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MAN AND HIS PHYSICAL ENVIRONMENT : A CASE STUDY OF LAHORE

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ABSTRACT.—*Lahore the second largest city of Pakistan is confronted with the deterioration of the quality of urban physical environment. In the following article an attempt has been made to describe some of the basic, geological, geomorphological, hydrological and hydro-meteorological parameters that govern the human environment in the city of Lahore. An understanding of these may be helpful to planners and the citizens in keeping the environment of the city free of pollution.*

Introduction

Lahore is an old city, its history goes back to first century A.D. It was a relatively small city until some 150 years ago. In the pre-Muslim period (to 1002) A.D. it occupied a small site close to the eastern bank of the Ravi and in the following 800 years under the Muslim influence the city's growth was prominently in a radial manner eastwards from the river with small outliers on the western side. The Sikh rule under Ranjit Singh (1790-1830) also witnessed a similar decline in the growth of population in Lahore. The British period (1849-1947) saw political stability returned, accompanied by improvements in communications, irrigation and in general conditions. Consequently the city expanded considerably especially in a south easterly direction. By the time of independence the outer urban limits were seven miles distant from the river.

Since independence Lahore has seen rapid growth, unparalleled in history. The outer limits have expanded for several miles from the river, new schemes of Lahore Development Authority now reach Kot Lakhpat and several miles towards the Multan Road. Similarly development on the other side of the river Ravi has also considerably increased. For quite some time since independence the growth to the east has not been encouraged due to the proximity of the Indian border. The population of Lahore has grown from 1.30 million in 1961 to 2.15 million in 1972 i.e. an increase of 65.74 per cent during the intra-censal period of 11 years. It has been estimated that 77,000 persons or about 15,000 families are being added to the city each year. A substantial portion of the population growth in the city is due largely to the urbanisation of the rural population.

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A journey through the city of Lahore shows that large parts of it in the past have grown in a piecemeal fashion. Many areas have been independently conceived with little or no coordination. Haphazard growth of the city has resulted into innumerable problems and hazards. The most fundamental question facing Lahore is the improvement of environment in which the Lahorites live. The problem is important today when the size of the city and its population have increased and are exerting ever greater pressure on the environment, threatening it with irreparable damage. The continuing growth and concentration of population and industry in Lahore in recent decades has caused complexly merging physical problems. The interrelationships of man and his use of the land and water resources are particularly singificant aspects of urbanization.

Geology

Geological history of Lahore alongwith that of the Punjab is linked with the uplift of Himalayas in the Tertiary times, where a subsiding through a foredeep was formed adjoining the mountains. The alluvium mostly derived from the Himalayan ranges has been deposited in the Punjab geosyncline by the present and the ancestral tributaries of the Indus river system. The exposed Lahore alluvial complex of pleistocene and recent age represents the latest phase of sedimentation and subsidence. Nearly all the deposits underlying the city of Lahore and the surrounding area are the products of events that evolved during pleistocene and recent geological times. The study of logs of boreholes and tubewells, done in and around Lahore show that the alluvium consists principally of fine to medium sand, silt and clay. Associated with the fine grained strata are concretionary zones of nodules of Kankar and silty clay, occasionally containing beds of reddish and ferrogeneous material. Drilling data obtained from several deep wells (Tables 1 & 2) shows the absence of thick horizons of clay within the alluvium. Clay lenses occur only locally and have little horizontal continuity. In 1961 bed rock (mica schist) was struck at 1,274 feet depth near Niaz Beg (Table 1) after which the drilling was abandoned by Water and Power Development Authority (WAPDA). In subsequent years drilling operations in and around Lahore did not exceed 800 feet depth. At present our knowledge of the deep geological formations underlying beneath the city of Lahore is incomplete.

Landforms

The study of topography superficial shape, microrelief, size, degree of erosion, active processes and the inherited features of the plains of Lahore show variety of landforms, which were formed at different times and are characterized

TABLE I.—*Geological Log-Test Hole 1 Bari Doab Area*

Depth (ft)	Formation	Description
0-22	Silty clay	Brown with rare Kr.
22-55	Gravel	With very fine sand, about 5% sand, earth gravel. Fairly well sorted, mica green and dark minerals.
55-104	Silty clay	Brown with gravel about 30% very, very fine sand earthy gray, rounded to subrounded. Fairly well sorted mica green and dark minerals.
104-124	Gravel	With clay and fine sand about 5%, earthy grey subrounded well sorted.
124-145	Gravel	With about 50% sand fine to medium grey, subrounded well sorted; mica green and dark minerals present, clay rare.
145-186	Sand	About 30% gravel; sand fine to medium grey subrounded well sorted, Meca green and dark minerals present.
186-207	Silt	With about 20% very fine sand, earthy grey, subrounded. Fairly well sorted; mica green and dark minerals.
207-248	Sand	With about 50% Kankar sand very, very fine earthy grey rounded mica. Fairly well sorted mica and dark minerals, about 10% silty clay.
248-309	Gravel	With about 40% sand, fine to medium, grey subrounded well sorted mica and dark minerals, about 10% silty clay.
309-331	Sand	Gray, very fine, rounded to subrounded. Fairly well sorted mica, dark and green minerals, about 15 gravel and silty clay.
331-406	Silty clay	Brown with about 30% very fine sand, rounded to subrounded. Fairly well sorted mica, dark and green minerals, about 10% gravel.
406-413	Sand	Gray, medium, subrounded, well sorted mica dark and green minerals, with about 15% gravel and about 5% silty clay.
413-474	Silty	With about 20% gravel, about 5% clay from 433 ft. to 454 ft. about 10% clay from 454 ft. to 474 ft.

Depth (ft)	Formation	Description
474-562	Sandy silt	With rare granules with about Kr. from 500 ft. to 516 ft. and about 10% Kr. from 516 ft. to 581 ft.
562-598	Sandy silt	With about 40% gravelk, rare clay.
598-702	Gravel	With fine to medium sand, gray, subrounded, well sorted mica, and dark green minerals, with about 10% silty clay.
702-722	Sandy silt	With about 40% gravel.
722-730	Gravel	With about 15% very, very fine sand, light rounded, Fairly well assorted mica, dark and green minerals.
730-804	Sandy silt	With about 20% gravel up to 743 ft. about 5% gravel from 743 ft to 804 ft.

TABLE II.—*Geological Log-Test Hole 1A Bari Doab Area.*

Depth (ft)	Formation	Description
0-5	Sand	Medium to fine, subangular to angular, fairly well sorted, biotite, muscovite, quartz, and dark green minerals.
5-45	Clay	Earthy brown in colour, gravel abundant which shows short distance transportation; gravel subangular to subrounded, fairly well sorted.
45-261	Sand	Fine to medium; subangular to angular. Fairly well sorted muscovite, biotite, and quartz and dark green minerals.
261-269	Gravel	Angular to rounded. Poorly sorted. Sand very rare.
269-309	Sand	Sand with gravel; sand very fine to medium well sorted quartz-mica dark green minerals.
309-353	Gravel	Pebble, angular to rounded; poorly sorted with sand (very fine).
353-496	Silt	Earthy brown in colour; silt with gravel and sand.
496-670	Sand	Medium to fine, well sorted, subrounded to rounded quartz, mica, dark green minerals, gravel rare.
670-702	Gravel	Pebble, angular to subrounded; fairly well sorted.
702-1238	Silt	Silt with sand, sand very, very fine, silt ash colour. Gravel rare (about gravel, 990-1103 ft).
1238-1250	Gravel	Mainly angular; poorly sorted (this may be scree).
1250-1274	Bedrock	Mica schist

Source: Water and Soil Investigation Division of WAPDA, Lahore.

by a distinctive surface expression which make them sufficiently conspicuous to be described. Air photos and mosaics on 1: 10,000 scale and topographical maps on 1: 12,000 scale were used to identify and map these landforms. The classification of landforms adopted for mapping is largely based on Leuders scheme,[1] the emphasis being on the physical features which are important to urban planning. Extensive field work proved useful especially in the built up areas where the land surface is obscured by buildings and roads etc. The field checking of mapping was confined up to a radius of ten miles from the built up areas. Fig. 1, shows the landforms which have been mapped in and around Lahore on reduced scale. For publication, the original maps have been reduced and some landforms having a small areal extent cannot be truly represented on this scale. The mapped landforms are:

1. Active Flood Plain
2. Recent Meander Flood Plain
3. Subrecent Cover Flood Plain.
4. Old Level Terrace
5. Old Basin and Channel Fills
6. Severely Eroded Land.

Active Flood Plain

This landform is located on the north eastern and south western flanks of the city. In recent years it has been partly bounded by flood protection embankments, on both sides of the river Ravi.

Geomorphologically it is composed of both loose sand and semi consolidated fine material derived by the sediments transported by the river. The flood plain is generally inundated every year during the summer season. Although from a distance its surface appears flat, close examination of the relief shows that it has most irregular surface configuration. Micro-relief varies from a fraction of a feet to almost 10 feet. Lenticular bar like forms, isolated swells, widely spaced channel like forms, micro-terraces, and erosional activity of banks characterize the surface. After the recession of floods the micro-relief of active flood plain changes its shape. The texture of material varies from place to place, coarse texture material is found near the active channel and fine texture farther away. There seems to be no pattern for the lateral and vertical distribution of material it depends mostly on the local conditions prevailing at the time of each flood and the character of flood sediments.

1. Lueder, D. R. *Aerial Photographic Interpretation, Principles and Application*, McGraw Hill Company, 1952, pp. 131-146.

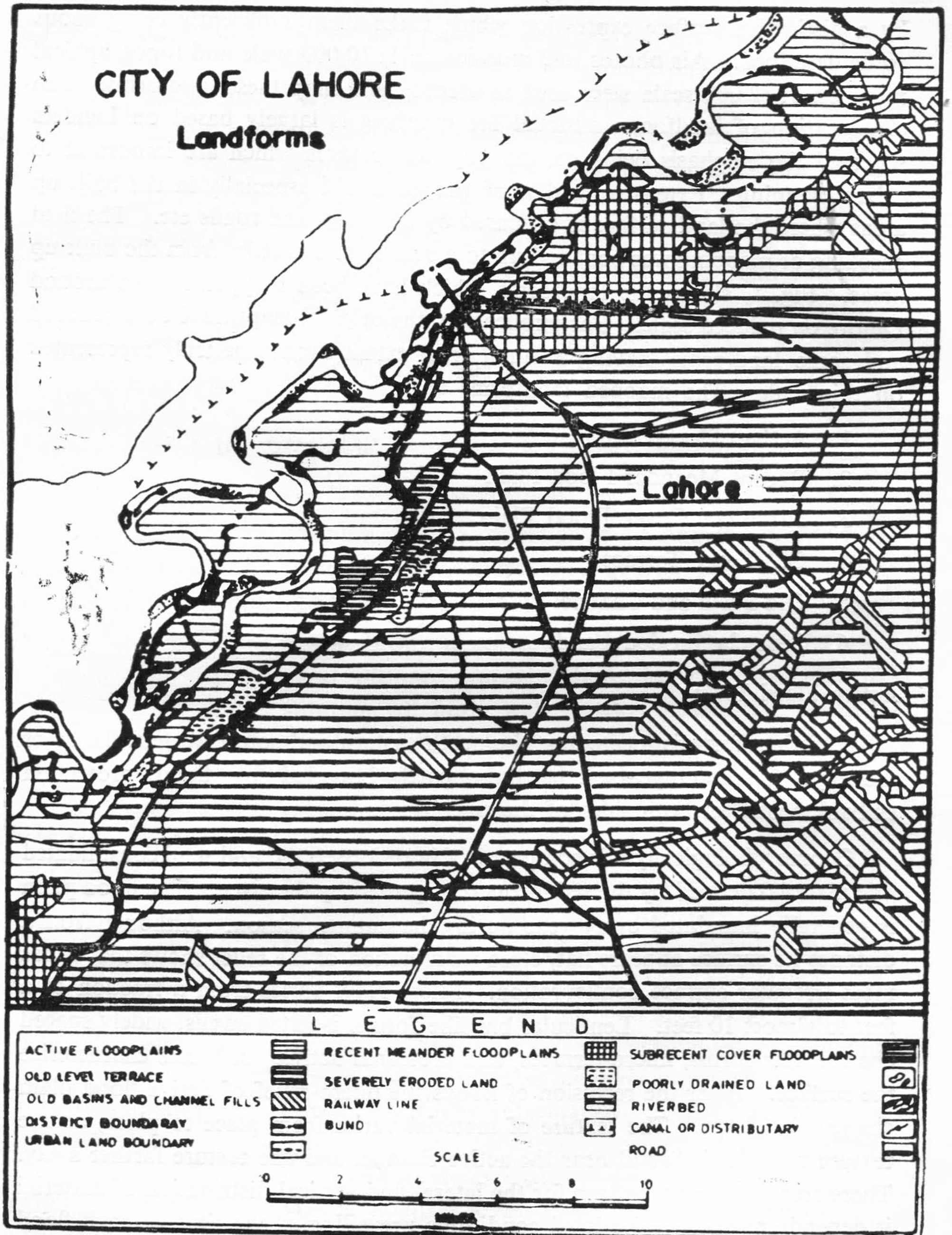

CITY OF LAHORE
Landforms
Lahore
LEGEND
ACTIVE FLOODPLAINS
RECENT MEANDER FLOODPLAINS
SUBRECENT COVER FLOODPLAINS
OLD LEVEL TERRACE
SEVERELY ERODED LAND
POORLY DRAINED LAND
OLD BASINS AND CHANNEL FILLS
RAILWAY LINE
RIVERBED
DISTRICT BOUNDARY
BUND
CANAL OR DISTRIBUTARY
URBAN LAND BOUNDARY
ROAD
SCALE
0
2
4
6
8
10

Fig. 1

Recent Meander Flood Plain

This landform is located in the north western and south western parts of the city flanking river Ravi and is slightly above the seasonal flood level and does not receive fresh sediments. The evidence of parent stream formerly flowing in the area can still be picked up on air photos. River meander patterns, at places through somewhat obscured by expansion of the city and the building construction can be noticed by a careful observer. Variation in texture of surface material from place to place is quite common. Generally silt loam, very fine sandy loam and sandy loam soils are found. Ravi is a graded stream in equilibrium, in which any change in any of its controlling factors causes a displacement of the equilibrium in a direction that tends to absorb the effect of change. It is largely engaged in lateral migration erosion, and vertical deposition. During the period of bankful floods the intensity of these processes increases and in this fashion the meander flood plains have come into existence.

Sub Recent Cover Flood Plain

This landform occurs in the southwest of the city. It has been formed due to the abandoning of the course of Ravi and by subsequent partly filling in of the microrelief by annual flood sediments. The signs of former meander scroll, levees generally found in the meander flood plains can still be seen and recognized on air photos.

Old Level Terrace

More than 75% of the city is located on the old level terrace. In the southwest of the city along the Multan Road the old level terrace has contact with the river cut scarp generally rising 20 to 30 feet from the Active Flood Plain. The surface is quite flat having imperceptible slope of about a foot per mile. Examination of several pits and trenches reveals that the material has distinct calcareous zone with kinkers' and 'Molluscan fauna' in moderately fine textured material. It may have been deposited under very different climatic and geologic environments possibly in the late pleistocene times.

Flood records of the last 100 years and field evidence shows little or no signs of reworking of these deposits by floods or river. With the introduction of perennial irrigation and extensive cultivation, levelling for roads building construction all the micromorphological features have been completely obliterated.

Old Basin and Channel Fills

This landform is generally found within the old level terrace at a slightly lower level in the form of broad and elongated shallow channels and depressions which are intricately linked with each other. It appears that these depressions are somewhat younger, and probably resulted due to flow and collection of runoff from the old level terrace. During the rainy season these areas collect large amount of water which either percolates into the ground or is lost by evaporation.

Severely Eroded Land

All along the confluence of the old level terrace and the active flood plain, is a zone of uneven topography where severe soil erosion has developed. Due to a difference of 20 to 30 feet in elevation between the two landforms runoff from the old terrace level passes with high velocity and produces severe gully and soil erosion. At many places the original surface of soil has been completely removed and only an intricate dendriatic pattern of gullies with residual kanker nodules exists. At places the sediments of old terrace level stand in vertical faces and during rainy season collapse and form fan like deposits at the bottom, which are either removed by flood water or by gully erosion.

Amongst the other causes of this havoc affecting the soils of the city the most important factor is the uncontrolled runoff resulting from torrential heavy rains. The rainfall pattern is seasonal; about 2 3 being received as torrential rains during the period from middle of July to middle of September and the remaining 1/3 as light showers during the months of December, January and part of February. The major damage is caused by the summer (or monsoon) rains when sometimes more than 6 inches of rain are received within 24 hours. Partly due to high intensity of rainfall and partly because of poor management of land, most of the water from those rains flows down-slope as runoff, carrying away thousands of tons of topsoil during the process and thereby proving to be the fore-runner of destruction by gully formation and depletion of soil.

The main soil texture in most of the built up and surrounding area, with the exception of active flood plains, is silty clay loam with clay contents ranging from 3% to 10%. Microtopography low water holding capacity and lack of vegetation cover are some of the other contributing factors to soil erosion.

The soil erosion of Lahore is a problem which has become aggravated through the use of land by men. The construction of roads, railways tracks, canals, buildings and haphazard mining of sand and mud from the areas lying in the urban orbit of Lahore has developed a break in natural surface slope. In most of the cut and fill areas of the city the soil erosion causes an extensive damage and becomes a severe problem.

