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School of Architecture, Engineering and Applied Science

Department of Petroleum Engineering

Major: Petroleum Engineering and Management

M. Sc. Thesis

RESERVOIR ARCHITECTURE ANALYSIS for PREDICTION of ENHANCED HYDROCARBON RECOVERY

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Karbohidrogenin zənginləşdirilərək çıxarılması və saxlanılmasının qiymətləndirilməsi üçün yatağın struktur analizi

Referat

Tezis neft resurslarının --- texniki həllinə və qiymətlərin qeyri-sabitliyinə dair neft sənayesinin üzləşdiyi problemə cavab verir. Belə problemlərin nəticələri iqtisadiyyatç, digər senayelər (xüsusi ilə enerji və nəqliyyat) ,qlobal siyasət və hətta hər bir adi insan üçün vacibdir. Belə məsələlər qlobal iqtisadi böhran və bir sıra başqa problemlərə səbəb olur: işsizlik, siyasi gərginlik, məhsuldarlığın azaldılması, layihələrin təxirə salınması və s.

Konstruksiyalaşdırılmış reservuar (RKS), yüksək istehlak yaxınlığına və ya təchizat ərazilərinə təklif olunur, daha sonra əlaqəli detallar təqdim olunur və konseptual və ilkin texniki sənayeyədək inkişaf müzakirə olunur.

Neft mühəndisi qismində, tədqiqat zənginləşdirilərək çıxarılma, saxlanma və davamlı təchizat üçün texniki yardımı təmin etməyə kömək edə bilən reservuarların təkmilləşdirilməsinə yönəldilib. Neftin qeyri- normal qiymətə alınması və ya satılmasına olan ehtiyaca güzəşt oluna və yeni imkanı yaradıla bilər.

Abstract

The thesis responses to the problem that oil industry faces regarding technical solution for the scare hydrocarbon resources and price uncertainty. Such problem's consequences are important to economy, other industries (specially power and transport), global politics and even to every common person. Such issues casues the global politics and further problems i.e. unemployment, political strains, lowering production, freezing of projects, etc.

A constructed reservoir system (CRS), near to high consumption or supply areas, is suggested then concerning details are introduced, and development up to conceptual and preliminary level is discussed.

As a petroleum engineer, research is focused on developing the reservoirs that can help to provide technical assistance for enhanced recovery and sustainable suppy. The need to buy or sale oil at abnorml price would be compromised, and a new business opportunity can be created.

Acknowledgement

I would like to convey my deepest regards to my research advisor Dr. GASHAM A. ZEYNALOV and Mr. MUHAMMAD SALEEM AKHTER (my father) for their support, guidance and continuous help throughout my research. Besides the great efforts and time they spent on this research, I am thankful to them for all the opportunities they provided.

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I express my gratitude and appreciation to the Khazar University for technical and academic support. I would like to dedicate this research to my family and friends without whose unconditional love and support I would not have completed the program and research.

Terminology

i. GSRO = Geological Storage and Reproduction of Oil

ii. HC = Hydrocarbon

iii. NPV = Net Present Value

iv. EOR = Enhanced Oil Recovery

v. ROCI = Return on Capital Invested

vi. MPC = Model Predictive Control

vii. IOC = International Oil Company

viii. NOC = National Oil Company

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Chapter 4

Chapter 5

INTRODUCTION

Chapter 1, 2 and 3 researched for geological architectural behavior for enhanced hydrocarbon recovery in innovative way and to find the effective storage with reproduction capacity and development plan. Forth chapter discussed unique plan of oil storage and supply geographically on the most suitable locations, in terms of constructing Oil Dam / Barrage for strategical, economical and business advantages. A mature conceptual and constructional plan is developed. The technical details of working plans are provided for geological and surface storages.

Chapter 5 is presenting the research and creative financial aspects for the hydrocarbon trades, supplies and price functioning. Sensitive and important matters (i.e. Dutch Disease, oil as 'product' standardization and geographically supplies stabilities) are provided solutions and effective discussions. The address having aim to solve modern political, financial and strategical complexes by technical options. The investment for huge storages is suggested for sustainable supplies, manage price shocks for importers and exporters.

Approach

The theme of research is based upon;

Search (finding new ways), research (analyzing the existing resources), creation (theoretical enhancement) and invention (operational development of model) for the commercial success (economical and profitable), that is the task of an engineer and differs to scientist.

To tackle problems ahead of industry and to solve complex issues of petroleum engineering, better is to go beyond standards, conventional techniques and traditional disciplines but towards multi-disciplinary solutions, such as constructed reservoir system as surface or subsurface reservoirs.

CRS construction would be based upon geo-technical data, oil supply network, commercial logics, generic business plans, unexploited reasoning for pricing and huge storages. CRS will differ from conventional reservoirs, unlike storage terminals, to tolerate petroleum price affects, supply uncertainty and supply rout difficulties with attributes of being tractable, robust, efficient and inexpensive. I highlighted role of constructing techniques and intelligent operations that make reliability upon characterization of geology, exploration, seismic data processing and characterization, well logging, reservoir mapping, engineering etc. The main goal is to integrate strategic, operational and business advantages by constructing concrete-reservoir or a subsurface reservoir.

My Future research would be focused on the integration of data and disciplinary knowledge to improve understanding of such reservoirs' needs, functioning and maximization of commercial value to reduce industry's uncertainties.

Thesis Proposal

The study performs a literature review that includes:

- Description of the oil reservoir environments
- Description and explanation of the methods used to analyze the reservoirs
- Information on various kind of reservoirs and characters specifications
- Analysis of selected options of reservoirs' development
- Strategic and commercial analysis of the CRS
- The locations suitable for commercial venture.

The papers owns in addition:

- Analyze and conclude performance of real a reservoir
- Define the physical parameters under such treatments applied to develop a reservoir capacity, location, designs and characteristics
- Study and analysis of construction of sealed subsurface reservoir for EOR
- Select the optimum standards to create a model for a perfect reservoir
- Construction and operational aspects of cost and efficiency.

The paper has:

- Gathered reservoir data from the institutes and organizations, enabling an overview of oil volume transformation process for storage plus reproduction capacity and enhanced hydrocarbon (HC) recovery analysis
- A cost efficiency calculation is made and development cost is compared
- Subsurface reservoir development analysis vs. surface development analysis (discuss the storage capacity and recovery factor of subsurface reservoir and

compare it with dam that having 100% recovery, while the safety factors are different, but multiple use of dam is additional attribute).

