POLITECNICO DI TORINO

Master’s Degree in Petroleum Engineering

Master’s Degree Thesis

Implementation of Petroleum Resources Management System (PRMS) in Kazakhstan

Supervisors

prof. Glenda TADDIA

prof. Martina GIZZI

prof. Alessandro BERTA

Candidate

Nursultan YESKALIYEV

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Abstract

The Petroleum Reserve and Resource Management System (PRMS) serves as a fundamental framework for assessing and categorizing petroleum reserves and resources, and it plays a critical role in directing management and decision-making procedures within the worldwide oil and gas industry. The Society of Petroleum Engineers (SPE) developed and maintains the PRMS, which offers a standardized approach and set of terminology to enable consistent and transparent reporting of petroleum reserves and resources across a variety of geological and geographic contexts.

The PRMS's primary function is to assess the commercial potential of hydrocarbon accumulations, a crucial factor in determining the profitability of exploration and production activities. The PRMS improves the accuracy and reliability of data exchanged among industry stakeholders, investors, regulators, and the general public by providing a systematic way to categorizing reserves and resources.

A variety of reserves and resources are covered by the PRMS classification scheme, from unexplored accumulations with exploration potential to proved deposits prepared for commercial extraction. It aids experts in classifying these assets according to the geological, engineering, and economic criteria that affect their ability to be recovered. Additionally, PRMS provides a platform for businesses to consistently declare their petroleum holdings, increasing transparency and enabling worldwide comparisons.

In PRMS hydrocarbons are classified as reserves, contingent resources, prospective resources, and unrecoverable resources based on applied project. Within these classifications hydrocarbons are categorized as low, best and high estimate based on geological uncertainty.

In contrast, Kazakhstan uses a specific reserve estimating approach known as the "GKZ System" to categorize and examine the country's hydrocarbon reserves. This system is monitored by the State Commission on Mineral Reserves (GKZ), which is responsible for overseeing and administering the classification, reporting, and assessment of oil and gas reserves in accordance with national legislation.

Key features and aspects of the reserve estimation system in Kazakhstan include:

1. **Categorization:** The GKZ System categorizes reserves into several classes based on available data and field development stage.
2. **Evaluation of Resources:** The system uses a sequential approach to evaluate and categorize reserves, moving from regional analysis through prospect identification, exploration drilling, field delineation, and finally field development planning. The assessment of recoverable reserves is improved with each stage.
3. **Reserve Upgrading:** Reserves can be upgraded as a field advances through its lifecycle stages.
4. **Economic Considerations:** The GKZ System considers the potential economic viability of reserves. It evaluates the factors such as recovery methods, production technologies, and market conditions. However, the system's focus on maximizing recoverable reserves can lead to overestimation.
5. **Regulatory control:** The GKZ, as the regulatory authority, reviews and approves reserve estimation reports submitted by companies. This monitoring guarantees that reserve estimations follow established norms and recommendations.
6. **Integration with Development Plans:** According to the GKZ System, field development plans must be in line with estimated recoverable reserve.

7. **Challenges and Considerations:** The GKZ System's approach to reserve estimation is questionable leading to potentially higher reported reserves. There are concerns about the practicality and feasibility of achieving these estimates, especially in cases where untested or costly technologies are considered.

Overall, Kazakhstan's GKZ reserve assessment system presents a unique approach that takes into account the country's geological, technological, and economic considerations. While its aim is to optimize recoverable reserves, ongoing discussions highlight the importance of aligning the system with global standards, enhancing transparency, and fostering sustainable resource management practices.

The objective of this study is to conduct a comprehensive comparison between two distinct reserves estimation methods, specifically the GKZ and PRMS systems. By analyzing the variations and commonalities between these approaches, the research seeks to provide valuable insights into the potential challenges and opportunities associated with transitioning from the GKZ to the PRMS system. Drawing on examples and experiences from other countries, the study aims to offer valuable guidance and lessons for making informed decisions regarding reserve estimation methodologies. This investigation holds significance in shedding light on the implications and considerations that arise during the adoption or adaptation of reserve estimation systems, particularly in the context of Kazakhstan's resource management.

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Sincerely,

Nursultan Yeskaliyev

Table of Contents

List of Figures

List of Tables

Introduction

The Petroleum Reserve and Resource Management System (PRMS) has become an essential tool for improving accountability, transparency, and efficient resource management in the worldwide oil and gas sector. For developing nations looking to maximize their hydrocarbon exploration and production efforts, this approach serves a crucial role in bridging the gap between technical assessments and financial decisions.

The adoption of PRMS will have a huge impact on developing countries like Kazakhstan, which have a large amount of unrealized hydrocarbon potential. In these countries, the energy industry frequently forms the foundation of national development and economic progress. The effective use of such precious assets must be balanced with long-term sustainability and responsible management, which calls for reliable and open reserve estimating approaches.

The use of PRMS in Kazakhstan can help with a number of significant issues that developing nations encounter while managing their petroleum assets. As a starting point, PRMS offers a uniform and widely accepted vocabulary for evaluating reserves, enabling communication between authorities, regulatory organizations, investors, and industry stakeholders. This standardization boosts investor trust, draws in foreign direct investment, and creates an atmosphere that is favorable for alliances and cooperation.

Second, PRMS encourages smart resource management and use. In order to maximize the value of their petroleum reserves, developing countries sometimes face a lack of financial and technological resources. Exploration, development, and production activities can be prioritized according to the nation's economic and energy goals due to PRMS's structured strategy.

Third, PRMS implementation encourages the creation of strong regulatory frameworks. Countries like Kazakhstan can improve their regulatory systems, ensuring fair competition, reducing corruption, and encouraging sustainable resource management by complying to internationally recognized norms. This can therefore encourage the development of a vibrant, transparent, and competitive energy market that draws in a variety of players and promotes further economic diversification.

In conclusion, the use of PRMS in the developing world, with an emphasis on Kazakhstan, is extremely important for improving the management of petroleum resources. These nations are given the tools they need by PRMS to unlock their hydrocarbon potential while preserving their long-term economic and environmental interests. PRMS does this by creating a shared vocabulary, promoting wise decision-making, and fostering open regulatory processes. The first step toward responsibly and sustainably unleashing the full value of petroleum reserves is the implementation of PRMS.

This introduction serves as an entry point into the complex world of PRMS, a system created to support accountability and openness while also being in line with the dynamic character of the petroleum sector. Understanding the foundations of PRMS is crucial for stakeholders seeking reliable and standardized insights into the world's essential energy resources as technological advancements and market factors continue to transform the landscape. The overall goal of this study is to provide more information about the goals, difficulties, and potential advantages of implementing PRMS in developing nations, particularly in Kazakhstan. The study seeks to achieve these goals in order to facilitate informed decision-making, advance sustainable resource management, and aid the expansion of the oil and gas sector in developing countries.

Overview of the Petroleum Resources Management System (PRMS)

1.1 The history of the PRMS

The PRMS was initiated in 1962 as a result of the realization by a number of international organizations and professional groups that a complete and uniform classification and reporting of oil and gas reserves and resources was required. The idea gained popularity as the global energy sector grew, creating a demand for a uniform framework that could be accepted and understood by all. Three years later, the SPE-PRMS set of regulations was developed and accepted by 12 individuals who were nominated by the SPE board (Mukanov & Zhumadil, 2021).

In 1978 the US Securities and Exchange Commission (SEC) established a legal framework for publicly traded companies to declare their oil and gas reserves based on concepts from PRMS. Although this project was primarily applicable within the United States, it was an important step toward standardized reporting.

The demand for a system that is acknowledged throughout the world increased as the energy environment became increasingly multinational. The Society of Petroleum Engineers (SPE) started working on creating a standard for reporting reserves that could be used globally in 1987. In the same year the World Petroleum Congress (WPC) developed a definition of reserves that was very similar to the idea of SPE. These efforts culminated in the joint launch of the reserves and resources classification in 1997, which provided a basis for further development (SPE et al, 2018).

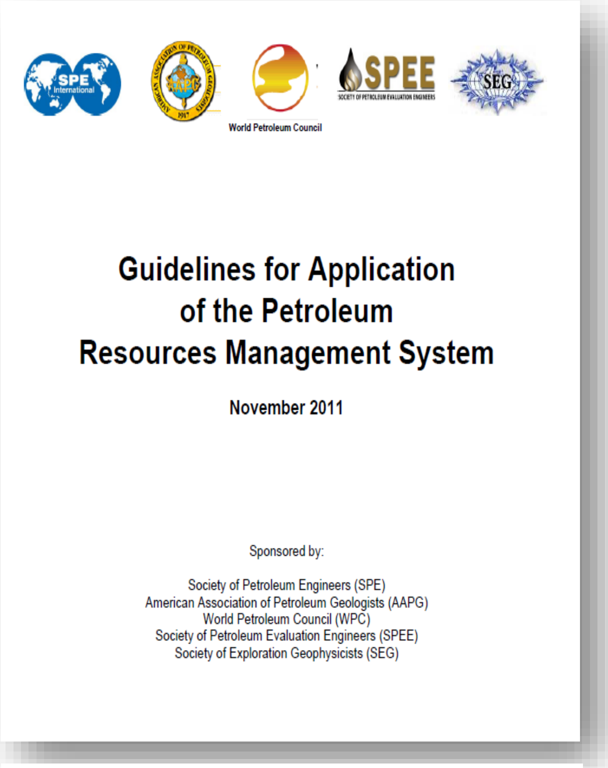
In 2000 and 2001, the SPE collaborated with the WPC and the American Association of Petroleum Geologists (AAPG) to establish the PRMS and guidelines for its application (SPE et al, 2018). In order to provide a single approach for classifying reserves and resources that could be applied globally, this comprehensive system incorporated the principles and concepts from pre-existing categorization systems.

In 2007 PRMS was officially launched by the SPE, WPC, APPG and the Society of Petroleum Evaluation Engineers (SPEE) that was followed by the updates in 2011 and 2018 (SPE et al, 2018). PRMS is constantly changing and adapting to industrial practices changes, technological breakthroughs, and the increasing significance of governance, social, and environmental factors. The history of the PRMS is briefly summarized in the Table 1 below. Examples of PRMS documents are shown in the Figure 1 and Figure 2 below.

Currently, the PRMS is used as a widely acknowledged and accepted standard for reporting reserves and resources. Numerous nations, governing organizations, and business stakeholders have adopted it, which has enhanced transparency, comparability, and reliability in the evaluation and reporting of hydrocarbon reserves and resources globally.

Table 1 PRMS history

Year	Authors	Definitions and rules
1936	American Petroleum Institute (**API**)	First description of oil reserves
1965	Society of Petroleum Engineers (**SPE**)	SPE-PRMS set of regulations
1978	US Securities and Exchange Commission (**SEC**)	Reserve description based on PRMS
1987	**WPC** (World Petroleum Congress)	Definition of reserves
1997	**SPE**, **WPC**	Reserves and resources classification
2000	**SPE**, **WPC, AAPG** (American Association of Petroleum Geologists)	Petroleum resources definitions
2001	**SPE**	Guidelines for the Evaluation of Petroleum Reserves and Resources
2007	**SPE**, **WPC, AAPG, SPEE** (Society of Petroleum Evaluation Engineers)	Petroleum Resources Management System (PRMS)
2011	**SPE**, **WPC, AAPG, SPEE, SEG** (Society of Exploration Geophysicists)	Guidelines for Application of the PRMS
2018	**SPE**, **WPC, AAPG, SPEE, SEG**	PRMS (revised June 2018)

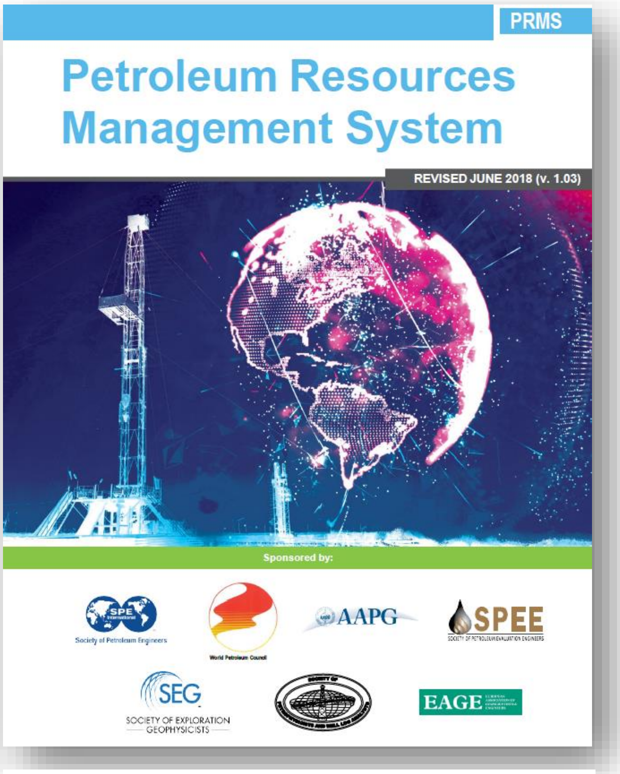


Guidelines for Application
of the Petroleum
Resources Management System

November 2011

Sponsored by:

Society of Petroleum Engineers (SPE)
American Association of Petroleum Geologists (AAPG)
World Petroleum Council (WPC)
Society of Petroleum Evaluation Engineers (SPEE)
Society of Exploration Geophysicists (SEG)



PRMS

Petroleum Resources
Management System

REVISED JUNE 2018 (v. 1.03)

Sponsored by:

Figure 1 Guidelines for application of the PRMS (SPE et al, 2011)

Figure 2 PRMS revised in 2018 (SPE et al, 2018)

1.2 PRMS principles

The PRMS employs a project-based methodology and offers comprehensive support throughout the reservoir's entire exploration and production lifecycle. This methodology introduces an elevated level of detail to project management, ensuring a thorough evaluation process. The resource assessment procedure encompasses the following steps:

1. Discovering a project related to recovery of reservoir
2. Estimating the hydrocarbons originally in place
3. Calculating the project's recoverable quantities
4. Sorting the project according to its maturity or chance of becoming commercially successful

Reserves are quantified with respect to sales products, enabling a practical assessment of their economic viability (Acquati, 2012).

1.3 PRMS matrix

PRMS recognizes the critical role of the availability of infrastructure in the production, transportation, and sale of petroleum apart from the assessment of petroleum in-place volumes (SPE et al, 2011). Consequently, it establishes a clear differentiation between two different aspects:

1. *Classification* that is based on the development project, which includes the scope of work for the development of the field(s). This aspect also considers the project's economic viability or the chance of commerciality.
2. *Categorization* that is based on the inherent uncertainty related to the estimation of petroleum quantities to be recovered in the future as part of a particular development project.

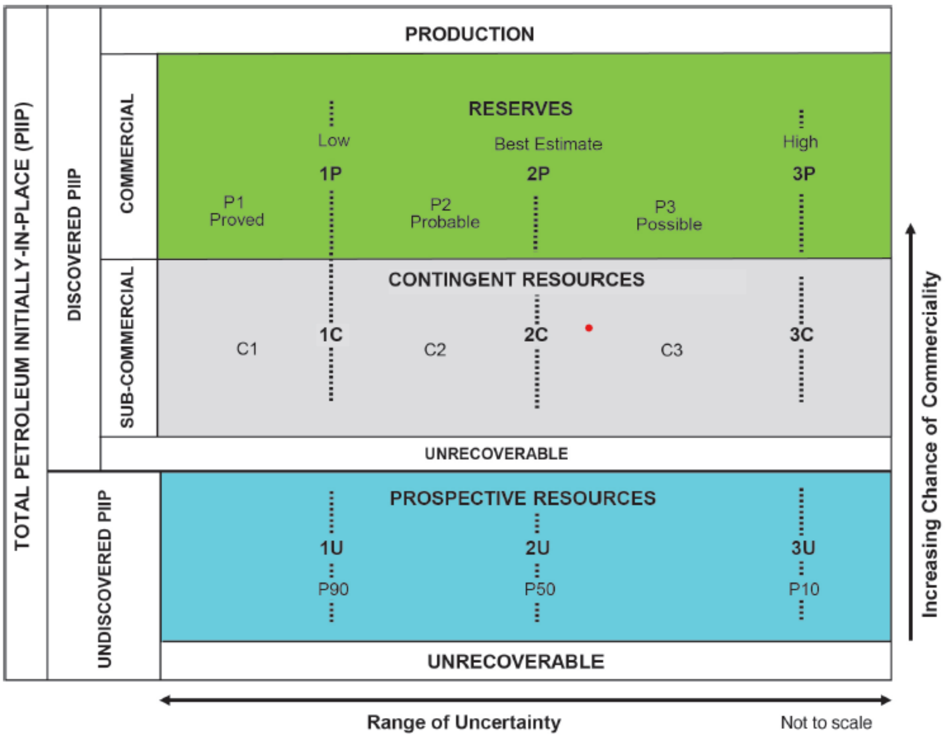


Figure 3 PRMS classification and categorization (SPE et al, 2018)

In Figure 3, PRMS classification is represented on the vertical axis, while categorization is depicted on the horizontal axis.

