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Systematic GIS Development and its Successful Implementation in SSGC-Pakistan

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Abstract:

Utilities have prime importance in the worldwide development of urban and commercial centers. Natural gas is the most economical and reliable source for commercial and domestic energy consumers. The natural gas pipeline network was developed in Pakistan during 1950-1960s, and major expansion occurred in 1980-1990s to cover almost all major urban and rural areas. Most of the information is stored on manual paper maps having variable scales and several geometrical problems. The satisfactory supply of gas from stakeholders up to end-users demands an efficient information management system to streamline all relevant data sources.

The rapid expansion and maintenance of gas pipeline network demands a proficient GIS, to serve as analytical decision support tool to foster the planning, development, and management process. This paper focuses on systematic development of GIS and its successful implementation as web based application in Sui Southern Gas Company (SSGC).

Introduction

The paper starts with the overview of the Sui Southern Gas Company, its strategic vision and initiatives taken for the improvement of business processes through the use of technology; then it discusses SSGC's GIS project background, vision & objectives, scope, its step by step development and its implementation as a web based GIS application for better understating of seamless information which was previously stored at different locations on several unconnected traditional maps having variable scales and various geometrical problems. The project for the enterprise level solution will be completed in two phases and this paper is being presented in the middle stage of the first phase which is the time for the finalization of GIS for two major cities of gas distribution and transmission network i.e. Karachi & Hyderabad which comprised of about 55% of the whole network.

SSGC's Overview

Pakistan is a country of more than 130 million populations (Census Report, 1998), where only two gas utility companies are engaged in the business of transmission and distribution of natural gas besides construction of high pressure transmission and low pressure distribution systems. These high & low pressure gas pipelines are located in all four provinces of Pakistan i.e. Sindh, Balochistan, N.W.F.P. & Punjab (Figure 1). The length is more than 100,000 Km; begin from Sui & 22 other gas producing fields, crossing many populated areas, fresh and saltwater bodies, highways, bridges, and areas of irregular topographical terrain to cover almost all major urban and rural areas of Pakistan for transmission and distribution of gas natural resource.



Figure 1 : Map of Pakistan

Sui Southern Gas Company (SSGC) is Pakistan's leading integrated gas company whose transmission system extends from Sui in Balochistan to Karachi in Sindh comprising over 2780 KM of high pressure pipeline ranging from 12 - 24" in diameter (Figure 2). The distribution activities covering over 650 towns and villages in the Sindh and Balochistan are organized through its regional offices.



Figure 2 : SSGC's Transmission Pipeline Network

An average of about 337,638 million cubic feet (MMCFD) gas was sold in 2004-2005 to over 1.78 million industrial, commercial and domestic consumers through a distribution network of over 25,764 Km (SSGC Annual Report, 2005) . The company also owns and operates the only gas meter manufacturing plant in the country, under an agreement with Schlumberger Industries-France, having an annual production capacity of over 300,000 meters.

SSGC's Strategic Vision

To become the most technology enabled company in Pakistan for achieving “higher organizational efficiencies & effectiveness and greater business, productivity & performance that translates into “lower cost of doing business & higher returns” on investment, resulting in “satisfied stakeholders” and “service with a smile” to customers.

Technology Initiatives

SSGC is recognized as most technology enabled utility company not only in Pakistan but also in the South Asia region. Keeping in view the strategic vision of the company and to streamline the process of efficient information system, SSGC has taken various technology initiatives in recent years. Implementation of SCADA system which provides real-time remote monitoring of gas transmission network is one of the major examples. In the information technology area, which forms the backbone of the business today, SSGC is implementing Enterprise Information System for company-wide connectivity using DSL and wireless links, Oracle eBusiness Suite for enterprise resource planning (ERP), SPL's world-class Customer Information System (CIS) for integration of sales, billing and customer services, and ESRI's Enterprise Geographic Information System (GIS).

For building strong foundation of an asset information system, SSGC is planning to deploy GIS through out the enterprise using ESRI products for analysis, visualization, and decision support. GIS information and processes will be available in the office, across the Intranet, and in the field.



Figure 3 : SSGC’s Plan for Deployment of GIS at Enterprise Level

SSGC's GIS Background

Utilities have prime importance in the development of urban and commercial centers all over the world. In the power and energy sector natural gas is the most economical and reliable source to meet daily requirements of the consumers. Natural gas is used not only on domestic level, but it has a major share in industrial and commercial sector, specially in third world countries where oil and other power resources are not readily and economically available.

In today's world, Supply of Gas (a basic social need) from stakeholders up to satisfactory level to end-users demands the best information management system. Diversified lengths of pipeline network, with large numbers of individual facilities (like Valves, PRS, TBS, SMS) – required surveys of their status, capacities and functions (while interacting in real time) with repeated maintenance and constant management if the system as a whole is to operate efficiently and effectively. Tied to each of this countless numbers of entities and links is information - the information on which operational decisions are made and monitored. Population, commercial and industrial sectors of Pakistan are increasing continuously; as a result, gas pipeline network is also expanding with the same pace. In this situation, management, operation, maintenance, safety, and inspection activities have become becoming very difficult.

With-in SSGC, most of the company's assets information is developed on paper with traditional techniques, without any automated system. No centralised data management system for development, storage and restoration of the maps is existed. Maps are stored at Karachi, Hyderabad and Quetta regional offices. Most of them are outdated and have unconnected information, having variable scales and several geometrical problems. To some extent, only Planning & Development department use plan maps/sheets that were developed by consultants in AutoCAD environment for different project of SSGC's transmission pipeline network.

In Pakistan, GIS & Remote Sensing Technology is in its infancy stage. City development authorities have not yet developed GIS system at parcel level for any city of Pakistan, which is a must requirement in today's world, not only for themselves but also for other government and private sectors. Most of the information that is available in the market is outdated and limited to particular residential scheme/societies. SSGC use these maps or develop their own for gas pipelines projects.

To meet the challenges of continuous expansion of gas pipeline network, there is a dire need of such information system which could help SSGC for better planning, development, management, analysis, maintenance and operation of existing and forthcoming pipeline network.

In year 2000, for the first time SSGC started thinking for the restoration & re-development of paper maps which was continuously damaging due to unavailability of any centralised system required for their care. Discussions with locally available GIS experts were started in 2001. Initially thoughts were only limited to scanning and vectorization of paper maps and their storage on digital media. The job of scanning and vectorization of 2000 drawings in AutoCAD environment was awarded to a local firm in 2002, which was completed in 22 months of time period. Meanwhile, serious research and discussions were also going on within the company for the centralization and streamlining of the assets' information. More than 3000 drawings were also left for scanning and vectorization to cover entire SSGC's franchise area. In 2005, SSGC took strong initiative and started developing GIS from scratch using in-house resources in terms of hardware, software, maps and human resource with the well defined vision and objectives. SSGC is the first utility company in Pakistan for the development of this large scale, detailed GIS system that could also be used in other utility companies for their asset management.

GIS Project Vision

The main vision of the project is to create and maintain an efficient GIS environment that fosters geographic data sharing within commercial, transmission, distribution, engineering, management and other departments of SSGC.