Hydrology

The city of Lahore is drained by the river Ravi which enters Pakistan near the village Auliapur in Sheikhupura district, from village Lcogil then curving south westwards it flows between Shahdara and the city of Lahore. Ravi, though one of the smallest of all the rivers of the Indus basin yet, from the point of view of floods, it is the most troublesome. In its reach from Ravi Syphon to Shahdara, a stretch of 20 miles, it has a slope of 0.117 feet per 1000 feet, and from Shahdara to Balloki a stretch of 60 miles its slope is 20 feet per 1000 feet. The catchment of Ravi river and its tributaries lies in India and the local rainfall at Lahore has no effect in producing floods. Figure No. 2 shows the runoff at Shahdara bridge for 95 years, along with yearly rainfall of Lahore. It can be seen that total yearly rainfall has no correlation with the individual flood peak. In 1882 the highest rainfall recorded was 37.43" and it produced one of the smallest peaks of 67,200 cusecs at Shahdara, where as highest peak discharge of 5,42,000 cusecs was recorded when the rainfall totalled 22.62 inches. With the melting of snow in the catchment area the discharge in the river gradually starts rising from March and reaches its maximum in monsoon season.

The peripheries of Lahore have repeatedly suffered from floods, bank erosions, and the changing of its course. During the Mughal period, the river flowed adjacent to the Badshahi Mosque and the Fort, during the same period Baradari of Kamran was located a few miles from the right bank of the river. In Emperor Aurangzeb's time the Ravi threatened the city on the north eastern side and four miles long brick protective bund was constructed, by the orders of the Emperor. Though the dyke of the Mughal period today has completely disappeared, still some of its remnants can be seen.

The Ravi now flows to the north, but during the Sikh and early British period the river ran by the city and over what its now Riwaz Garden by the Chauburji on Multan Road..From British period till to date several river training works for flood protection, construction of bridges, for railways and roads, erection of electric and gas transmission lines have been carried out. Now the river in its reach from Shahdara upto the village Badro flows in almost a straight channel. It has now shifted its bank erosion activity a few miles down stream from Shahdara. (Fig. 3 & 4).

Ravi has two prominent discharges which are quite different from each other. It is a graded stream in equilibrium, in which any change in its discharge, bed load, slope, width and depth of channel cause a displacement of the equilibrium in a direction that tends to absorb the effect of change. It is largely engaged in lateral migration, erosion and vertical deposition. With the urban sprawl of Lahore on both sides of river Ravi, the hydrologic environment of the river is constantly changing. It is especially effected by the stabilizations of the river channel near Shahdara to protect the town from flood water, construction of different types of spurs and embankments to protect the bridges, engineering structures and historical monuments, which have constricted the meandering

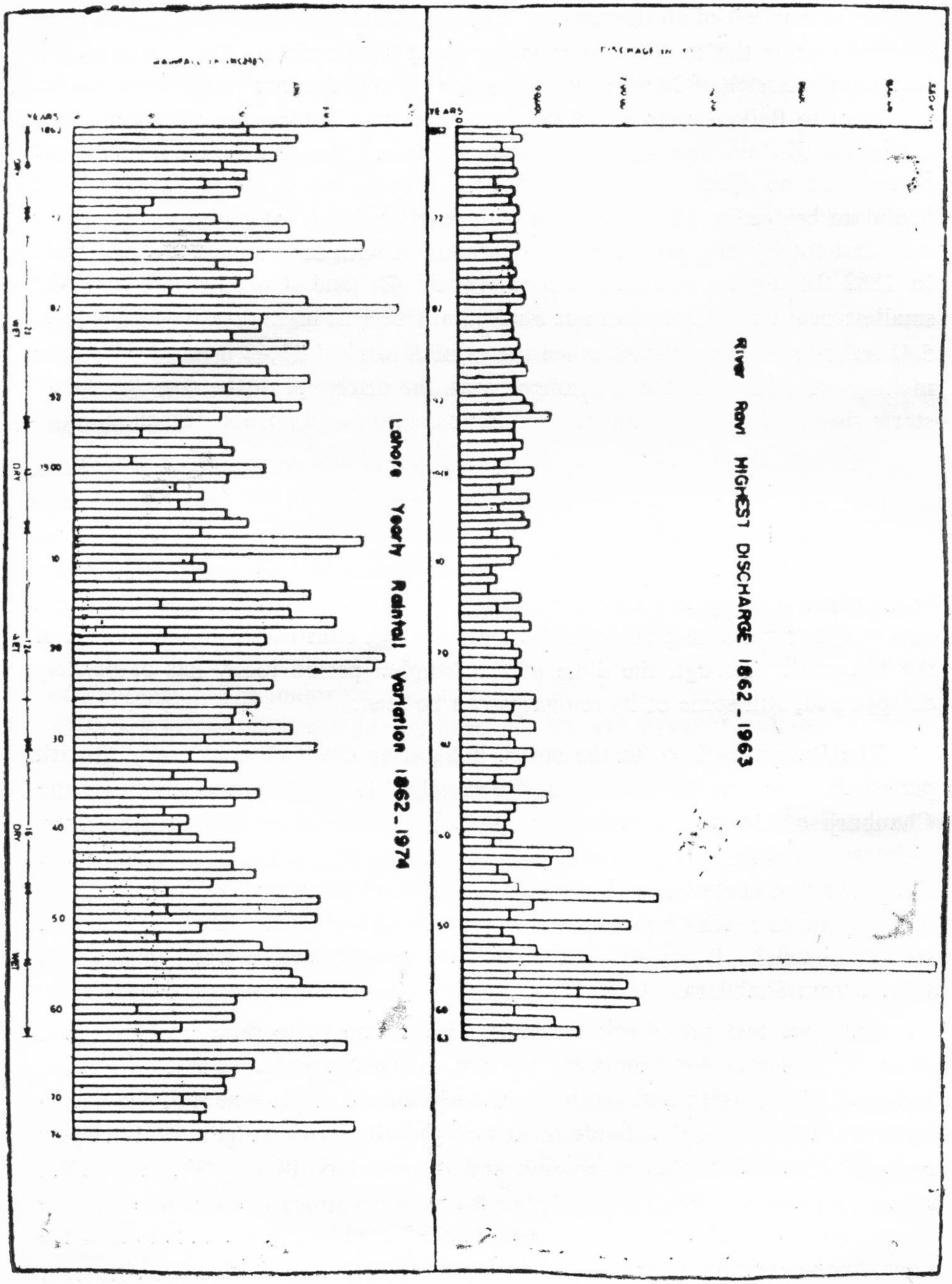

Lahore Yearly Rainfall Variation 1862_1974
River Ravi HIGHEST DISCHARGE 1862-1963

Fig.

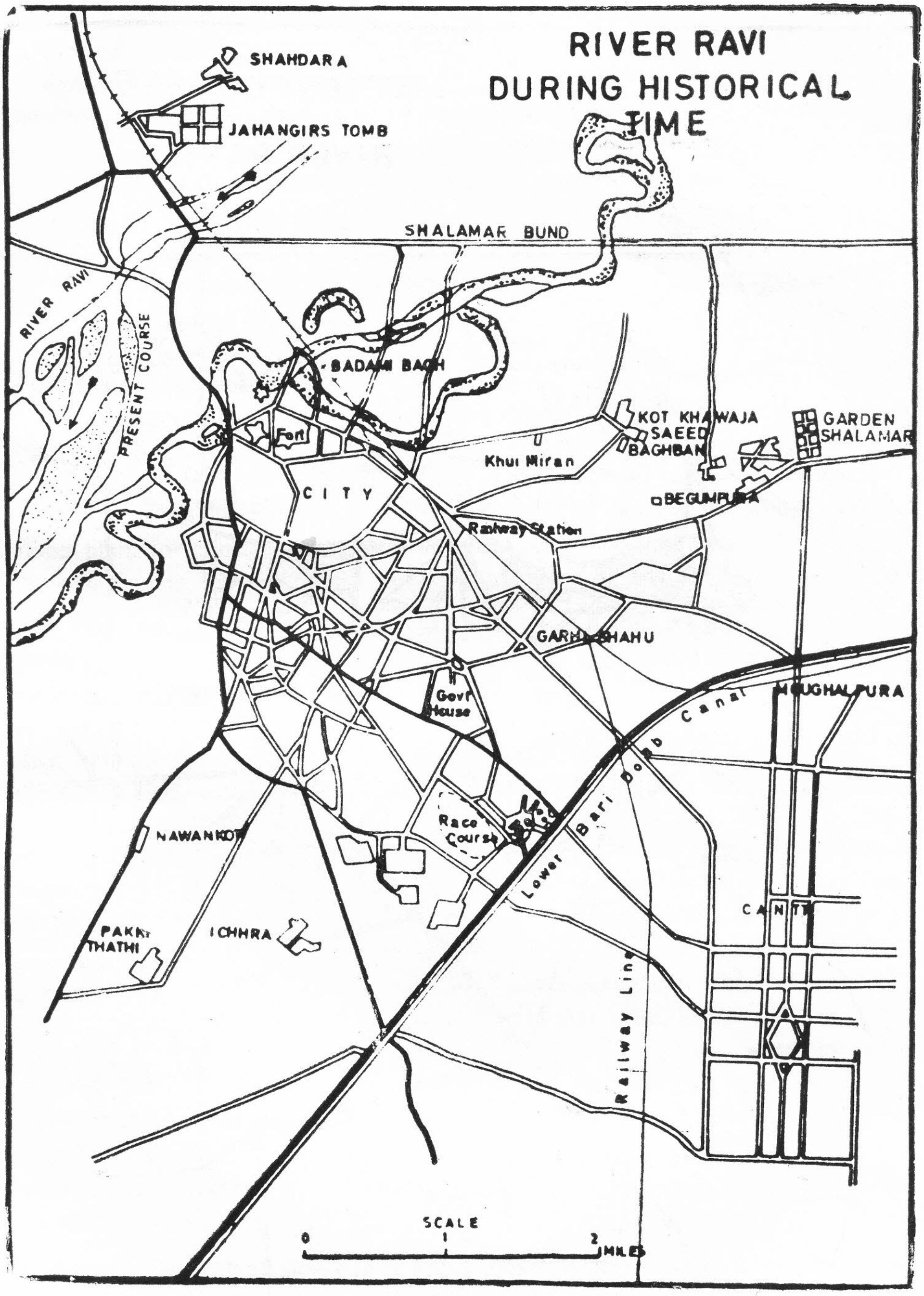

RIVER RAVI DURING HISTORICAL TIME
SHAHDARA
JAHANGIRS TOMB
SHALAMAR BUND
RIVER RAVI
PRESENT COURSE
BADAMI BAGH
Fort
CITY
KOT KHAWAJA SAEED
BAGHBAN
GARDEN SHALAMAR
Khui Miran
BEGUMPURA
Railway Station
GARHI SHAHU
Govt House
MOGHALPURA
Lower Bari Doab Canal
Race Course
NAWANKOT
PAKKI THATHI
ICHHRA
CANTT
Railway Line
SCALE
0
1
2
MILES

Fig. 3

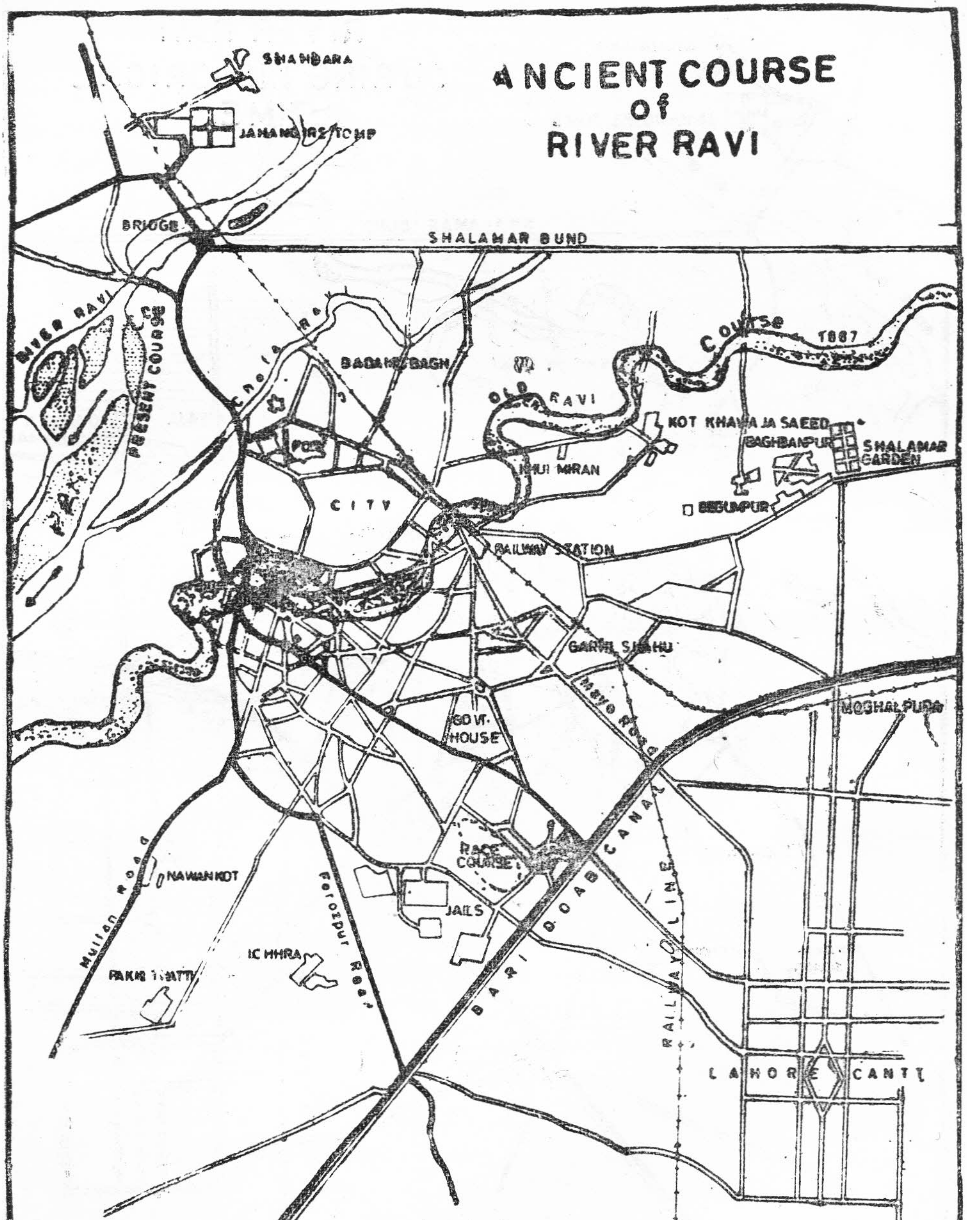

ANCIENT COURSE
of
RIVER RAVI
SHAHDARA
BRIDGE
SHALAMAR BUND
RIVER RAVI
PRESENT COURSE
BAGAH-E-BAGH
OLD RAVI
Course 1887
KOT KHAWAJA SAEED
BAGHBANPURA
SHALAMAR GARDEN
CITY
BEGUMPUR
RAILWAY STATION
GARHI SHAHU
MOGHALPURA
GOVT. HOUSE
Mayo Road
RACE COURSE
BARI DOAB CANAL
RAILWAY LINE
NAWANKOT
Multan Road
Ferozpur Road
JAILS
ICHHRA
LAHORE CANTT
SCALE
1
0
1
Miles

Fig. 4

course of the river. The sudden opening of the river channel in the untrained or partially trained parts of its flood plain has made river violent in bank erosion, downstream from Lahore. Each year the threat of erosion to either bank becomes eminent. Immediate steps to prevent the threatened land are taken by either making new spurs or digging of channels to short circuit the flow of river from its meandering course. The building of spurs channelling of the river diverting in course and mining of sand from active flood plain for construction purposes results in playing a game with its natural regime to which the river tries to adjust in response to the changes brought by man in its course. Today the active river bed is hardly a few furlongs from the densely populated area located to the west of Multan road in the vicinity of the offices of the Soil Survey of Pakistan. The active bed of the river is clearly visible from the Pakistan Soil Survey offices. If the present tendency of the river continues, the Soil Survey office, Multan road and densely populated area along the river across Multan road may be threatened by river erosion in a few years. Channelization, river training, construction in the river bed, securing of burrow material from the flood plain for construction of embankments, mining of sand for the building construction in the city must be weighted against erosional losses of good agricultural land.

Lahore is located in Semi-arid region. Rainfall is by far the most variable element of its climate. Average annual rainfall is 490.22 mm. In some years amount almost half of the total annual rainfall occasionally falls in a single day. Heavy rains, 210.05, 167.8 and 128.5 milimeters were expereinced on 12th July 1953, 15th August 1959 and 24th September 1954, respectively which caused extensive flooding in the city. Seventy percent rain falls from July to September, July and August being the wettest months. Monsoon rainfall in some years cannot be relied while other months may receive heavy rainfall. April, May, June, October, November and December are usually the direct months. Generally monsoon season lasts from mid June to mid September and is characterized by high humidity, reduced evaporation, and considerable increase in cloud cover. Occasional depressions from the east, give four to five days of rain fall, with an interlude a few days of bright sunshine and Muggy weather. The frequency and severity of these storms varies considerably from year to year. During the monsoon season especially after a few rainfalls the ability of the ground surface to absorb precipitation as rapidly as it is falling ceases, rainwater rises to overflow land which is not normally submerged.