By acknowledging this distinction, PRMS ensures that both the feasibility of the development project and the range of uncertainty in projecting future petroleum recovery are taken into account. This comprehensive approach enables stakeholders to make well-informed choices regarding investments, production planning, and the valuation of reserves (OGRC, 2007).

1.4 Resources classification

Based on discovery status, total petroleum initially-in-place (PIIP) is subdivided into:

1. Discovered PIIP
2. Undiscovered PIIP

The verification of the discovery status involves drilling an exploration well(s) and analyzing well sampling, testing, and logging results to confirm the presence of substantial petroleum accumulations (Acquati, 2012). If the required data is unavailable, analog reservoirs can be utilized to validate the discovery status.

1.4.1 Discovered PIIP

Based on available technologies and the commerciality of the project, discovered PIIP comprises:

1. Discovered unrecoverable
2. Contingent resources
3. Reserves

If discovered hydrocarbons cannot be produced using existing or pilot technologies they are considered as discovered unrecoverable hydrocarbons (SPE et al, 2018). In this case, technological constraints or economic impossibility prevent actual production of the identified reserves. This categorization emphasizes the significance of hydrocarbon discovery as well as the viability of their extraction and commercial application.

If feasible production methods exist, but certain contingencies or uncertainties are present that need to be addressed, these resources are classified as contingent resources (Petrowiki, 2023). Contingencies could be the following:

- No final approval by government/partners
- Absence of gas sales agreement/markets
- Legal, social, and environmental issues

To transition from contingent resources to reserves, a comprehensive development plan is required. This plan must include an executable schedule, financial and economic analysis, infrastructure considerations, and a robust legal framework.

Reserves are commercially recoverable petroleum quantities anticipated to be produced by carrying out a development project on a known reservoir within clearly defined conditions (Acquati, 2012).

1.4.2 Undiscovered PIIP

Undiscovered PIIP represent prospective resources that are potentially recoverable and should be confirmed by drilling exploration well(s) (Acquati, 2012).

1.5 Resources classification based on maturity

For a more transparent illustration, the resources system is subdivided based on the maturity level of the project. This subdivision allows for a clearer understanding of the various stages of development and provides a more comprehensive overview of the resources system as a whole (see Figure 4).

As the project progresses in its development and the likelihood of commercial success increases, it typically goes through various stages. However, it is important to note that these stages may not always occur in every project. The stages are provided below:

Play represents a project with a potential range of prospects that necessitates additional data acquisition and evaluation (SPE, 2001).

Lead is a project characterized by the potential for a hydrocarbon accumulation, but it requires additional evaluation to assess the likelihood of geological discovery, as outlined by (SPE et al, 2018).

Prospect - a project that is distinguished by a clear potential accumulation, signifying its viability as a drilling target (SPE, 2001).

Once the discovery criteria are met, which typically involve drilling an exploration well(s) and conducting activities such as well testing, logging, or sampling, the previously undiscovered potentially-in-place (PIIP) hydrocarbon resources are reclassified as discovered PIIP.

Development not viable refers to a situation where the discovered hydrocarbon resources are deemed economically unviable for further development at present.

Development unclarified or on hold - discovered accumulation holds potential for commercial viability. Further appraisal work is required to clarify the economic feasibility of developing the resources. Or a situation in which the advancement of a discovered reservoir towards development is significantly delayed due to external contingencies. These could be technical, environmental or even political unresolved issues (SPE, 2001).

Development pending refers to a case when accumulation has potential and data acquisition activities are ongoing. Any contingencies are planned to be timely resolved and the basis for the development plan is present.

Commercial criteria are met as soon as the field development project with all the components is ready.

Justified for development - development project to be approved within a reasonable time frame.

Approved for development - the development project is approved by all stakeholders.

On production - hydrocarbons are being produced and sold.

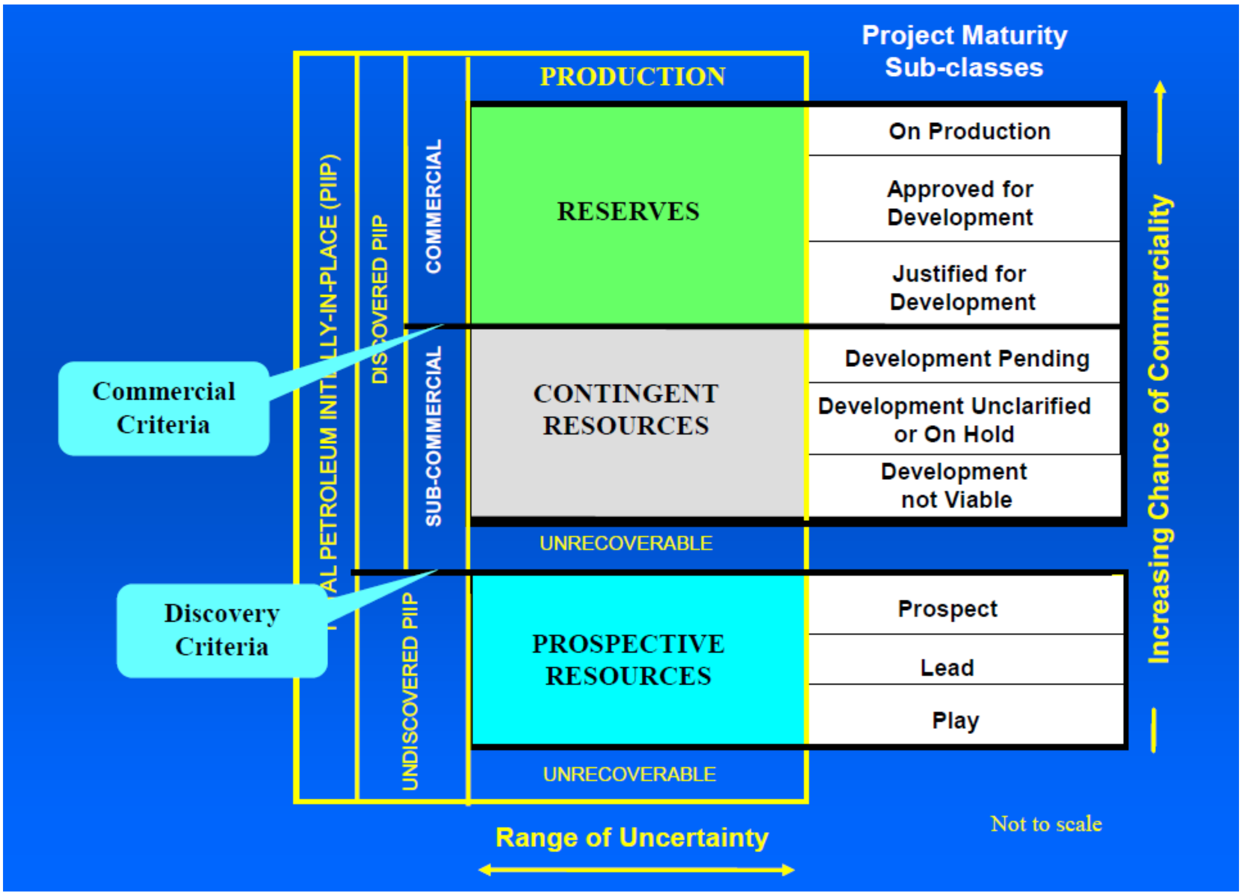


Figure 4 PRMS based on maturity of the project (SPE et al, 2018)

1.6 Status of reserves

Upon fulfilling the criteria of commercial maturity, the corresponding quantities are moved to **Reserves** category (SPE et al, 2018). Depending on the existing operational conditions of the wells and infrastructure, as well as budget allocations for forthcoming activities within the field development plan, these quantities can be categorized as follows:

1. **Developed Reserves**
    - Developed reserves are hydrocarbons that are planned to be produced from available wells and using existing infrastructure.
    - Developed producing reserves are planned to be produced from already open intervals.
    - Developed non-producing reserves necessitate supplementary funding for tasks such as perforating non-producing intervals or reactivating shut-in wells.
2. **Undeveloped Reserves**
   Undeveloped reserves refer to hydrocarbon resources that necessitate substantial additional costs for their production.

1.7 Resources categorization

Quantities of reserves, contingent resources, and prospective resources are categorized according to the degree of uncertainty, as shown on the horizontal axis within the PRMS matrix (Figure 3):

- **Low Estimate/1C/1P**
  A cautious projection (with high probability) of the anticipated recoverable hydrocarbons.
- **Best Estimate/2C/2P**
  The most pragmatic projection (considered the most realistic) of the anticipated recoverable hydrocarbons.
- **High Estimate/3C/3P**
  An optimistic projection (with a low degree of confidence) of the anticipated recoverable hydrocarbons.

Resource categorization is determined through the utilization of various analytical methods to calculate resources, including:

1. Analog method
2. Volumetric estimation
3. Performance-based estimation

Applied analytical methods provide a range of values for recoverable resources, taking into account uncertainties related to both potentially-in-place (PIIP) volume and recovery efficiency (SPE et al, 2018). Utilizing multiple analytical methods enhances the accuracy of resource estimation.

1.7.1 Analog method

Analog method proves useful when direct measurements or calculation parameters are unavailable, which commonly occurs during exploration or early development stages (SPE et al, 2018). Analog reservoirs are chosen based on their resemblance to the target reservoir, focusing on critical characteristics that significantly influence resource estimation, including reservoir and fluid properties. Other factors, such as deposition process, rock type, lithology, depth, pressure, temperature, among others, are considered when selecting analogs (SPE et al, 2018). By using multiple analogs, the accuracy of estimation is improved, as a broader range of reservoir and fluid characteristics that closely align with the target reservoir are taken into account.

1.7.2 Volumetric estimation

Volumetric estimation is utilized to calculate the initial volume of petroleum in place and its potential for recovery, depending on a specific development project. This method is subject to uncertainties associated with the reservoir geometry, porosity, fluid contacts, and fluid type (SPE et al, 2018).

For estimating the initial petroleum resources, average net-to-gross ratio, porosity, and saturation are essential parameters (SPE et al, 2018).

Volumetric resource calculation is done using the following formula:

$$PIIP = \frac{A * h * \emptyset * (1 - S_{wi})}{B_{hi}}$$

Where:

A – area, h – net pay, Ø – porosity, S_{wi} – initial water saturation, B_{hi} – initial HC formation volume factor.

After estimating the resources, the recovery potential of the project is evaluated based on analog data or a simulation model if available.

1.7.3 Performance-based estimation

Performance-based estimation is used after production start-up. Two primary approaches for this estimation are material balance and reservoir simulation.

Material balance estimation relies on data such as cumulative production and changes in formation pressure to calculate ultimate recoverable reserves. This method is particularly effective in reservoirs driven primarily by depletion. However, in cases where an aquifer or additional external energy sources significantly impact reservoir performance, reservoir simulation is the preferred approach (Tarek, 2010).

There are two main approaches for evaluating resources taking into account related uncertainties:

1. Deterministic approach
2. Probabilistic approach

1.7.4 Deterministic approach

In the deterministic approach, utilizing a single value for each parameter results in a singular outcome for the estimation of reserves (Figure 5). Hydrocarbon resources are categorized as low, best and high-case estimates to represent different scenarios or levels of uncertainty (SPE et al, 2018). In other words, a low case represents a pessimistic estimate, the best case is the most likely estimate, and a high case represents optimistic estimate (see Table 2).

Table 2 PRMS classification and categorization

Classification	Categorization	Note
Reserves	Low (1P) Best (2P) High (3P)	Proved Proved + Probable Proved + Probable + Possible
Contingent resources	Low (1C) Best (2C) High (3C)	C1 C1 + C2 C1 + C2 + C3
Prospective resources	Low (1U) Best (2U) High (3U)	

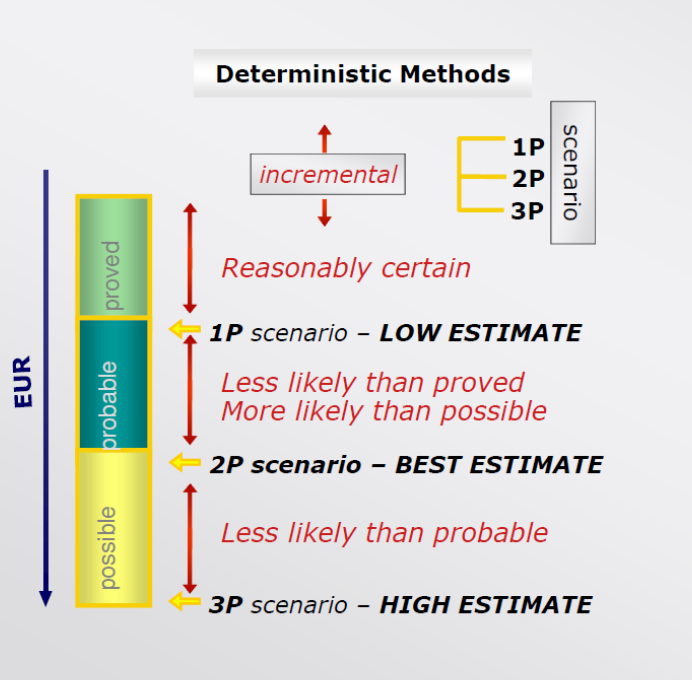


Figure 5 Deterministic method for reserve categorization (Acquati, 2012)

The process of resource categorization involves the review and analysis of all available geological and engineering data to determine the most appropriate inputs for each category. Consequently, the categorization of resources depends not only on the quality and reliability of data but also on the knowledge and experience of evaluating specialists.

The resources estimated using a deterministic approach during both the exploration and appraisal phases of the field can be illustrated through the following examples.

Pre-discovery stage

Seismic and geological data were utilized to determine the reservoir's shape and spill point. Structural cross-section, as depicted in Figure 6, is employed for estimating the gross rock volume in volumetric analysis. The high estimate of resources extends down to the spill point, while the low estimate is conservatively projected at a depth of 6120 ft subsea. The best estimate is positioned as the midpoint between the low and high cases.

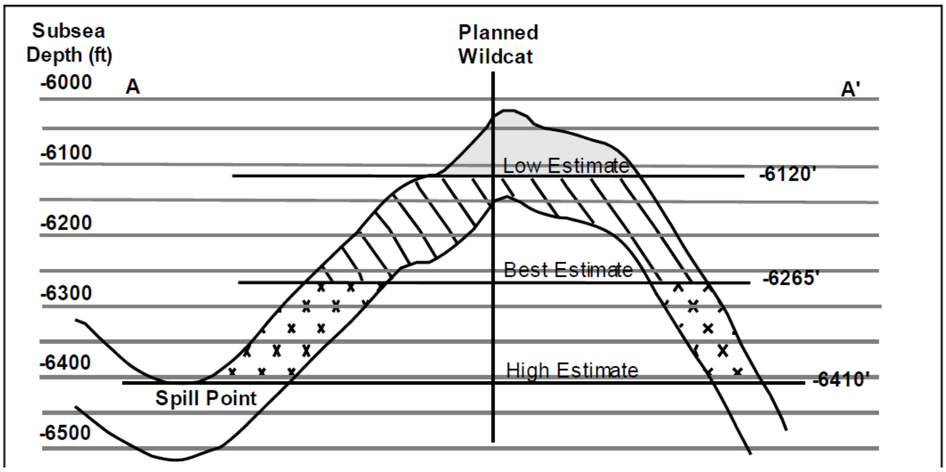


Figure 6 AA' structural cross-section (SPE et al, 2011)

Net-to-gross (NTG) data from analogs, when combined with gross rock volume, is used to create net pay isochore maps (shown in Figure 7). As gross rock volume increases, average porosity values decrease due to the incorporation of peripheral areas with lower porosity, leading to variations in average porosity between the best estimate case, which includes these areas, and the low case, which excludes them (SPE et al, 2011).

