Transformation of Survey of India

By

Prithvish Nag

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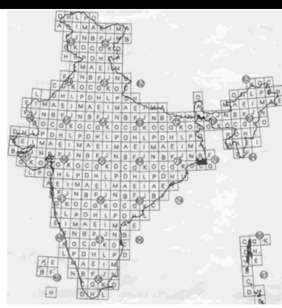
Dedication

This book is dedicated to my parents,
Dr Pradyumna Chandra Nag and **Mrs Sucharoo Nag**

The author, taking over the charge as Surveyor General of India on 3rd December 2001 from Lt. Gen A.K. Ahuja

"The relevance comes from the fact that the scientific basis of this entire experiment has not changed while technology has changed. You see this in several areas. Our entire communication system today is electro-magnetic and digital, but the technology has changed. The digital revolution happened 20 years ago and is getting upgraded. The basic principles of mapping and surveying have set at that time and new technologies are coming into the picture. It is important because there is greater realisation that the domain in which maps will be useful has considerably broadened. Therefore we have to tell our people that we have a tradition in mapping so that everybody becomes familiar with the kind of knowledge maps provide them."

V.S. Ramamurthy



"Many countries have mapping organisations within which the production processes for topographical mapping date from colonial times. Such organisations have a hard time to keep pace, in terms of production rates, with the fast development of their country. Traditional approaches are too slow. I think that along with new mapping techniques we should develop new concepts for core data production and provision which avoid the slow processes of traditional map production. If we do not dwell too much on interpretation but instead correlate data geographically sufficiently correctly with GPS, then we can work on the provision of a good core dataset capable of being linked to other types of information, like vegetation and soil data. In training and conceptual development there should come a move away from traditional map concept still so often found in the definition of products."

Martien Molennar

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About the Author

Dr. Prithvish Nag, M.Sc. (Gold Medallist), Ph.D. has been the Vice-Chancellor of the Mahatma Gandhi Kashi Vidyapith, Varanasi; Uttar Pradesh Rajarshi Tandon Open University, Prayagraj; Samoornanand Sanskrit Visvavidyalaya, Varanasi; and Deen Dayal Upadhyay Gorakhpur University. He was elected as a Fellow of the Royal Geographial Society, London and receipient of the Commonwealth Geographical Bursary on the 150 anniversary of the Royal Geographical Society.

Dr Nag was Senior Visiting Member of the School of Oriental and African Studies, University of London. He has been Scientist/Engineer in the Indian Space Research Organisation (ISRO). He was also Visiting Professor in the Department of Civil Engineering of the Indian Institute of Technology, Banaras Hindu University. He is an author and editor of 77 books and 135 research papers. His well known books are *Geography of India, Population Geography* and *Digital Remote Sensing*.

Dr Nag has been the President of the of Indian National Cartographic Association, Indian Association of Special Libraries and Information Centre, Institute of Indian Geographers, Indian Institute of Geomorphologist, Professor S.P.Chatterjee Memorial Foundation and Regional Science Association of India. At the International level, he was the Chairman of the International Cartographic Association (ICA), Commission on Population Cartography, UN / PCGIAP Committee on Institutional Strengthening for Asia and Pacific, International Steering Committee on Global Mapping (ISCGM) Working Group on Data Standardization; Full member of the International Geographical Union (IGU) Commission on Population Geography, and Member, Editorial Board, International Journal on Geographical Information System.

Dr. Nag was the Director in the National Atlas & Thematic Mapping Organisation (NATMO) of the Ministry of Science & Technology, Government of India, UN Consultant in Cartography in the Sultanate of Oman and the Surveyor General of India. He has been chairmen of several Department of Science & Technology (DST) Expert Committees, such National Geospatial Programme (earlier Natural Resource Data Management System), National Spatial Data Infrastructure, Geospatial Chair Professors; and Member of the DST/FIST Expert Committee on Earth & Atmospheric Sciences. He is the former Chairman, GIS Executive Advisory Committee of the Kolkata Municipal Corporation.

He was Principal Expert in the Nanjing Normal University, Nanjing Project on "Dynamic Mapping and Service for Regional Ecological Civilization based on Big Data", December 2019; and was honoured as an Expert in the Home of Zhejiang Academicians in Moganshan, P. R. China, 2019. At present, Dr Nag is the Director of the SHEPA Group of Educational Institutions in Varanasi.

Preface

I was highly impressed by the documentations about different activities and procedures of Survey of India. These printed documents sometimes are known as records, manuals, papers, or memoirs. Mostly they were for internal use in order to have parity while mapping the massive mapping activities covering the undivided South Asia. This region includes India, Pakistan and Bangladesh and beyond including Afghanistan, Nepal, Bhutan Sri Lanka and Myanmar. Nevertheless, Survey of India was sometimes responsible to map areas like Hong Kong, Karakoram, northern Africa and the like. The record of mapping these areas is well preserved in different establishments of Survey of India, particularly in Dehra Dun and Kolkata.

The reports and documents, mostly printed, cover wide range of topics. They include annual reports of topographical surveys, account and results of operations of great trigonometrical survey (standard, major & the baseline), triangulation of Hong Kong and New Territories, selection records of trigonometrical and topographical surveys, tidal records, auxiliary tables for graticules of maps, report of land revenue administration of North Western Frontier Province (settlement), settlement report of Bannu district (now in Pakistan), sketches on services during the Indian frontier campaigns, and the like. The standard operating procedures of ancillary activities were also well documented. Some of them were concerning (a) rules of printing and binding, (b) norms for ministerial and lower sub-ordinate establishments, (c) fieldwork operations, (d) procedures of raising camps, and on similar issues.