Objectives

To achieve the vision of GIS project, implementation of GIS in SSGC has been divided in to two phases. First phase of the project is only related to the development of seamless information for pipeline and its associated features along with landuse data on UTM Zone 42 coordinate system at a scale of 1:1000; second phase is the deployment of this GIS system at enterprise level for various departments. Objectives of 1st phase are (1) Conversion of paper drawings/maps into digital drawings, to save them from further loss or damage. (2) Development of GIS system and its implementation as web base GIS application. (3) Identification of areas that requires survey

for up-gradation/correction of information. Objective of 2nd phase is the deployment of GIS system in various departments by integrating it with other information systems like Customer Information System (CIS), Enterprise Resource Planning (ERP) etc. (Figure 4).

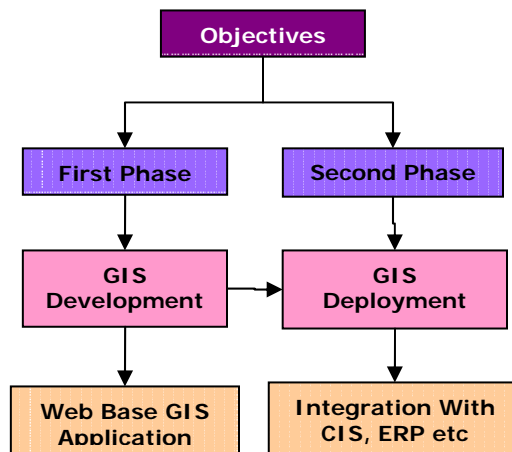


Figure 4 : GIS Project Objectives

Scope:

The estimated completion time for the 1st phase of the project is 18 to 24 months in which 10 to 12 months are only for two major cities of distribution & transmission pipeline network i.e. Karachi & Hyderabad. According to current estimations, out of 1.9 million customers, 70% customers live only in these cities.

The work scope of the 1st phase of the project is (1) Scanning of more than 3000 paper drawings/maps for their storage on digital media. (2) Survey for the collection of ground control points using DGPS for the geo-referencing & mosaicing of 60 SPOT 5 (2.5m resolution, panchromatic) satellite scenes. (3) Geo-referencing of more than 5000 paper drawings/maps with the help of geo-referenced satellite data. (4) Vectorization and rectification of land data at parcel level and gas pipeline network for 650 towns & villages, using geo-referenced satellite data and

the information available on scanned maps. (5) Development of customized application for the integration/entry of attribute information with the vectorized maps. (6) DGPS survey for collection of GCPs for benchmarks and various installations of transmission pipeline (2780 Km) for the development of exact route/corridor and its integration with gas distribution network. (6) Development of web portal for SSGC's GIS for the visualization and better understating of seamless information within a company, across the intranet. (7) GPS base survey for the up-gradation/correction of information, noted/identified during the development phase of GIS.

Resources

SSGC is using state-of-the-art technology for the development of its GIS system. Software includes *Adobe Photoshop* for scanned data processing/cleaning; *Erdas Imagine* for satellite data processing; *AutoCAD* for vectorization; *ArcGIS Desktop* for GIS; ArcSDE for Spatial Database in Oracle 9i; *ArcIMS* for web base GIS application; *ArcEngine* for the development of standalone customized GIS application; *Magellan Mapsite*, *Trimble Pathfinder Office* & *TerraSync* for GPS data processing .

Hardware includes *Magellan Color Meridian GPS* and *Trimble ProXRS SDGPS* for field data collection, *Contex 36"* large format high resolution scanner, *HP 42"* large format and high resolution plotter; *HP & IBM's* Pentium 4 desktop computers and high speed *Dell* servers.

Satellite data includes *SPOT 5 Pan* (2.5m resolution) and *Landsat TM* (28.5 and 14.25m resolution) satellite data.

Data Standards

With the help of information available from satellite data and scanned paper maps, data/layer has been standardized for vectorization to be used for the development of GIS. Landuse functions, administrative units, water resources and gas supply network structures are *polygon feature classes/layers*. *Line feature classes/layers* are road network, railway network, water resources, gas pipeline network whereas administrative headquarters, gas pipeline fittings & benchmarks, major & minor landmarks are for point *feature classes/layers*.

In polygon feature class, major landuse functions at parcel level include residence or accommodation, general sales or service, manufacturing and wholesale trade, transportation, communication, information, and utilities, arts, entertainment, and recreation, education, public administration, health care, and other institutions, construction related businesses, mining and extraction establishments, agriculture, forestry, fishing and hunting; miscellaneous information, mix landuse, open/barren land ; Administrative units include provincial, district, taluka, village, town and union council boundaries, SSGC's regional, zonal and sub-zonal boundaries; Layer of water resources include sea, river, lake, pond, natural or other reservoir ; Major gas distribution & transmission installations include TBS (town boarder station), PRS (pressure reducing station), CPS (cathode post station), SMS (sales meter station), MVA (main valve assembly), pig launcher/receiver trap point, RS (repeater station), compressor station and terminal points.

As line feature class rail/road network includes highway, primary or major road, secondary or minor roads, street/lane and tracks; Water resources as drains, stream, water course; Gas distribution supply as supply, link and distribution network whereas gas transmission supply in terms of main and loop line network.

As point feature class administrative units includes provincial, district, taluka head quarters as well as locations of city, towns and villages; Gas fittings include all pipeline fittings like Muller tee, equal tee, steel valve, weld cap etc; Benchmarks include km/mile post, cathode test post markers, turning points, crossings, gas delivery points etc.; Major and minor landmarks along the road network for landuse.