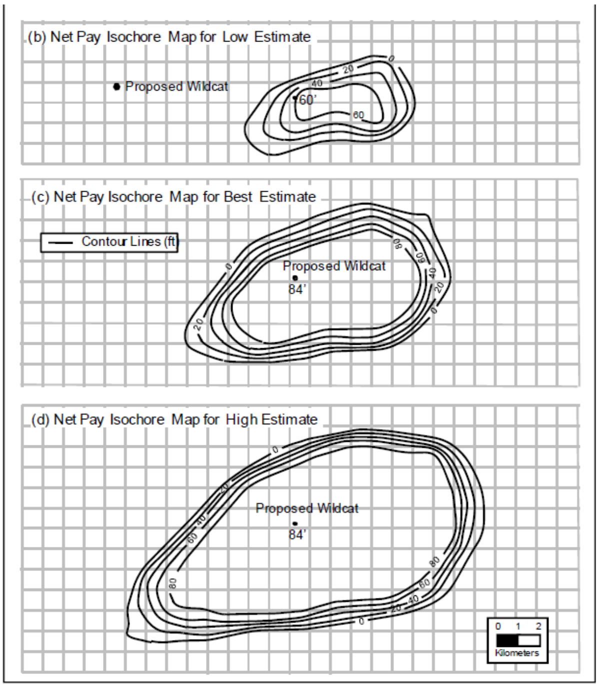


Figure 7 Net pay isochore maps for three cases (SPE et al, 2011)

Post-Discovery Stage

The drilled exploration well confirmed the presence of petroleum down to the well's bottom, prompting adjustments in resource estimates: the low estimate was raised by shifting the lowest known oil level to 6155 ft subsea; the high estimate was revised with larger closure and improved recovery efficiency; and the best estimate was calculated as the average between the low and high cases (Figure 8). Porosity values decrease from low to high estimate due to the inclusion of low porosity peripheral areas, while water saturation increases due to the incorporation of areas expected to have higher water content (SPE et al, 2011). Despite these adjustments, the potential for commercial viability remained uncertain, awaiting further clarification during the appraisal stage.

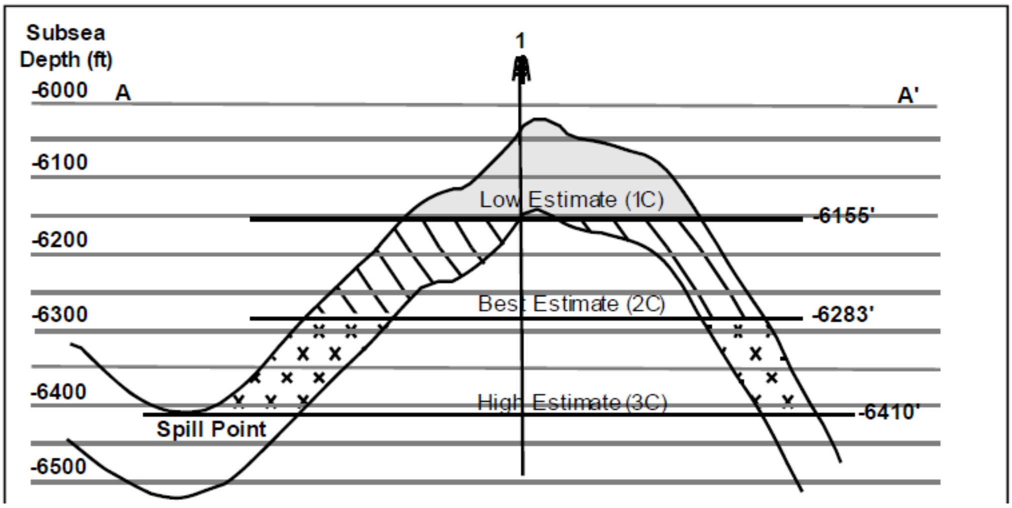


Figure 8 Revised cross-section after discovery (SPE et al, 2011)

Appraisal stage

Two wells were drilled, allowing for the collection of PVT samples and execution of well tests. This led to an increase in the low estimate as the known hydrocarbon level was shifted to 6240 ft subsea (Figure 9).

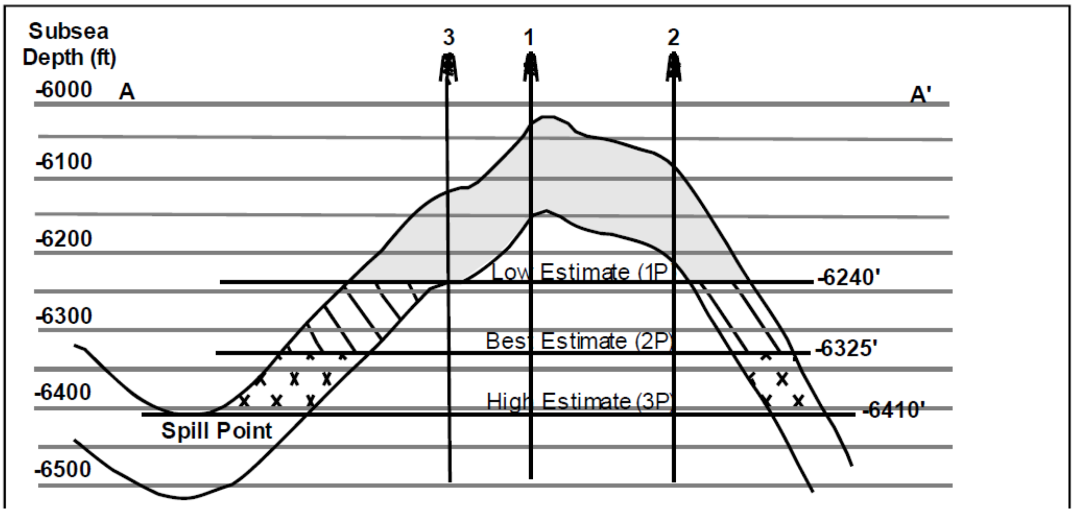


Figure 9 Updated cross-section after appraisal (SPE et al, 2011)

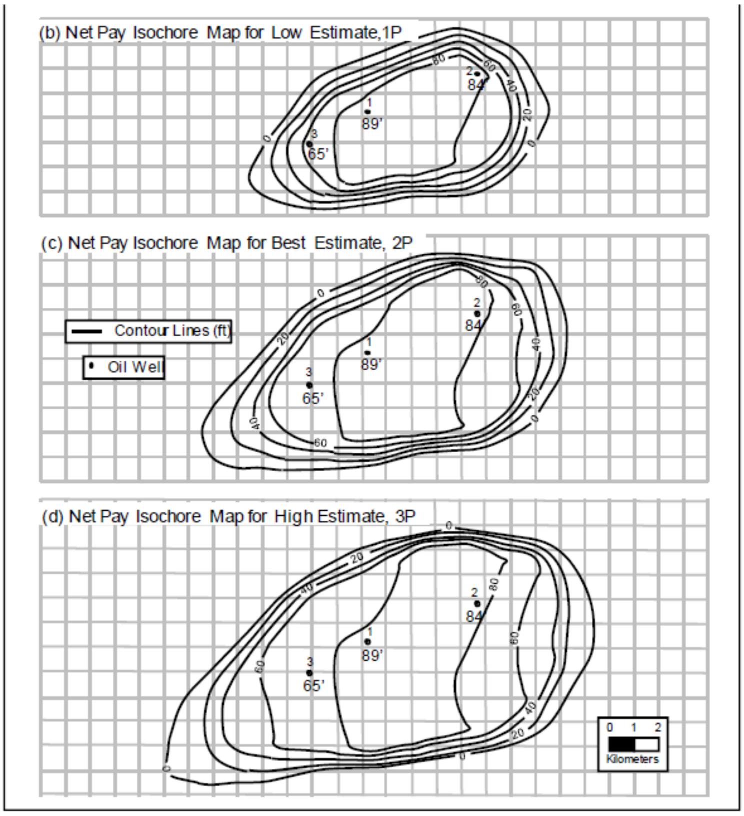


Figure 10 Updated net pay isochore maps after appraisal (SPE et al, 2011)

The net pay isochore maps were updated with new net-to-gross (NTG) values obtained from each well (Figure 10). To estimate recovery efficiency, nearby analog reservoirs were studied, utilizing the same pressure maintenance system involving peripheral water injection (SPE et al, 2011).

With no expected contingencies, the project received development approval, resulting in the reclassification of recoverable hydrocarbon volumes from contingent resources to reserves.

1.7.5 Probabilistic approach

The probabilistic approach encompasses the entire spectrum of potential input parameters to establish a range of possible reserves estimations (SPE et al, 2011). This process is implemented using the Monte Carlo technique, involving iterations of random parameters to produce a distribution of estimated reserves.

As a result of the probabilistic approach and the Monte Carlo simulation, probability scenarios such as P10, P50, and P90 can be derived. These scenarios represent the low, best, and high estimates of the hydrocarbon resources, respectively (Figure 11).

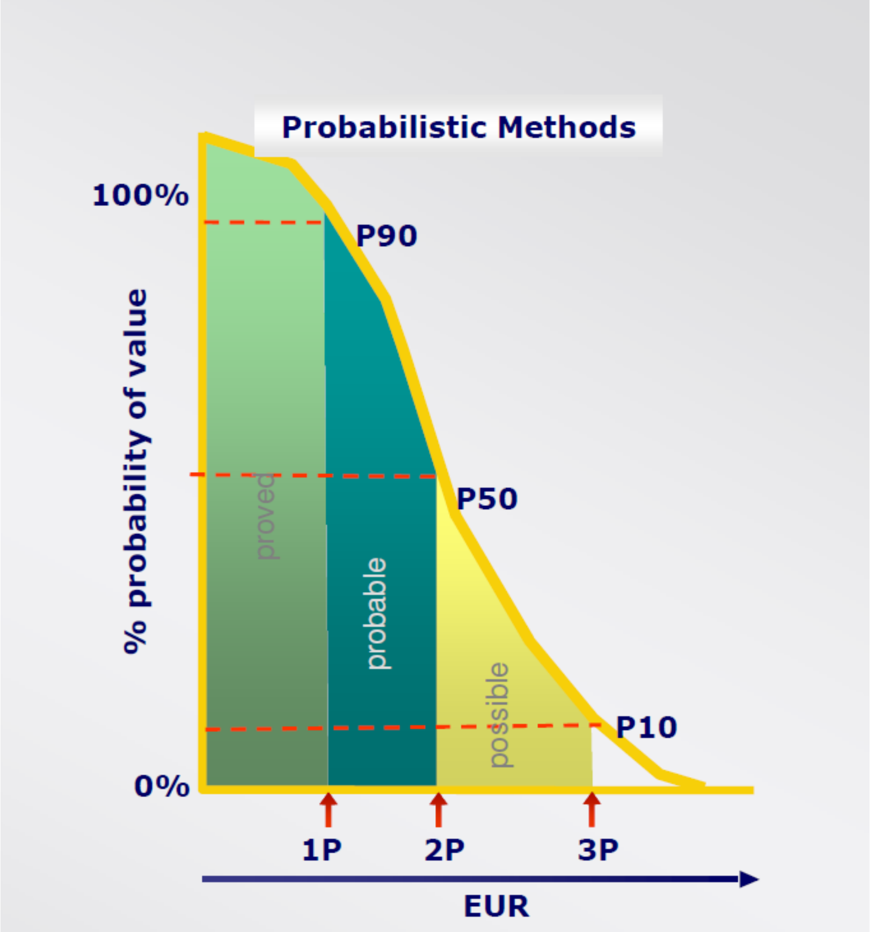


Figure 11 Probabilistic method for Reserve categorization (Acquati, 2012)

Uncertainties are associated with factors including gross rock volume, porosity, net-to-gross ratio, fluid properties, and projected recovery factor (SPE et al, 2011). Estimators assign various distribution functions (such as normal distribution, log-normal distribution, etc.) to each parameter, relying on the mean value to precisely represent the actual scenario.

For instance, consider the Figure 12 below depicting reservoir porosity and local porosity from log or core. While log or core porosity values can include zero, reservoir porosity must always exceed zero. This exemplifies the differentiation in distributions to be employed.

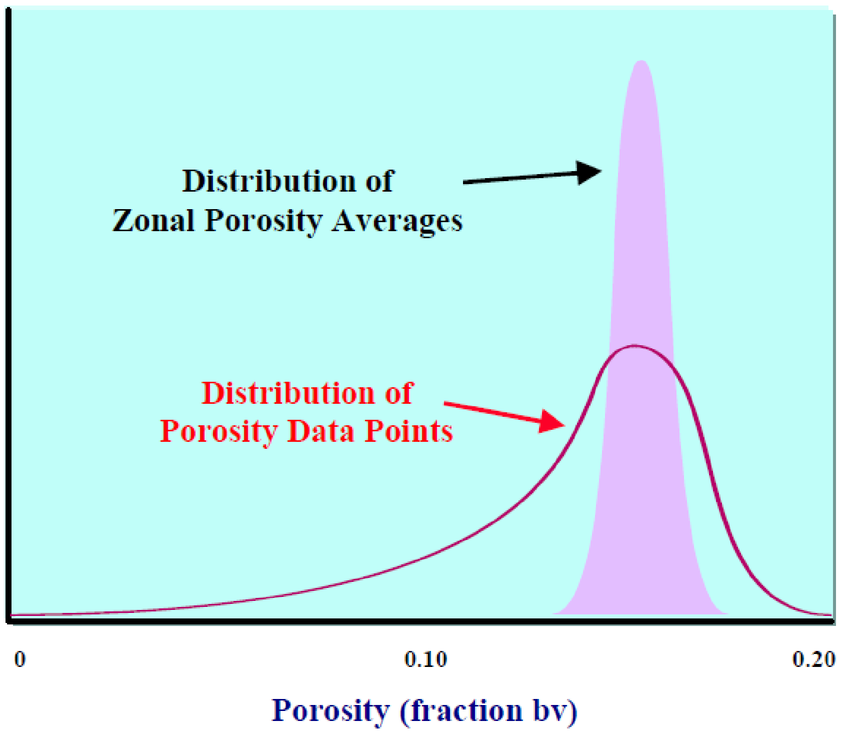


Figure 12 Porosity distribution (SPE et al, 2011)

1.7.6 Deterministic and probabilistic approach

A combination of deterministic and probabilistic methods can be employed to obtain reserve estimation along with its associated probability. The probability tree analysis illustrated in Figure 13 below provides further support for this approach.

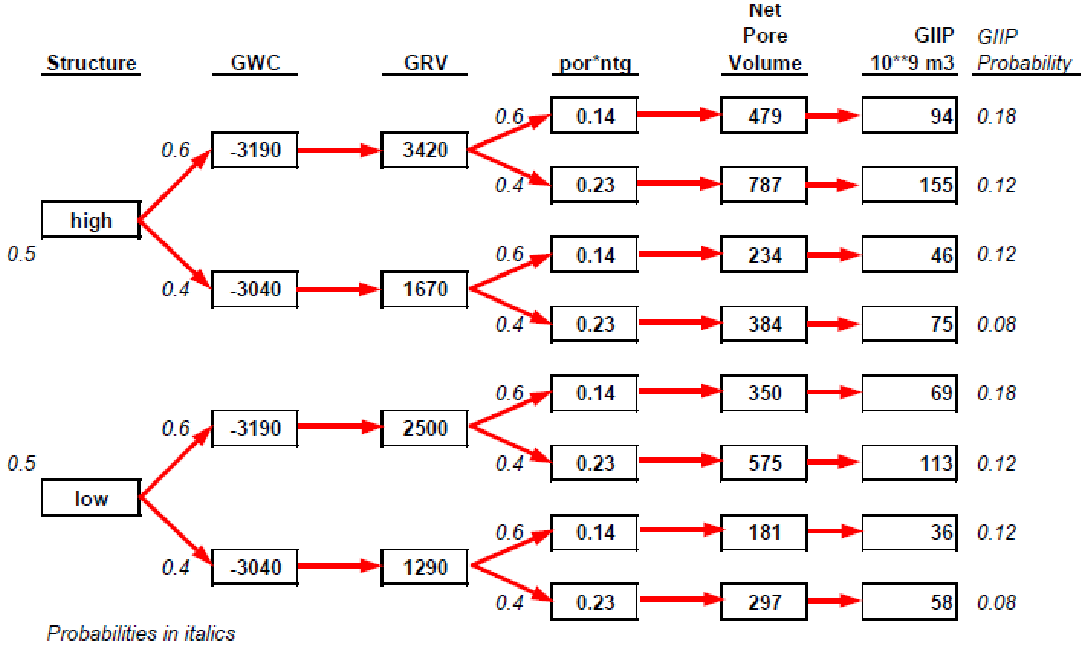


Figure 13 Probability tree analysis (SPE et al, 2011)

1.8 Example of resource classification and categorization

Figure 14 illustrates two distinct reservoirs in grey that have not been drilled yet. These reservoirs are considered prospective resources and their estimation is based on seismic data, as well as other geological and petrophysical information. The estimates include low, best, and high scenarios to account for varying levels of potential outcomes.