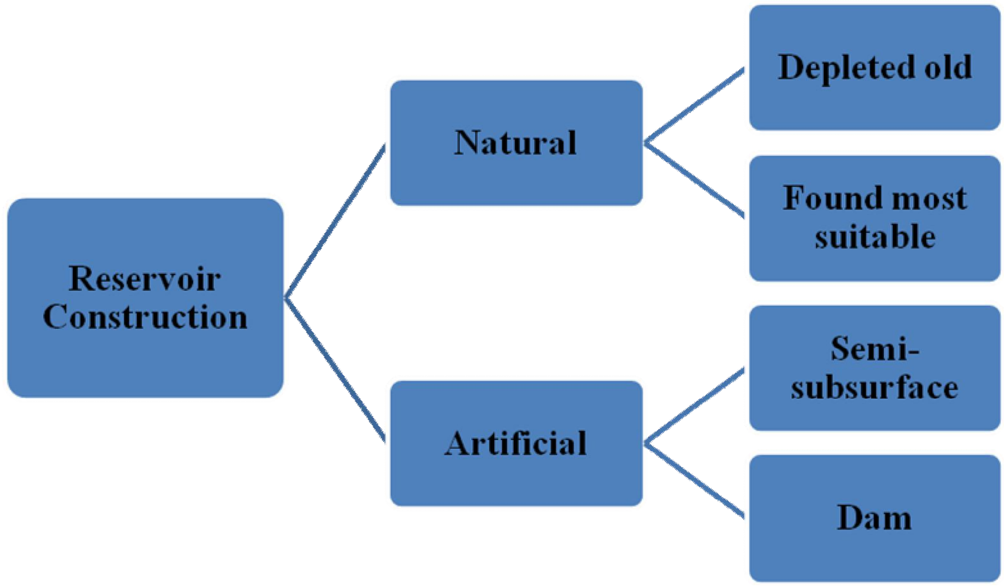
Objectives of Thesis

- To develop an understanding of the fundamentals of reservoir performance
- To provide an exposure to a range of reservoir conditions and constructions
- To optimize technical/economical resources of firms & create additional value
- To provide international network for storage and supply.

The achievements to be sought here are:

- Finding the geologically perfect (or almost perfect) subsurface reservoir to store oil with nearer to 100% capacity
- Development of subsurface reservoir to achieve nearer to 100% recovery
- Construction of reservoir on most suitable geological/geographical location
- Construction oil storage (full or semi concrete) for the megalopolis
- Analysis of sealing reservoir, can be used to recover;
    - oil from thief zones
    - blocked oil release
- Analysis of CRS to makes it possible to anticipate calibration problems in dynamic models (natural reservoirs) and limited supply resources (storage tanks).

The options and selection process (fig- 1.1)



Chapter 1

HYDROCARBON RESERVOIR

1.1. Reservoir General Characteristics

Improving reservoir performance depends on improved knowledge of formation behavior and characterization i.e. quantifying and modeling of heterogeneities, sedimentology, diagenesis and fracturation. It uses subsurface or outcrop data or depositional environment.

1.1.2. Reservoir Environments

Reservoir environments are described to predict reservoir quality and trends, while directional permeability, layering characteristics are important to reservoir engineering.

(i) **Alluvial Fan Environment**

Alluvial fan forms at margin of an uplift area, i.e. mountain range front, stream in narrow canyons. They carry recently eroded material and spread out their sediment load onto plain at the base of the upland where slope suddenly flattens. Typically alluvial fans are thick wedges of poorly sorted and often coarse-grained debris. Three-dimensional geometry depends upon the extent of tectonic activity and on rate of volume of sediment being deposited by the streams. Stream flow deposits are usually coarse-grained and fairly well sorted and stratified, with much of clay matrix washed out of them.

(ii) **Braided Stream Environment**

It's high-energy river systems carrying coarse-grained sands and gravels while characteristics depend on climate, source area and local slope. Laterally extensive coarse sends and gravels from excellent reservoir rocks, which are characterized by high porosity and permeabilities that range from hundred of millidercies to over several decries, create tremendous reservoir potential. Shale occurs only as thin, discontinuous lenses and comprises only 5-15% of total reservoir rock in deposits.

(iii) **Meandering Stream Environment**

It's created when streams flow within a single, highly sinuous channel- generally have a lower gradient and usually shows less fluctuation in their discharge rates. Their sediment load and resulting deposits are characterized by finer sand, gravels, silt and clay material.

Meandering streams leave sand bodies composed primarily of overlapping point bars and coarse channel sand and gravel deposits within the meander belt. More shale in the form of clay lenses within the send body then found in other environments.

(iv) Deltaic Environment

A sediment-laden river system discharges into a permanent body of water, loses its channeled energy and spreads out a deposit as it drops load. Deltas are sites of the largest amount of sediment accumulation on earth. The geometry and distribution of the deposits vary, depend on which of these forces is dominant.
As delta builds out a basin, the lateral sequence of sediment builds *progrades* over itself. The result is a vertical sequence with *marine clays* (non-reservoir) at the base, overlain in order by *prodelta clays, laminated delta front silts / fine sands* (poor reservoir sands) and *bar sands* (good reservoir sands) which become progressively coarser upward, these eventually become overlain by marsh deposits.

Distributary channel patterns shift across the delta, portion of delta front and delta plain will alternately build out and then subside, becoming inundated by sea, form on alternating sequence of clay and sands.

(v) Barrier Island Environment

It's a chain of sand bodies running parallel to shoreline of an ocean or other large body of water. They occur as long, narrow and mostly linear belts of sand containing a number of associated sub-environments which are separated from mainland by a lagoon and marsh system. Individual islands may or may not be capped by a dune field. It forms excellent reservoirs in upper shoreface, beach dune, and facies. Washover fan and tidal channel sands also form reservoir-quality rock but are more limited in extent.

(vi) Eolian Environment

Eolian sediments are deposited primarily by action of wind, deposited in coastal dune areas, sandy beaches, on barrier islands and fields of major desert areas. Wind action over large sand sea regions produces a wide variety of dune forms, which migrate and coalesce to form sand bodies up to several hundred feet or more thick. Interdune can have a great influence on reservoir continuity and producing characteristics.

(vii) Shallow Marine Shelf Environment

The shallow marine shelf environment covers gently sloping submarine shelf region, which lies between coastline and continental shelf break, where seafloor begins to dip steeply into deep ocean basin.

(viii) Deep Marine Environment

Most potential rock sequences in deep marine environments are created by depositions as coarse-grained sediment gravity flows or turbidity currents. These originate as submarine slumps that move rapidly down canyons in steep continental slope to finally spread out over ocean basin plain in broad fin lobes.

(ix) Sandstone Pore Systems and Diagenesis

In sandstones, original pore system geometry is determined by textural features of sediments (grain size, sorting, roundness, packing, etc) and by manner in which sediments deposited. The pore geometry is major factor limits quality and producing characteristics of reservoir. After deposition, original pore system of sediments can be altered by physical and chemical changes that result from progressive burial (called *Diagenetic*) that act to reduce original porosity and permeability.

Antigenic minerals, particularly clay minerals, can lead to a number of formation evaluation, completion, stimulation and production performance problems. Clay minerals that commonly form authigenity within the pore system of sandstones, consist of *chlorite, kaolinite, smectite* (including *montmorillonite*) and *illite* families.

(x) Carbonate Reservoir Environment

"C*arbonate sediments are born, not made*", by organisms of corals, clams, or algae, or by direct precipitation from seawater, have large variables. Majority of carbonate sediment is produced by bio-chemical organic activity, and most carbonate-metabolizing organisms require a special marine environment containing clear, warm, fairly shallow, agitated (oxygenated) water. These conditions are typically found along offshore banks or shallow shelves in tropical latitudes. The specific type depends largely on organisms that are dominant in that locale.

