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A Case Study of the Development and Optimization of Geothermal Information Systems in Tianjin

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ABSTRACT

The development of geothermal resources has been applied in various fields more frequently than ever in last 40 years in Tianjin. In heating, tapping water, and further applications from domestic water to agricultural irrigation, more than 500 geothermal resources facilities have been installed, along with an amount of the geothermal flowrate close to 4000×104m3. While the demand for geothermal energy has been rapidly increased and the geothermal utilization become more sophisticated, numbers of difficulties in conventional methods of monitor in field have been revealed. The manual procedure of monitoring has implied several issues, for example, the instability of measurements, short service life of devices, and inappropriate operation. In addition to the drawbacks caused by manual monitor, the extended procedures that are required for those developed facilities, and the increased amount of data collected all result in a very challenging question which is asking for an optimal solution that can contributes to the modern monitoring system. This paper introduces a geothermal resources development and management project in Dongli Lake area, Tianjin. Since 2006, a set of automatic geothermal monitoring systems that are designed for measurement of the water level and flowrate have been installed and tested in numbers of wells across the Dongli area. The goal of the project is to unify and establish a geothermal information system for the lake area that is able to centralize well information, drilling status, reservoir monitoring parameters, information of space heating stations, etc. By developing database systems, the information system can realize a quick collection and transmission of data, live monitoring of stations and process flow, and conduct models for real time calculation. While the essential data and timely reports are provided by the project, users are therefore able to perform decision-making more efficiently and improve the management into a macroscopic level.

1. INTRODUCTION

Tianjin contains plenty of geothermal resources ranged from mid to low temperature, with the highest temperature of 96 C and 4 km as the mining depth. Using the standard of geothermal gradient of larger than 3.5 per 100 meter, 10 abnormal geothermal districts are found, while later the partition of three large geothermal fields and six geothermal reservoirs is set, spreading across an area of 8700 km2. Geothermal energy is widely used in heating, bathing, domestic water and other uses in industry and agriculture in Tianjin. Till 2015, these are in total of 511 registered geothermal wells in Tianjin, among which 375 are mining wells and 136 are recharge wells. The total amount of geothermal energy mining is 38 million cubic meters.

2. GENERAL STRUCTURE OF GEOTHERMAL INFORMATION SYSTEM

The current geothermal information system in Tianjin is designed using SQL Server 2005 and above, ArcGIS, 3D visualization and remote GPRS techniques. It is developed with PB, VB languages, and it operates on Windows 2003 server series, and supports Windows 2000, Windows XP, Windows Vista and other products based on NT technique. It can also be performed on SQL server, MS Office 2000 and other database system.

2.1 Geothermal resources database, the Tianjin urban geological information system as a standard, the main contents are: geothermal borehole basic information, geothermal well dynamic data, water quality information, mining statistics, thermal reservoir analysis, pumping test data, Description, density corresponding to temperature data, logging data and logging well pressure data.

2.2 Geothermal well remote monitoring system: The geothermal well remote monitoring data management center uses the GPRS master station, remotely uses the GPRS sub-station, applies for the APN special network to the mobile company, and binds the fixed IP on the SIM card which the GPRS module uses, The GPRS data transmission module of the system master station and the built-in GPRS data communication module of each monitoring terminal can access the APN private network so as to realize bidirectional communication of the data between the monitoring center and the on-site monitoring and control terminal so as to realize the water level, temperature and flow rate real-time monitoring.

2.3 geothermal resources information system: geothermal resources evaluation and early warning management model, with geothermal drilling data, spatial data and attribute data for information management, query statistical analysis, report generation and output functions, and according to the relevant spatial data, the establishment of geological model , Resource evaluation and early warning analysis.

2.4 Geothermal resources Internet publishing system: According to the network database and related configuration, automatically generate external publishing pages to meet the relevant technical and management personnel to keep abreast of geothermal data related to information and dynamic changes, with query, statistics, generate reports and download basic functions.