Slushy pools of all sizes can be seen on most of city roads. Smaller and less important roads are more pitiable. Pedestrians and cyclists shudder at the idea of going on smaller roads due to splashes of slush water left behind by every passing motor vehicle. Conditions in slums are even worse. During persistent rain spells life becomes still more miserable, especially in low-lying localities where roads became impassable for hours on account of rain flood. Many residential localities such as Samanabad, Krishan Nagar Wassanpura, are cut off from the rest of the city as water flows over roads and streets.

Due to haphazard growth and construction in the city, the material surface conditions for flow of rain water have changed. Large low lying areas which were formerly excavated for years for burrow and constructions material have been encroached by built up area and roads, thus posing serious problems of drainage Fig. 5. The maximum rainfall in Lahore occurs during July and August which may range from 5″ to 20″ and is highly variable.

Single storm may bring 6′ to 10′ of rainfall in 24 hours. On such occasions the sewers, gutters and drains over flow, the roads in low lying areas are under knee deep water, low lying localities like Samanabad, Krishan Nagar, Sant Nagar, Wassanpura, Shad Bagh, Misri Shah, Rehmanpura, Ichhra, Wahdat Colony, Mozang are cut off from each other most miserable is the plight of residents of shack dwelling and the people in places like Krishan Nagar where waist deep water flows through bazar. Depending upon the nature of storm these conditions may prevail from one to three days and some of these more.

The major causes of flooding in the city may be due to ill planned drainage system which are not functioning properly, the drains have lost their original design capacities, and overflow during heavy rains.

(*ii*) Low lying pockets within the city such as the Sabzi Mandi, area south of Shahalmi and Mochi Gate and Mohammad Nagar are too low to drains efficiently into the New Mozang and Civil Lines drainage system. Krishan Nagar, Sant Nagar and Rajgarh have no well developed surface drains and are subject to frequent flooding. The out fall channel of Mian Mir drains has no capacity to carry entire storm water runoff which results in back pondage of water in its upper reaches. The channel of Chhota Ravi is inadequate to carry the drainage of area lying between G. T. Road, Railway and the south of bund. No adequate drainage system exists for Ichhra, Rehmanpura and Shah Jamal.

The fast growth of the city with its changing land water use has affected its environment to a great extent.

Major changes in land and water use in recent past

1. Decrease in flow of water in river Ravi as a result of diversion of water by India.
2. Decline in ground water level due to accessive pumping for water supply.
3. Great increase in volume of sewerage disposed to river Ravi.

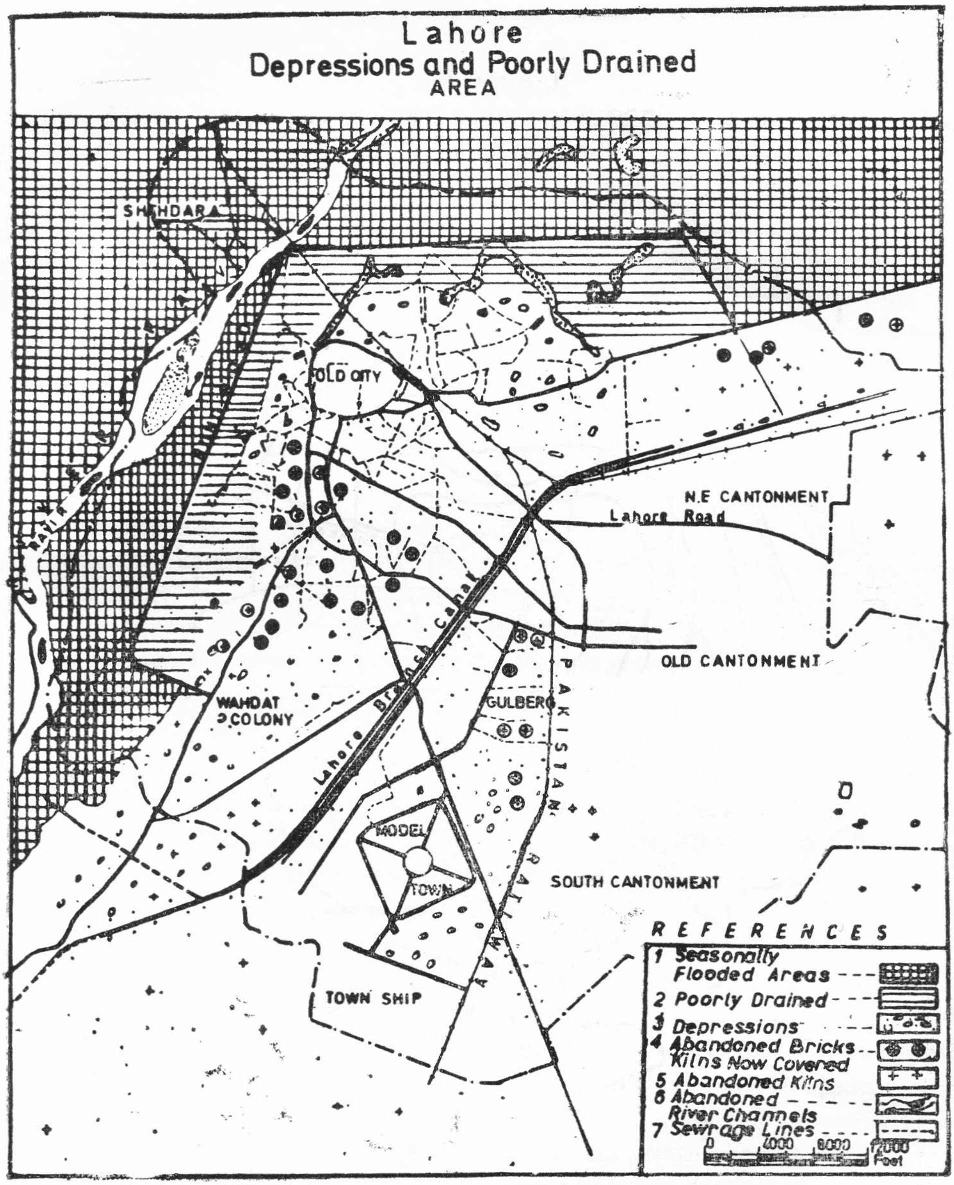


Fig. 5

4. Increase in reuse of sewerage water in agriculture within urban orbit of Lahore.
5. Increase in pollution of groundwater due to accessive infiltration from leaky and open channel sewers and septic tanks.

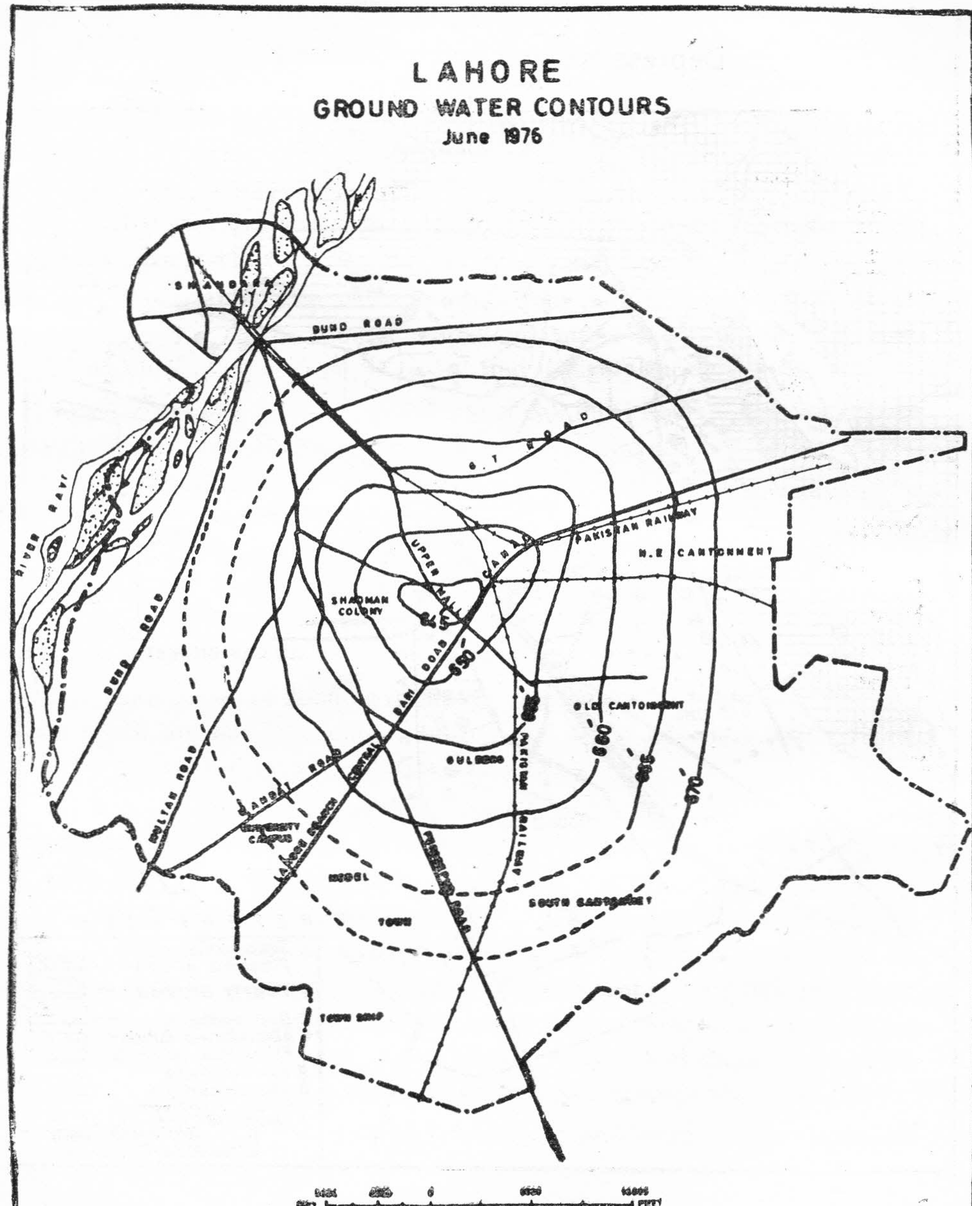


Fig. 6—(a)

6. Great sprawl of scattered city type houses with limited water and sewage facilities.

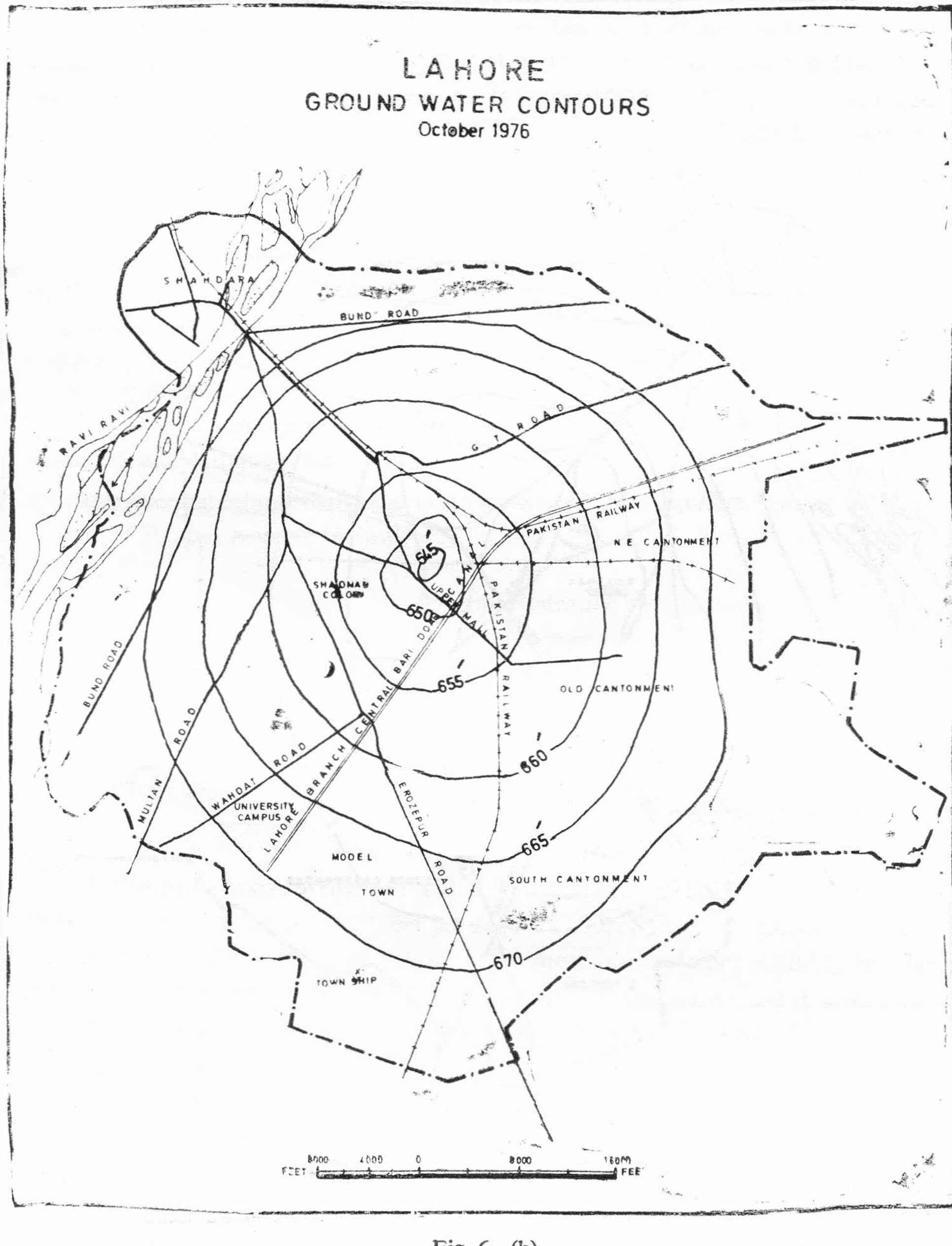


Fig. 6—(b)

7. Large increase in number of houses, roads, streets and paved areas.
8. Numerous river training works on Ravi near the city.

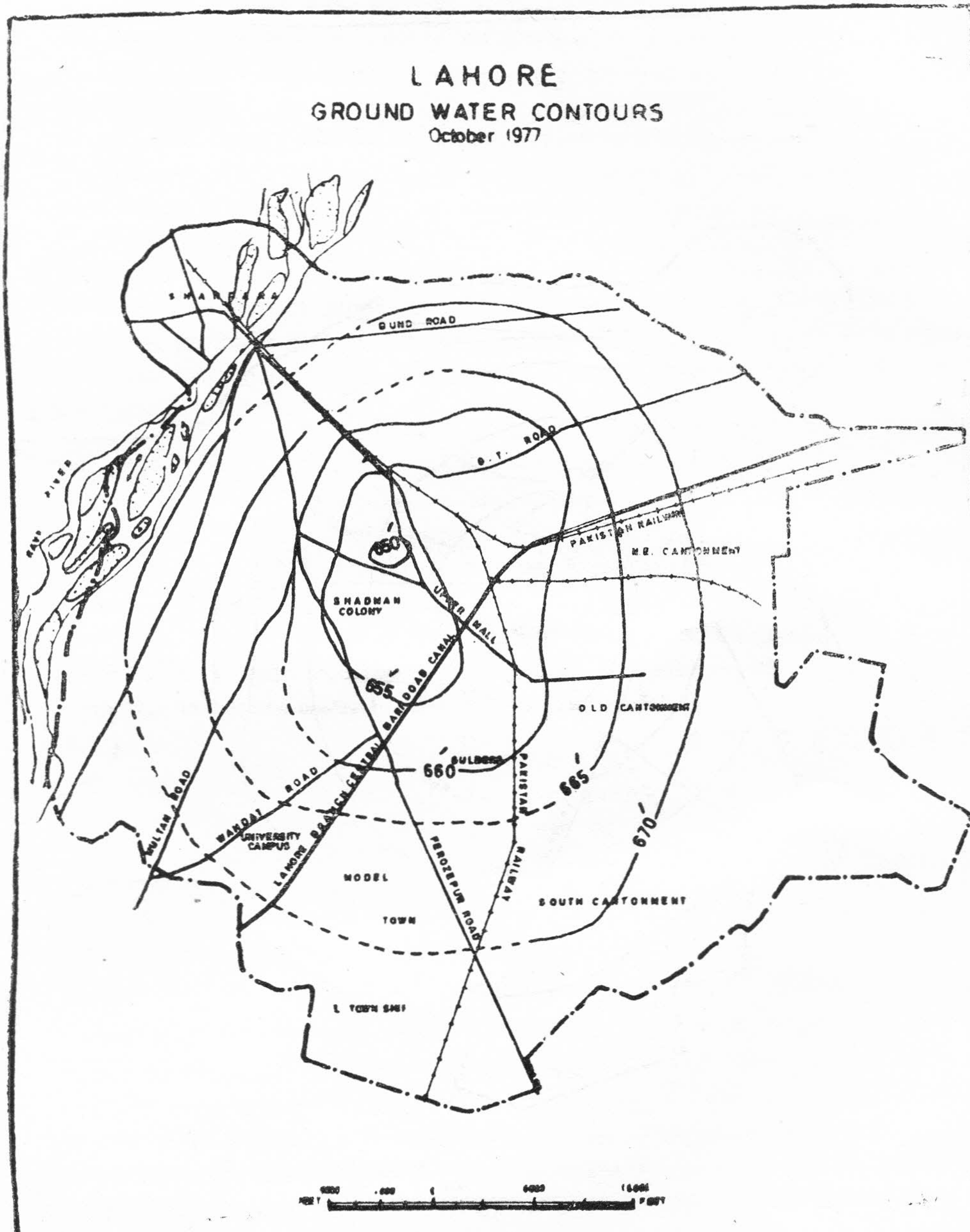


Fig. 6—(c)

9. Increase in the solid waste burial in low lying areas of the city and its use as manure in the urban agricultural lands.