Regarding the technical work, the *Handbook of Topography*, having different chapters in printed form were most important. The vital chapters were on *Introductory* (Ch I), *Constitution and Duties of a Survey Party* (Ch II), *Triangulation and its Computation* (Ch III), *Theodolite Traversing* (Ch IV), Plane-Tabling (Ch V), Fair Drawing (Ch VI), Trans Frontier Reconnaissance (Ch VII), Survey in War (Ch VIII), *Geographical Maps* (Ch XI), *Map Reproduction* (Ch X), *Forest Survey & Maps* (Ch IX), and *Air Surveys* (Ch XII). These chapters have written before independence and revised several times after independence as well. For example, the Chapter X on Map Production was first published in 1911 and the second edition in 1919. Further, the chapters on Triangulation and its Computation and Plane-Tabling were six times revised under the orders of the then Surveyor General of India, Brigadier J.S. Paintal in 1966. They were printed in Survey of India's 103 (P.Z.O.) Printing Group located in Dehra Dun. The tradition of bringing out reports and manuals continued. Hence, we find publications (sometimes mimeographs) on map projection, different aspects of geodesy, important meeting minutes and the like. Recently, Technical Paper No. 01/2020 on the Development of Geoid Model for Uttar Pradesh & Part of Uttarakhand under National Hydrology Project (NHP) was brought by the Director of the Geodetic & Research Branch (G&RB). However, with the introduction of computer-based techniques, digital disruption took place. The earlier manuals and handbooks became less relevant. They were taken over by software-based technologies which keeps on changing with every new version.

Writings on Survey of India was not always an in-house activity. Several authors were attracted to the then biggest scientific activities under the aegis of Survey of India. Attempts were made to document the events however the objectives and intentions were different. Some of the authors had close connections with the Survey either due to army or colonial background. This is apparent from the book by Jerry Brotton (2012) on *A History of the World in 12 Maps* (p. 344).

> "In contrast to the Ordnance Survey's difficulty in providing standardized maps of England's complex and entrenched system of land ownership and management, the English East India Company assumed it would be much easier to survey the overseas possessions like India by using new scientific techniques and simply ignoring the local methods of mapping and owning land, notwithstanding the country's size. In the 1760s the company began providing financial support to individuals like Rennel for surveys that cumulated in the Great Trigonometrical Survey of India. The survey was judged complete by 1843, but work carried on decades, and, like Cassini surveys, it has no decisive terminal date. In the words of Matthew Edney, the survey's most distinguished historians, the surveyors 'did not map the "real" India. They mapped the India they perceived and that they governed', and as a consequence created 'a British India."

Reference has been made to the book entitled *Mapping an Empire: The Geographical Construction of British India, 1765-1843* by Matthew Edney (1997). The colonial inclination of both the books under reference has been quite apparent. The interest of documenting the activities of Survey of India continued after independence as well. The R.H. Phillimore's five volumes on *Historical Records of Survey of India* are classic example. However, they cover a limited period. He described survey operations in different parts and stretches of undivided India. The five volumes provide details about marine surveys, revenue surveys, Pindari and Maratha wars, military routes, methods of surveys, details of great trigonometrical surveys, astronomical observations, natural history, metrological observations, instruments, projections and scales and the like. They include coloured maps, pictures, sketches and biographical notes of the surveyors. The whole operation appears to be a semi-military in nature involving army officers. Phillimore in the Preface of volume III made following observations:

> "Of the five great surveyors Mackenzie was the only Engineer, Lambton and Hodgson were Infantry officers, Blacker a Cavalry man, and Everest a Gunner. It is not generally recognized how few of the early surveyors of India came from corps of Engineers."

Mackenzie was the first Surveyor General of Madras and later of India as well; and 'pioneer of topographical surveys. Phillimore was himself a Colonel in the Royal Engineers and Survey of India. The volumes by him are considered to be an authentic account of the Indian surveys. Though documents do exist, the befitting historical account of 19th century onwards had not been attempted. However, on the occasion of bicentenary of Survey of India, under the guidance of Lt. General G.C. Agarwal, the then Surveyor General of India, *A brief History of Survey of India, 1767-1967* was brought out. This mimeographed volume contained the important features during different historical periods. It includes narration about the beginning of scientific surveys and challenges of post-independence India. Further, in 1990, a souvenir was brought out by the Survey of India on the occasion of birth bicentenary of Col. Sir George Everest. Lt. General S.M. Chadha was then the Surveyor General of India. This was also a mimeographed volume centered around the contributions of Col. Everest. Recently, K.G. Behl brought a poetic account in his book entitled, *Glimpses from Survey of India: Covering 250 Years*. Further, what Suresh Prabhu and Shobhit Mathur

(2003) wrote for educational institutions is true for scientific establishments like Survey of India as well:

> "A biography of an educational institution additionally serves as a model for other institutions, highlighting best practices and successful strategies that can be applied elsewhere. It could show the value risks and trying new things, which can encourage younger institution builders to do the same."

