Pairing Mega events and Hydrological Systems for Urban Sustainability

Strategy Framework for Delhi beyond the Commonwealth Games 2010

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Submitted to the Department of Urban Studies and Planning in Partial Fulfillment of the Requirements for the Degree of

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at the Massachusetts Institute of Technology, September 2004.

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ABSTRACT

This thesis studies the inter-influence of urban hydrological systems and mega congregative events, as basis for urban strategy for sustainability. It questions how structuring the Commonwealth Games 2010 around Delhi's stream networks and the Yamuna River front create a more sustainable city.

Millennia of continuous urban settlement have evolved hydraulic networks that allow extensive human control of Delhi's hydrological complex. This hierarchical system of water retaining, diverting and flood control structures made large populations possible in an otherwise arid landscape. Delhi's topography and this network of streams, lakes, step wells, canals and the Yamuna River determined the size and shape of successive settlements through critical urban functions, such as defense, transport, drinking water supply, irrigation and flood control. Identifying persistent aspects of this framework can help determine the range and nature of physical effects triggered by the Commonwealth Games.

The thesis hypothesizes that strategy frameworks that employ Delhi's hydrological system to frame large, planned events are more likely to be beneficial and sustainable over time. It attempts to identify the utility and crucial nature of Delhi's hydrological system to the success of the Commonwealth Games (CWG) 2010. I aim to demonstrate the potential of Delhi's hydrological system in informing strategies to pool existing resources and make future investments.

The thesis also aims to exploit the opportunity provided by the Games to establish Delhi's hydrological systems as the guiding force of future planning efforts. This entails making the city more self-aware and stimulating an envisioning process. It expects to raise public awareness and debate to initiate a process by which the city learns to seize opportunities through benign and sustainable change. Furthermore, this thesis intends to inform decision makers with a checklist of crucial tradeoffs, risks and benefits involved in incorporating water systems as a strategy framework.

Eventually, the thesis argues that CWG 2010 organizers cannot ignore the crucial nature or threats posed by the neglect of Delhi's Water Systems. It proves that CWG 2010 organizers can benefit from the inherent utility offered by Delhi's Water Systems. Finally, it demonstrates that Delhi's hydrological systems allow an advantageous compatibility of the CWG's short-term objectives and the city's long-term objectives.

Thesis Supervisor: Anne Whiston Spirn
Title: Professor of Landscape Architecture and Planning

ACKNOWLEDGEMENTS

This thesis builds on the work and encouragement of several exceptional people. My advisor, Professor Anne Whiston Spirn allowed me profound insight and inexhaustible patience. I thank her for sharing her meticulous critique, intellectual fervor and immense environmental planning knowledge. I would like to thank Professor John de Monchaux for his critical guidance in the thesis's formulation and integrity of conceptual framework. His erudition and capacity to encompass complex arguments in effortless sentences, was pivotal to crafting a public policy document. Professor Lawrence Vale, I would thank for being my *Hazrat Khizr* (the recurrent patron saint of water and guide to explorers), and having spurred me through the urban morphology research that forms the basis of this thesis.

I would like to thank Professor Dennis Frenchman, Professor Nasser Rabbat and Professor Malay Chatterjee for helping me chart different chapters of my research about Delhi's waterworks and their influences on urbanism. I am indebted to Professor Nalini Thakur, Professor James Wescoat and Professor Jawed Ashraf for their invaluable guidance while I explored some of these issues in 2000-01. My special thanks to the wonderful people at the British Library St. Pancras, India Archives, MIT Rotch and Hayden Libraries. This thesis would not be possible without the travel and research grants conferred by the Aga Khan Travel Fund, Harold Horowitz Prize and the Kelly Douglass Fund at MIT.

I express gratitude to two dear friends at either ends of this globe. Ozgur Basak Alkan in Cambridge, MA for leading the way with her graduate thesis, "Choices and Benefits: Alternative Access and Venue Sites for Istanbul Olympics" and making available extensive reading material. Kanika Singal in Delhi for scurrying around bleak government offices and libraries, searching unpublished and out-of-print documents. I am particularly grateful for her unquestioning enthusiasm and patience.

I thank my family for their wholehearted support and inexplicable confidence. Finally, deepest thanks to my mother, Lizy Cherian, for having taught me to relish the fight.

Danny Cherian
Cambridge, Massachusetts, 2004.

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INTRODUCTION

The Mega-Event as a Vehicle for Desired Urban Change

Mega-events are premeditated spurts of concentrated urban activity. They are not isolated, singular occurrences but are usually a sequence of events of varying intensity and impact. The term mega-event is commonly used to refer to large international gatherings such as world expositions, fairs or sporting events characterized by monumental scales of media attention, spectator generated revenues and image-building exercises.[1] Progress in media technologies has allowed an ever-growing audience from distant ends of the globe. Allusions to economic prosperity and the rotating host cycles of mega-events create parallels with mythical treasure laden ships wooed by ports.

"*Today, the award of the Olympics usually heralds major new developments and enables existing plans to be 'fast-tracked' through the planning and development stages much sooner than would have otherwise been the case*".

Essex and Chalkley (1998: 87)

Perspectives that ignore long-term changes dominate studies of event determined urban form. An emphasis on short-term economic gain with few environmental or social considerations is creating spectacular, unsustainable 'showcase' cities. This phenomenon produces irreparable damage in mega-cities of the developing world, which perceive 'spectacle cities' and mega-events as the quickest means of bridging the development gap. However, the Delhi Commonwealth Games are emblematic with a relatively modest capital budget and re-use of most sports facilities. They are more of an opportunity to champion sidelined objectives, and inspire citizen momentum for policy change. The CWG 2010 can serve as an excuse for a systematic rather than spectacular transformation of Delhi.

How can the Commonwealth Games 2010 Leave Delhi a More Sustainable City?

Mega events are increasingly looked upon as opportunities to achieve city goals. They are hailed as a tool for a menagerie of city managers and urban professionals to orchestrate rapid change for prosperity, including the much-abused term: sustainability. My question is based on a belief that the Commonwealth Games *can* induce greater environmental, social and economic sustainability in Delhi. This belief is based on the assumption that Delhi *can replicate and enhance* the much-studied success of cities such as Sydney or Barcelona (as Olympic Games hosts) in harnessing a mega-event's momentum to further sustainability concerns. The question should be of interest to both the organizers of the Games and campaigners against existing social inequity, environmental degradation and economic stagnation issues in Delhi.

There is no question that linking a mega-event with principles of development adds to the complexity of planning and implementation when factors such as cost sensitivity, tight timetables, competing visions and organizational differences already add considerable strain. But it is a risk that is worthwhile to counterbalance the crass commercialism and excessive materialism that has been characteristic of recent (Olympic) games.

Harry Hiller[2] (1999: 117).

The organizers currently understand the CWG 2010 as a deadline-determined event with little need for public participation. They do not recognize negative effects beyond temporary traffic congestion or increased municipal services loads. They cite instead, gains in world visibility, urban infrastructure and tourism. Public interest groups only marginally recognize the potential effects of the CWG 2010. Their concerns are largely limited to the problems of immigrant influx and exploitation, forced evacuations and environmental degradation. My question bridges the missing gap between both camps. A discussion based on their shared concern for Delhi's future could help resolve the organizers' fear of

public 'interference' and the campaigner's fear of insensitive government action.

An Urban Strategy for the Games Can Trigger Sustainable and Beneficial Changes

This hypothesis rests on two convictions, which are related. First, environment professionals (collaborating with multi-disciplinary teams) *can* plan and coordinate the extended effects of mega-events, such as the Commonwealth Games. Second, a comprehensive urban vision drafted with primary stakeholders is *essential* to direct such plans. Admittedly, most prevalent planning methods are not suitable to verifying either belief.

Global mega-events have a relatively common set of induced gains and losses. However, the scope of these changes is usually governed by city characteristics shaped by inherent resources and previous events. One can thus prepare to maximize benefits and reduce negative impacts by collating studied 'character' of both event and city. In this manner, mega-events could be used as tools to catalyze politico-socio-economic structures for sustainability.

Global Dreams and Local Risks: The Need for Context-Specific Mega-Event Strategies

The growing scale of mega-events has progressively increased the vulnerability of modern cities. This is illustrated through the inability of conventional planning mechanisms to prepare for immense fluctuations of urban activity. There is today, an unparalleled need to address the growing risks of urban development spurred by mega-events in mega poleis across the globe. Overt optimism in a global identity is a common excuse for misplaced investments at infeasible social and environmental expense. Ironically, the costs of such global visions are nearly always localized. A context-specific and geography-bound counterfoil to global event strategies appears incumbent. The continued significance and influence of Delhi's water systems on its urban form makes it a good choice to test this hypothesis.

Harnessing Benefits of the CWG 2010 through Delhi's Hydrological System

Delhi's stream networks afford planners of the Commonwealth Games (CWG) 2010 such opportunities. Constant tussle between urban settlers and Delhi's landscape has sculpted a time-tested skeleton for infrastructure services and urban amenities. A reappraisal of Delhi's stream networks reveals several possibilities beyond the desperately needed overhaul of gravity-based, piped services for the CWG 2010. Urban waters are of immense consequence in sustenance, disease prevention, transport, territorial definition and structural safety in the feverish pace of a mega-event.

This thesis demonstrates lowered financial and environmental costs through the reuse of historic infrastructure. It points to opportunities to conserve urban environments, cultural landscape and built heritage. This thesis presents the strategic choices we could make using ecological systems for mega events, which are more likely to produce sustainable and beneficial change. It promotes an approach to address long-term sustainability issues through incremental short-term projects. Delhi's hydrology is explored as a thematic framework to coordinate the city's myriad objectives, pressure groups and actors on a common platform. Many federal and state departments and agencies, industry associations, business groups, community groups, sporting organizations and social groups shall be pursuing opportunities generated by the CWG 2010. A water theme based strategy shall foster coordinated city response to the opportunities offered by mega events. 'Such coordination is essential to avoid different groups counteracting each other as well as duplication of effort'.

Deciphering and Tapping Underlying Frameworks to Configure the Future

Similar events might produce entirely different outcomes in different cities. A mapping of Delhi's water and institutional landscape is necessary to strategize the Commonwealth Games for tangible benefits. I expect to find for Delhi, a *pattern of response* to both unforeseen natural calamities and deliberate

human decisions governed by its environmental characteristics. There obviously are similar and connected patterns for the city's economic and social characteristics that are beyond the range of this thesis.

My audience consists of policy and decision makers in various planning and implementation agencies at the federal, state and municipal levels. These groups presently attribute varying degrees of influence and incoherence to different events in Delhi's past depending upon professional, age and economic group biases. This thesis challenges the 'isolated event' perception and establishes how effects of initial events often trigger or condition the effects of subsequent events.

Maps, Numbers and Perceptions

The thesis's central question (and the method adopted to answer it) necessitates the use of both qualitative and quantitative data. Before and after comparisons of key indicators for crucial issues (such as air pollution, loss of forest cover or population growth) relevant to each event would require reliable annual statistical data. Changes to urban form, infrastructure layouts, built fabric dispersal etc were studied from 1:25,000 Survey of India maps for the Delhi region. Investigations of equity issues such as citizen empowerment required literature surveys of social commentaries, newspapers etc. and interviews with citizen-witnesses of the studied events.

My visits to the British and Indian map archives accumulated a collection of rare revenue and administrative maps that have proved invaluable over the course of research. Assisting Prof. Malay Chatterjee on a yet unpublished oral history of Delhi's master plan provided a wealth of citizen perspectives. [3] I was limited by a lack of statistical data for some important indicators, over certain investigated years (especially early or turbulent events). The lack of research perspectives on events (like the 1947 partition's effects on Delhi's environment) and the different schedules of statistical and cartographic records complicated matters. A cross-reference between statistical, cartographic and literature surveys, thus forms the thesis's evidential basis.

(Endnotes)

[1] "The attraction of stadiums in the cities that financially support them lies in the fact that city officials from Florence to Florida believe that they are vital for the projection of a world class image, and that stadiums provide tangible economic benefits for the cities in which they are found." John Bale (1993) in *Sport, Space and the City*. London: Routledge, 161.

[2] Hiller, Harry in 'Mega-events and Urban Social Transformation' in *The Impact of Mega-Events.* Östersund, Sweden: European Tourism Research Institute, 1999, 117.

[3] The book titled, '*A Tale of Two Cities: The Oral History of the Delhi Master Plan*' is the fruit of Prof. Chatterjee's two decades of research of the planning and development of the capital city since the 1962 Master Plan. The importance of oral history and the need to document city development through citizen perspectives underlie the rationale of this yet to be published opus. Prof. Malay Chatterjee is a professor of Architecture and Urban Planning at the School of Planning and Architecture, Delhi.

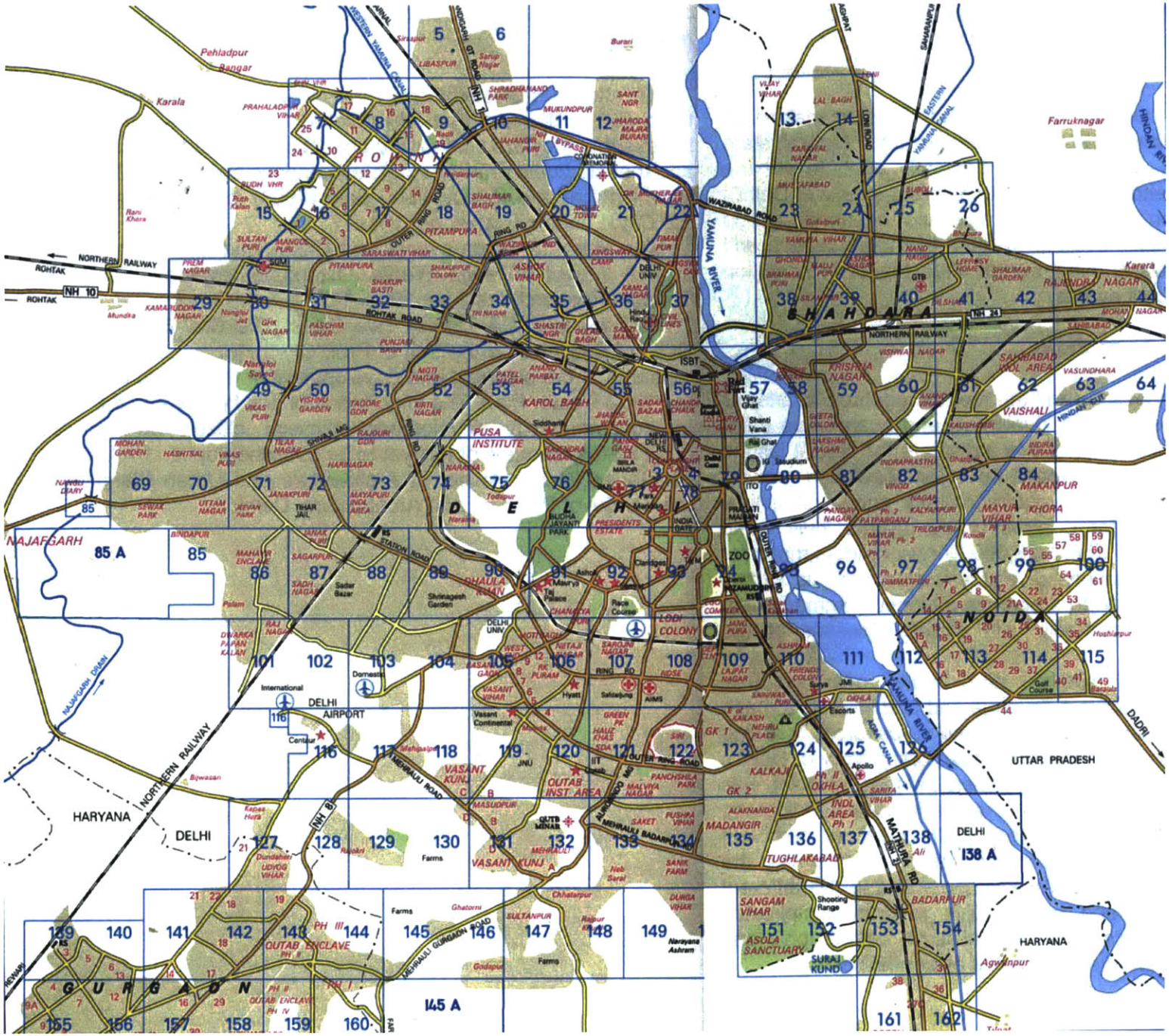


FIG. i-1. Delhi Reference Grid Map. Based on the Eicher City Map, 1996.

<u>Some Localities & Grid number referenced in the thesis</u>:
Shakarpur [81]
Anand Vihar [60]
Gazipur [83]
Kalyanpuri [82]
Madangir [135]
Andrews Ganj [108]
Jangpura [109]
INA colony [107]
Kashmere Gate [57]
Sarai Kale Khan [95]
Jahangirpuri [10]
Model Town [20]
Subhash Nagar [73]
Timarpur [22]
Mangolpuri [15]
Kondli [98]
Papankalan [101]
Rithala [16]
Nilothi [70]
Rikabganj [77]
Gole Market [77]
Shahdara [40]
Seelampur [39]
Trilokpuri [97]
Pandav Nagar [81]
Mayur Vihar [97]
NOIDA [113-115]
Rohini [7-9, 17-18]
Dwaraka [85A]
Dakshinpuri [135]
Nand Nagri [40]
Zamrudpur [123]
Chattarpur [148]
Lalkot [132]
Munirka [119]
Junapur [145A]
Sultanpur [147]
Rajokri [128]
Mehramnagar [103]

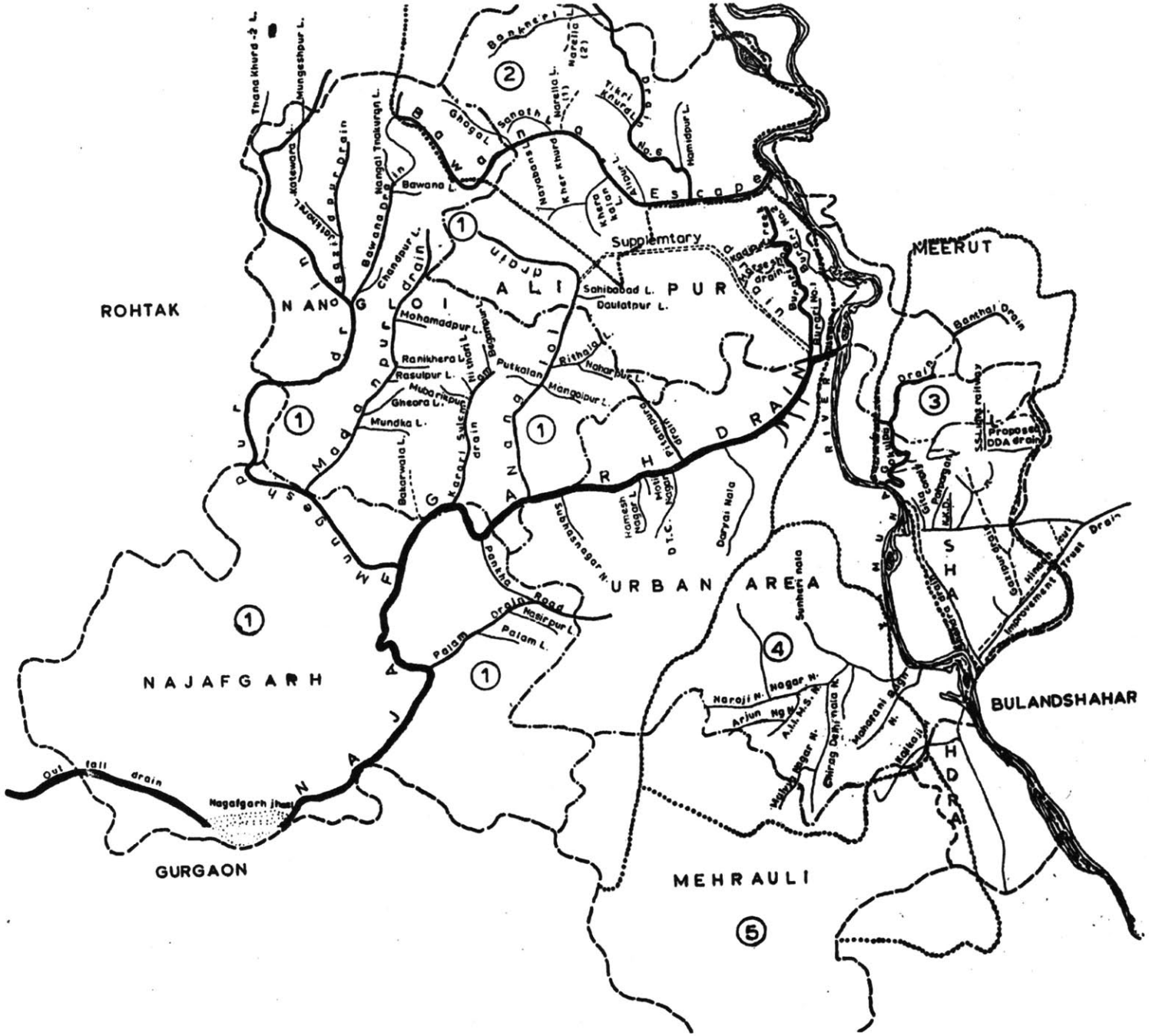
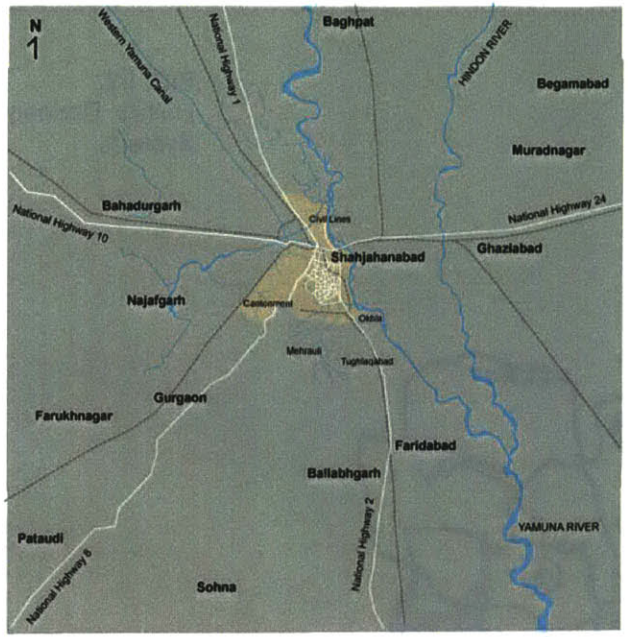
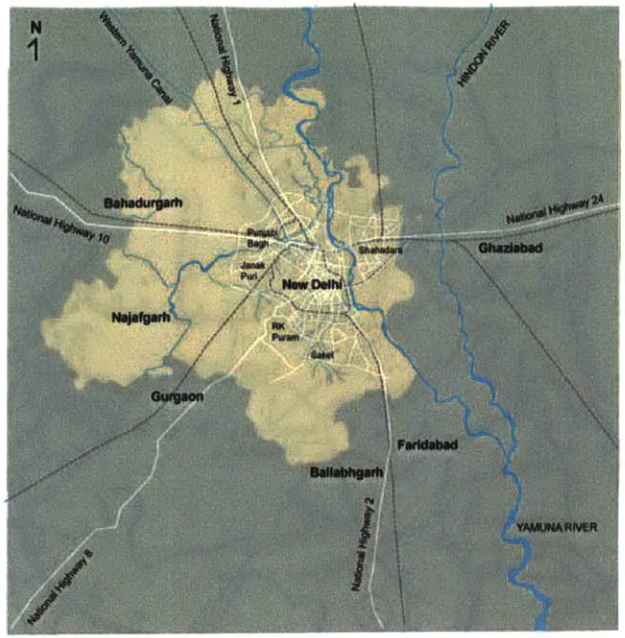
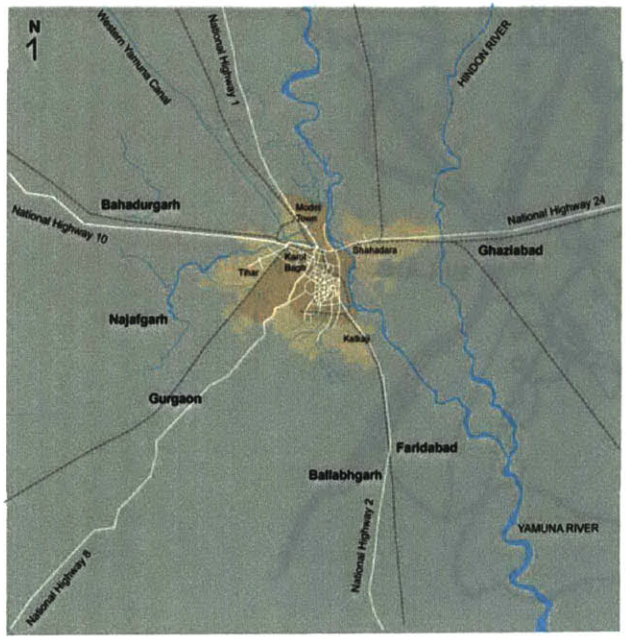


FIG. i-2.
Delhi's Drainage System.







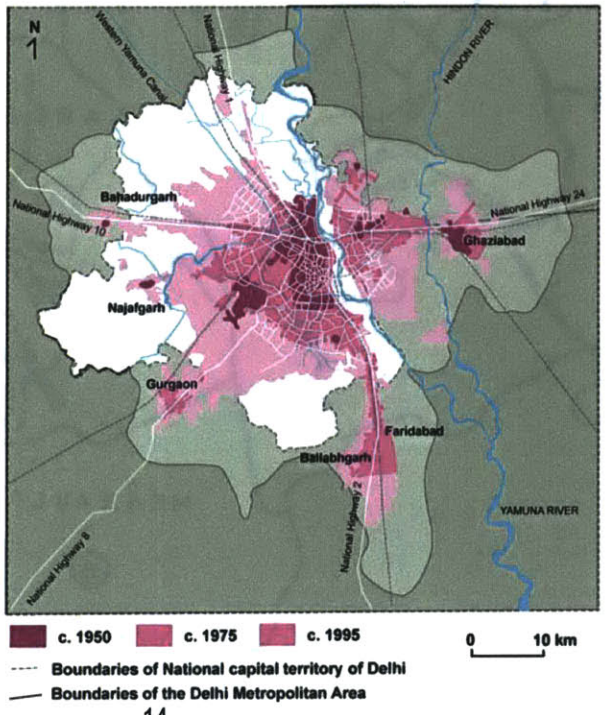


FIG. i-3. Delhi's Urbanization in the Nineteenth Century.

Hydrology and the Commonwealth Games 2010

Disregard of natural processes in the city is, always has been, and always will be both costly and dangerous.

Anne Whiston Spirn (1984: 10)

Commonwealth Games (CWG) 2010 organizers cannot ignore the threats posed by neglect of Delhi's hydrology. Floods, disease, pollution and subsidence are recurrent hazards faced by many parts of Delhi. Eight of the eleven CWG venues, including the proposed Games Village, vulnerable to greatest intensity of damage, lie in a calamitous cusp between both seismic and flood hazard zones of the city. Five of these are in the immediate and deleterious vicinity of the city's worse levels of air and water pollution.[1] Event organizers find deceptive comfort in the seasonal, and thus approximately predictable nature of the greatest supposed perceived risk, the monsoon floods.[2] However, some of Delhi's worst floods (1988 and 1995) occurred in months proposed to host the CWG 2010. The Yamuna River's approximately eight to nine year flood cycle (1978, 1987, 1995) suggests a very high probability of destructive floods in years immediately preceding the CWG. Thus, the threat of disruption by natural catastrophe is not limited to 2010. It exists in increasing order of risk over the entire construction period, starting 2006. Furthermore, effects of such catastrophes might not be limited to specific sites. Major traffic arteries and public functions along the river shall inevitably transfer or magnify disruptive stress from other locales to the Games venues.