After 1970, India according to Indus Waters Treaty diverted the water river Ravi. Today the river above Lahore has an average discharge of 400 cusecs over three ten days periods for the past six years. During low flow period practically all the river discharge is used up at Madhopur in India and there is practically little contribution of water from its catchment area lying in Pakistan. The flow in the river consists entirely of seepage from the adjoining ground water reservoirs and from the city sewerage disposal into the river.

Since the withdrawal of water of river Ravi, recharge into the Lahore aquifer seems to have been gradually declining. The lowering of groundwater may also be attributed to increased pumpage of water due to increase in the population, expansion in industry and greater demands for recreation and gardening purposes and diminishing of recharge from Ravi to the ground water aquifer Fig. 6. At present the available groundwater data of Lahore is incomplete and inadequate.

The average lateral hydraulic conductivity of 141 aquifers tests in different Doabs of Punjab is given below:[1]

Doab	Lateral Hydraulic conductivity
Rachna Doab	0.0032 feet per second
Chaj Doab	0.0038 feet per second
Thal Doab	0.0033 feet per second
Bari Doab	0.0021 feet per second

In 19 aquifer tests carried out within 75 kilometers of Lahore. The average hydraulic conductivity is .0027 feet per second. Dr. Spiegal comments on these values as rather too high, and "chose as its most probable permeability for the entire alluvium a value of 0.0016 feet per second".[2] On conversion it works out to a transmissivity of 362,000 U.S. Gallons per day per foot, which is less than 25% less than a value of 0.0027.

"Dr. Spiegal, however, appears to disagree strongly with the methods of analysis of the pumping tests which has been used by the USGS. Dr. Spiegal refers in one place to a transmissivity of 200,000 gpd/ft and in another place to a

1. CAMP, Dresser & Mckee Limited draft interim report No. 3 part I Water Supply, Sewerage and Drainage in Lahore, 1975, p. 4.

2. Gordon D. Bennett, Ata ur-Rehman, Ijaz Ahmad Sheikh and Sabir Ali, analysis of Aquifer Tests is the Punjab Region of West Pakistan, U. S. G. S. Water Supply Paper No. 1608-G Washington 1967.

109,000 gpd/ft as being more reasonable figures than those imputed from the U.S.G.S. reports".

The study of U.S.G.S. Water Supply Papers 1608 H, 1708, G, 1608 T and 1662 D shows that the fears expressed by Dr. Spiegal regarding the deminishing recharge into Lahore aquifier from river Ravi are somewhat exaggerated. During rainy season and flood flows, the aquifer is replenished by infiltration from the river, canals and surface runoff.

Greenman and his Co-workers have estimated that in Punjab rainfall infiltrates into ground water only when the rainfall exceeds 10 to 14 inches a years. There are many poorly drained areas in Lahore, like Krishen Nagar, Misri Shah, Santnagar, Budha River. Where stagnant waters remain standing for quite some time after the rainy season is over, are likely to replenish the ground water to some meager extent.[1]

The lack of detail geohydrological data the relationship between river Ravi and recharge into Lahore alluvial aquifer cannot be precisely established. Unless more detail geological, ground water, studies are carried out, the future availability of potable water in the city cannot be safely predicted. The study on the alternative and supplementary surface water supply would also prove beneficial.

Excreta and Solid Waste Disposal

It has been estimated that about 2,000 tons of solid waste accumulates in the city every day. The data on the type of refuse collected and disposed ward wise does not exist. It is believed that major components of the solid waste is human excreta, waste paper polythene bags, rags, waste food and vegetables. Although the Municipal Corporation has provided separate garbage and filth collection depots throughout the city, in practice both human excreta and garbage are dumped together by the sweepers, who make collection from house to house and carry it in baskets or baskets on their head. The entire operation is offensive, often the sweepers sprinkle filth on their way to filth depot or open Corporation trucks and bullock carts carry the refuse to dumping grounds. Dumping grounds for solid waste disposal are not sanitary at all, only one located near seventh mile stone on Multan Road operated in the past where 100 trenches of 40 feet by 8 feet and about three feet deep existed, this ground has also been abandoned. The dumping is carelessly done and thousands of tons of garbage is left on the open ground and is not properly placed in the trenches for composting. A major portion of the raw solid waste is irregularly lifted by local agriculturist who use it as manure in adjoining urban agricultural land irrespective of soils and geological, and ground water conditions prevailing there.

1. Greenman D. W., Swargenski and G. D. Bannet Groundwater, Hydrology of the Punjab, USGS Water Supply Paper No. 1608H.

There are no geologic considerations in the disposal of solids and Municipal water in Lahore. Solid waste landfill accumulation is not compacted with a layer of earth each day so that leakage of gases and fluids takes place by chemical and biological action and escape into the atmosphere and ground water system. It becomes breeding ground for insects and rodents. The pollution potential of Landfills is high as it contains high percentage of organic matter in addition to inorganic constituents. No consideration is given to physical stability of the refuse in terms of its compaction as decomposition advances. No survey for geological and geohydrological parameters of the site such as porosity permeability of the alluvium in which it is located is carried out. Neither the upper surface of the fill is protected from wind, rain and insects and scavengers which spread pollution to far off places. The solid waste used as fertilizer in agricultural fields around Lahore almost creates the same problem as the insanitary landfills. The author carried out a reconnaissance study of hand pumps and private tube wells in the active flood plain and poorly drained areas and found water from these sources containing chloride in excess of 300 mg/1 and trace amount of nitrogen (Nitrite) both of which indicate pollution.

Quality of Water

The quality of ground water in Lahore is controlled largely by its geology, climate and the length of the time the water has been in contact with the alluvial sediments. The greater the distance water moves underground, the greater is the chance to dissolve minerals from the alluvium. Most tube wells in Lahore intercept water that has been in contact with the aquifer for only a short period of time. Wells which are generally drilled deeper, yield more mineralized water that has been in contact with the aquifer for a longer period of time. With the enormous expansion of the city greater and deeper development and use of ground water shall continue. Increased reuse of water, and encroachment by man, movement of saline water from neighbouring zones will further increase chances of ground water quality deterioration.

The River water, upstream of Lahore, and ground water from Lahore aquifer have low mineral concentration and are good for domestic use and for irrigation.

There are certain substances which, if present in supplies of drinking water at concentration above certain levels may be hazardous to health. The following discussion on the quality of groundwater in Lahore is based on the work of Shamsi and Hamid.[1] Most of the active flood plain and the areas which have been under Ravi in relatively recent geological time have salts less than 500 ppm

1. Shamsi, R. A. and Hamid Abdul, *Quality of Groundwater Bari Doab, Basic Data Release*, WASID, WAPDA, Lahore, 1960.

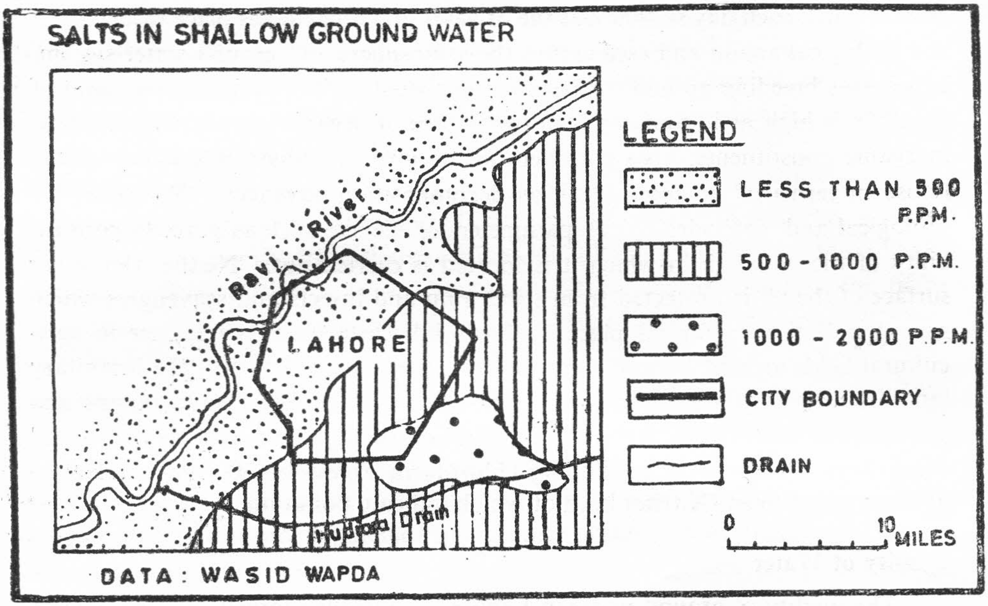
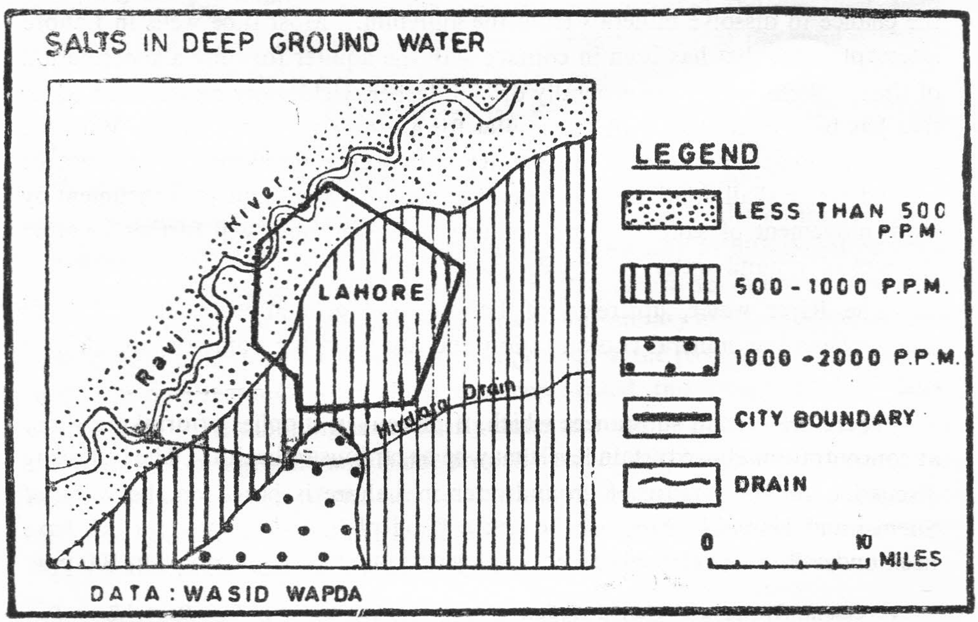

SALTS IN SHALLOW GROUND WATER
Ravi River
LAHORE
Hudiara Drain
LEGEND
LESS THAN 500 P.P.M.
500 - 1000 P.P.M.
1000 - 2000 P.P.M.
CITY BOUNDARY
DRAIN
0 10 MILES
DATA : WASID WAPDA

Fig. 7


SALTS IN DEEP GROUND WATER
Ravi River
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LESS THAN 500 P.P.M.
500 - 1000 P.P.M.
1000 - 2000 P.P.M.
CITY BOUNDARY
DRAIN
0 10 MILES
DATA : WASID WAPDA

Fig. 8

in shallow ground water. The areas lying to the southeast of the cantonment in the proximity of Hudiara drain have 1000 ppm to 2000 ppm salts (Fig. 7) Whereas the deep ground water is concerned the active flood plain areas have less than 500 ppm of salt. In most of Lahore the range of salt in deep ground water varies between 500 ppm to 1,000 ppm. (Fig. 8).

It is only in the extreme south, that an elongated belt in which water quality ranges from 1,000 ppm to 2,000 ppm exists. Another belt of 2 000 ppm to 4,000 ppm lies about 8 miles south of the Hudria drain. A narrow belt of more than 4,000 ppm, lies in the middle of the Bari Doab. World Health Organizations recommendations for drinking water is 500 ppm as the highest desirable level and 1500 ppm as the maximum permissible level of the total dissolved solids. A re-survey of the ground water quality especially in the south and south east of the city is essential to conclude whether the ground water is fit for human consumption if the city is to expand in this direction. Ground water recharge studies in this area shall also be required to ascertain that pumping of ground water shall be replenished by recharge and ground water.

Water Pollution

The chemical and bacteriological quality of deep ground water is good and harmless. However shallow ground water in low lying areas around river Ravi where sewerage water is disposed is polluted and contains both bacteriological and chemical pollutents. The horizontal and vertical movement of polluted water depends upon on infiltration capacity and permeability of soil and underlying sediments. Studies carried out in different parts of the world confirm that the contamination from excreta disposal system tends to travel downwards until it reaches, the shallow water table, then moves along with the ground water flow across a path which increases in width to a limited extent before gradual disappearance. The California State Water Pollution Control Boards publication[1] show that bacteria can be transported upto 100 feet from a recharge well in 33 hours, and that the chemical pollution travels twice as fast. It appears that no such studies have been carried out in Lahore. However, widespread diseases such as typhoid, paratyphoid fevers, dysentery, infant diarrhoeas, hookworm and many intestinal infections in areas exploiting shallow ground water by handpumps, and water wells indicate that some relationship exists between shallow ground water pollution and these diseases. The incidence of these diseases increases during monsoon season when local infiltration due to rainfall, runoff, irrigation and seepage from sewerage channels increases considerably.[2]

1. Wanger E. G. Lanoix, N. J. Excreta Disposal for several area and small communities, 1058, Monograph Series No. 30, p. 29.

2. California State Water Pollution Central Board (1954), *Report on the Investigation of Travel of Pollution*, Sacraments, Calif, (Publication No. 11).

Since there are large number of sanitary sewers, unlined sanitary drains and poorly drained areas containing sewerage water, leakage from them has resulted in pollution of shallow ground water in unplanned, parts of the city. The areas of polluted ground water are generally located around the open seweiages and poorly drained area. According to a rough estimate still twenty-five per cent of the people residing within the municipal areas have to rely on water fiom handpumps drawing water from shallow ground water sources. Handpumps water samples from many localities like Ichhra, Sant Nagar, Misri Shah, and in villages located in the urban orbit of Lahore were examined, most of them give a distinct odour and taste. An extensive of research is required to study the ground water pollution in the city of Lahore. So far no consistent effort has been made in this direction.

The problem of ground water pollution is likely to become more acute as the sewerage service does not exist for all the settled areas. The present system of sewerage disposal is inadequate and insanitary. Large part of the city untreated sewerage is diverted by farmers in the active flood plain areas for growing vegetables which are sold in the city. Vegetables from these fields are thoroughly polluted. If taken in raw condition many possibly cause diseases of stomach and intestines. Most of us are in the habit of eating raw tomatoes, cucumbers, onions, green pepper, mint, carrots and salad. It is advisable at least to dip such vegetables in boiling water for few minutes before serving them.

A picture of the existing conditions shows that the Areas which have well planned drainage systems are not functioning properly because the drains have lost their original capacities due to siltage or blocking. This condition is found throughout the Mian Mir drainage system. Low lying pockets within the city which are too low to drain freely into the New Mozang or the Civil Lines drainage systems. These are the Sabzi Mandi, areas south of the Shahalmi and Mochi Gates and the Mohammad Nagar area east of Railway Headquarter officers. Low lying areas to the west of the city which are lower than normal level of the city, have no well developed surface drains and are subject to frequent flooding. These are Sant Nagar, Krishan Nagar and Rajgarh, areas flooded because of inadequate storm drainage channels. An example of this condition is the outfall channel of the Mian Mir Drain. The section from Multan Road to the bund is not sufficient to carry the discharge. In consequence storm water locks up in the channel and the upperreaches cannot discharge freely. The Chhota Ravi drainage area lying to the south of the bund and north of G. T. Road and the Railway, properly developed drainage system. The channel of Chhota Ravi itself is blocked in many places by cultivators and the outfall channel to the bund is inadequate. Newly developed residential areas to the south of Mian Mir Drain such as

Samanabad, Ichhra, Rahmanpura, Shah Jamal and Wahdat Colony. No drainage system has been built for these areas and the mature drainage is poorly developed. Rain water stands in local depressions until absorbed by the ground or evaporated by sun. Finally a broad area south of the city extending towards Hudiara Drain towards which Greater Lahore is expanding, only natural drainage channels exists as yet in this area.

Conclusion

Urbanization of Lahore continues to increase. Large areas of land are being converted to urban use, which involves considerable changes and modification of the natural environment of its geological, geomorphological and hydrological characteristics. In some cases these changes have created situations which effect the urban dweller of Lahore.

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THE POST-WORLD WAR II IRANIAN INDUSTRIAL ECONOMY

HASAN GARANEJAD*

Although there was insufficient industry to support Iran's economy before World War II, in some parts of the country there were a few small industries. Some had no economic value, some closed because of foreign competition. Even agricultural production was carried on by antiquated and inefficient methods, resulting in importation of even such key grains as corn, rice, and wheat. After World War II, the victorious allies dumped their surplus goods and armaments into the Iranian economy, worsening the situation.

In the last few years, however, Iran's economic leadership have realized that a sound, geographically informed economic system could eliminate Iran's dependence upon foreign goods and make it one of the most developed countries of the Middle East.