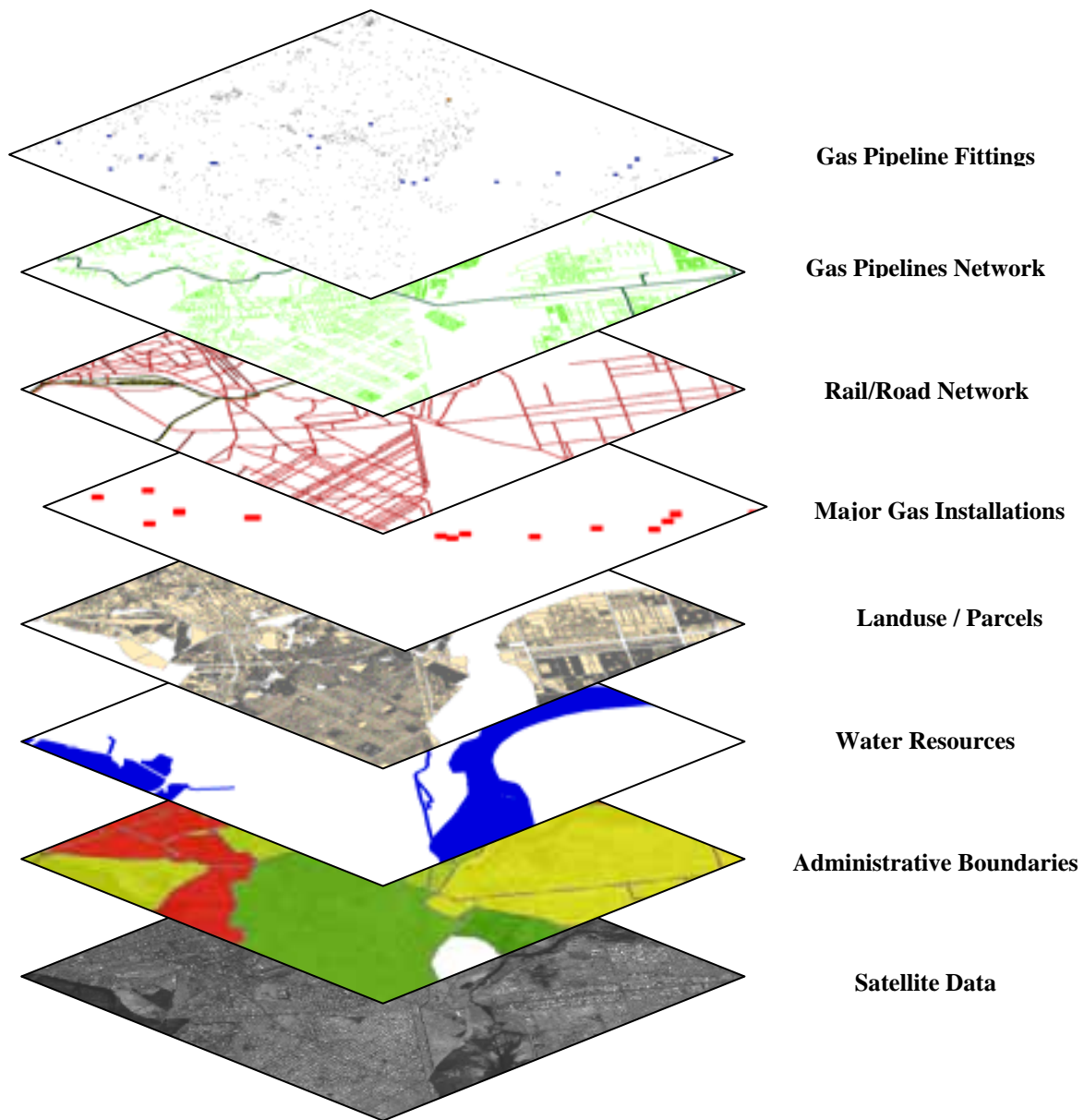


Figure 5 : Major Layers for SSGC's GIS

GIS Work Flow

Expertise of GIS and other related professionals are being used to maintain the work flow for 1st phase of the project (Figure 6). Responsibilities of the *Project Manager* are not limited to the planning, management and administration of project but report writing, procurement, development of proposals presentations are also included. Other resources' responsibilities are; *Technical Manager* involves in overall technical assignments and issues related to survey, satellite data processing, database development, CAD, GIS and customized applications as well as correspondence with user departments for the solution of the issues and arrangement of data;

Remote Sensing Expert is responsible for GCPs site selection, geo-referencing & mosaicing of satellite data and scanned paper maps, image contrast and enhancement; *Survey Supervisor* for planning and GPS/DGPS base field survey related to satellite data, landuse and gas distribution and transmission pipeline networks; *Database Developer* for GIS Geo-database development and maintenance related issues; *CAD/GIS Programmer* for the development of customized applications in AutoCAD, ArcGIS and ArcIMS environment; *Core CAD/GIS Experts* for overall data management and development, scanning, backups, quality assurance, supervision to GIS groups which has been made for the distribution of GIS work (Figure 7), arrangement of short trainings for GIS groups.