(xi) Restricted Low-Energy Carbonate Shelf Environment

These environments are found on wide shallow shelves, far removed from major shelf margins and in shallow shelf margin buildup or '*ooid shoal*' barrier. The intertidal deposits are composed primarily of '*lime-muds*' representing deposit ion in restricted lagoon or tidal flat, with minor amounts of higher-energy *ooid* carbonate sands.

The shallowing-upward sequence often shows vertical sequence of deposits with basal units in sequence usually be *fossiliferous lime mud* and productive if *dolomitized* or fossil fragments selectively leached out to create porous and permeable rock.

(xii) Open Marine, High-Energy Carbonate Shelf Environment

High-energy intertidal deposits are dominantly carbonate sand, composed largely of inorganic *ooids* and shell fragments. Cyclic depositional patterns have occurs in response to sea level changes. The *oolitic* carbonate sand deposits from excellent reservoir rocks if porosity and permeability are not destroyed diagenesis.

(xiii) Carbonate Sand Shoal Environment

It's characterized by inorganic, *oolitic* carbonate sands; resemble intertidal facies of high-energy carbonate shelves but usually occur in fairly well-defined, narrow belts parallel to shoreline. Productive zones show evidence of cementation between *ooid* grains, to the point where localized flow barriers exist within the porous interval.

(vix) Shelf Margin Environment: Reefs, Mounds, and Slope Deposits

Three different types of shelf margin profiles are based on slope steepness, water energy and type of indigenous organisms. *Bioherms* is used to describe a carbonate buildup dominantly made up of in-place organic growth that contrasts with a piling up of loose sediments by wave or tidal action. Bioherms may be reefs or mounds. Reefs consist of branching, massive, or *encrusting organisms*, which require a high-energy setting at or above levels of maximum wave and tidal influence.

1.2. Reservoir Structure (Internal Anatomy)

The structural configuration represented by a '*structure contour map',* shows interpreted topography of surface. Usually, the top of productive geological formation, relative to horizontal reference plane (commonly sea level).

(i) Seismic Stratigraphy

Seismic reflection data defines extent of prospects of reservoirs and to locate major faults. Higher frequencies (shorter wavelength and higher resolving power) are more strongly attenuated in earth. Seismic modeling is used to anticipate reservoir heterogeneities as discontinuous sand lenses. Comparison between actual and modeled seismic responses to predict reservoir continuity used to determine acoustic properties of rocks.

(ii) **Drill Cuttings**; determine gross lithology (sandstone versus shale versus carbonate) and general stratigraphy (as grain size, sorting, and mineralogy), but cores are better because of their larger sizes, coherence and more precise knowledge of depth they came from.

(iii) **Well Logs;** are essential for reservoir characterization to evaluate continuity and quantitative data on porosity and saturations. Gama ray log, resistivity log and porosity log are run in wells for reservoir description information. As correlation tool, well logs are used to construct both structural and stratigraphic cross sections and from cross-plots of two different log responses.

1.3. Integrating Field Pressure and Production Performance Data

Production history provides help to delineate distribution of pressures and production trends. It's direct result of interaction between well completion and production practices and flow units in reservoir, used for predictions of future field performance.

(i) **Contour Maps;** of reservoir performance data is used for characterization and predictions. Contour maps are several kinds, and used for:

- Well potential
- Producing water cut
- Well potential flow capacity ratio
- Well potential
- Isobaric maps shows reservoir pressure distribution at various points and time.

(ii) **Well Tests and Production Logging**

Pressure transient tests are used to obtain reservoir description information, include both single and multiple well testing techniques. Single well tests determine reservoir properties in immediate vicinity of relevant well, to estimate average pressure in drainage area of well, and in calculations of wellbore condition. Multiple-well pressure transient tests are suited to investigate reservoir heterogeneities in formation between wells to estimate formation transmissibility. Another method uses tracers (chemical or radioactive materials), introduced into injection wells and periodically fluid is tested from production wells to identify presence of tracers. Tracers detect the presence of fractures or channeling communication between wells, directional permeability trends, flow barriers in reservoir, and so forth, but program is designed for specific reservoir system and test objectives (due to expense and time consumption).

Chapter 2

SUBSURFACE RESERVOIR DEVELOPMENT

2.1. Reservoir Characterization for Site Selection

This section addresses how to determine the capacity of geological formation at a particular site to store oil for higher reproduction. A deal with subsurface system with inherent technical uncertainties, crucially important commercial, economic, environmental and public policy issues is actual task. It is important to develop an acceptable and consistent scheme that is understandable to the engineers, industry and financial community, to establish projects 'bankable'.

2.2 Geological Storage and Reproduction of Oil (GSRO)

Storage capacity is considered related to reproduction availability. Three categories are proposed:

I. **Operational storage capacity**: discovered pore volume, commercially viable i.e. oil is injectable under existing technical, economic and regulatory conditions, and further classified as;

- *Proved* (1P)
- *Proved plus probable* (2P)
- *Proved plus probable plus possible* (3P).

(Categories follow standard petroleum industry nomenclature).

II. **Contingent storage capacity**; discovered pore volume, commercial in future.

III. **Prospective storage capacity**; undiscovered pore volume which might become commercial at some future time.

Country or state screening; involves identification of appropriate geological site which screens and ranks as to overall suitability for GSRO. Evaluation of size and thickness of formation, gives an indication of *total pore volume.* Detailed assessment allows the estimation of prospective PGSR capacity in traps.

2.3. Oil Subsurface Behavior and Trapping Mechanisms

Oil can geologically be stored in new sites, depleted or still producing oil/gas fields. The required parameters are almost same, but later have proven advantages of containment and production potential by operations of many years, and typically large amounts of geological and engineering data available for detailed site characterization.

Possible drawback is physical sizes of structural/ stratigraphic trap and pore pressure depletion has led to pore collapse which will reduce GSRO. The presence of existing old wells may provide potential reproduction points and timing of availability of petroleum. Factors influence GSRO include density of oil (API^0) at subsurface reservoir conditions, amount of interconnected pore volume of reservoir rock and nature of formation fluids.

In subsurface, not all potentially available pore volume will become utilized during injection and migration, with flow preferentially occurring either upward due to buoyancy forces or laterally below low permeability zones (i.e. spreading out in thin layers beneath intra-formational seals or regional top seal rather than filling entire pore volume). This can make GSRO difficult to calculate, particularly in reservoir rocks underlying defined structural or stratigraphic closures, where much of available rock pore volume can be bypassed by oil preferentially utilising higher permeability zones but interconnected pore space, accounting for factors such as injection rate, rate of migration, dip of the reservoir, heterogeneity of reservoir, potential for fill-to-spill structural closures encountered along the migration path, initial formation pressure and specially reproduction.

Long-term prospects for GSRO, including residual trapping, dissolution into formation water or mineral trapping can also be considered. Such issues are best addressed by building geological models and running numerical flow simulations to test various factors inherent to each specific site.

2.4. Storage Capacity Estimation in Aqueous Formations

Oil storage capacity in aqueous formations can be expressed by equation:

$$\mathbf{G_{oil} = A\, h_g\, \varphi_{tot}\, \rho\, E} \qquad \text{———————— (eqn- 2.1)}$$

G_{oil} = oil storage capacity, A = geographical area,
h_g = gross thickness of formations, φ_{tot} = formation average porosity
ρ = oil density at formation pressure and temperature, E = storage efficiency.