Iran has a wide range of climates which have different agricultural uses; rainfall varies greatly from north to south, and from east to west, as does temperature, as shown below:[2]

Place	Latitude	Average January Temperature (°C)	Average Precipitation (mm)
Tabriz	38°, 0.8′	—10.8	283
Astara	38°, 26′	4.2	1372
Gurgan	36°, 51′	8.7	560
Mashhad	36°, 16′	—15.8	270
Ahwaz	31°, 20′	11.5	235
Abadan	30°, 22′	11.5	170
Shiraz	29°, 36′	4.7	350
Kirman	30°, 15′	3.2	135
Zahedan	29°, 28′	4.9	77.5

The land of Iran has an interesting distribution of structural and morphological qualities. Twenty million hectares of land, 12.1% of Iran's territory, is composed of alluvial soil suited to a variety of agricultural uses. Seven per cent of this land saw use before World War II, and this figure has now risen to 11%.

Mining has even greater potential; high quality deposits of copper, chromite, iron, lead, manganese, zinc, barite, sulfur, and coal are readily available.

One of the most important and best developed mining industries of Iran is of course petroleum, production of which increased 50% between 1920 and 1940.

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Production has further increased since World War II due to increased exports and domestic demands:

Year	Production of Crude Petroleum (million tons)
1928	5.5
1930	6
1940	8
1950	32
1960	51
1970	191
1974	301

Refineries in Abadan have also greatly expanded operations, in that prior to World War II only four petroleum products could be produced there, now the whole range may be produced. Last year, refineries have been built in Kermanshah, Tehran, Shiraz, and Tabriz, and petro-chemical factories have been operating in Iran for the last few years. These developments have led to a 374% increase in Iran's income from oil over the last ten years.

Year	Petroleum Income (million dollars)
1934	6.47
1940	12
1950	—
1955	96
1960	303
1965	549
1968	800
1970	1,136
1974	17,400

Since petroleum is cheap, other energy sources are relatively undeveloped. Before World War II high quality coal was mined in the Elborz Mountains and used locally. After the war, however, coal production has increased to supply the needs of sugar, cement, textile, and other industries. Between 1958 and 1964, coal production increased 15% to 77,000 tons. With the establishment of the iron and steel mill in Esfahan, Kerman's coal production has reached one million tons per annum. White coal has come into use since 1961, such that now 3.5 milliard kilowatt-hours energy is obtained from this source.

Before World War II, the Denmark Krupp Corporation had contracted to establish an iron and steel mill in Iran, but this project could not be realized owing to Germany's defeat. In 1967 the U.S.S.R. began construction of a

600,000 ton annual capacity iron and steel mill in Esfahan in exchange for Iranian natural gas. This mill began production in 1972, and will come to employ 10,000 workers.

Before World War II transportation in Iran was primarily a matter of animals, coaches, wagons, etc., but subsequently automobile industries have been developed. In about 1957 the first jeep assembly plant was established. Now 70% of Iran's spare parts and 85% of its whole motorized vehicles are made in Iran.

A construction industry has sprung up over a brief period. For instance, prior to the World War II there was only a single cement factory with a capacity of 300 tons per diem. Following the war, modern building designs and construction methods increased the need for cement. Now, 12 cement factories with a capacity of 16,000 tons per day produce more than 5.5 million tons of cement annually, which in turn promotes the use of modern construction methods.

The change in agriculture following World War II is very pronounced. Land reform, the foundation of industrial co-operatives, use of chemicals, importation of machinery, and dam construction has accounted for a 25% increase in agricultural production since the war.

Industrial production has likewise developed. For instance, prior to World War II 38 textile mills existed with a capacity of 60 million meters annually. In 1966, however, there were 680,000 spindles and 15,000 looms producing cotton and synthetic cloths, and 75,000 spindles and 850 looms producing woolens. The capacity of these mills was as follows:

Utilized Capacity of the Textile in 1966

Branch of Industry	No. of Mills	No. of Spindles	No. of Looms
Cotton and Synthetics	54	650.000	14.200
Wool	10	40.000	720
Silk	1	90 machines	—
Jute	3	2,290	262

In 1966 cotton production reached 380 million meters, of which 320 million were produced by mills, the rest coming from hand mills. In the same year, production of woolen textiles and blankets totaled 8.5 million meters. Together, they show a 43% increase in the years 1940-1966, and employment in textiles has risen from 15,000 to 55,000 in that period, distributed as follows:

Branch	No. of Employees
Cotton and synthetics	46,310
Wool	8,216
Jute	1,624
Silk	265
Total:	56,415

It should be noted that the above figures refer to permanent workers only. Temporary workers and those engaged in agriculture and animal husbandry, producing raw materials for the mills, are not included.

The sugar industry is likewise developing. Before World War II, 8 factories produced 19% of domestic needs, 35,000 tons annually, but now 34 factories produce 75% of Iran's needs.

The carpet industry maintains its importance in Iran, representing 20-25% of the value of Iran's exports, excluding petroleum. In 1940, Iran received 120 million rials from carpet exports, and in 1975, carpets brought in 1 milliard rials while employing 243,000 people.

Changes such as that in the Urban-rural distribution of the population have been provoked in Iran by industrialization. In 1956, 68% of the population lived in villages, but increased industrial employment has lowered this figure to 61% in ten years' time, during which urban population rose 7%. This growth has affected the cities and prompted the development of new urban centers.

Urban development over the last 15 years has instigated the execution of projects such as drinking water and sewage systems, electrification, street-asphalting, slaughter houses, flood control, and public baths. These have been among the most successful developments in Iran's economic expansion. A town development programme has given a complete face-lift to some 300 Iranian towns and brought about basic changes in the lives of their residents.

The following figures should indicate the advancements made in transportation: Before the World War II, Iran had 25 km. of asphalt road and 12,000 km. of earth road. Vehicles were few, motorized vehicles much fewer yet, a very unpromising condition for industrialization. In 1968, by contrast, Iran had 7,670 km. of asphalt road, 24,653 km. of earth road, and 2,000 km. of other, substandard roads. Railroads have likewise expanded, from 1896 km. total before World War II, to 3507 in 1968, and 5000 km. now, 14% increase since 1968.

Iran lacked good harbours, or income from harbours, prior to World War II, but this factor gained importance after the war. Good harbours now exist at Khorramshahr, Shahpur, Busher, Kjark, Bandar Abbas, Bandar

Pahlavi, and Bandar Shah, and there is a transportation company in the Persian Gulf.

Air transportation has also developed, with 3,000 air passengers annually prior to World War II increasing to 11,000 in 1953, and, with the advancements of industry and greater need for such transportation, 1,000,000 people in 1975.

Thus, tremendous developments have been made in Iran since the World War II through aplication of a sound programme of industrialization based on the geographic strengths of the country.

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MONEX
THE MONSOON EXPERIMENT

MUHAMMAD RAHMATULLAH*

1. Introduction

The Global Atmospheric Research Programme GARP is one of the most ambitious programmes of international cooperation in the field of meteorology undertaken by the World Meteorological Organization WMO in conjunction with the International Council of Scientific Union ICSU. The purpose of the programme is to understand:

(*i*) The behaviour of the atmosphere and the large scale fluctuations which control changes of weather;

(*ii*) The factors that determine statistical properties on the general circulation of the atmosphere which would lead to better understanding of the physical basis of climate.

The World Meteorological Organization is planning the First GARP Global Experiment FGGE in 1978-79. Before undertaking this Global Experiment it is planned to have a few Sub-Programmes.

Monex Sub-Programme

The First Sub-Programme known as GARP Atlantic Programme GATE was successfully undertaken over the Atlantic Ocean in the summer of 1974. The data from the GATE Experiment have been analysed and published by WMO in GATE Reports.

The Monsoon Sub-Programme forms an important component of GARP. The present plans provide for a 2-phase approach to the implementation of the Sub-Programme. The First phase would consist of a series of field experiments designed to provide experience and expertise for the main MONEX programme proposed to be conducted in 1978-79. Initially a joint Indo-Soviet Monsoon Experiment ISMEX was conducted over the Arabian Sea in 1973. This experiment yielded much valuable data which are now being processed. Another experiment of the series called MONEX-77 was undertaken in 1977 to provide further experience for the main MONEX 1978-79. The Joint GARP Organizing Committee GOC at its Plenary Session in Tokyo in October 1975 had proposed that an experiment in 1977 be carried out for both the summer monsoon, May-July, as well as the winter monsoon, November-December.

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Large-Scale Aspects of Monsoon

The Asia, Europe and Africa continents constitute the largest land mass which affects the planetary global circulation. The monsoon experiment Monex is designed to develop a better scientific understanding of the major features of the large-scale circulation pertaining to the following:—

(*a*) Summer Monsoon.
(*b*) Winter Monsoon.
(*c*) Orographic Studies.
(*d*) Oceanographic Process.

To undertake the Numerical Experiment Programme it is necessary to devise an adequate data management system for the acquisition, processing, dissemination and achieving of the data planned to be obtained during the experiment for achieving its full utilization for research purposes.

The ambitious Monex Programme aims in solving the problems associated with the occurrence, maintenance and decay of the monsoon. The Programme for International Cooperation comprises the following aspects:

(*a*) Study of the synoptic situation over the monsoon region and its variations in time and space;

(*b*) Understanding of the mechanism of the large scale and regional monsoon circulation and the process resulting in its variation;

(*c*) Development of techniques for forecasting the various features of the monsoon circulation;

(*d*) Development of Models of Numerical Weather Prediction.

Regional Aspects of Monsoon

It is generally accepted that the seasonal atmospheric response to the presence of the huge Asia, Europe and Africa land mass is the basic cause of the monsoon. In order to understand the energetics of the phenomenon one has to deal with the atmospheric-ocean-land system as a whole. It would, therefore, be desirable to construct joint Ocean-Atmospheric models capable of reproducing seasonal inter-annual variations of the monsoon.

For studying the regional aspects of the monsoon circulation it is necessary to have a denser network of observations in the cyclogenetic region of the North Bay of Bengal and the East China Sea, over Eastern Arabian Sea and along the Somali Coast in the region of low level strong winds. The main components as decided by JOC of the scientific programme for Monex are given below:—

(*a*) *Summer Monsoon:*

(*i*) Arabian Sea Studies;
(*ii*) Monsoon Disturbances;
(*iii*) Onset of Monsoon-active and break periods;
(*iv*) Inter-action of monsoon circulation and other circulation regimes;
(*v*) Mean Heat Sources and their variations.

(*b*) *Winter Monsoon*

(*i*) Cold Monsoon Surges;

Monex Observing System

The Monex experiment would utilise the surface-based and space-based global observation system developed under the World Weather Watch WWW Programme with additional observations planned in the scientifically sensitive areas. The space-based system comprises the polar-orbiting satellite capable of providing profiles of temperature and moisture and high resolution pictures of the cloud cover. The geo-stationary satellites will be launched by the USSR and in conjunction with the Japanese and US satellites would provide cloud winds at 850 and 200 mbs levels.

The equatorial ship network, carrier balloons and aircraft drop-wind-sonde systems would provide detailed wind data over the equatorial Indian Ocean. The drifting buoys and the carrier-balloon system of the southern hemisphere would provide data over the south Indian Ocean. For the Arabian Sea an augmented radiowind and Pibal network over Somalia coasts and in the nearby islands is required. It is also proposed to have stationary ships and buoys and aircraft probes of the Somali Jet during May and June.

Over the northern Bay of Bengal it is proposed to have a closer network of stationary ships in addition to coastal stations for probing 3-dimensional structure of the monsoon disturbances during May-June and July.

It is proposed to have stationary ships, buoys and aircraft probes over East China Sea during May-June and to activate island and coastal stations in and around South China Sea. It is further proposed to augment the rainfall network over the Malaysian peninsula, Indonesian regions and Tibet for the study of heat budget of the monsoon region.

For investigating the structural features of strong north-east monsoon surge originating from an intense anti-cyclonic cell over Siberia and northern China a special regional programme is to be worked out.

The augmented network as discussed above should enable meteorologists to study the inter-action of the monsoon circulation with the southern hemi-sphere, mid-latitude westerly waves of the northern hemisphere and with the Pacific Circulation Systems. The various components of Monsoon Experiment

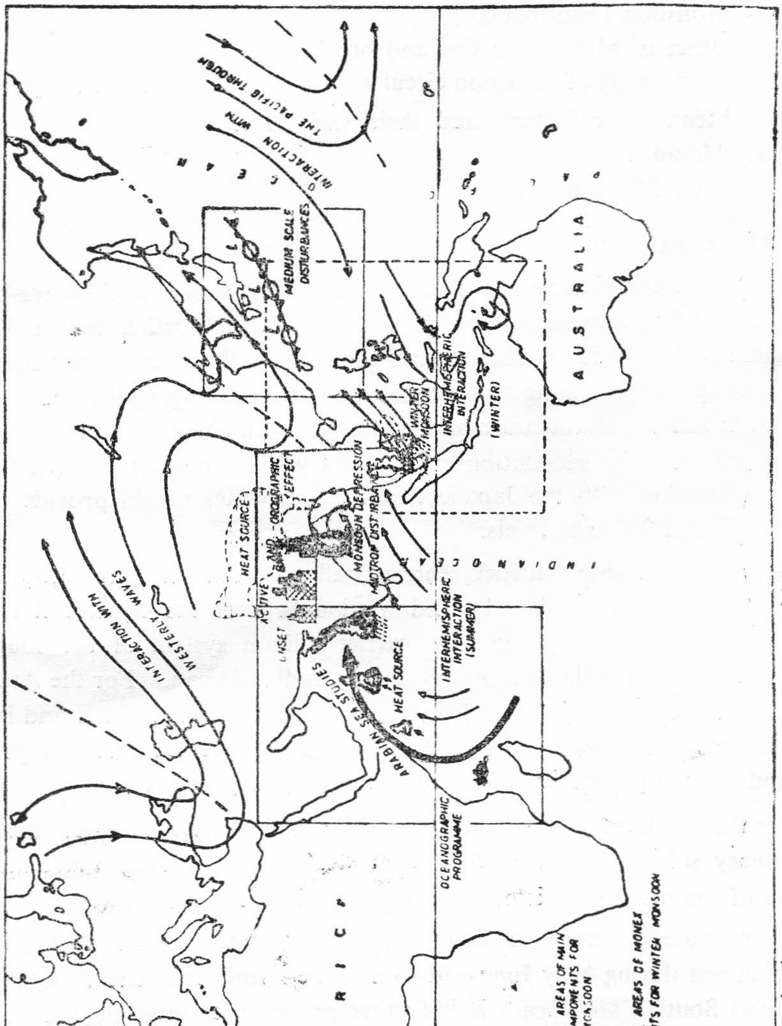

Fig. 1

are illustrated in Fig. 1. As the voluminous data collected during the Monex experiment should result in a consistent data set of initial state parameters, it would be necessary to establish two data collecting and processing centres over the region.

Monex—77

A planning meeting for MONEX-77 was held in Colombo in April 1976 to which all countries in the general monsoon area were invited by the World Meteorological Organization. This experiment would provide the necessary expertise and experience for the full MONEX 1978-79. A tentative plan calls for deployment of six ships from USSR for simultaneous observations over the Indian Ocean and the Arabian Sea. Five of the ships will act in formation along a parallel and a meridian, the central ship being at their centre, whereas the sixth ship would take simultaneous observations at special location.

In the first stage the ship proceeded from near the equator along 70° East on to the port of Bombay from 8th to 12th May 1977. They then proceeded to the centre of the Arabian Sea for the initial phase of the monsoon in the last week of May to the first of June, 1977. Thereafter the ships shifted to a site near 10°N and 55°E to study the intensive development of the monsoon. In the 3rd stage the ship formation was located around 15°N and 70°E in the second to third week of July in the eastern part of the Arabian Sea. The sixth ship shifted during all the three stages to suitable locations for taking simultaneous observations in conjunction with the five ships formation.

For studying the winter monsoon a 6-week programme commencing about the middle of November 1977 was planned. The additional observations would cover an area bounded by 20 S and 10°N and longitude 60°E and 110°E.

Third Planning Meeting on Monex

The Third Planning Meeting on Monex was held in New Delhi from 28th February to 3rd March, 1977, which reviewed the various components of the programme. A committee was formed for this purpose and its recommendations for opening of new observatories to augment the present network of meteorological stations were approved. Japan, USSR and India informed the participants of the programme of launching Artificial Earth Satellites in 1978 as part of the monsoon observational programme. The French delegate presented the programme for launching constant level balloons for upper air studies. It was also decided that under Monex two planning centres will be established one in New Delhi for the summer monsoon and the other at Kuala Lumpur for the winter season.

Pakistan Meteorological Department has been made responsible for operating seven Rawin-Sonde observatories and to take upper wind and temerature observations twice daily for the Monex intervals. Pakistan is also required to establish a Radio-Wind observatory at Panjghur. Besides, Pakistan Meteorological Department is to operate four weather radar stations and five solar radiation observatories. Pakistan is also required to establish two ground stations for receiving cloud pictures from artificial weather satellites.

Numerical Experimentation Programme

Numerical Experimentation Programme would play an important role in Monex as it would provide a powerful tool for studying the principal machanism of the monsoon circulation and understanding the main features which control its variations. The observations during Monex may contribute to improve numerical models. The experience gained by the experimental prediction based on extensive data collected over the Monex area would be the ground for an operational system of short-range and medium-range numerical weather prediction.

URBAN HIERARCHY IN COVENTRY*

MOHAMMAD ASLAM KHAN**

This paper attempts to analyse the varying retail distribution within the city of Coventry. The study is primarily based on the central place theory which relates the purpose, frequency and length of shopping trips to a hierarchy of service centres.

