Geodesy as a Fundamental Data Set in the Mexican SDI (Idemex)

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Key words: Geodesy, IDEMEX, Reference System, access

SUMMARY

Geodetic data is a fundamental data set in the context of the Spatial Data Infrastructure of Mexico (IDEMEX). A brief historical account of geodesy in Mexico is given, as well as an overview of IDEMEX. Geodetic activities at the National Institute of Statistics, Geography and Informatics (INEGI) are described in terms of types and specific purposes. An account of relatively new developments is presented, meaning the change to a new Geodetic Reference System (ITRF2000, epoch 2004.0 in the GRS80), the establishment of a main network represented by the National Active Geodetic Net conformed by 15 permanent GPS stations evenly distributed along the country and the development of the Passive Network conformed to date by more than 50,000 marks. A brief account on standards is given, namely the National Geodetic System and the National Positional Accuracy Standards. The connection with the IDEMEX is provided through metadata development for geodesy according to standards and through the services provided by the geodetic data bank. As a new policy free access to geodetic data is provided through the Website of INEGI. With these concepts INEGI is trying to provide a rationalization on the use of geodetic data linked to the IDEMEX, reaffirming its fundamental character which has permitted, among other things, the total national topographic mapping coverage at 1:50K scale, as well as letting geodetic data to be totally available and accessible to all users.

SUMARIO

Los datos geodésicos constituyen un conjunto fundamental en el contexto de la Infraestructura de Datos Espaciales de México (IDEMEX). Se hace una corta reseña histórica de la Geodesia en México, así como una breve relación de la IDEMEX. Las actividades geodésicas en el Instituto Nacional de Estadística, Geografía e Informática (INEGI) se describen en términos de sus tipos y propósitos específicos. Se hace una relación de los relativamente nuevos desarrollos; esto es, el cambio a un nuevo sistema de referencia (ITRF2000, época 2004.0 en el GRS80), el establecimiento de una red principal representada por la Red Geodésica Nacional Activa, conformada por 15 estaciones permanentes GPS distribuidas a lo largo del país, y el desarrollo de la Red Pasiva, conformada a la fecha por más de 50,000 marcas. Se hace una breve referencia a los estándares en geodesia, esto es, el Sistema Geodésico Nacional y los Estándares de exactitud Posicional. La conexión con la IDEMEX se da a través del desarrollo de metadatos geodésicos conforme a estándares y mediante los servicios proporcionados por el Banco de Datos Geodésicos. Como una nueva política, se proporciona libre acceso a los datos geodésicos a través del sitio Web del INEGI. Mediante estos conceptos, el INEGI pretende racionalizar el uso de datos geodésicos vinculados con la IDEMEX, reafirmando así su carácter fundamental, lo que ha permitido, entre otras cosas, completar el cubrimiento cartográfico nacional en la escala de 1:50K, así como que los datos estén totalmente disponibles y accesibles a todos los usuarios.

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1. INTRODUCTION

Geodetic Information in its different modalities is accepted to be a fundamental data set as considered in the Spatial Data Infrastructure of Mexico. This is congruent with the characterization of data in the modern conception of geographic or geospatial information along the world, as many organizations upon defining their fundamental or framework data places geodesy in the first place. We may recall a few ideas around the concept of fundamental data as related to all data:

The notion on fundamental data is intuitive. Fundamental (FD) data is a reality in a geospatial information environment, where it is absolutely necessary for the development of cartographic projects, studies and geographic information systems, independently of the presence of other data. Also FD is defined as data which is the core, the common denominator of all geospatial information sets, as well as the minimum required to spatially represent a given theme.

FD has an outstanding place as inherent elements of SDIs which answer and are conform with certain characteristics which have to deal with the several components integrating them, such as metadata, standardization and organization, so becoming critical components.

Geodetic information plays a crucial role in developing all FD data and applications data, as it provides the spatial reference frame to georeference all other spatial data. Geodesy as the first FD provides the main frame and a common system to establish the geographic coordinates of geographic data, providing the means for connecting all geographic features to common, nationally used horizontal and vertical coordinate systems. The physical materialization of geodetic information are monumented geodetic points. These marks include in several cases active Global Positioning System control stations, like those we have in Mexico. The geodetic component of the FD consists of both control stations and related information which includes their identification, geodetic and rectangular coordinates, heights, both orthometric and ellipsoidal, and metadata for each point. The metadata, according to standards, contains descriptive data, positional accuracy, condition, and other pertinent characteristics for that point.