Inspired by the authors who have contributed towards documenting, recording and publishing the narrative of the Indian survey department, I mooted the idea of writing this *Memoir of an Indian Surveyor General*. This will at least cover the period of which I was with the Surveys. I have been associated with Survey of India in different capacities. Before joining this department, I was associated with different committees as a representative of another national level mapping institution, *i.e.* the National Atlas & Thematic Mapping Organisation or NATMO. Common strategies for preparing the District Planning Map Series (DPMS) or commercialization of maps were developed. I was entrusted with the responsibility of the Surveyor General of India three times: (a) December 2001 – February 2005, (b) July 2007, and (c) July 2008 – October 2008. Later, I have been chairmen and member of different Union Department of Science & Technology (DST) committees which have directly or indirectly links with the Survey of India. Some of these committees were National Geospatial Programme (erstwhile Natural Resources Data Management System), National Spatial Data Infrastructure, Survey Board, Reorganization of Survey of India, National Geospatial Policy, selection of mapping software for Survey of India, Central Survey Programming and Planning Board, Empowered Committee for Survey of India and the like. Hence, this memoir will have the reflections of my above-mentioned associations with the Survey for over 25 years. As a result, I may be considered to be insider or even outsider of the system. In both capacities, there are certain advantageous and limitations as well.

It is not the first time a treatise has been attempted related to the work of Survey of India; or a book on scientific or technical matters written by a Surveyor General. Charles E.D. Black in 1891 brought out *Memoirs on the Indian Surveyors 1875-1890* covering a period of 15 years only. It was published by the order of Her Majesty's Secretary of India in Council, London. Further, Sir Clements Robert Markhan brought out two books entitled (a) *A Memoir on the Indian Surveyors*, published by W.H. Allen & Company in 1871 (2nd edition in 1878); and (b) *Major James Rennel and the Rise of Modern English Geography*, published by Cassell & Company in 1895. Even Sir George Everest brought out following books describing measurement of the arc:

1. *An account of the measurement of an arc of the meridian between the parallels of 18^{0} 3′ and 24^{0} 7′ : being a continuation of the grand meridional arc of India as detailed by the late Lieut.-Col. Lambton* in 1830.

2. *An account of the measurement of two sections of the meridional arc of India: bounded by the parallels of 18° 3′ 15″; 24° 7′ 11″; & 29° 30′48″* in 1847.

On the occasion of the bicentenary functions, several publications were brought out. One was *The Great Arc 200 Years: Celebrating the Quest – A Saga of the Agony, Passion and Triumph of Precision Inch by Inch along the 78th Meridian* (Nag 2002). It was published by the Union Department of Science & Technology. A coffee-table book on the *Great Arc* was also produced to mark the occasion. In addition, several pamphlets, booklets, souvenirs and other publications were brought out to observe this event. All these activities motivated me to write the memoirs in order to records the major events which took place during my involvement with Survey of India. Nevertheless, I am still associated with this great organization, both at individual and institutional levels.

It is about two decades when I took up the responsibility of a Surveyor General of India. Over the years I have collected materials to write this memoir. They are in the form of copy of notes, meeting minutes, lectures, published research papers, interviews to the media, power point presentations, tender documents, entries in dairies, printed and published materials, photographs, and correspondences. Some are in the form of hard and soft copies. As a result, I have to go through thousands of pages, compact disks, pen drives, e-mails and sometimes old floppies as well. Nevertheless, all the desired materials were not always with me. Hence, I have to take help of the offices of the Survey of India, particularly Survey General's Office (SGO), Geodetic and Research Branch – both located in Dehra Dun, and its office in Kolkata, mainly the libraries of these offices. I had additional advantage of being in Kolkata because the earlier headquarters of the Survey was located in this city. It was a pleasure to get cooperation the officers of this office. Furthermore, due to corona pandemic, I got the advantage of getting ample time to concentrate in writing this Memoir.

I am particularly indebted to Dr S. Chandrasekhar, Secretary to the Government of India, Department of Science & Technology for encouraging me in this pursuit. He kindly agreed to write the Foreword of this volume. I take this opportunity to thank Prof K.M. Pandey, Head of Department of English, Banaras Hindu University for going through the manuscript and giving valuable suggestions.

The whole objective of this memoir is to record the scientific and technical initiatives taken during my tenure so that they are not overshadowed by other activities taken during the same period. Some of such initiatives lead to the establishing of National Spatial Data Infrastructure (NSDI) and National Geo-technical Facilities (NGF). Both were initially established as a part of Survey of India. NSDI, based in New Delhi, was taken over by the Department of Science & Technology having close cooperation with its National Geospatial Programme. NGF, the latter one, came under the control of other institutions and finally it has been reverted to the G&RB Directorate of the Survey of India. The other initiatives were conversion of topographical details on colour separated on thick glass plate to digital data; transformation of field operations, introduction of remote sensing in a limited way; geodesy, large scale mapping, implementation of dual map series; reorganization of the whole setup spread all over the country; establishment of modern printing facilities and special cell for the Ministry of External Affairs (MEA) in Palam, New Delhi; creation of survey office (later GDC) in Chennai for Tamil Nadu; construction of buildings in Jaipur and Gandhinagar; development of SGO GIS Cell and the like. Implementation of all such enterprises was not easy in an organization which is known for its heritage and traditions.

This volume is likely to demonstrate how a 250-year-old setup has been transformed to a modern mapping, geospatial and survey organisation. The whole process may become a role-model for other countries undergoing similar processes of change with continuity. Each major initiative has been dealt as a separate chapter in this book.

Dr Prithvish Nag, May 2023

Chapter 1

Introduction

"The old order changeth yielding place to new".

Lord Tennyson in The Passing of King Arthur

Cartography is about maps. This includes the art, science and technology of map making. Cartography has always been closely associated with geography and surveying. The early mapping may be associated with the development of symbolization (or presentation) method that was used by early mapmakers. The definitions tend to emphasize map-making while recent descriptions also include map use within the scope of cartography. The history of Survey of India (SOI) has been a part of the saga of nation building. It was never realized that the foundation of modern India will become synonymous with the activities of this department, but its contribution has never been emphasized – not even by the SOI itself. How scientific foundation or development initiatives could have been possible without the anticipatory actions taken by the department? The process of understanding of the priorities in development and defence has been the forerunner in all respect.

