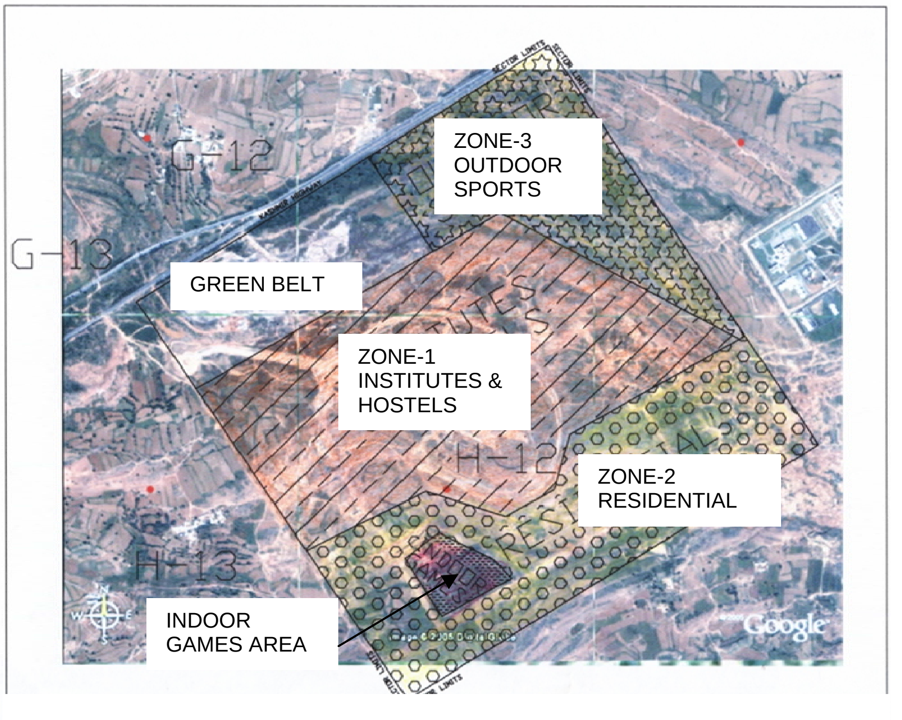

Fig. 4: Zoning for Master Plan.

Location of Recreational Points

Students residing in hostels do require covered recreational buildings to pass their leisure time in healthy activities. For that purpose, few such buildings are to be placed in areas close to the hostels. See Fig. 4 for reference.

Location of Playing Areas

Open play areas require a lot of space. Studies of satellite imagery revealed that North-Eastern corner of the sector is best suitable for this purpose because it is high enough and natural level difference of topography naturally isolates this area for a separate use. Refer Fig. 4 to see the site.

WATER SUPPLY SYSTEM

Study of site from imagery and survey (contour) plan shows that the said area could be divided into three zones as shown in Fig. 5:

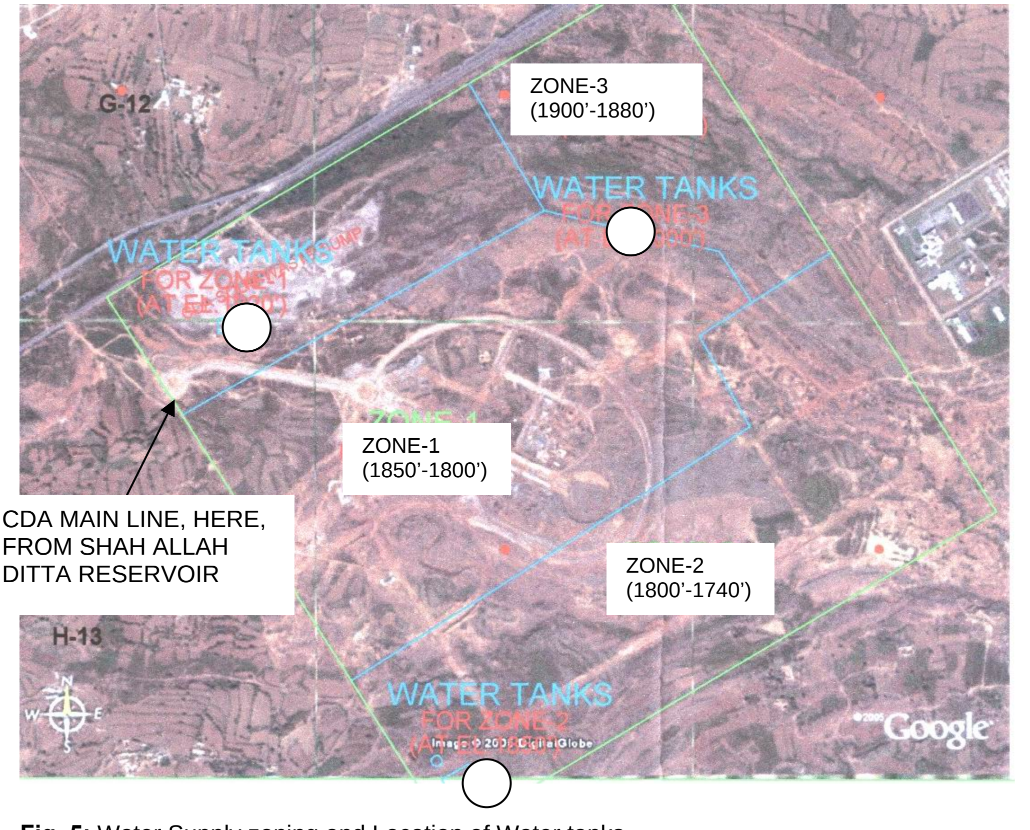

Fig. 5: Water Supply zoning and Location of Water tanks.