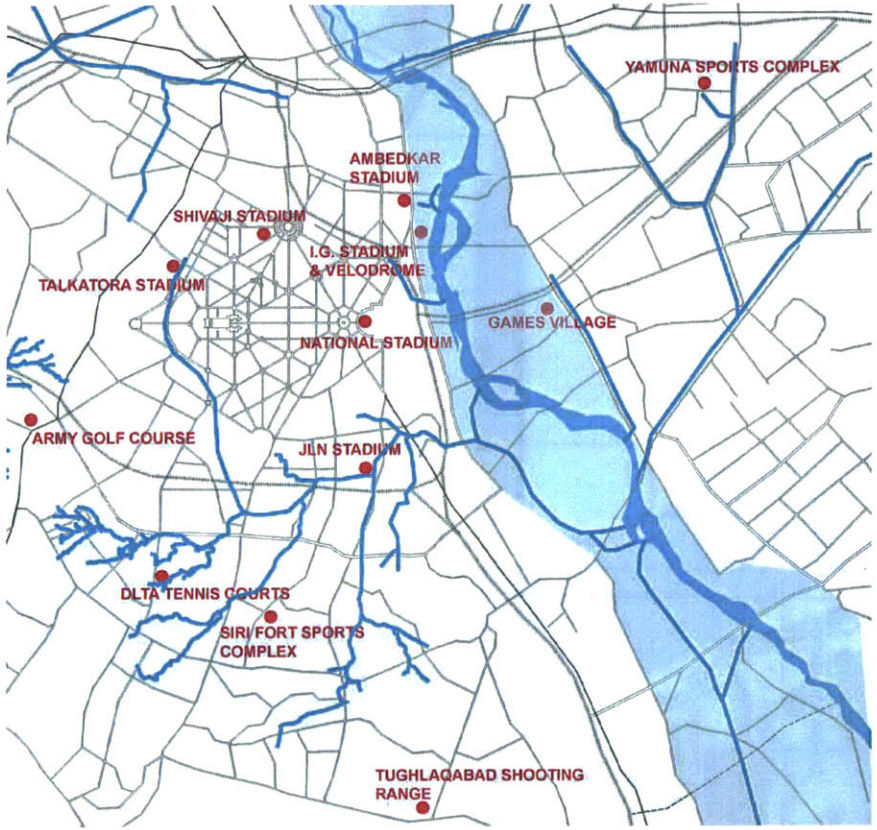


FIG. 1-1. Most CWG 2010 Venues flank Delhi's Streams and the Yamuna River. The proposed Games Village site lies in the annual floodplain. All but three sites are prone to water logging or flood threats.

Crafting a Disaster

Delhi was announced host to the CWG 2010 by the Commonwealth Games Federation General Assembly on November 13th, 2003 at Jamaica. Delhi's bid was prepared behind closed doors by the Indian Olympic Association (IOA) with little input from local government, planning authorities or citizens. The bid's success caught Delhi's city planners and citizens by surprise, and created a euphoria that masked violations of the city master plan. Plans were announced to upgrade and reuse

FIG. 1-2. The Yamuna Riparian Corridor with Cultural, Heritage, Recreational and Infrastructure Resources.

ten sports facilities on the western bank of the Yamuna River, which were largely constructed to house the 1982 Asian Games. New construction was to be limited to the eastern bank of the river, consisting of a 47.3-hectare (118-acre) dedicated Games Village and an indoor sports complex.[3]

Delhi's hydrological system is of substantial but little recognized significance to the CWG 2010. Networks of rivulets and wooded gullies connect venues to the river's west bank (but the Shivaji hockey stadium). Three large stadiums (including gymnastics, cycling, netball and one hockey venue) are built along the riverbanks. On the river's east bank, both the Yamuna Sports Complex and the proposed CWG Village occupy low-lying, flood-prone sites with soft, sandy soils. Planners and architects for each facility must address challenges posed by urban water or face potential disaster.

> "Hazards can be prevented, mitigated, or avoided by proper siting, construction, and building design. Every city should know the hazards to which it is subject, the most hazardous places, and how many people are at risk."
>
> **Anne Whiston Spirn** (1984: 111)

Hazards of floods, land subsidence, and water-borne epidemic, which might be overlooked or purposefully ignored, and are of special consequence to the 2010 CWG venues are hence delineated. These shall be studied in depth for two venue sites: the proposed CWG Village [96] and the largest sports facility, the Jawahar Lal Nehru (JLN) stadium [109]. Limitations of time and information restrict similar detailed studies for remainder sites. However, inferences could be drawn considering their analogous development along water channels, transport arteries and municipal boundaries. Crucial to this chapter's objective is an acknowledgment of the CWG's differential impacts on Delhi's ecology, society and economy. These impacts are expected to range from physical to the most intangible, between manufacturing and tertiary sectors, between middle class and elite and, between city forests and stadium sites. This chapter shall outline a narrow set of some extreme and grave ecological concerns caused by water, while recognizing other ecological, social and economic concerns as important but beyond the scope of this thesis.

Possible effects of Delhi's hydrology on the execution of the 2010 Games are discussed, but I stop short of visualizing possible long or short-term effects on the hydrological systems. This is primarily due to the lack of new building activity beyond the $40 million CWG Village (plans for which are yet to be announced, and thus criticized), and partly to avoid repetition of the vast body of professional literature investigating long-term urban effects of mega-events. The hazards discussed are not exclusive to the CWG 2010 or specific sports venues. Such dangers are acknowledged as of equal if not greater significance to several other parts of Delhi. The thesis intends to transfer insights gained from case studies, to activate a citywide restructure of perception and infrastructure.

Floods and Water Logging of CWG 2010 Venues

Delhi accepts the inevitability of disruption following heavy rain, especially during the monsoons. A closer look reveals two distinct but rarely distinguished problems in Delhi- floods and water-logging. Floods threaten low-lying areas bordering flowing water (Yamuna River, Najafgarh drain, Bawana escape, Sahibi River etc), usually after rains, and do not necessarily originate locally. Water-logging threatens areas with restricted drainage, increased impervious surface area and is not necessarily governed by the intensity or duration of rainfall.

Thus, while four[4] Games sites are flood-prone because of their adjacency to Yamuna River, all but three[5] of the eleven venues are prone to water logging as a consequence of insensitive engineering and inadequate drainage. Higher and longer dykes might shift flood risks elsewhere, but detailed study and restructure of civic infrastructure is compulsory to counter water-logging. Outdated water management technologies, especially at the regional, inter-state level also threaten the Games. The release of excess water from the Tajewala headwork upstream, into the Western and the Eastern Yamuna Canals that rejoin the river at Delhi could the four CWG riverbank sites. Without coordinated discharge at the Okhla barrage (in South Delhi), such waters might be trapped and interrupt connections between the primary eastern sites[6] (Games Village and Yamuna sports complex) and western sites (The Indira Gandhi stadium, Yamuna Velodrome, Dr. Ambedkar and JLN stadiums).[7]

> The Indraprastha Sports Complex was scheduled to sprawl over 44 Ha of low-lying ground on the right bank of the Yamuna River. The whole area was subject to accumulation of rainwater during the Monsoon season. From the layman's point of view, the area might not be the most suitable. For the builder, the top layer of the ground was not suitable for building construction, and this was confirmed by extensive soil investigation.
>
> **Chaudhuri and Chetal** (1982: 23)

The proposed CWG Athlete Village site lies within a non-building, agricultural belt stipulated by the Delhi Master Plan (1962, 1990, 2001). This violation could prompt public protests and litigation like the legal controversy surrounding the adjacent Akshardham Temple. In September 1999, Delhi Development Authority (DDA) amended the Master Plan to show this 50-acre temple site as public use from its initial classification of agricultural and water body.[8] The Supreme Court of India (SC) issued notices on 9th August 2004 to the Uttar Pradesh Irrigation Department, the original custodian of the riverbed, and DDA stating the temple to be an encroachment on government land.

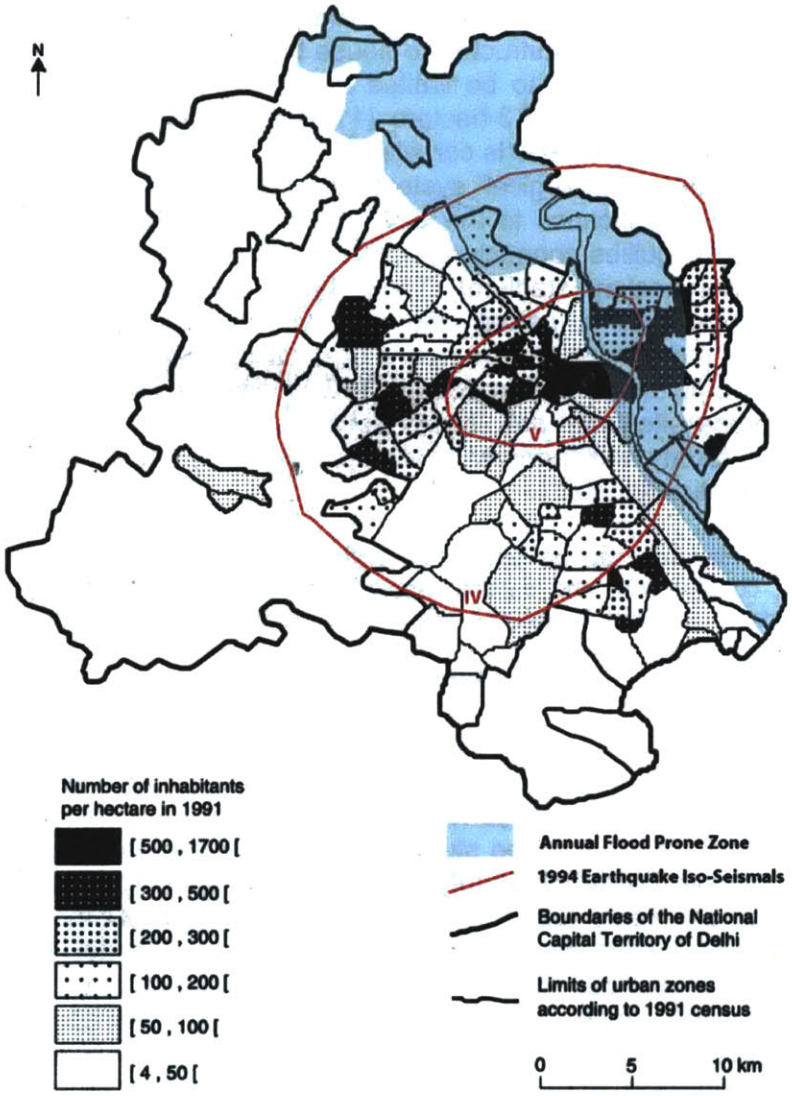


FIG. 1-3. Delhi's Highest Population Density Regions are clustered along the Highest Flood and Seismic Hazard Zones.

FIG. 1-4. Construction of Access Road to the Proposed CWG Village Site. The road is being built atop an existing flood embankment. Note the sand deposits from recent river floods, and the elevated

FIG. 1-5. Earth Piled Atop Flood Embankment along the CWG Village Site. The sandy, flood-prone soils cannot sustain most tree species. Note the withered plantation.

FIG. 1-6. Drains and Embankments to Protect the CWG Village Site.

FIG. 1-7. The Worrisome Level Difference Between Road Level and Ground Level at the CWG Village Site

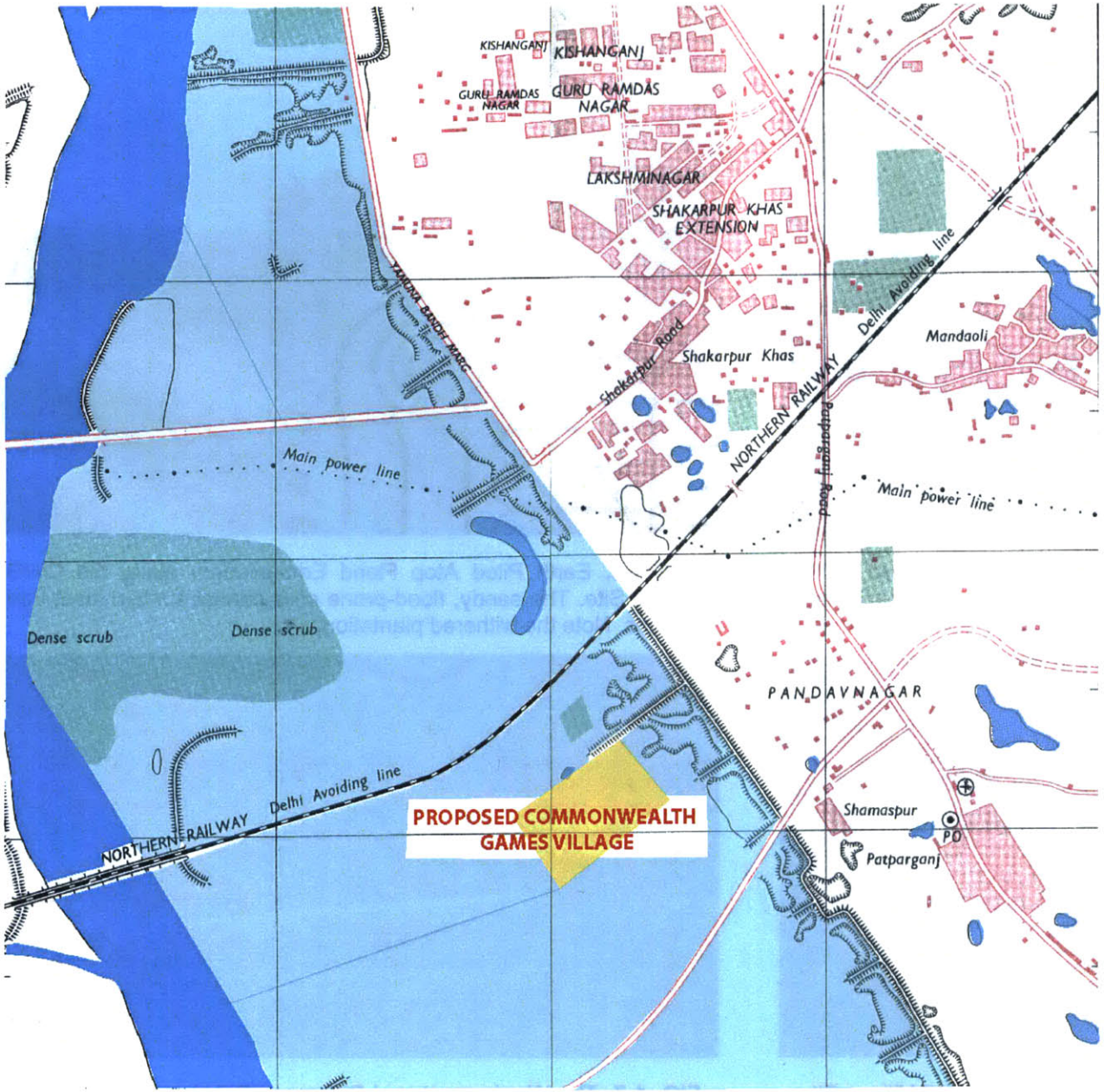
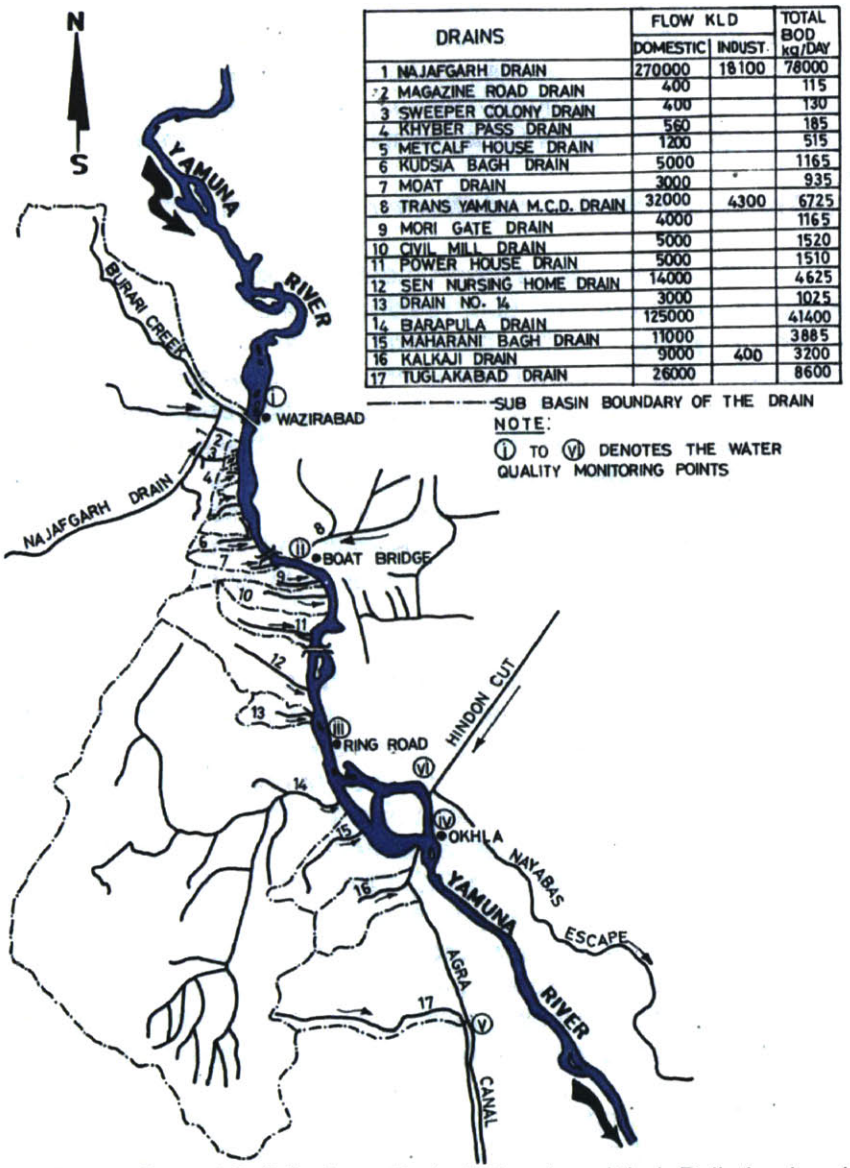


FIG. 1-8. The Proposed CWG Village Site, as seen on the 1972 Survey Map. The shaded region shows the areas inundated by the 1995 Yamuna River flood. All regions on this map were submerged during the 1978 flood. Note the numerous marshes and lakes that have been since built over.

"The SC notices brought back into focus the blatant disregard for environmental concerns by mega projects. Urban planners and architects have consistently raised their voices against projects like DND flyway, Commonwealth Games village and Metro's Operation Control Center as posing a threat to the ecological balance and confining Yamuna to a narrow channel."[9] The CWG Village site's immediate proximity to the temple and similar legal status could incite an equally embarrassing episode.

The CWG Village site lies within the 25-year floodplain belt of River Yamuna. The rectangular land parcel lies to the west of the first girdle of East Delhi's development, and thus closer to the River than any previous construction in its floodplain. The site is bound on all four sides by earth embankments, and lies more than six meters below adjacent roads and four meters below the infamous 1978 flood's water level.[10] The Kolkata branch railway line, NOIDA city link road and flood control dykes restrict drainage possibilities and limit drainage solutions to expensive mechanical dewatering. River floods, water-logging and the high groundwater table create a perennial menace to any development, with high risks of structural damage and inflated construction costs.

Other sports venues like the SP Mukherji swimming pool [77], Talkatora and JLN stadiums on the west and higher riverbank are vulnerable to floods of Delhi's streams or *nallahs*. These facilities border major drains (Kushak and Nizamuddin *Nallahs* respectively), which overloaded by the city's tremendous effluent discharge can barely manage increased storm run-off from growing areas of impervious surface. The ruin of traditional hydraulic structures (such as controlling dams, valves and diverting channels) along these streams has rendered these sites vulnerable to back-flows from relatively distant and minor river floods. Extensive re-engineering of traditional drainage systems in the early twentieth century, including the diversion, burial and lining of *nallahs* have compounded flood risks at the site.[11] Flashfloods in the 18 drainage channels can only be pumped out slowly, unlike river floodwaters that could theoretically be diverted down stream. These stream floods damage dense city



DRAINS	FLOW KLD		TOTAL BOD kg/DAY
	DOMESTIC	INDUST.	
1 NAJAFGARH DRAIN	270000	18100	78000
2 MAGAZINE ROAD DRAIN	400		115
3 SWEEPER COLONY DRAIN	400		130
4 KHYBER PASS DRAIN	560		185
5 METCALF HOUSE DRAIN	1200		515
6 KUDSIA BAGH DRAIN	5000		1165
7 MOAT DRAIN	3000		935
8 TRANS YAMUNA M.C.D. DRAIN	32000	4300	6725
9 MORI GATE DRAIN	4000		1165
10 CIVIL MILL DRAIN	5000		1520
11 POWER HOUSE DRAIN	5000		1510
12 SEN NURSING HOME DRAIN	14000		4625
13 DRAIN NO. 14	3000		1025
14 BARAPULA DRAIN	125000		41400
15 MAHARANI BAGH DRAIN	11000		3885
16 KALKAJI DRAIN	9000	400	3200
17 TUGLAKABAD DRAIN	26000		8600

FIG. 1-9. Central Delhi's Open Drain Network and their Pollution Loads on the Yamuna River.

neighborhoods and disrupt prime traffic arteries, causing great socio-economic damage. The JLN stadium is particularly prone to flooding. It's position at the confluence of the Kushak, Khirki, Hauz Khas and Nizamuddin *Nallahs*, which drain most of South and Central Delhi, renders it vulnerable to periodic stream floods.

The Threat of Pollution and Disease to the CWG 2010

Delhi is the world's fourth most polluted city[12] and despite measures to control vehicular, residential and industrial pollution in recent years, health problems have continued to rise unabated.[13] The Yamuna River is one of its greatest victims. The city's daily discharge of 1393 MLD of sewerage and 1880 MLD of wastewater reduces the river to a stinking, black drain. Delhi's groundwater contains high concentrations of nitrates and fluorides (often more than 45 mg/liter and at some places it is even more than 100mg/liter).[14] Hospitals and informal industries often discharge untreated liquid wastes onto or in the vicinity of the city's streams.

Delhi's sports facilities in proximity of these water bodies are exposed to perilous health risks. The increased metabolism and outdoor exposure of sportspersons at these facilities magnifies this danger. Greater volumes of polluted air and water absorbed by athletes could accentuate a Delhi visitor's expected risks of respiratory and intestinal ailment. The controversy about poor air quality at the Mexico City Olympics (1968) reminds the import of environment quality to sport mega-events. The vicinity of prime city roads, bridges and potential bottlenecks to sports venues shall further expose participating athletes to increased vehicular pollution. Health risks faced are amplified by the concentration of five venues along the river's pollution corridor.

The low-lying Games Village site is a natural pollution sink, sandwiched between soil-borne leaching of toxicants from east Delhi neighborhoods and seepage of pollutants from the river in the west. The soil consisting of clay/silt mixed with mica flakes promotes capillary action and an accelerated propagation of dissolved compounds. A high water table following the monsoons and during the scheduled Games, would deposit high concentrations of heavy metals, pesticides and other carcinogenic compounds at the site from the heavily polluted river. Leaching from the large city landfill sites and Indraprastha thermal power plant [79] on the opposite riverbank could worsen this harm. Such contamination risk is great from sanitary landfills like the present day Smriti Van Park[15] [95] where "the water table is higher than the base of the dump and the water actually sits in the refuse for a considerable length of time" (Leveson 1980:78). Coagulation or settling along the riverbed accounts for nearly 50% of the BOD, 50% of the SS and almost all heavy metal and pesticide loads added in Delhi.[16] The risks of years of polluted sediments and their seepage into Delhi's aquifer systems has yet to be evaluated.

Delhi's industrial wastewater amounts to 70 MGD[17], most of which is untreated industrial effluent discharged from small-scale industries. Many of these illegally operate from residential localities such as Shakarpur, Anand Vihar, Gazipur, and Kalyanpuri [81-82, 97] to the immediate east of the CWG Village site. Unfortunately, most CWG sites border the three-drainage channels- the Najafgarh, Trans Yamuna and Kalkaji *Nallahs* (out of Delhi's seventeen *nallahs*) that have significant concentrations of industries. Worse still, most Delhi's neighborhoods are not served by municipal sewers are also sited in these drainage basins. This threat is magnified when floods wash down from the industrial areas along the *nallahs*.[18] The largest of these semi-industrial parks pose severe risk of industrial disasters, given their present state of flood preparedness.[19] Ground water studies in immediate vicinity of the Yamuna Velodrome and I.G Stadium, following the 1995 floods revealed a sinister excess of total dissolved solids, alkalinity, and metals such as Ca, Fe and Mn.[20]

Poor surface drainage in East Delhi, results in a higher ground absorption of pollutants and their subsurface transfer to

the river (especially in the dry summer months). The CWG Village site's concentration of harmful chemicals could increase through floodwater inundation. The Central Pollution Control Board's (CPCB) study[21] highlighted the "contamination of surface and underground water bodies in terms of excess levels of physico-chemical, bacteriological, heavy metals and pesticides due to mixing of waste with flood waters".

The JLN stadium with its well-drained alluvium soil and rubble masonry lined *nallahs* would appear better in comparison. However, it faces challenges of a different order and magnitude. The Nizamuddin, Khirkee and Kushak *Nallahs* transport large quantities of polluted runoff from paved surfaces in south and central Delhi (approximately 15,677 kilometers[22]), which are serve the majority of Delhi's 3,551,690 registered vehicles. This diffused water pollution consists of heavy metals such lead, sulphur, hydrocarbons such as benzene, rubber and other toxic chemicals.

These *nallahs* also carry surface runoffs and wastewater from 32 city hospitals and over 300 private nursing homes by the time they pass the stadium site. There are no present studies to suggest hazardous bio-medical and radioactive wastes in the streams. However, significant risks exist given the laxity of rules governing liquid wastes from such facilities, and the proliferation of illegal nursing homes.[23] The *nallahs* today, are indisputable channels of disease and dirt. Planned development has treated them as public dumps or territorial markers, making them natural receptacles of slum settlements. Slums like the settlements at Madangir [135], Andrews Ganj [108], Jangpura [109], INA colony [107], increase bacteriological pollution and epidemic risks posed by the *nallahs*. Delhi annually faces serious epidemics —cholera, gastroenteritis, amoebiosis, typhoid, jaundice, fluorosis, malaria, hepatitis, and other sickness from water and vector-born diseases.[24]

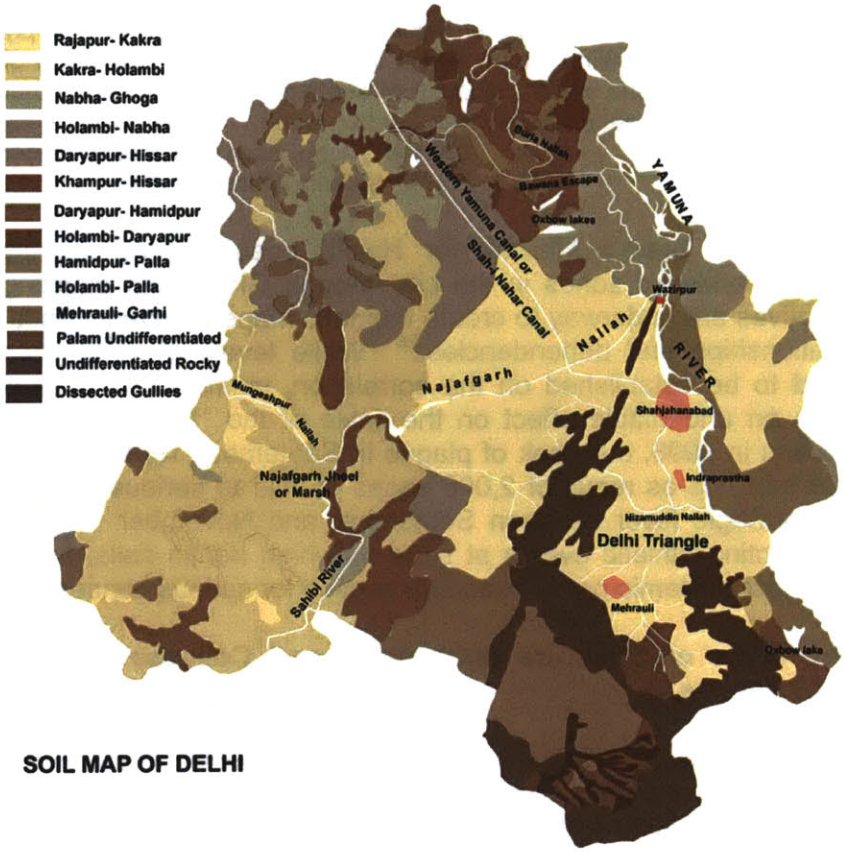
" There have yet been 1,172 reported cases of cholera and 44,857 cases of gastroenteritis this year (2004). It is up to the sanitation department to prevent water-logging and for DJB to supply uncontaminated drinking water. Rains inevitably mean a worsening of the quality of ground water, because of seepage of garbage and other contaminants that get dissolved with the rain water."