2. A BRIEF HISTORIC ACCOUNT.

Since Geodesy in Mexico has been mainly used from the practical point of view to aid in the elaboration of cartography, most of any historic account refers to the development of mapping with only some specific references to geodesy. It is possible to trace some geodetic information development to the XVIIIth. Century, with increasing data coverage in the following two centuries. For example, beginning 1769 the Corps of Military Engineers of the former colonial New Spain are reported to have performed the first topographic surveys in several places of Mexico; by the second half of the XVIIIth. Century mining activities were considered among the most important and called for surveying and cartographic mapping for the development of mineral resources.

In 1822, following the War of Independence a concern from the young government developed to organize the territory in political and economic terms, so a first Commission was established to elaborate the first General Map of Mexico with no so much success. In 1833 the National Institute of Statistics and Geography was created, becoming in 1839 the Mexican Society of Geography and Statistics, an institution still living, which compiled a Geographic Chart of Mexico. In 1856 a Geographic and Historical Atlas of Mexico was elaborated, which was followed in 1873 by a "Carte du Mexique", a product of the French intervention in Mexico.

In 1877 The Geographic Exploration Commission was created with the responsibility to develop a new General Map of Mexico which was the cartographic forerunner for the following century. Positioning methods resorted to geodetic triangulation, a method which had to be abandoned due to high costs and lack of funds. During the life of the Commission the Mexican part of the measurement of the 98º West longitude meridian going up to Canada was performed. The geodetic control for the map was represented by around 800 stations measured by astro observations through double meridian distances for latitude determination and telegraph signals for longitude. 1899 saw the establishment of the Geodetic Mexican Commission which did not last too much and which in 1912 made the first gravity surveys.

In 1913 an Agreement to unify geodetic systems in North America was signed by the revolutionary Mexican government with the U.S.A and Canada, by which Mexico adopted the reference system which in a few years became the 1927 North American Datum, as well as the Clarke 1866 Ellipsoid as the reference surface. This NAD27 and Ellipsoid were in use in Mexico for almost the rest of the Century.

After these dates and up to 1968 several cartographic organizations were created like the Directorate of Geographic and Climatologic Studies, the Military Geographic Commission, the Intersecretarial Coordination for the Production of the Geographic Chart of the Republic, and so on; many of them short lived and some instituted with a specific purpose within a wider organization like Mexican Railways, Mexican Petroleum (PEMEX), the Federal Commission of Electricity, which by the nature of their activities had to rely on and develop geodetic information.

In the first days of October 1968 the Commission of Studies for the National Territory (CETENAL) was created, with the responsibility to develop the inventory of natural resources and infrastructure of the country through the production of the Topographic Map at the scale of 1:50,000 as well as the corresponding natural resources mapping in the themes of Geology, Soils, Actual Land Use, and Land Use Capability at the same scale. This Commission was the forerunner of the actual Directorate of Geography (DGG by its initials in Spanish) at INEGI and the official main organization dealing with the generation of geodetic information at the national level.

3. THE IDEMEX

Growing influence of geospatial information has increased the demands for opportune, congruent, of quality, accessible and shared information useful for everybody. The National Institute of Statistics, Geography and Informatics (INEGI) of Mexico has been developing the idea of a national SDI within the concepts contained in the Statistical and Geographic Information Law which regulates the national information in these matters and defines as the fundamental objective the integration and development of the National Geographic Information System (SNIG by its initials in Spanish), and along with this objective, the prime seed of the National Spatial Data Infrastructure of Mexico, IDEMEX.

In this context producers and users of geospatial information have pointed out the need to coordinate efforts, work together, generate and apply agreed standards, avoid duplicities, rationalize the production, facilitate access to all interested people, and summing up, to manage the mexican geospatial information in better ways.

In February 2003 INEGI organized the National Geography 2003 Convention where the main and governing subject was the IDEMEX. It was agreed during this Convention that it is necessary to foster the communication and interchange of ideas and experiences among geospatial information producers and users and to strengthen ties among organizations. Later on, a First Shop on the IDEMEX was organized, in which subjects on Standards, National Geographic Frame, Fundamental Data and Access and Dissemination of Geospatial Information were discussed.