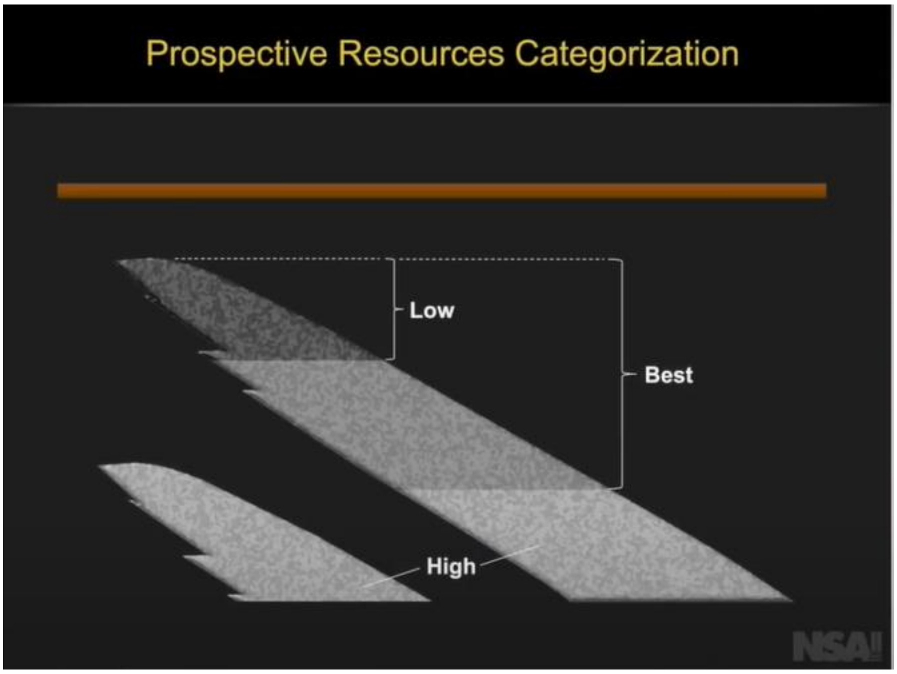


Figure 14 Prospective resources categorization (Netherland Sewell & Associates, 2019)

Following the drilling of a well at the top of the structure, a hydrocarbon discovery has been made (see Figure 15). Hydrocarbons are present all the way to the bottom of the well, which represents lowest estimate scenario corresponding to C1 or 1C category. Additionally, 2C and 3C categories have also been derived.

The second reservoir has not been penetrated so it is still prospective resources.

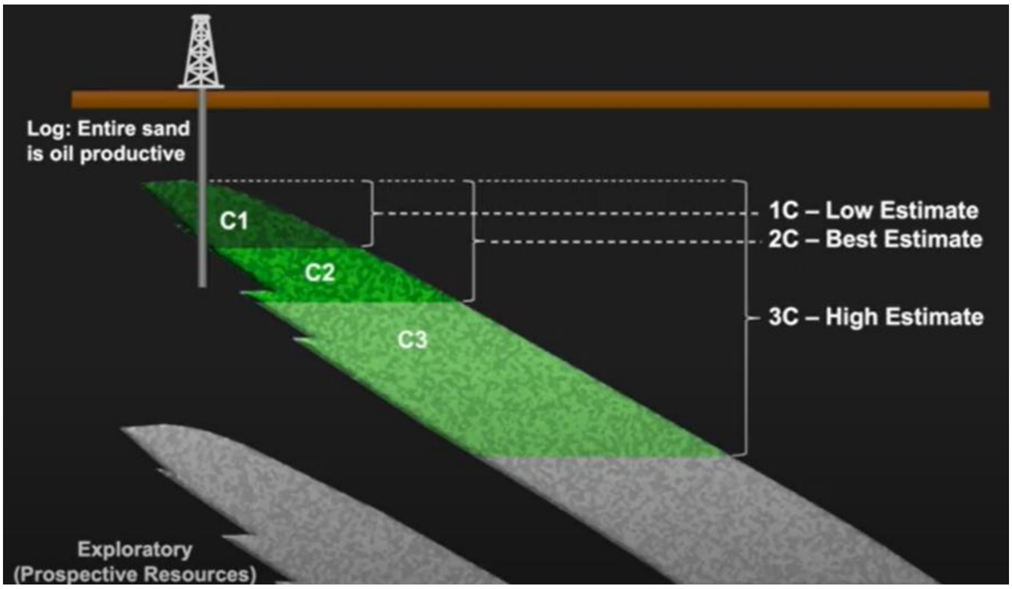


Figure 15 After drilling of an exploration well (Netherland Sewell & Associates, 2019)

Upon reaching the final investment decision (FID) or receiving approval to develop the field, contingent resources are reclassified as reserves (see Figure 16). Hydrocarbon quantities that can be recovered from the well all the way to the bottom are categorized as proved reserves (1P). Combined with probable reserves, they form the most likely estimate (2P). Adding possible reserves results in the optimistic estimate (3P).

The status of the second reservoir remains unchanged, and it is classified as prospective.

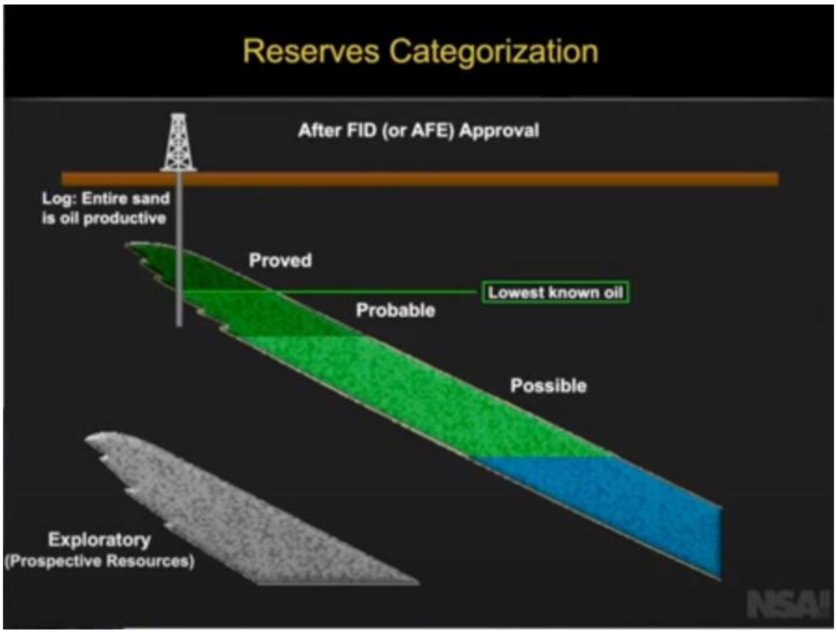


Figure 16 After FID approval (Netherland Sewell & Associates, 2019)

According to Figure 17, drilling of the second well resulted in presence of hydrocarbons from the surface to the bottom of the well. As a result, proved reserves are pushed down further to a deeper level. We now anticipate probable reserves at a slightly greater depth than before, and there is a possibility of discovering hydrocarbons even deeper than our initial optimistic projections.

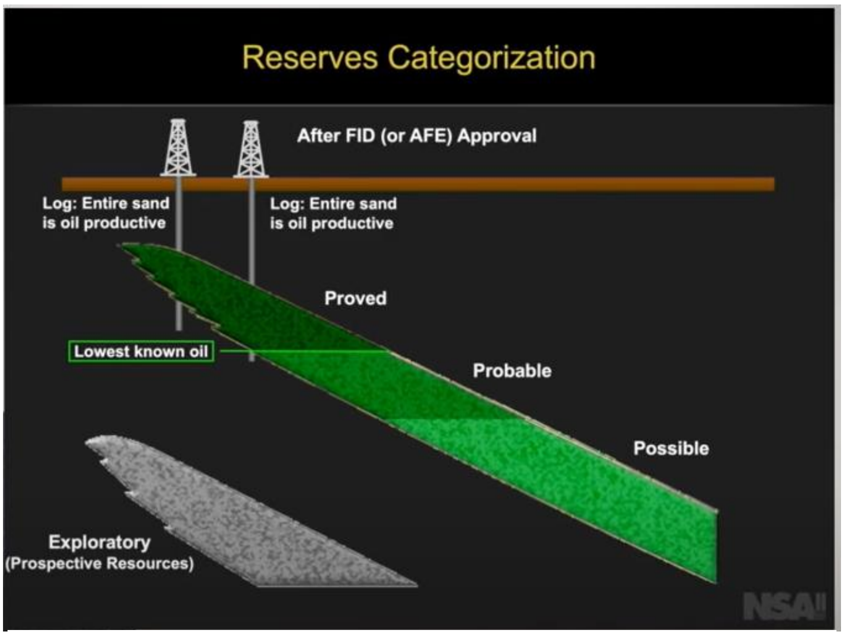


Figure 17 After drilling the second well (Netherland Sewell & Associates, 2019)

Second reservoir still remains as prospective resources.

Upon drilling a third well, it becomes evident that the drilling has exceeded the productive limit of the reservoir (see Figure 18). The well is found to be filled with water, indicating that there are no hydrocarbons below a certain depth. Considering this, the area between the wells would contain a range of probable and possible reserves within the high-side case.

Again, there are no changes in the classification of the second sand, which remains as prospective resources.

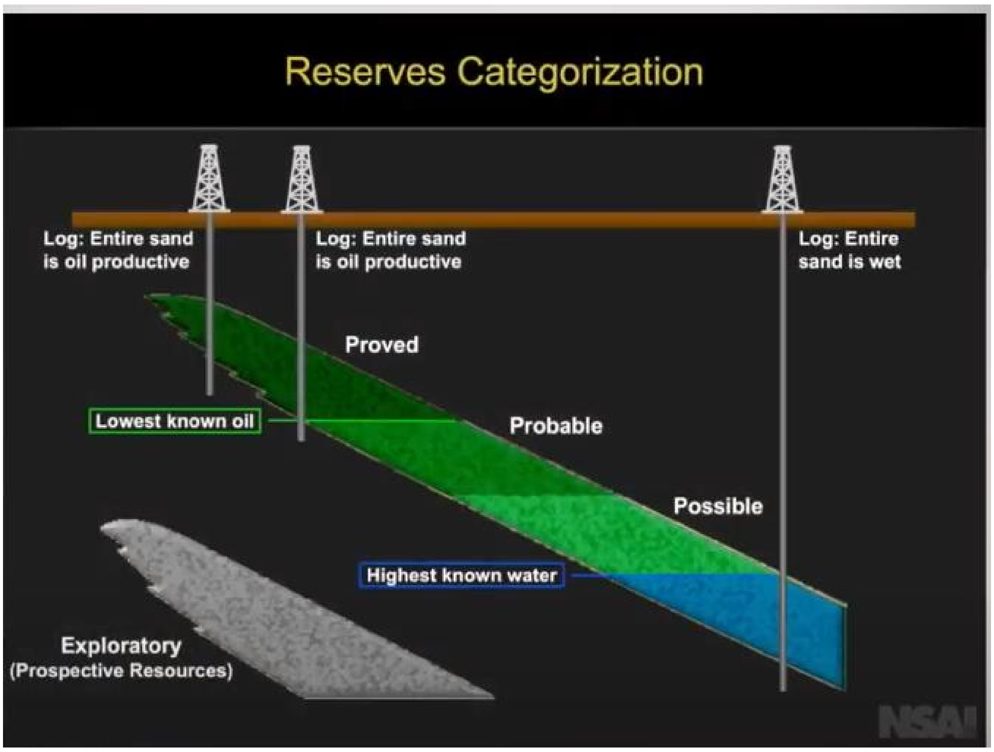


Figure 18 After drilling the third well (Netherland Sewell & Associates, 2019)

Estimation of hydrocarbon resources in Kazakhstan

2.1 History of oil and gas industry of Kazakhstan

Over a century long, the history of Kazakhstan's oil and gas sector is a vast chronicle characterized by the dynamic interaction of geopolitics, technological development, and economic change. It traces a region's development from its modest beginnings as a small-scale oil producer to its rise as a prominent player in the world energy scene. This historical journey serves as evidence of Kazakhstan's determination and strategic vision in making use of its hydrocarbon resources.

1. Pioneering exploration (Late 19th - Early 20th Century):

In the year 1899, a significant milestone was achieved with the successful extraction of the first oil from the pioneering Karashungul oilfield, marking the inception of Kazakhstan's growing oil industry («ZP International» LLP, 2015). These earliest initiatives marked Kazakhstan's emergence as a prospective oil-producing region, although one of small magnitude. A gradual increase in exploration and production activity was observed in the region as the world came to understand the economic possibilities of oil. As depicted in the Figure 19, reminiscent of that era, oil derricks in neighboring Azerbaijan's Baku provide a visual glimpse into the prevailing landscape of oil exploration at that time.

Figure 19 Oil derrick in Baku in the beginning of 20th century (Chapple, 2021)

2. Industrialization during USSR period (1920s - 1991):

The Soviet era brought about a seismic shift in Kazakhstan's oil and gas landscape. The oil fields in the area became significant economic drivers for the Soviet Union and supported the country's overall industrialization ambitions. Major oil fields like Dossor, Makat and Uzen were found, which sped up industrial development and made Kazakhstan a prominent oil-producing region inside the USSR.

3. Independence and the debut of foreign investments (1991 - 2000s):

The Soviet Union's collapse in 1991 was a turning point for Kazakhstan's oil and gas sector. After gaining its independence, the country set out to reformat its energy industry. Kazakhstan was constantly seeking out foreign investments and expertise as it tried to profit from its large hydrocarbon reserves. Partnerships were formed with foreign oil businesses during this time, which sparked an increase in exploration, production, and infrastructure building.

One of the most transformative moments in Kazakhstan's oil and gas journey occurred with the discovery of the Tengiz field, a monumental find that profoundly reshaped the landscape and attracted substantial investments (Figure 20). The Tengiz field currently produces an average of approximately 600,000 barrels of oil per day. It is estimated to hold recoverable reserves ranging from 6 to 9 billion barrels (KazEnergy, 2021).

Figure 20 Tengiz oilfield (Konyrova, 2016)

4. Historical initiatives and technological difficulties (2000s - 2010s):

The early 2000s witnessed the launch of transformative projects that aimed to continue to unlock Kazakhstan's hydrocarbon potential. Among these projects, the Kashagan oil field stood out as a proof to human inventiveness and engineering competence (Figure 21). Situated on the Caspian Sea shelf, Kashagan employs artificial islands for production operations. Its daily oil production averages around 400,000 barrels, and its recoverable reserves are estimated to exceed 10 billion barrels. However, its development was affected by technical complexities, cost overruns, and environmental considerations, highlighting the challenges of extracting oil from complex and remote environments. During this era, Kazakhstan also embarked on infrastructure initiatives, including the construction of pipelines and export routes.

Figure 21 Kashagan oilfield (Parkhomchik, 2020)

5. Sustainable development and managing global dynamics (2010s - Present):

The latter part of the 2010s marked a phase of strategic recalibration for Kazakhstan's oil and gas industry. The sector struggled with evolving global energy dynamics, including fluctuations in oil prices, changing consumer preferences, and a growing emphasis on sustainability. Kazakhstan responded by modernizing regulations, embracing advanced technologies, and exploring avenues for sustainable energy development. Efforts to optimize oil recovery techniques, adopt environmentally responsible practices, and diversify energy sources gained prominence.

Overall, the history of Kazakhstan's oil and gas industry showcases the intricate interplay between geopolitical forces, technological innovation, economic imperatives, and environmental consciousness. As Kazakhstan continues to shape its energy future, its historical journey serves as a valuable lesson in navigating the complexities of a dynamic global energy landscape.

Based on official records, Kazakhstan has discovered a little more than 250 fields up to the present time. Within this context, approximately 55 active oil and gas fields are presently involved in production activities (KazEnergy, 2021). Fields of significant prominence include Kashagan, Tengiz, Uzen, Karachaganak, Zhanazhol, and Kalamkas, which collectively contribute to about 90% of the country's total oil production. The remainder of oil production is managed by smaller enterprises operating within the region.

2.2 Global oil and natural gas reserves

The distribution of global oil reserves by countries is as follows (Figure 22). In terms of oil reserves, the leading countries are Venezuela, Saudi Arabia, and Canada, while Kazakhstan ranks 12th with approximately 3.9 billion tons of oil reserves.