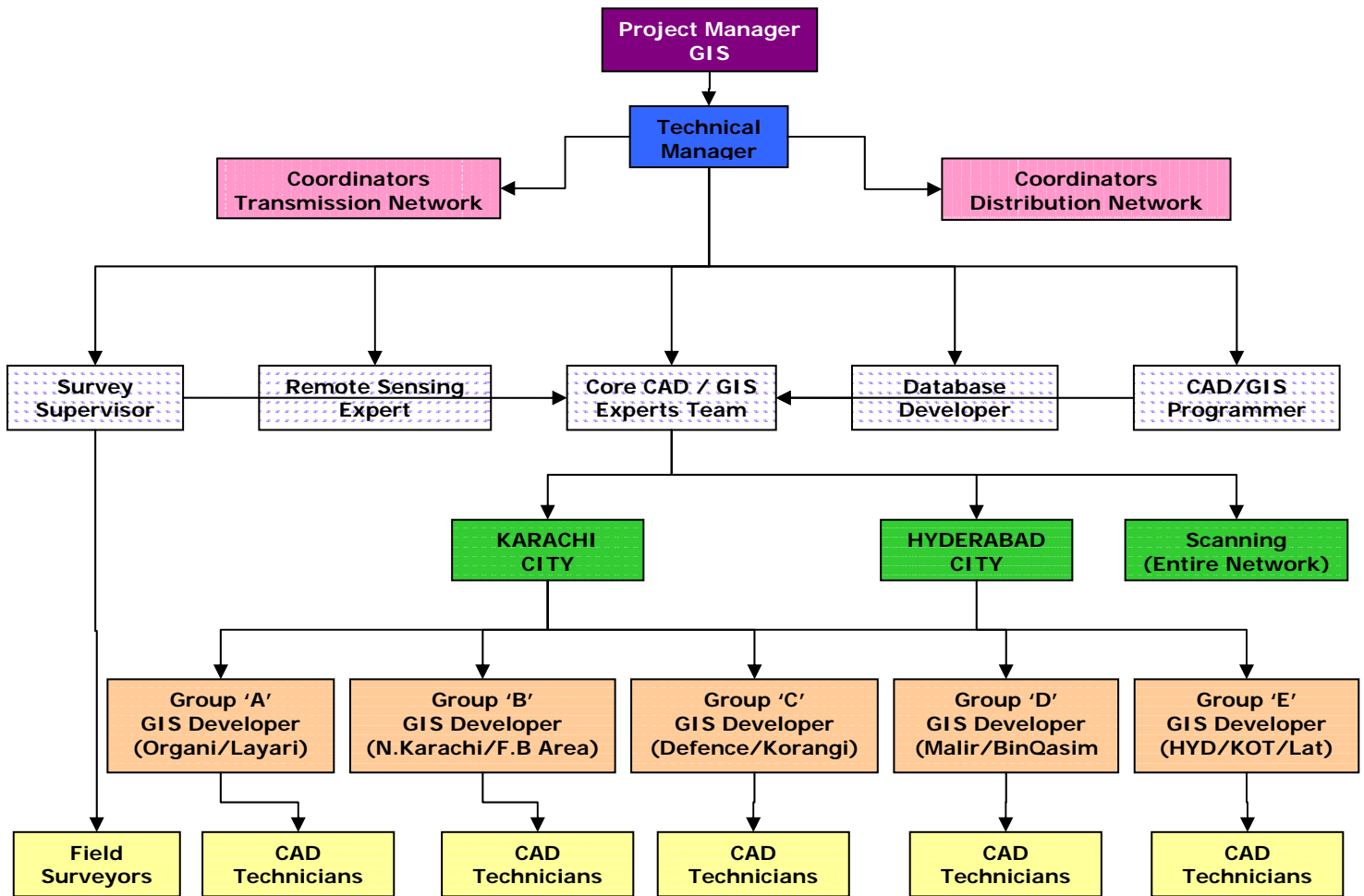


Figure 6 : GIS Work Flow Management

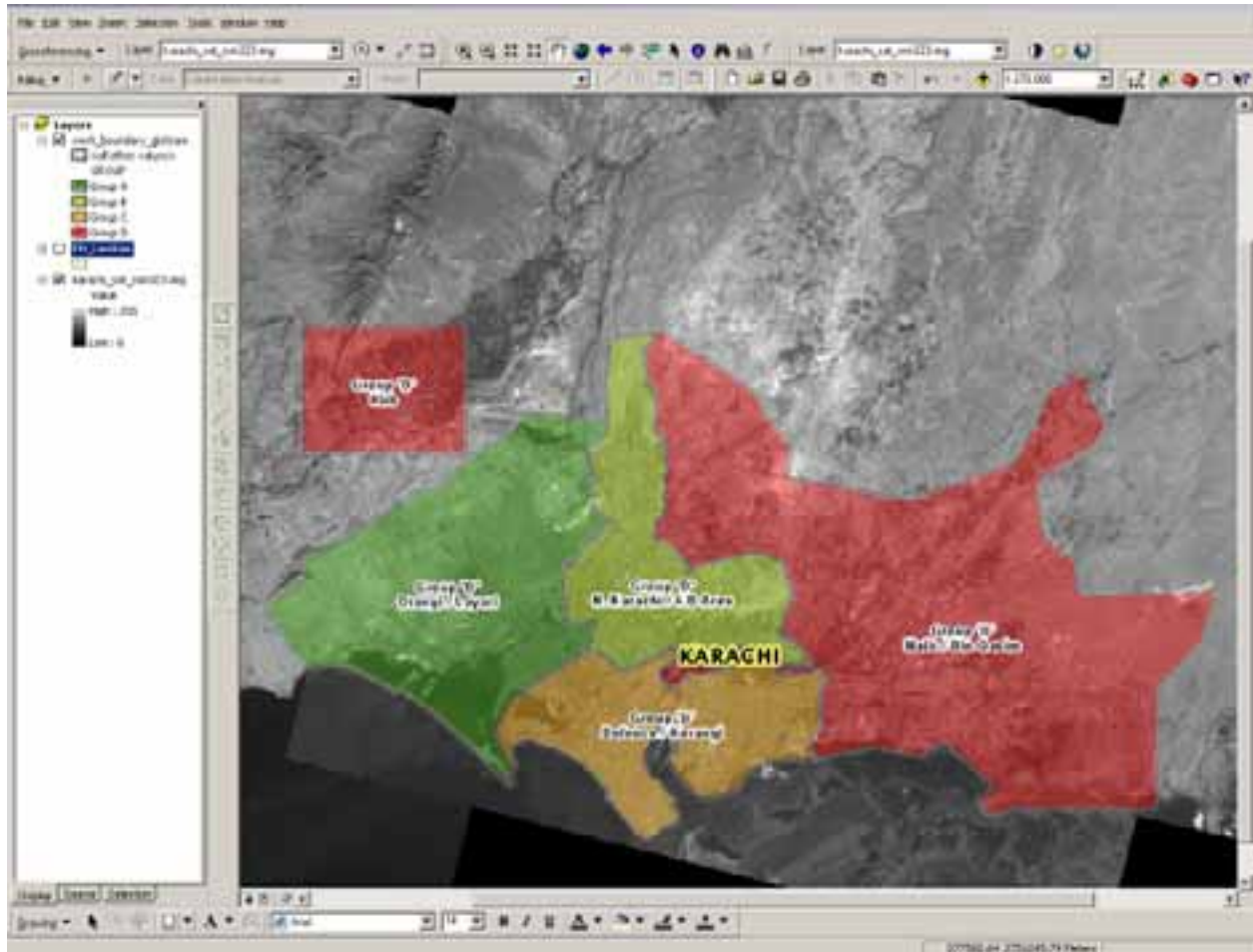


Figure 7 : Distribution of Work for GIS Groups

Development Stages

For the quick look and better understandings of all steps/stages that were used for the development of SSGC’s GIS, flow chart has been given as annexure ‘A’.

In SSGC, most of the traditional paper maps (more than 5000) are stored at Karachi, Hyderabad and Quetta regional offices. The first priority of the project was the collection of these paper maps from regional offices to maintain inventory and then their conversion into digital format for storage on digital media. These maps were collected and scanned in small phases at a resolution of 300dpi (as standard) using 36” wide Contex large format high resolution scanner. After scanning, post scanning process (cleaning/bordering etc) on these maps was also done in Adobe Photoshop software, while inventory was maintained in MS Excel software. Digital maps were stored on dedicated server which are now available across the intranet for reprinting or any other use, both in raw and post processed form (Figure 8).