For the integration and development of the SNIG, the Law indicates the establishment of Technical Committees and the elaboration of the National Development Geographic Information Program. The Consultative Technical Committee on Geographic Information has the function to orient and define priorities for the execution of the Program, which is the basic instance for the ordering and regulation of national geographic productive activities, establishing priorities and putting objectives and goals in proper order. In its conceptual aspects the Program holds specific considerations on the IDEMEX.

At INEGI several steps have been taken contributing to the IDEMEX, which go from the continuous production of geographic information, to the incorporation of the most modern technologies, concepts development on fundamental data, metadata generation, establishment and operation of a Clearinghouse and Gateway, the development of a program on generation and updating of geospatial standards, the conception and present development of the Geographic Database, the building of important alliances and links to other national, regional and worldwide organizations, as well as other actions as related to the implementation of the IDEMEX.

3.1 Fundamental Data

Fundamental Data as every body knows is that data for which there is a basic necessity, having different degrees of coverage; they are sets of geospatial data which constitute the foundation for the production of added value information, applications development and the acquisition of other data; they are those data required by the great majority of users, having a widespread usability, constitute the building blocks of any SDI, should be widely accessible and should be created and distributed under accepted standards.

Te notion about fundamental data is intuitive; fundamental data is a reality in a geospatial information environment, which results absolutely necessary and essential for geographic projects development, studies and geographic information systems. Consequently, Fundamental Data are those data without which it is impossible to construct logical, consistent, accurate, rational and interchangeable geographic information buildings

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The fundamental data set should include all geospatial data required for the conformation of any SDI. It must be realized that while applications of geospatial data are very ample, most users have a recurring need of just a few types of data. However in several instances these needs are not quite satisfied mostly because data is not known, nor their characteristics and access facilities and distribution.

Categories of Fundamental Data are rather limited and include only a few items. In the case of Mexico we talk about groups of data, so the categories of Fundamental Data within the IDEMEX comprise the next groups:

- Group on geodetic references,
- Group on aerial photography and satellite imagery,
- Group on data about relief, including DEMs,
- Group on Hydrographic nets,
- Group on communications and planimetric features
- Group on international, state and municipal, including, coastal boundaries,
- Group on Cadastral data,
- Group on Geographic Names data.

Geodesy holds the first position, so recognizing its most important role in the development of geospatial information as the means to geographically reference any feature. This is most congruent with the notion of Geospatial Data as any data characterized for having a place in the space and described by a set of attributes. The first part of this definition is only possible through subjecting geospatial data to a geodetic positioning process, either directly by geodetic surveys or through indirect means which have been previously defined by geodetic surveys and photogrammetric processes, i.e. a topographic map or chart. This may be traced to early times when formal map making was only possible by resorting to baseline and astrogeodetic measurements, triangulation and plane table or detail surveys, so geodetic referencing has been fundamental since then.

4. GEODESY AT INEGI.

The geodetic activities at INEGI are performed through three different types of surveys comprising the whole spectrum of geodesy, namely:

- Horizontal surveys
- Vertical surveys,
- Gravity surveys

4.1 Horizontal Surveys

These surveys developed through 2 stages, as follows:
A First stage beginning 1968 when the actual Directorate of Geography was established, characterized by geodetic surveys using traditional equipment and the former methodologies of triangulation, trilateration, traversing, astro observations, Laplace azimuths and inertial and Doppler positioning. These surveys were initially performed by contractors with some supervision from the Secretariat of Defense personnel and later on by internally organizing field parties after proper training. At that time the Datum was the NAD27 in the 1866 Clarke Ellipsoid. Around 7,500 horizontal stations were established. This stage lasted up to 1990 when the Global Positioning System (GPS) was adopted.

The second stage is characterized up to these times by using the GPS survey technology, which began by observing some points of the former geodetic net for comparison purposes and later on by establishing some stations to initiate the establishment of the new geodetic nets which will be discussed in a more detail later on in this paper.