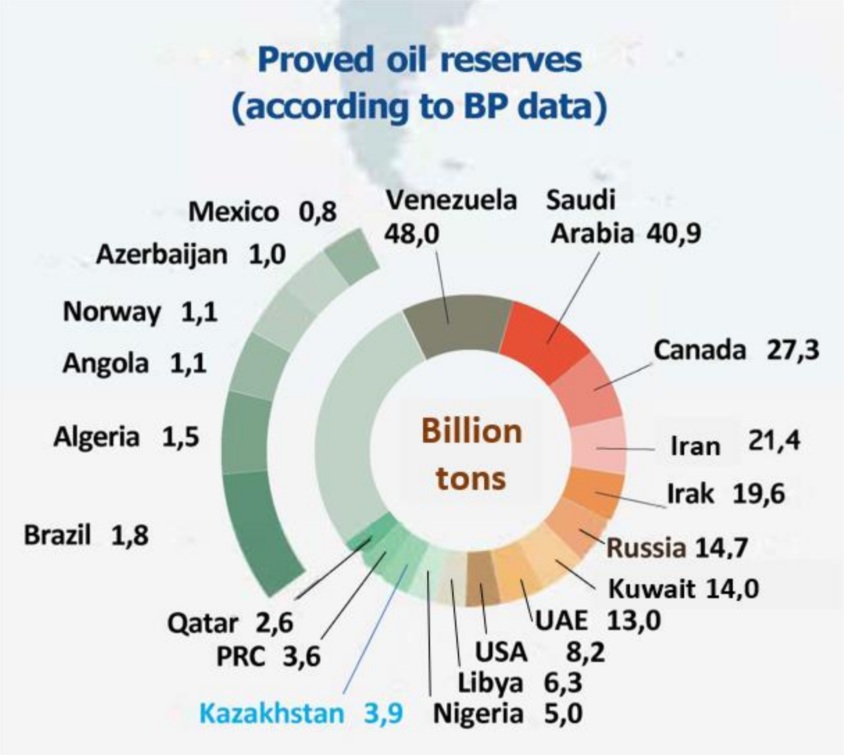


Figure 22 Proved oil reserves (KazEnergy, 2021)

Proved natural gas reserves on a global scale, categorized by countries, are outlined below (Figure 23). The top three nations in terms of natural gas reserves are Russia, Iran, and Qatar. Kazakhstan holds the 14th position with an estimated 2.7 trillion cubic meters of natural gas reserves.

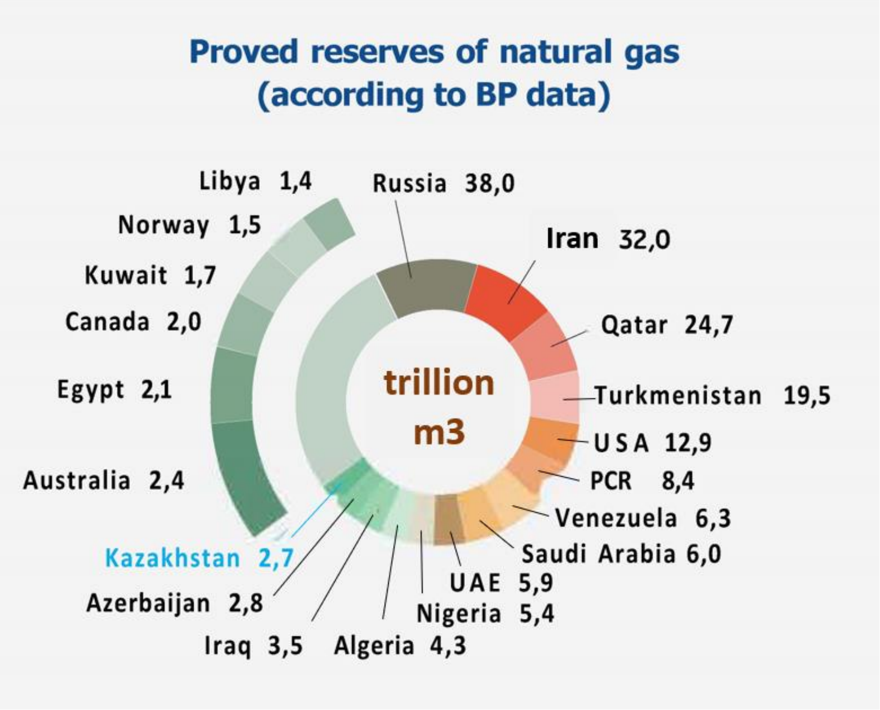


Figure 23 Proved natural gas reserves (KazEnergy, 2021)

2.3 Current system for hydrocarbon resources calculation in Kazakhstan (GKZ)

In Kazakhstan, hydrocarbon resource estimation dates back to 1928, when the country used to be a part of the USSR. During this pivotal year, the Soviet system for reserve assessment was first implemented. This pioneering initiative adopted ideas from estimating techniques used in the field of minerals and ores that had its beginnings in the corridors of the London Institute of Mining and Metallurgy in 1902 and the United States in 1907 (Mukanov & Zhumadil, 2021).

The first Soviet definitions encompassed the following distinctive categories:

1. **Category A**: Reserves that could be effectively extracted using the existing wells.
2. **Category B**: Reserves that held the potential for successful extraction through new wells.
3. **Category C**: Prospective reserves lying beyond the confines of the explored territory.

This classification system set out on a path of improvement, progressively changing over time. After that, Category C was divided into the more distinct parts C1, C2, and C3. Moreover, this evolution resulted in the introduction of reserves categorized as D1, D2, and D3. Following Kazakhstan's attainment of independence in 1991, the nation continued the use of the Soviet reserves estimation system, albeit with certain adaptations. Based on local field experience, subsequent upgrades were implemented in 2005 and 2023.

Today GKZ system comprises proven reserves (categories A, B, C1) and prospective resources (categories C2, C3, D1, D2). Further details outlining the reserve estimation system can be found in Table 3.

GKZ main principles are as following:

- Incorporation of Soviet legacy: The GKZ system has its roots in the Soviet oil industry's practices and methodologies.
- Emphasis on geological exploration: The GKZ system places a strong emphasis on geological exploration and understanding the geological characteristics of reservoirs.
- Complex classification: Reserves are classified into multiple categories based on their level of geological certainty and development maturity.
- Reliance on government approval: Reserves estimation and reporting in the GKZ system often require government approval and validation.

Table 3 Description of the categories of reserves

Reserves	Category	Description
Proven reserves	A	• Well-detailed reserves from a developed (drilled) reservoir • Calculated within an approved field development plan • Extensively studied including detailed structural, reservoir, and fluid parameters (Committee of Geology of the Ministry of Industry and Infrastructural Development of the RoK, 2023). • Form the foundation for optimizing hydrocarbon extraction processes. • Category A is applied when production exceeds 80%.
	B	• Sufficiently detailed reserves from a developed (drilled) reservoir • Provides a reliable understanding of structure, reservoir attributes, fluids, and productivity.
	C1	• Reserves confirmed by well testing or well logging • Provides basis for field development planning • During the exploration (appraisal) stage, the reserves calculation boundaries are established within a radius twice the distance of the well drainage zone, determined empirically. • At the production stage the boundaries are set within a radius twice the distance between production wells.
Prospective resources	C2	• Resources in undiscovered parts of the reservoir supported by geological and geophysical studies • To be proved by drilling a well • Used in the design of exploration projects and projects of trial operation of the reservoir.
	C3	• Perspective resources used for planning exploration drilling. • Shape, size, and occurrence are estimated using geological and geophysical studies • Compared to known analogs.
	D1, D2	• Potential resources according to the regional geology. • Category D1 involves forecasted resources within larger regional structures with proven commercial potential, assessed using regional geological and geophysical data and comparisons to known reservoirs. • Category D2 represents forecasted resources within large regional structures without proven commercial potential.

The McKelvey box provides a visual representation that effectively demonstrates the difference between reserves and resources (see Figure 24).

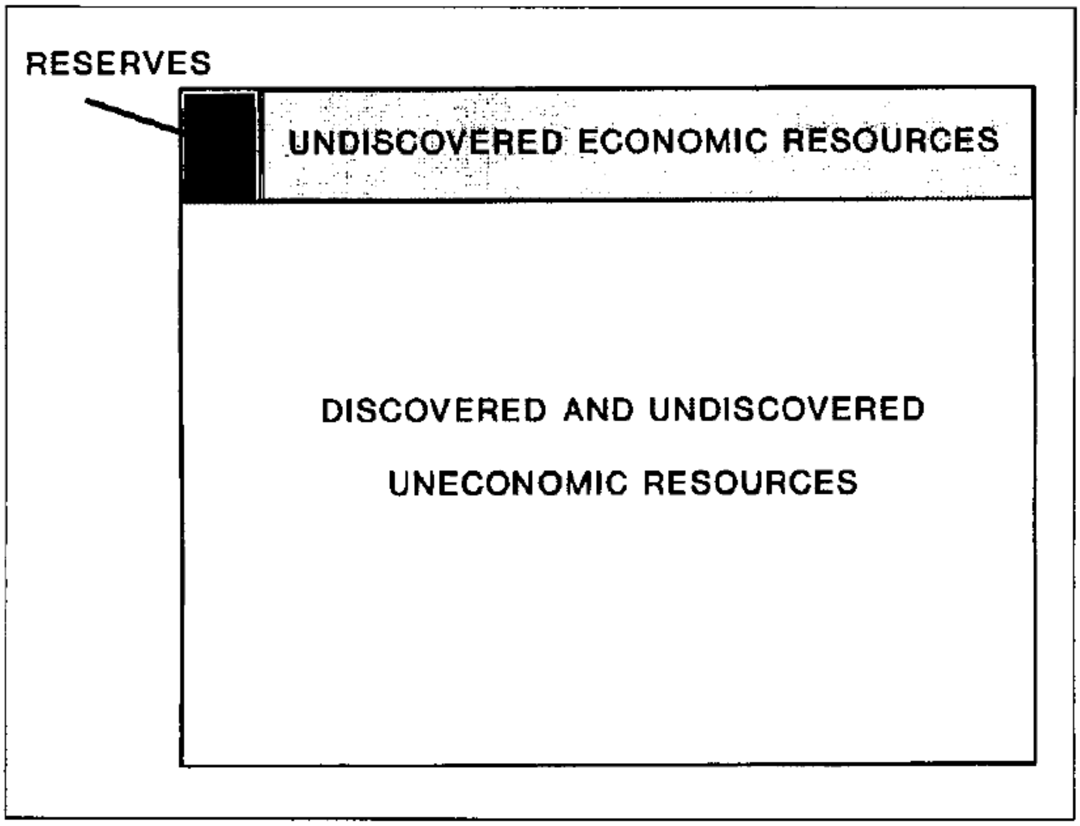


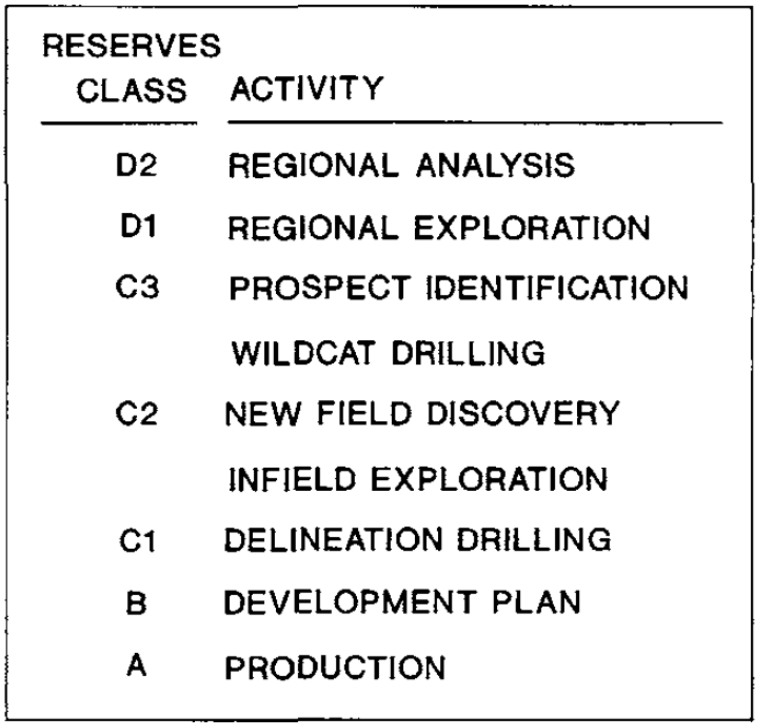
Figure 24 McKelvey box with reserve and resource scaled distinction (Grace, Caldwell, & Heather, 1993)

The diagram depicts a scaled comparison of their sizes, clearly showing that reserves are notably smaller than resources. This visual emphasizes the ongoing importance of the conversion of resources into reserves for long-term planning and development.

In the Kazakh approach, resource and reserve allocation follows a systematic sequence, starting from resource identification, moving through delineation, and culminating in the conversion of resources into reserves (Grace, Caldwell, & Heather, 1993). This classification distinguishes resources and reserves based on their stage within this progression. For a clearer grasp of reserve allocation, refer to Figure 25 below.

As an illustrative example, consider an exploration and production program for a promising area. It will follow the following sequence:

1. Begin with a regional analysis to calculate D2 reserves.
2. If the area shows potential, initiate regional exploration, advancing to D1 reserves.
3. Identify prospective targets for exploration drilling, marking the transition to C3 reserves.
4. Upon a new field discovery, categorize the reserves as C2.
5. Delineate the reservoir to precisely determine its size, leading to C1 reserves.
6. Develop a field development plan, resulting in B reserves.
7. Finally, commence production, resulting in A reserves.



RESERVES CLASS	ACTIVITY
D2	REGIONAL ANALYSIS
D1	REGIONAL EXPLORATION
C3	PROSPECT IDENTIFICATION
	WILDCAT DRILLING
C2	NEW FIELD DISCOVERY
	INFIELD EXPLORATION
C1	DELINEATION DRILLING
B	DEVELOPMENT PLAN
A	PRODUCTION

Figure 25 Reserve classification based on stage of activity (Grace, Caldwell, & Heather, 1993)

Regional analysis and exploration

Initially, a regional geological analysis and study of analogous reservoirs are conducted to obtain a rough estimate of resources, which correspond to D2 reserves. If other field discoveries exist in the same region, D2 reserves can be upgraded to D1. At this point, hydrocarbon accumulations can be identified, although wildcat drilling is not yet initiated (Grace, Caldwell, & Heather, 1993).

Prospect identification

The exploration stage is initiated to assess potential prospects. Utilizing seismic and geological data, an estimation is performed, categorizing reserves as C3. Subsequently, a wildcat well is drilled to confirm the presence of hydrocarbons. If discovery is confirmed, the reserves are upgraded from C3 to C2 category.

Field delineation

Continuing the process, the field is further delineated through the drilling of confirmation wells, accompanied by well testing and logging. This information guides the reclassification of reserves from C2 to C1 category. The distinction between C2 and C1 reserves is depicted in the Figure 26. Additionally, simultaneous exploration efforts may lead to the identification of potential accumulations, initially categorized as C3 reserves until confirmed.

Approval of field development plan and production

Once C1 reserves are confirmed and granted approval by GKZ, a field development plan is crafted, facilitating the elevation of C1 reserves to the B category (Grace, Caldwell, & Heather, 1993). This transition is influenced by the inclusion of surface infrastructure design and market sales strategies outlined in the field development plan. Subsequently, upon the initiation of production, B reserves are elevated to the A category. It is important to note that both A and B category reserves align closely with the concept of proved reserves as per PRMS.

It is crucial to adhere strictly to this sequential process of reserves upgrade, avoiding any deviations. As development activities persist and fresh data becomes available, reserves progress methodically to the subsequent category within the predefined sequence.

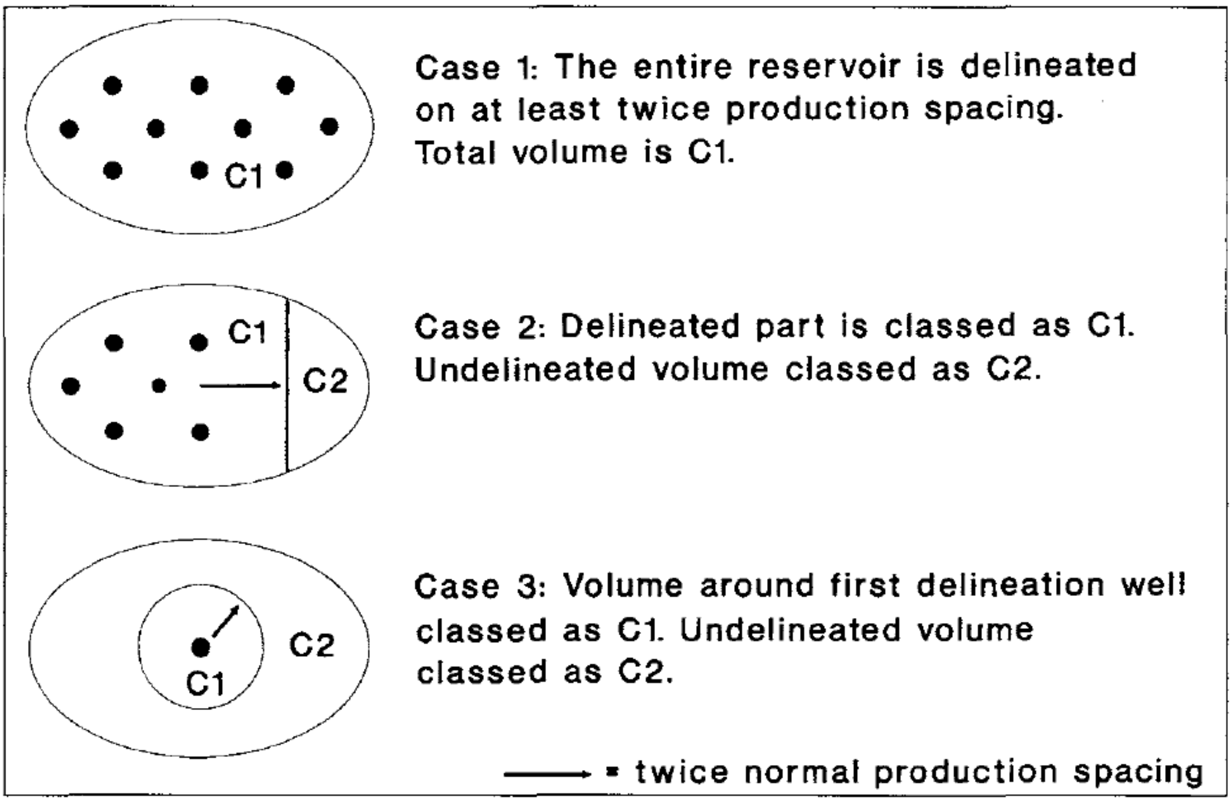


Figure 26 C2 and C1 reserves differentiation (Grace, Caldwell, & Heather, 1993)

2.4 Approval process

The process of estimating reserves is backed by a relevant report, which must include a section providing both technical and economic rationale for the recovery factor. These reports are subjected to evaluation and presentation at the regional branches of the Committee of Geology, culminating in endorsement by state examination of the Committee of Geology (referred to as GKZ).