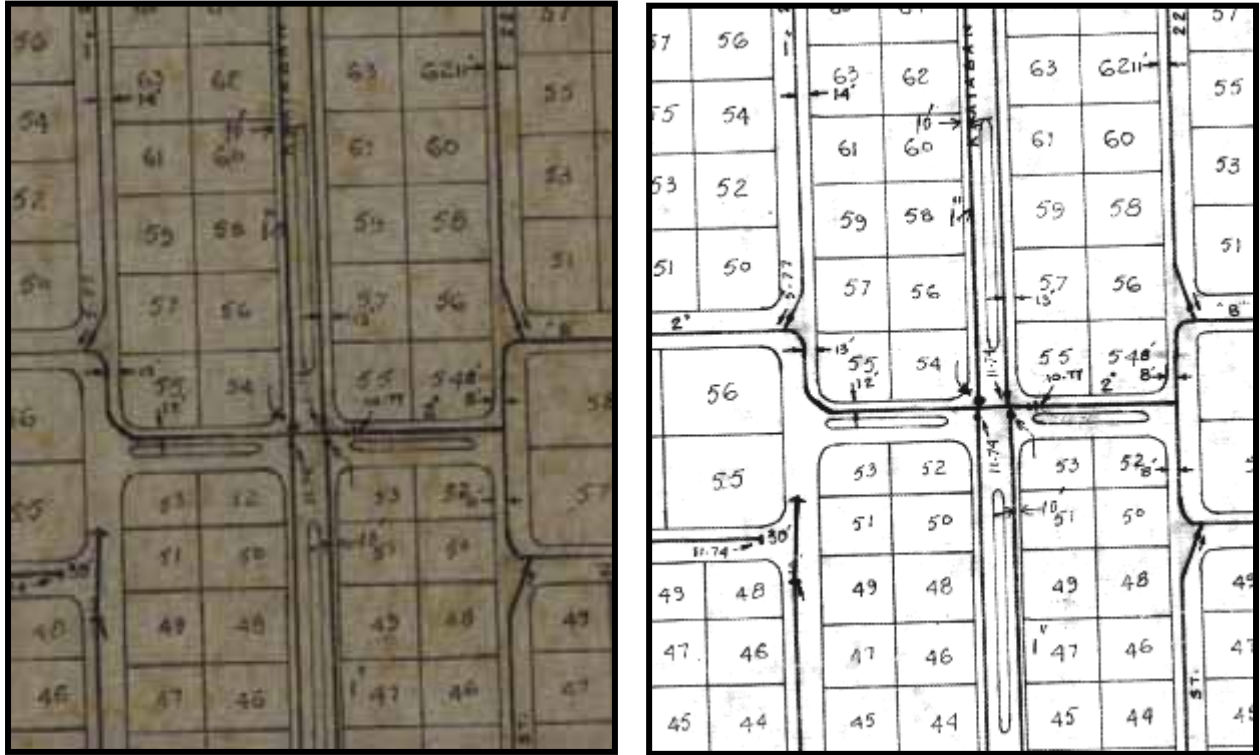


Figure 8 : Raw & Processed Scanned Maps

At this stage, for optimal performance of the PCs, the processed scanned maps were stored also at a resolution of 150dpi for later use in ArcGIS & AutoCAD for geo-referencing and vectorization respectively.

Selection of coordinate system was one of major challenge for SSGC for the development of GIS. Survey of Pakistan (a government organization) use Lambert Conformal Conic (with two Standard Parallels) Projection, which divides Pakistan into two Grids; grid I for Northern Pakistan and grid II for southern Pakistan. This system is used for military purpose only which is not available for public sectors. In SSGC, since only traditional maps are being used for the planning and management therefore no coordinate system was existed. Universal Transverse Mercator (UTM) system is a specialized application of the Transverse Mercator projection which is used for large scale topographic mapping. It gives accurate representation of small shapes and minimal distortion of larger shapes within the zone. Scale is constant along the central meridian. On Universal Transverse Mercator System, Pakistan falls in Zone 41, 42 and 43. Since UTM

Zone 42 (WGS 84) covers entire transmission and distribution network of SSGC, therefore it was selected as base coordinate system for the project.

Due to un-availability of pre-developed GIS system for franchise areas/cities of SSGC, it was decided that SSGC will develop parcel level GIS from scratch. Satellite data/aerial photograph or any other base as background is a must requirement, if development of GIS is required from scratch. Several constraints were present at the time of selection of satellite data. Since, SSGC have large area of its gas network (approx. 216000 Sq Km), therefore, satellite data having medium cost, good coverage (per scene) and high pixel resolution was the main objective. Now a days, for the development of landuse data, satellite images from low resolution (LandSat) to very high (QuickBird/IKONOS), is commercially available in the local & international markets. Satellite data with qualities of large aerial swath have low resolution (pixel size) but are economical where as satellite data with high resolution are very expensive and have small covered area. However, SPOT 5 satellite data with 2.5m pixel resolution, 2A processing level (a level at which image is ortho-rectified using satellite coordinates & global DEM of 1 Km pixel resolution) and 3600 Sq Km of area (per scene) was purchased from a local organization (SUPARCO) with the objective that QuickBird 0.6m pixel resolution satellite data will also be purchased if it is required for specific area (densely populated/congested) during the time of GIS development.

The default horizontal accuracy of SPOT 2.5m with 2A processing level was 60 to 75 meters. To increase the accuracy level (up to 10meter or less) survey for the collection of Ground Control Points (GCPs) using Trimble ProXRS DGPS (with OmniStar worldwide differential correction subscription service) was conducted. GCPs' site selection and planning for optimal routes was done during desktop study (Figure 9). To access GCPs site, survey team used real-time self tracking system which was possible using Trimble Pathfinder TerraSync field device software. After collection and processing of field data in Trimble Pathfinder Office software, GCPs was used for the geo-referencing and mosaicing of satellite data (as a block of 20 scenes). The geo-referencing and mosaicing of satellite data was done in Erdas Imagine software (Figure 10).

The geo-referenced satellite data with a horizontal accuracy of less than 10m was then used to assign ground coordinates to scanned paper maps in ArcGIS Desktop software (Figure 11).

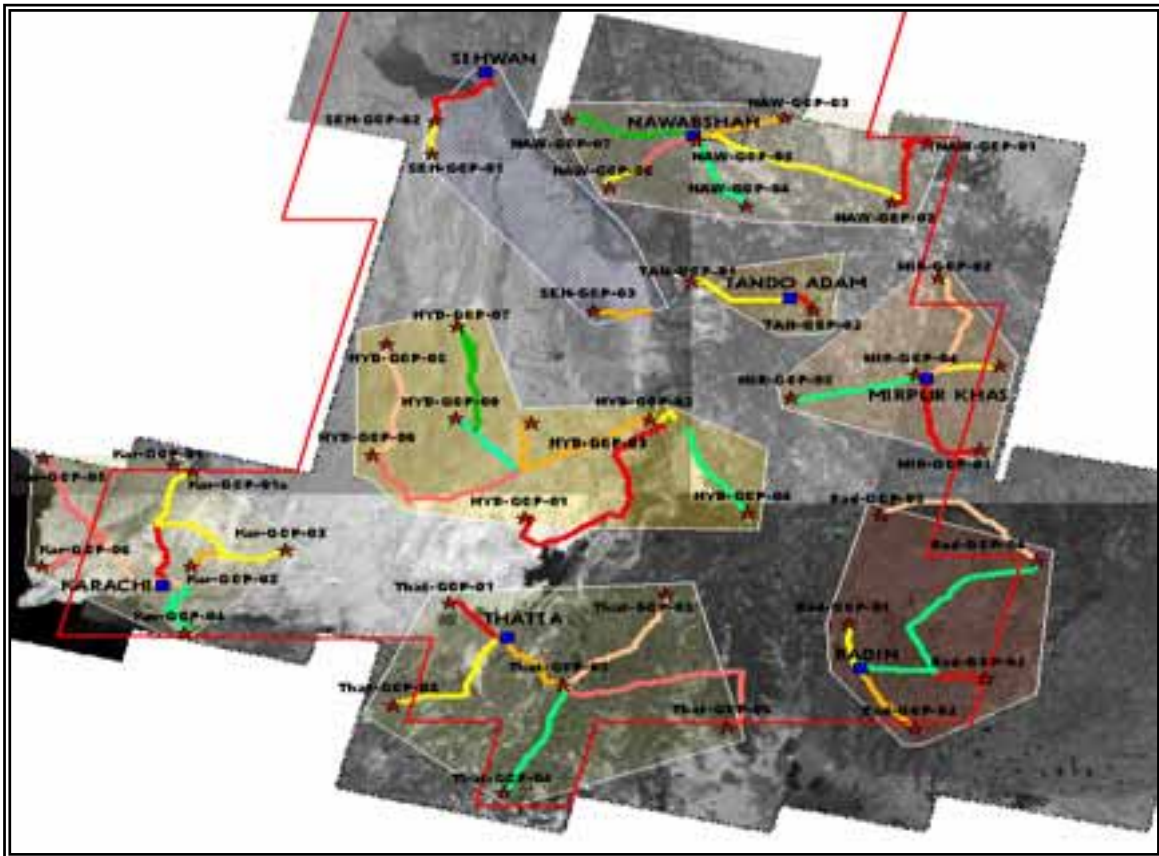


Figure 9 : Desktop Study for Site Selection & Route Planning for Collection of GCPs