2.5. Storage Capacity Estimation in Depleted Oil and Gas Fields

Depleted or near depleted oil/gas fields are considered as a single discrete system, and GSRO estimates are made by data available, based initially on two assumptions:

i. volume previously occupied by produced HC is available

ii. existing caprock-seal works to increase pressure above formation pressure prior to production.

The first point is valid for fields neither in hydrodynamic contact with an aquifer or nor flooded (during EOR), that leads to an increase in water saturation (due to wettability, capillarity, viscous fingering and gravity effects) to balance volume. The second shows that reservoir behaves elastically during pressure depletion and subsequent re-pressurization, with limiting factor (depends on rate of injectivity), and constraint imposed by not increasing pressures above virgin (pre-production) reservoir pressures (that may limit volumes able to be injected over life of project, or increase costs associated with having to drill a larger number of injection/ reproduction wells).

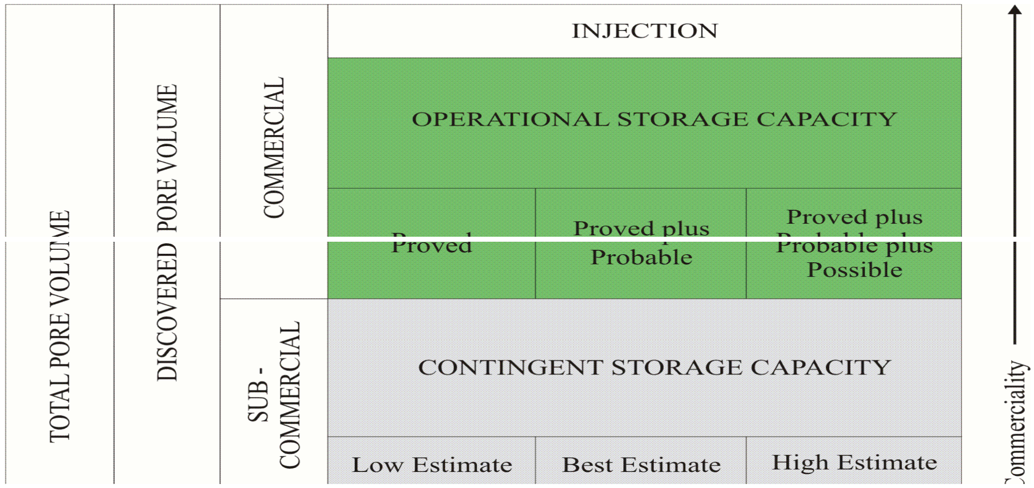
Two alternative estimating methods are:

I. **Volumetric-based volume estimate;** A *geometric factor* (g) which accounts for the geometry of the trap (i.e. 4-way dip structural versus stratigraphic);

$$\mathbf{G_{oil} = A\ h_n\ g\ \varphi_e\ \rho\ E} \qquad \text{(eqn- 2.2)}$$

Compositional simulation models to store per stock tank barrel oil. In such cases;

$$\mathbf{G_{oil} = A\ h_n\ g\ \varphi_e\ 1/B_o\ (1 - S_w - S_{oirr})\ \rho\ V} \qquad \text{(eqn- 2.3)}$$

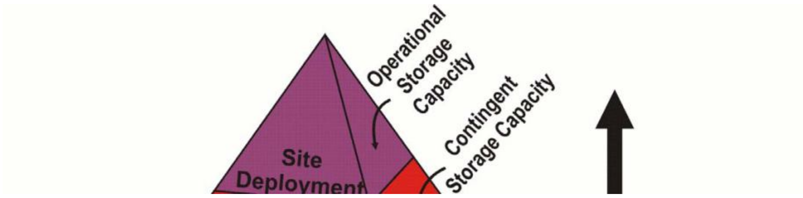


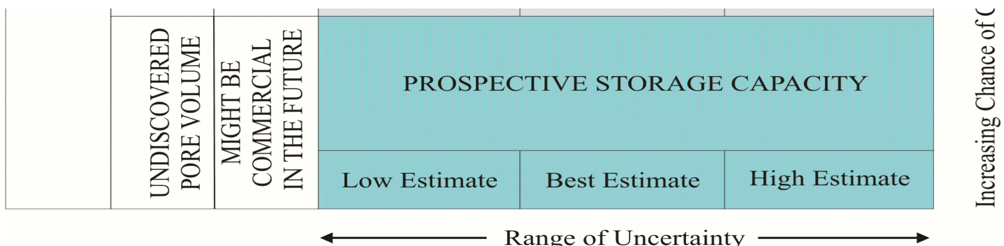
B_o=oil shrinkage factor, S_w=water saturation, S_{oirr}=irreducible oil saturation in rock, V=oil volume per stock tank barrel of original oil in place (scf_{oil}/stbOOIP).

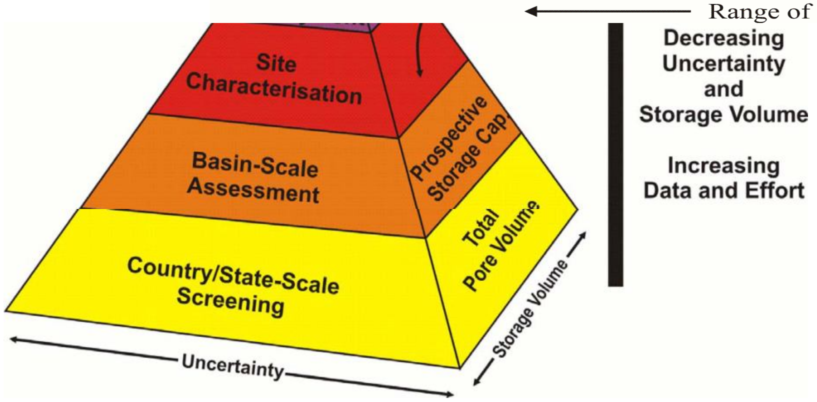
II. **Production-based volume estimate;** gives production-based estimates and important parameters are produced/injected water, solution gas volumes, miscibility, dissolution of oil into residual plus associated gas, mineral trapping, pressure variations within formation during production and pressure decline as a result of production.

(fig- 2.1)

Oil storage volume classification system proposed on hypothesis (modified SPE, 2007).







(fig- 2.2)

Integrated scales of site assessment and storage capacity pyramid for geological storage of Oil (modified).

Hydrogeology; describes the natural dynamic flow system and potential for trapping within formation cause to immobilise free-phase oil.

Geothermal; conditions impact as density of oil is higher in colder than in warmer formations, allowing more oil to be stored within same unit volume.

Seal pairs; provide the vertical containment. A generalized stratigraphic column or a simplified chronostratigraphic chart is used to screen a qualitative assessment of presence, distribution and frequency of reservoir-seal pairs.

Hydrocarbon potential; indicates suitability of formation for containing and pressure build up for reproduction.

Maturity of industries; in the region reflects the likely database and technology.

Onshore or **offshore;** economic consideration, as cheaper and technically easier.

Climate; influences likely surface temperatures, geothermal conditions, depth of water table and likely ease of development.

Accessibility and **infrastructure;** reflect technological feasibility and ease of future developments.