Zone 1

Where mostly academic buildings along with few hostel blocks are planned has an elevation range in between 1850 ft and 1800 ft. This zone will have almost 30% of the total water requirement; but covers about half of the sector.

Zone 2

Where mostly residential buildings are planned having an elevation range in between 1800ft and 1740ft. This zone will have almost 60% of the total water requirement.

Zone 3

This is a minor zone consisting of sports area at elevations ranging from 1900ft to 1880ft. It is located in Northeastern corner of sector. It accounts for only 10% of the total water requirement.

Master plan, road layout and zone formation calls for provision of grid iron system. Each zone shall have separate water storage and supply system as indicated in Fig. 5. All main loops shall run along roads in respective service corridors. Points for future extensions will help connections for future buildings. Source for water supply to the sector is CDA supply coming from Shah Allah Ditta Reservoir. CDA main line of 36" diameter passes along Western boundary of Sector H-12. There is high pressure available in this line to feed directly up to an elevation of almost 1980ft.

SEWERAGE SYSTEM

Study of site from imagery and survey (contour) plan shows that the said area could be divided into three zones as seen in Fig. 6. These zones have been constituted by studying natural topographic barriers of the area.

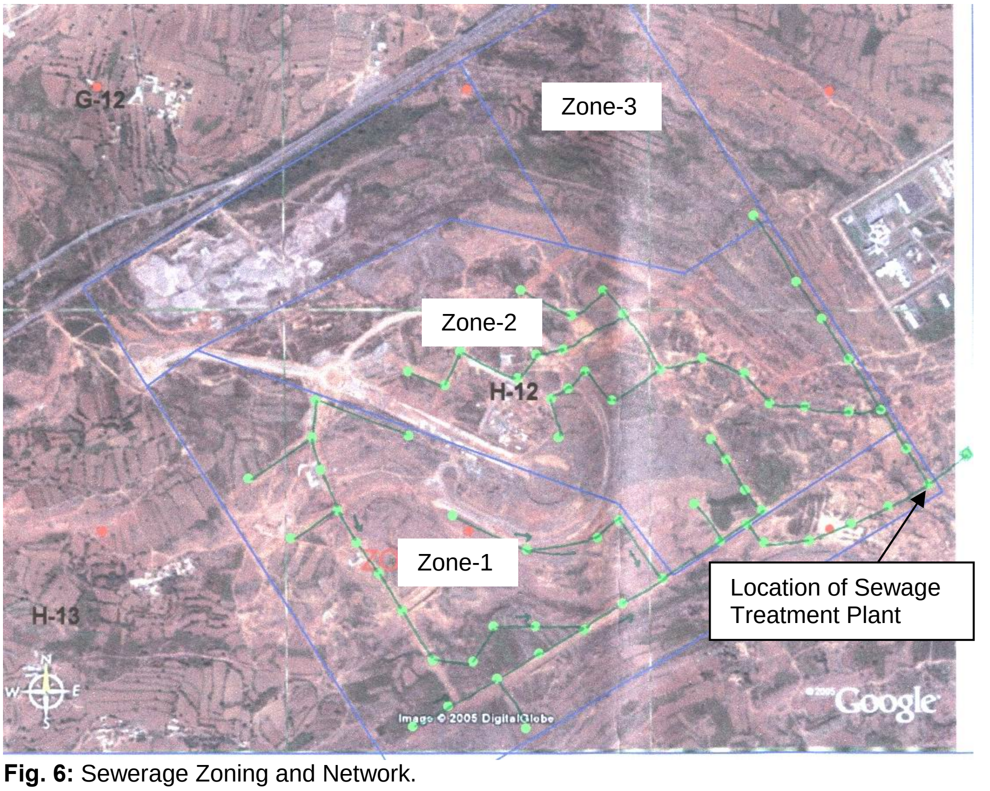

Fig. 6: Sewerage Zoning and Network.
(Dots in this Figure show manholes, Blue lines show zone limits).

Zone 1
It constitutes an area located along right side of main access road leading to NUST Headquater. This zone constitutes all buildings located in sub-sector H-12/1 and half triangular portion of sub-sector H-12/2.

Zone 2
This zone consists of few academic buildings and a major portion of residential area. It is marked on sewage zoning plan.