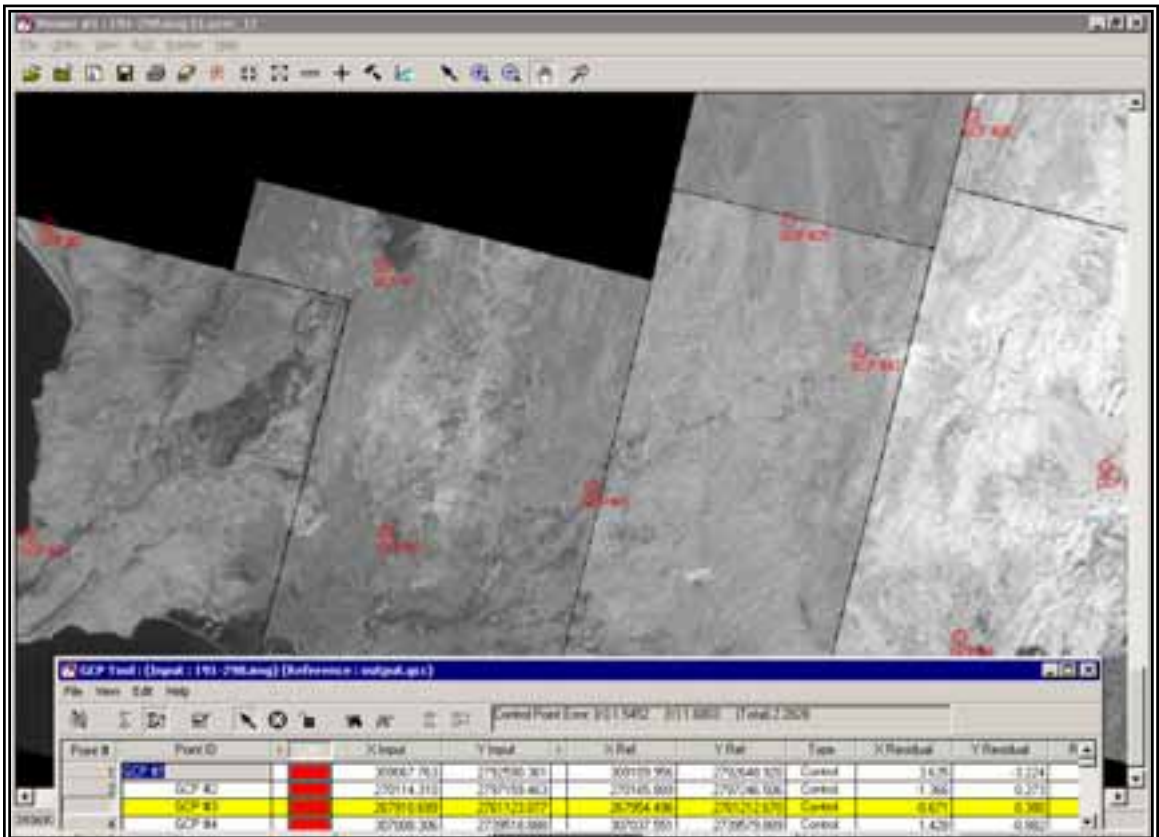


Figure 10 : Satellite Data Geo-referencing & Mosaicing



Figure 11 : Geo-referencing of Scanned Maps with Reference to Satellite Data

Before starting vectorization, all standardised data layers were created in AutoCAD. Geo-referenced satellite data and scanned paper maps were imported directly in their proper layers. The imported data was in UTM Zone 42 coordinate system. At this stage, for vectorization of information from scanned maps, rubber-sheeting of the scanned data with reference to satellite data in small parts was necessary to control or reduce geometrical errors already present in the maps, which was also done in AutoCAD.

Customized tools were developed in AutoCAD for the better control on layers' On/Off. Standard gas fittings & dimensions with reference to gas pipelines were also inserted with the help of these tools (Figure 12).