Dr K N Tiwari, Municipal health officer
(Times of India 4th Aug 2004)[25]

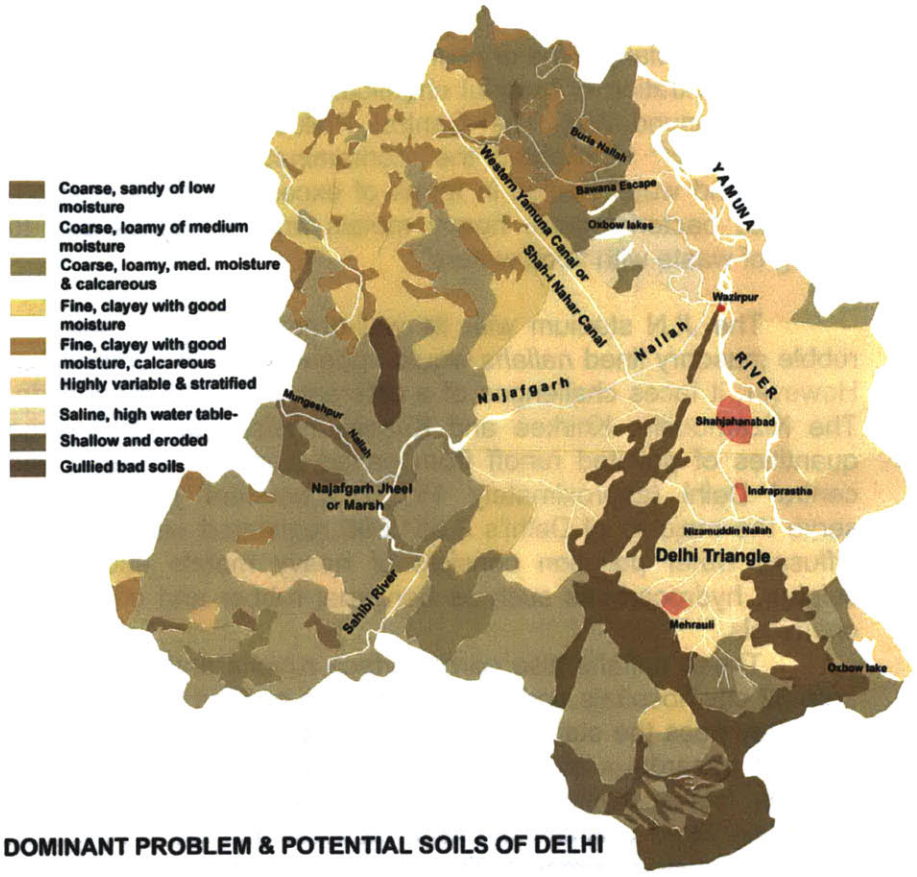
The State's Ministry for Health does not yet identify disease-endemic zones in the city, though GIS health mapping initiatives are underway to create thematic maps to reveal trends, relationships and dependencies.[26] While levels of confidence need to be established on the correlation, slums along *nallahs* have an undeniable affect on the scale of the "7,167 cases of malaria in 1996, outbreak of plague in September 1994, and the 200 fatalities as result of 2,000 cases of mild to serious dengue hemorrhagic fever between September and November 1996".[27] Conducting athletic events at sites with high health risks during the most epidemic-prone season is reason for serious concern.

The Risks of Structure Subsidence and Collapse at CWG 2010 Venues

Structure subsidence is the least perceived threat to the 2010 Commonwealth Games, but this inattention is not merited by the low incidence of this hazard. On the contrary, several parts of Delhi[28] have periodically lost millions of Rupees due to sinking buildings and infrastructure. This insouciance might result from a lack of public information and city-planning application of available urban geological studies.[29] The torpor could be an effect of the myopic view of subsidence as a rare seismic phenomenon, or the incomprehensible perspectives of geo-experts. For instance, subsidence caused specifically by water could be investigated separately through hydrogeology (depth of ground aquifers), hydraulics (static and dynamic behavior of ground and surface water), hydrology (distribution and effects of water on the earth's surface) or geochemistry (chemistry of the composition and alterations of ground matter). Structural collapse because of



SOIL MAP OF DELHI



DOMINANT PROBLEM & POTENTIAL SOILS OF DELHI

FIG. 1-10. The Delhi Soil Map.
This map is drastically handicapped by the present lack of data regarding soil types within urbanized areas. The author generated this map from data available for low-density land or agricultural use land from soil surveys conducted in 1970s. While patterns begin to emerge along the path of the seventeenth century Shah-i Nahr canal, the Delhi triangle with its different historic settlements cannot yet be studied.

FIG. 1-11. A Map of Dominant Problems & Potential.
This map builds from FIG. 1-5 to map out trouble spots and 'no-no' buildable zones. With additional data for the soils of the Delhi triangle, the author aims to correlate historic development patterns with geographic constraint patterns to determine the extent of environment determined urban design in Delhi.

water, especially the failure of building foundations, could result from either land subsidence/ depression or soil expansion/ swelling. Drastic drops in water level by extraction of non-replenished fluids could trigger the former. Soil expansion might occur in poorly compacted clay/ sand soil base, which might swell on contact with water.

The CWG Village site is classified as highly variable stratified soil[30] with uniform, poorly graded, gray, river sand till at least nine meters below ground level (BGL).[31] Subsurface lithology investigations[32] reveal that the first sand layer extends till 20 meters BGL and is followed by an impermeable, 10 meter thick layer of sand, silt and *kankar* (calcareous concretions / pebbles). The proximity to the river, large flood overflow basins and continued hydraulic pressure from the eastward shift of the river has saturated the site's top most sand layer. The relatively slower absorption through the lower composite layer culminates in high water tables after the monsoon rains that could be significantly high in the proposed CWG hosting months.

Excavation of soil from the site to create the adjacent embankment (today the NOIDA link road), further lowered the site's elevation and transformed it into a marsh, and a seasonal lake. Extensive development north and east of the site has led to significant drops (beyond three meters) in the region's high underground water.[33] Given the nature of the site's soil, ground elevation and overtaxing of underground water resources, any construction shall be prone to unequal settling of foundations, seepage and corrosion of infrastructure. Reducing floodwater basin areas or overt irrigation for ornamental landscapes shall disturb the region's hydraulic balance.

Deeper study of the JLN stadium site presents some geologic surprises. Despite its considerable distance (at least two kilometers) from the present riverbed, it geologically resembles the CWG Village site, with a poorly graded sand layer till nine meter BGL. The site lies amidst a ribbon of such sandy soil, distinct from Central Delhi's alluvial plain that traces the course of the buried Nizamuddin *Nallah*. Similar sand belts along the Najafgarh *Nallah* point to possible silt deposition by the larger Delhi streams over time. The site thus needs to be studied for susceptibility to undersurface flows along the original stream course.

The site notably, also sits atop a small two square kilometer tract of elevated bedrock (30 meter BGL)[34] within the larger alluvial plain. Furthermore, site preparation during the 1982 Asian Games involved large-scale earth-filling and compaction that could today be vulnerable to water absorption from surface and underground water flows. Detailed investigations are required to define the possible scale of what is conspicuously an emerging danger. Other sports venues, intended for use by the CWG already demonstrate the high costs of neglecting water caused geological hazards. The Talkatora stadium [91], built along the Delhi Ridge derives it name from a medieval garden at the site. The name is an amalgamation of two words describing the site's geomorphic context, *tal* or lake and *katora* or bowl-like depression. True to its name, the site featured high subsoil water levels that had to be mechanically depressed in an expensive, emergency operation before the 1982 Asiad, to prevent structural damage. "In August, 1982 the bottom slab of the diving pool cracked due to subsoil water pressure, resulting in leakage of subsoil water into the floor of the diving pool" (Basu and Majumder 1988:34).

Amplifying Seismic Vulnerability of the CWG 2010 Venues

Delhi's water systems may not trigger but could dramatically heighten the damage wreaked by earthquakes. Risks from weak, shifting or shallow soils worsen when coincident with fluvial flows, seepage weakened soil cohesiveness and structural foundations. The abuse of Delhi's hydrological complex with construction atop unstable soils in a tectonic hotbed is a sure recipe for disaster. Delhi lies at the spearhead of the Aravalli mountain belt's northeastward thrust into the Himalayan crumple zone. The city lies in the seismic zone IV, and is classified to

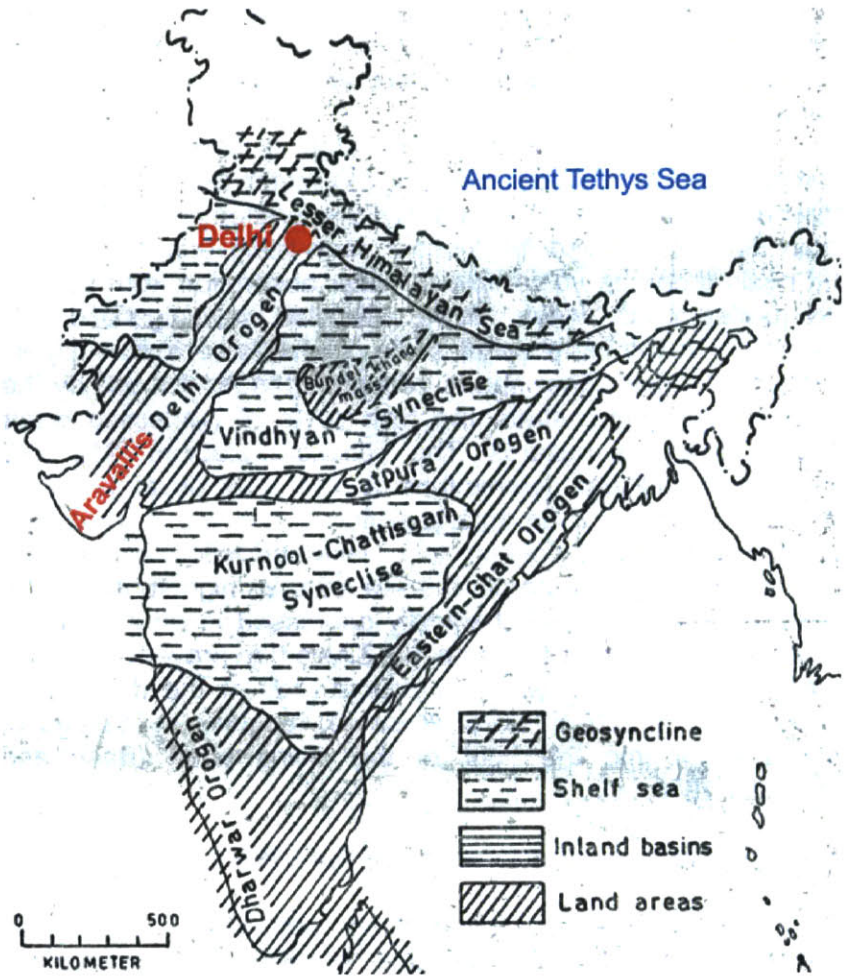


FIG. 1-12. Palaeogeographic Map of India.
Delhi lies at the tail end of the Delhi Orogen and is the youngest in the sequence of rocks. It once formed the spur of land jutting into the Tethys Sea, and later the Lesser Himalayan Sea.

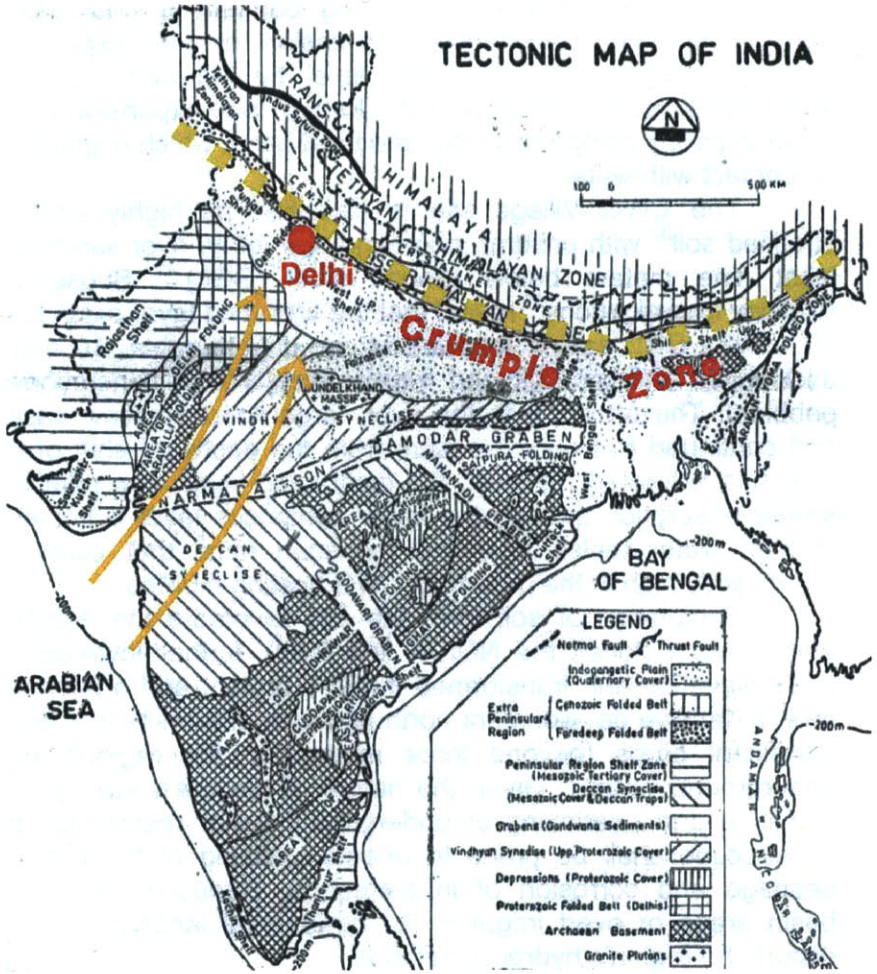


FIG. 1-13. Palaeotectonic Map of India.
Past tectonic movements inferred on the basis of palaeography & structure of rocks.

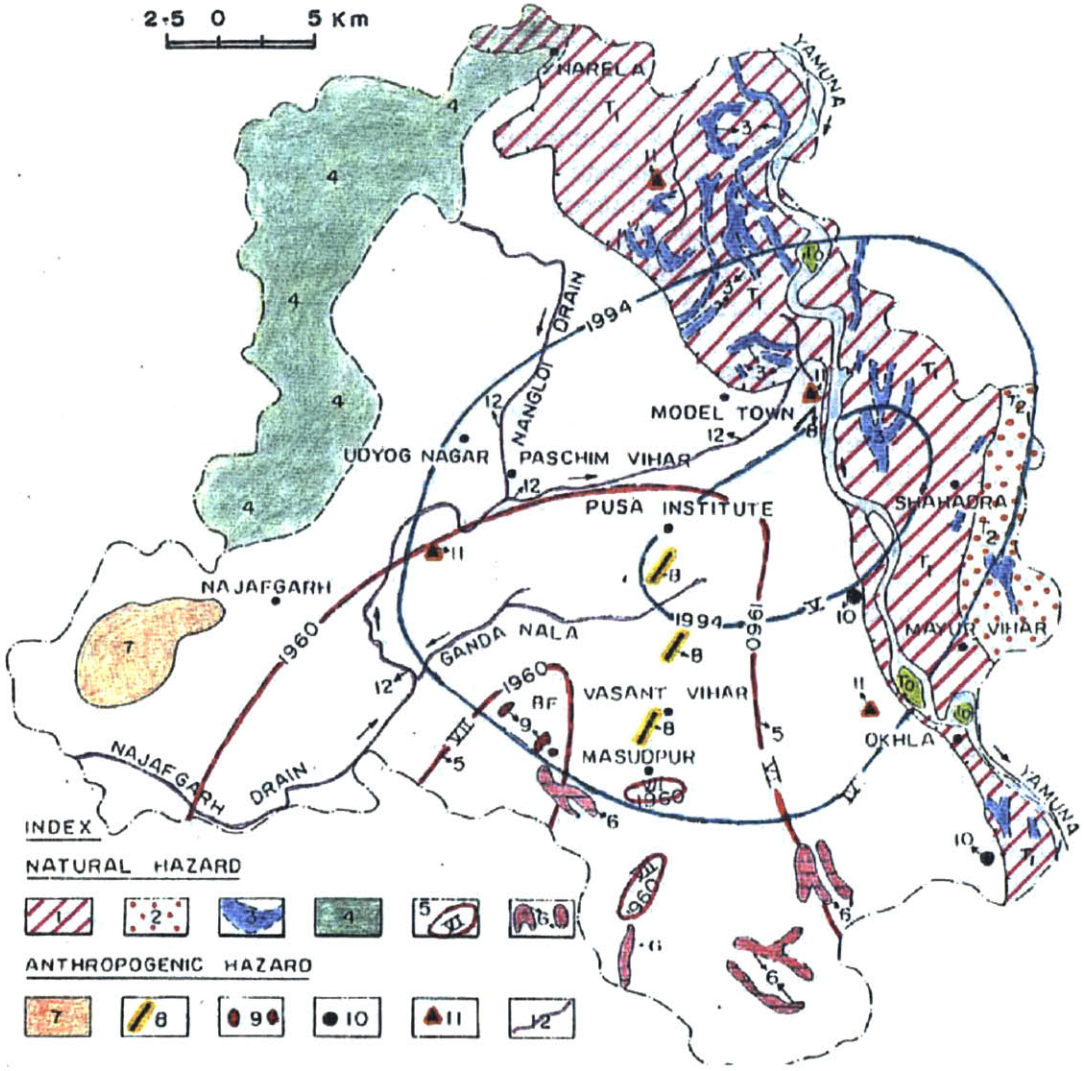


FIG. 1-14 Natural Hazard Map of Delhi.
1) Annual Flood Prone, 2) Occasional Flood Prone, 3) Seasonally/ perennially water logged, 4) Saline Ground Water, 5) Iso-Seismals, 6) Bad land and Bedrock Collapse, 7) Ground Water Overdraft, 8) Scarification by Mining, 9) Brickfields caused degradation, 10) Fly Ash Dumps, 11) Solid Waste Dumps, 12) Polluted Ground Water.

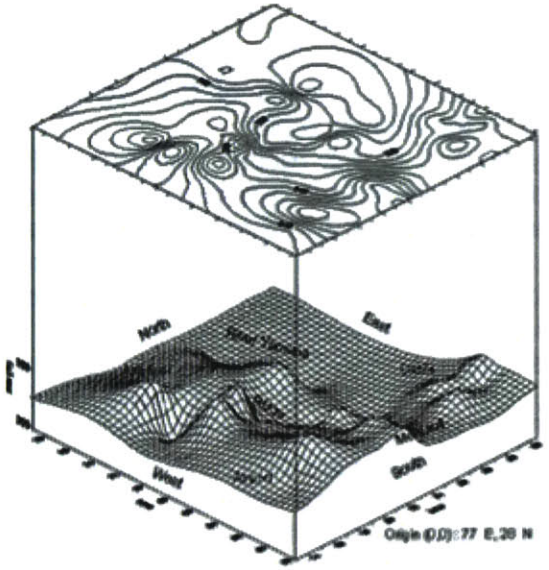


Fig.1 : Topography of Delhi

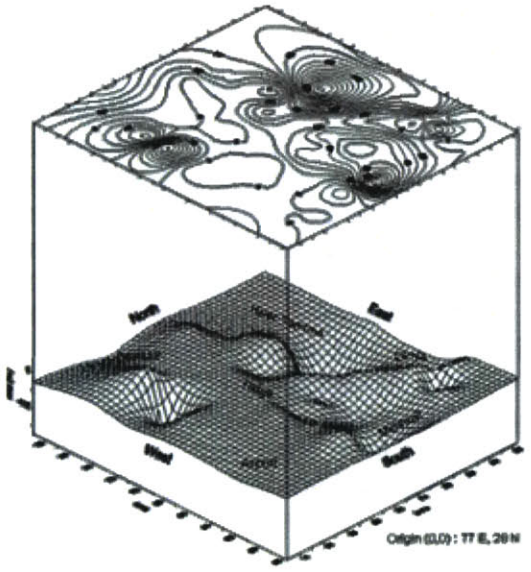


Fig.2 : Thickness of sedimentary deposits in Delhi

FIG. 1-15 Topography Surface Modeling to Determine Vulnerability of Different Neighborhoods along the Streams and the River.

have a high probability of tremors measuring 5-6 on the Richter scale, low probability of shocks of 6-7 scale, and occasional shocks of 7-8 on the Richter scale.

Many quakes of 4-5 Richter scale have had epicenters along the northeast-southwest axis of the Delhi fold. Delhi is also prone to the more frequent and intense earthquakes along the Himalayan fold (Uttarkashi earthquake, October 1991 and Chamoli earthquake, March 1999). The city experienced major earthquakes (6-7 on the Richter scale) in August 1803, October 1956, August 1960 and 1994. Moderate quakes were recorded in 1720, 1819, 1905, 1934, 1937, 1945, 1949, 1958, 1966, 1975, and 1980. There has been little recent tectonic activity. 'Such a decline in frequency leads to build-up of the stress, which can be released any time, and the intensity of earthquake shocks depends on the amount of such energy stored in the rocks'.[35] Not surprisingly, the region's tectonic activity is the prime instigator of the Yamuna River's eastward shift, down cutting, creation of sand banks and swampy terraces.

The CWG Village sits over an unstable base of deep sediment layer. The first relatively stable layer of consolidated clay begins at 40 meters BGL, while bedrock begins at depths around 100 meters BGL. 'Ground motions are substantially amplified near the ground surface with thick sedimentary cover' (Milne, 1898). The site invariably lies in the most seismically vulnerable part with the highest peak ground acceleration expected in the city. The high water table and poor drainage further this perilous condition. Damage may intensify as a result of liquefaction, or flow of water-saturated sand or silt. Liquefied soil may flow like a mudslide towards the Yamuna River, sinking or uprooting all structures in its path. The site thus is prone to tremendous damage from even mild tremors that may disturb the progressively abused and precarious geo-hydraulic balance.

Damage to or Loss of Critical Infrastructure Crippling the CWG 2010

The greatest probability of disruptive threat to the CWG 2010 lies in the city's high vulnerability of critical infrastructure at the regional, district and neighborhood levels. There is a conspicuous lack of comprehensive disaster management plans with the ability to mitigate, preparedness to counter, capacity to respond[36] and resources to recover. The CWG 2010's vulnerability shall persist in spite of temporal investments in resistance to expected risks, because of its high degree of risk exposure caused by its high dependence on vulnerable urban infrastructure.

Bridges across the Yamuna, linking the Games Village and Yamuna Sports Complex [60] in East Delhi with the remaining nine venues in Central Delhi are vulnerable to closure by late monsoon floods around October (the proposed event schedule). The structural capacity of the four older bridges (designed for pressure of floods ranging between 200,000 to 300,000 cusecs) is inadequate to withstand the increasing intensity of the Yamuna River's floods (500,000 cusecs noted in 1978). In 1978, flood water levels of the river rose three meters higher than the danger mark of 204.83 meters, causing all connections across the river to be closed for two days. A decision to blow up the Old Delhi Rail cum Road Bridge had nearly been taken[37], to prevent the obstruction of floodwater by debris trapped by bridge piers. The Interstate Bus Terminals (ISBT) at Kashmere Gate [57], Sarai Kale Khan [95] and Anand Vihar [61] and interstate highways 2 and 24 lie within the river's 50-year flood plains. The primary metro rail and Delhi Transport Corporation (DTC) bus depots constructed along the riverbed could cripple public transit services while flooding of the prime traffic artery along the river, the Ring Road, could stall the city's pivotal north-south connections. The busy GT Road or National Highway 1 was submerged between Jahangirpuri [10] and Model Town [20] for several days in the floods of 1978[38] and 1995.

Delhi's electric supply faces a precarious condition with all three local power stations sited along the Yamuna riverbed and the multitude of electric distribution facilities constructed on public land flanking streams. The vulnerability of water supply services can be estimated from the system's overt dependence on the extraction plants along the river at Wazirabad (64.4% of total available raw water) and Okhla (2.3%). The six aquifer extraction Ranney wells (3.8%) at Wazirabad, Shahdara and Chandrawal [37] are similarly prone to pollution and failure from floodwaters.[39] Water treatment plants at Bawana, Haiderpur, Okhla (31.2% of the city's treatment capacity), Nangloi [49] and Sonia Vihar [41] could suffer long-term damage from floods and water-logging. The underground reservoirs (UGR) and booster pumping stations (BPS) in Subhash Nagar [73], Mangolpuri and Kondli [98] could be paralyzed and stall the entire water extraction, treatment and storage network. The sewage treatment plants (STPs) at Coronation Pillar wastewater treatment plant (9.5% of the city's waste water treatment capacity), Timarpur [22], Sen Nursing Home, Papankalan [101], Rithala [16], Keshopur (5.7%), Kondli and Nilothi [70] are also susceptible to flood damage. The flood vulnerability of all of the city's existent landfill sites at Okhla, Ghazipur, Bhalswa and the proposed new landfill at Jaitpur [138A] exacerbates dangers of epidemic outbreaks.

But, This Need Not Be: The Ever Present Choice

"For every city a choice is possible: harmonious accommodation may be reached in which natural opportunities are made best use of and natural restrictions respected, or strenuous efforts may be exerted to ignore or override the natural world if it interferes with certain visions or desires. In either case, the natural environment must be dealt with, successfully or unsuccessfully; the necessities of life have to be furnished; the hazards of the universe avoided or lessened in their impact" (Leveson 1980:1).

Delhi's planners and citizens now need to make a choice that they have repeatedly faced at stages of the city's growth over centuries. They have chosen wisely to benefit and foolishly to severe loss in the past. While modern Delhi has grown with wasteful and dangerous disregard and abuse of its underlying ecosystems, we know of times when this was not the case. Awareness and time-honed knowledge of Delhi's terrain has been used by enlightened city-founders, to guide urban environment towards achievement of its maximum potential. A study of Delhi's urban form, like for many other cities, exposes deep hydrologic influence. Valuable lessons for the future could be thus derived from examination of past episodes of hydrologic foresight and benefit, and of ignorance and blunder.

(Endnotes)

[1] The Indira Gandhi stadium, Yamuna velodrome, Games Village, Shivaji stadium and Dr. Ambedkar stadium lie within the heaviest air pollution zones of the city. The first three are also prone to the poisoned waters of the Yamuna River.

[2] The Games announced to be held from 23rd October till 3rd November 2004, lie in the traditionally 'low flood threat' period, which usually peaks in August-September.

[3] Originally envisaged by the Delhi master plan as a district level stadium, the recently constructed Yamuna sports complex is now being added to and scaled up to provide international sport standards.

[4] The Indira Gandhi stadium, Yamuna velodrome, Games Village and Dr. Ambedkar stadium lie within the declared Yamuna River flood plain. Entire sites and access to them were inundated in the 1978, 1988 and 1995 floods.

[5] The National Stadium, Karni Singh shooting range and Shivaji stadium are relatively safe due to their ground elevation, and partly due to heavy investments in local high capacity drains.

[6] This headwork, 224km upstream from Delhi's first barrage at Wazirabad, lies in the state of Haryana and allocates Yamuna River water between the three states of Haryana, Delhi and Uttar Pradesh.

[7] "Previously in 1980, a discharge of 2.75 lakh (hundreds of thousands) cusecs at the Tajewala headwork had resulted in flood level of 212.15 meters (eight meters above danger level) at the *bundh* near Palla village in Delhi" in Taranjot Kaur Gadhok's *Floods in Delhi.* Research paper accessible at http://www.gisdevelopment.net/application/natural_hazards/floods/nhcy0008a.htm

[8] Accessed from the World Wide Web on 10th August 2004 from *the Times of India* daily newspaper website: http://www1.timesofindia.indiatimes.com/articleshow/msid-808906,curpg-1.cms. Article titled 'Temple Construction Would Pollute the Yamuna Further: PIL' on 10th August 2004.

[9] Accessed from the World Wide Web on 11th August 2004 from *the Times of India* daily newspaper website: http://www1.timesofindia.indiatimes.com/articleshow/808876.cms. Article titled 'SC rings Alarm Bells on Akshardham' on 10th August 2004.

[10] Gadhok, Taranjot Kaur's *Floods in Delhi.* Ibid. pg.4.

[11] The Nizamuddin *nallah*, originating from the Delhi Ridge near the locality of Karol Bagh was the city's largest and longest drain channel till the nineteenth century. It was entirely buried into sewers and emerges to daylight at the Jawahar Nehru stadium site.

[12] In terms of Suspended Particulate Matter (SPM) by the World Health Organization (WHO), in Taranjot Kaur's *Risks in Delhi: Environmental concerns.* Research paper accessed at: www.gisdevelopment.net/application/natural_hazards/overview/nho0019.htm

[13] The number of premature deaths due to ambient air SPM has increased from 7491 in 1991/92 to 9859 in 1995 according to estimates in the *State of Environment Report for Delhi 2001.* TERI. Ibid.