In this second stage the objective was set to establish horizontal geodetic stations with GPS equipment under proper accuracy standards to support the development of several projects, including:
Airborne GPS surveys,
- Support to LIDAR surveys,
- Topographic and cadastre mapping support,
- Development of baselines for Economical Exclusive Zone delimitation,
- Urban positioning surveys,
- Surveys to develop a greater density of stations,
- International Boundaries support surveys,
- Information services to users.

4.2 Vertical Surveys

The main objective of these surveys is to establish, increase coverage and maintain the national first order and lower orders geodetic vertical net to support the development of the several topographic and mapping projects, special national projects, help determine a geoidal model and provide with information on heights to users requiring it. Geodetic leveling started in 1950 through a collaborative effort from the Military Cartographic Department and the

Interamerican Geodetic Survey (IAGS) to do high precision leveling along the country and afterwards through an agreement between the IAGS and the National University of Mexico. A second stage began with CETENAL when control of first order leveling was assumed by this organization, which is operating at the time through the General Directorate of Geography at INEGI using the North American 1988 Vertical Datum (NAVD88). At the present time the net has more than 38,000 bench marks. A view of the geodetic leveling net in Mexico can be appreciated in figure 1.

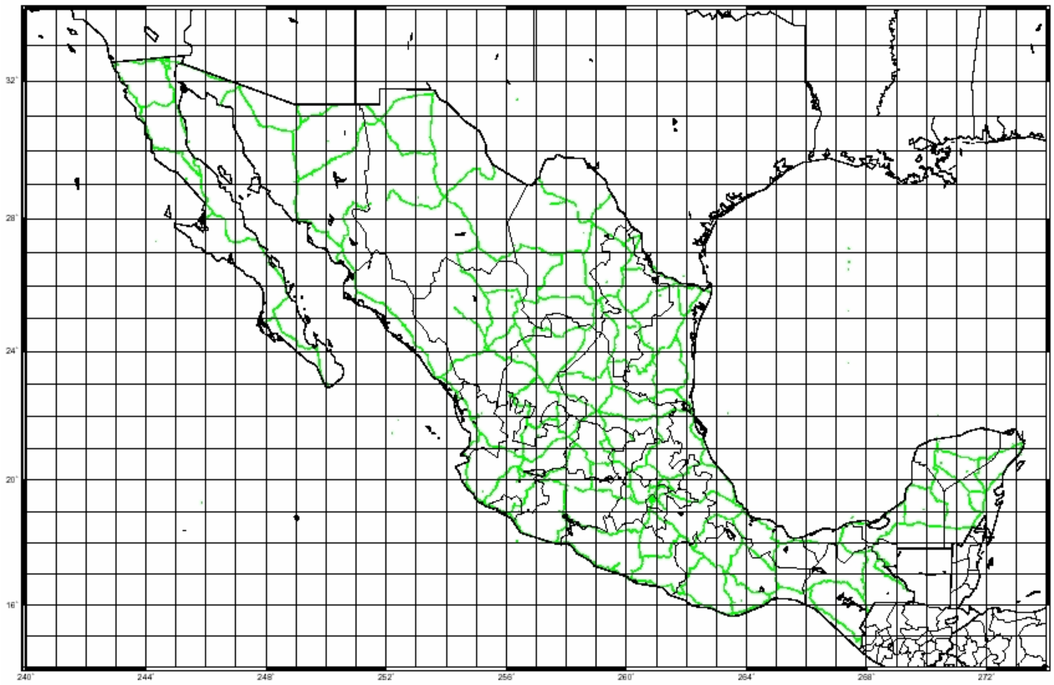

Figure 1: The Mexican Vertical Net

4.3 Gravity Surveys

The DGG began making gravity measurements in the 80´s with the aid of equipment loaned by the IAGS. The objective was to develop the Gravity Mexican Net with the main purpose of providing data to support the development of the Geoid and provide information to agencies and users requiring gravity data. At this time DGG has its own equipment and works on a yearly systematic program of gravity surveys along the country. Figure 2 shows the density of gravity coverage in Mexico to date, with more than 43,000 measured marks. Any point belonging to a gravity survey of geodetic scope must be referred to the Gravity International Standardization Net of 1971 (IGSN71), to which Mexico belongs.