Although many studies have identified a hierarchical pattern of service centres making use of identical or different techniques in the same or widely separated cities of the world, yet there is hardly any agreement on the structural orders designated or their grading. In three independent studies of Chicago for example—Berry,[1] Simmons,[2] and Garner,[3] produced three different classifications of shopping centres. Alternative ranking of service centres in British cities by Smailes,[4] (London), Carruther,[5] (London) Weekely,[6] (Nottingham). Thorpe & Rhodes,[7] (Tyneside Conurbation), and Mcevoy,[8] (Manchester) also produced different results in terms of ranks, hierarchical orders, and frequency specification of service centres (See Tables I & II). From the varying results

TABLE I.—*Frequency Specification of Service Centres in British Cities.*

LONDON (Smailes-1961)		LONDON (Carruthers-1962)		NOTTINGHAM (Weekley-1956)	
Grades	Frequency	Grades	Frequency	Grades	Frequency
1	2	3	4	5	6
A	12	A	1	A	4
A-	21	3a	8	B	4
B	17	3b	21	C	2
B-	28	3c	34	D	6
C..	27	4a	42	E	18
C	75	—	—	F	8

*This Article is based on Ph.D. Thesis Work carried out at Birmingham University U.K. Data was collected in 1970-71.

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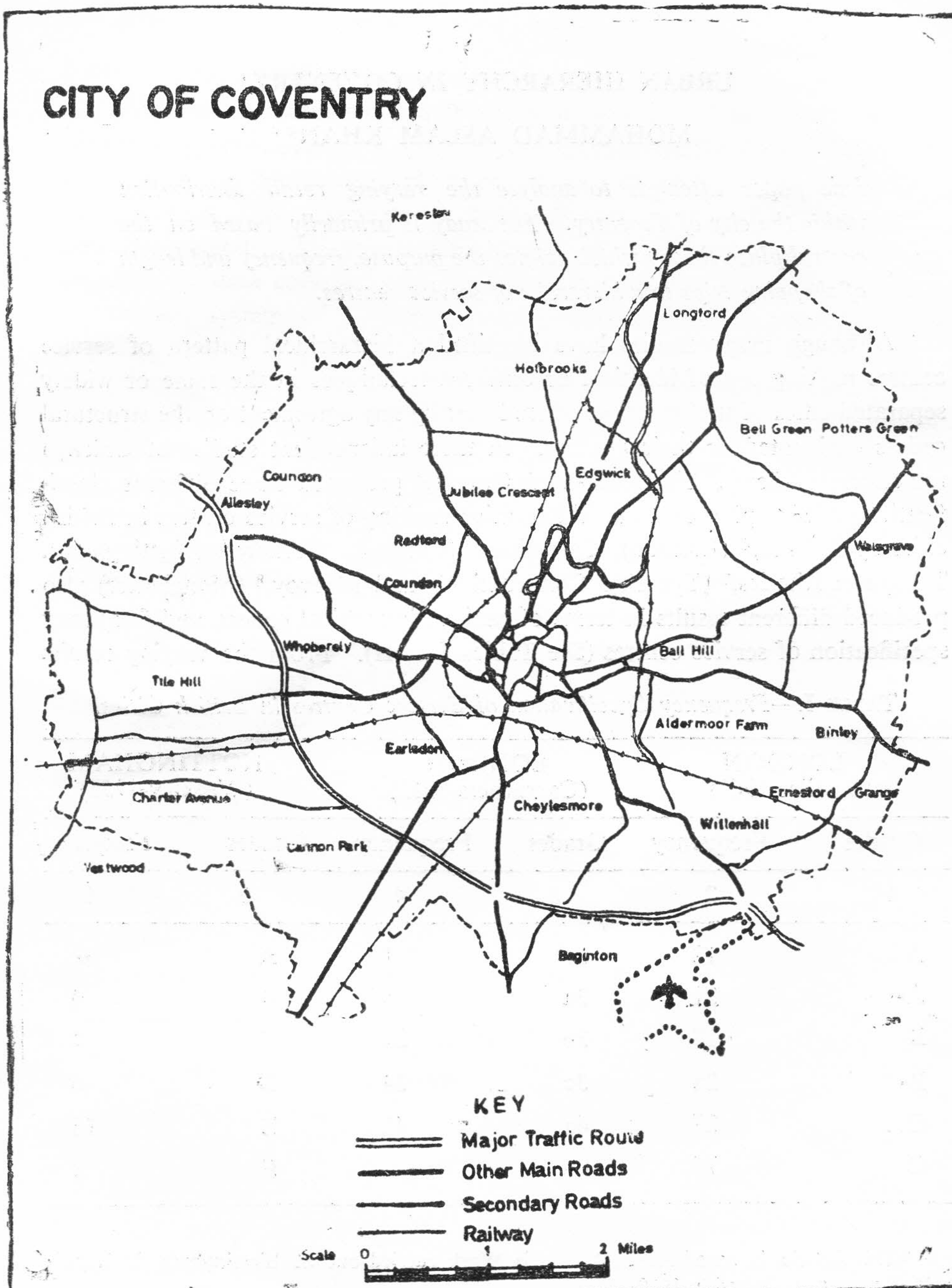
CITY OF COVENTRY
Longford
Holbrooks
Bell Green
Potters Green
Coundon
Allesley
Jubilee Crescent
Edgwick
Radford
Walsgrave
Coundon
Whoberely
Ball Hill
Tile Hill
Aldermoor Farm
Binley
Earlsdon
Ernesford
Grange
Charter Avenue
Cheylesmore
Willenhall
Cannon Park
Baginton
KEY
Major Traffic Route
Other Main Roads
Secondary Roads
Railway
Scale 0 1 2 Miles

TABLE II.—*Relative Rankings of Centres in Manchester Conurbation by Five Different Methods* (*Mcevoy*-1968).

Centres	Ranks by Methods				
1	2	3	4	5	6
	A	B	C	D	E
Manchester	1	1	1	1	1
Bolton	2	2	2	2	2
Ashton-Under-Lyne	4	4	4	7	6
Oldham	3	3	3	4	4
Stockport	5	5	6	3	3
Rochdale	6	6	5	5	5
Bury	7	7	7	6	7
Middleton	8	9	8	9	9
Stretford	9	8	9	8	8

produced in these and other classifications, it was felt that some procedure should be followed which may be able to take into consideration all or majority of variables of different classifications to give a balanced pattern of grouping. A cluster analysis technique was used for this purpose in this study. The work has been divided into two parts. The first part classifies the shopping centres using varying data and techniques and compares their results while the second part concerned with the cluster analysis, synthesises the results of other classifications, thereby producing a final grouping of centres. The technique also analyses the magnitude of variables in each order of centres.

Retail Distribution and Delimitation of Shopping Centres

The distribution of shopping facilities within Coventry has three main features (Fig. 1). Firstly, there is the nodality of the central area with an intense concentration of shops. Then there are strings of shops forming the suburban nuclei along the main arterial roads. The third and most important feature is the wide divergence between densities of shopping facilities in the inner areas (railway triangle) and outer fringe of the city. This is not only related to a difference of population but also to a number of socio-economic variables as well as the historical growth of retailing in the proliferation of secondary and corner shops in the older areas of the city.

There are some 3498 shops in the city (including banks and betting offices). More than 2850 of these shops are located in groups of three shops or more. The distribution of all such groups alongwith the proposed ones is shown in

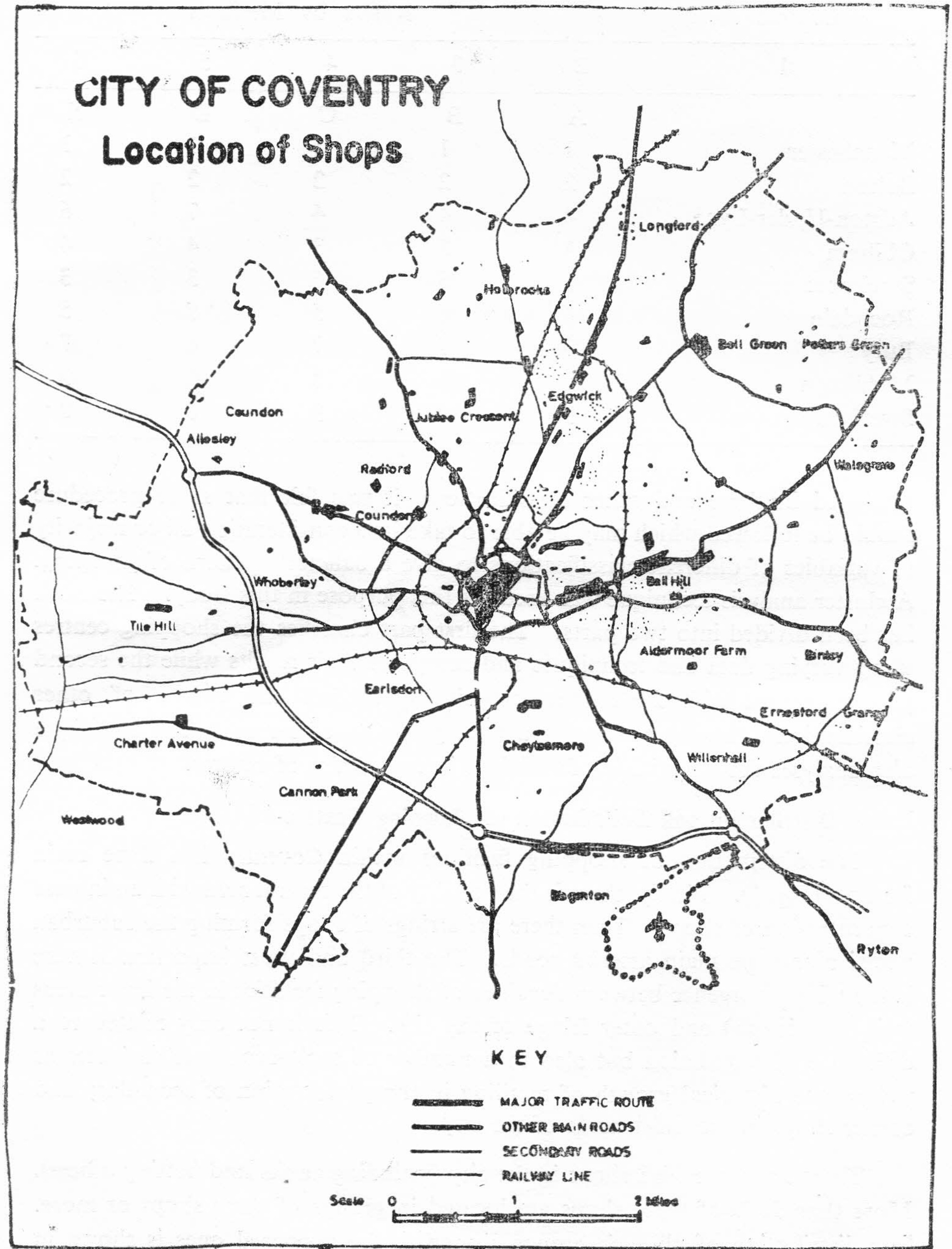
CITY OF COVENTRY
Location of Shops
Longford
Holbrooks
Bell Green
Potters Green
Edgwick
Coundon
Jubilee Crescent
Allesley
Radford
Walsgrave
Coundon
Whoberley
Bell Hill
Tile Hill
Aldermoor Farm
Binley
Earlsdon
Ernesford Grange
Charter Avenue
Cheylesmore
Willenhall
Cannon Park
Westwood
Baginton
Ryton
KEY
MAJOR TRAFFIC ROUTE
OTHER MAIN ROADS
SECONDARY ROADS
RAILWAY LINE
Scale 0 1 2 Miles

Fig. 1

Fig. 2. This map was compared with the Coventry development plan map 1966. The shopping clusters shown on the later map had a much better qualitative level in the sense that most of them had a share in the distribution of cooperative stores, post offices, supermarkets and/or grocery multiples. It is worth noting, however, that the map omitted* a centre like the Butts with as many as ten shops. These observations and further field studies led the author to include all service centres shown on the development plan map and also those which had ten shops or more but were omitted from the said map for some reason. The study thus covered 97 shopping centres including the Central Area, omitting about 995 shops (28.7%) which occurred either in very small clusters or street corner locations. Although such shops stock numerous items (in fact Wilfred Burns[9] listed no less than one hundred and seventy items) they hardly constituted a service centre by themselves.

Every centre was delimited by field observation. The delimitation of planned centres (Bell Green, Tile Hill and Willenhall) did not present any problems because strict segregation here kept shops isolated from other functions at ground floor level. The same was more or less true of some unplanned centres such as jubilee Crescent and Walsgrave Road (Forum). Some difficulty, however, was involved in defining ribbon extensions or string street developments such as Foleshill Road and Holbrook Lane. Delimitations in these cases were carried out with the utmost care in the field and if establishments near to a centre conformed with the general character of the main body, they were included as part of that instead of forming an unsatisfactory centre by themselves. For example Earlsdon Street Albany Road area. In contrast to this, long drawn out centres like Foleshill Road with several separate nodes had to be split in more than one part.

Collection of Data

All retail establishments and a selected number of services were included in this analysis. Neither car showrooms, garages, cinemas or theatres nor offices (with the exception of banks and post offices which have very strong affiliation with retailing) were included in the data. Information on type of shop, floor area and retail employment were collected through a questionnaire circulated by the Planning Department at Coventry in 1970. The response rate was as high as 93%. The remaining 7% non-respondents were covered by visual assessment in the field and cross-checked against the existing sample. The data thus defined was collected for 97 service centres including 2503 retail and service establishments.

*This omission represents the future policy of the Planning Department.

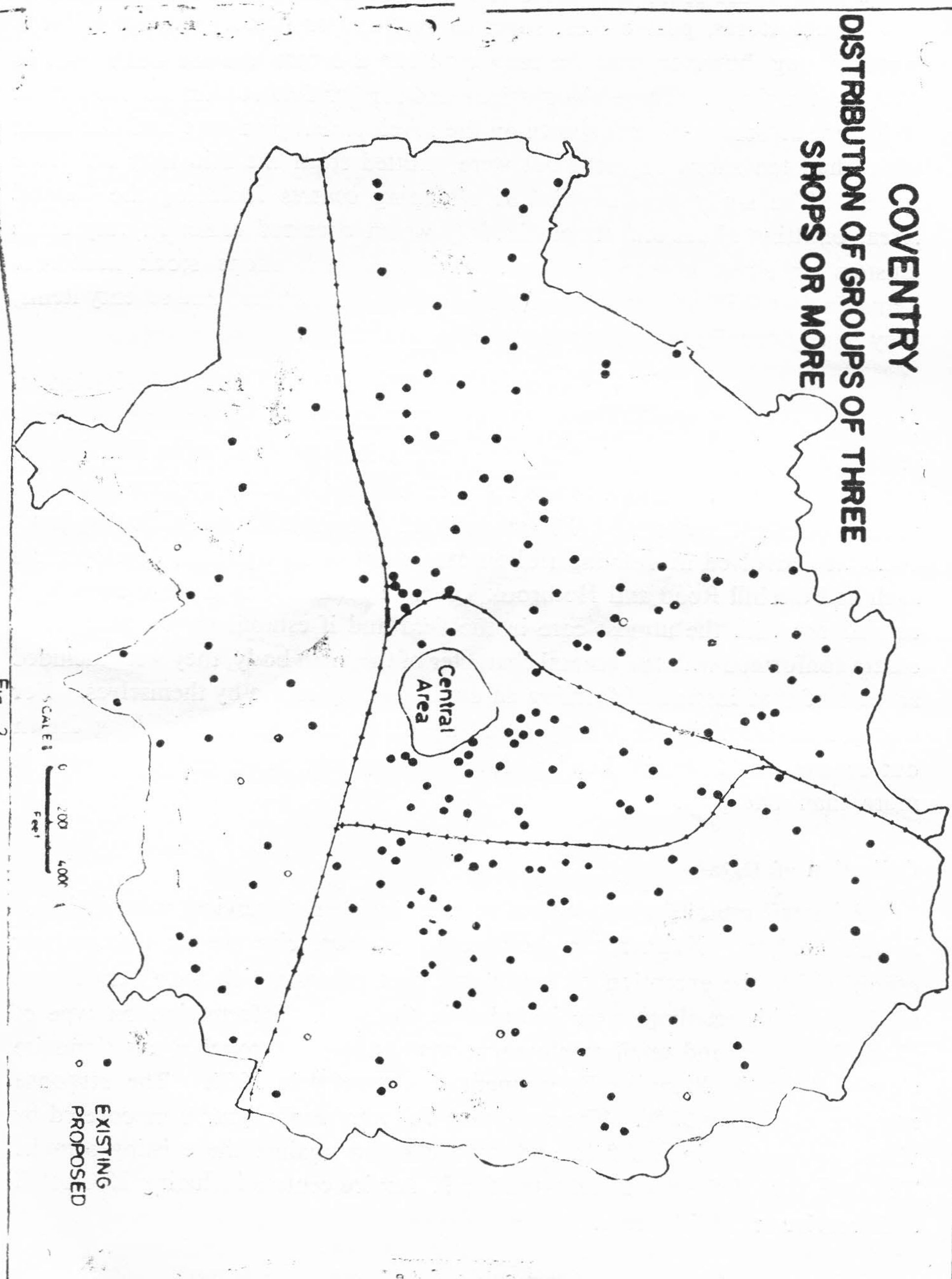
COVENTRY
DISTRIBUTION OF GROUPS OF THREE SHOPS OR MORE
Central Area
SCALE
0
4000
Feet
EXISTING
PROPOSED

Fig. 2

Analysis of Data

The range of classification techniques used in this study are as follows: —

1. Size/function method.
2. Size/floorspace method.
3. Size/employment method.
4. Multiple store method.
5. The points system.[10]
6. The chain store or Haydock method.[11]
7. Index of centralization method.[12]
8. Cluster analysis.