[14] Taranjot Kaur's *Risks in Delhi: Environmental concerns.* Ibid. pg. 4.

[15] Along the Ring Road and the Yamuna River, near the NH24 Hapur Bypass bridge and across the River opposite the Games Village site.

[16] CPCB. 1979. *Union Territory of Delhi (Detailed).* Delhi: CPCB Press, 29.

[17] Taranjot Kaur's *Risks in Delhi: Environmental concerns.* Ibid. 3.

[18] Only three of the twenty-eight industrial estates have common effluent treatment plants (CETPs), as reported in the *Delhi Urban Environment and Infrastructure Improvement Project* (DUEIIP) *Project Report* No.1, part II, February 2001 by the Government of India (GoI) and the Government of the National Capital Territory of Delhi (GNCTD).

[19] Such as the Jahangirpuri industrial area, Rajasthan Udyog Nagar, Wazirpur industrial area, Arya Nagar industrial area, GT Karnal Road industrial area, Loni industrial area, Anand industrial estate, Rajinder Nagar industrial area, Mohan Coop industrial area.

[20] CPCB. 1995. *Groundwater Quality in Flood Affected Areas of Delhi.* Delhi: CPCB Press. Table 5.1, 12.

[21] CPCB. 1995.

[22] Planning Department, GNCTD. Socio-economic Profile of Delhi 2001-02. Census report. Accessed from: www.delhiplanning.nic.in/Socioecoprofiles/ socioecoprofile.pdf

[23] The fifth largest drain of the major seventeen city drains is ironically termed the 'Dr. Sen Nursing Home Drain' in all municipal records and maps.

[24] *State of Environment Report for Delhi 2001.* TERI. Ibid.

[25] Accessed from the World Wide Web on 11th August 2004 from *the Times of India* daily newspaper website: http://timesofindia.indiatimes.com/articleshow/802207.cms. Article

titled 'Water-borne Diseases on the Rise due to Monsoon' on 4th August 2004.

[26] Johnson and Johnson. 2001. *GIS: A Tool for Monitoring and Management of Epidemics*. Paper presented at the Map India 2001 Conference, New Delhi, February 2001, 2.

[27] *Delhi: The Pollution Capital*. Article accessed from: http://cesimo.ing.ula.ve/GAIA/CASES/IND/DEL/DELproblem.html

[28] Especially in localities like Rohini, Pitampura, and Paschim Vihar in the city's northern and northwestern blocks of Alipur and Kanjhawala. Rapid urbanization and withdrawal of fluids, from the largely high moisture level soils has resulted in large-scale subsidence of multi-storied residential buildings.

[29] Several national institutions like the Geological Survey of India (GSI), the Central Soil and Material Research Institute and the Soil Research Institute regularly publish technical reports and recommendations, focusing on the Delhi region.

[30] 'Dominant Problem and Potential Soils of Delhi Territory'. 1976. NBSS and LUP (ICAR) map in K.V Paliwal's *Irrigation water quality and crop management in the Union Territory of Delhi*. New Delhi: Water Technology Center, Indian Agricultural Research Institute.

[31] 'Disposition of Various Soil Groups at 3m, 6m and 9m BGL'. 1997. GSI map in *Contributions of Geological Survey of India in Delhi Area- a resume*. Lucknow: GSI press.

[32] 'Interpreted Subsurface Lithology: East of Yamuna, Delhi'. 1997. Result diagram in *Contributions of Geological Survey of India in Delhi Area- a resume*. Lucknow: GSI press.

[33]'Water Table Fluctuation Map of U.T. Delhi (1960-61 to 1983)'. 1997. GSI map in *Contributions of Geological Survey of India in Delhi Area- a resume*. Lucknow: GSI press.

[34] 'Geotechnical Map of Delhi'. 1997. Result diagram in *Contributions of Geological Survey of India in Delhi Area- a resume*. Lucknow: GSI press.

[35] *State of Environment Report for Delhi 2001*. TERI. Ibid.

[36] The Centralized Accident and Trauma Services (CAT) force in Delhi has but 20 ambulances, the Delhi Fire Service has 165 service vehicles and city's bed patient ratio is 2.2 beds per thousand population compared to the WHO standard of a minimal 5 per thousand.

[37] GNCTD. *The Tide and Triumph: An Account of 1978 Floods*. Delhi: Directorate of Information and Publicity, Delhi Administration. 2.

[38] GNCTD. *The Tide and Triumph: An Account of 1978 Floods*, 7.

[39] The Yamuna River provides 950 MLD and the Ranney wells provide 365 MLD out of a total of 2670 MLD raw water supply received by Delhi, as quoted by the *DUEIIP Status report 2001*, Chapter 7, 5.

A Pattern of Choices: Contest or Concert with Nature

Delhi's hydrological complex has always offered choices between opportunity and disaster. Citizens have sometimes responded positively to create prosperous cities, and sometimes negatively to draw nature's destructive ire. Examples of ingenuous adaptation are accompanied by episodes of inexcusable naiveté. The present century presents a sequence of the latter, which if not discontinued, could irreversibly destroy benefits offered by Delhi's hydrology.

In modern times, powered excavation and earth-moving equipment has promoted disregard for terrain-dictated building limits. However, the inflated costs of such initiatives often results in a desultory compliance with ambits imposed by Delhi's hydrological system. Occasionally, hydrology directly molds urban growth through the enormity or scarcity of surface and underground water in different tracts of the city. Such interventions often act through momentous events like flash floods that would leave deep impacts on public memory and planning. The relationship with cataclysmic events goes further. Delhi's streams and river have discreetly structured built form repercussions of seemingly unrelated political, social and legal upheavals.

> "The evolutionary paths of a complex system, depend on the relationship between timing of perturbation and exact initial conditions and are inherently unpredictable, but not inexplicable, over time. Here explanation becomes essentially historical- the charting of the history of the eco system."
>
> **David Bryne** (1997:55)

A parallel review of Delhi's determinative events and hydrological system reveals how different possible outcomes were varyingly precipitated, nullified or exaggerated. This admittedly is a stochastic process that appears random in short term observations but whose outcome is directional, much like a drunkard's walk. I present Delhi's hydrology, not as a causal but rather as a wholly ignored influence in the city's urban form.

Ignorance and Mistakes

Contemporary planning in Delhi has consistently ignored the mandate of the city's hydrological system. It has repeatedly ignored warnings that were there for anyone to see. And it has persistently used Delhi's streams and river as tools to detestable political and social agendas. Such willful ignorance and abuse has not gone unanswered. Today, water is Delhi's chief incurable woe. Its perennial lack, irremediable pollution, irrepressible floods and role in disease can no longer be seen as distinct problems. Urban planning in Delhi cannot afford to not have a distinct and comprehensive policy for its hydrological complex.

Competing interest groups shall inevitably abuse a tool of such potency for narrow interests and at great expense to the city. A holistic perspective stretching across multiple political, administrative and geographic divisions is essential. Sadly enough, there exists no public memory of past achievements in hydraulic control. An enormous water infrastructure network constructed in the medieval Delhi sultanate has fallen into disuse. An understanding of the regional system was lost in the sixteenth century though the Mughal dynasty used isolated fragments till the late eighteenth century. Delhi's British rulers found the collapsed network a health hazard and an obstacle to their grid- iron settlements. Modern development has ever since systematically dismantled the hydraulic network. Dams have been demolished and rivulets buried and converted to sewers.

The perils of disregarding and misusing Delhi's hydrology can be better understood by exploring its inter-influence with successive critical events in the city's modern history.

The Abuse of Streams by New Delhi (1912-20s)

New Delhi was constructed as a show case city and has continued to be a built political expression. Little studied is the use of Delhi's streams for the primary characteristics of the new city: inspiring servitude, and establishing British legitimacy, racial and economic segregation. The New Delhi Town Planning Committee rejected the original north Delhi site, on the grounds of flood and related health risks. The committee (on May 2, 1912) chose a site three miles southwest of Shahjahanabad for 'its aspects, altitude, water, health, virgin soil and views to ruined tombs to the East'.[1] This rectangular flat field tract was defined on the long North-South sides by stream gullies, the west by the Delhi Ridge and on the east by the Nizamuddin *Nallah*.

The site's streams were reinterpreted as circulation routes. The Curzon / Great College Street-Metcalf Road axis from Connaught place (through the India Gate Hexagon), today runs atop portions of the buried Nizamuddin *Nallah*. The Queen Victoria Road, North of the Central Axis replicates the course of the buried Talkatora *Nallah*. This stream once flew down Rikabganj and Raisina Villages [77] into the Nizamuddin *Nallah*. Similarly, the Clive-Dupleix and King Edward Roads were laid atop the Kushak *Nallah* that defined the southern edge of the site. Ashoka Road today traces the erstwhile Khillauli Bagh stream. These streams were diverted or buried by military engineers, as typical of colonial city building initiatives in India.

While stream courses were reinterpreted as roadways, care was taken to erase terrain that could physically or visually connect the new city's race and class based neighborhoods. Thus, streams originating near the Indian Clerk's housing at Gole Market [77] were not allowed to visibly flow south through the elite Windsor Place and Princes Park quadrants. City greens were not to be planted in snaking-parks, trails or greenways but were limited to the new city's periphery, to act as a *cordon sanitaire*. *Nallahs* flowing through the site were diverted around New Delhi's periphery to insulate one of the largest gated

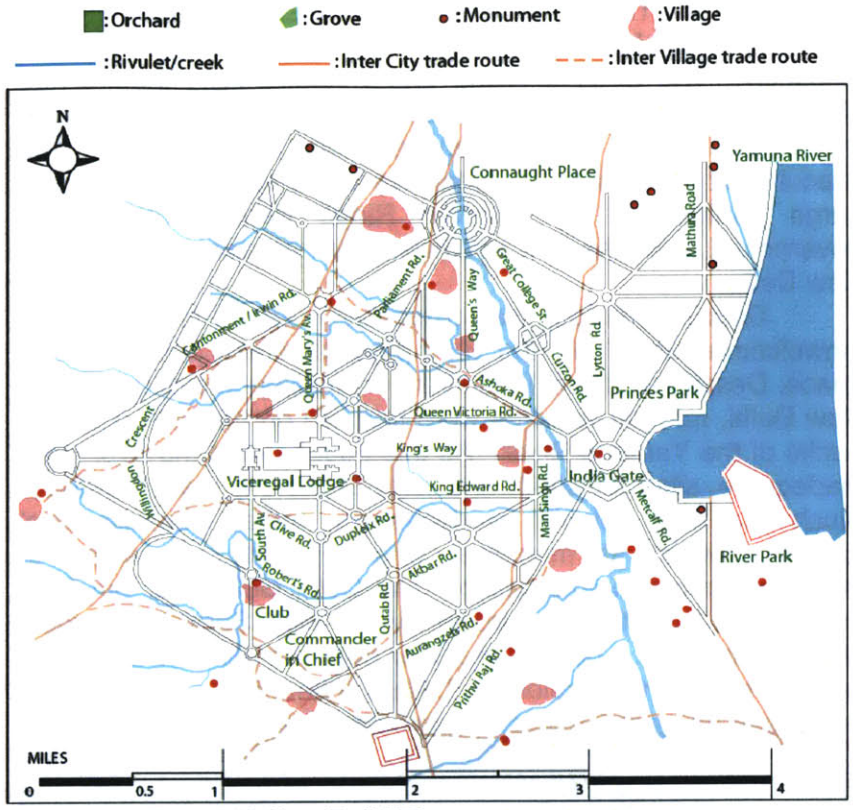


FIG. 2-1. The 1912 New Delhi Plan
The underlay of previously existent water bodies, hills and village routes reveals their conscious and subconscious influences on what is often read as a 'pure political diagram'.

communities. Green preserves instead of public recreation, suburban bungalow aspirations and a lack of pedestrian connectivity has ensured New Delhi's continued elitism.

Pattern of Misuse wrought by the Partition of India (1945-50s)

The Partition and ensuing influx of millions of refugees (in 1947-48) was undoubtedly the most determining event in Delhi's

modern history. The increase in an alien, distraught and destitute population transformed the city's physical and socio-cultural landscape. The Second World War's volatile Asia theatre had already initiated the first violations of the new city's planning guidelines. Urban development projects were planned and executed at rapid pace, at extensive costs to the environment. Large portions of the forested Ridge were developed as government enclaves in a southwestward expansion of colonial New Delhi.

Delhi's hydrology was extensively utilized to incorporate 'unwelcome guests' into the city's physical, social and economic space. Despite available land at the immediate southern edge of New Delhi, refugee colonies were first laid on the low-lying east banks of the Yamuna River.[2] As this tract beyond the river grew inadequate, sites far south and west of the city were identified. Much like their colonial predecessors, Indian planners kept 'unruly crowds' at municipal edges, poorly connected to livelihood or civic infrastructure. The Delhi Golf Club, Siri Fort, Jahapanah Forest [123] girdled by the Neb Sarai-Nizamuddin *Nallah* served as a defensive buffer between elite enclaves and refugee resettlement colonies. Delhi's monument parks and city forests, enmeshed by streams, were wielded as weapons of social exclusion.

FIG. 2-2. The 1978 Flood in the Jahangirpuri Neighborhood. Delhi's floods have a greater nuisance and epidemic consequence rather than drowning related human danger.

Attempts to limit the partition's refugees to established zones led to state sponsorship of small, low-skill industries in the largely residential resettlement localities. Delhi's polluting and indirectly subsidized neighborhood factories began as a result of this early violation of the 1962 Master Plan. State owned land along stream channels was developed as industrial parks, resulting in ribbons of effluent spewing complexes along Delhi's *nallahs*. Latter-day efforts to insert missing civic facilities and green spaces in the hastily developed resettlement colonies led to their construction on the remaining undeveloped public land along the stream valleys.

Priming Floods and Other 'Emergencies' (1975-80s)

The national emergency declared in 1975 triggered off episodes of state terror and violations of democratic freedoms. Though largely remembered as an embarrassing political and institutional tumult, the eviction and relocation of 7,00,000 people in city beautification projects had decisive physical effects. The resettlement of slums in poorly drained, flood and subsidence-prone land, east of the Yamuna River, reused water as a tool for social repression, exclusion and marginalization. Infernal environment and geographic barriers between social groups still blight Trans-Yamuna localities, where nearly three-fourths of Delhi's populace resides.

> During the emergency, five resettlement colonies of Gokalpuri, Khichripur, Kalyanpuri, Sultanpuri and Trilokpuri with an area of 335.58 hectares were developed outside the urban limit of 1981, for which the land had originally been designated as 'green and marshy'.
>
> **Mishra and Gupta** (1981: 26-27)

The subsequent flood of 1978 was the hydrological complex's single greatest act of significance to the city's urban form and planning processes. The evacuation and rehabilitation

of over 250,000 slum dwellers with uncalculated loss to livelihood and property was compounded by widespread pollution of underground and surface water sources. Water and vector-borne epidemics were in spate as seven major city drains flowed back into residential areas. The Najafgarh *Nallah* and Bawana Escape waterways were inundated with increased flows from upstream and backflow from the Yamuna River. This spurt in flow volume breached containing embankments to flood large portions of north and east Delhi. New settlements along the low-lying eastern banks of the Yamuna River were submerged by sheet flows from the Hindon River watershed (from further east) and the surging waters of the Yamuna in the west.

This flood had severe repercussions in land price and development patterns in the city's Alipur (North), Najafgarh (West) and Shahdara (East) blocks.[3] Large investments were made to construct supplementary drains and embankments. Stringent rules preventing development in flood-risk areas were enforced. Flood vulnerability of the north, west and east blocks reinforced Delhi's southward expansion and concentration of elites. Delhi's hydrological complex has repeatedly overwhelmed conventional plans. Inadequacy of outdated, sewer-based systems, lack of resources and an inertia of thinking beyond given technical solutions adds to the quagmire.

The proposed October schedule for the 2010 Games is especially prone to flood damage. Yamuna River has exceeded dangerous flood levels (fixed at 204.83m in Delhi) 25 times in the past 33 years.[4] In modern times, the city faced six extensive floods in 1924, 1947, 1976, 1978, 1988 and 1995, with greatest danger recorded on 6th September 1978, and on 27th September 1988. In all incidents, the low-lying eastern bank of the river was inundated, often till four kilometers from the riverbed center. Vulnerability increased as populations settled in a southeastward pattern in localities of Shahdara [40], Seelampur [39], Trilokpuri [97], Pandav Nagar [81], Mayur Vihar [97], and NOIDA [113-115].

Roads were built atop parallel dykes, linking poor neighborhoods (usually resettled slums from across the city) that mushroomed within these sunken basins. These dyke-now roads form visual and physical demarcations between the three development belts that constitute the East Delhi zone. The Rural Marginal Embankment (RME), Jagathpur and Yamuna Bazaar *bundh* protect the west riverbank while the Left Forward (LF), Shahdara Marginal (SM) and LM *bundh* protect the east riverbank. Only the RME meets requirements of a 25-year frequency flood, while all fall short in case of a 100-year frequency flood (Sharma 1996). The Yamuna River is hemmed in by high embankments in a 210-kilometer stretch upstream of Delhi, which has resulted in decreased valley storage and increased peak flood discharge levels during floods.[5]

Asian Games, Mega-development and Abuse of Streams (1980-84)

The 1982 Asian Games are until now, Delhi's greatest sports event. Preparations for the CWG 2010 shall inevitably be compared to the spectacular development pre and post Asiad. A plethora of hotels, convention centers, auditoria, road flyovers, sports facilities and an exposition center had been constructed. Many of these were sited along the riverbank and stream valleys that had been used earlier to separate Delhi's elite from the immigrants. The larger sport facilities were used as physical and land use barriers between residential localities.

> "Access to population, open spaces and greenfield sites, motorway links, plus proximity to a major railway line are emerging as rational locational factors for stadiums. In addition, the site would need to be sufficiently distanced from residences to allow negative externalities to be neutralized in a *cordon sanitaire* around the stadium."
>
> **Bale** (1993: 146)

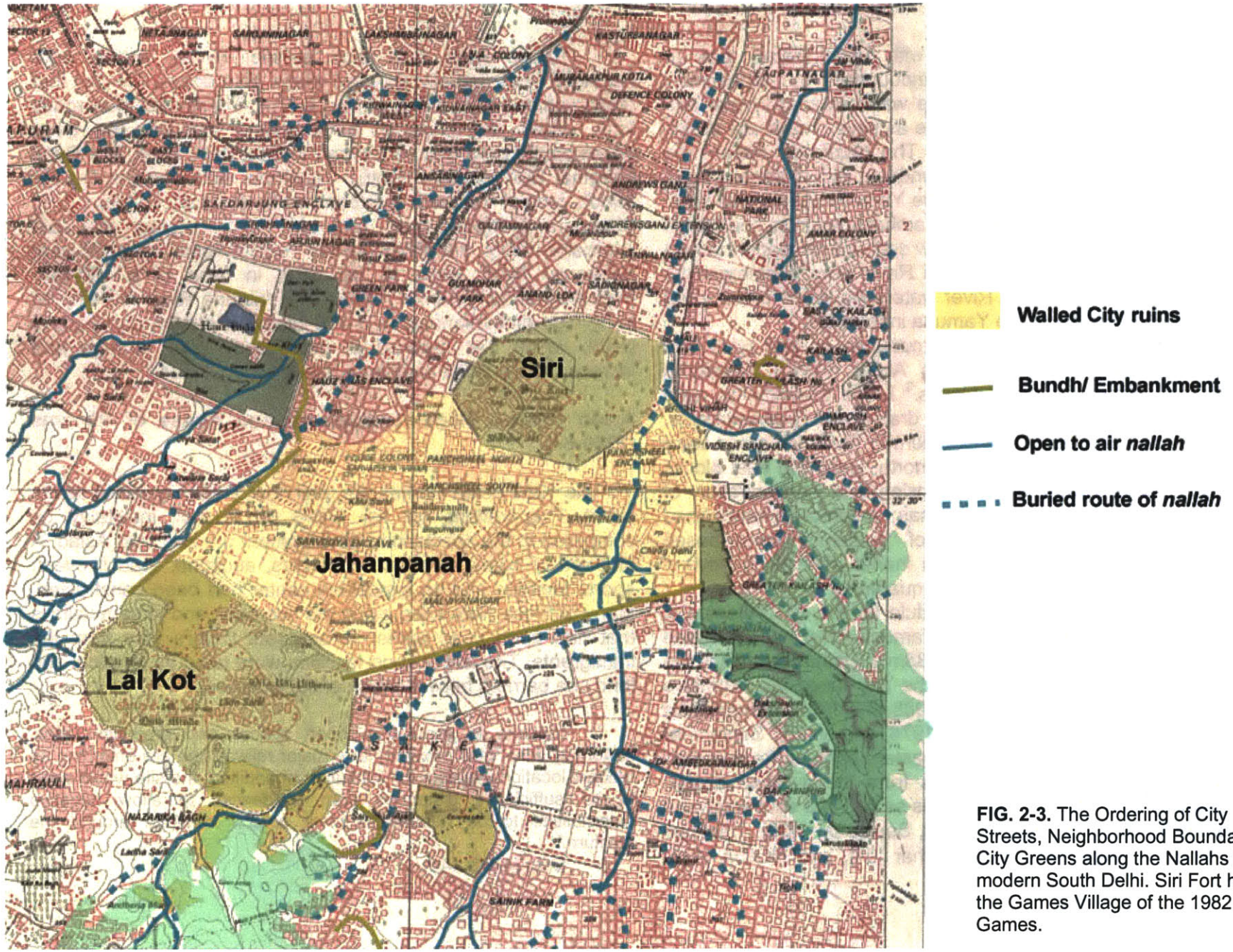


FIG. 2-3. The Ordering of City Streets, Neighborhood Boundaries, City Greens along the Nallahs in modern South Delhi. Siri Fort housed the Games Village of the 1982 Asian Games.

Many drainage channels were buried and diverted to construct flyover bridges and high-speed vehicular roads. Several gargantuan urban design projects such as the CGO complex, the Rohini [7-9, 17-18] and Dwaraka [85A] mini cities were laid along the Barapallah, Nangloi and Najafgarh *Nallahs* respectively. This severed pedestrian linkages along the waterways and often, economic connections between neighborhoods. Streams were frequently used to fragment neighborhoods and create enclaves. The city's legibility and cohesion was further jeopardized. Sports facilities along the waterways had often been, and continue to be contested spaces between urban villages, elite enclaves and municipal wards. Such spaces continue as inevitable backwaters for urban crime. The shanty settlements of Dakshinpuri [135], Nand Nagri [40], Kalyanpuri [82], Trilokpuri, Jahangirpuri [10], Mangolpuri [15] and Sanjay Amar Colony [79] mushroomed along the Naulakha-Barapallah Nallah, Mandoli *Nallah*, Hindan Cut, Bhalswa Drain, Nangloi *Nallah* and the Yamuna River respectively. Much of the unskilled immigrant labor stayed back after the 1982 Asiad, in slums on public land along Delhi's streams. Sociologists in recent works, like the *Mirrors of Violence* (Das 1990) suggest that such unemployed immigrants played a significant role in the severity of the 1984 riots.

Riots and Unseen Facilitators (1984-1990)

Delhi was cudgeled by tragic anti-Sikh riots in 1984. The majority of violent riots occurred in localities with poor connections to adjacent urban fabric but with immediate access to the city's peripheral artery. Moat-like city drains and canals encircle the sites of worst violence, such as the resettlement colonies of Trilokpuri [97] and Mangolpuri [15]. Such segregated neighborhoods appear to have provided vehicle-borne mobs deadly access, and residents no escape. Similarly, the epicenter of the 1972 Shahdara riots "was in a low-lying and marshy area, surrounded on one side by the Yamuna River and by the Hindon

FIG. 2-4. The Anti-Sikh Riots of 1984.

River and Hindon Canal on the other, and used to get flooded every year" (Misra 1973). Delhi's *nallahs* were also used as dumping-grounds of murdered riot victims. Sixteen bodies were discovered in the Hindon Canal, NOIDA and Kalyanpuri *Nallahs* during communal violence in 1987.[6] The Delhi riots if studied through the Chicago School's ecological approach to urban violence, demonstrates a strong association with landscape caused blight and barriers.

Beyond the occasional water riot, Delhi's hydrological complex has not manifestly fomented violence. But its blatant and repeated use as 'social moats' points to a significant role in the psyche of both rioter and victim.[7] Though cognitive mapping and distance-decay functions have been extensively researched in urban riots, it would be too early to presume that mental calculations of visibility were used to select neighborhoods during the 1984 riots. However, arsonists did appear to target Delhi's nether tracts, which were relatively isolated from public gaze by physical obstructions (usually large drain channels).

"...Urged the mobs to loot, burn and kill. The women were herded together. Some of them ran away but were pursued to the nearby *nallahs* where they were raped".

Report of the Citizen's Commission (1985: 18)

Even if this intensity of violence was purely a tragic consequence of the lack of civic infrastructure in these neighborhoods, the use of water channels and dykes to create such ghettos cannot be ignored. Immigrants and religious minorities have used *nallahs* to reinforce the demarcated, homogeneous enclave typology. Such concentrations of mono cultural, traumatized households have set an overwhelming precedent of sequestered territories in Delhi.

Acknowledgement and Benefits

In the past, there was greater attention paid to Delhi's hydrology. Delhi's citizens had reaped immense economic, defensive and environmental benefit, from successful management of the region's water. They seized opportunities inherent in the city's hydrological resources through a comprehensive understanding of Delhi's terrain and ecosystems. Technological limitations allowed a gradual learning process through incremental improvements and interventions. Planning was site-specific and passed down with experience. Delhi's natural arid terrain was in this manner tended to sustain a large urban conurbation, camping armies and local agriculture

Sustainable habitation in modern Delhi needs to begin with a study of ecology-determined urban design in its distant past. Contemporary planners have conspicuously ignored the streams watering Delhi, and the numerous waterworks constructed along them. The socio-politico-cultural relationships recognized between Delhi's settlement clusters, military, funerary, religious and palatial complexes have rarely been studied in the context of their position along these streams. Despite evident patterns of building typologies, tribe and dynastic patronage along individual streams, the concept of a human tended stream network was not proposed till early 2001.

Stream Networks of the Delhi Sultanate (1210-1526)

The author discovered 15 historic *bundhs* (water-harvesting mud embankments) in September-December 2000, along the forested slopes of the Delhi Ridge. These *bundhs* lay between (previously assumed) isolated hydraulic structures, to define a network of 25 water structures along 40 miles of the

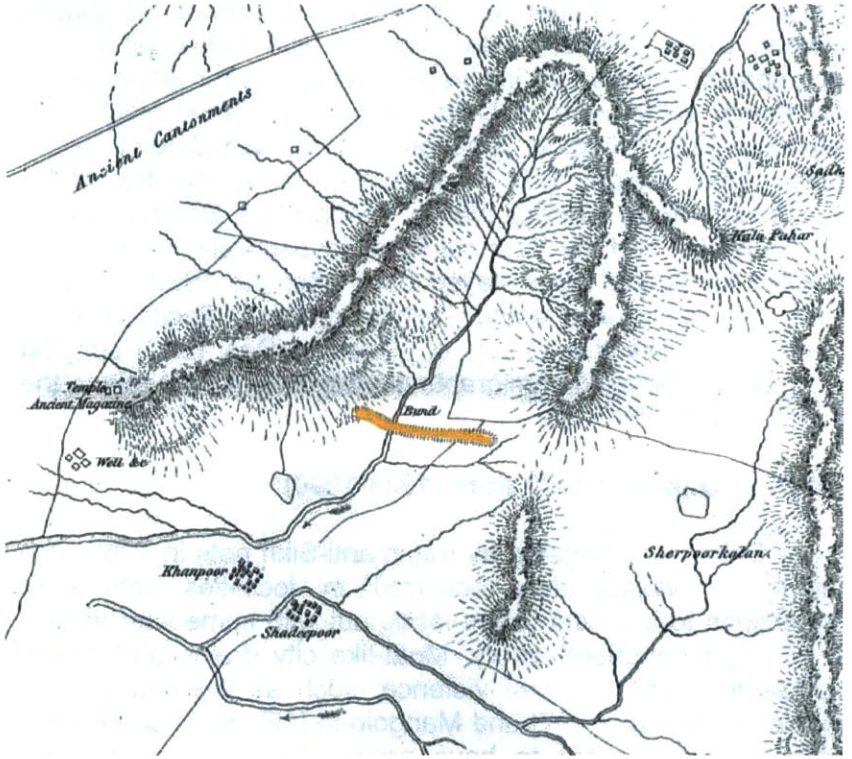


FIG. 2-5. A Typical Delhi Bundh and its Catchments Area.
Bundhs bordering villages, harnessed rain fed rivulets or sheet drainage along slopes of the Delhi Ridge to create perennial reservoirs, for use in the dry winter months.