A field with established recoverable reserves is handed over to a subsoil user for commercial exploitation under specific conditions:

- An official assessment of reserves and a feasibility study for recovery factors have been approved by state examination.
- The environmental impact analysis has been evaluated.
- The level of knowledge of the reservoir based on categories (A + B + C1) exceeds 50%.

In fields undergoing development, the progression of reserves is systematically updated from category C2 to category C1 and then to category "B" as per data from drilling and well testing (Committee of Geology of the Ministry of Industry and Infrastructural Development of the RoK, 2023).

2.5 Guidelines for reserve estimation

State examination (GKZ) appointed by the Committee of Geology has established guidelines for reserve estimation, against which all reserve estimation reports are evaluated. The key criteria for the total reserves' calculation section include:

- Reserve estimation necessitates support from a 2D or 3D geological model.
- When data is limited, applicable analog field data can be employed.
- Volumetric analysis should utilize weighted average values of input parameters.

The prerequisites for justifying the recovery factor include:

- Evaluation of recoverable hydrocarbon reserves based on technical and economic assessments of various reservoir development approaches (feasibility study).
- Utilization of material balance, statistical techniques, and 3D geological and dynamic models to calculate technological development indicators.
- Incorporation of internationally recognized technologies for production optimization.

A feasibility study of oil recovery factor is conducted based on data from a minimum of 5 development options (see Table 4). The calculation of technological indicators for development options involves the methods described in Table 5.

Table 4 Description of development options

Development option	Description
1	The base scenario aligned with approved option according to the ongoing project document.
2	A scenario with the optimal location of the grid of wells with the reservoir pressure maintenance system (if feasible).
3	A scenario with an increased number of production wells with reservoir pressure maintenance (if feasible).
4	If applicable, a recommended option previously endorsed in reserves calculation.
5	If applicable, the first 4 recommended options, but utilizing new oil recovery technologies or established but previously unused methods.

Table 5 Methods for calculation of development option indicators

Method	Description
Coefficient Method	Recovery factor is determined through coefficients like displacement efficiency, sweep efficiency, and waterflooding coefficient.
Material Balance Method	Applies the law of the constancy of matter, equating initial fluid amounts to produced and remaining hydrocarbons. Calculation of recoverable reserves relies on changes in reservoir pressure and liquid-gas ratios during development.
Statistical Method	Analyzes well flow rate decline curves, generalizing statistical data from the past and extrapolating future patterns.

Comparison of PRMS and GKZ reserve estimation systems

PRMS and the Kazakhstan GKZ system differ primarily in their approach to reserves. PRMS focuses on separating and localizing reserves to assess commercial viability, while GKZ spreads reserves for unexplored reservoir parts, emphasizing exploration and evaluation. This divergence stems from the Soviet oil industry's emphasis on geological exploration, whereas Western practices prioritize economically efficient, detailed reserves for oil production (Mukanov & Zhumadil, 2021).

Moreover, the disparity between PRMS and GKZ reserve estimation systems lies in their methodologies for calculating economically recoverable reserves. PRMS adopts a conservative method grounded in existing technology and economic feasibility. In contrast, GKZ emphasizes achieving the maximum attainable recoverable reserves based on theoretical considerations. For instance, GKZ might incorporate untested techniques like Enhanced Oil Recovery (EOR) for production enhancement or costly chemicals for increased recovery, without necessarily factoring in their practicality. As a result, the GKZ system tends to lead to overestimation of reserves compared to the PRMS approach.

To address the issue of overestimated reserves, the GKZ approach introduces a further subdivision of reserves and resources into distinct "booked" and "unbooked" categories (Grace, Caldwell, & Heather, 1993). The "booked" category encompasses economically feasible reserves and resources that align with the technology available up to that point. In contrast, the "unbooked" category pertains to economically unviable reserves and resources.

Additionally, within the "booked" category, a finer division occurs, resulting in extractable and unextractable subcategories. Extractable reserves and resources go beyond technological considerations to include the budget allocated by the company. This nuanced approach acknowledges both technological feasibility and the financial capacity to extract those resources.

A visual representation comparing the PRMS and GKZ (Soviet) reserves estimation approaches is presented below (Figure 27). The geological certainty exhibits a degree of similarity and convergence between these two systems, resulting in some overlap within categories. The correlation between the reserve and resource classifications of PRMS and GKZ is detailed in the Table 6.

Table 6 Categories of reserves and resources in PRMS and GKZ

PRMS category	GKZ category
Proved Developed Producing Reserves	A
Proved Developed Non-Producing Reserves	B
Proved Undeveloped Reserves	C1
Probable Reserves	C1 and C2
Possible Reserves	C2
Possible Resources	C3
Potential Resources	D1 and D2

However, it is worth noting that due to their distinct approaches and definitions, the alignment of reserve and resource categories between PRMS and GKZ is challenging. An especially notable divergence emerges in terms of economic feasibility. GKZ often tends to overestimate economic reserves and resources, illustrated by the dotted line in Figure 27. This divergence hampers the seamless alignment of the systems and presents a challenge in accurately reconciling recoverable reserves.

The GKZ system aims to address overestimated recoverable reserves and resources by introducing "booked" and extractable categories, which conceptually resemble PRMS's proved reserves. However, it is evident that the outcomes will not be directly comparable, necessitating new calculations that begin with geological reserves to accurately compute recoverable reserves according to PRMS standards.

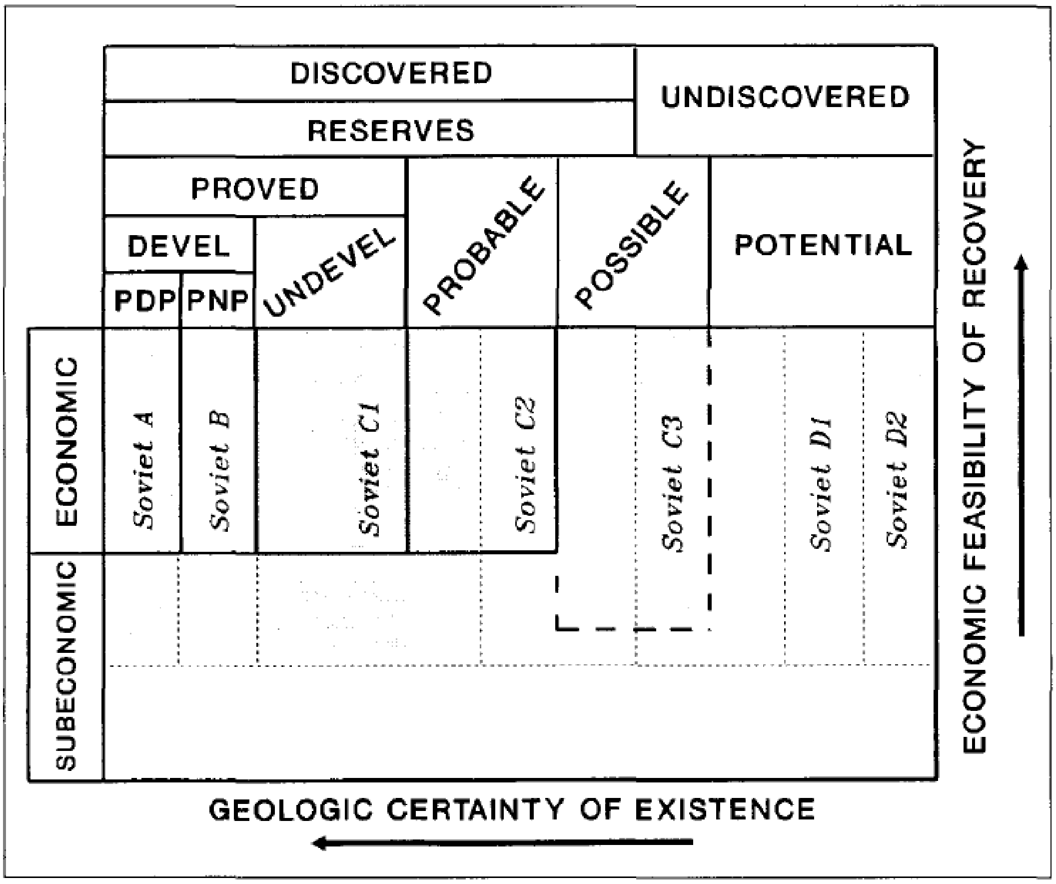


Figure 27 Comparison of PRMS and GKZ systems (Grace, Caldwell, & Heather, 1993)

Below are additional parameters that distinctly differentiate the two reserve estimation systems.

3.1 Reserves classification and categorization

As described above GKZ reserve estimation system comprises seven categories - A, B, C1, C2, C3, D1, and D2, but in practical terms, oil and gas companies mainly consider four categories: A, B, C1, and C2 (Mukanov & Zhumadil, 2021). A and B are relevant for development, C2 - for exploration, C1 - for both stages. In practice A, B, and C1 serve similar purposes in development, with the movement of reserves between categories due to maturity of the field not significantly impacting field development, economics, or technology. The distinction among categories A, B, and C1 in the GKZ system lacks practical significance for operators.

Conversely, PRMS system categorizes reserves into proven, contingent, and prospective resources, with varying probabilities (90%, 50%, 10%), which is not present in the GKZ system.

3.2 Evaluation of recovery factor

In GKZ reserve estimation approach recovery factor is calculated using the empirical formula below:

$$Recovery\,factor = E_p * E_a * E_v$$

Where E_p – displacement efficiency, E_a – areal sweep efficiency, E_v – vertical sweep efficiency (Mukanov & Zhumadil, 2021).

Displacement efficiency is established through core analysis, areal sweep efficiency relies on well grid configuration, and vertical sweep efficiency is influenced by the pattern of waterflooding. Given that areal and vertical sweep efficiencies tend to remain relatively constant, the recovery factor is primarily contingent on the displacement efficiency derived from laboratory conditions.

Instances exist where core analysis outcomes exaggerate displacement efficiency and thus recovery factor. Additionally, scenarios arise where waterflooding is not applicable or has not been tested in the field, leading to inaccuracies in estimating recoverable reserves (Mukanov & Zhumadil, 2021).

In PRMS, the recovery factor is derived from analogous fields, which is considered more dependable than the coefficient method mentioned earlier. Additionally, recovery factor is variable and influenced by factors such as enhanced recovery methods and waterflooding strategies.

In summary, PRMS takes a cautious stance, considering only proven technologies and economic realities for recoverable reserves, while the GKZ system encompasses both existing and theoretical, unproven technologies, potentially leading to an overestimation of commercially recoverable reserves (Mukanov & Zhumadil, 2021).

3.3 Economics

In the GKZ reserve calculation process, the first stage involves establishing the technological oil recovery factor, representing the maximum theoretically attainable recoverable reserves. Subsequently, these reserves are subjected to economic feasibility adjustments, which include manipulating factors like costs and hydrocarbon prices (Mukanov & Zhumadil, 2021). Moreover, the absence of economics specialists in the GKZ state commission often results in overlooking the economic aspect. This can lead to inflated recovery factors and reserves that are economically unviable.

In contrast, the PRMS system prioritizes economics as a fundamental factor in the assessment of reserves.

3.4 Commerciality

GKZ system requires a significant portion of C1 category reserves for commercial operation. In all other cases development and production of reserves is restricted. A practical example is illustrated below.

Two wells were drilled in a licensed area shortly before the contract's expiration. The first well produced oil, classifying it as C1 reserves. The second well identified similar layers, but due to time constraints, it was not tested, resulting in its classification as C2 reserves during estimation. This yielded a C1 to C2 ratio of 1 to 4 (Figure 28).

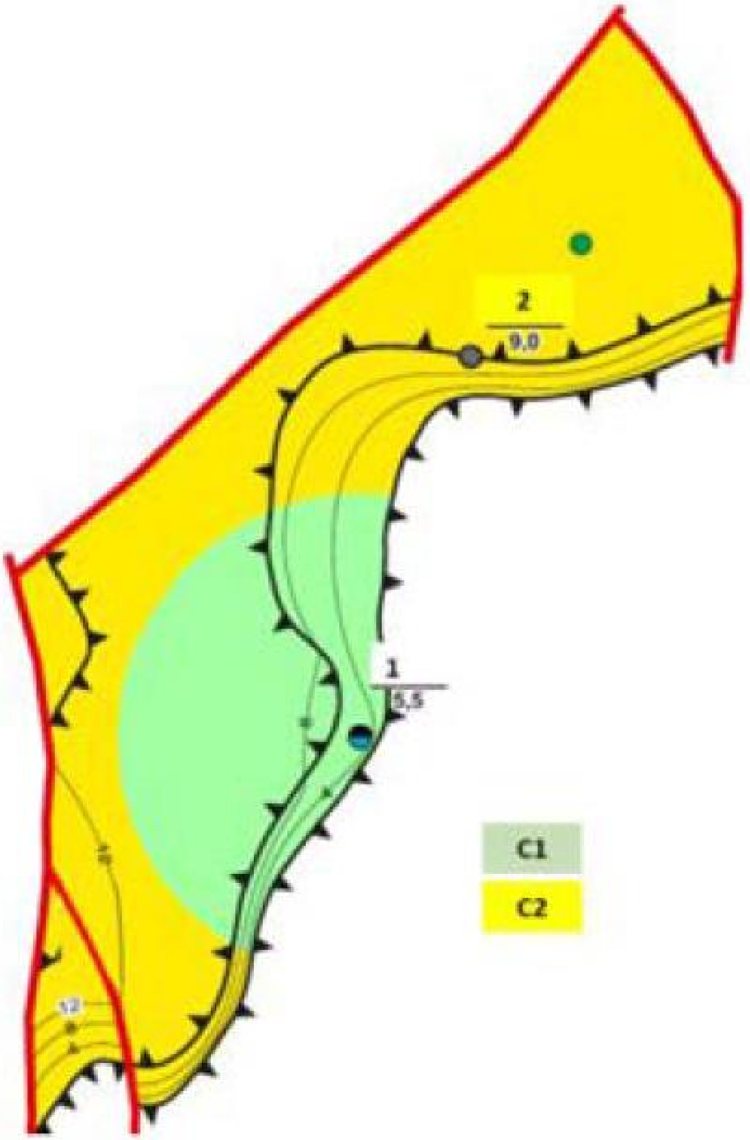


Figure 28 C1 and C2 reserve distribution
(Mukanov & Zhumadil, 2021)

In this context, the GKZ's refusal to accept the reserve estimate report as commercially viable results in lost opportunities for the company. This approach seems to discourage exploration investment and adds unnecessary complexity to converting exploratory wells into production wells, requiring additional time, effort, and financial resources (Mukanov & Zhumadil, 2021). Given the significant number of mature fields, such an approach hampers exploration efforts and could even contribute to company closures and regional social instability.

PRMS does not impose constraints on the commercial readiness of a reservoir. If an operator drills one or two wells and achieves economically viable production, they can promptly commence operations.

3.5 Procedure for approval of reserve estimation reports

In the GKZ system, reports are 200-300 pages long, including geological and oil recovery factor sections. The feasibility study of oil recovery factor often duplicates 70% of geological content, and reporting can take months to even years depending on reservoir size (Mukanov & Zhumadil, 2021).