Of the first three methods, the size/function method is the simplest and crudest measure of centrality. It consists of adding all the establishments that are found in a central place. The totals which provide a measure of the status of a centre are then plotted on a dispersion diagram to see if any relationship between the size in terms of number of establishments and position in the hierarchy could be distinguished. In size/floorspace and size/employment method, the number of establishments is replaced by total floorspace and total full time employment in each centre respectively.

In the remaining methods,* the classification of service centres is based on the distribution of multiple chains or selection of indices. One of the most important problems in using multiple stores as a variable is that there is no way of finding whether similar chains attract customers to the same extent or they attract the same type or class of customers.

It may be argued that these considerations are unimportant as far as the overall distribution of shops is concerned, but at the level of the smaller centres, these factors of personal choice and individual likes and dislikes may become quite important. Indeed, a much bigger problem arises when the same weighting is given to a city multiple as to a national multiple but then allocation of points and selection of indices is equally subjective and arbitrary.

Although this problem has not been solved entirely in this study, consideration has been given to alternative methods to cover several possibilities.

In the following four techniques, the first deals with the overall distribution of multiple shops in each centre, while the second is based on the selection of chain stores (Haydock method).[13] The remaining two methods have been based on the allocation of scores by point system of west Midland Shopping study[14] and Index of Centralisation[15] method devised by Rhodes and Thorpe respectively.

*With the exception of cluster analysis.

The multiple store method utilised simply the distribution of all kinds of multiple stores (National, Regional and City Multiples) which are now a characteristic feature of even small shopping centres. Only nine centres were excluded from this classification because they did not have any facility of this type. The point system in all excluded seven centres, index of centralisation thirty-seven centres and Haydock method eighteen centres, which failed to get any score in the respective techniques because of lack of required facilities.

Comparative Assessment

The seven techniques of classification discussed in the foregoing account based on different assessment of shop size and key service facilities showed certain similarities but there are many differences between them as illustrated by the following table:—

TABLE III.—*Frequency Specification of Shopping Centres by Different Methods.*

No. of Shops	Floor space	Employ-ment	M. Store.	Index of Centrali-sation	Point system	Haydock Method
1	2	3	4	5	6	7
1	1	1	1	1	1	1
5	4	6	5	7	8	11
91	2	4	9	8	20	10
	2	7	73	9	36	20
	15	13	—	35	25	37
	73	66	—	—	—	—

The classification by number of shops did not produce any clear grouping. The floorspace method produced more subdivided but less balanced classification. In the remaining five techniques, Haydock method, point system and index of centralisation produced five groupings each but with different frequencies of shopping centres.

Cluster Analysis

Cluster analysis is a mathematical method of classification which has been applied in a number of fields, particularly biological taxonomy.[16]

By this method, a measure of resemblance or similarity is computed between all possible pairs of objects being classified; the objects then are linked progressively to form groups, by the criterion that the average similarity between members of the same group is greater than the average similarity between members of different groups.

The R mode clustering in this study has related each variable with the other variables while the Q mode has related each shopping centre to the other centres. The relationship between variables is shown in Table IV, while the linked groups of shopping centres is shown in Fig. 3, where each pair of observation and subsequently groups are joined together on the basis of similarity coefficient.

The main feature which emerges from the R mode clustering is that the seven variables* are very closely co-related as shown in the following table:—

TABLE IV

	No. of shops.	Floorspace.	Employment (F.T.)	Employment (P. T.)	Index of Centralization	No. of Multiples.	Point System.
No. of shops	1.000						
Floorspace	0.906	1.000					
Employment (F.T.)	0.957	0.977	1.000				
Employment (P.T.)	0.750	0.874	0.856	1.000			
Index of Centralization	0.939	0.918	0.953	0.857	1.000		
No. of Multiples	0.885	0.923	0.940	0.910	0.954	1.000	
Point System	0.790	0.836	0.835	0.798	0.838	0.866	1.000

The significance of correlation coefficient as found by t test is more than 99.5 for 94 degree of freedom.

The analysis of shopping centres (Fig. 3), produced four groups of centres (apart from the Central Area**). These four levels of shopping centres, the average structure of which is shown in Table V, can be referred as District (A). Neighbourhood (B) Local (Ca) and Convenience (Cb) Centres.

It can be seen from the Table V (based on R mode clustering that the average magnitude of every variable varies with the order of centres for example the centres of first order have all the variables higher than the second order centres and so on. There is, however, a certain amount of overlap in the range of variables between various groups of centres (see the range of shops in the first and second order centres).

Having identified the four orders of centres by cluster analysis, it remains now to analyse two further aspects of central place theory. The first concerns the distribution of the actual centres at different levels in the hierarchy while the

*The variable did not include any element of the Haydock method because the results were not in the form of scores. The remaining six variables were supplemented by a part time employment factor not included in any method used so far.

**The Central Area was excluded from the analysis because its inclusion distorts the variable relationships.

TABLE V.—*R-mode Cluster Analysis showing the Structure of Shopping Centres*

Centres Variables	Ist Order Average	(A) Range	2nd Order Average	(B) Range	3rd Order Average	(Cb) Range	4th Order Average	(Ca) Range	Total Centre Average	Total Centre Range
No. of shops	77.70	34.126	23.64	17-47	12	4-28	6.97	2-13	20.33	2-126
Floospace (sq. ft.)	77176	34356-124500	20294	10757-29328	7242	2439-14759	3737	1623-6612	15378	1623-124500
Employment (F. T)	210.72	112.309	65.21	40-91	25.19	6-72	12.55	5-24	46.53	5-309
Employment (P. T.)	76.40	42-134	25.79	9-61	12.56	1-25	5.21	0-14	18.92	0-134
No. of Multiple Stores	22.04	12-32	9.13	5.6-13.4	2	0-7	.76	0-3.74	4.75	0-32.4
Index of Centralisation on (Points)	29.90	18-42	10.79	4-21	4.21	1-11	1.31	3-4	6.93	0-42
Point System	111.22	51-164	49.64	19-69	29.91	3-52	2.59	0-16	33.00	0-164

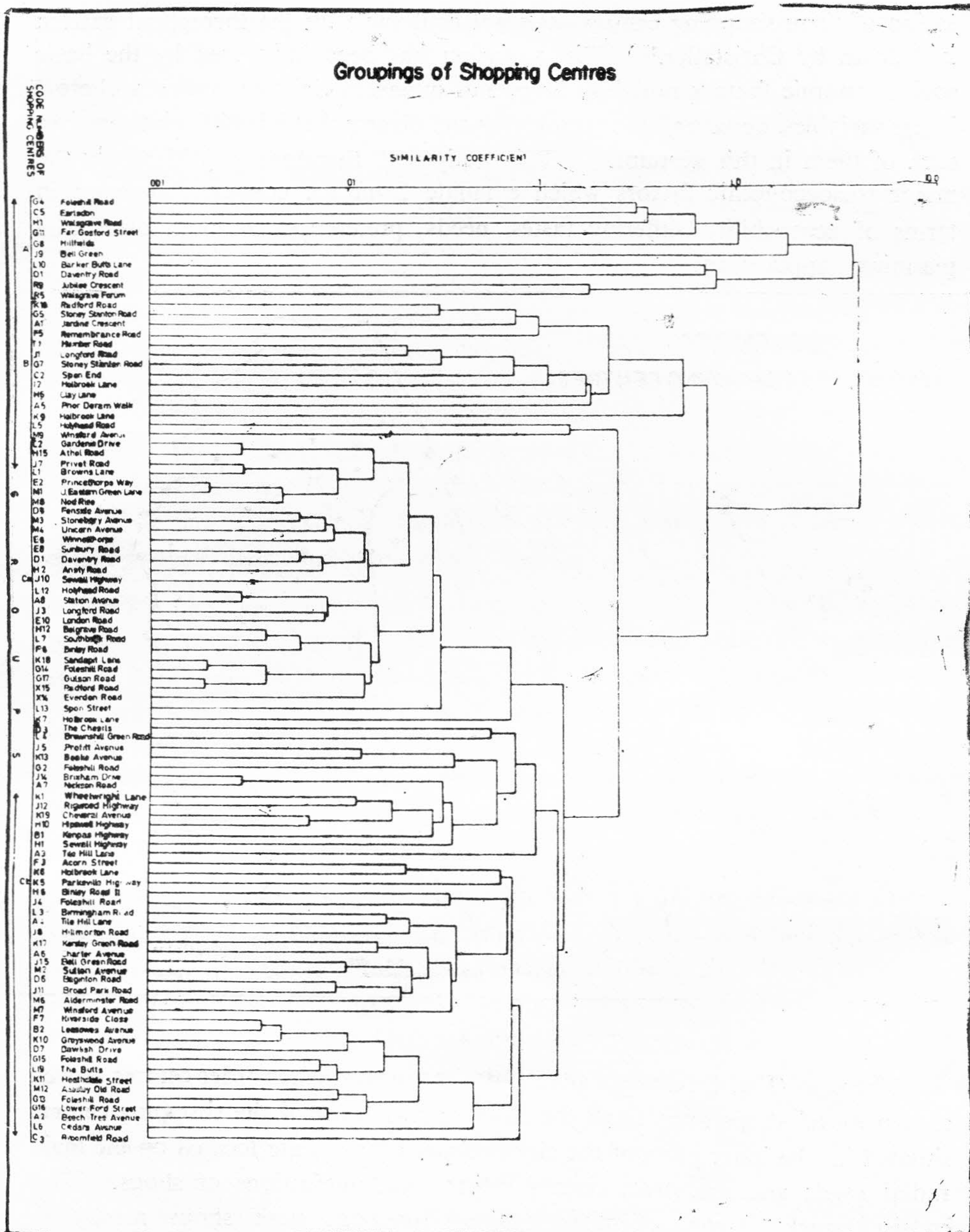

Fig. 3

second concerns the interrelation between them in terms of range of facilities offered.

The distribution of the various grades of 96 centres included in this study is shown in Fig. 4, along with the central shopping area. The horizontal organisation of these shopping centres does not conform with the theoretical pattern laid down by Christaller.[17] This variation has been influenced by the basic socio-economic factors noted by Berry and others in Chicago and elsewhere.* These variables, however, are so numerous and diverse that it is difficult to analyse each of them in this account. This study will, therefore, consider only the major socioeconomic factors which emanate from the consumer demand in terms of accessibility, differing tastes, needs, preferences, market forces and planning applications.

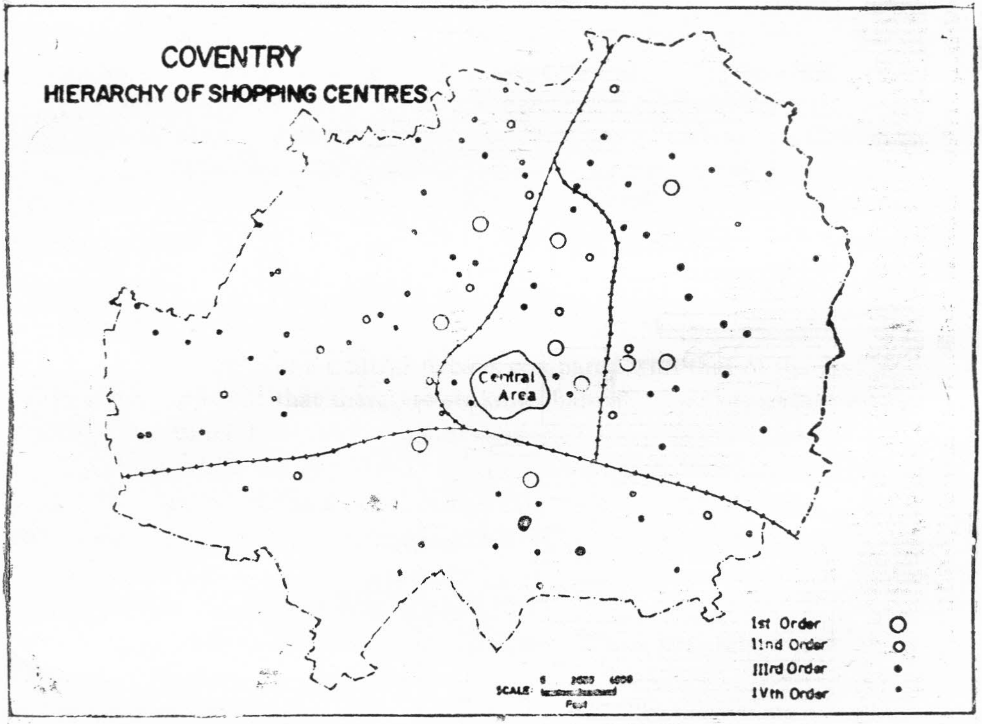

Fig. 4

The map (Fig. 4) reveals a general decline in the higher order centres as well as density of shops away from the city centre. Most of the shopping centres situated in the inner parts of the city (railway triangle) are located on the main radial roads and are street centres rather than nucleations of shops. They consist largely of rows of mixed business functions with shops mostly in converted houses. The decay of transitional zones round the CBD is a well documented feature of the British and American cities but it has been accentuated in Coventry by local historical factors. The bombing during the second

*Berry. B. J. L., and Pred. A., "Central Place Studies; A Bibliography of Theory and Applications". 1964.

World War destroyed a substantial part of the Central Area and forced many functions including shops to move out. Many of the displaced traders moved to the existing radial centres and preferred to stay there inspite of the city centre redevelopment because they could not afford large overheads for new premises.

Planning and rehabilitation also had a profound affect in the modification of the retail system directly by interfering with the retail facilities and indirectly by the development of suburban housing estates thus increasing the spending power at the edge of the city. The Spon End and Hillfields development schemes within the railway triangle have caused the demolition of a substantial number of shops which have been replaced mainly by residential blocks in these areas. Planning has also been conspicuous in the creation of nucleated centres. The Bell Green district centre, and two neighbourhood centres at Tile Hill (Jardine Crescent) and Willenhall (Remembrance Road) are specific examples. There are at least seven centres on the list of proposed future shopping development (Fig. 2). The existing planned centres have generally a smaller number of shops than their unplanned counterparts.

It has been previously suggested that the social structure of a centre's local hinterland has a considerable effect on the functional structure of a centre. Huff[18] found that amongst the factors which influence consumer habits, occupation and income were the most important. Also Davies.[9] has shown in Leeds that though few actual shops may be found in lower income areas compared to higher income areas, the shops are much more diversified and the local population is much more dependent on these than in the case of higher income areas.

A study of general ecological conditions in Coventry reveals a distinct concentration of working class and immigrant population within the railway triangle which also has relatively poor housing condition, high density of population, congestion and intermixing of land-uses.* The effect of these variables on the character of shopping facilities is not only reflected in the high density of shops in the area but also in the relatively inferior type of shops. Although there are three first order centres in the railway triangle with the largest concentration of shops i.e. Hillfields, Foleshill Road (Station Street), and Far Gosford Street, yet none of these centres can be rated particularly good on the quality scale. The impact of immigrant population is already becoming apparent in the large number of shops owned by them. These shops cater primarily for their grocery and clothing needs which are not satisfied fully by the local retailers.

*See Khan M. A., "Growth and Morphology of the Central Area of Coventry" Ph.D. Thesis University of Birmingham (U.K.) 1972.

Shopping Centres Structure

The average structure of each group or order of shopping centres alongwith the Central Area is presented in the following Table:—

TABLE VI.—*Shopping Centres—Functional Structure.*

	Central Area	1st order	2nd order	3rd order	4th order
1	2	3	4	5	6
Food, drinks & tobacco	22.5%	33.1%	40.5%	47.5%	52.5%
Variety Stores	1.6%	.6%	—	—	—
Banks	3.3%	4.0%	1.1%	0.2%	—
Clothing	22.9%	16.1%	13.8%	10.3%	9.4%
Other non-food	17.4%	12.5%	13.8%	13.8%	6.4%
Household	14.3%	16.0%	11.8%	10.6%	7.4%
Services	9.6%	14.4%	16.0%	14.7%	18.8%
Vacant Premises	8.4%	3.3%	3.0%	2.9%	5.5%

If the structure of the Central Area is compared with that of the first grade centres, it is apparent that there are striking changes. The percentage of both clothing and other non-food shops as well as variety stores increases in the Central Area while the proportion of food shops falls sharply. The service group also slumps in the Central Area retail zone and house-hold goods too have a diminished proportion as compared with the first grade centres. The first grade centres are well represented by all categories of shops except for variety stores. There are only three centres outside the Central Area which have a Woolworth. These include Walsgrave Road, Bell Green and Jubilee Crescent. Walsgrave Forum has Hogarth and Foleshill Road (Station Street) has a large Co-op Emporium. The rest of the centres do not have any such facility.

As expected there is a proportional decline in the number of food shops, as one moves up in the level of hierarchy. The non-food shops as a whole show a reverse tendency but there is some variation within this group. The services increase in proportion particularly in the fourth grade centres. This shows that in the location of such types of shops the convenience factor plays a much more important role at lower order scale rather than selectivity or status value.

Conclusion

The comparison of different techniques for classifying and ranking of shopping centres reveal a major shortcoming in the central place theory in that the results differ according to the nature of data used. This indicates that a particular type of technique or data may mask a complementarity among the centres which means that in a series of closely related centres given the same status each might specialise to some extent functionally but in a very close relationship with other centres. A definite gap in the hierarchy may well be an indication of this particular phenomenon but might well be hidden according to the type of analysis made.[20] It might therefore be useful in this respect to employ a technique that may take into account maximum amount of available data and techniques. One of the limitations, however, is that many techniques which have been used to classify major shopping centres in large cities or regions may not be applicable to the whole range of centres in a medium or small city.