Comments

Previously a little range of approaches and methodologies were practiced to stabilize oil demand, production and supplies business, so need is to extend the views.

GSRO is a mean for reducing pressure on continues financial and administrational operations on oil business and supply. The estimation of storage capacity, location and reproduction are fundamental issues for the banking. GSRO estimates would be imperfect, and there is a need for development of such projects that can give firm and diversified agreements on oil production and supplies.

2.6. Construction Plan for Subsurface Reservoir

Indicators of Performance:

- Select appropriate methodology for required characteristics of reservoir
- Apply fundamental aspects of stress, strain and mechanical behavior of rock materials for analysis and solution of structural geological problems
- Construct and interpret maps, fence diagrams, and sections using drill hole, surface geology and geophysical data
- Analyze subsurface data for geological maping of stratigraphic sequences
- Identify and interpret structural and stratigraphic traps for suitable operations
- Analyze depositional environment using basic criteria of facies models
- Interpret topographic maps to assist resource for GSRO
- Interpret geologic maps to assist in GSRO
- Interpret air photos to assist in GSRO
- Identify and interpret possible migration routes or leakages for HC
- Interpret seismic data
- Test and identify pore fluids in host rocks
- Test host rock porosity and permeability
- Prepare master plan for reservoir construction (sealing boundaries)
- Prepare risk plan if any fault found
- Continuous monitoring of execution and operation

- Interpret surveys, maps, land divisions, acquisition procedures, and indicators of performance.

Chapter 3

GEOLOGICAL RESERVOIR CONSTUCTION

3.1. Retrograde Process and Sealed Reservoir

3.1.1. Geological and Development Characteristics of Bulla-Deniz

The gas-condensate-oil field Bulla-Deniz is located in north of Baku Archipeage at distance of 55 km to south from Baku and 10 km to south-east from

Sangachali-deniz-khere Zire-Adasi gas-condensate-oil field. The sea water depth varies from 18 up to 30 m, and Sea bottom high-power clayey stratum. The initial seismic prospecting operations fulfilled by Marine Geological Office in 1950-57, and drilling started in 1965, first commercial production obtained from VII-horizon (quaternary periods deposits) in 1973.

The section is *intonotonic clay* with electric resistance 2 to 4 ohm, and by not differentiated line. Clay layer is dark-gray, brownish-red, dense, carbonate while content of sand interbeds compounds 70%. The average thickness; VII_{up} – 47m, VII_l–25 m and tectonic is anticline fold, structure is little asymmetrical; angles of dip on north flank are changed from 22^o on roof reservoir area up to 15^o, on submergence on southwest side from 22^o up to 11^o, and in periclinal parts of northeast side angles of dip are 11^o–12^o.

Parameters

No.	Parameters for VII-Horizon	Value
1	Average reservoir depth H, m	5700
2	Reservoir size: length * width, m^2	14000 * 4000
3	Gas-bearing area S, m^2	$6134 * 10^4$
4	Average thickness of gas-saturated formation h, m	89
5	Initial gas-saturated factor	0.67 – 0.78
6	Formation connate water saturation factor	0.33 – 0.28
7	Porosity factor	0.14 – 0.17
9	Formation pressure MPa, initial	71.3
10	Formation pressure MPa, current (01.01.2000)	8.6
11	Formation temperature , C^0	103
12	Gas viscosity, centipoises	0.0096

13	Initial free gas reserves category C_1, million m^3	71,809
I4	Initial condensate reserves on category C_1, million m^3	26,367

(table- 3.1)

3.1.2. Physical and Chemical Characteristics of Gas, Condensate and Oil in Bulla-Deniz Gas-Condensate-Oil Field

Physical and chemical properties of gas, condensate and oil of VII-horizon are studied on bottom-hole and subsurface samples obtained from gas-condensate wells. Well #20 started operation on VII-horizon of V-block (on 25-04-1976) with daily production rate of gas -1050 million m^3, condensate 270 tons through the choke by diameter of 15/10 mm.The wellhead pressure was 26.7 Mpa and tubing-casing annulus 18.0 MPa.

Well was liquidated for technical reasons and in total from well were obtained: gas 1,026,443 thousand m^3 and condensate -270,725 thousand tons and water 749 tons. The sample shows results of component composition of contents of components of HC, as follow: (table- 3.2)

Compo-nent of gas	Separation gas		Degassed gas		Contents of C_{5+}, g/mole	contents compo-nents	Formtion gas mole content, %
	gas %	g-mole	mole%	g-mole			
C_1	92.42	942.2	66.08	22.70	-	947.59	87.57
C_2	4.46	44.6	12.65	4.37	-	48.97	4.52
C_3	1.62	16.2	8.68	2.96	-	19.19	1.77
C_4	0.77	7.7	6.36	2.18	-	10.00	0.92
C_{5+}	0.33	3.3	5.61	1.93	46.67	52.3	4.83
CO_2	0.40	4.0	0.62	0.21		4.26	0.39
Total	100	1000	100	34.35	46.67	1082.32	100

Results of Separation & Account of Component Composition of Gas

Gas Component	Separation gas		Degassed gas		contents C_{5+},debutanizer condnsat g/mole	contents compo-nents in gas,g-mole	Formtion gas mole content,%
	gas %	g-mole	mole%	g-mole			
C_1	91.77	917.78	69.37	23.59	-	941.29	87.44
C_2	5.65	56.5	12.67	4.31	-	60.81	5.65
C_3	1.48	14.8	7.7	2.62	-	17.42	1.62
C_4	0.58	5.8	5.6	1.9	-	7.7	0.72
C_{5+}	0.36	3.6	4.29	1.46	42.45	47.51	4.41
CO_2	0.16	1.6	0.37	0.12		1.72	0.16
Total	100	1000	100	34	42.45	1076.45	100

(table- 3.3)

Comparing two tables e.g. difference of contents of HC in reservoir fluids during one year of production. By the time removal of reserves cause heavier HC remain in larger parts, as lighter HC tends to flow out earlier. So confining the reservoir can cause release of lower HC from liquid.

3.1.3. Features of Phase Transformations in Gas-Condensate-Oil Systems and Study of Influence of High-Gravity HC Contents in Reservoir

Every hydrocarbon component of natural gas can be liquefied by increasing pressure or lowering temperature. Condensation is possible in the region of subcritical temperature and pressure. At above-critical pressure and temperature, the difference between liquid and gas disappears and any hydrocarbon is in a single gaseous state.

Retrograde Phenomena

(fig- 3.1)

Direct vaporization of pure HC occurs when pressure is lowered and temperature is raised simultaneously and abruptly, skipping the two-phase state. It is observed in closed vessels filled with separate HC when pressure and temperature are changed in subcritical region. A mixture of HC vapors may completely condense when it passes through intermediate two-phase state. The critical parameters of such a mixture differ from those of components which vary depending on pressure and temperature.