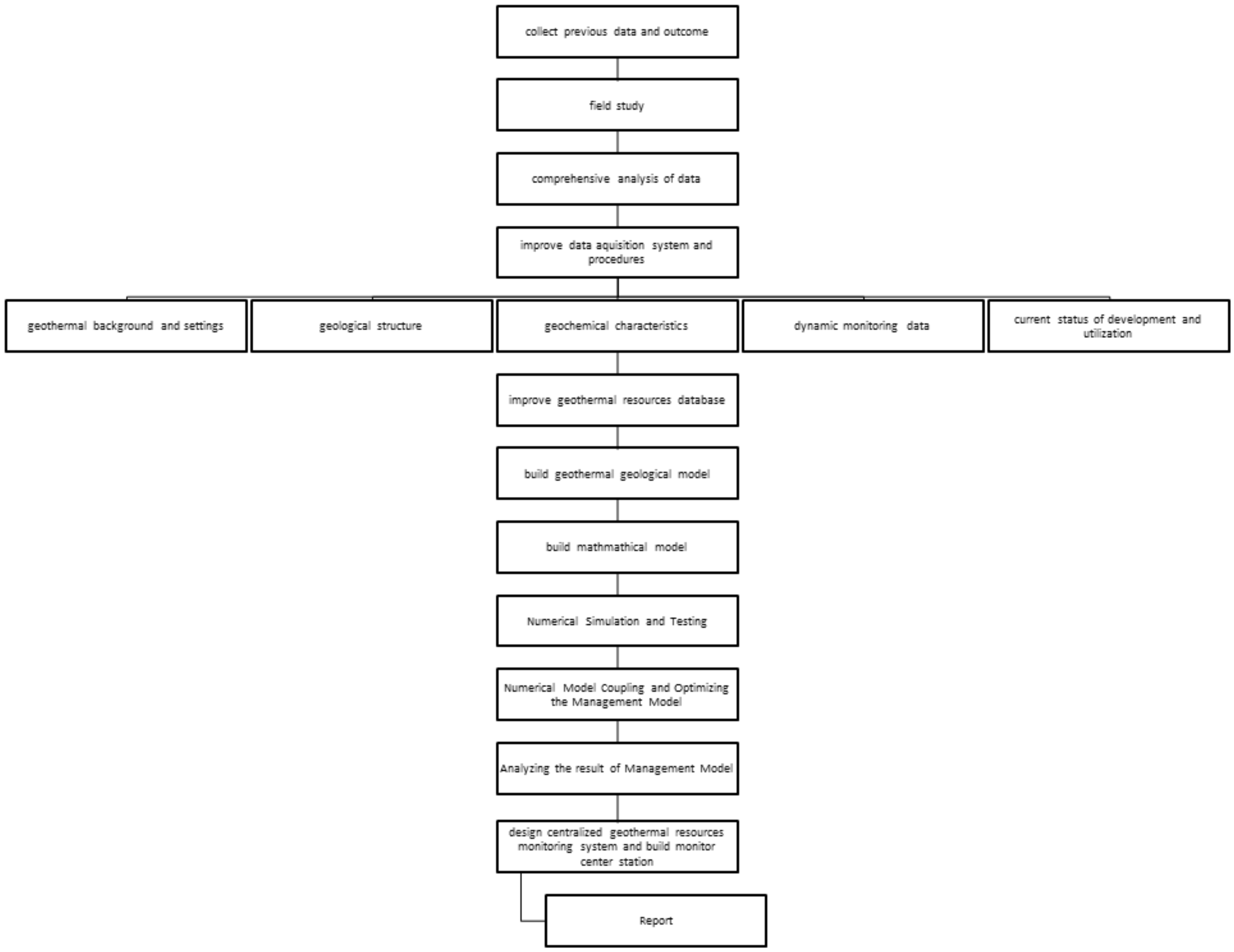

Figure 1: Overall Diagram of System Framework

Programming also uses ADO technology, that is, Active Data Objects (Active Data Objects): Actually is to provide access to various types of data connection mechanism. ADO through the ODBC (Open Database Connectivity Standard) method connected with the database interface. Users can use any ODBC data source. That is not only suitable for SQL Server, Oracle, Access and other database applications, but also for Excel forms, text files, graphics files and unformatted data files.

3. DATA INFORMATION MANAGEMENT SUBSYSTEM

3.1 database structure design

The database is based on Tianjin 3-D Geo-Information System Database. On this basis, the KC value table corresponding to the ionic strength and the corresponding KC value table for the total solids are mainly used to automatically calculate the corrosive / fouling function. Geothermal resources database structure table shown in Table 1.

3.2 Spatial Data

As the main basis of geographic map information; as the focus of system management, in accordance with the National Geological Survey Bureau standards and guidelines for the construction of spatial databases, the standardization of spatial data processing, given a variety of map layer coding and division programs, To ensure data versatility.