The results of cluster analysis technique reveal that the shopping centres in Coventry are units in a system which is organised in such a way that there are different grades of centres which perform distinct range of functions. This system is compatible with the classical central place theory. The spatial pattern of shopping centres, however, does not conform to networks predicted by Christaller,[2] and this appears to result from the irregular distribution of socio-economic variables. These variables include social structure and distribution of population, income, transportation (incorporating car ownership as well as parking) and planned intervention. All these aspects are very relevant in order to explain fully the distribution and structure of individual shopping centres. Any new proposal must take the above factors into consideration and in fact most of the retail prediction models are based on them. Central place theory as it stands originally cannot take these variables into account because of assumption of homogeneity. The theory can point out the factors but it is difficult to incorporate them whereas tools such as the gravity model can deal with the input of these variables more definitely. Nevertheless as pointed out by the report "Urban Models in Shopping Study"[22] the two approaches together with rent theory are not competitive but complementary. Developers or planners working on problems relating to the provision of land and buildings for shops may use all three, incorporating each in separate stages of a procedure or "step by step" approach.

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AN OUTLINE OF WATER BUDGET FOR IRAN

SHAHPUR GUDARZINEJAD*

1. Introduction

In classification of the earth's climate zone, Iran which is located in South Western Asia is listed as an arid and semi-arid region. The annual average precipitation of the whole country has been estimated to be between 250 and 300 millimetres; but a latest report of the Energy Ministry's Directorate General of Surface Waters, derived from 1800 raingauges during the period (1965-69), showed that the average annual precipitation during those years amounted to only 225 millimetres.** Iranian Meteorological Organization's report for the period (1965-69) gave almost identical figures (Table 2).

Although through this short period we could not obtain precise reliable figures for the rainwater volume, nevertheless the report of (D.G.S.W.) is the latest valuable as a provisional estimate of the volume of derived surface water in Iran, and I myself have used it as the basis for the outline of a water budget for Iran which I present in this article.

A comparison of figure one and figure two shows vividly that the parts of Iran receiving high precipitation belong to the Caspian coastal region and to the northern, north-western, and western mountain systems. It can also be seen from the isohyet map (Figure 2) now the amount of rainfall decreases from north to south and west to east. The region with the least rainfall being Dasht-e-Lut and Dasht-e-Kavir deserts which cover most of Central Iran. The focal points of high rainfall are located in the *divides* of the drainage basins in the Alborz mountains in the north and the Zagros chains in the west and are often closely ringed by the successive isohyet lines. In the mountains the isohyet lines lie close together but in the vast plains they soon become further apart. Seen from the other direction, the number and closeness of the isohyet lines increases from Central Iran onward to the north, the north-west and the west. The isohyet line of 200 millimetres generally coincides with the dividing between the mountainous regions and the vast central plains of the plateau. It also divides the south-western and southern mountain slopes from the hot and desertic regions of the Persian Gulf Coast.

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**Bilan-e-Abhay-e-Sathi-Ye Iran, 1971.

Table one and two show the extents of the various drainage basins in Iran and total volumes of the precipitation and of the surface water derived there from which each of these basins annually receives (Figure 3).

TABLE 1.—*Rainwater by Drainage Basins*, 1965-1969.

No.	Basin Name	Area 1000 (Km.^{2})	Rainwater Billion cu.m.	Total Area %	Total Volume %
B1	Caspian Sea	179	83.60	10.90	22.70
B2	Persian Gulf	410	115.20	24.90	31.20
B3	Lake Rezaeyeh	56	25.40	3.40	6.90
B4	Lake Hoz Soltan	129	30.30	7.80	8.20
B5	Gavkhuny	100	15.4	6.10	4.20
B6	Lake Bakhtegan	35	10.70	2.10	2.90
B7	Jaz Murian	69	10.20	4.20	2.80
B8	Central Basins	511.5	53.00	31.10	14.40
B9	Eastern Basins	156	25.00	9.50	6.70
9	Total	1645.5	368.80	100.00	100.00

TABLE 2.—*The Average Precipitation by Drainage Basins*, 1965-1969.

Name	Area Km.^{2}	Rainwater Vol. cu.m.
Caspian Sea	178125	8437 $\times$ 10^6
Persian Gulf	415000	12553 $\times$ 10^6
Lake Rezaeyeh	56250	25750 $\times$ 10^6
Lake Hoz Soltan	130625	29026 $\times$ 10^6
Gavkhuny	1006235	12800 $\times$ 10'
Lake Bakhtegan	39375	7709 $\times$ 10^6
Jaz Murian	69375	8281 $\times$ 10^6
Central Basins	506250	50509 $\times$ 10^6
Eastern Basins	159375	24494 $\times$ 10^6
Total	1645000	368404 $\times$ 106

Source: Meteorological Organization of Iran, 1971.

Fig. 1· Relief map of Iran

2. Iran's Water Budget

Iran's water resources are almost totally derived from precipitation. As mentioned earlier an estimate based on a combination of isohyet lines methods and evaluation of the different drainage basins in the period 1965-69 puts the average annual volume of surface water in the whole of Iran at 369 billion cubic metres.*

*This figure does not include the volume of water derived from river entering Iranian territory from abroad, which was estimated at 7.5 millard cubic meters (Vahidi, 66).

Underground percolation of water from Iranian to other Territories and vice versa has never been calculated and also been omitted.

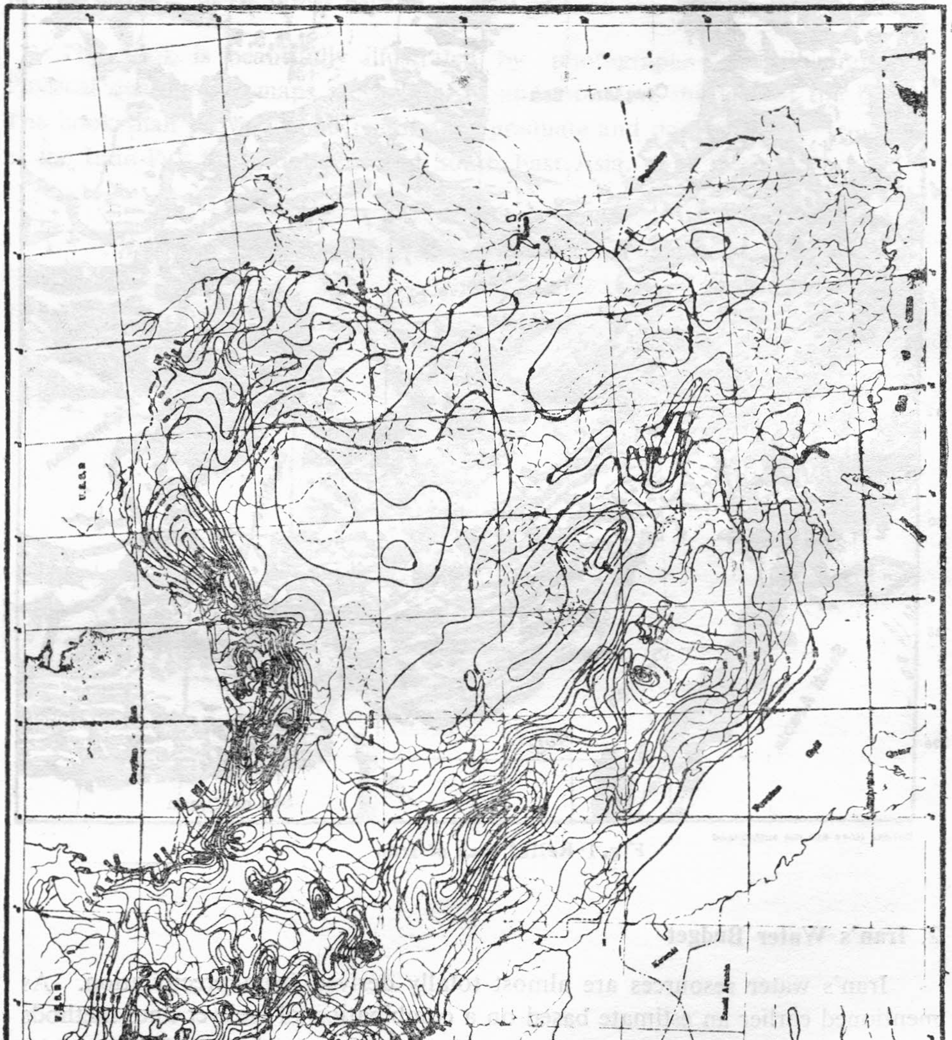

Fig. 8: Isohyet Map of IRAN

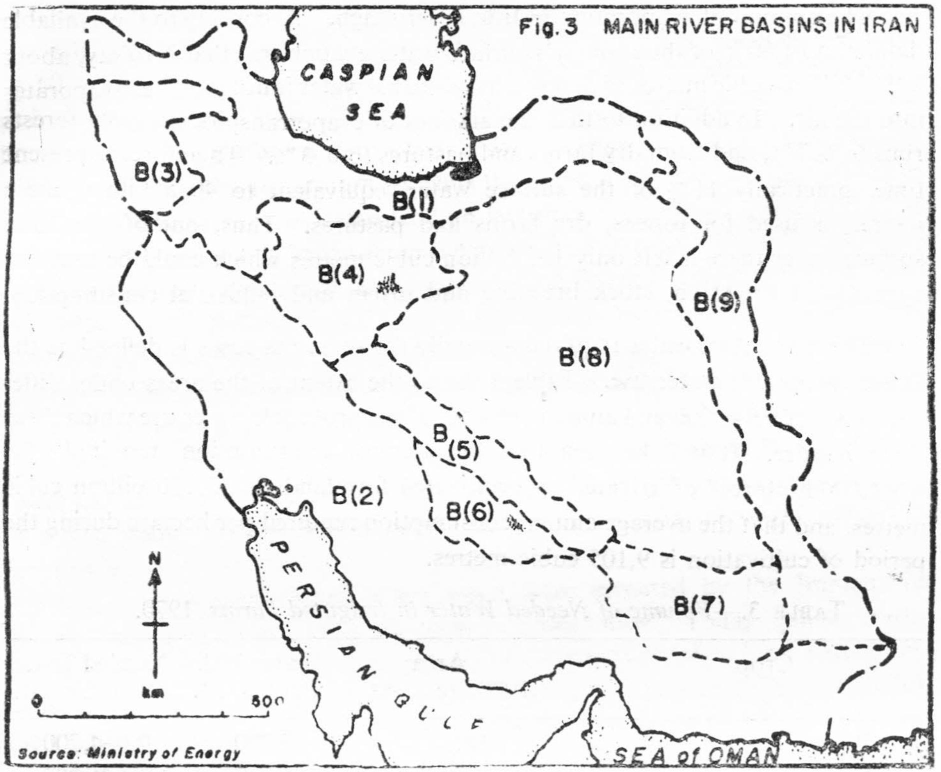

Fig. 3 MAIN RIVER BASINS IN IRAN

Yearly Water Budget

Import		*Export* (*Billion cubic metres*).		
225 mm. precipitation	= 369 billion cubic metres	Evaporation waste	60 % =	221.5
		Forest, Pastures and dry farming	11 % =	40.5
		Total	71 % =	262.0

Available water		29 % =	107
Profitable use	A. Irrigation	..	37.020
	B. Urban, Industries	..	1.500
	Total	..	38.520
Waste	A. Waste of Irrigation	..	38480
	B. Unused	..	30.000
	Total	..	68.480
	Balance	..	107.000

The amount of evaporation in Iran is very high. According to the available data, almost 60% of the country's surface water evaporates; that is to say, about 221.5 billion cubic metres of potentially available water is not used but evaporates into the air. In addition to this, the amount of evapotranspiration from forests runs to 4.7%, and from dry farms and pastures to 6.3%. Therefore, at present time, practically 11% of the surface water, equivalent to 40.5 billion cubic metres, is used for forests, dry farms and pastures. Thus, out of the total surface water there is left only 107 billion cubic metres which could be used for agricultural irrigation, stock breeding and urban and industrial consumption.

The amount of water required annually for these purposes is defined as the annual profitable water use. Table 3 shows the extent of the areas under different types of irrigation and annual volumes of the profitable water use which these areas require. It will be seen that the annual consumption required for 4 066,000 hectares* of irrigated and cultivated farmlands is 37.020 billion cubic metres, and that the average annual consumption required per hectare during the period of cultivation is 9,105 cubic metres.

TABLE 3.—*Volume of Needed Water in Irrigated Farms*, 1970.

Crop	Area 1000 Hectares	Water Vol. Per Cu. M.	Needed Water 1000 Cu. M.
Wheat	141	4,700	7,054,700
Barley	394	4,700	1,851,800
Rice	344	35.000	12,040,000
Legumes	210	4,300	903,000
Vegetables, Potatoes	174	8,000	1,392,000
Fodder	460	11,000	5,060,000
Sugar Beet	150	8,000	1,200,000
Sugar Cane	5	60,000	300,000
Cotton	307	8,000	2,456,000
Tobacco	15	5,500	82,500
Oil Seeds	76	5,000	380,000
Fruits	430	10,000	4,300,000
Total	4,066	Av. 9,105	37,020,000

Sources: 1. Statistical Centre for Iran, 1971.
(*i*) Vahidi, 1966.
(*ii*) Water and Irrigation in Iran, Plan Organization, IRAN.

*Hectare=2.471 acres.

Surface water from rivers and streams, is used to irrigate 2,439,600 hectares or 60% of the total area of irrigated farmland in the country. The average ratio of the profitable water use requirement to the actual water consumption on farms irrigated by surface water in Iran is 35%. Thus, to supply 22.212 billion cubic metres of water per annum which is the amount required for profitable use on 2,439,600 hectares of irrigated land no less than 63.5 billion cubic metres of surface water is actually taken from the rivers and streams. If the proportion of the irrigation water which drains back to the rivers is estimated to be 15% and if the total volume of such water is accordingly reckoned to be 9.5 billion cubic metres then the final surface water taken up for irrigation must amount approximately to 54 billion cubic metres. Since an additional volume of about one billion cubic metres per annum is used for livestock and in urban and industrial consumption, the aggregate volume of the surface water actually taken from rivers and streams for all these uses must be approximately 55 billion cubic metres, of which about 31.788 billion cubic metres are wasted through irrigation farmlands.

Means to extract underground water were invented by the Iranians in ancient times and have been in use from then until now. Today, qanats, traditional wells, and deep wells drilled by modern methods supply a large part of the underground water available for human use in Iran. The average proportion of the extracted underground water which can be profitably used is 70%. Thus, for the remaining 16,26,400 hectares of irrigated farms in Iran the profitable use requirement is 14.808 billion cubic metres per annum, and the annual volume of the underground water which must annually be extracted is 21.5 billion cubic metres. Since the annual use of water from underground sources for human and animal consumption is calculated to be half a billion cubic metres the aggregate extraction of underground water must be approximately 22 billion cubic metres per annum. Again, 6.692 billion cubic metres are wasted through irrigating farmlands.

With respect to 30 billion cubic metres water which is discharged annually in different basins and from these figures we may draw the conclusion that the waste of irrigation water in Iranian farming is very great. At the same time a large part, amounting to roughly 68,480 billion cubic metres of the annual available surface water being unused. With the aid of scientific studies, building more dams and barrages, and modern engineering methods, it should be possible to minimize the waste and use much of this unused water to increase the agricultural production of the existing irrigated areas more, to extend these areas and irrigate new areas, and to satisfy Iran's future industrial and urban needs.

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BOOK REVIEW

Class and Power in a Punjabi Village, SAGHIR AHMAD, *Punjab Adbi Markaz, Lahore*, 1977, pp. 163, *appendix, bibliography Rs.* 35.00.

Most sociological and geographic studies on rural settlements of Pakistan that have come out in the past 30 years have been mainly of descriptive nature. Dr. Saghir Ahmad's work is of significance in that is of a pioneering nature. This research has been the product of intensive field work that Mr. Ahmad undertook in 1964-65 at Sahiwal (formerly Montgomery) in the province of Punjab, Pakistan. The work provides a dynamic characterization of the changing instrumentation of power and status in the everyday life of a typical Punjabi village of Pakistan.

One of the significant findings of Mr. Ahmad is that the land reform, per se, does not really intimate the political power and social status of the landlord. In fact, it is observed that the introduction of cash crop oriented agriculture has further intensified the process of accelerating the change from tenants farming to capitalist farming based on wage labour. This process, in turn, has tended to widen the gap between the 'haves' and 'have nots'.

Although lacking in geographic orientation and content the book is never the less of considerable use for reference by geographers interested in research related to social and economic problem of rural settlements in Pakistan.

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Bangladesh by B. L. C. JOHNSON, Heinemann Educational Books, London, Barnes & Noble Books, New York, 1975

Book aims to present a balance view of this newly independent country. It covers the historical background of the country's existence, its physical environment and their liability to hazard. A large part of the book has been devoted towards the economic development of the country since 1947. Keeping in view the difficult physical environment with alternating floods and droughts devastating cyclones, poverty and diseases, the author clearly demonstrates the developing pace of the country. The agricultural basis of the economy, traditional agriculture is examined and the extent of modernization through the green revolution. It also discusses the industrial problems of the country with little in the way of resources beyond natural gas and the product of its fields.

The book is beautifully illustrated by photographs and illustrations. Physical quantitative maps are helpful in understanding the text of the book. The book shall prove a good reading for graduate and post-graduate students of the Indo-Pak Sub-Continent and South East Asia.

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