Delhi Ridge. Further study exposed relationships between this system of hydraulic structures and medieval settlement patterns. A forgotten symbiosis of hydraulics, urban ecology and governance had begun to emerge. It demonstrated the continued understanding and use of Delhi's geo-physical morphology by various ruling houses to political, military and economic ends.

> "The sultan warned the seditious that if it was brought to his notice that some one has attempted to close the water passage of the reservoir, he would order for their limbs to be amputated and separated."[8]

Hydraulic structures in Delhi are now understood as part of a large-scale geographic network that spanned several centuries and encompassed Delhi's several historic cities. This chapter realizes the scale, technological innovation and ecology determined urban design unknown for Delhi.

The *Bundhs* as Nodes of the Networks

The *bundhs* present a sequence, with sites at every *'kruh'* (approximately two miles) along the approximately 40 miles of the Delhi Ridge.[9] The sequence starts from the villages of Zamrudpur [123], Tughluqabad [136], Deoli [150], Chattarpur [148], Hauz-i Shamsi lake, Lalkot [132], Mahipalpur, Munirka [119], Jharera [104], Majra [91], Dasghara [75], Malcha [91], Talkatora [76], Bhuli Bhattyari [77], Pir Gaib [37] till Wazirabad, on the Yamuna riverbank. These discovered structures can be viewed as three parallel networks of water embankments, along the ridge:

a) The outermost (on the streams flowing west to the Najafgarh *Nallah*) consists of *bundhs* at the villages of Arangpur, Asola [151], Junapur [145A], Sultanpur [147], Rajokri [128], Nangal Dewat [116], Mehramnagar [103], Dasghara and Naraina [74].
b) The central one (first grid on the eastern slopes) consists of *bundhs* at the villages of Tughluqabad, Deoli, Mahipalpur,

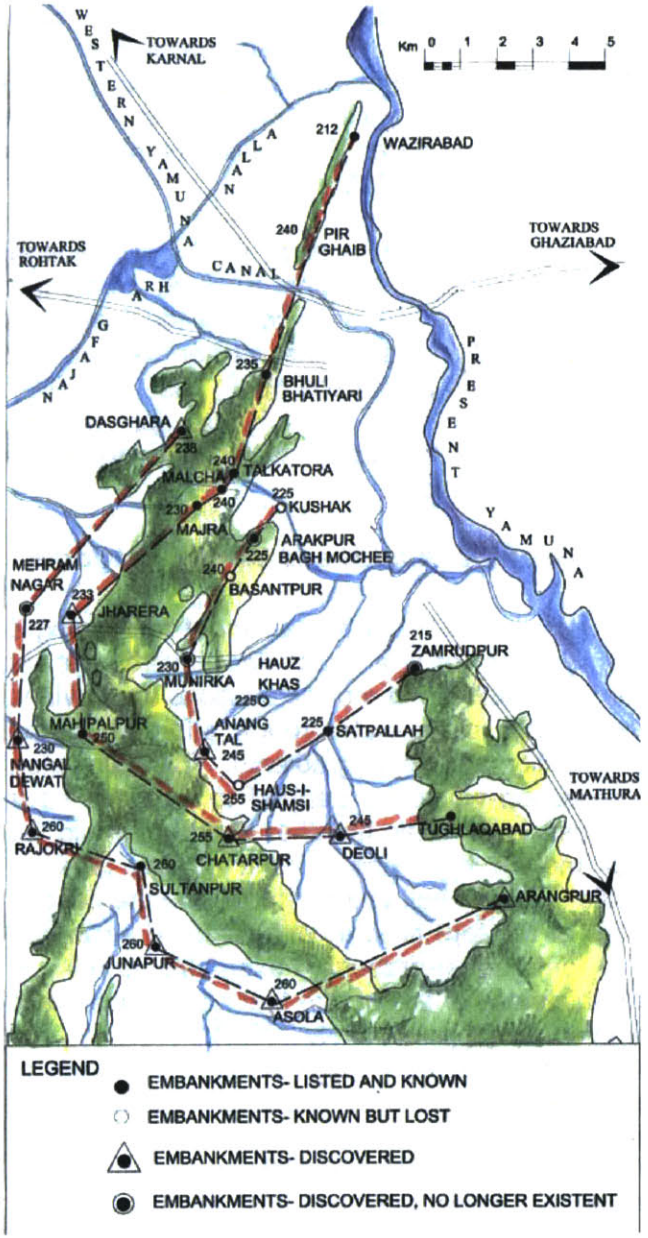


FIG. 2-6. The *Bundh* Network along the Delhi Ridge. The red dash lines help visualize the three contour aligned tiers of waterworks, and do not signify physical structures or connections.

Jharera, Jawaharpur or Dhaula Kuan [90], Malcha, Bhuli Bhattiyari, Qadam Sharif [56], Pir Ghaib and Wazirabad.

c) The inner most (the second grid on streams flowing east) consists of *bundhs* at the villages of Zamrudpur, Yakutpur [123], Satpallah [134], Ber Sarai [120], Arakpur Mochibagh [106] and Khanpoor or Kushak [92].

There remains today, no physical trace of the Mochibagh, Munirka, Ber Sarai, Mehramnagar, Naraina, Kushak, Zamrudpur and Yakutpur *bundhs* while only the mud core of the *bundhs* at Arangpur, Rajokri and Deoli remain. The former can be last traced to the Survey of India maps of Delhi 1939, 1959 and 1964. These sites were razed in the mid 1960s for housing development that did not recognize water structures as monuments worthy of preservation.

The Working Principle of the *Bundhs* and Stream Networks

The typical Delhi *bundh* is an embankment restraining a stream in its upper reaches, or is a check-dam diverting sheet flows of storm-water. It is built along rocky elevations and ravines to make best use of high storm-water runoff afforded by the Ridge's poor permeability and high gradients. This rainwater, harvested in the monsoon would be trapped to create a *hauz* (lake), for gradual use over drier months. *Bundhs* would be approximately four meters high and consist of two tapering rubble masonry walls (two and half to three meters at the base to one and half meters at the top) filled in with rammed earth and stone. There are in some better-preserved examples rooms and stairs built into the thickness of the *bundh* that allow passage to the top, at regular intervals (approximately 200m).

The water level of the reservoirs was maintained by *'moris'* or regulated apertures built into a thicker rectangular projection on the embankment wall. Monolithic slabs of worked granite, approx. 600 x 800 mm with circular 100-120mm diameter holes were inset into masonry. These were laid flush on the reservoir

FIG. 2-7. The *Bundh* at Dasghara Village, as viewed from the erstwhile reservoir. The typical 'mori' (round apertures) opening could be variably opened.

FIG. 2-8. The *Bundh* at Dasghara Village, as viewed from the Village. The sluiceway or *jhal* (waterfall), allowed released water into to an irrigation canal.

side and opened to an arcuated channel built into the thickness of the bastion. These holes then could be plugged by wooden caps and pulled out to release harvested water. An arrangement of *moris* at different heights and varying proximities would allow for control of water pressure and volume.

"When the rainy season came on and the rains were at their height, officers were appointed to examine the banks of all water courses and embankments."

Shams-i-Siraj in *Tarikh-i-Firuzshahi* (Elliot and Dowson, Vol III: 345)

Some structures in the second grid, downstream like the *Satpallah* involved larger volumes of water and thus greater masonry, labor and complexity. Here a system of sluices running over a sequence of pulleys and locking members was constructed over tapering masonry abutments. Thus, the first *bundh* sequence on either side of the ridge entrapped the rain runoff and the second sequence controlled and channeled water to city reservoirs, defense moats or irrigation canals. This 40-mile network with over 15 rivulets and 60 miles of running-water was possibly in continued use over two centuries.

Urban Form as dictated by the Stream Networks

The interface of the stream networks with human settlements in Delhi can be understood within the hierarchy of urban settlements. Two basic settlement themes are found in Delhi: of the increasing settlement size along the streams from village to village group to the city, and a belt of riverbank settlements at the tail end of the stream networks. These development patterns can be barely discerned today through Delhi's hopscotch urban sprawl.

The Primary Settlement

The *'mauza'* (village) was the first level of human settlement to be served by the *bundh* network. The dam would create *hauz* or lakes to provide assured water supply through the year to the villagers, their animals and fields. Fortifications of the *bundh* and attached garrisons would help assume an additional role of defense for the *bundh* network. Literary references to defense posts, built by Sultanate rulers, support this assumption.

"Because of the troublesome *Mewatis*[10], Balban established *'thanas'* (posts) around the city; and divided these jurisdictions among his troops. So that each might watch the area assigned to him."

Khwaja Nizamuddin Ahmad in *Tabaqat-i-Akbari*, Vol.1: 105.

These fortified garrisons at every *kruh* (approximately two miles) formed a chain along the Delhi spine with unobstructed views of the plains. Minhaj al Din's *Tabaqat-i-Nasiri*[11] mentions Sultanate ruler Balban's (1200-1287) *thana* (defensive outposts on high ground) against the Mongols led by Halagu Khan (1217-1265). [12] Mongol raids later in Jalal-ud Din Khilji's (1290-96) reign caused a further clearing of forests and extension of the *thana* network. [13] Thus, military needs forced the first recognition and use of Delhi's hydrology in the sultanate. Streams were tapped to provide water to troops stationed in the *thanas*. As the sultanate and its army grew, the water supply mechanism was spruced up. This process intensified with the rapid growth of dependent population. Each of the *bundhs* of the first sequence is a mile or more long, providing for easy traverse of the ridge's broken ground. The logistical advantage of these were inevitably recognized by both Ala-ud Din Khilji (1296-1316) and Muhammad bin Tughlaq (1325-51), who added functions of the *'dak chauki'* (node or station along a postal network).

"Every *dak chauki* is studded with a mosque and rest house. There are tanks for water and *bazaars* for purchase." [14]

Shihab al Din al Umari, *Masalik al Absar* (1971: 58)

The aristocracy would often inspect troops or stay for hunts here. Imperial visits and the accompanying paraphernalia attracted traders and the service class. Support infrastructure

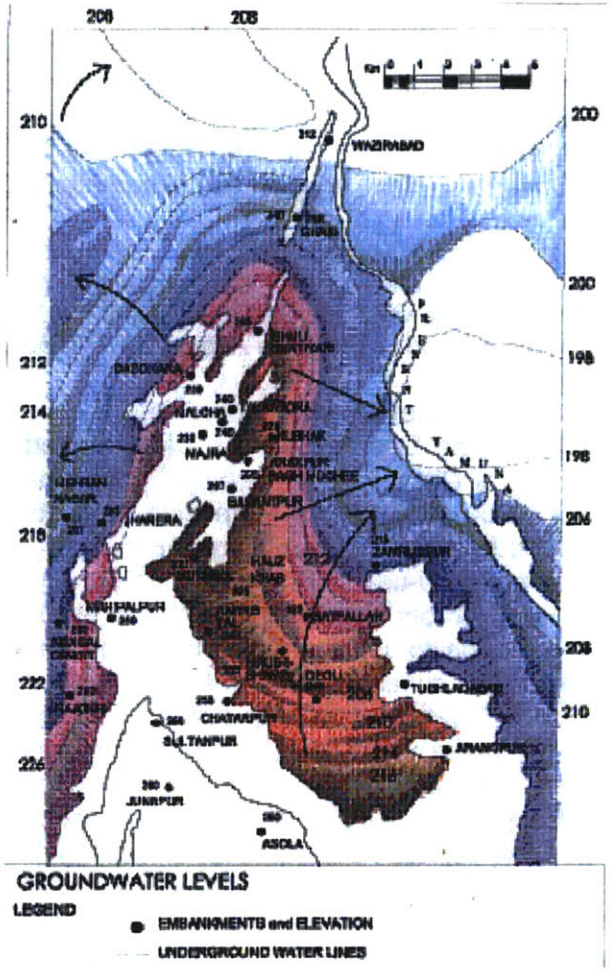
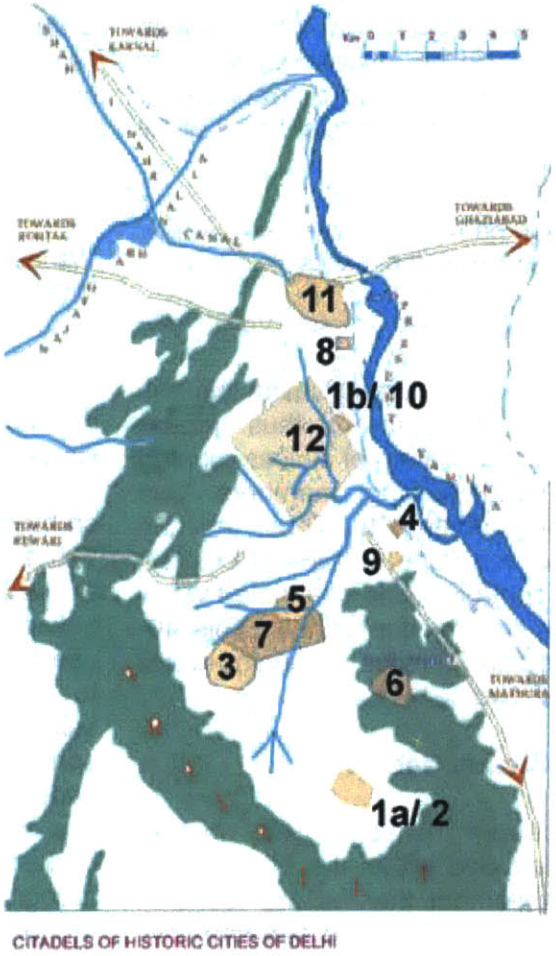


FIG. 2-9. Groundwater Levels and the *Bundhs*. The water table rises as one descends either side of the Delhi Ridge.



1a. Prehistoric Settlements
1b. Indraprastha (approx. 1450 BC)
2. Arangpur (1020)
3. Yoginipura & Qila Rai Pithora (1170)
4. Kilokheri (1286)
5. Siri (1302)
6. Tughlaqabad (1320)
7. Jahanpanah (1344)
8. Firozabad (1351)
9. Mubarakabad (1433)
10. Dinpanah (1530)
11. Shahjahanabad (1648)
12. New Delhi (1912)

FIG. 2-10. Delhi's Successive and often Contemporary Urban Settlements.

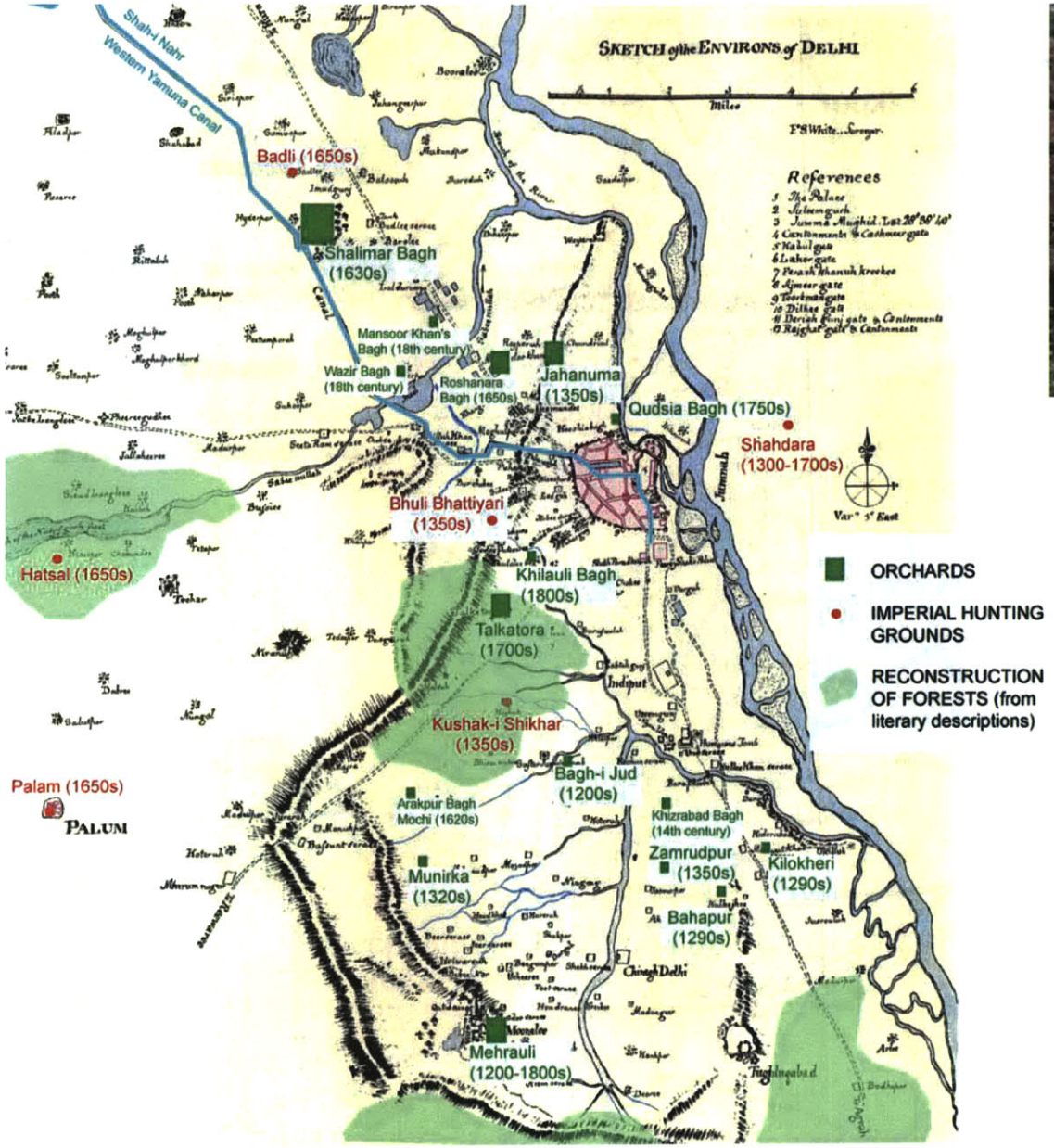


FIG. 2-11. Orchards, Hunting Reserves and Forests in the Delhi Plains during the 16th Century. These sites are typically also house a *bundh* and ancillary reservoir.

FIG. 2-12. The Talkatora *Bundh*, showing Rubble Masonry of the Dyke. The *bundhs* have survived largely as a result of the care ensured in their water-proof construction.

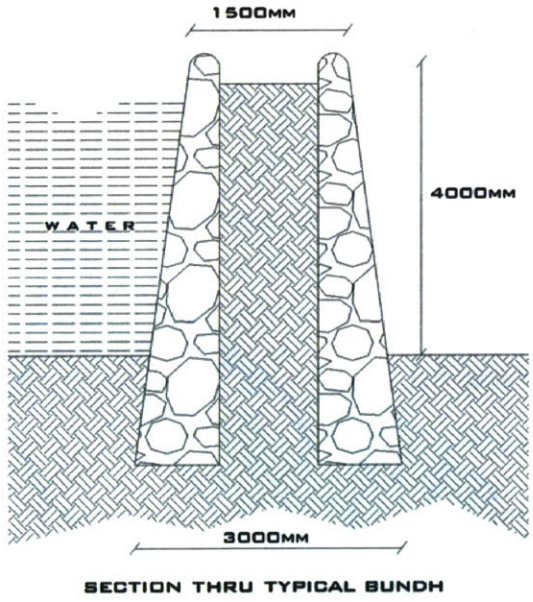


FIG. 2-13. Section through the Typical *Bundh*.

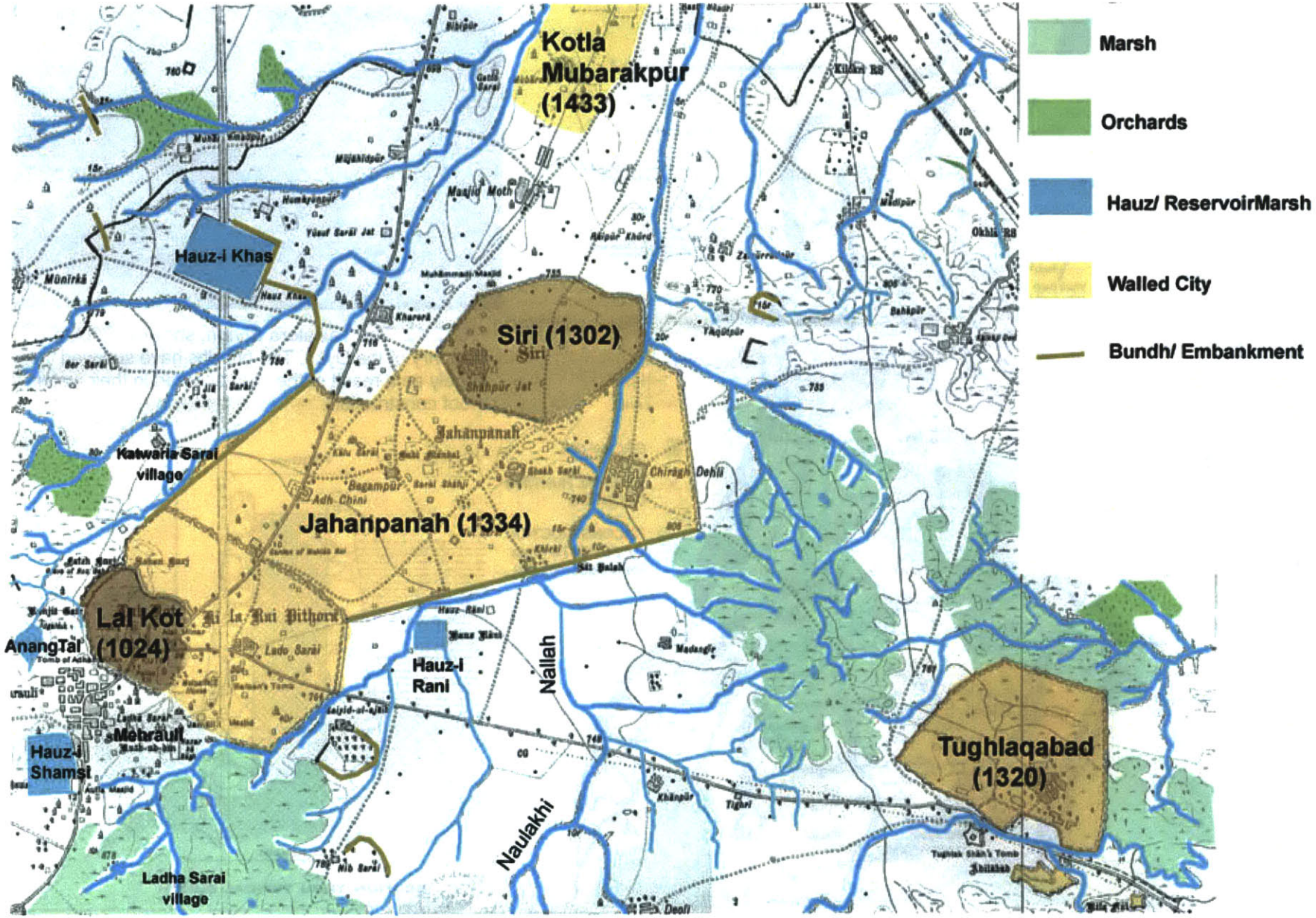


FIG. 2-14. The Relationship of the *Nallahs*, Citadels, Villages and Water Reservoirs in South Delhi. This apparent order has been lost since Delhi sprawled over this landscape in the early 1960s.

grew and the settlements were soon referred to as *'Qasrs'*, after the networked fort villages of Ghur, in present day Afghanistan. The *bundh-hauz-qasr* system began to emerge.

The *Mandal* (Village Group)

Famines in Muhammad bin Tughlaq's reign had led to a state policy of intensive irrigation in defined groups of villages in Delhi. Ibn Battuta[15] (1304-1368) records,

> "The territories of Delhi were divided in groups of villages with reservoirs, each hundred of which has a *'chaudhari'* (chief)."
>
> **Ibn Battuta**, *Kitab al Rehla* (1953:32)

Rectangles of thirty *kurohs* were identified and provided with new wells and canals. *'Taqavi'* (special loans) were issued for construction of water works. Tughlaq ruler Firoz Tughlaq (1351-88), the greatest hydraulic engineer of the sultanate instituted the *'sharb'*[16] (water) tax[16], to earn revenue from village clusters irrigated by state waterworks. An understanding of villages networked by water as distinct revenue and defense units was beginning to emerge. Firoz Tughlaq's revival of permanent land grants to nobility formed the next development stage of the *bundh* network.[17] Well-irrigated fields were converted to orchards and retreats on the outskirts of the city. The siting, size and landscape of these was determined by the prevalent *bundh-hauz* system. Hereditary grant of villages reinforced the *bundh* network and expanded it to include the *'bagh'* (orchard).

The City of *Hazrat-I-Dehli* [18]

The *bundh-hauz-bagh* mechanism tied the suburbs to the city. The expanse of the *bundh* network had afforded the Rai Pithora-Siri city conurbation, a larger radius of suburbs than the later cities of Dinpanah [94] or Shahjahanabad [56] ever did. The palaces of Sultanate ruler Iltumish (1211-36) at Kilughari [110], Balban at Ghiaspur [94] to Ala ud Din Khilji at Siri [122] were located along different stages of the hydraulic network to avail of the advantages of defense, water supply and a pleasant microclimate. Most were titled *'nau shahr'* (new city)[19] and were invested in by the aristocracy to often grow into a complete city. The phenomenon of Delhi's multiple cities was made easier by opportunities afforded by the *bundh* network.

Two *nallahs* originating in Katwaria Sarai Village [120] and the Chattarpur Village determined the physical boundaries of the early city of Qila Rai Pithora. The Badaon, Barka, Ranjit and Hauz Rani gates of this city were arguably determined by locations of easy ford over the *nallah*-cum moats. The citadels of Siri and Jahanpanah that followed also strictly followed the boundaries created downstream by the very same *nallahs*. Waterworks of the second grid at Hauz Rani, Hauz-i Alai (Hauz Khas), Khirki (*Satpallah*) and Siri were built along the new city walls. Extensive hydraulic engineering at the next citadel of Tughluqabad plugged it into the existent *bundh* network. Thus, the extents, profiles and siting of the sultanate citadels were extensively suggested by the *bundh-hauz-qasr-bagh-shahr* system.

Today's Need of the Big Picture

A new holistic attitude to Delhi's waters and urban form is desperately needed. This could be inspired by the fourteenth century system that envisaged the region's land and water as a single, fluid system. Technological advancements allow increasing scales of deleterious intervention and fragmented approach. Delhi's water-caused predicaments cannot be solved by piecemeal action. Effective solutions can be achieved only by placing the city within the larger regional context. A comprehensive understanding is needed to "perceive the consequences of the myriad, seemingly unrelated actions that make up daily city life, and to coordinate thousands of incremental improvement" (Spirn 1984:5).

(Endnotes)

[1] First Report of the Delhi Town Planning Committee on the Choice of a Site for the New Imperial Capital, Vol. 20 (East India: Reports of the Commissioners), Cd. 6885, 1913.

[2] Geeta Colony in Shahdara was one of the first Trans-Yamuna enclaves laid out by the government in 1954. Today it is one of the city's greatest crime-havens.

[3] One of the earliest Delhi suburbs, on the east bank of the Yamuna River. Shahdara derives its name from a Persian word, meaning 'royal threshold' because of its function as the last stop before entering the city, along the ancient Grand Trunk Highway.

[4] Gadhok, Taranjot Kaur's *Floods in Delhi.* Ibid. pg.2.

[5] *State of Environment Report for Delhi 2001*. TERI. Accessed 16th March 2004 from:
http://www.teriin.org/reports/rep09/rep091.htm

[6] From news article titled, "When Will We Learn?" in the daily newspaper, *Indian Express*, 27th May 1987.

[7] Interestingly enough, danger to water (poisoning by militant Sikhs) was a falsely spread rumor used to incite communal violence in the Delhi 1984 riots.

[8] Anonymous, *Sirat-i-Firozshahi*, Khudabaksh. Oriental Institute and Library, ac. no. HL 99, Patna.

[9] The *Kruh* or *Kuroh* was once a common unit to measure distance like the *Kos* or *Farsang* in medieval India.

[10] The *Mewatis* belong to the cultural zone of *Mewat* in North India, between Delhi and Agra. Their rebellious spirit and guerilla warfare have pestered Delhi rulers from Iltumish to the last Mughal emperor.