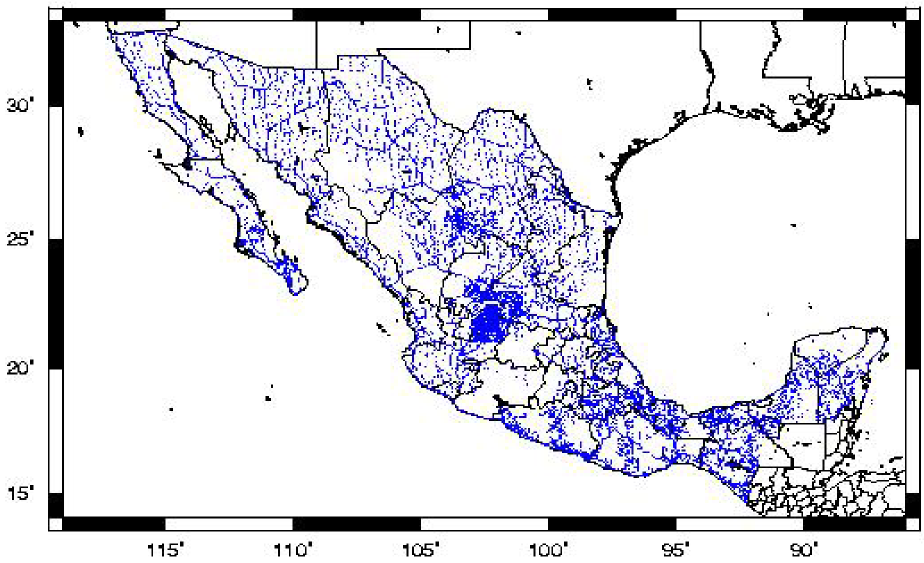

Figure 2: Gravity data density coverage

5. RECENT DEVELOPMENTS.

5.1 A New Geodetic Reference System

Beginning the 90´s the necessity was detected to establish a new geodetic reference system better than the NAD27. The alternatives were to choose between NAD-83, WGS-84, and the ITRF. After some considerations it was decided that the best option for Mexico was to adopt the ITRF as the new Geodetic Reference System. The conditions were appropriate; there was already a new environment of digital cartographic production and the incorporation of a good amount of GPS equipment to support geographic information production, especially the Rural Cadastre Project which called for a higher accuracy than could be achieved by traditional means.

In this context a decision was taken to change to the ITRF92, Epoch 1988.0 in the GRS80 as the Official Geodetic Reference Datum for Mexico. Recently a new change developed to go to the ITRF2000, epoch 2004.0 in the same ellipsoid, taking into consideration the now more close compatibility of the WGS84 with this new approach and the fact that from the practical, cartographic, point of view, no significant differences will arise regarding the former ITRF92.

The above is linked with the SIRGAS project (Geocentric Reference System for the Americas). This project was established in October 1993 with the purpose to work towards the definition of a Geocentric Reference System for South America. In later times the coverage was increased to the rest of America. The development of the project comprises the necessary activities to adopt in the Continent a reference system compatible with actual positioning techniques, especially those associated to the GPS, as well as the adoption of the

International Terrestrial Reference System (ITRS), through an International Reference Frame (ITRF2000, epoch 2004.0 in the GRS80)**.** This will eventually allow for and guarantee a consistent integration with the geodetic nets of other continents, contributing so to the development of a global geodesy.

The SIRGAS, to which Mexico is adhered, is a project of continental scope which has significant advances to date, is conceived to be used as a geodetic reference base to help build the Spatial Data Infrastructure of the American Continent and as seen in this paper, is totally compatible with the reference system adopted by Mexico.

5.2 The National Active Geodetic Net (RGNA by its initials in Spanish)

Closely connected with the new Reference System a new geodetic horizontal net was established through the National Active Geodetic Net and the corresponding passive net. The RGNA is a set of 15 fixed and permanently operating GPS stations distributed along the country (figure 3), which has the following characteristics:

To establish these stations the National Geodetic Survey of the USA (NGS) collaborated with Mexico. Connections to VLBI stations were made to reach the maximum possible accuracy. The stations, established in the 5 cm. accuracy positional standard, are located so any point in the country is covered by at least two stations to a distance of no more than 500 km. The stations register in a permanent fashion the information transmitted by the NAVSTAR constellation integrating the space sector of the Global Positioning System. Products of the RGNA are files with observations for each station, giving the coordinates in the adopted reference system, latitude, longitude and ellipsoidal height.