In subcritical region, HC mixture obeys law of direct condensation which on isothermal increase of pressure, follows the usual sequence vapor (point 1-2) via the two-phase state (point 2-3) to liquid (point3-4). The process of direct vaporization on isobaric increase of temperature takes place in the reverse sequence, i.e. from liquid (point a-b) via the two-phase state (point b-c) to vapor (point c-d). In supercritical region, mixture of HC behaves in usual way. On isothermal increase of pressure and isobaric increase of temperature beyond critical parameters of mixture with following effects:

I. Recondensation from vapor (point 5-6) via the two-phase state (point 6-8) and back again to vapor (point 8-9)

II. Revaporizaton from the liquid (point e-f) via the two-phase state (point f-h) and again to liquid (point h-k).

The retrograde phenomena is critical temperature of HC mixture, has boundary of possible existence of liquid phase, as case with individual HC. It is typical of these processes that vaporization of liquid occurs when pressure is increased (point 7-9) and condensate when temperature is increased (point g-h), i.e. directly opposite of what is observed in direct processes. In essence, due to increase in compressibility factor of gaseous mixture and increase in volatility of its components at increased pressure, which results in heavy components dissolving in mass of lighter gaseous components.

Under natural conditions these effects characterize so-called gas-condensate reservoirs which are characterized by single or two-phase state, high pressure and temperature these hydrocarbons mixtures exhibit phenomena of retrograde condensate and vaporization. In certain case, gas is present above or alongside oil, quantity of which is comparatively small. The commercial products of gas-condensate deposits, at different stages of development, are gas, condensate with gasoline, ligroin, kerosene and even solar oil HC fractions.

The following types of gas-condensate reservoirs are distinguished, depending on special features of their development:

I. Two-phase (DEF) region

II. Single-phase;
   i. Saturated (region close to the condensation line DE
   ii. Unsaturated (region MDEN)
   iii. Superheated (region right of line NE).

Deep-seated gas-capped oil deposits are classified as two-phase gas-condensate reservoirs, depend upon composition of gas. Effects of re-vaporization are observed at pressure above 60 atm, includes HC heavier then propane. Separation of condensate from rich gas occurs due to reduction of pressure at constant temperature, while heavier components are first to condense followed by lighter. The pressure at which greatest quantity of condensate is formed is termed '*maximum condensation pressure*'.

The staff of 'VNH Gas and Oil Industry Designing Bureau' developed special installation which introduced in field practice. The important component of installation is '*rocking PVT bomb*', which is sealed with moving potions. The bomb is filled with gas and condensate, while formation condition of pressure and temperature are created in it. The observation data are used to determine behavior of gas, condensate and reserves of reservoir for development pattern.

3.1.4. Oil Quantity and Properties Influence in Gasification in Reservoir

In compositions of coexisted phases the great influence renders common composition of system, i.e. both property and quantity of gas phase and fluid phase, effect during reservoir's forming and production. The task estimates influencing of high-gravity hydrocarbon on losses of condensate in formation and on properties as precipitated in formation, and recovered condensate.

The researchers of faculty 'Gas and Gas-Condensate Fields Engineering' of Azerbaijan State Oil Academy conducted experimental studies on influence of admixture of oil on phase transferring of gas condensate systems under reservoir condition. The results of studies held with gas-condensate-oil systems, composed from various gases and oils of Azerbaijan and Tyumen fields are brought in work. On the basis of complete discharges of gas and fluid phases the compositions and properties of gases and stable condensate released from gas phase and stable condensate are counted. For estimation of influence of oil fringe on losses of condensate in formation test with Tyumen oil experiments held at temperatures 353 K^o and 413 K^o with density (ρ_o) 0.8384 t/m^3. Compositions with 6 systems are given.

(Lower values of liquid V_l (cm^3) resembles conditions of porosity of rocks).

Composition of source systems at P_i = 80 Mpa.

Component composition of the system

Systm #	**Temp K^0**	**Component composition of the system, mole %**									
		C_1	C_2	C_3	IC_4	NC_4	IC_5	NC_5	C_6	CO_2	C_{7+}

1	353	92.11	3.0	1.01	0.22	0.198	0.132	0.11	0.132	0.265	2.28
2	413	92.11	3.0	1.01	0.22	0.198	0.132	0.11	0.132	0.265	2.28
3	353	90.51	2.92	0.98	0.185	0.292	0.132	0.106	0.133	0.398	4.348
4	413	90.51	2.92	0.98	0.185	0.292	0.132	0.106	0.133	0.398	4.348
5	353	86.73	2.79	0.94	0.174	0.279	0.139	0.105	0.139	0.349	8.342
6	413	86.73	2.79	0.94	0.174	0.279	0.139	0.105	0.139	0.349	8.342

(Table- 3.4)

Isotherms of contact condensation

Pressure	System 1 (T=353k^o)	System 2 (T=413k^o)	System 3 (T=353k^o)	System 4 (T=413k^o)	System 5 (T=353k^o)	System 6 (T=413k^o)
MPa	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3
80	-	-	-	-	-	-
70	122.5	97.2	358.6	234.2	893.1	499.6
60	160.7	131.1	436.6	374.8	1073.2	983.6
50	196.0	164.2	502.1	452.8	1170.2	1124.1
40	229.2	195.9	558.2	512.2	1219.1	11889.7
30	257.9	230.4	597.2	549.7	1241.1	1217.8
20	291.9	259.2	611.2	565.3	1231.8	1202.2
10	324.3	289.5	608.1	562.2	1139.4	1064.8

(table- 3.5)

Results show that at constant temperature as pressure is gradually lowered volume of gas constantly increased. At constant temperature as pressure is gradually lowered volume ratio of gas continuously increases.

Isotherms of differential condensation

Pressure	System 1 (T=353k°)	System 2 (T=413k°)	System 3 (T=353k°)	System 4 (T=413k°)	System 5 (T=353k°)	System 6 (T=413k°)
Mpa	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3
70	44.94	29.06	183.61	99.66	565.8	286.4
60	104.3	68.8	304.23	209.66	770.6	586.1
50	140.85	108.9	379.31	306.24	892.2	760.1
40	175.6	142.62	458.37	378.02	981.4	870.7
30	190.57	163.53	481.2	403.89	943.8	890.5
20	206.93	173.43	453.47	401.47	937.0	865.4

(table- 3.6)

As pressure is continually and gradually decreased liquid content is increasing volume compare to gas, converting gas into liquid at specific and high temperature that is the case in most of reservoirs. As these results are experimented in PVT bombs providing almost ideal conditions of applied parameters, while natural reservoir, behaves far different to PVT bomb especially pressure and volume changes due to production than expansion/ liberation of gases and encroachment of non-hydrocarbon fluids due to capillary pressure and volume decrease after production causing pulling effects inside and pushing effects outside from reservoir.

In the case of gas reservoir the sealed reservoir can enhance recovery by building more vacuum-pressure if restricted for water/ brine encroachments into reservoir that compensates the volume of gas produced and reduce the capacity to convert gas from liquid hydrocarbons and stop lowering pressure effects.

In case vice versa the oil – condensate reservoir (if sealed) pressure loss due to production is usually compensated by injecting gas and/or water, production of oil-condensates increases, until specific time when break through occurs and increase of injected water and gas take place. The encroached water and liberated was increase volume share in production directly cause increase in cost and other losses. The sealed reservoir can be treated as a PVT bomb, as pressure build-up can confine the gas from liberating out from oil-condensate, and prevent injected fluid losses into adjacent layer of pay zones. If the reservoir doesn't has water around the injected gas (CO_2 or else) as pressure boaster loss partial pressure in surrounding of reservoir while sealed reservoir can work to control these loses and can build pressure more than non-sealed as shown in PVT bomb characteristics.