Zone 3
This is a minor zone consisting of sports area at elevations ranging from 1900ft to 1880ft. It is located in Northeastern corner of Sub-sector H-12/3.
Master plan, road layout and zone formation calls for provision of three separate gravity systems located along natural drainage corridors. One combined sewage treatment plant is proposed at the Southeastern lowermost (El.=1725ft) corner of the sector. Treated sewage will ultimately be used for irrigation purposes of the sector. However, overflow from this treatment plant will join nearby CDA system.

STORM DRAINAGE SYSTEM
- Study of project area of NUST campus from satellite imagery and available survey plan shows paths of natural drainage galleries.
- There are major directions of study as also marked in Fig. 7 below:

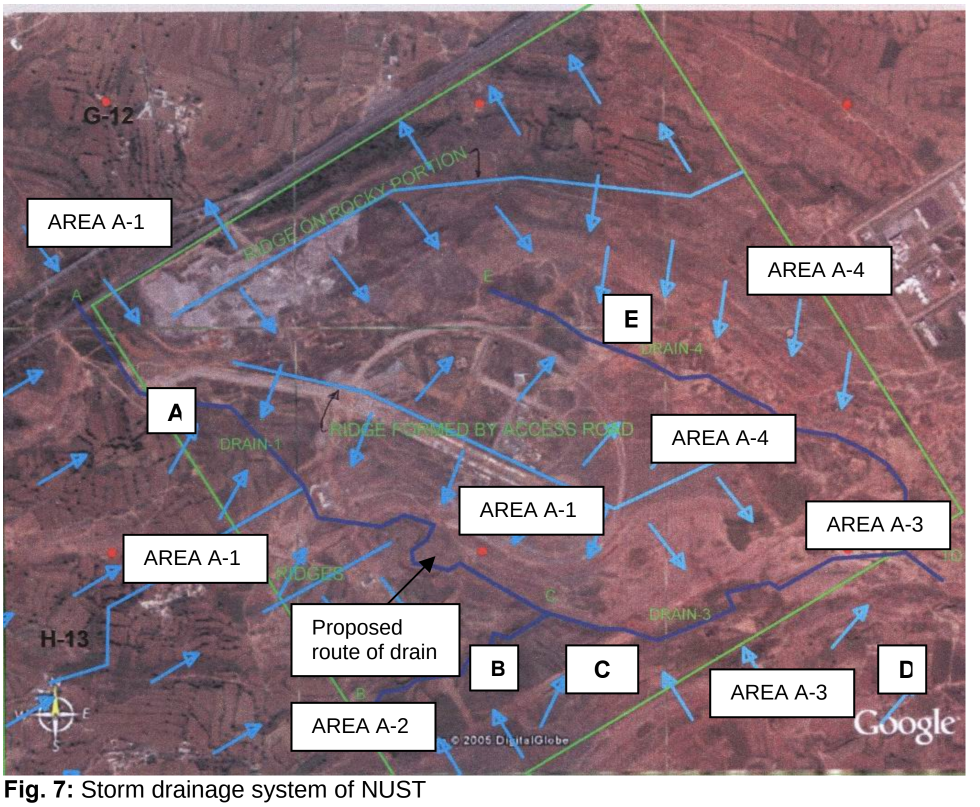

Fig. 7: Storm drainage system of NUST

(i). Point (A) to Point (C): This drainage length has a catchment's area marked as area A1 within the site. But broader study of catchment's area from satellite imagery reveals that 1/6th portion each of sectors G-13 also G-14 also make contribution of flow to point (A). Hence, culverts falling in this drainage gallery are to be designed for this much catchment's area.

(ii). Point (B) to Point (C): Area marked as area A2 contributes flow in this reach from within the site area. Again broader study of the area teaches consideration of catchment's areas from sector H-13 also.

(iii). Point (C) to Point (D): Catchment's area of this portion is highlighted as area A3. Anything (culvert or a drain section) falling within this reach will be designed for all catchment's areas contributing flows here.

(iv). Point (E) to Point (D): It has a catchment's area locally created, which is marked, as area A4.

- Along roads, drains are required at few locations as marked on relevant drawings. No complex type of drainage network is required to be developed at any location because entire area slopes adequately in these identified natural drainage galleries.

CONCLUSIONS

In this study, an effort has been made to plan Infrastructure components using GIS. The study reveals:

1. **How to read ground features while doing master planning?** Location of Access road, placement of nucleus NUST headquarter and thereafter zoning for institutes, residences, hostels, playing areas etc. have been made by deep study of ground realities revealed by satellite imagery and then verification from site visits and contour plans. Figs. 2, 3 and 4 explain the results.
2. **How to plan water supply schemes?** Zoning for water supply schemes and location of water structures have been done by what imagery dictated. Fig. 5 shows the results.
3. **How to do sewage disposal?** For sewerage, natural corridors have been utilized to avoid deep excavations. Fig. 6 indicates the planning of sewerage.
4. **How to plan storm drainage system?** It is always a good practice that natural drainage galleries should not be disturbed and the same shall be used for this purpose. In H-12 sector, imagery clearly identified path of storm channel. Fig. 7 illustrates how to mark natural or man-made ridges and to follow the natural basins and storm drainage paths.

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