The stations are considered as fiducially and monitoring stations aimed to the definition in position of the national territory, detection and registry of changes associated to the reference system, as a basis for the development of the National Passive Geodetic Net, and as support to users which need to connect and reference their surveys to the National Geodetic System. In this context, the RGNA is the national fundamental reference frame for all geodetic positioning surveys performed along the country. This net is supposed to grow in number as other agencies establish permanent stations and agree to integrate.

5.3 The National Passive Geodetic Net (RGNP by its initials in Spanish)

The National Passive Geodetic Net is composed by more than 50,000 points distributed all over the national territory with the common denomination of “GPS points” as all of them have been measured through this technology. Its main characteristics are as follows:

All of these are physical marks represented by monuments of parts of solid structures with a metal embedded plate identifying the precise location of the point. The horizontal coordinates defining the position of each station were generated through GPS measurements linked to the RGNA, which specifies position values referred to the adopted geodetic Reference System. Figure 4 shows to date the general density of coverage of this Passive Net.

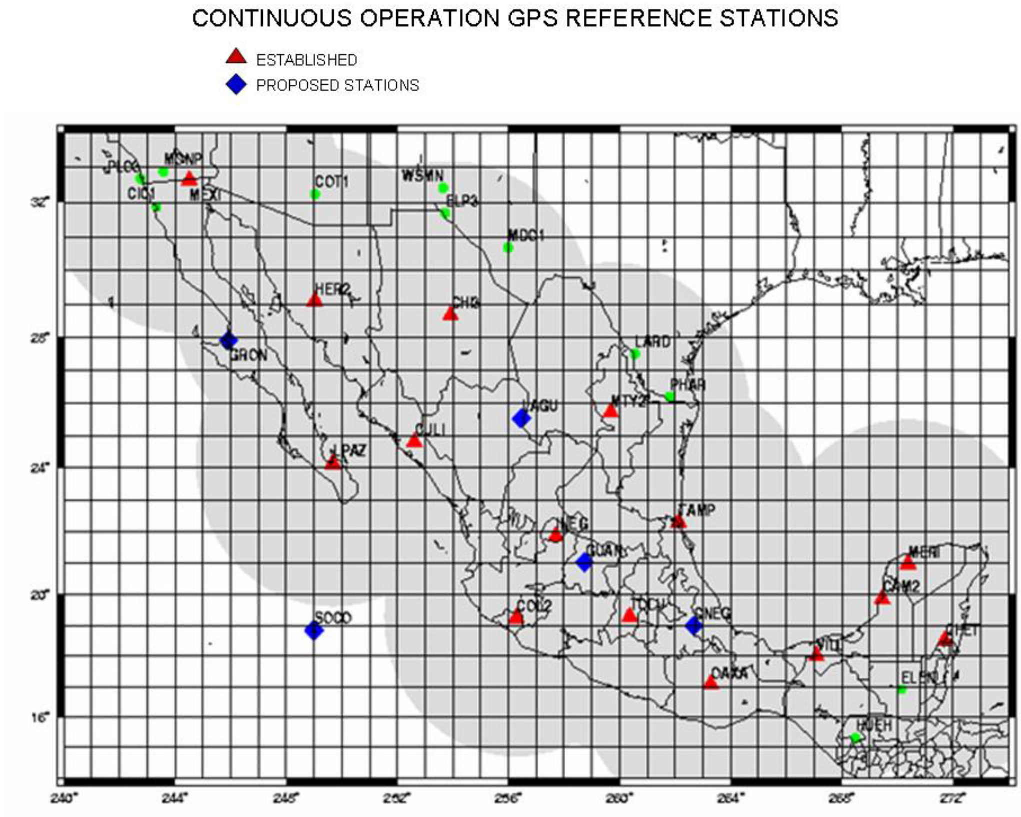

Figure 3: The National Geodetic Active Net

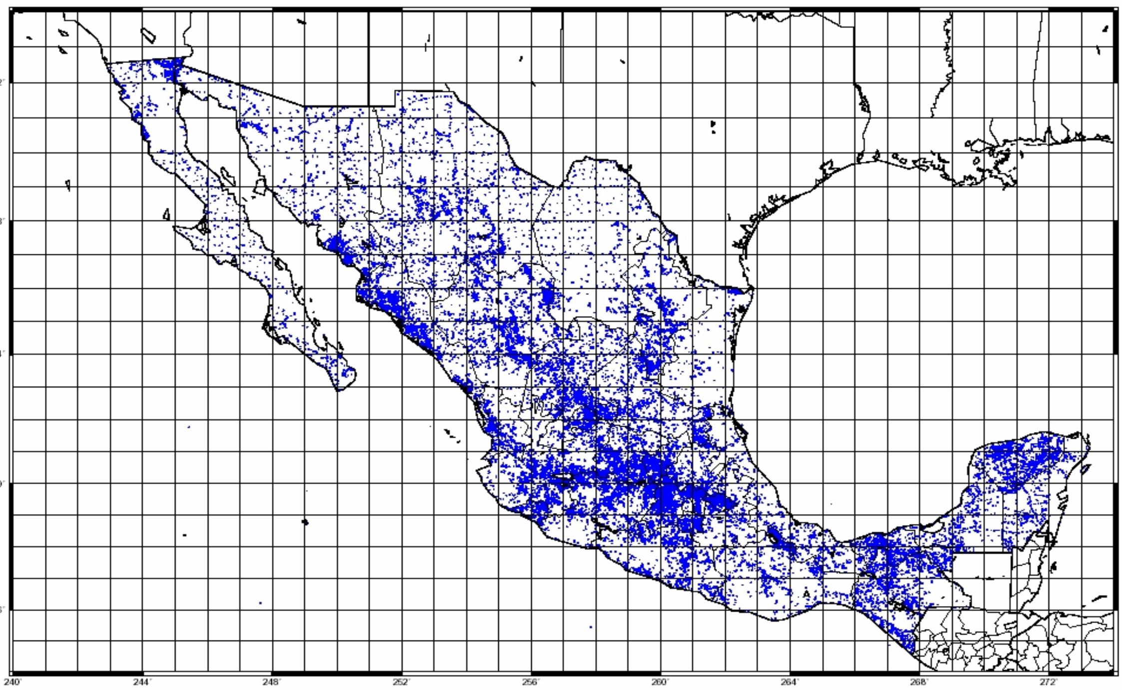

Figure 4: Density of the Mexican Geodetic Passive Net

6. GEODETIC SANDARDS

Standards are a key component of the IDEMEX. Through a recent reorganization of DGG a full working area was established to deal with this initiative and within it there is another area devoted to standards through a program named PRODENOR, meaning the Normative Development Program in operation at this moment at the institutional level of INEGI, with extensions to provide for the national level in the context of the IDEMEX.