[11] Minhaj Siraj, *Tabaqat-i-Nasiri*, ed. Capt. W. Nassau and Maulvi Khadim Hussain, Asiatic Society of Bengal, Calcutta, 1864.

[12] Halagu Khan, chief of the Golden Horde and grandson of Genghis or Changez Khan (1167-1227) was later the pillager of Baghdad and destroyer of the Abassid Caliphate (758-1258).

[13] The series of Mongol raids led by Hulagu Khan (1260), Abdullah (1292), Saldi (1298), Khwaja Qutlugh (1299), Targhi Beg (1303-05) and Iqbalmand (1306) that would grant the Delhi sultanate no peace.

[14] Shihab al Din al Umari, *Masalik al Absar* in *a 14th century Arab account of India*, ed. Siddiqui and Ahmad, Aligarh, 1971, 58.

[15] Abu 'abd Muhammad Ibn 'abd Ibn Battutah, born in Tangier, Morocco was one of the greatest medieval Arab traveler and author of one of the most famous travel books, the *Rihlah* (*Travels*), which describes his extensive journeys covering some 75,000 miles (more than 120,000 km) to almost all the Muslim countries and to regions as far as China and Sumatra.

[16] Water was initially provided free of cost for two or more harvests, after which cultivators attracted to irrigated land were required to pay a tenth of their produce as tax.

[17] The *'Iqta'* revenue system of Firoz Tughlaq in M. Shokoohy's (1998) monograph titled, *Hisar-i-Firuza.* London.

[18] Shihab al Din al Umari, *Masalik-i-Absar*, 36.

[19] Kaikubad's (1287-90) palace at Kilughari or Kilokheri was the first titled *Nau Shahr*. The name was later also given to Alla ud Din Khalji's Siri and Ghiyas ud Din Tughlaq's (1320-25) Tughlaqabad.

Comprehensive Understanding for Comprehensive Strategy

Every city deserves a comprehensive planning mechanism, and each urban plan requires a comprehensive understanding of a city's bigger environmental, geographical and geological setting. An understanding of urban process as directly linked to natural process is crucial to effective urban strategies. "A keen and persistent sense of the earth helps ensure that the growth and design of cities takes place in a way that will make most of economic and environmental advantages of urban sites, and lessen irrational land use and encounters with natural hazards" (Leveson 1980:10). Decisions about single events, such as the CWG 2010 should be made within a larger comprehensive planning framework for Delhi. Planners need to think comprehensively and globally to act incrementally and locally.

In the natural environment of every city, there are elements of both the distinctive and the common. It is to the distinctive features of their natural environment that many cities owe their historic growth and population distribution, and even the character of their buildings, streets, and parks.

Anne Whiston Spirn (1984: 11)

It is not in the scope of this thesis to arrive at a comprehensive planning framework for Delhi. However, I could sketch out one possible manner of aligning future incremental actions. Water as Delhi's greatest need, potential hazard-source and potent ecosystem emerges as "the essential force that permeates the city" (Spirn 1884: 5), and could be utilized as a planning tool. Delhi's planners and CWG 2010 organizers can benefit from the inherent utility offered by Delhi's hydrological systems. This would however, require a deeper understanding of the region's hydrological complex and reappraisal of the city's long-term objectives.

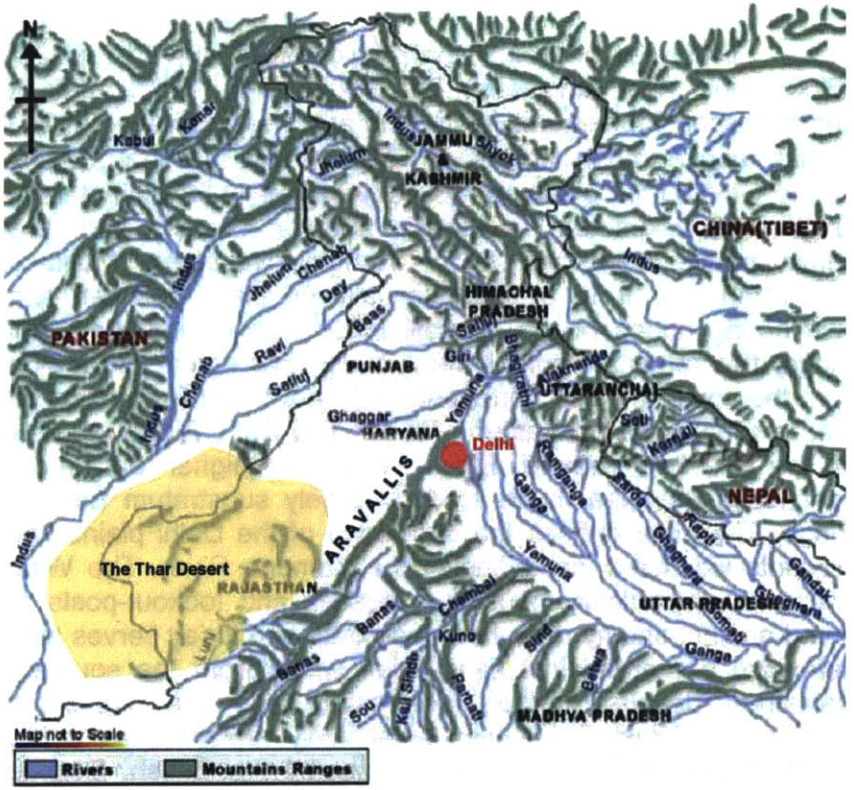


FIG. 3-1. The North Indian Sub Continental Watershed.
The Ganga and Indus River systems are wedged apart by the Aravalli range. The Yamuna River switched east from the Indus watershed to become a tributary of the Ganga..

Understanding Delhi's Hydrological Complex

'A city like Dehli! Hills around it and a river in its midst!'
Amir Khusrao, in *Wasat ul Hayat*[1]

Delhi lies between North latitudes 28° 14'15" and 28° 53'00", and east longitudes 76° 75'30" and 77° 21'30". It encompasses 1485 square kilometers at a mean elevation of 250 meters above mean sea level (MSL). The National Capital Territory (NCT) of Delhi measures approximately 52 kilometers in length, 48 kilometers in width and is divided into five administrative blocks viz. Alipur, Nangloi, Najafgarh, Mehrauli and Shahdara. It is a triangular alluvial plain between two culminating ridges of the Aravalli Hills.[2] Also called the Delhi Ridge, this terminal spur of the Aravalli Hills enters the region from the south to move northeastwards in a finger-like projection that terminates at the Yamuna River.[3] The Delhi Ridge consists of the Western Aravalli Ridge, which is higher and more continuous than the much eroded, largely substratum Eastern Ridge. The latter defines the east edge of the Delhi plains and prevents westward incursions of the Yamuna River. The West Ridge has historically housed fortresses and lookout-posts to guard against enemy raids from the north, and today serves as a defensive barrier against sand-laden winds from the southern Rajasthan deserts. Largely deforested over the eighteenth century, the West Ridge was extensively replanted as a city forest in the beginning of this century by the British. Despite rampant illegal constructions and encroachments since 1947, four state protected regional parks along this ridge constitute over 90% of Delhi's green area.[4]

The East Ridge has in contrast served as stable bedrock for numerous riverbank cities, villages and palaces. A natural rampart against the Yamuna River, this rocky spine separates fertile but structurally unreliable alluvial plains (*bangar* soil) from sand deposits (*khaddar* soil) along the river's east bank. This created a distinct spine of settlements along the river, and flooded marshes on either side.[5] The Delhi Ridge's relatively low

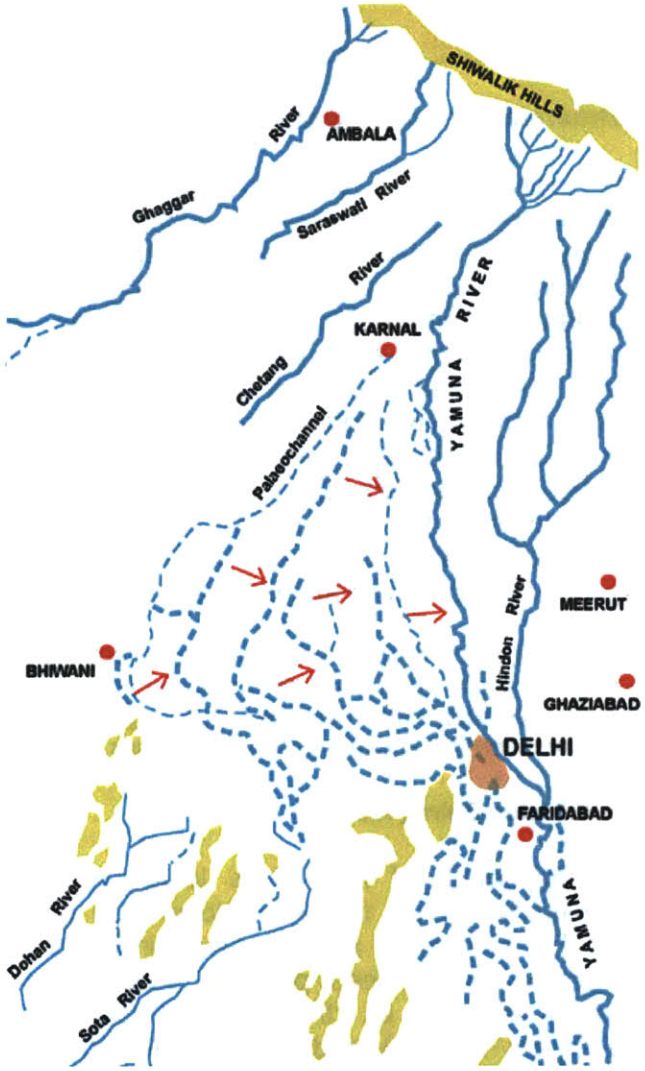


FIG. 3-2. The Yamuna River Watershed
Palaeo-channels abandoned by the River still retain high water table and occasional surface flows during heavy rains. The building of new towns, highways or other infrastructure attracted by the water resource in an otherwise arid region should be regulated.

outcrops often mislead one about their role in the region's drainage basins, hydrogeology and microenvironment. They can be imagined as a string of igneous rock-icebergs, only partly visible over an impervious 'retaining' wall (approximately five kilometers deep and two kilometers wide) that separates subterranean hydraulic and soil systems on either side.

"Physiographically the NCT can be broadly understood as four units: a) the hard rocky area of the ridge; b) the alluvial plain on the east side of the ridge; c) the alluvial plain on the west side of the ridge, and d) the closed basin of Chattarpur" [147] (Paliwal and Yadav 1976:5).

The Yamuna River

The Yamuna is a perennial river fed by a Himalayan glacier.[6] It once belonged to the Indus River system in the Tertiary[7] and Holocene[8] periods, but then moved east into the Ganga River system. The migratory nature of the river can be best studied through cut-off meanders and ox-bow lakes within a larger palaeo-channel system, west of the Delhi Ridge.[9] Today, these palaeo-channels are thickly cultivated or vegetated ribbons of gentle surface depression, indicative of high soil moisture content. Soils of high porosity and permeability parallel these channels, with sizable aquifers of ground water. The migration of the Yamuna left its seasonal tributaries from the southeast (the Sahibi[10] and Banganga[11] Rivers), discharging water into a previous Yamuna flood plain, to create the Najafgarh[12] Marsh [101A]. This marsh drains northwards through the Najafgarh *Nallah* (rivulet or storm water drain) into the Yamuna River at Wazirpur Village [22].[13] This *nallah* flows along an abandoned palaeo-channel, and often flows back during seasonal river floods. The Najafgarh *Nallah* once formed the outlet of the Sahibi River into the Yamuna River, till the Dhansa Bundh dammed the latter. The Sahibi River's post monsoon peak flow of 8 million KLD still causes an occasional breach of this *bundh* and floods parts of west Delhi.

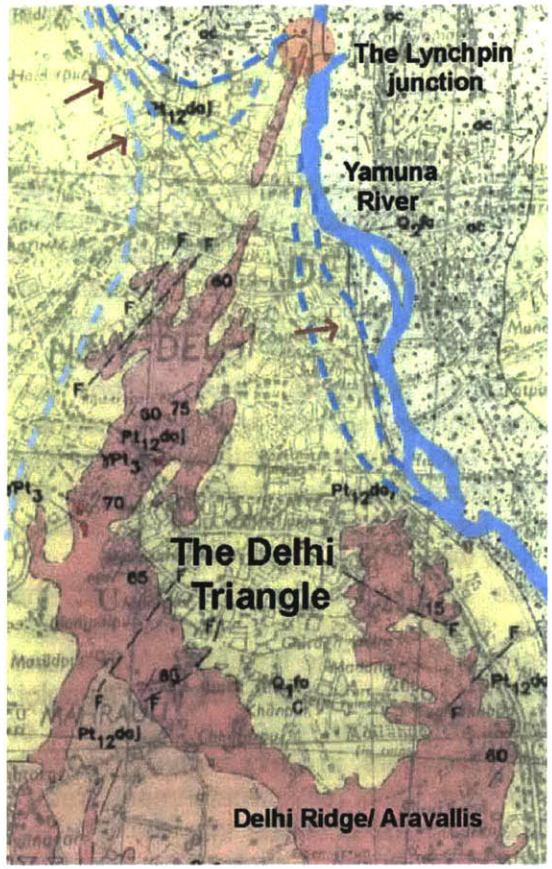


FIG. 3-3.
The Delhi Triangle
The Yamuna River's flow, rate of siltation and migration eastwards has been influenced by the terminal spur of the Delhi Ridge at the locality of Wazirpur. This has created a protected triangular alluvial plain, bordered by the Aravallis and the Yamuna.

The Yamuna's shift varied from 100 kilometers in the area north and west of Delhi to 40 kilometers in the area south of the city. The last four thousand years have seen a more or less static river, the only variation being a relatively sudden eastward shift of 200 meters recorded in the late seventeenth century.[14] There are at least six abandoned palaeo-channels of the river tracing its gradual eastward shift. Many of these were reused as irrigation canals in between the twelfth and sixteenth centuries. The river's shift has continually molded the soil, flora and fauna of the various tracts in the region. The river now

enters Delhi at a height of 215 meters above MSL and leaves at 190 meters above MSL.

Delhi's Streams or Nallahs

Rapid deforestation of the *Shivaliks*, or the lower Himalayas in the early twentieth century resulted in massive silting along the eastern Delhi Ridge. This created a geographical feature much like the space between an outstretched first finger and thumb. In the triangle created between, Delhi's alluvial plain is watered by a number of seasonal and perennial *nallahs* (streams). These *nallahs* flow down the Aravalli Hill slopes through eroded gullies and ravines, into the Yamuna River. Two primary systems of surface drainage exist in Delhi. More than ten streams drain the triangular plain eastwards, into the Yamuna River. The second consists of streams that flow west to the Najafgarh *Nallah*.

The NCT consists of five major drainage viz. the Najafgarh basin, Alipur basin, Shahdara basin, Kushak-Barapullah basin and Mehrauli basin. The Najafgarh *Nallah* and its main tributaries (the Mungeshpur, Karari Suleman, Nangloi, Palam and Pitampura *Nallahs*), drain a catchment area of approximately 544 square kilometers, in Delhi's west and north zones. The Alipur basin in north Delhi (with a catchment area of approximately 222 square kilometers) drains into the Bawana Escape, Drain No.6 and the Burari Creek. The low-lying Shahdara basin (with a catchment area of approximately 7706 hectares) lies on the east banks of the Yamuna River, and is inadequately served by small drains like the Gita Colony, Patparganj, Khureji Khas, Radheypur, Krishna Nagar, Kasturba Nagar, Bhatta Road, Gokulpur and Shahdara drains. Almost all *nallahs* in the Shahdara basin are man-made after the 1950s, while the majority of *nallahs* in the other basins were originally natural creeks. The Kushak-Barapullah basin drains the built-up regions of south and central Delhi (with a catchment area of approximately 137 square kilometers), and consists of the Diplomatic Enclave, Nauroji Nagar, AIIIMS, Karballa, Chirag Delhi, Sunehri Pul and Lajpat Nagar *Nallahs*. The rocky ridge along southwest Delhi defines the Mehrauli basin. It drains both eastwards into the Kushak-Barapullah system and westward into the Najafgarh system.

The Central Delhi plains act like a bowl created by the Delhi Ridge, with the water flowing down slopes to the center. The largest of the east-flowing streams, the Barapullah or Nizamuddin[15] *Nallah*[16] (often justifiably referred to as a *Darya* or river) traverses a circuit approximately 10 kilometers long and reach widths greater than 100 meters at the village of Okhla [111], where it joins the Yamuna River. The Nizamuddin *Nallah* was fed by three primary tributary systems, consisting extensions of the *Shah-i Nahr* (King's Canal) or Western Yamuna Canal (WYC) from north, the Khilauli Bagh Nallah (or the stream of the Khilauli Orchard) from the west and the Naulakha *Nallah* (or the nine-pronged stream) from the southern Aravalli slopes. The flow from the north and west were modified and diverted in New Delhi's construction, though the southern drainage system with a number of medieval hydraulic constructions partly retains its original pattern.

The streams were buried as sewers in the twentieth century, for the rapidly expanding city. Diversions, embankments, increased impermeability and runoff altered peak flow. This exceeded the carrying capacities and channel profiles of nearly all the waterways. Several minor creeks and fragments of the disrupted Nizamuddin *Darya* have emerged as major drainage channels. However, all but the upper reaches of the Barapullah *Nallah* along the Aravalli Hills are termed city drains. The flow and ebb of water in the *nallahs* has also been affected by natural discontinuities in soil and terrain. Strips of poor permeability aeolic soils over Aravalli bedrock impede subterranean and surface water flows, to create aquifers.

Canals, Step-Wells and Lakes

Delhi's rulers inherited and extended a vital tradition of hydraulic engineering that could be traced to the water systems of the Indus valley. The use of check-dams to harvest monsoon rain in the Gangetic plains has continued to the present day. Though most waterworks in Delhi can be dated only as early as the Delhi Sultanate[17] (1210-1526), the first Islamic dynasty in India, the Hauz Rani[18] [133], Lal Kot *tal*[19] (132), Anangpur [152] and Mahipalpur [117] dams are attributed to the pre-Sultanate era. A synthesis of vernacular knowledge with Islam's heritage of hydraulic engineering created a system of *nahrs* (canals), *baolis* (step wells), *bundhs* (embankments) and *hauz* (lakes) that rival the water systems of Samarkand, Istanbul or Rome.

East-flowing streams were tapped to feed large, lined lakes such as the Anangtal [152], *Hauz-i Shamsi* [132], *Hauz-i Rani* [133] and *Hauz Khas* or *Hauz–i-Alai* [121] which sustained the cities of Anangpur (1000-1190), Mehrauli (1196-1290), Jahanpanah (1334-1351) and Siri (1302-1316) respectively. Despite the immediate presence of the river, most of Delhi's populace depended on underground or stored water till the arrival of piped water supply in the late nineteenth century. In 1843, Shahjahanabad (b. 1648) alone had 607 wells, of which 52 provided potable water.[20] Subterranean flows and water tables recharged by *nallahs* allowed a complex hierarchy of wells[21], ranging from unlined pit wells, *digghis* (square or circular reservoir of about 0.38 m x 0.38 m with steps to enter) to elaborate *baolis* (large step wells built with several levels). The quality of groundwater shows wide variations with the depth of the aquifers, but at most locations water quality has been found to deteriorate with depth. "The water quality of shallow dug wells was found to be superior to that of tube-wells in the same area" (Paliwal and Yadav 1976:88). Canals and streams doubtlessly play a crucial role in sustaining fresh water aquifers in Delhi's upper strata of water-bearing soil.

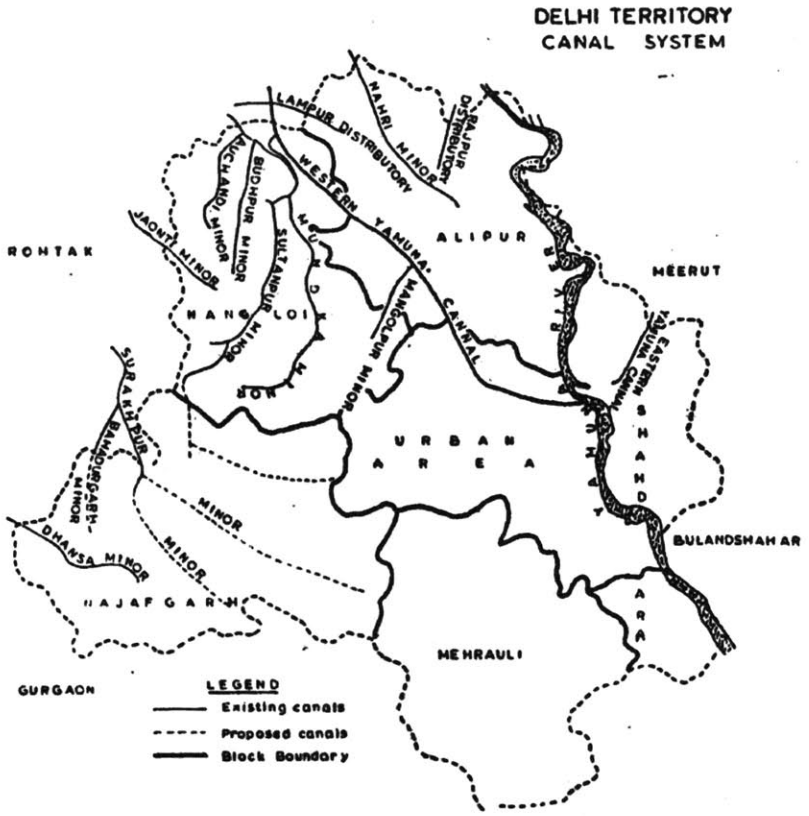


FIG. 3-4. The Delhi Canal System and Delhi's Six Administrative Blocks. The various irrigation canals reuse several palaeochannels abandoned by the River and dried rivulet beds.

Three major canals transport Yamuna water to the city's hinterlands for irrigation. The Western Yamuna Canal (WYC) was partly built by Tughlaq ruler Firoz Tughlaq (1351-88) and then extended by Mughal ruler Shah Jahan (1628-1658) as the *Shah-i Nahr*.[22] The WYC diverts Yamuna's water from the town of Tajewala to pass through Yamuna Nagar, Karnal and Panipat districts of Haryana before reaching the Haiderpur treatment plant (which supplies part of Delhi's water. See [18]). Almost all

of the remaining river water is routed through the Mughal era Doab Canal or Eastern Yamuna Canal (EYC). The original riverbed runs dry in the summers for the subsequent 224-kilometer stretch till the WYC and EYC rejoin the river at Delhi. The Agra Canal (b.1874) diverts water off the Delhi region, starting from the Okhla weir, following high land between the Khari-nadi and the Yamuna. Extremely polluted by Delhi's outflow of toxicants, this canal pollutes soil in the Gurgaon, Mathura, Agra and Bharatpur districts on neighboring states.

Comprehensive Plans and Strategy Frameworks

"One must take advantage of the situation exactly as if he were setting a ball in motion on a steep slope. The force applied is minute, but the results are enormous."

Sun Tzu. *The Art of War*. V.25 Chang Yu.[23]

Adaptable strategy frameworks can "provide a space for multiple decision makers to display strategic options, their inherent tradeoffs, then debate the merits of competing choices to finally decide on a specific strategy" (McGinn 2002:2). This thesis recognizes that several 'themes' reflective of any city's multitude interests can and need to be combined within a strategy framework, to create adaptable structures of resource investment and control. Strategy frameworks help guide priorities for initiatives. They do not consist of 'direct initiatives but identify proposals and the public or private institutions' that would be needed to execute them.

The Special Context of Delhi

Strategies designed by resource constrained planning departments rarely matches up to the complexity of the various city systems. Planners invariably tend to create totalizing images and suppress aspects that do not conform to pre-conceived images. The economic and social dangers of such all-encompassing visions are magnified by the image-based mass media economics of modern mega-events.

This phenomenon could be exaggeratedly powerful in an excessively historicized, politicized and centralized capital city with a long established, state sponsored 'personality'. Sociologists like Veronique Dupont (2000)[24] and Veena Das (1990)[25] have exposed relations between Delhi's historic city stereotype and its citizen's violence, aggression and dispassion. Ironically, Delhi's simplified image is one of discontinuities, fractures and polar opposites. Delhi is more often than not, remembered by residents, migrants and visitors in a chaotic cusp between ancient ruins and gaudy structures, between squatter slums and opulent villas, and between the neighboring states of Uttar Pradesh and Haryana. Travel accounts and chronicles from the medieval past describe Delhi as a collection of towns, castles and tombs. The British with their colonial perspectives, chose not to discuss explicit relations between each constituent and reinforced the notion of Delhi as a region connected by 'points of interest'.

Imperial Delhi! Dowered with sovereign grace,
To thy renascent glory still there clings
The splendid tragedy of ancient kings,.....
The changing Kings and Kingdoms pass away,
The gorgeous legends of a bygone day
But thou dost still immutably remain
Unbroken symbol of proud histories,
Unaging priestess of Old mysteries
Before whose shrine the spells of Death are vain.

Sarojini Naidu (1928: 240)

Colonial historians striving to establish Delhi as the subcontinent's historic capital and sanction British succession to power arranged the city's evolution in water tight, dynastic compartments. The 'Nine Cities of Delhi' theory[26] furthered the differential preservation of individual precincts. Delhi was since reduced to a collection of emblems, monuments and snapshots in

time. Subsequent events resulted in an incomprehensive urban patchwork. Strategy development for Delhi, has to account for disjoints in both subjective (equality, access, security etc) as well as objective (multiplicity of actors, changing political environment, lack of housing etc) aspects

Mapping Long-Term Objectives along Delhi's Hydrology

A comprehensive strategy framework necessitates the formulation of strategic objectives. While numerous objectives of varying import could be proposed, this thesis shall limit itself to the physical domain. Using water as an entry point for intervention in Delhi could further refine the enormity of this task. The benefits of planning Delhi in concert with its dominant hydrological complex are apparent and acceptable to all. In this chapter, I intend to discuss some of Delhi's pressing urban issues along opportunities and challenges offered by its hydrology.

A) Improving Water Quality, Availability and Reducing Pollution

i) *Issues & Opportunities*:

a) Unmonitored Dumping of Wastes into the Streams and the River: Eighteen drains insidiously jettison waste from fourteen million citizens into the Yamuna River. The efficiency and operation of the few sewage treatment plants (STPs) goes unaccounted due to a lack of physical access and effective institutional checks. Delhi's three most polluted drains[27] flow into the Yamuna River, directly opposite the CWG 2010 Village site.

b) Insufficient Self-Cleansing Flow Volume of the River: The River requires a minimal flow of 285 cubic meters per second to flush its present load of solid wastes. At present, this flow is barely 50 cum per second, which falls to a dismal 5 cum in summer.[28] The three barrages at Wazirabad, ITO and Okhla reduce the Yamuna to a series of cesspools. Health risks posed by stagnating polluted water along the CWG 2010 venues would increase as the present gap between raw water volume drawn and returned to the Yamuna River increases.

ii) *Existing Initiatives that could be used to exploit opportunities*:

a) Developing Wetlands and Oxidation Ponds under the National River Action Plan (NRAP) shall encourage low cost, non-energy consuming sewage treatment methods such as root zone, reed treatment belts and sand filters. This controlled release of treated waste could reduce risks of concentrated pollutant leaks, with dividends from pisci-culture, agricultural fertilizer and flood retention possibilities.

