ABSTRACT
dissertation submitted for the degree of Doctor of Philosophy (PhD) degree
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**Scientific and methodological aspects of the system for
obtaining, analyzing information and making decisions in the development of
deposits with hard to recover reserves**

Introduction. Currently, due to the transition of various countries to a market economyсходят, significant changes are also taking place in the management of oil and gas enterprises. At the same time, the main distinguishing feature in field development is the presence of problems associated with hard-to-recover reserves and cyclical uncertainties that occur when making decisions. In this regard, one of the priority tasks of decision-making at oil-producing enterprises is the classification of hard-to-recover reserves and assessment of the degree of difficulty in extracting these reserves, justification of the choice of methods for increasing oil recovery for the conditions under consideration, and decision-making when choosing geological and technical measures. At the same time, insufficient attention is paid to the factors of uncertainty and the risk of making erroneous decisions in literary sources. Therefore, the problem of making informed decisions in managing the field development process is particularly relevant for the domestic oil and gas science and industry. Historical data indicate high levels of production, as well as current oil recovery factors (ORF). Despite this, more than half of the geological reserves of oil still remain in the subsurface. The main scientific research of researchers in the field of oil field development related to various geological conditions is aimed at finding methods of their treatment. This is also confirmed by a number of literature sources.

The relevance of the work. Currently, there is a gradual decline in the level of production, which is associated with the presence of deposits with hard-to-recover reserves in many regions. This process causes a smooth shift of emphasis towards areas with low filtration-capacity properties (FCP) and high water cut values. In order to effectively develop hard-to-recover reserves in the current situation, it is necessary to combine existing mathematical methods, necessary information and modern technological solutions. In this regard, the problem of improving the system for obtaining, analyzing information and making decisions in the development of deposits with hard-to-recover reserves is relevant and still on the agenda.

The relevance of the dissertation topic is also directly related to its great practical significance. The insufficiently developed practical aspects of managing field development under conditions of uncertainty justify the expediency of conducting research within the framework of this dissertation and its focus. This explains the choice of the topic of this dissertation.

Justification of the need to conduct this research work on the topic. First of all, the need to conduct this work within the framework of the dissertation topic is justified by the attention of researchers to this problem. It should be noted that the problem of decision-making and improving the efficiency of developing hard-to-

recover deposits is covered by the works of many researchers who have made a great contribution to the development of the scientific foundations of this area. Thanks to the efforts of these scientists, interesting results were obtained from a scientific and practical point of view. Despite numerous studies in this area, some issues still require a number of studies related to a deeper study of the impact of geological conditions, as well as technical and technological factors on the effectiveness of geological and technical measures, as well as making decisions to improve their effectiveness.

The purpose of the dissertation work. Improvement of models and algorithms **within** the decision-making system to improve the efficiency of geological and technical measures in fields with hard-to-recover reserves.

The scientific novelty of the dissertation consists in improving the basics and methodology of modeling performance indicators of geological and technical measures and decision-making in conditions of uncertainty; development and implementation of complexa mathematical support for models and methods of decision-making using probabilistic and statistical methods and fuzzy logic; within the framework of the noted:

- as a result of statistical data processing and information analysis, the most significant factors in evaluating the results of geological and engineering operations are justified and established, and a calculation scheme is proposed that allows us to build mathematical models of their performance indicators;

- a scientifically based criterion for the effectiveness of measures is proposed - "a comprehensive indicator of the effectiveness of geological and technical measures", and a methodology for assessing the influence of the main factors on its values, based on models in the form of fuzzy rules.

Object of research. The object of the study is a system for obtaining and analyzing information during geological and technical measures in fields with hard-to-recover reserves.

Subject of the study. The subject of the study is modeling and decision-making when choosing geological and technical measures in fields with hard-to-recover reserves.

Research objectives:

- analysis of global experience in developing information analysis and decision-making systems to improve the efficiency of field development;

- development of a methodology for assessing the impact of the main factors on the performance indicators of geological and technical measures in conditions of insufficient information based on fuzzy models;

- analysis of factors influencing the effectiveness of geological and technical measures applied in the fields of Kazakhstan with hard-to-recover reserves;

- development of models for forecasting performance indicators of geological and technical measures in various conditions and decision-making;

- analysis of the experience of applying the selected types of geological and technical measures and evaluation of the comparative effectiveness of the applied measures.

The main provisions submitted for defense:

- methodology for modeling performance indicators of geological and technical measures and decision-making under conditions of uncertainty;
- mathematical support of models and methods of decision-making in the selection of geological and technical measures using probabilistic and statistical methods and the apparatus of fuzzy set theory;
- The criterion for the effectiveness of measures is "a comprehensive indicator of the effectiveness of a geological and technical measure", and a methodology for assessing the influence of the main factors on its values, based on models in the form of fuzzy rules.