As early as 1985 a first effort to develop geodetic standards was undertaken at DGG, which resulted in a document labeled as "Minimal Standards Frame for Geodetic Surveying" which at the time covered most of the then prevailing technology, that is, triangulation, trilaterion, traversing, astronomic observations, Doppler technology, geodetic leveling and gravity surveys. These standards covered both numerical specifications and basic procedures to reach those specifications. The document was officially published and became a standard for all agencies within the federal government dealing with geodetic information. It was also recommended to be observed by other government institutions at the state level and both the academy and private sectors.

Though at that time the concept of Fundamental Data had not developed, it is necessary to recognize it was an underlying idea. That is why Geodetic Information as well as Air Photography were the first subjects selected for standardization; that is, considering them to be the most important ones for any geographic information development effort.

These first standards were in force up to 1998 when a reform was made in terms of putting aside and deleting most of the procedures and also under the consideration of the advent of the new GPS technology which sent to the obsolescence level all former horizontal geodetic surveying techniques. It was also the time when the ITRF92, Epoch 1988.0 and the GRS80 were formally legalized, though the change to a new reference system had been operable since 1993.

In 2003 a new change took place within the frame of PRODENOR, meaning the development of two standards; the National Geodetic System, and the Positional Accuracy Standards. At the time of writing this paper both standards have been subjected to the scrutiny and opinion of the Technical Consultative Committee on Geographic Information mentioned early in this paper when talking about the IDEMEX. Corrections were suggested and in a short time both documents will be legalized , distributed and put in the website of INEGI.