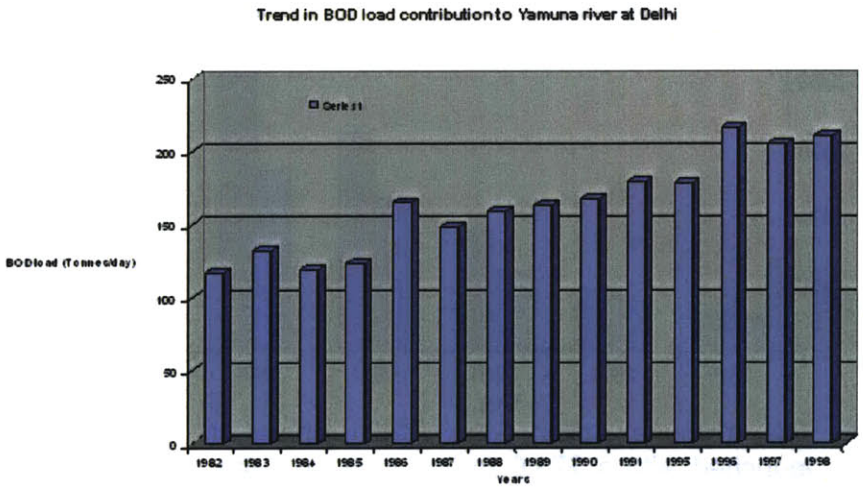
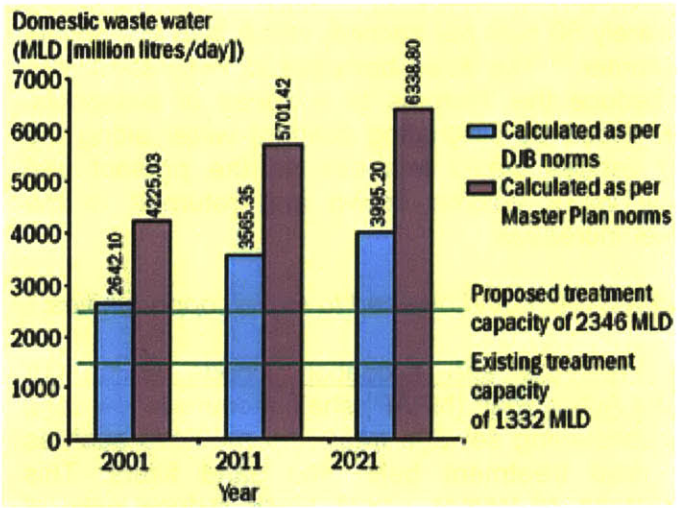


FIG. 3-5. Trends in BOD load contribution to Yamuna River at Delhi (1982-1998).



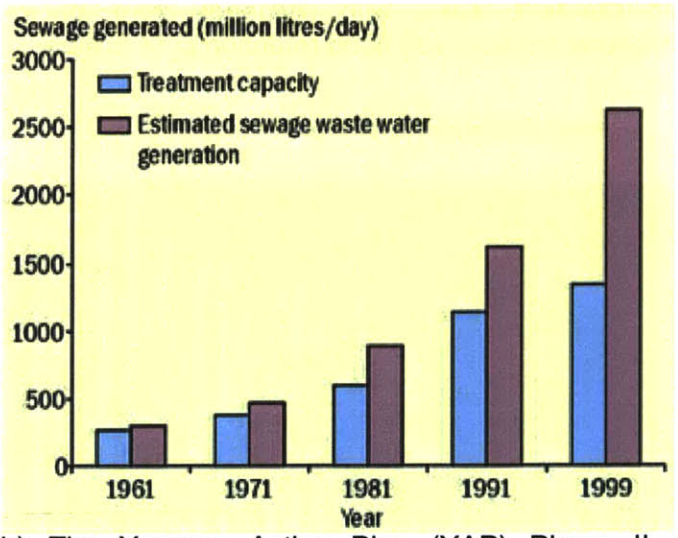


FIG. 3-6. The Severe Shortfall of Water Related Civic Services.

b) <u>The Yamuna Action Plan (YAP)</u> Phase II launched with a $73.6 million loan from the Japan Bank for International Corporation (JBIC) in 2001, envisages the construction of 1146 community toilet complexes (CTC)[29] to prevent direct flow of sanitary waste into the river. This shall reduce the practice of open defecation and outflow of drains from adjacent squatter slums and resettlement colonies.

c) <u>Upgrade and Construct Sewage Treatment Plants (STPs)</u> along the most polluted streams, instead of expensive treatment plants along the river. The DJB is constructing mini-plants with tertiary treatment along the Power House and Sen Nursing Home drains. The recovered sludge and raw water shall service approximately 45 square kilometers of horticulture.

B) Flood Protection and Management

i) *Issues & Opportunities*:

c) <u>Large Populations Vulnerable to Seasonal Floods</u>: The annual costs of life, property, evacuation, rescue and repatriation of thousands of informal housing clusters along the riverbed and streams have spiraled in the past decade. Almost all the venues of the CWG 2010 are prone to flooding, and face great risks of disruption of vehicular access and other infrastructure services.

d) <u>Violation of the Non-Building Statutes of the Master Plan</u>: The strict 'agricultural and water use' stipulated in the flood zones has been violated by both state and private bodies. The DMRC depot, the Akshardham temple and the proposed CWG 2010 Games Village [96] are all digressions of the Delhi Master Plan 1960, 1980 and 2001. The consequent mushrooming of ancillary settlements is reminiscent of the repeated 'authorizations' of illegal colonies that characterize Delhi's development.

ii) *Existing Initiatives that could be used to exploit opportunities*:

a) Off Channel Storage for Flood Prevention proposed by the IFCD could considerably reduce water-logging vulnerability through channel widening, repair of ancient reservoirs, and construction of impounding channels. Such storage could also generate as much as 340 MLD (or approximately 12% of Delhi's daily consumption of raw water).[30] This could considerably increase lag time and reduce flood water levels in the main river channel, to reduce risks to the primary CWG 2010 sites along the river.

C) Restoring Riparian Eco-systems and Biodiversity

i) *Issues & Opportunities*:

a) Destruction of Riparian Environment has meant a loss of wetland habitat, organic energy flows, irregular flood cycles, and erratic changes in soil moisture levels, alkalinity and plastic strength. Channelization, embanking, damming and diversion of Delhi's hydrological complex have altered natural pulsations of water, affecting bio-communities in the region. The relentless reclamation of marshes and swamps, especially in the city's Alipur block has led to a dramatic drop in populations of migratory birds visiting Delhi each winter.[31] The lowering groundwater levels, isolation of floodplains from the main channel and deforestation along stream banks, have had terrible impacts on the aquatic, semi-aquatic and terrestrial biotopes of stream corridors.

b) Polluting Thermal Power Plants, Landfills and Sewage Treatment Plants along the Waterways: Built in violation of the 1960 Master Plan, the two coal plants along the riverbank have minimal treatment of discharged atmospheric pollutants. Their fly ash beds and hot mix plants add to the SPM level, and release Sulphur and Nitrogen oxides into the River. High water temperatures and leaching from sanitary fills and sewage treatment plants has nurtured algae booms, which wipe out the river's remaining aquatic life.

FIG. 3-7. The Heavily Polluted River near the Indraprastha Thermal Power Plant and the Yamuna Pushta Slums.

ii) *Existing Initiatives that could be used to exploit opportunities*:

a) The Yamuna Biodiversity Park designed along 160 acres (64 hectares) of the riverbank near Wazirabad is to be extended to over 500 acres (202 hectares).[32] This reserve could be

strung along a linear park system to connect the riverbank parks of Shantivan [57], the Millenium Park, Ashok Park [111] and Kalindi Kunj [111]. The National Biodiversity Authority (NBA) could sponsor such a green network, through its mandate to promote and protect local biological resource. Delhi based research institutions like the National Institute of Immunology (NII), Indian Council of Medical Research (ICMR), Council of Scientific and Industrial Research Institute (CSIR) etc could integrate with the proposed riverside agricultural biotechnology park of the Greater NOIDA Industrial Development Authority (GNIDA).

D) Networking Heritage Resources, Recreational & Sport Facilities

i) *Issues & Opportunities*:

a) Fragmentation of neighborhoods, inequitable distribution and underutilization of public facilities have been an unfortunate consequence of Delhi's rapid and uncontrolled development in past decades. The abuse of boundaries defined by geographic, administrative units and transport corridors has resulted in severely distorted land values, infrastructure levels and economic distinctions. Delhi's elite enclaves and ghetto polarity could be undone by an institution-based re-stitch of urban fabric along Delhi's streams. This would allow a greater variety of safe and inclusive communities, destinations and modes of access to the tourists, participants and international media attracted by the CWG 2010.

ii) *Existing Initiatives that could be used to exploit opportunities*:

a) Plying a High Capacity Bus System (HCBS) along the North-South River Corridor (along the Josip Broz Tito Avenue and Outer Ring Road corridors), would connect the three east-west metro lines at ISBT, Pragati Maidan [79] and Nizamuddin Rail Station [94]. Road re-engineering required by these segregated bus lanes could simultaneously create pedestrian corridors along landscaped parkways. Trails along the stream valleys could connect nodes along the HCBS–river corridor.

b) Tap the Yamuna River's Navigational Potential as recommended by studies conducted by the Inland Waterways Authority of India (IWAI) in 1989[33], especially along the high volume New Okhla Industrial Area (NOIDA)-Okhla, NOIDA-Inter State Bus Terminal (ISBT)s and NOIDA-Income Tax Office (ITO) routes. This would depend on systematic river flow and level management between the Wazirabad, ITO and Okhla barrages.

E) Re-centering Development

i) *Issues & Opportunities*:

a) Urban Sprawl and Growth Management by Utilizing Land along Waterways: Optimal utilization of Central Delhi's underused public resources could be the first step in a larger institutional restructuring, land management and cost recovery effort. The management of CWG 2010 would benefit tremendously from a compact arrangement of venues and support facilities centered on the inner city.

Delhi's population growth of 1,000 persons per day (of which approximately 615 result from the 14 million populace's 1.6% growth rate) has resulted in ribbon development along major highways linking satellite towns.[34] Assuming only 250,000 of the annual increase of 350,000 persons need new serviced land, the city still needs to increase 500 hectares at a gross density of 500 persons per hectare.[35] This suggests a particularly acute shortage of serviced land, and enormous market potential for center city

revitalization. Disparities in density, incongruous land use allocation and inflated land prices have resulted in hopscotch residential and commercial development with inadequate social and physical infrastructure.[36]

b) Lack of Housing Stock and the Untapped Potential of the Yamuna Riverfront: Large stretches of the Yamuna Riverfront are ecologically sensitive, flood prone and impractical to build upon. However, significant lands parcels with unparalleled access to transit, public institutions and services, are or could be made available without compromising ecosystems or human safety. Comprehensive feasibility and environmental impact studies are needed to determine the nature and location of development along the Yamuna riverbank. A cohesive urban development policy, instead of blanket bans and piecemeal violations needs to determine the character of this compelling opportunity.

The large scale government acquisition of land, the Delhi Development Authority (DDA)'s inability to cope with demand single-handedly and resultant real estate distortions have led to geography based inequalities in housing quantity and quality. Opaque tenancy laws and obsolete land legislations have resulted in unsustainably high vacancy rates. Studies revealed 277,253 vacant housing units in 1997, and possibly 342,000 in 2002.[37] CWG 2010 organizers shall inevitably face huge shortfalls in short and long term accommodation facilities for visitors and personnel drawn for construction and management.

c) Relocation, Rehabilitation or Up-gradation of Slum Settlements along Delhi's Waterways: The Sanjay Amar Colony and the Yamuna Pushta slum settlements occupy some of the intensive-development capable land on the riverfront. However these also form one of the few affordable housing clusters for low-income citizens in Central Delhi. Ensuring a diverse mix of housing and unhindered public access to facilities created for the CWG 2010 needs to be high on the agenda.

Any comprehensive riverfront development or large scale urban revitalization program in Delhi has to consider the 38,440 slum dwellings from Pushta, 9,600 from Barapulla *Nallah*, 10,620 from Najafgarh Drain, 581 from Shahdara Drain and 3,000 from Sen Nursing Home Drain.[38] Forced clearance of land and resettlement at city fringes has proved to be an ineffective, expensive and traumatic exercise. The concentration of slums along the proposed CWG 2010 venues paves way for complicated land acquisition processes, unsavory social protests and negative publicity.

ii) *Existing Initiatives that could be used to exploit opportunities*:

a) The Delhi High Court order (3rd March 2003) to the Delhi and Central governments, to clear the banks of the Yamuna of illegal slum settlements and encroachments. This ruling allows for the recovery of government lands, networked CWG 2010 venues and betterment of the abused riverfront. The allocated powers also demand extra caution against draconian state action, insular gentrification, real estate profiteering and environmental damage from overbuilding.

b) The Delhi Master Plan 2001 envisions "channelization of the river to help improvement of the riverfront". In 1998, the DDA submitted a plan to develop 24,250 acres of the riverbed. "The cost of developing this land has been put at Rs. 800 (approx. $16) per square meter, and its sale price at Rs. 2,660 (approx. $ 53) per square meter, going up to 15,960 (approx. $319) per square meter for commercial property".[39] While this sanctions developing the riverbank to alleviate Delhi's land pressure (especially the CWG 2010) and the use of the private sector, concern for the migratory, spasmodic and unpredictable nature of the Yamuna River should predominate.

(Endnotes)

[1] Amir Khusrao Dehlawi, *Wasat ul Hayat*, ed. Iqbal Salahuddin, Lahore, 1975, p. 35.

[2] The Aravalli hill system in north India stretches 350 miles (560 km) through Rajasthan state to end at Delhi. Divided into the Sambhar-Sirohi and the Sambhar-Khetri ranges, the hills are one of the world's oldest metamorphic ranges and contain a variety of minerals, including large amounts of quartzite. Most of the hills are 1,000 to 3,000 ft (300 to 900 m) in elevation and from 6 to 60 miles (10 to 100 km) in width. In the Delhi region, these taper down to 30 to 45 ft (10 to 15 m) above the general land surface and approximately 2 miles (3.5 km) in width. Its maximum elevation in the area is 320.3 meters above sea level at Dehri.

[3] This protrusion creates the present bend and slowing down of the Yamuna River at Wazirabad in North Delhi, allowing for the historic ford and barrage. The Wazirabad waterworks supply the largest chunk of Delhi's drinking water supply.

[4] The northern (87 ha), central (864 ha), south central (626 ha) and southern ridge (6200 ha) regional parks amount to 7777 ha out of the Delhi Master Plan's 8722 ha marked for greens.

[5] The cities of Kilokheri (b.1287), Tughlaqabad (b.1320), Firozabad (b.1354), Deenpanah (b.1530) and Shahjahanabad (b.1639) developed edge to edge along the 22-kilometer long west bank.

[6] Literally the 'black river' and named after sister of *Yama*, the Hindu deity of death, the Yamuna flows south and southeast for 855 miles (1,376 kilometers) through the north Indian plains into the Ganges River at Allahabad.

[7] A geologic period from 66.4 to 1.6 million years ago, that constitutes most of the Cenozoic age, the most recent of the geologic ages. This period witnessed the evolution of higher mammals.

[8] Also commonly known as the Anthropogene or the 'Age of Man', because most of our recorded history dates from this period, from over 11,000 years back. The Holocene has been a relatively warm period after the last major glacial epoch.

[9] A. K Sharma, *Prehistoric Delhi and it's Neighbourhood*, Delhi, 1993, 10.

[10] The Sahibi is a seasonal river that originates in the Jaipur District of Rajasthan, and travels northeastwards through the Alwar District of Rajasthan and Gurgaon District of Haryana to enter Delhi near the village of Dhansa. It flows into the Yamuna through the Najafgarh *Nallah*, and has been increasing in flow volumes since the past decades. Its flash floods in 1964 and 1977 breached the Najafgarh *Nallah* embankments and submerged urban tracts for over 100 days.

[11] The Banganga is a seasonal, 240-kilometer long river, originating from the low hills of Bairath (Jaipur district), to flow towards the east, and enter the Sawai Madhopur and Bharatpur districts where its water spreads over a large area. Its 8878 square kilometer catchment area is limited to the state of Rajasthan.

[12] Named after a powerful Persian noble of the later Mughal court, Mirza Najaf Khan (1733-1782), whose country seat in the suburbs beyond the capital city later became a fortified stronghold of Rohilla Afghan chieftain Zabita Khan (b. 1785). The marsh was a favored duck-shoot ground of the British, but was eventually drained out into the Najafgarh *Nallah*.

[13] The greatest stream of the region, it flows through heavily industrialized areas along its 47 kilometers stretch to the River Yamuna. It's catchment area spreads over 10939 square kilometers and it discharges 1.028 million cubic meters of untreated sewage per day (source: 1982-86 statistics of the Central Pollution Control Board).

[14] A smaller channel of the Yamuna that flew along the foot of the royal quarters in the Mughal citadel, *Qila-i mubarak* or red fort, shifted eastward with the main river channel during ruler Aurangzeb's (1658-1707) rule. Modern Delhi's prime traffic artery, the Ring Road or M.G Road traces the original riverbed.

[15] Named after the village of Nizamuddin, which itself derives its name from Hazrat Nizamuddin Awliya (1258-1325), the famous Chistiyya sect *sufi* and patron saint of Delhi.

[16] With an average width of 70 meters this drain covers an area of 9.60 Ha. This drain collects the discharges of other internal, peripheral and trunk drains to further discharge its contents- 125,000 KLD of domestic sewage into the Yamuna (source: 1982-86 statistics of the Central Pollution Control Board).

[17] The Delhi Sultanate refers to the various Turko-Afghan dynasties that ruled North India from Delhi (1210 till 1526). These could be understood as five distinct periods: the Slave Dynasty (1206-90), the Khilji dynasty (1290-1320), the Tughlaq dynasty (1320-1413), the Sayyid dynasty (1414-1451), and the Lodhi dynasty (1451-1526).

[18] *'Hauz Rani'* literally means lake of the queen. The reservoir situated to the immediate north east of the pre islamic city of Qila Rai Pithora (built by Prithvi Raj Chauhan III) is survived today by a village by the same name.

[19] *'Lal Kot'* literally means the Red Fort. It was one of the fist citadels of Delhi, built in Mehrauli, then Yoginpuri by Anang Pal Tomar.

[20] 'History's Wisdom', article on traditional water harvesting systems from the Center for Science and Environment's web site. Accessed on 19th July 2004 from: http://www.rainwaterharvesting.org/Solution/History_tour6.htm

[21] Over 508 water bodies in the city can still be restored to functional levels, according to Saurabh Sinha's article 'Freshwater flows into Historic Baoli' in the *Times of India* daily newspaper, dated 19th July 2004.

[22] Also spelled Mogul, this Muslim dynasty founded by Zahir ud Din Babur (1483-1530) in 1526, ruled most of northern India from the early 16th to the mid-18th century. The Mughal dynasty was notable for about two centuries of effective rule over much of India, for the ability of its rulers, who through seven generations maintained a record of unusual talent, patronage of the arts and for its administrative organization.

[23] Tzu, Sun. 6th Century B.C. *The Art of War.* Published 1963. London: Oxford University Press.

[24] Dupont, Veronique, Emma Tarlo and Denis Vidal. 2000. *Delhi: Urban Space and Human Destinies.* Delhi: Manohar Publishers.

[25] Das, Veena (ed). 1990. *Mirrors of Violence: Communities, Riots and Survivors in South Asia.* Delhi: Oxford University Press.

[26] This theory propounded the shift of nine successive dynastic capitals through the Delhi plains, reinforcing the contention of Delhi as the natural capital of India. Despite their variations in size, lifespan and even simultaneous inhabitation, the cities (really citadels) chosen were: Indraprastha, Qila Rai Pithora, Siri, Tughlaqabad, Jahanpanah, Firozabad, Dinpanah, Shahjahanabad and New Delhi. Often citadels such as those at Kilokheri and Mubarakpur are included in this list.

[27] The Delhi Gate drain, Dr. Sen Nursing Home *Nallah* and Drain No.14 with BOD levels of 190, 280 and 320 mg/l respectively. Together these account for 17% of the BOD loading of the river per day.

[28] Accessed from the World Wide Web on 9th July 2004 from *the Tribune* daily newspaper website: http://www.tribuneindia.com/2002/20020214/ncr1.htm. Article titled 'Yama's Sister Badly Requires the Kiss of Life' by Cecil Victor on 13th February 2002.

[29] Accessed from the World Wide Web on 10th July 2004 from the Yamuna Action Plan website, hosted by the National River Conservation Directorate, GoI: http://yap.nic.in/news_dynamic.asp. Article titled 'Yamuna Action Plan- Extended Phase' by the Press Information Bureau on 31st May 2001.

[30] DJB estimate in *DUEIIP Status Report 2001.* The GoI and GNCTD. Chapter 7. 6.

[31] Drop in common woodland birds such as Warblers and Wagtails, and rare long distance travelers such as the Siberian

Cranes have been diligently reported by ornithologists, wildlife associations, the Ministry of Wildlife and newspaper reports such as *the Times of India* (on 9th Sept. 2001and 8th March 2002).

[32] Accessed from the World Wide Web on 9th July 2004 from *the Hindu* national daily newspaper of Feb. 22nd 2004. http://www.hindu.com/2004/02/23/stories/2004022308690400.htm. Article titled 'Foundation of Biodiversity Park Laid'.

[33] *DUEIIP 2001. Delhi 21 report.* The GoI and GNCTD. Chapter 11. 6.

[34] The east-west corridor between Rohtak (Haryana) and Ghaziabad (Uttar Pradesh) gives Delhi a length of approximately 51.9 km while the north-south corridor between Sonipat (Haryana) and Faridabad (Haryana) determines a width 48.48 km. A significant northeast-southwest axis from Meerut (Uttar Pradesh) to Gurgaon (Haryana) has emerged in the recent decades.

[35] *DUEIIP 2001. Delhi 21 report.* The GoI and GNCTD, 6.

[36] Approximately 3.5 million of Delhi's inhabitants live in slums and another 2.5 million in service deficient areas, as reported by the DUEIIP status report, Chapter III, 9.

[37] Survey conducted by Socio-Economic Research Foundation, New Delhi in 1988 that was quoted in the *DUEIIP 2001 report* titled, 'Delhi 21'. 26.

[38] Quoted from an article titled 'Grand Plan to Clean Up Yamuna' from the National daily newspaper, *The Hindu* on 17th July 2001.

[39] Accessed from the World Wide Web on 9th July 2004 from http://www.countercurrents.org/hr-adve290404.htm. Article titled 'Demolishing Lives and Livelihoods in Delhi' by Nagraj Adve on 29th April 2004.

Water as a Strategy Framework for Investments

"Every city should construct a framework within which both the consequences of major metropolitan efforts and the cumulative effect of individual actions can be appreciated"

Anne Whiston Spirn (1984:166)

Delhi's hydrological system allows an advantageous compatibility of the CWG 2010's short-term objectives with the city's long-term objectives. A localized, geography-based strategy for the CWG 2010 also allows benefits from the larger decentralization of municipal services initiated since the 1980s. It contributes to the greater challenge of marshalling different levels of planning and implementation bodies together on a common set of priorities and course of action. This approach builds upon creating a multi-option roadmap that allows different local bodies, interest groups and institutions to pursue distinct, identifiable targets. Such collective change could add up to a coherent whole, irrespective of the sequence or possible failure of some initiatives. "Incremental change through small projects is often more manageable, more feasible, less daunting, and more adaptable to local needs and values. When coordinated, incremental changes can have a far-reaching effect. Solutions need not be comprehensive, but the understanding of the problem *must* be." (Spirn 1984: 10). Such a geography-based breakup of challenges and tools also allows easier resource allocation, efficient coordination, and diversity of implementation routes. Working within existing administrative-political geo-tracts, it allows a better use of existing state resources, integration of existing projects and legislations.

A water-based strategy enforces evaluation, use and promotion of environmental resources that are consistently ignored by mega-event urban development strategies. A context specific strategy could help counter 'the (a) standardized

FIG. 4-1. Waterfront Development along Yarra River, Melbourne. Preparations for the CWG 2006 have been focused along the 'leisure corridor' along the river's stretch through downtown.

environments inherent in internationalized, globally televised, synthetic entertainment; (b) gigantism reflected in the formlessness and lack of human scale; (c) tendency towards impractical futurism or museumization' (Bale 1993: 41). CWG 2010's attention to Delhi's water systems could protect the city from 'placelessness' typical of mega-event host cities. "The potential of the natural environment to contribute to a distinctive, memorable, and symbolic urban form is unrecognized and forfeited"(Spirn 1984: 10).

There exist great disparities in the size of lots, land use, levels of state control and institutions along the river and stream banks. Stitching together concerned institutions, stakeholders, potential projects and legislative tools reveal two distinct trains of reason, dictated by the Delhi's geographic, institutional and economic landscape. First, of the 'River as City Vertebrae'

involving large, federal institutions, projects and expanses of undeveloped, state owned land along the Yamuna River. These land parcels possess potential for large, long-term Greenfield projects of regional scale. Second, of 'Urban Streams as an Infrastructure Lattice' involving smaller lot sizes, diversity of land ownership, uses and governing rules. This theme would involve restructure and restoration instead of new development. The nature of intervention in both approaches could be generated to the inherently common purposes of (a) prioritizing projects and programs and (b) strategic alignment of capital budgets.

Traditionally, mega-events have been associated with new mega-development in the manner of the 'River as City Vertebrae' theme though events structured around urban rehabilitation projects are also gaining credence.[1] This thesis uses both approaches to generate interest, reassessment and action by generating an urban 'aquosity'. "Aquosity is a French term that gives us a qualitative description of the environment in which we live. It suggests a form of sociability, a kind of everyday familiarity with water" (Frieling 1995: 20).

Water: Most Crucial Determinant of Delhi

> "To facilitate a comprehensive plan or the management of the urban ecosystem and to establish a frame within which individual components can be designed, every city should identify its most critical problems and most significant resources, explore the potential links between them, and establish priorities for their resolution and protection."
>
> **Anne Whiston Spirn** (1984: 260)

Water has always been a subject of controversy in Delhi. It is distributed extremely unevenly, both in space and time, by nature and man over Delhi's 1483 square kilometers. Furthermore, the distribution does not match patterns or scale of demand. Political and economic structures have exaggerated geography-borne disparities in water supply and drainage.

Almost all sources of water in urban Delhi are located in its northern parts. "As a consequence, water being piped to the southern blocks has been plagued by low pressure and inadequate supply subject to the long distance from the source" (Misra and Sarma 1979:13). Today, inadequate water-based municipal services have emerged as the biggest limiting constraint to Delhi's urban growth. Amongst the city's ecosystems, water undoubtedly plays the most decisive role in shaping urban form, real estate market, and epidemic incidence.

I identify some crucial urban issues and present potential resources, tools and actors furnished by Delhi's water resources, in the following text. Irrespective of choices or combinations made, the framework assists in formulating operational strategies and scenarios for an effective management of Delhi's water and land resource.

Enmeshing Mega-Event and Ecological Systems based Themes for a Comprehensive Framework

> "The rewards of designing the city in concert with nature apply equally to all cities, old and new, large and small...The opportunities for a fresh approach to resources and waste are enormous, and the potential for costly blunders is equally vast.
>
> **Anne Whiston Spirn** (1984: 9)

Amongst the most popular tools used to guide strategic investment plans in modern cities, mega events and eco-focus strategies have come to embody vastly different models of urban development. While there are tomes of criticism of each approach, the debate seems limited to the sustainability of ecological systems-based strategies and the negative effects of event-based strategies. A deeper study of purported differences between the two approaches reveals synergies that might help discreet investments in a city be catalytic and add beyond a sum of parts.

A possible synthesis of these two approaches shall however, be distinct from the concept of 'green events' that gained circulation after the Winter Olympics at Lillehammer (1994). The use of 'green' building materials and technology for infrastructure, energy conservation in event organization, construction and brown field restoration forms an important part but not the crux of an ecological systems-based urban development strategy. In the latter, planning emphasis is not limited to a sustainable event or means to it. But to a long-term urban development model that structures the immense momentum afforded by mega-events along an underlying physical network intrinsic to the settlement.

Applying such hybrid strategy to Delhi involves choosing amongst the various air, water, soil and bio-systems in the city to feasibly coordinate with the CWG 2010 and Olympic bid 2016[2]. This thesis has focused upon Delhi's hydrological complex (consisting of its stream networks and the River Yamuna) to establish its persistent relevance to the city's pattern of growth and response to previous mega events. The physical scale, connectivity, visibility and plethora of applicable legislations and institutions allowed by this natural water network make it the most amenable ecosystem to this experiment. Mega-event hosts throughout the world face similar challenges. The strategies and methods employed in Delhi will, with the CWG spotlight, be given world attention.

Yamuna River as City Vertebrae

Ever since the late 1970s, urban revitalization projects have used waterfronts as corridors of commerce, communication and connectors of ceremonial or leisure space. Increasingly, public events, like 'Water Fire' at Providence, Rhode Island are being designed around restored water landscapes. There has been a growing penchant to center mega-events around urban water bodies.[3] Dramatic views of signature architecture along waterfront sites has often directly influenced site selection in host cities.[4] Rivers are also beginning to be seen as development corridors by mega event organizers, as demonstrated by plans to enmesh Melbourne's cultural and sports precincts along the Yarra River for the CWG 2006.