Theoretical and practical significance of the work. The use of the developed mathematical models makes it possible to select for specific conditions the type of geological and technical measures that will provide the maximum technological and economic effect for these geological conditions. The paper пpresents new scientific and practical results. Thus, the combined use of mathematical statistics and fuzzy logic methods allowed us to build models that express the dependencies of performance indicators of geological and technical measures and propose a decision-making method based on fuzzy clustering of performance indicators. Thus, the improvement of research methodology with the use of modern methods of data processing and information analysis made it possible to successfully solve current problems related to the extraction of hard-to-recover reserves and decision-making to improve the efficiency of geological and technical measures in various geological conditions, which increases both the theoretical and practical significance of the dissertation work.

The results of the study can be used by design organizations and oil and gas companies to improve methods for evaluating the effectiveness of geological and technical measures, substantiate the need for investment support for projects to intensify production and increase oil recovery.

Approbation of the results of the dissertation work

The results of the dissertation were tested at several international scientific conferences: Almaty 2021, Almaty 2022, Tyumen 2022, Almaty 2024.

Publications. The main results of the dissertation are published in highly rated scientific journals and publications. Among them: 3 articles in journals included in the Scopus database, 6 articles in CQASHE journals, 4 articles in the materials of the international conference, 2 articles in other journals and 1 patent.

Structure and scope of the dissertation. The dissertation consists of an introduction, 4 chapters, a conclusion, and a list of 121 references. The paper is presented on 153 pages and includes 13 figures and 19 tables.

The research work on the dissertation was carried out within the framework of the projects Zhas Galym IRN AR22682919 "Scientific and technical foundations of monitoring the use of polymer flooding to enhance oil recovery in fields of the Republic of Kazakhstan" and the targeted financing project BR21881822 "Development of technical solutions for optimizing geological and technical operations during drilling and oil production at the final stage of field operation".

The first chapter provides an analysis of the current state of the problem of modeling, information analysis and decision-making when choosing geological and

technical measures.

An analysis of the world experience in applying various technologies and methods for increasing oil recovery in fields with hard-to-recover reserves has shown the need for research to find and identify ways to improve the efficiency of geological and technical measures by modeling and evaluating their comparative effectiveness in various geological conditions and making decisions taking into account various types of uncertainties.

Therefore, some studies are devoted to evaluating the effectiveness of existing technologies, developing methods and technical solutions to improve the effectiveness of a particular impact, modeling and evaluating the impact of various factors on the effectiveness indicators of geological and technical measures.

In general, the analysis of the current state of knowledge of the problems associated with hard-to-recover reserves has made it possible to establish the need for extensive research to justify the effectiveness of implementing a particular technology in accordance with accumulated field experience in this and/or a similar field. Therefore, the most important thing for various fields, in particular, in Kazakhstan, is the development of the most effective methods, as well as various modifications of existing technologies.

The results of the analysisa, presented in the first chapter, made it possible to substantiate and formulate the purpose, main methodological principles and tasks of the research in the framework of this dissertation.

The second chapter is devoted to the analysis of methods for assessing the technological effectiveness of geological and technical measures.

The basic principles of constructing models and developing methods for assessing the technological efficiency of geological and technical measures are given. The, initial data in this caseюare data on применении the use of various geological and technical measures in various geological and physical conditions. A calculation scheme is proposed that allows statistical data processing, analysis of the information obtained, and thereby prepare an information array for decision-making in the event of statistical uncertainty.

The study of the second chapter allowed us to build statistical models based on the example of some geological and technical measures. At the same time, the degree of importance of each feature was assessed first. To assess the reliability, the degree of identity was determined. After the most important features were identified, the insignificant features were discarded. After that, the models were identified again with an assessment of their degree of identity, in order to make sure that after discarding insignificant features, the models retained their reliability. In the marked models, the following features are used: ototal reservoir thickness, oil-saturated thickness, exposed oil-saturated thickness, sand content coefficient, porosity, permeability, oil viscosity, oil density, gas content, initial oil saturation, reservoir temperature, paraffin content in oil, sulfur content in oil, oil production rate before geological and technical measures, liquid flow rate before the geological and technical event, water availability before the geological and technical event. The following indicators of a geological and technical event are: duration of the effect, additional oil production, increase in oil production rate, oil production rate after a geological and technical event, waterlogging after a geological and technical event.

The third chapter discusses the possibility of modeling geological and technical activities based on fuzzy cluster –analysis. It should be noted that in the case of insufficient information for conducting statistical analysis and building statistical models, models based on fuzzy cluster analysis have recently been used in many areas. These models allow you to build dependencies at the qualitative level, where factors and output variables are expressed not in numbers, but in qualitative expressions.