The Geodetic Standards are explicitly declared to be part of the IDEMEX and are also considered to be inscribed in the Fundamental Data Group on Geodetic references.

6.1 The National Geodetic System.

This standard defines the three modes of geodetic surveys (horizontal, vertical and gravity), establishes the GRS80 as the reference ellipsoid and gives its parameters; defines the Horizontal Geodetic System and establishes the ITRF2000, epoch 2004.0 in the GRS80 as the official geodetic reference system for Mexico within the IDEMEX, defines both the RGNA and the RGNP and also establishes the basic standards for the vertical and gravity systems.

6.2 The Positional Accuracy Standards

These standards have the main purpose to establish the orders of positional accuracy which should be observed for any geographic referencing work done over features lying on or near the surface of the Earth. Taking into consideration the actual fast growth and changes on geodetic positioning, references regarding instrumentation and procedures to attain these standards are not included in the document. In this context the intention is to give the members of the geodetic community and other users of geographic referencing techniques the positional accuracy standards for three dimensional surveys within the frame of the RGNA. The idea is to norm on the product, on the “what” and not on the “how”. Similarly, the purpose is also to have and use accuracy standards similar to those adopted in other countries in order to promote compatibility among surveys performed on the national and international level.

The development of the GPS technology initially devised for navigation purposes and then experiencing an accelerated adoption for high accuracy position determinations, have modified the capacity to reach accuracies on positions up to a level of a few centimeters within the frame of the new reference system and the RGNA.

The standard specifies the different orders of accuracy for horizontal surveys to be evaluated through the Circle of Probable Error (CEP for its initials in Spanish) in the 95% confidence level, from the most accurate order of 1 centimeter, up to an order of 500 meters, along with established or would be applications for each one. In a similar fashion is treated the vertical component by establishing the standards for geodetic leveling and the corresponding applications for each order. The standard includes considerations for GPS determined heights.

7. GEODETIC INFORMATION SERVICES.

From the very beginning the information about the three geodetic nets has been available to other organizations and the general public. This called for the organization of a Geodetic Data Bank which provided for information through station descriptions and coordinates to any user, subjected to a small cost to cover for copying and administration services.

Taking into due consideration that the IDEMEX requires to develop a policy to grant access and provide for dissemination and proper distribution of geographic information, by the middle of 2003 a directive was issued to put all geodetic information in the website of INEGI, with no cost to any interested user and without any strings attached. This is under compliance at the present time and represents a policy for free sharing of information as an initiative from INEGI which we hope will be followed by other organizations in the federal government. In this fashion there is the establishment of a formal connection between geodetic information and the IDEMEX. The above includes information services on the Web provided to the users of the RGNA at no cost where all pertaining information is included for each one of the 15 stations for the last 90 days of operation. The only requisite is to register as user.

The provision of geodetic information on the RGNP through the Web as a service to users, either directly or through the Clearinghouse of INEGI requires such information to be dully documented. In this context there is a decision taken to develop metadata for geodetic information which at the time of writing this paper is under conceptual development. Metadata production is already an operation dedicated to document what are known as the Basic Digital Geographic Products, that is, Topographic Maps, Orthophotos, Digital Elevation Models and Geographic Names, under the FGDC Metadata Standard. Consideration is being given to keep using this Standard for geodetic information, or to follow the 19115 ISO/TC211 Metadata Standard, or even to develop our own standard on the basis of the existing ones. The idea includes the incorporation of this information in the Geographic Data Base of INEGI, now under development.

8. CONCLUSION.

With the concepts as exposed in this paper we are at INEGI working towards a rationalization of geodetic data and information closely connected to the IDEMEX, reaffirming its character as a fundamental most important data set which has permitted as a principal outcome in Mexico the total national topographic mapping coverage at the 1:50,000 scale and now to support the new project of topographic mapping in the new 1:20,000 scale. As stated in this paper geodetic data is totally available and accessible to all interested users at no cost and without any strings attached, favoring with this approach the sharing of information. All of this is closely related to the purposes and objectives of the Mexican Spatial Data Infrastructure, in general conformance with the overall concept of SDI.

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