All such developments were of course not without price and efforts. The scientific measurement of the country had several ramifications. Surveyors traversed from regions to regions, waiting for an opportune time free from natural, man-made and logistic problems in order to pursue their task. Hazards, diseases, snakebites, dacoity, hostile local people, battles and the like came in the way of their mission. Surveyors penetrated the jungles, climbed mountains, crossed rivers and fixed poles, stations and control points throughout the length and width of the country. There was no respite whether it may be on the slopes of Western Ghats, or swampy areas of Sundarbans, or ponds and tanks, ox-bow lakes and meandering rivers of Bengal, Madurai or Ganga basin. The deserts, mighty Himalayas, Rann, River Chambal or Gandak, *terai* or *dooars* were also not spared. The survey has been associated with the waves of Arabian Sea or Bay of Bengal, dust storms of Rajasthan, cyclones of Eastern Coast, cold waves of the north and the widespread monsoons and heat all over the country.

It was against this price, determination and missionary zeal that the foundation of the country was laid. The knowledge assets built over years and generated with whatever technology then available proved to be valuable. The best part of the whole process is that a new information set which may be based on latest technology like aerial photography or global positioning system takes benefits of the earlier generated information. No piece of information is wasted and has relevance even after decades. How such an empire of knowledge has been built up? It is not only a technological feat that is most important but it is an emblem of pursuance of one of the longest scientific experiments carried out in the world *i.e.* mapping the nation against all odds. The legacy and traditions continue. It is a matter of great interest to know how such a super structure of information has been built. How this great scientific experiment has been carried out for so long. What were the compulsions and apparent benefits? Why the colonial rulers and later the independent government with limited resources continued their interest in this expensive exercise? These are some the questions that will keep on bothering the people interested in the history of science of this country.

The science of map-making could have not been possible without the knowledge of shape and size of the earth. This was required for determining the coordinate of points on the earth's surface, which have been used for map-making. Efforts were made from the very beginning by various philosophers and scientists for determining shape and size of the earth. Man's first conception of the earth's shape was a plane. Greek philosopher thought it a sphere. Sir Issac Newton pointed out that it must be spheroid. However, development of science of surveying and mapping of earth's surface in an orderly manner has been ascribed to Eratosthenes (276-198 BC) who based the compilation of his comprehensive map of the world upon his famous determination of the circumference of the earth. Claudius Ptolemy, a mathematician, astronomer and geographer produced a map of India in the 2nd century AD. However, the golden age of Indian renaissance started when in 5th century, genius Aryabhat calculated the earth circumference to be 25,080 miles and wrote *Surya Sidhanta*. The next contributor to Indian geography were Chinese and Arab travellers who left the interesting and detailed accounts of their journey. It is not wonder that this mystic land attracted so many adventurers.

The basic concepts of map-making *i.e.* scale, generalization of features etc. were known in India as evidenced in *Purana.* Various references in the *Vedas* testify to lead to this conclusion. It has been established that art of surveying technique of mensuration of areas were well developed in ancient India; the manual known as "*Sulva Sutra*" (science of mensuration). In *Vedic* literature *sutras* (formulae) were provided for the measurement of angles, distances and areas. Our ancient knowledge of astronomy, astrology, rocketry and geography is well known and has been apparent to Indian scholars that the *Vedas* and later Sanskrit works contain these truths. In *Vedas, Upanishads,* the great epics *Ramayana* and *Mahabharata, Puranas*, *Manusmriti*, works of Panini, Patanjali and Kautilya and poem of Kalidasa, there has been reflection of geographical accounts of India. The Vedic concept of motherland, mentioned in *Prithvi Sukta* in the *Atharvaveda,* has no parallel in any other literature written outside India. The Indian astronomers and mathematicians like Aryabhat, Baraha-Mihir and Bhaskaracharya discovered several truths like shape of the earth, its rotation around the sun, and even the force of gravitation.

Although, geographical knowledge traces its historical background from very beginning of civilization, but that has been the domain of history. Knowledge of maps as a science grew with time and religious thinkers also started delving into its mysteries. The age of great exploration started with the quest for uncorrupted truth. The major exploration got underway at the end of fifteenth century with Columbus crossing the Atlantic in 1492, Vasco da Gama circumnavigated Africa in 1497 and the Magellan's expeditions circumnavigated the world between 1519-1522. The Dutchman Snell (1591-1626) carried out the first measurement of angles and distances and made the rigorous study of refraction. The French Clergyman Picard, in 1670 made the measurement of size of earth. His results of 6,275 km for the radius of earth were the first improvement on Eratosthenes determination of the size of the earth. Newton's theory, that the earth should be oblate because of the centrifugal force, caused by the spin was validated by the measurements of two meridian arcs, one at the equator and the other closer to pole measured by two survey expeditions organized by French Academy of Sciences.