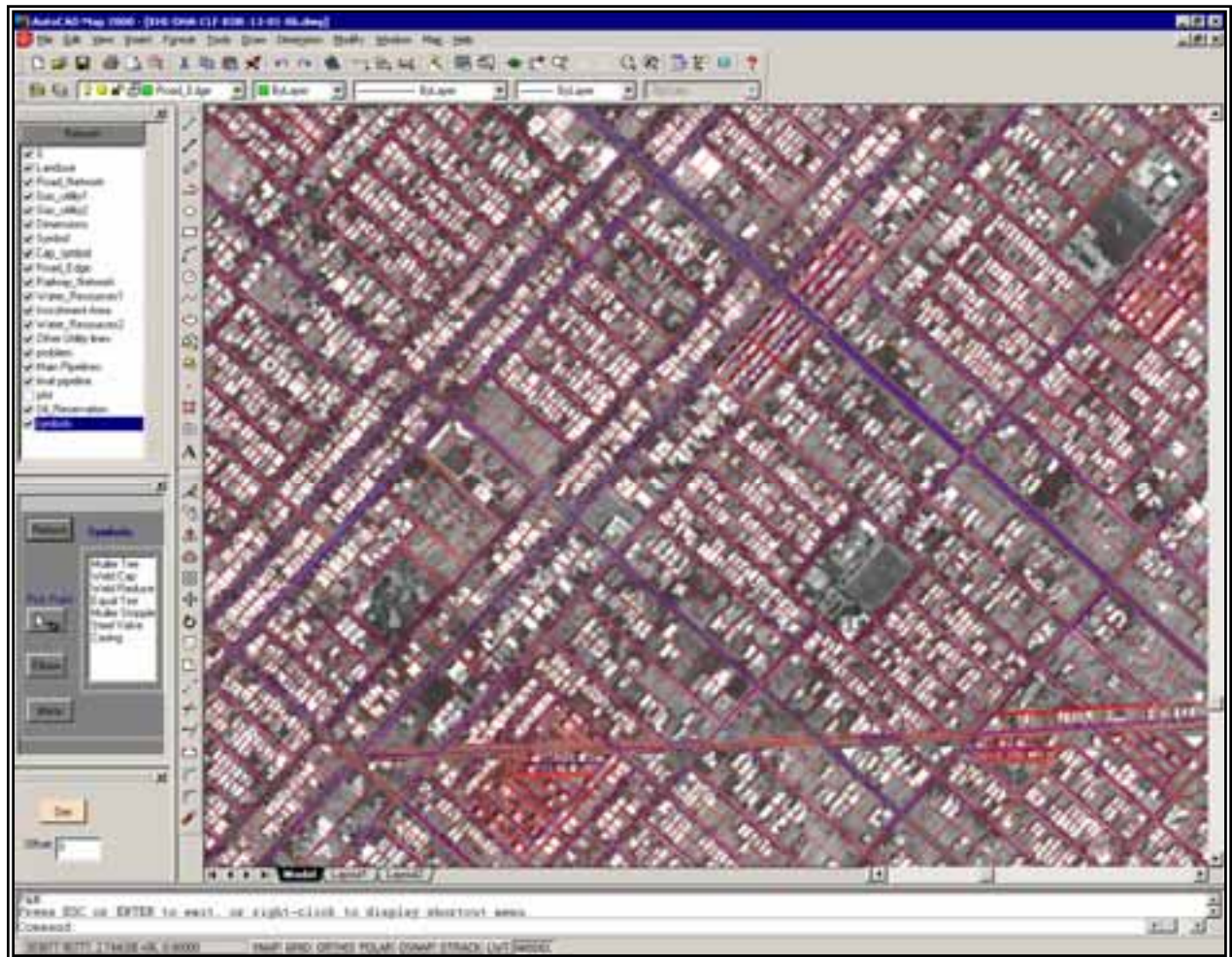


Figure 12 : Vectorization of Information with Reference to Scanned Maps & Satellite Data

Geo-referenced satellite data with Trimble ProXRS DGPS was also used to conduct field survey for the collection of ground coordinates for benchmarks and various installation of transmission pipeline network between Karachi & Hyderabad. The field data after processing in Pathfinder Office software was imported directly into AutoCAD for vectorization and development of accurate transmission pipeline and its corridor. Simultaneously, GPS survey for the collection of various gas installations (TBS, PRS or CP stations) for Karachi & Hyderabad was also conducted for the development of gas distribution network in ArcGIS.

After vectorization of information, vector data layers was then directly imported one by one for the development of ArcSDE geo-database in Oracle 9i (RDBMS). Feature classes were organized in standard datasets. Standard fields for each feature class were also defined. At this stage, entry of precise and accurate information for each and every object/records of the geo-

database in multi-developers environment was another major challenge. To avoid discrepancies in the data, attribute entry at client side through ArcGIS was done using customized application. (Figure 13).

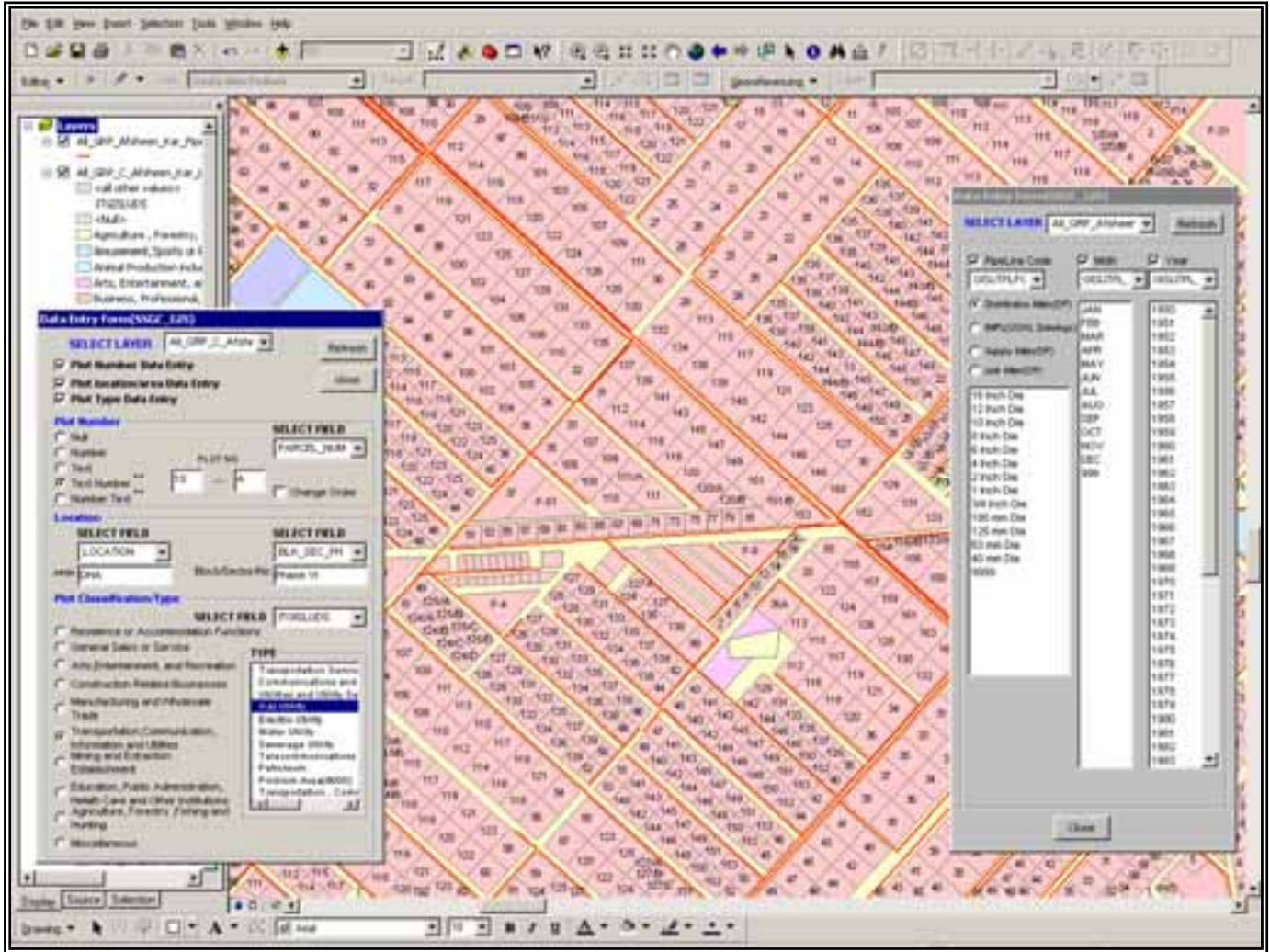


Figure 13 : Attribute Entry at Client Side through ArcGIS Using Customized Applications

Another important and final step was the integration, organization/management and classification of GIS information developed by GIS developers in groups. Integration of all GIS data was done in ArcGIS. Gas pipeline network connectivity using survey data was also done at the same stage. With the help of attribute information entered earlier, GIS data was organized in various layers for creation of services in ArcIMS for launching of web based application across the intranet with best possible performance. With slight modifications/customization,

development of website was done using ESRI ArcIMS material available for java viewers (Figure 14).