The vector graphics are mainly dependent on the input of the scanner, and the vectorization tool provided by the ArcGIS system is used for vectorization. The existing input results, through the necessary data format conversion added to the graphics library. Graphics library is composed of various types of layers, the graphics library through the target attribute keywords and database connection.

3.3 thematic map spatial database

In order to facilitate the professional inquiries, to build a thematic gallery. Thematic maps include geography, basic geology, geothermal geology, geothermal development status, geothermal resources and geothermal resources development and utilization planning and so on. Geothermal development of the current map is in accordance with the heat reservoir and the year were prepared, added to the thematic map spatial database.

Index	Datasets	Properties
1	Basic Information on Geothermal Wells	Primary Table
2	Basic Information on Geothermal Borehole Modeling	Primary Table
3	Information on Bore Strata	Auxiliary Table
4	Well Exploitation Yield	Auxiliary Table
5	Reinjection Quantity	Auxiliary Table
6	Water Level Status	Auxiliary Table
7	Well Water Quality	Auxiliary Table
8	Introduction to Development and Utilization Status	Auxiliary Table
9	Ionic Strength corresponding to Kc Value Table	Auxiliary Table
10	Total Solid corresponding to Kc Value Table	Auxiliary Table

Table 1: Gerthermal Resources Database Structure

Geothermal geology topics include borehole histogram, thermal reservoir map, thermal reservoir geological profile, geothermal gradient map, groundwater temperature 25 ℃ and 45 lC contour map of the aquifer roof depth; groundwater development topics include Water level, water level decline rate and other content contour map of the development and utilization of geothermal resources; geothermal resources, including water prediction topics include water quality, land subsidence forecast.

4. RESOURCE EVALUATION AND EARLY WARNING MANAGEMENT MODEL SUBSYSTEM SYSTEM

Resource evaluation and early warning management model subsystem is mainly obtained from the database data, combined with GIS-related functions and mathematical model analysis results obtained data.

For example, the lumped parameter model of thermal storage resource evaluation is one of the modules used for thermal reservoir pressure simulation prediction. The model is automatically divided into three-dimensional blocks according to the thermal storage conditions, and then, according to the interconnection and storage properties, Heat storage pressure and mining potential for accurate prediction and calculation.

Lumped parameter model thermal reservoir pressure prediction

The system also implements a pumping simulation module which will calculate the relationship between water volume and drawdown in the pumping test and generate a Q-S map to evaluate the geothermal geological conditions or recharge effect. The Monte Carlo volume method is used to calculate the energy stored in the heterogeneous thermal reservoir, and the results are calculated by the probabilistic method. The results show that the heat storage volume method can be used to calculate the heat storage volume. Histogram representation.

4.1 Statistical analysis model

In addition to using international thermal storage method to calculate the amount of resources, the system uses correlation analysis, regression analysis, cluster analysis, nonlinear iteration, multivariate statistical analysis and other methods, for a large number of geothermal geological data, such as stratum structure, And thickness, cap rock lithology, geothermal gradient, geothermal well development and utilization data, classification statistics. According to different regions, the data are classified and summarized and simulated forecasts, in the form of charts to be displayed.

4.1.1 Regression analysis method

The linear regression, univariate nonlinear regression and multivariate regression are used to predict the water level. According to the size of the correlation coefficient, the corresponding equation is selected for forecasting, and the multi-point batch processing is carried out to form contour map. The model is based on the single parameter regression model.

4.1.2 Gray system theory prediction method

The GM (1, N) model in the gray system theory is used to forecast the water level and forecast the land subsidence. The GM (1, N) model is a first-order linear dynamic model of n sequences. It is mainly used for state analysis. The model can reflect the influence of n-1 variables on the first derivative of a variable. The GM (1,1) gray prediction model is embedded in the central data analysis and management system using the PB program development software. The model is fully compatible (Figure. 2).