The dissemination of geographical knowledge was limited till 15th century before the invent of printing technique due to the labour and skill involved in duplicating graphic data. Once, however, lithographic techniques were discovered map-making got a stimulus, particularly in Europe where adventurous men were out to conquer new worlds for religion and commerce. Father Monserrate, a Jesuit Missionary, brought out a map after a visit to Akbar's court. This was a first of those maps which are based on measured routes and astronomical observations. Sher Shah Suri and Todar Mal's revenue maps, based on regular land survey systems, were well known in the medieval period and continued to be in practice during the mid-eighteenth century. These are available information of the surveys instituted by Akbar during 16th century; measurements being made by a hempen rope which was replaced by a "*Jarib*" of bamboos joined by iron rings. The other noted cartographers of the time also published their vision of maps of India, but in 1752 the French geographer, Jean-Baptiste Bougigon d'Anville published map of India and put Indian geographical knowledge on a scientific footing. Further, the pioneering work done by French expeditions showed that terrestrial measurements (angles & distances) were the main tools for the task of relative positioning. The technique of triangulation, astronomical determination of positions and azimuths as well as leveling were started mid seventeenth century.

In the early days of the imperial powers in India, the geographical knowledge of southern parts of the country was greatly increased during the period of wars of political supremacy but northern parts of the country (Bengal, Uttar Pradesh etc.) was sketchy. Nevertheless, attempts were made from very early times to establish the geographical locations of important places. Raja Jai Singh Sawai of Jaipur of pre-British period established astronomical observatories at Jaipur, Delhi, Mathura, Ujjain and Varanasi and determined geographical positions of various locations.

During the middle of 18th century, latitude could be easily determined by observing the meridian altitude of the sun or stars. For longitude determination, one had to wait for favourable phenomenon such as an eclipse of sun, moon or satellites in clear sky with similar observations to be made at some known places. In 1787, astronomical observations for latitudes and longitudes at various places were made covering India. The proper astronomical centres were established in due course of time using sextants, chronometers and telescopes. The results of these instruments were imperfect because of their accuracy level and faulty mathematical tables. It is interesting to note that because of difficulty in determining longitude, early maps of India did not indicate longitude with reference to Greenwich meridian but are referred to arbitrary meridian passing through Madras or Calcutta.

Most of the early maps were based on local surveys carried out by cursory methods. In 1776, comprehensive instructions for preparing the maps on the scale two mile to an inch formulated: in which distances were measured by perambulator rather with chains and bearing to the conspicuous hills. Short base lines were laid and measured and distant points were fixed by triangulation. According to Murli Manohar Joshi (Appendix VII):

> "In hindsight, the Great Arc odyssey is capable of being viewed in many different ways and at many levels. Conventionally, it has been seen as the mapping of an empire - a typically grandiose, colonial enterprise to consolidate the military, economic and territorial gains of an imperial state. Scratching beneath the surface, we begin to see the magnificent obsession of a few individuals, using the cloak of imperialistic ends to justify their fascination with a particular branch of science and an almost fetishistic passion for measurement and empirical observation. If we go a little deeper we can see the unfolding of a still larger, grander, story - that of a unique partnership of minds. We need to see through the colonial context and the asymmetry of political power at that time, to appreciate the collaborative nature of the project and the strength of the team effort which went into it. The Survey was not a military campaign with star British generals leading an army of passive Indian subalterns and foot soldiers. Nor was it an industrial enterprise which could employ armies of cheap Indian wage labourers regimented into an assembly-line order. The utilitarian ends of the exercise were not apparent enough. There was no pot of gold or buried treasure at the end of it. Yet, thousands and thousands of men offered their skills, their brainpower, their brawn, their patience and indeed their lives, for a scientific pursuit."

Historical Background

The Survey of India traces its birth starting from Major James Rennell appointed as Surveyor General of Bengal on the 1st of January 1767. In those days, there was an urgent need for having a picture of the country showing general course of main rivers and the location of principal towns. This task was taken up with speed, and in the process, produced some serviceable maps of areas of Bengal and Bihar in less than twelve years. These maps, however, could lay no claim to accuracy of details but were sufficient to meet the needs of the time. Rennell also produced "*Map of Hindoostan*" in 1783 after relinquishing the post of Surveyor General.

Till the beginning of the 19th century, the progress of topographical surveys in Madras and Bombay presidencies was more or less independent and uncoordinated with the work of Bengal presidency. This was not a satisfactory situation and retarded the progress considerably. It was only in 1787 that an accurate survey of the seacoast from Madras to southernmost extremity of the peninsula was taken up by running a 300-mile line of triangles along the coast with a view not only to ascertain the actual line of the seacoast but a complete survey of peninsular of India. This survey was the first Indian survey based on triangulation.

Towards the close of 18th century, theodolites now considered primitive had been brought in use. The angles and bearings were measured with theodolite and pocket compass for direction of the road etc. The technique of plane tabling was first used in 1792. Plane tabling survey was subsequently developed into an art and has been extensively used down to present time for topographical surveys in all types of terrain. Even now, though the modern techniques of surveying are coming up, yet this simple technique has been widely used in various surveys such as large-scale mapping, engineering survey, cadastral survey and the like.

The period of piecemeal surveys was over by end of 18th century. A new era of William Lambton and George Everest began that was a coordinated consolidation. The foundation of a truly scientific Survey of India was laid which was the beginning of a stupendous work and occupied the lifetime score of noble and devoted surveyors. A network of primary triangles was established by the trigonometrical surveys. It was a magnificent scheme, timely conceived and brilliantly executed. Although, technique of triangulation, astronomical determination of positioning and azimuths as well as levelling were initiated in mid seventeenth century, but the scientific procedures started only by the end of 18^{th} century when a project for the measurement of an arc of the meridian through a network of trigonometrical surveys covering the Indian peninsula was mooted.