The sealed or compartmentalized reservoir can be set on process to run several cycles of injecting and recovering oil or circulating injected fluids into pay zone layers. Under such conditions the heavy oil and the oil from thief zones can be mobilized and the waxed oil sticked to pores can be removed by improved mechanical influence.

3.1.5. Heavy Oil Reservoirs and Sealing Impacts

These results show that retrograde phenomena can be practiced and convert condensate / light-oil into gas with heavier HC molecules (C_{5+}). Sealing of reservoir (like as PVT bomb) can be applied for the magnification of pressure applied to high-gravity HC in source system then confinement of system can influence to gain higher formation and fluid pressure by injecting water or gases without pressure breakthrough. And mechanical energy to hydrocarbon molecules can be increased by the push created in a process of closing well head and continued injection.

Formation losses dependences on contents C_{5+} in formation

Pressure MPa	237.7gr/m^3 (T=353k^o)	446.4gr/m^3 (T=353k^o)	850.0gr/m^3 (T=353k^o)	237.5gr/m^3 (T=413k^o)	446.4gr/m^3 (T=413k^o)	850.0gr/m^3 (T=413k^o)
formation losses	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3	V_l/V_g Cm^3 / m^3
70	122.5	358.6	893.1	97.2	234.2	499.6
60	160.7	436.6	1073.2	131.1	374.8	983.6
50	196.0	502.1	1170.2	164.2	452.8	1124.1
40	229.2	558.2	1219.1	195.9	512.2	1189.7
30	257.9	597.2	1241.1	230.4	549.7	1217.8
20	291.9	611.2	1231.8	259.2	565.3	1202.2
10	324.3	608.1	1139.4	289.5	262.2	1064.8

(table- 3.7)

Results support phenomena that as much the pressure is lowered that much more heavier carbon (C_{5+}) is liberated into gas phase (support for gas production) the lowered pressure can be achieved by reservoir sealing and gas can be sucked by pumps.

3.1.6. Phase State Formation of HC of System of Reservoir VII-horizon

The formation pressure for period 23 years has decreased more, than on 75% from initial value and to the present time does not exceed 14.0 MPa. For these periods condensate essentially has decreased and tends to further drop

(fig- 3.3, 3.4). For this period there were some variations in chemical and thermodynamic properties of formation systems; the gravity of a stable condensate has decreased from 811.5 kg /m3 to 730 kg/m^3 and, as the consequent it, stress of a beginning of condensation has fallen from 71.5 MPa up to 10.5 MPa. The essential variation was undergone by (with) composition of condensate for the indicated period of development.

Comments

On basis of laboratory results, production analysis, of specific contents HC in formation VII-horizon of Bulla-deniz field, following conclusions are made:

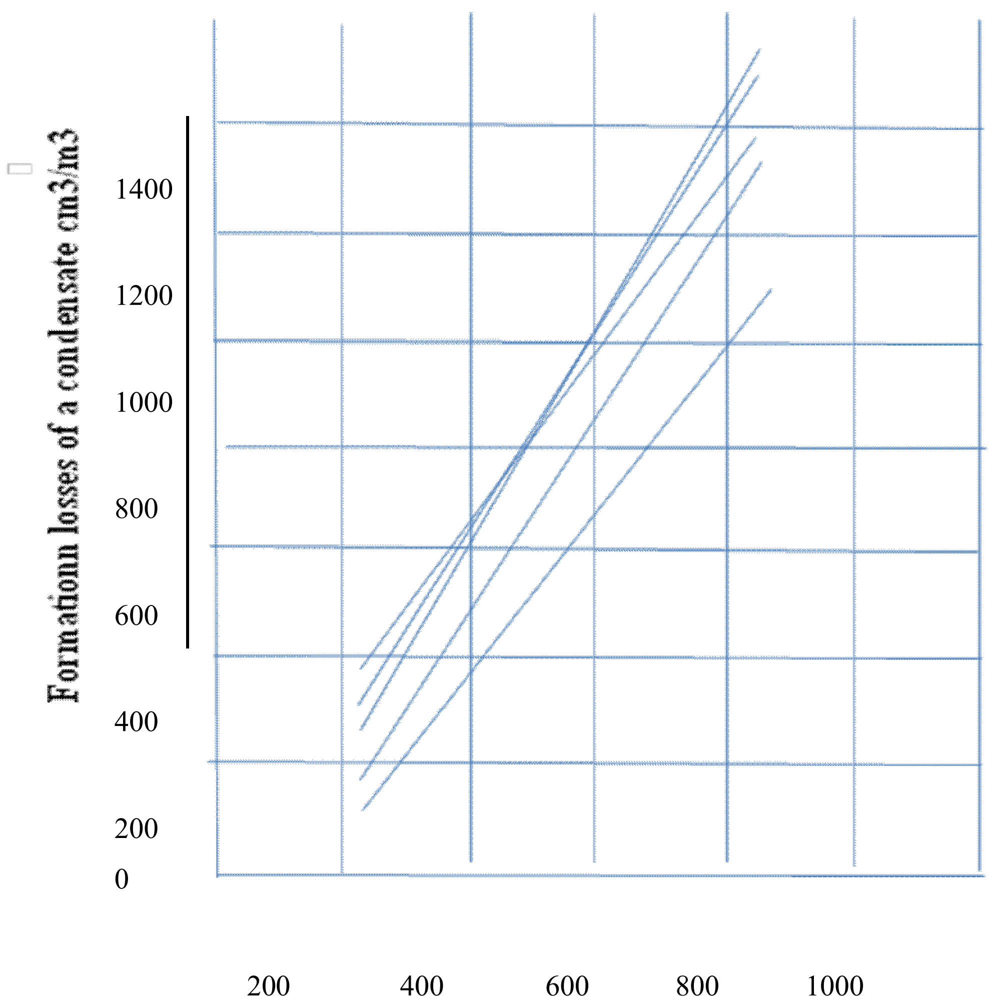
I. The estimations of production activity and losses of condensate is produced under reservoir conditions at development

II. The dependences of specific contents liquid HC loss of condensate in rock are obtained at various thermo-bar conditions

III. Determine that at magnification of contents of high-gravity hydrocarbon in formation, the loss of condensate in process is augmented