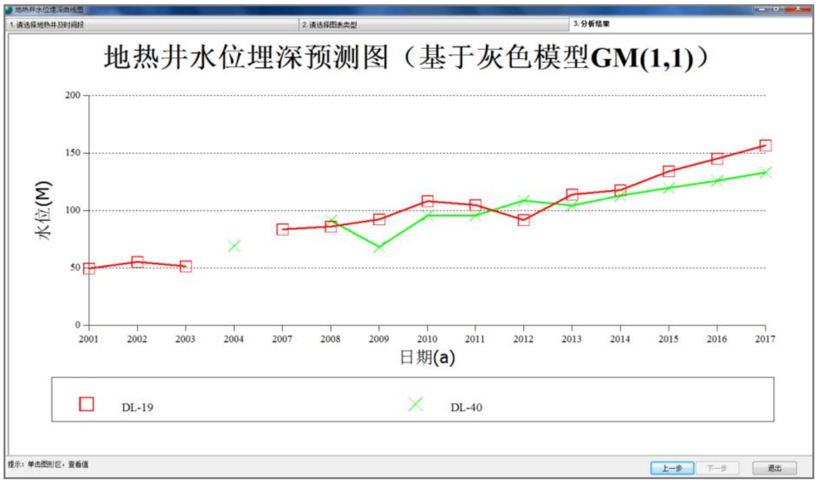

Figure 2: The Prediction Graph (Title: Predicted Water Depth of Geothermal Wells; Y-axis：Water Level(meter); X-axis: Date(annual))

4.2 Comprehensive evaluation model based on GIS spatial analysis

Using GIS spatial analysis functions, such as superposition model and digital elevation model, single factor evaluation can be carried out on single factor target layer, and multi-factor superposition can be used to evaluate groundwater environmental quality and engineering geology , Geological hazard evaluation and many other aspects.

Its idea is to participate in the evaluation of single-element layer, according to the rules of the grid division of the different layers in accordance with its importance to different weight coefficients, obtained for each layer of each unit sub-index, and then use Rule network superposition analysis model to get the unit comprehensive index, the comprehensive index of the final formation of a comprehensive evaluation layer. The computational steps include the rule grid generation, single factor evaluation, AHP to determine the weight coefficient, comprehensive evaluation and so on.

4.3 Water quality assessment model

The system provides comprehensive index superposition, fuzzy comprehensive evaluation, BP neural network and other methods for the evaluation of domestic water. With reference to the industrial use of corrosion coefficient to measure the corrosion of geothermal water, with the total amount of boiler scale to measure the scale of geothermal water for industrial water evaluation. Evaluation of irrigation water using irrigation.

Firstly, the water quality evaluation table is set up in the database, the water quality data is input, the evaluation coefficient and the evaluation result field are set up respectively. The method of updating the query is used to compute the formula and update the evaluation coefficient and evaluation result. In the information system platform can query and browse the evaluation results.

4.4 Resource evaluation and early warning model

In order to alleviate the downward trend of thermal reservoir water level, it is necessary to develop and utilize geothermal resources in a scientific and rational way, and balance the relationship between the development and protection of geothermal reservoirs in Tianjin area in order to reduce the water level burial depth and heat reservoir pressure. The use of geothermal resources development and utilization of early warning system to assist decision-makers to make decisions, combined with the overall planning of mineral resources and geothermal resources development and utilization of long-term planning, so that limited resources not only serve the market economy construction, and sustainable development and utilization.

How the early warning system works:

(1) Extraction of geothermal borehole water, water level, water quality, water temperature, sedimentation rate and other relevant data from the database.

(2) The Kriging method is used to mesh the base map of Tianjin.

(3) According to different evaluation factors (extraction volume, water level, sedimentation rate, water quality, etc.), in the network diagram to draw the various elements of the evaluation map.

(4) Comprehensive evaluation of each factor evaluation factor map, according to the risk ratio of each element evaluation map overlay, and then compare the warning degree of conclusion.

5. CONSTRUCTION OF 3D GEOTHERMAL GEOLOGICAL MODEL

In 2016, based on the geological survey of Tianjin bedrock and the evaluation of regional crustal stability, three-dimensional geothermal geology model was established by SKUA software.

By using multi - source data constraint, such as geologic zoning map + profile + drilling, the model is constructed as a whole structure, and the modeling method of partition modeling and human - computer interaction is used synthetically. The method is as follows: firstly, the structure is constrained by the structure, and the strata contents are filled up. The depth information is controlled by the depth information of the stratigraphic interface map between upper and lower adjacent layers, and the distribution of the lateral strata is controlled by plane partition map information. And then the 3D model of the whole area is completed by using the profile and drilling data to refine the modeling, processing and verification of the relevant horizons (Figure 3).