Upon completion, the report undergoes about two months of evaluation within the regional branches of the Committee of Geology, followed by a three-month independent expert review. The final step involves a state examination, resulting in the issuance of a meeting minute. Overall, the coordination and approval process take up to six months. Thus, for subsoil users discovering a reservoir, the reserve calculation and approval procedure spans from a minimum of six months to potentially several years.

Beyond report compilation and approval, operators are also required to formulate and endorse a field development plan aligned with the reserves, a process that can be equally time-consuming. The reserve estimation report includes a section where the recovery factor is calculated using the coefficient method, followed by adjusting the development plan to these recoverable reserves. This approach raises concerns about the feasibility of a plan based on unverified recoverable reserves. Notably, a field development plan is eventually formulated after reserve estimation, often with a different development system from the initial indication but based on the approved recovery factor. This raises questions about the rationale behind including a potentially unfeasible plan in the calculation of reserves.

This standardized process translates to a timeline of 2 to 3 years from discovery to commissioning and development, irrespective of the discovery's size (see Table 7). Such uniformity may deter operators with smaller reserves and hinder proactive geological exploration endeavors.

Table 7 Timeline for approval by government

Steps	Description	Duration	Note
1	Compilation of GKZ reserve estimation report	~ 6-12 months	Depends on reservoir size
2	Evaluation at the regional branches of the Committee of Geology	2 months	
3	Independent expert review	3 months	
4	State examination and issuance of MOM	~ 7-10 days	
5	Compilation of field development plan with corresponding approvals	~ 1-1,5 years	Depends on reservoir size
Total		**~ 2-3 years**	

Under PRMS, operators must submit a detailed field development plan that outlines strategies for extracting, transporting, and selling reserves via existing pipelines. Moreover, the field development plan is influenced by factors such as the exploitation area, duration, production limits, and contract terms (Nascimento, Santos, & Schiozer, 2018). This plan offers evaluators insight into the operator's intentions and future actions.

3.6 PRMS and GKZ similarities

PRMS and GKZ similarities can be summarized as follows:

1) Reserves Estimation Methods: Both PRMS and GKZ utilize similar methods for estimating hydrocarbons originally in place, including analog, volumetric, and performance-based approaches. These methods aim to provide a comprehensive understanding of the potential resources in a reservoir.
2) Geological Certainty and Economic Feasibility: Both PRMS and GKZ take into account the geological certainty of reserves' existence and the economic feasibility of their recovery. This dual consideration ensures that estimates are not only based on geological data but also aligned with the economic viability of extraction.
3) Field Development Planning: Both systems recognize the importance of developing a comprehensive field development plan once resource estimation is completed. This plan outlines the strategies, technologies, and investments required to bring the reserves into production effectively.
4) Resource Classification: Both systems incorporate a classification framework for categorizing hydrocarbon resources based on geological certainty and development maturity.
5) Framework Evolution: Over time, both PRMS and GKZ have undergone updates and modifications to reflect changing industry practices, advancements in technology, and the need for accurate resource assessments. These updates ensure that both systems remain relevant and effective.

These similarities highlight the foundational principles that underlie both PRMS and GKZ, contributing to standardized and accountable reserve estimation practices.

3.7 PRMS and GKZ differences

PRMS and GKZ differences are shown in the Table 8 below.

Table 8 PRMS and GKZ differences

No.	PRMS	GKZ
1	Focuses on separating and localizing reserves to assess commercial viability	Prioritizes unexplored segments of reservoir, highlighting the significance of exploration.
2	Adopts a conservative method grounded in existing technology and economic feasibility	Seeks to achieving the maximum recoverable reserves based on theoretical considerations
3	Recovery factor is based on analog fields	Recovery factor is calculated by empirical formula
4	Resources are classified based on maturity level and categorized based on geological knowledge	Resources are classified based on stages of exploration and development
5	Reserves, contingent, and prospective resources	A, B, C1, C2, C3, D1, and D2 categories of resources
6	Uncertainty is considered by using deterministic or probabilistic approach	Uncertainty is not taken into account
7	Does not impose constraints on the commercial readiness of a reservoir	Requires a significant portion of C1 (proved) category reserves for commercial operation

PRMS and other reserve estimation systems

In several regions throughout the world, PRMS has become widely used, especially in areas with sizable oil and gas operations. Here are the countries where PRMS is frequently used:

- **Australia:** To maintain transparency in the energy industry, Australia uses PRMS to assure accurate and regular reporting of its oil and gas reserves.
- **Brazil:** As a significant participant in the global oil market, Brazil uses PRMS to evaluate and disclose its hydrocarbon reserves in order to draw both domestic and foreign investment.
- **Saudi Arabia:** A significant OPEC member, Saudi Arabia uses PRMS to deliver accurate data on its enormous oil reserves, which is essential for the stability of the world energy market.
- **United Arab Emirates:** The UAE, which has sizable oil reserves, uses PRMS to maintain international credibility and openness in its reporting of reserves.
- **Kuwait:** As a major player in the oil market, Kuwait uses PRMS to determine and share the extent of its hydrocarbon reserves.
- **Mexico:** As its energy industry undergoes reforms, Mexico has implemented PRMS to improve the credibility and consistency of its reserves reporting.
- **Nigeria:** As a significant oil exporter, Nigeria uses PRMS to deliver accurate data on its oil and gas reserves.
- A few **Latin American** countries have incorporated the PRMS audit alongside their existing local reserve evaluation methods for assessing reserves (Espinoza, Siciliano, Escobar, & Romero, 2020).

These examples highlight how PRMS is used universally in a variety of oil and gas economies, encouraging consistent and accurate reserve evaluations across the global energy landscape.

The following are other reserve estimating methods used globally:

1. US Securities and Exchange Commission (US SEC)

The US SEC accepted PRMS as the foundation for oil and gas companies doing business in the US to declare their reserves. Both PRMS and the SEC's method for calculating proved reserves employ deterministic and probabilistic techniques (Mukanov & Zhumadil, 2021). This alignment ensures a consistent and transparent approach to reserves estimation and reporting, fostering credibility and reliability in the industry.

In 2009, the SEC conducted updates to its definitions to reflect evolving industry practices. These updates included several key changes:

- The calculation of economics shifted to be based on annual oil prices rather than year-end prices.
- The introduction of the concept of practical technology, encompassing technologies that had been pilot-tested and yielded satisfactory results.

- The inclusion of non-conventional hydrocarbons within the scope of reserves.
- The optional addition of probable and possible reserves alongside proved reserves.

These updates brought the SEC's approach into closer alignment with PRMS, reflecting the dynamic nature of the industry and ensuring consistency in the assessment of hydrocarbon reserves (Acquati, 2012).

2. UK Statement of Recommended Practices (UK SORP)

The UK SORP is a significant guideline aligned with PRMS for the reporting of reserves by companies listed on the London Stock Exchange and provides guidance on its application.

3. Canadian Oil and Gas Evaluation Handbook (COGEH)

The COGEH recognizes the importance of PRMS for Canadian oil and gas companies' reporting of reserves. The COGEH adoption of PRMS demonstrates its dedication to accurate energy resource assessments, which are necessary for sound decision-making and industry credibility in Canada's energy sector.

4. Norwegian Petroleum Directorate (NPD)

The NPD, responsible for overseeing Norway's petroleum resources, aligns its reserves reporting practices with PRMS. By integrating PRMS principles, the NPD ensures transparency, accuracy, and global comparability in its reserve evaluations. This harmonization of reserves reporting enhances the credibility of Norway's reserves data, enabling the country's petroleum industry to manage resources effectively and make informed strategic decisions.

5. United Nations Framework Classification (UNFC)

The UNFC incorporates the foundational principles and guidelines of PRMS while also encompassing social and economic considerations (Figure 29). Axis E stands for economic viability, axis F – for feasibility, axis G – for geological uncertainty (United Nations, 2013).

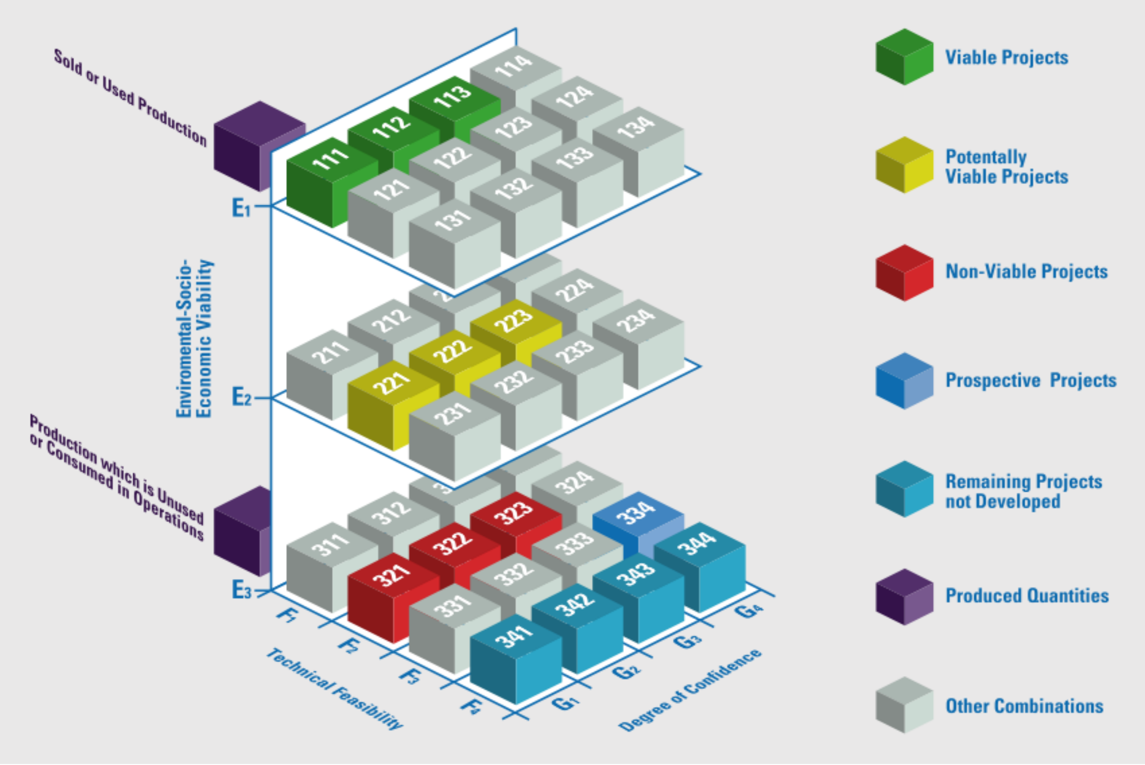


Figure 29 United Nations Framework Classification (Kral, 2020)

E1, E2, and E3 are examples of projects that went from being economically viable to potentially viable to being unprofitable. This inclusive approach factors in elements such as geographical location, existing infrastructure, and environmental impact to facilitate a comprehensive assessment of potential effects. UNFC, like PRMS, emphasizes sustainable development goals for both current and future resource needs (Al-Ghnemi, et al., 2020).

6. Russian Ministry of Natural Resources

On the basis of the lessons learned during the Soviet era, the Ministry of Natural Resources of Russia adopts a similar strategy to the GKZ. The divergence becomes apparent in the project documentation phase. Unlike the GKZ, the Russian system designates separate entities for the initial endorsement of hydrocarbons in place and the determination of the recovery factor (Mukanov & Zhumadil, 2021).

In Russia, the method for estimating oil and gas reserves had been based on a Soviet-era system since 2001 until 2016. However, in 2016, there was a transition to a new reserve estimation system that aligned with the 2009 UN reserve estimation framework. This shift was driven by the intention to better align with global standards and international practices.

The transition to the new reserve estimation system was initially proposed in 2009. However, because of the substantial workload involved in recalculating reserves for all existing fields, the transition process extended until 2016. The findings of the most recent update are shown in the Figure 30.

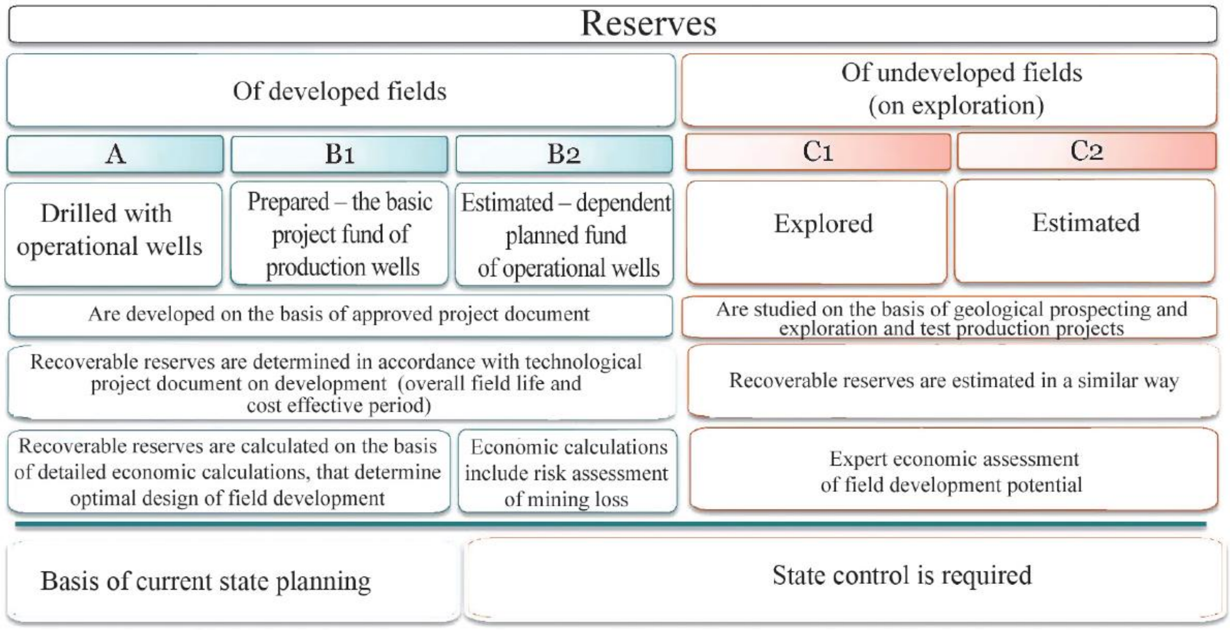


Figure 30 Russian system for reserve estimation (Muslimov, 2016)

Brief review of each category is provided below:

1. **Category A** reserves refer to developed fields, specifically areas that have been drilled by production wells. Historical data indicates that these reserves are typically developed up to around 80%, taking into consideration even full waterflooding. Efficiency is heavily influenced by the geological structure of the field.
2. **Category B** reserves are further subdivided into B1 and B2. Originally, category B referred to areas in fact drilled in accordance with the development project. In the updated interpretation: **B1** represents the prepared primary stock of production wells, while **B2**

encompasses the forecasted and dependent production well stock. Given this unclear definition surrounding categories B1 and B2, they can include areas with wells marked on the map but not drilled.

3. **Categories C1** and **C2** are also unclear. It is possible to classify reserves from C1 and C2 as category B2 without the need for actual well drilling, simply by indicating project wells on the map.

As a result, C1 and C2 in old classification becomes B2 in the new classification and B category in old classification is subdivided into A and B1 (see Figure 31 below).

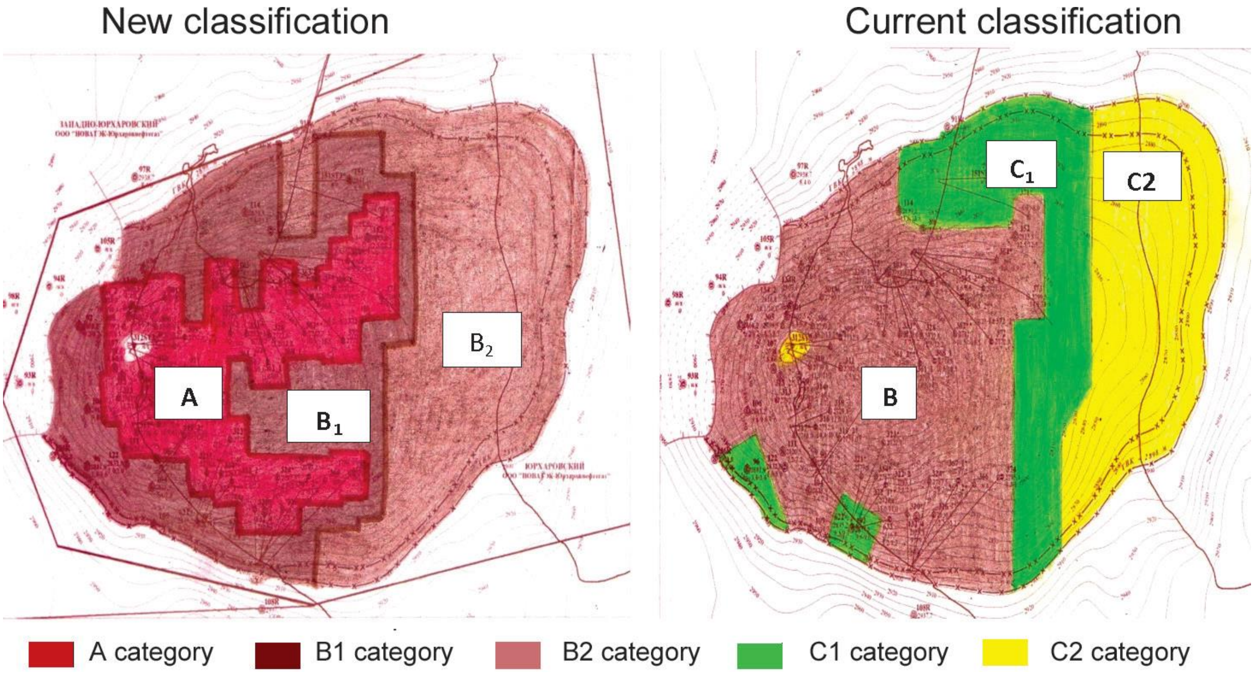


Figure 31 Comparison of old and new classification (Muslimov, 2016)

An additional feature of the new classification is the presence of technological and economical recovery factor. Technologically recoverable reserves are all the hydrocarbons that could be recovered without taking into account the economics.