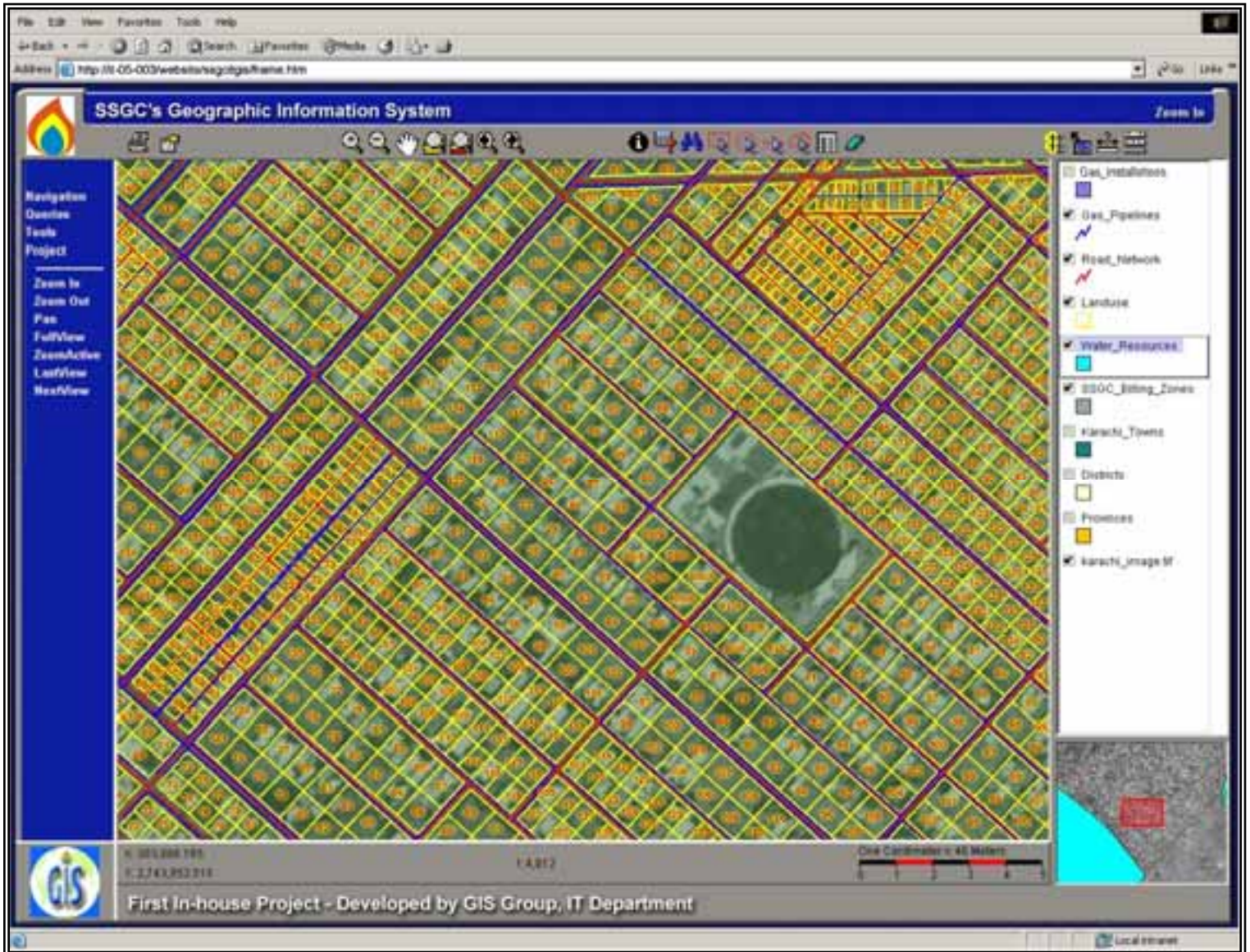
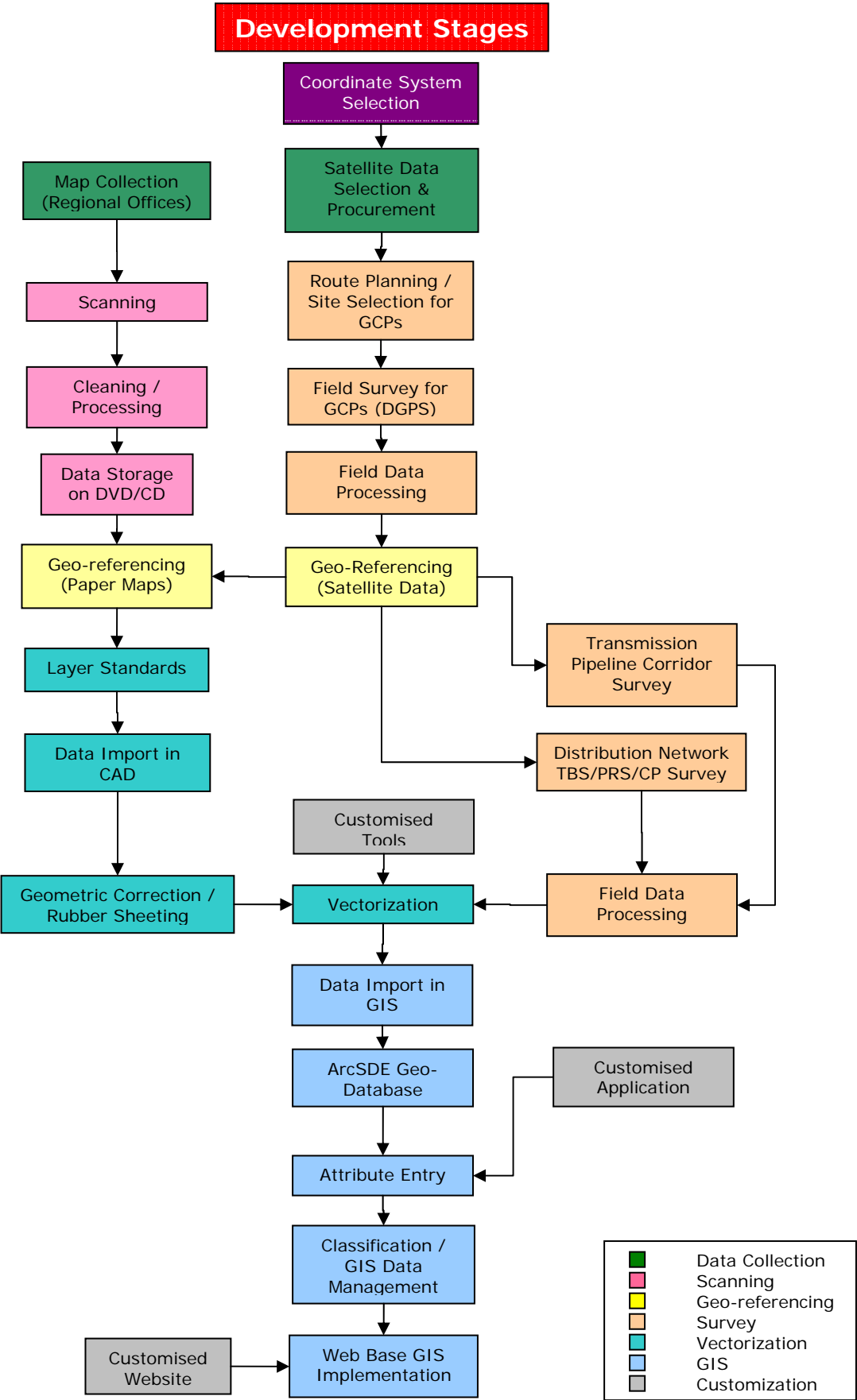


Figure 14 : SSGC's Web base GIS Application



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