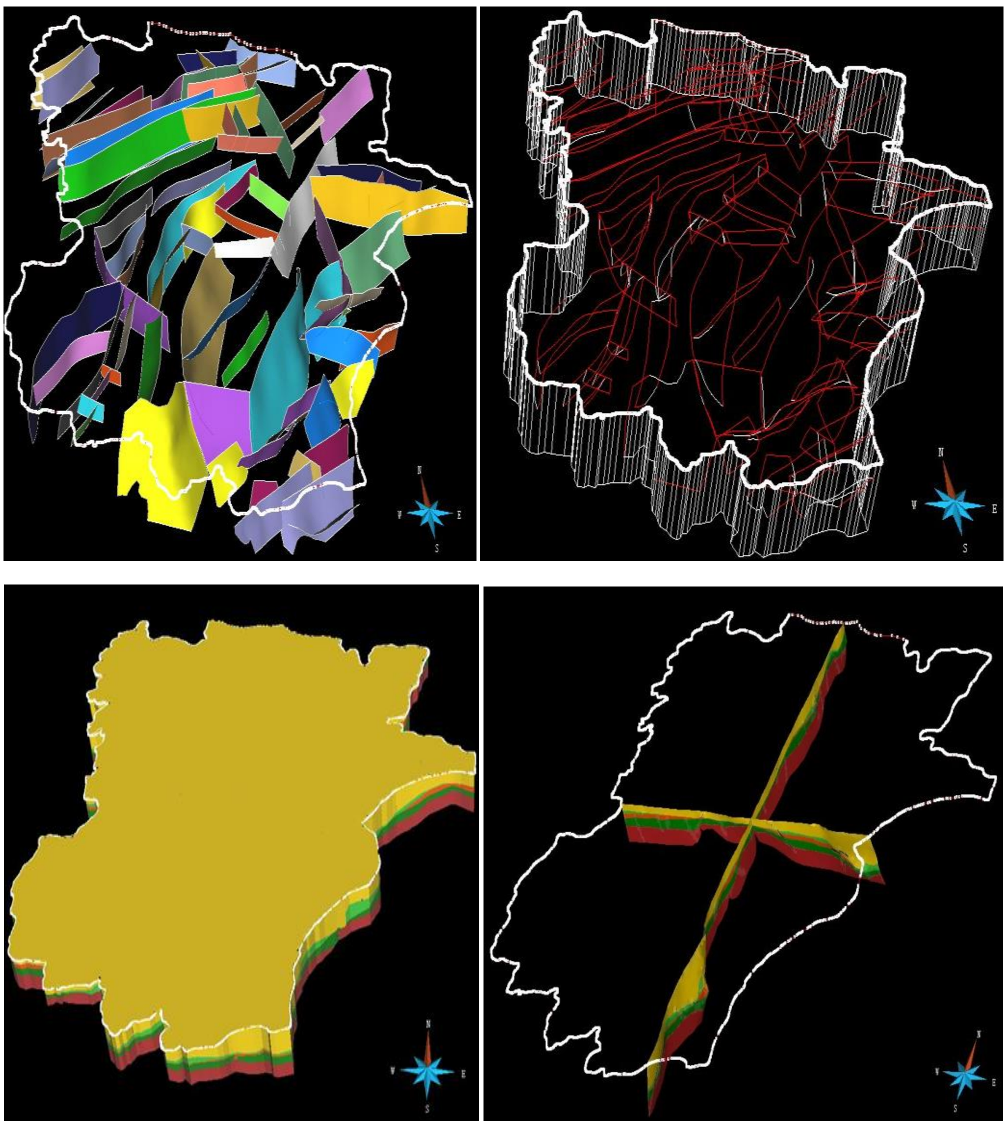

Figure 3: The Establishment of Workflow and Network of Bedrock Model in Plain Area (Plane resolution is 500m, total units is 232×248×150＝8630400)

6. CONCLUSION

This paper introduces the working methods and contents of Tianjin Geothermal Information Management System. The geothermal resource database and spatial database are established based on the national standard. The geothermal information system is established by using GIS secondary development tools and VB programming language. In this system platform can easily query, statistics, spatial analysis, prediction analysis and comprehensive evaluation. Can meet the geothermal resources monitoring, management, and planning needs.

In view of the complexity of geological structure, the current three-dimensional geological model of the bedrock is still relatively rough, can only show three-dimensional geological structure of Tianjin bedrock, the database contains only 124 bedrock drilling, there are a considerable number Of the boreholes were not incorporated. Dimensional geological model of bedrock has to be improved and further refined, for Tianjin characteristics on the basis of this need to carry out geothermal heat reservoir 3D model development and construction, through the integration of geothermal resources exploration, development of dynamic monitoring results, the development of geothermal resources, three-dimensional visual management , Resource potential analysis, forecasting and early warning functions, to further promote the development and utilization of geothermal resources, protection and management level, and thus better for the Tianjin city construction and economic development services.

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