The actual work of the great trigonometrical survey was commenced on 10^{th} April 1802 by the measurement of a baseline near Madras. This baseline was established using steel chain which consists of 40 links of 2 1/2 feet each, measuring in the whole 100 feet. This baseline was measured with the aid of coffers (long boxes) as it was required for the triangulation of the *Great Arc* where utmost possible accuracy was aimed at. From this baseline, measurement of a series of triangles was carried up to the Mysore and the second base was measured near Bangalore in 1804. To start with primary reference station of origin was the Astronomical Observatory at Madras (now Chennai). Having connected the two sides of the peninsula, Lambton devoted much of his labour to the measurement of an *arc of meridian*. The series measured for the purpose is known as the *Great Arc Series*. In addition to the measurements of these series, webs of triangle extended for establishing the positions of main cities. This idea of web of triangles was replaced due to cost effectiveness by an all-India grid composed of criss-crossing ‘chains’ or ‘bars’ of triangles centred on the *Great Arc*. The holes on the grid could be filled later by cheaper and less rigorous topographical surveys. This idea gave birth of the name “grid-iron” (Appendix II).

The *grid-iron* layout consisted generally of an outer frame of two extreme meridional and two longitudinal series closing at each junction on a measured baseline. In order to bring the *Great Arc* across the plains, masonry tower stations were built which were about 50 feet high. The first essentials of every observation station, whether on hilltop or tower, or otherwise was the stability of the instrument and immovability of the mark over which instrument and signals were centred. Since these marks were established after putting hard work, thereafter, they were handed over to the civil authorities when all connections were completed. In 1866, it was ordered that all stations of *Great Trigonometrical Survey* should be placed under the official protection of district magistrates and were visited periodically. This practice is still in vogue till the present time for all primary *Great Theodolite* (GT) stations and benchmarks.

Lambton main instrument referred as the GT which was a marvel workmanship of those days. The horizontal circle was 36 inches in diameter and the vertical circle 18 inches; each was read by two microscopes. This theodolite was used by him and his assistants and then by Everest and others till 1866. Various other theodolites were used for observations for meridional series *viz.* 36-inch theodolite, which was built up from Lambton great theodolite, and 34-inch, 24-inch, 18 inch and 15-inch theodolites. For laying out the series and running secondary and minor triangulations, small theodolites were used *i.e.* 14″, 12″ and 7″. For baseline measurements, compensation bars and other baseline apparatus were used. The compensation bars remained, however, the only means available for measuring the baseline of the main triangulation framework - Vizagapatnam and Cape Comorin base were measured during 1862 to 1869. In 1856 standard yard arrived from England and the following year a special room at Dehra Dun was set aside where subsidiary standard could be laid off or compared by microscope as and when marking of staves for levelling operations required. Standard spirit levels were used during those days.

Triangulation or levelling computation were made to a routinely, adapting rules and formulae of the department. Computation forms were lithographed at Calcutta under the direction of the chief computer. One of the greatest contributions which Radhanath Sickdhar, chief computer, made to the *Great Trigonometrical Survey* was the preparation and publication of a set of tables to be used with departmental formulae, and the computation forms. The first official lists of geographical coordinates were published in 1842; and the first edition, entitled *Tables to facilitate the computation of a Trigonometrical Survey and the Projection of Maps,* was published in 1851. Further, auxiliary tables to facilitate the calculations were published in 1868.

For the dispersal of triangular error, method followed by Everest was tested against new method devised by Gauss. Radhanath Sickdhar first tried two simple figures and obtained results closely agreeing with old method. He tried this on complicated figures that occur in the trigonometrical survey. The results were highly satisfactory, showing that the greatest discrepancy between Gauss's and Everest's methods would not exceed 0.14 arc seconds.

The final distribution of errors and reduction of results of the triangulation of the *Great Trigonometrical Survey* was carried out under the direction of General James Walker whilst he was superintendent of the trigonometrical survey. For this purpose the whole triangulation was divided into five zones – northwest, northeast, southwest, southeast quadrilaterals and the southern trigon.

Lambton and Everest did not go deeply into the subject of heights above sea level. Lambton first connected to the sea at Madras in 1802, but for his great Central Arc he preferred the connection made at Cape Comorin in 1809. From this he brought up his height by vertical angles from station to station. Surveyors in India had no professional interest in the measurement of the vertical rise and fall of tides along the coast except to find the level of the sea from which to calculate their land heights. Lambton followed the practice of his time in calculating his heights from low water. It was only in 1837, when the mean between high and low tide observations for at least for half a month were proved to agree closely from one place to another. Self-registering tide gauges were invented during 1830-33 and was established at Colaba observatory, Bombay (now Mumbai) in 1842. Tide gauges at various other places were also connected through spirit level during 1851 to 1860. Leveling was initiated on scientific lines in 1858. It was General Walker who was the founder of this activity and bestowed upon the subject before he initiated the field work.

Waugh took over in 1843 from Everest and during seventeen years of his administration, triangulation series was advanced eastward to over Ganga valley to Calcutta and extended up to Assam. Regular observations to the Himalayan peaks were taken. He was responsible for the discovery of the highest mountain in the world, 29002 feet above the sea, which he recommended should be named after George Everest who had built up the triangulation system by which the discovery was made possible (C&Q 16).

Regular astronomical observations for azimuth and meridian were continued along both meridional and longitudinal chains of triangles as check against accumulation of errors in different directions. Both, Lambton and Everest, had been well aware that their observations were influenced by visible mountain masses and variation of density. Various other mathematician and geodesists worked on this subject and attracted wide attention suggesting the value of pendulum observations for the determination of variations of gravity and introduced the *theory of compensation or isostacy*.