As noted in the literature, there are more than a hundred different clustering algorithms. In recent years, these methods have been widely used in the tasks of information mining, data collecting and processing (Data mining). This method is based on the theory of L. Zadeh, which has become widely used, thanks to which it was possible to solve a number of problems that were previously impossible to solve. In order to solve this problem, we have collected and processed additional data, including the characteristics of geological and physical conditions and technological data noted above. This data was subjected to cluster analysis based on fuzzy logic, i.e., using the fuzzy cluster analysis algorithm, the entire data array was divided into homogeneous groups-clusters.

In this task, the same attributes and performance indicators are used as in statistical models.

As can be seen, the task in this case is multi-criteria, and it is necessary to select the features in such a way that the selected set provides the maximum values of the efficiency indicators of geological and technical measures.

Summarizing the results of statistical processing, analysis and construction of statistical models mentioned above, we note that to solve this problem of data processing, obtaining and analyzing information, it is necessary:

- from the selected five performance indicators, we get one generalized:

$$K = \sum_{i=1}^{5} \alpha_i \, y_i$$

, where α_{ai} are coefficients that characterize the weight contribution of each criterion to the generalized

$$\alpha_i = \frac{\sum_{k=1}^{n} y_{ik}}{\sum_{i=1}^{5} (\sum_{k=1}^{n} y_{ik})}$$

- by implementing the fuzzy cluster analysis algorithm, we obtain three homogeneous groups-clusters.
- each group of values for each feature within the same cluster is assigned "linguistic" values, i.e. values expressed in words (low, medium, high).
- Each cluster is assigned in accordance with the generalized performance indicator K.;
- fuzzy rules are constructed based on the "if..., then..." principle.

The fourth chapter is devoted to evaluating the effectiveness of geological and technical measures for various objects based on statistical analysis of complex information.

In order to model and evaluate the best geological and technical measures for

the conditions under consideration, as already noted, the method of fuzzy forecasting and modeling was used. For this purpose, the conditions were classified according to the relative efficiency of geological and technical measures .

Classification was carried out by the method of fuzzy cluster analysis, which has recently been successfully used in solving problems of classification of geological features.

By implementing a fuzzy cluster analysis program, the data array was divided into 4 classes. These classes are characterized by membership functions, the highest value of which indicates that the object belongs to this class.

The paper presents an array that includes the values of attributes and performance indicators of the geological and technical measures, as well as the functions of belonging to different classes of the object.

Each of the classes (clusters) is characterized by its own efficiency, which can be expressed using words.

To assess the effectiveness of geological and technical measures used in various reservoirs, based on efficiency data, clusters can be characterized as follows: high efficiency, good efficiency, medium efficiency, satisfactory efficiency.

The work shows the mutual correspondence of layers and geological and technical measures, the use of which has proven highly effective.

These results allow us to give approximate preference to one or another type of geological and technical measures in the case of the reservoir under consideration in conditions of insufficient information.

Key findings and recommendations

1. As follows from the review of publications accumulated to date, the issue of creating the basis of a system that allows modeling, taking into account uncertainty, in particular, multi-criteria, multifactorial nature, as well as making adequate decisions on the choice of a method of impact on the reservoir in the specific conditions under consideration, has not been sufficiently studied.

2. The basic principles are substantiated and a methodology for data processing and information analysis systems is proposed for decision-making in the problems of selecting geological and technical measures based on a probabilistic approach to determining the values of weighting coefficients, assessing their significance, constructing models and evaluating their reliability.

3. A methodological approach is proposed that makes it possible to assess the impact of the main factors on the integrated performance indicator of a geological and technical event, based on models in the form of fuzzy rules.

4. A methodology has been developed to determine the optimal values of the factors affecting the effectiveness of geological and technical measures. An improved calculation scheme is proposed based on the use of information on the conditions of geological and technical measures using mathematical statistics and fuzzy logic, as well as a multi-criteria assessment of their effectiveness.

5. Through variant calculations and analysis of the comparative effectiveness of geological and technical measures in various conditions, the ways are shown and the results of decision-making on choosing the best geological and technical measures are obtained.

6. The proposed approaches, involving the use of methods that take

uncertainty into account when modeling results, allow for the construction of appropriate cause-and-effect relationships and make informed decisions when planning geological and technical measures**.,**

7. Improved statistical models are proposed that allow making decisions on improving the efficiency of geological and technical measures.

8. The results of the study can be used by design organizations and oil and gas companies to improve methods for evaluating the effectiveness of geological and technical measures, substantiate the need for investment support for projects to intensify production and increase oil recovery.