However, such possibilities need to be considered with caution in Delhi, along the Yamuna River's flood-prone stretch. Although selective land reclamation and development is possible, this must be preceded by extensive hydrological, geological and EIA studies. Tremendous potential exists in the civic investments already made along the Yamuna riverbanks. The existing concentration of sports facilities, recreational zones,

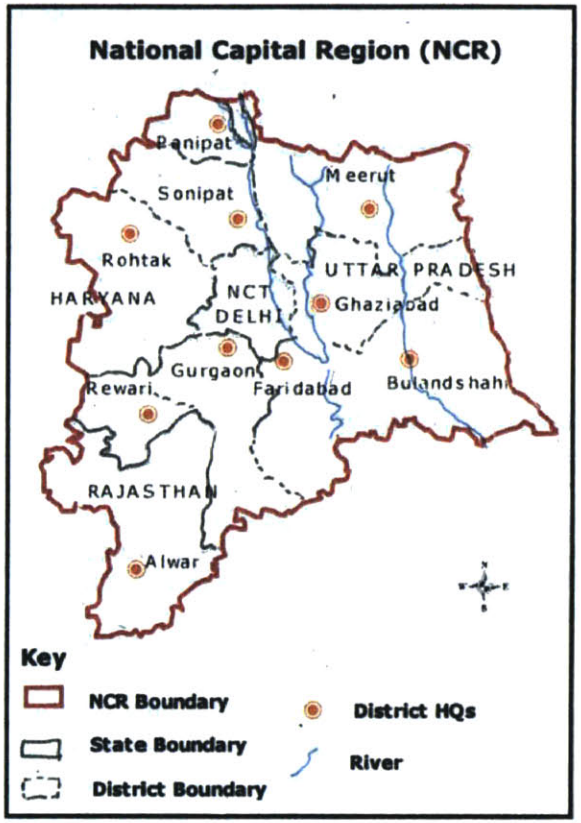


FIG. 4-2. The National Capital Region (NCR). Showing districts and satellite towns of the neighboring states of Rajasthan, Haryana and Uttar Pradesh.

institutions, transport corridors and cultural resources along the Yamuna River suggests an inevitable riparian theme for the Delhi CWG 2010.

Streams as Infrastructure Lattice

Urban stream rehabilitation and restoration programs have been a global phenomenon since the mid 1980s. However, this movement has been largely confined to environmental and ecology interest groups with few exceptions such as the Indore Slum Networking Project (1998). In Indore, roads, storm drainage and sewerage were coordinated along natural gradient to achieve incremental improvements of gravity-based infrastructure.[5] The London Olympic bid (2012) already speaks of 'a revitalized network of waterways serving new communities and businesses that will be the start of a regeneration'.[6] The typical concentration of institutions, public space, transport corridors and civic infrastructure along streams allows restoration initiatives tremendous potential to promote mobility and connectivity between isolated pockets of the city. Delhi's streams, though much abused and fragmented, still offer an impressive lattice for incremental revitalization and networking projects.

Convergence of Interests: Identifying Issues, Resources, Initiatives and Actors

> The Games presented a golden opportunity as it not only virtually forced all levels of authorities to co-operate in a process that might have taken more than a decade for such a large undertaking, but it also simplified the all important access to finance.
>
> **De Lange** (1998: 133)

Two criteria were used to identify issues from the diverse challenges faced by Delhi: first, the long term benefits of investing in the city's riparian corridor and stream network; second, the selected urban issue's capacity to assist in the successful planning, execution and legacy of the CWG 2010. These were then verified for synergies with the Government of National Capital Territory of Delhi (GNCTD)'s perspective plans (20-year visions), compatibility with structure plans (10 years) and achievability through local area plans (5 years). As each issue's objective, tools and actors vary in significance to the CWG 2010, decision-makers could choose an adaptable menu of actions compatible with contemporary political and administrative opportunities. The thesis recognizes limitations in its fieldwork investigations (through surveys, in depth interviews etc). These were crucial to identify stakeholders and resources, diagnose each actor's past, present and future commitment and analyze outcomes with different scenarios.

The methodology adopted by the study of 'Water Resource Quality Management of the Yamuna River in Delhi'[7] by the Centre de Sciences Humaines (CSH), Delhi was adapted to this context, to pinpoint consensus, dissensions and conditional commitments to be negotiated among actors. Such a strategy framework shall assist stakeholders in crafting a common patrimony out of the ever-changing ecological, social, political and economic contexts of the Yamuna riverbank.

Mapping CWG 2010 Objectives along Delhi's Hydrology

A) Development of Venues, Visitor Accommodation and Transport Infrastructure.

Recommendations:

a) Recreate a riverfront to integrate the majority of the city's population (in East Delhi) with its largest cluster of civic facilities and opportunities (in South and West Delhi) through the present ribbon of institutions and recreational spaces along the river. Over 4,891 hectares of land are available from this 6,100-hectare stretch within Delhi State jurisdiction.[8] Funding and technical assistance could be

accessed through the Urban Management Program (UMP)[9] or the Asia Urbs Program.[10]

b) Exploit Multiple Land Ownership along Waterways to Promote Public-Private Partnerships for mixed residential development consisting middle and lower income, in the stretches opposite the Millennium Park [95] or between Badarpur and Sarita Vihar [138]. The ineludible engagement of disparate social and economic classes for projects along the stream networks could pioneer a model of participatory planning and development in Delhi.

c) Attempt a Review of Obsolete Development Laws in a Waterways Theme Special Project in new development areas to prevent perversion of property values, tax revenues and tenancy rates. This would provide opportunity to demonstrate the primitivism of and need to repeal the Rent Control Act (1958), the Urban Land Ceiling Act (1976) and archaic development controls. Large, relatively undeveloped land parcels that are interconnected by stream networks, such as the Indian Institute of Technology (IIT) campus (320 acres/ 129 hectares), Pusa Institute campus (900 acres/ 364 hectares) and the Safdarjung Aerodrome (253 acres/102 hectares) could be offered FAR advantages for design sensitivity to the *nallahs*.

iv) *Actors*:

a) Federal- Government of India (GoI), DDA, Ministry of Urban Development (MoUD), Ministry of Railways (MoRlys), Delhi Metro Rail Corporation (DMRC), Central Public Works Department (CPWD), Public Works Department (PWD), Housing and Urban Development Corporation (HUDCO), National Capital Region Planning Board (NCRPB) and Central Road Research Institute (CRRI);

FIG. 4-3. The Inevitable Water Theme of the CWG 2010.

b) State: GNCTD, Department of Land and Building Department (DoLBD), Municipal Corporation of Delhi (MCD), Delhi Jal Board (DJB), Delhi Transport Corporation (DTC), Delhi Urban Art Commission (DUAC) and the Trans Yamuna Development Board (TYDB);
c) International & Private: World Bank, Asia Development Bank (ADB), Department for International Development (DFID), Japan Bank for International Cooperation (JBIC), UN Center on Human Settlements (UNCHS), Tata Energy Research Institute (TERI) and NGOs such as Delhi Science Forum, Navjyoti, 'Visthapan Virodhi Abhiyan' and the Master Plan Implementation Support Group (MPISG).

B) Eco-friendly and 'Picturesque Venue' Concept.

Recommendations:

a) Create Green Corridors along Streams to link regional (7,777 ha), district (630.78 ha) and neighborhood park (316.06 ha) systems. The forested banks of the Najafgarh *Nallah*, for instance link the Dwarka district Park (13.7 ha), Bharat Vandana Park (80 ha), the Yamuna Biodiversity Park (80 ha), the Paschim Vihar district Park, Bhalswa lake complex (92 ha), West Punjabi Bagh and Indra Vihar green belts with the orchards at Nangloi, Shastri Nagar and Keshopur. Similarly the Barapullah *Nallah* connects the Central Ridge forests (864 ha), the South Central Ridge forests (626 ha), the Southern Ridge forests (6200 ha), Lado Sarai golf course (56 ha), the Delhi Golf Club, the Silver Oak Park and the Jahanpanah city forest. These networked urban greens of varying scales and typology, along the eighteen major city streams could eventually be interlaced with a river corridor park system. "Riparian woods are also effective water-quality filters utilizing or transforming 90% of the nitrogen and 80% of the phosphorus in through flow" (Cosgrove 1990:23).

FIG. 4-4. Grass and scrubland along the Yamuna riverbank, and flood terrace. A greenway could be designed here to accommodate floodwaters and recreation.

b) Create Environmental Monitoring Networks along Waterways to provide information, regulation and enforcement nodes acting through the proposed Delhi Pollution Control Committee (DPCC)[11], under the aegis of the Department of Environment (DoE). This public realm commitment to 'environmental impact assessment, environmental management and performance aftercare' would help counter Delhi's infamous claim to being the world's fourth most polluted city.

c) Day-light Buried Stream Networks could reduce discharge flows, flow velocities, and increase BOD levels before outflow into the river. Different methods of re-vegetation,

wetland creation, slope stabilization and creation of pool-riffle arrangements could be undertaken along stretches of the buried Kushak, Barapullah, Tughlaqabad and Maharani Bagh *Nallahs*.

iv) *Actors*:

a) Federal- GoI, DDA, MoUD, Ministry of Power (MoP), National River Action Plan (NRAP), NRCD, Yamuna Action Plan (YAP), National Biodiversity Authority (NBA), Department of Biotechnology (GoI), National Environment Appellate Authority (NEAA), MoRlys, DMRC, CPWD, PWD, Central Pollution Control Board (CPCB), Monitoring of Indian National Aquatic Resources (MINAR), National Thermal Power Corporation (NTPC), National Highways Authority of India (NHAI), Indian Agricultural Research Institute (IARI) and Forest Research Institute (FRI);
b) State: GNCTD, DoLBD, MCD, DJB, DTC, NCRPB;
c) International & Private: World Bank, ADB, DFID, JBIC, World Wildlife Fund (WWF), The World Conservation Union (IUCN) and the Center for Management of Degraded Eco-Systems (Delhi University), Peoples Commission on Environment and Development (PCED).

C) Visitor and Traffic Management.

Recommendations:

a) Network the Institutions along the Yamuna River, to spearhead civic revitalization efforts. Their common concerns for convention space, hotel rooms, parking, lower vehicular pollution and support services could forge an alliance between institutions like the School of Planning and Architecture (SPA), DDA, National Sample Survey Organization, Northern Railway, World Health Organization (WHO), Institute of Engineers, Indian Medical Association (IMA), Institute of Town Planners (ITP), Indian Institute of Public Administration (IIPA), the Delhi Police Head Quarters and the Gandhi Peace Foundation. Educational facilities along the streams could collaborate to create a CWG youth network and facilitate much-needed vocational training in languages, construction, information technology etc to maximize the employment opportunities created by the CWG 2010. Such a network could also help assemble the legions of volunteers that characterize modern mega events.

b) Create Heritage Trails, Greenways and Nature Walks along the planted slopes of the stream networks to connect Delhi's monuments and popular tourist destinations. Landscaped walkways could improve the upkeep of isolated historical

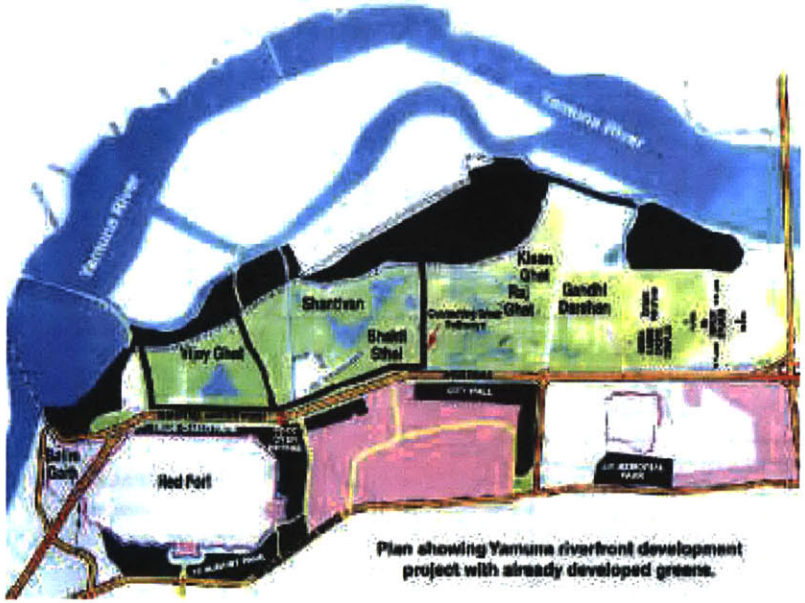


FIG. 4-5. A Proposal for Riverfront Development between the Red Fort and I.G Stadium stretches of the Yamuna River. Several plans envisaging a heritage, leisure or commercial corridors along the river's west bank have been tabled in vain.

structures, increase tourist revenues, generate neighborhood pride and reduce horticulture expenses with consolidation. The historic sites of Shah Alam at Wazirabad, Majnu ka Tila [22], Qudsia Gardens [37], Red Fort [57], Raj Ghat [57], Firoz Kotla [79], Old Fort [94], Humayun's Tomb [94] and Khizrabad [111] could be connected by a river promenade. The Barapullah *Nallah* could be developed as a pilot project by the Ministry of Tourism (MoT), Archaeological Survey of India (ASI), and the Indian National Trust for Art and Cultural Heritage (INTACH) to connect the Humayun's tomb World Heritage Site, Barapullah Bridge, Siri Fort, Satpallah Dam, ruins of Jahanpanah City and Hauz Khas University. The cultural landscape of ancient villages, shrines and inns at Deoli, Khirkee, Sheikh Sarai, Chiragh Delhi, Muhammadpur, Mubarak Kotla and Nizamuddin along this stream could be reintegrated with the modern city.

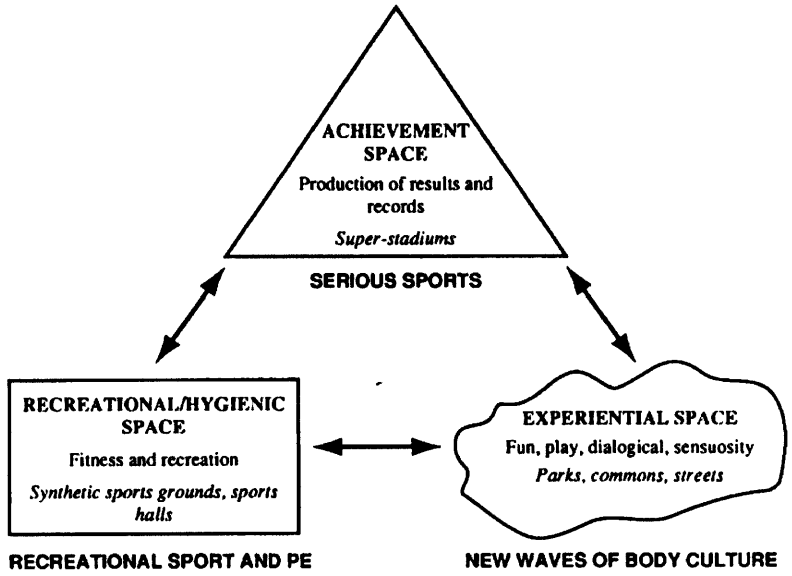


FIG. 4-6. A Landscape of Sport, with Different Levels and Themes (Bale 1993:178)

c) Create Infrastructure and Amenity Corridors along the Stream Networks to provide emergency access to event venues, dedicated critical service corridors and connected nodes for information and gravity based or networked civic amenities dispersal. Large sports venues such as the Dr. Ambedkar stadium [79], Firoz Shah Kotla Cricket Stadium, Indira Gandhi Indoor Stadium, Yamuna Velodrome [79], Jawaharlal Nehru Stadium, Maharaja Surajmal Stadium [30], Major Dhyan Chand Sports Complex [34], Talkatora Stadium, Polo Ground [91], Tyag Raj Nagar Sports Complex [108] and the Yamuna Sports Complex could be connected with smaller training and neighborhood level facilities sited along the river and stream beds.[12]

iv) *Actors*:

a) Federal- GoI, DDA, MoUD, MoRlys, DMRC, CPWD, PWD, ASI, Inland Waterways Authority of India (IWAI), Ministry of Surface Transport (MoST), Sports Authority of India (SAI), CRRI and School of Planning and Architecture (SPA), Delhi;
b) State: GNCTD, DoLBD, MCD, DJB, DTC, DUAC, NCRPB, State Transport Authority (STA) and Delhi Traffic Police (DTP);
c) International & Private: World Bank, ADB, DFID, JBIC, INTACH, World Heritage Center (WHC) and the Aga Khan Development Network (AKDN).

D) Crisis Management and Security.

Recommendations:

a) Revaluation of the Riverside Roads and Embankments to reduce water-logging and back-flow flood risks created by the obstruction of natural drainage patterns in the river floodplain. Updated contour, hydrology and geology studies

are necessary to design supplementary drains and inundation adaptable landscapes, which could also function as gray-water treatment zones. Such studies would also provide crucial information regarding flood threats to the Yamuna Sports Complex and the CWG Village, which lie in nether tracts primarily shielded by the LM embankment.

b) Re-appraisal of Flood Risk to Critical Infrastructure, such as the six road bridges, two power plants, two National Highways, Railway mainlines, metro lines, W&S treatment plants and emergency services including police and medical aid. Crisis management plans to cope with varying levels of vulnerability at site, urban and regional level are crucial to hosting a high visibility, human volume event in the highest flood risk season.

c) Create Rapid Reaction Resources and Emergency Management Plans through coordination of emergency services (such as police, fire and medical aid), communication networks and essential services, along the stream corridors. City wards could extend use of this primarily flood crisis management network for their differential vulnerability to existing natural, technological, biological and terrorist risks. Emergency command centers could be established at pivotal water and transport corridor junctions to network sensitive facilities. Information portals for security agencies, municipal services and visitors could help both monitor and relay critical information through secure, high capacity and interactive systems like GIS based intelligent emergency response system (GIERS). Wide band digital circuits lain along the stream corridors could connect CWG 2010 venues with hospitals, to allow remote diagnostics and speedier medical aid.

iv) *Actors*:

a) Federal- GoI, DDA, MoUD, MoRlys, MoH, DMRC, CPWD, Yamuna Action Plan (YAP), Central Flood Forecasting Division (CFFD), Irrigation and Flood Control Department (IFCD);
b) State: GNCTD, MCD, DJB, Delhi Police, Centralized Accident and Trauma Services (CATS);
c) International & Private: World Bank, ADB, DFID and JBIC.

(Endnotes)

[1] Fortunately, this seems to be changing with London's Olympic 2012 bid featuring six hundred hectares of reclaimed land, a revitalized network of waterways and regeneration of large parts of East London. Paris's bid includes a fifty-hectare urban rehabilitation project in Batignolles designed along a sustainable development and "Environmental High Quality" concept.
[2] As published in Indian and international media, with one of the first declarations by *CNN* on 12th January 2004 (as of 28th June 2004, at http://www.cnn.com/2004/SPORT/01/12/olympics.india.reut/).
[3] Fire sculptures and installations by artist Barnaby Evans (1994), in and along the three restored rivers of downtown Providence, RI attract multitudes of people from New England and beyond, between March and October.
[4] As seen in the Chicago World's Fair (1893) and Olympic bids of Toronto (1996), Sydney (2000) and New York (2012).
[5] Slum networking is a community-based sanitation and environmental improvement program where slum upgrading focused on sewer, storm drainage, and fresh water services following the natural courses of Indore's two small rivers near the heart of the city. Indore is a textile manufacturing and

industrial engineering town in the state of Madhya Pradesh, India.

[6] Accessed from the World Wide Web on 12th July 2004 from the London 2012 bid website: http://www.london2012.org/en/bid/regeneration/

[7] Research publication summarizing a year long, action-oriented research project by the CSH, French Ministry of Foreign Affairs to study effective management of water resource quality in Delhi.

[8] Of which government land is approximated to be 3,380 hectare, private land of 1,359 hectare and notified and acquired land under 1,342 hectares. Quoted from an article titled 'Grand Plan to Clean Up Yamuna' from the National daily newspaper, *The Hindu* on 17th July 2001.

[9] Urban Management Program (UMP) Asia-Pacific is a joint initiative of the United Nations Development Program (UNDP) and United Nations Center for Human Settlements (UNCHS-Habitat) to improve urban management practices in the region and support sustainable development in urban areas.

[10] Asia Urbs is a city partnership project co-financed by the European Commission, where sister cities in the European Union and Asia help each other through urban cooperation projects.

[11] Proposed by the DUEIIP status report, Chapter 12, 73.

[12] Creating a 'landscape of sport' including super stadiums, sports halls, parks and streets as envisaged by John Bale (1993) in *Sport, Space and the City*. London: Routledge, 178. This is distinct from John W. Sommer's (1975) concept of 'Hedonopolis', where a broad girdle of land dedicated to leisure or a 'zone of repose' surrounds the city.

APPENDIX

Applicable Urban Management Laws

i) Constitution (64th Amendment) Act, 1991.
ii) The Government of the National Capital Territory of Delhi (GNCTD) Act, 1992.
iii) The Environment (Protection) Act, 1986.
iv) The Water (Prevention and Control of Pollution) Act, 1974.
v) The Air (Prevention and Control of Pollution) Act, 1981.
vi) The Slum Areas (Improvement and Clearance) Act, 1956.
vii) The Delhi Urban Art Commission (DUAC) Act, 1973.
viii) The NCR Planning Board Act, 1985.
ix) The Land Acquisition Act, 1894.
x) The Delhi Municipal Corporation (MCD) Act, 1957.
xi) The Delhi Development Authority Act (DDA), 1957.
xii) The New Delhi Municipal Council (NDMC) Act, 1994.
xiii) The Road Transport Corporation Act, 1950.
xiv) The Indian Electricity Act, 1910.
xv) The Forest (Conservation) Act, 1980. Amended 1988.
xvi) Water Cess Act, 1977. Amended 2003.
xvii) The Delhi Water Board (Delhi State) Act, 1998.

Official Planning Efforts in Delhi

i) Lutyens' Plan for the New Delhi (the Imperial Capital), now the NDMC area.
ii) Interim General Plan for Delhi prepared by TPO in 1956.
iii) Master Plan for Delhi (MPD) with perspective of 1981, prepared by DDA in 1962.
iv) Modified Master Plan with perspective of 2001, prepared by DDA in 1990.
v) National Capital Region Plan (NRCP) with perspective of 2001, by National Capital Region Planning Board (NRCPB) in 1989.

Supreme Court of India (SCI) Orders of Environmental Significance to Delhi

i) November, 1996	On shifting of Industries
ii) November, 1997	On Public Transport
iii) December, 1997	On Public Transport
iv) July, 1998	On Control of Vehicular Pollution
v) December, 1998	On Motor Vehicles Act and Traffic Control
vi) February, 2000	On Habitable Environment
vii) February, 2000	On Improving the Water Quality of the Yamuna River

ACRONYMS / ABBREVIATIONS

Federal or Central Government Agencies

ASI	Archaeological Survey of India
CFFD	Central Flood Forecasting Division
CGWA	Central Ground Water Authority
CPCB	Central Pollution Control Board
CPWD	Central Public Works Department
CRRI	Central Road Research Institute
DCB	Delhi Cantonment Board
DDA	Delhi Development Authority
DMRC	Delhi Metro Rail Corporation
FRI	Forest Research Institute
GoI	Government of India
GSI	Geological Survey of India
HUDCO	Housing and Urban Development Corporation
IARI	Indian Agricultural Research Institute
IFCD	Irrigation and Flood Control Department
IWAI	Inland Waterways Authority of India
MINAR	Monitoring of Indian National Aquatic Resources
MoE	Ministry of Environment
MoP	Ministry of Power
MoRlys	Ministry of Railways
MoST	Ministry of Surface Transport
MoUD	Ministry of Urban Development
MoT	Ministry of Tourism
NBA	National Biodiversity Authority
NCRPB	National Capital Region Planning Board
NDMC	New Delhi Municipal Council
NEAA	National Environment Appellate Authority
NHAI	National Highways Authority of India
NRAP	National River Action Plan
NTPC	National Thermal Power Corporation
PWD	Public Works Department
SAI	Sports Authority of India
SI	Survey of India
SCI	Supreme Court of India
SPA	School of Planning and Architecture
TPO	Town Planning Organization
YAP	Yamuna Action Plan

State or Delhi Government Agencies

CATs	Centralized Accident and Trauma Services
DJB	Delhi Jal Board
DoLBD	Department of Land and Building Department
DPCC	Delhi Pollution Control Committee
DSIDC	Delhi State Industrial Development Corporation
DTC	Delhi Transport Corporation
DTP	Delhi Traffic Police
DUAC	Delhi Urban Art Commission
DWSDU	Delhi Water Supply & Sewage Disposal Undertaking
GNCTD	Government of National Capital Territory of Delhi
MCD	Municipal Corporation of Delhi
STA	State Transport Authority
TYDB	Trans Yamuna Development Board

International or Private Institutions

AKDN	Aga Khan Development Network
ADB	Asia Development Bank
CSH	Centre de Sciences Humaines
CSE	Center for Science and Environment
CSIR	Council of Scientific and Industrial Research Institute
DFID	Department for International Development
ICMR	Indian Council of Medical Research
IIPA	Indian Institute of Public Administration
INTACH	Indian National Trust for Art and Cultural Heritage
IOA	Indian Olympic Association

IUCN	The World Conservation Union
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
MPISG	Master Plan Implementation Support Group
NII	National Institute of Immunology
UMP	Urban Management Program
UNCHS	UN Center on Human Settlements
TERI	Tata Energy Research Institute
WB	World Bank
WHC	World Heritage Center
WHO	World Health Organization
WWF	World Wildlife Fund

Miscellaneous

BGL	Below Ground Level
BOD	Biological Oxygen Demand
BPS	Booster Pumping Station
CETP	Common effluent treatment plant
CTC	Community toilet complex
CWG	Commonwealth Games
DMA	Delhi Metropolitan Area (3,182 sq km)
EIA	Environmental Impact Assessment
EYC	Eastern Yamuna Canal
FAR	Floor Area Ratio
GT Road	Grand Trunk Road
INA Colony	Indian National Army Colony
ISBT	Inter State Bus Terminal
ITO	Income Tax Office
JLN	Jawahar Lal Nehru
KLD	Kilo Liters per Day
LME	Left Marginal Embankment
Mcg/m3	Micrograms per cubic meter
MG/L	Milligrams per liter
MLD	Million Liters per Day
MPD	Master Plan for Delhi
MSL	Mean Sea Level
NCR	National Capital Region (30, 241 sq km)
NCRP	National Capital Region Plan
NCT	National Capital Territory (1,483 sq km)
NH	National Highway
NOIDA	New Okhla Industrial Area
RME	Rural Marginal Embankment
SPM	Suspended Particulate Material
STP	Sewage treatment plant
UP	Uttar Pradesh
WYC	Western Yamuna Canal

GLOSSARY of TERMS

Abadi	Human settlement can denote a city, town, village or a hamlet.
Alluvial	Having to do with streams.
Alluvium	Stream-deposited sediment.
Bagh	Walled in gardens often divided into several compartments.
Bangar	Old alluvial soil usually clayey and dark in color.
Baoli	A deep stepped well. These provided drinking water and were often used together with Persian-style water wheels to supply water to gardens and palaces.
Bedrock	Any solid rock underlying soil or sediment.
Bundh	An embankment or dam. Also spelled *bund*.
Colony	A residential enclave in Delhi (distinct from a neighborhood in their common lack of community). These typically are distinguishable by their date of establishment, developer or homogeneous construction style. Colonies vary in size and are often concentrations of certain socio-economic classes and religious minorities.
Darya	Large expanse of water, which could denote a river or the sea.
Dak Chauki	Node or station of a postal network.
Digghi	A square or circular reservoir with steps to enter.
Doab	A tongue or tract of alluvial land included between two rivers; as, the *doab* between the Ganga and the Yamuna Rivers.
Floodplain	Flat areas adjacent to a stream that are covered by water in times of flood.
Hauz	Man made pool, tank
Imranat	Suburb
Jhal	Waterfall
Jheel	A natural, unbound lake.
Kankar	Calcareous concretions / pebbles
Khadar	New alluvial soil, usually sandy and light in color.
Kruh	A measure of distance common during the Sultanate. Approximately three kilometers.
Kushak	Fortified palace
Liquefaction	The process by whereby particles of sediment within water-saturated sand or silt are shaken into suspension, so that the entire mass temporarily loses its strength and enters a fluid-like state.
Madrassah	College of religious and theological education
Mauza	Village
Mori	An aperture in a dyke or dam to release water
Nadi	River. Sometimes refers to a rivulet.
Nahr	Canal or the main canal of a garden
Nallah	A water course, a ravine. Can be both a dry or flowing water or stream. Also spelt n*ullah* or *nala*
Qasr	Small fort
Sarai	Inn for travelers, merchants and their beasts of burden. A fortified rectangular enclosure, with corner bastions and often a single gate. On the city outskirts, the courtyards may contain a mosque, wells or bazaars.
Seismic	Pertaining to earth vibrations, usually those caused by earthquakes.
Shahr	City
Sharb	Water.
Tal	A lake
Thana	Post or picket, usually for postal services or watch.

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