In the recorded history it has been mentioned that the Indians were being employed for menial jobs, carrying instruments and equipment, clearing obstacles in the line of sight, jungle clearing, erect hill stations and take Instruments and equipment to the tops, sending signals with flags, making measurements with chains and help in spreading baseline. Those who learnt English were tried to act as *munshi* or writer to record details of tours. Precision work of observations was being done by the British officers and their European retinue till 1830. Major George Everest, who later succeeded Colonel William Lambton, introduced a lot of changes in field operations and was a creative and innovative genius and his introduction of compensation bars for measuring bases, heliotrope flashes and lamps for signals for observing stations, method of ray tracing, erecting flag staffs, designing of survey towers and the like were unique but needed more trained Indians to manoeuvre those. Though initially reluctant but started inducting more and more Indians as the work expanded and his faith in them grew. Lord William Bentinck, the Governor General, in 1833 decided to encourage the employment of educated Indians in their service. About this whole operation, Murli Manohar Joshi mentions on the occasion of India Day in London in 2004 (Appendix VIII):

> "One, that the spirit of conscious scientific enquiry is a part of every segment of Indian society and is not limited to those who are fortunate enough to attend a University course in it. That is why we could have a lowly clerk like Ramanujan dedicate his total life to the pursuit of mathematical abstractions. A Radhanath Sikdar who became George Everest's, Chief Computer and without whom the Great Arc could literally not have achieved the heights of Mount Everest. A Syed Mir Mohsin Hussain - a watchmaker who went on to engineer, on his own, the most complex mathematical instruments, some of which are on display here. The *pundits* - Nain Singh and Kishen Singh - ordinary school teachers in a vernacular tradition who became pioneering surveyors and geographers."

Meridional Chains & Arc

The measurement of *Great Arc* from Cape Comorin to Himalayas was completed by 1843. The '*grid iron*' system consists of meridional chains of triangle tied together at upper and lower ends by longitudinal chains. Ambitious scheme of triangulation commenced with the Great Arc Series, having Dehra Dun base at the north and Sironj base in central India as the southern end. From Dehra Dun base northwestern Himalayan series was extended while from Sironj base the Calcutta longitudinal series was extend up to Karachi base. In 1887, observation of a series from north-western Himalayan known as Kashmir series was started. The height of stations averaged 17,000 ft in this series. The second highest peak, next to Mount Everest, was found during this triangulation which was 28,290 ft high and was named K2.

The *Great Trigonometrical Survey Triangulation Network* of India and adjacent countries was started in the year 1802 and by about 1880, several triangulation series had been observed to warrant their simultaneous adjustments. This triangulation network was first adjusted to form a self-consistent whole in 1880. Adjustment of this horizontal network was based on Indian Geodetic Datum. Everest ellipsoid was used as reference surface in India. This surface has been named after Sir George Everest. A reference ellipsoid was defined by various components *viz.* semi-major axis (a), flattening (f) and coordinates *viz* latitude, longitude and deflections of the vertical: meridional and prime vertical, and geoidal undulation at the origin. Everest adopted Kalianpur in the central India as origin. Various components of Everest ellipsoid or spheroid and its orientation at origin worked out in piecemeal manner in various campaigns.

In the year 1937, another adjustment was attempted, incorporating the new triangulation series observed after 1880, the LaPlace stations to control directions and new baselines measured with wires between the year 1930 to 1934 to control the scale of the triangulation series. In this adjustment, instead of resolving the simultaneous normal equations formed after incorporating new data, graphical technique of adjustment was employed. This technique was not considered appropriate, and the adjustments found no practical use. Nevertheless, the adjustment of 1880 has remained the basis of all India triangulation and mapping except for a constant change of –

(2′27″.18) in longitude. The mapping activities were scientifically executed and based on triangulation series adjusted in 1880. Most of the maps were on the scale half inch or larger. This change was essential as longitude of Madras observatory was revised in 1905. One of the objectives of the above enterprise was to prepare an *Atlas of India* to be published by the East India Company. According to the *Scientific Intelligence* journal of 1829 (p. 347) (Q&C 16):

> "This noble work, of itself a splendid monument of the munificence of the East India Company, is upon a scale of four miles to an inch, and takes from actual surveys, which when completed, will for a map of India on one uniform plan. The project was first conceived by Colonel McKenzie, and a large portion of those parts already published were surveyed under his superintendence. The surveys on the northern parts of the peninsula have for their basis the triangulation of Colonel Lambton, who extended a set of principal and secondary triangles over the whole country.
>
> The sheets are published as they are completed; some of them have blank spaces, to be filled up as the surveys proceed; nothing allowed to go forth to the world which is not founded upon actual survey."

Mapping activities opened new possibilities with the introduction of aerial photographs during early years of war. The science of photogrammetry had not developed but their immense value impressed the surveyors. The aerial survey techniques were however not much used in the department up to 1939 except for training for military survey purpose and for survey of inaccessible areas. The primary map scale 1 inch to a mile was adopted in Survey of India in 1905. It was also decided that these maps may be produced in colours and show the relief by rigorous contouring. The requirement of printed maps increased during 1939. The main printing organization at Calcutta (now Kolkata) could not meet the mapping requirement. Therefore, the present site at Dehra Dun was selected and the printing machines were installed and by middle of 1943, the printing group was in operation with three large high-speed machines. At the time of independence (1947) about 60 per cent of the country was covered by primary scale of mapping on 1 inch to 1 mile.

Post-independence Developments

During 1947 onwards, there was an immense increase in the developmental activities which continue in one form or other. SOI was more entrusted with the development schemes considering the post-independence reconstructions priorities. The normal topographic survey became secondary.