Economically recoverable reserves are constrained by the period of commercial viability and is necessary to review and approve each development option. This innovation increases the number of calculations and tables in the report, which leads to an increase in preparation time and reduces the quality of work (Muslimov, 2016).

In essence, the wide adoption of PRMS by some countries and its utilization as a foundational framework in others highlights its universal applicability and practicality. This prevalence across diverse geographical and regulatory contexts speaks to the robustness and adaptability of the PRMS methodology.

Opportunities Offered by PRMS

Improved resource management and planning

Kazakhstan can build a uniform and consistent system for calculating reserves and resources by adopting the PRMS methodology. The data generated is accurate, dependable, and comparable across many fields and initiatives due to this standardization. As a result, those who make decisions about exploration, production, and investment have access to reliable information, enabling them to make decisions that are in line with the nation's larger energy goals.

Attracting domestic and foreign investment

Investment from both domestic and foreign sources may be attracted by the PRMS deployment. One of the main factors affecting investor trust is the transparency and predictability of reserves reporting. The methodical approach of PRMS ensures a precise and consistent portrayal of reserves for potential investors. This increased precision may attract more investment, providing the sector with crucial financial resources and promoting its expansion. Additionally, integrating approval processes with PRMS standards may help to significantly lower the risks connected to postponing exploration and production, especially in the case of minor discoveries.

Facilitating sustainable development and local content

Sustainable growth is another important aspect that PRMS may promote. Long-term resource extraction planning is made easier by the framework's emphasis on accurate and reliable reserves estimation. By incorporating sustainable methods into the extraction process, Kazakhstan can ensure the right and responsible exploitation of its hydrocarbon resources. This safeguards not only the environment but also the industry's long-term viability and its contributions to the nation's economic prosperity. The method also promotes the growth of local capacity and knowledge because reserves assessment calls for standardized technical capabilities.

Enhancing transparency and accountability

The improvement of openness and accountability within the sector is a major result of PRMS adoption. The framework promotes open reporting of reserves and resources, creating a climate in which businesses and regulatory bodies are held responsible for their deeds. This transparency extends to a range of stakeholders, including local communities and investors, fostering confidence, and enhancing the sector's reputation for ethics.

The PRMS approach's adoption in Kazakhstan's oil and gas industry is a strategic step with enormous potential for improvement. Standardized reserves estimation can help the nation manage resources more effectively, draw in investment, promote sustainable growth, and increase transparency. By taking advantage of these chances, Kazakhstan can steer its oil and gas sector toward a future marked by development, sustainability, and prudent resource management.

Challenges in Successful PRMS Implementation

Enhancing data management and gathering processes

A crucial element in ensuring the effective application of the PRMS framework in developing nations like Kazakhstan is the improvement of data collecting and management systems. In order to do this, strong processes must be put in place that make it possible for essential geological, technical, and economic information about oil and gas reserves to be thoroughly collected, verified, and stored securely.

Utilizing cutting-edge technology solutions is crucial to enhancing the efficiency of data collection in the contemporary digital environment. Using contemporary software tools, digital databases, and cloud-based platforms can substantially simplify the process. These solutions lessen the potential of errors and inconsistencies originating from human data management by automating data entry, validation, and reconciliation processes.

The ability to easily cross-reference and analyze numerous data sources is made possible by centralizing them into one unified digital repository. Making informed decisions about exploration, production, and investment plans requires access to reliable, up-to-date information. The integration of various datasets, including geological surveys, well logs, seismic data, and economic indicators, is also made possible by a well-structured data management system, which contributes to a thorough and all-encompassing assessment of reserves.

Implementing data security protocols is also essential for safeguarding private and sensitive data. To prevent data loss and breaches, this includes encryption, access limits, and regular backups.

Strong data management systems have advantages that go beyond estimating reserves. They serve as a foundation for future technical developments like artificial intelligence and machine learning, which can give the oil and gas sector better insights and predictive analytics.

Enhancing technical infrastructure and capacities

The PRMS framework for reserves evaluation must be successfully implemented, and this requires both investments in modern infrastructure and advancements in technological know-how. This tactical approach not only speeds up the evaluation process but also ensures the precision and dependability of estimates by allocating cash to the procurement and integration of cutting-edge technologies.

One of the key areas of investment is in contemporary geophysical instruments. These tools, such as seismic imaging and electromagnetic surveys, provide invaluable knowledge on subsurface geological formations. Geophysical technologies allow us to precisely map the structural complexity of reservoirs and their fluid dynamics, which improves our understanding of the distribution of reserves. As a result, it is simpler to make decisions about drilling locations, reservoir management, and eventually extraction techniques.

Another crucial development in technology is software for reservoir modeling. These cutting-edge software frameworks simulate the behavior of oil reservoirs by modeling various situations. Through reservoir modeling, reservoir engineers can assess variables such as fluid flow dynamics, pressure variations, and production projections. This data-driven approach aids in optimizing production strategy and reserve calculations.

Data analytics technology can be used to improve the accuracy of the reserves evaluation procedure. Data analytics techniques can be used to process huge amounts of geological, geophysical, and production data to look for patterns, trends, and correlations. Better risk analysis, better strategic planning, and more informed decision-making are made possible by these discoveries.

A solid IT infrastructure must be developed in order to process, store, and share data effectively. Stakeholders can collaborate and access crucial data from various locations due to the scalability and accessibility provided by cloud-based solutions.

The oil and gas sector is driven to innovate and enhance the accuracy of reserve evaluations through the promotion of technological advancements. By implementing modern tools and practices, nations like Kazakhstan may increase exploration and production efforts, reduce operational risks, and keep their competitiveness in the global energy market.

Promoting efficient governance and regulatory frameworks

A key element of a successful PRMS deployment for reserves assessment is the development of strong regulatory frameworks and governance mechanisms. This tactical strategy entails the creation and use of rules that specify how reserves should be handled, reported, and estimated. A strong basis for consistency, transparency, and responsibility within the oil and gas business is provided by clear and thorough regulatory requirements.

First and foremost, it is crucial to create legislation that adhere to global norms. Countries like Kazakhstan may make sure that their systems for estimating reserves are open, precise, and comparable to those of other important participants in the energy industry by adopting practices that are widely accepted. Additionally, this alignment makes it simpler to collaborate, share data, and do global benchmarking.

Equally essential is having a strong governance framework. This system monitors adherence to the rules set out and makes sure that reporting procedures are accurate and consistent with accepted business practices. The governing body may be made up of government organizations, business professionals, and unbiased auditors who collaborate to confirm and validate reserve data.

Effective regulatory frameworks and governance structures strive to promote transparency as a fundamental concept. Increased credibility and confidence among stakeholders, such as investors, regulatory bodies, and the general public, are two benefits of transparent reporting. Countries can improve their position in the world energy market and draw investment by fostering a culture of transparency.

It is crucial to have systems for constant development and adaptation. Along with technology improvements and shifting industry dynamics, the regulatory framework should be structured to change. The framework is kept up-to-date and relevant by conducting regular evaluations to address new opportunities and problems.

In the end, encouraging efficient governance and regulatory frameworks results in a more dependable, accountable, and long-lasting oil and gas sector. Countries may increase investor trust, encourage ethical resource extraction, and contribute to the long-term development of their energy sector by offering a clear roadmap for reserves assessment, reporting, and management.

Benefits and practical proposals for PRMS Implementation in Kazakhstan

1. Calculating recovery factors and corresponding recoverable reserves using analog reservoirs, similar to PRMS, is recommended. The existing GKZ reserve estimation system tends to overestimate recoverable reserves, resulting in potentially inflated overall recoverable reserves for Kazakhstan. While this might improve the country's global ranking, it compromises the accuracy and reliability of data, preventing a true representation of the current state of total reserves. Shifting away from a focus on high recovery factors and embracing transparency would allow economic indicators to accurately assess project viability. This shift would encourage subsoil users to prioritize precise economic metrics, benefiting both the state and companies. Additionally, such transparency would attract foreign investor interest.
2. Adopting PRMS-style classification and categorization of reserves would clarify GKZ's reserve classification. Additionally, probabilistic and deterministic approaches for estimating reserves could be employed. Probabilistic approaches, which evaluate reserves based on numerous conceivable outcomes and their corresponding probability, can give a more accurate and thorough picture of reserve potential. Conversely, deterministic methods for estimating reserves rely on particular facts and presumptions. Combining these methods enables a more thorough assessment of reserves, accounting for uncertainties and giving a clearer picture of what may be anticipated from a particular reservoir.
3. To simplify the process, reports should be submitted as needed. Depending on the size of reserves approval process should be different, allowing for smaller discoveries to get simplified approval. This approach aims to promote exploration and accelerate reservoir development and production.
4. Introducing PRMS reserve calculations will lead to cost reduction in project documentation and consequently overall cost optimization. The savings could be allocated towards production enhancement activities or exploration. Furthermore, this transition is expected to streamline operations by eliminating unnecessary work scopes, ultimately resulting in significant time savings.
5. The field development plan should incorporate PRMS reserves calculation and be submitted simultaneously, given that reserves assessment usually follows the approval of the development plan. Alternatively, approach where the reserves committee approves in-place reserves and recovery factor is determined in the development plan could be considered.
6. Proposed is the evaluation and endorsement of field development plans considering company and field size. With a few large companies driving most production and numerous smaller ones contributing a smaller share, the approach suggests approving major projects at the state level, while smaller ones can be assessed regionally. This prioritizes strategic projects at the national level and encourages regional involvement. Moreover, exploration and evaluation stage projects can be reviewed and approved separately from those in commercial development.
7. The Russian transformation model, which involves transitioning from the previous Soviet-era reserve estimation system to a more contemporary and globally recognized approach, should be thoroughly assessed. This evaluation is essential to avoid any discrepancies or inconsistencies between the resource categories defined under the new system and those from the previous Soviet system.
8. Reports should be available in English as well to improve accessibility for foreign businesses.

Conclusion

The examination of how the Petroleum Resources Management System (PRMS) can be applied in developing countries, with Kazakhstan as a focal point, has revealed a landscape of potential benefits and challenges. The adoption of PRMS in these nations offers a range of advantages, including the enhancement of reserve management and estimation practices, the promotion of transparency and accountability, and the attraction of both domestic and foreign investors. However, its successful implementation necessitates the development of technical capabilities, the establishment of effective regulatory frameworks, and the reinforcement of data collection and management systems.

The analysis also encompassed a thorough comparison of the current reserve estimation system in Kazakhstan, known as the State Reserves System (GKZ), with the PRMS. The evaluation indicated that the GKZ system encounters several issues that could potentially be addressed through the adoption of PRMS. A series of recommendations has been formulated to overcome these challenges and leverage the opportunities presented by PRMS.

The utilization of PRMS extends beyond national boundaries, offering a unified platform for the assessment and administration of petroleum resources on a global scale. By advocating for accurate reserve estimation, transparent reporting, and informed decision-making, PRMS supports responsible and sustainable resource utilization. It facilitates strategic planning, elevates investor confidence, and facilitates international collaboration.

In conclusion, the implementation of PRMS in emerging economies like Kazakhstan has the potential to reshape the landscape of the oil and gas sector. By harnessing its benefits and addressing its associated challenges, countries can optimize their resource management endeavors, attract investment, and contribute to the broader global objective of efficient and ethical exploitation of petroleum resources.

References

Al-Ghnemi, M., Al-Sane, A., Dhote, P., Bora, A., Al-Bahar, M., Purewal, S., . . . Hornbrook, J. (2020). Application of United Nations Framework Classification for Hydrocarbon Reserves and Resources Volumes for a Mature Oil Reservoir in Kuwait. *SPE Annual Technical Conference and Exhibition.* SPE.

«ZP International» LLP. (2015). Retrieved from ZP International: https://zp.kz/en/25/28.html

Acquati, L. (2012). *The Successful Application of PRMS (SPE Petroleum Resources Management System).* EuroMed E&P.

Chapman, C. (1991). Reserves and Probabilities - Synergism or Anachronism? *JPT*, 1258-1264.

Chapple, A. (2021, June 15). Retrieved from Radio Free Europe Radio Liberty: https://www.rferl.org/a/baku-oil-fields-historical-photos-nobel/31309153.html

Committee of Geology of the Ministry of Industry and Infrastructural Development of the RoK. (2023). Методика классификации запасов месторождений и прогнозных ресурсов [Methodology for classifying field reserves and forecast resources]. Kazakhstan.

Espinoza, R., Siciliano, Y., Escobar, E., & Romero, M. (2020). Review of Current Status of Reserves Estimation Standardization in Latin America; A Third-Party Auditor Opinion. *SPE Latin American and Caribbean Petroleum Engineering Conference.* SPE.

Grace, J. D., Caldwell, R. H., & Heather, D. I. (1993). Comparative Reserves Definitions: U.S.A., Europe, and the Former Soviet Union. *Journal of Petroleum Technology*, 8.

Jacques, H. (1992). Discussion of Reserves and Probabilities - Synergism or Anachronism? *JPT*, 366-369.

KazEnergy. (2021). *Нефть и Газ Казахстана. 30 лет независимости. Путь созидания [Oil and Gas of Kazakhstan. 30 years of independence. The path of creation].* Astana: KazEnergy Association.

Konyrova, K. (2016, November 18). Retrieved from New Europe: https://www.neweurope.eu/article/large-scale-construction-begins-massive-tengiz-oil-field/

Kral, U. (2020, April). Retrieved from Research Gate Web site: https://www.researchgate.net/figure/Value-chain-life-cycle-for-materi-als-resources-in-the-anthroposphe-re-white-Box_fig4_341056139

Mukanov, A., & Zhumadil, A. (2021). Transition to New Reserves Reporting System in Kazakhstan: Challenges and Benefits. *SPE Annual Caspian Technical Conference.* SPE.

Muslimov, R. K. (2016). The New Classification of Reserves and Resources of Oil and Combustible Gas – Movement Onward or Backward? In *Georesursy = Georesources* (pp. 80-87). Kazan.

Nascimento, J., Santos, A., & Schiozer, D. (2018). Dynamic Uncertainties Appraisal throughout a Development Project, Applying PRMS Indicators of Resource and Reserves Categorization. *Offshore Technology Conference.* Houston: SPE.

Netherland Sewell & Associates. (2019, June 27). *SGX Group*. Retrieved from youtube.com: https://www.youtube.com/playlist?list=PLNKnhKVK1TqQ8mseBcJezdNUMx76AKItF

OGRC. (2007). *SPE/WPC/AAPG/SPEE Petroleum Resources Management System (PRMS).* Society of Petroleum Engineers.

Parkhomchik, L. (2020). Retrieved from Eurasian Research Institute: https://www.eurasian-research.org/publication/current-challenges-for-the-kashagan-offshore-oil-field-project/

Petrowiki. (2023, April 13). Retrieved from Petrowiki: https://petrowiki.spe.org/Petroleum_Resources_Management_System#2.2_Resources_categorization

SPE. (2001). *Guidelines for the Evaluation of Petroleum Reserves and Resources.* Richardson, TX: Society of Petroleum Engineers.

SPE et al. (2011). *Guidelines for Application of the Petroleum Resources Management System.* Society of Petroleum Engineers.

SPE et al. (2018). *Petroleum Resources Management System.* Society of Petroleum Engineers.

Tarek, A. (2010). *Reservoir Engineering Handbook. Fourth edition.* Elsevier.

United Nations. (2013). *United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application.* New York and Geneva: United Nations Publication.