During the first and second five-year plan, the department faced with demands for survey which required for more survey potential than it had. During the first five-year plan (1951-56), nearly 70 per cent of the department's potential was employed in developmental surveys and in second five-year plan about 60 per cent potential could be directed for this purpose. The department had diverted workload with the switching over to metric system in 1956, the basic map scale having been changed to 1:50,000 from 1 inch to 1 mile. It was during second five-year plan, when advancement in various techniques of mapping were available and there was pressing demands for maps for the development of the country. Survey of India, keeping pace with modern technologies of surveying and mapping continue to adopt various activities in the field of geodesy and geophysics, topography, photogrammetry, cartography, printing and manpower development.

Map-making has evolved in response to theoretical developments, technological advancements and changes in society's information needs. With the advancement of technology, mapping technology has undergone major changes. Experiments with photography, aerial photography and remote sensing then added new dimensions to the methods of map making and reduce the time involved in the production of a map. Topographic maps were produced using these technologies with ground control points to ensure positional accuracy. However, not all maps were concerned with location of physical features. Thematic mapping expanded rapidly following the introduction of censuses and other surveys which were taking into consideration of extensive demographic and socio-economic data.

The past two decades have seen dramatic changes in cartography due to the development in digital and communication technologies. Earth observation satellites now provide coverage of earth surface at a variety of spatial resolution ranges from few meters to several kilometres. Global

Positioning System (GPS) allow precise determination of horizontal and vertical positions. Computer mapping systems have advanced in the form of Geographical Information System (GIS) which are now widely used in planning, resource management and facilities management applications. Development of desktop mapping technology and internet access to electronic data sets had made powerful map-making technology available to anyone having a personnel computer.

Mapping embraces production of various topographical, engineering, geographical, thematic and earth science and research maps, which are essential tools for planning and developmental activities. Cartographic products have been the base material for planned development, sound administration, national security and military operation, management of natural resources, peaceful coexistence and every facet of nationwide activities. The defence forces, planners and other law and order enforcement agencies, economists, geologist and all other working in creative sciences find a map an indispensable tool.

Large scale maps are being prepared in different parts of the country for developmental projects *viz.* hydroelectric projects, irrigation projects, industries establishments, canal area development, flood plain zoning and other various developmental activities. Tunnel alignments, underground power houses, monitoring geometrical shapes of various structures require accurate determination of coordinates in plan and height which are prerequisite for any such activity. It is imperative to say that cartography and planning must be properly interlinked and have to be dovetailed for scientific developments of a region.

All the developmental activities require prior mapping. The ecological complexities of the environment can be assessed only with periodic preparation of maps of the concerned areas. A topographical map of region depicting its landforms, drainage, coastal features, vegetation, communication and other detailed distributions provides the knowledge of the relationships of various factors necessary to plan and carryout intensive development activities effectively. With sophistication in the field of aviation, communication, meteorology, hydrology, forestry, tourism, urban and rural development, environmental planning and education, the demand for cartographic products have multiplies over the year.

Existing Setup

Survey of India in its assigned role as the nation's principal mapping agency continues to bear a special responsibility to ensure that the country's domain is explored and mapped suitably to provide base maps for expeditious and integrated development; and ensure that all resources contribute their full measure to the progress, prosperity and security of the country for now and for generations to come as well. Further, it continues to function as adviser to the government on all survey matters, *viz* geodesy, photogrammetry, mapping and map reproduction. However, the main duties and responsibilities of SOI have been enumerated below:

- All geodetic control (horizontal and vertical) and geodetic surveys
- All topographical control, surveys and mapping within India.
- Mapping and production of geographical maps and aeronautical charts.
- Surveys for developmental projects.
- Survey of forests, cantonments, large sale city surveys, guide maps and the like.
- Survey and mapping of special maps.
- Spellings of geographical names.
- Demarcation of the external boundaries of the country and advice on the demarcation of inter-state boundaries.
- Training of officers and staff for human resource development within the department, trainees from central or state governments and from other countries.
- Research and development in cartography, printing, geodesy, photogrammetry, topographical surveys and indigenisation.
- Gravity surveys.

Apart from the above responsibilities, it has been entrusted to make predictions of tides at 44 ports including 14 foreign ports; and publication of *Tide Tables* one year in advance in order to support navigational activities.

Organisation Setup

At the time of the beginning of the millennium (2001 AD), SOI had a traditional setup keeping in view of the administrative, technical, and field requirements. There were four zones and 18 directorates out of which seven were specialized directorates. In order to carry out field surveys, there were 58 fields units or '*topo parties*' spread all over the countries and attached to different directorates. Apart from the field data, another source of ground information was aerial photography. Large dependence on this source could be understood by the fact that there were 17 'photo units'. In addition, there have been specialized units in different directorates such as (a) Geodetic & Research Branch, (b) Directorate, Survey Air, and (c) Survey Training Institute. Later, other directorates were added for meeting the requirements of the modern technology. Map printing was a major activity then in the SOI. Such maps were required by the security forces. Hence, it had five printing groups located in Dehra Dun (2), Kolkata, Hyderabad and New Delhi (vide Chapter 6).

Printed Products

As mentioned earlier, the primary role of SOI had been the production of topographical maps (Fig 1.1) at standard scales (Table 1.1):

Scale	Contour interval	No. of sheets
1:250,000	100m/200m in hills	394
1:50,000	10m/20m in hills	5,104
1:25,000	5m/10m in hills	19,540

Table 1.1 *Topographical scales*