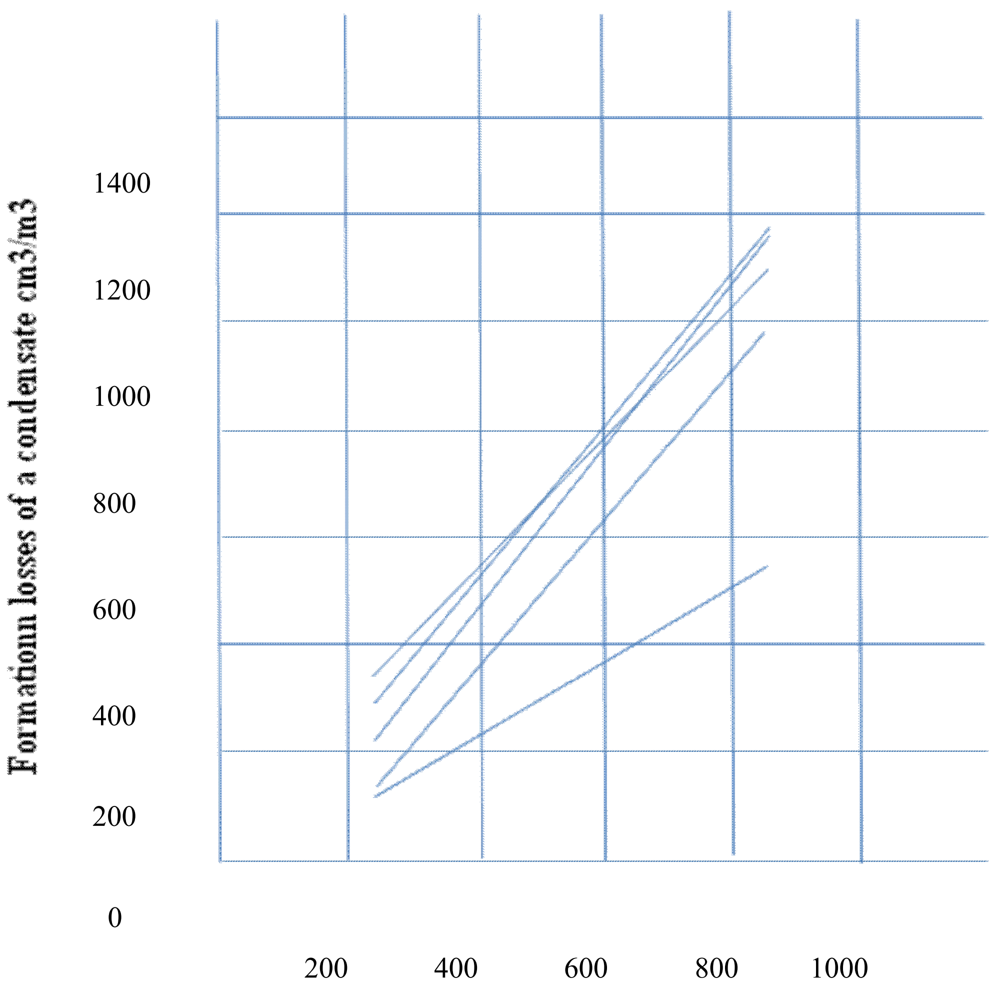
IV. The value of specific contents of liquid HC (C_{3+}, C_{4+}, C_{5+}) in gas bed, during period from beginning till last has decreased approximately 5 times that testified to increases in losses of condensate in layer.

V. Dependence formation losses of a condensate from the potential maintenance of heavy HC in formation gas at various pressures.



Potential content, C5+ , gr/m3 , figure- 3.3

Dependence formation losses of a condensate from the potential maintenance of heavy hydrocabons in formationn at variouus pressures



Potential content, C5+ , gr/m3 -figure- 3.4

VI. Figure 3.3 and 3.4 express that as much heavy oil contents are larger that much increase in formation losses.

3.2. Geothermal / Brine Invasion and Sealing HC Reservoirs

The connate water production with oil/gas is impacting seriously the commercial feasibility of the field. Its null commercial value causes reinjection into the formation to maintain reservoir pressure. This negative process increases with production rate and time enormously if aquifer is surrounding to reservoir.

3.2.1. Geothermal Aquifers with HC Reservoirs

In geothermal areas, interstitial hot water in pores alters several parameters of reservoirs. The non-isothermal conditions affect saturations and relative permeabilities of both immiscible phases by increase of temperature. At the same time dynamic viscosities of water and oil diminish, affecting the displacement of both fluids. The water flows vertically and laterally toward production wells, through conductive faults and porous (connect oil zone with aquifer), geothermal brine (50-250°C) have density of 1150 kg/m3 or much more.

This phenomenon produces a gradual decrease of volume of oil and vertical displacement of oil water contact. The well receives more and more water until it becomes completely invaded and cures costing millions of dollars every year.

3.2.2. Hypothesis and Qualitative Information

The brine in formation has different physical behavior compared to HC. Water conducts as substance having molecular weight larger than 18 and intra-molecular forces of water are more intense than those of oil. Due to superficial tensions a great amount of oil is caught into the pores and mobility of invasion water prevails. For heavier and more viscous oils, the mobility of water will dominate in immiscible mixture of both fluids.

This phenomenon is described by the total mixture rate;

$$\mathbf{q = q_w + q_o} \qquad \text{———————} \qquad \text{(eqn- 3.1)}$$

$$\mathbf{q_w / q_o = \lambda_w / \lambda_o > 1} \qquad \text{———————} \qquad \text{(eqn- 3.2)}$$

$$\mathbf{\lambda_j = \mu_j / \kappa_j} \quad \text{(phase mobility)} \qquad \text{———————} \qquad \text{(eqn- 3.3)}$$

$\mathbf{\mu_j}$ - dynamic viscosity and $\mathbf{\kappa_j}$ – permeability, (**j** = water, oil).

If volumetric rate of well is high, produced fluid is predominantly water.

$$\mathbf{B_w = \rho_{wS} / \rho_{wR}} \qquad \text{———————} \qquad \text{(eqn- 3.4)}$$

$\mathbf{B_w}$ = volume factor of water in formation

$\mathbf{\rho_{wS}}$ = density of water at standard condition

$\mathbf{\rho_{wR}}$ = density of water at reservoir condition.

This factor represents expansion of volume of water between formation and surface. Assuming expansion is small, we take value; $\mathbf{B_w \approx 1}$.

The following information can be useful:

- Geothermal water invades reservoir through faults with high temperature
- Geothermal aquifer and reservoir forms geologic unit system, delimited boundaries by impermeable rocks forming closed and isothermal volume
- Water flows aquifer to reservoir by pressure variations at oil-water contact
- Darcy's Law and Continuity equation are valid in both phases
- Relative permeability and capillary pressure only depend on saturations.

Following parameters are considered constant:

- Viscosities
- Rock permeability
- Densities of both phases.

3.2. Subsurface Reservoir Development Program

The above analysis and results are encouraging to take steps to develop reservoirs in a way that can help to maximize the HC recovery, and sealing the reservoirs can be vital option. The sealing by cementing boundaries is discussed with other related technologies to achieve better and higher HC recovery.

The use of this research is control of water invasion and estimation of the critical volumetric rate in oil wells for which the invasion has been stopped. The model should allow predicting with precision this critical rate and consequently, to be able to reduce water extraction rates in wells just on time, maximizing its productive life. A physical model is developed, able to perform this task by sealing the reservoir. The treatment is making reservoirs impervious for hydraulic intrusions and made the oil field closed.

3.3.1. Mapping the Reservoir

The tracers can be used to map path of injection slurry around reservoir, and can give extremely valuable information regarding dynamic characteristics of reservoir fluids. A limitation of current tracer programs is lack of qualified tracers and many of them have negative influence on environment. DNA tracers are environment friendly with similar physical properties. Ideal tracers must withstand large pressures and elevated temperatures found in reservoirs, and follow the flow of water through the porous reservoir minerals.

DNA tracers degrade at higher temperatures and tend to adsorb to sandstone. Chemically modified tracers that were designed and tested for improved results have demonstrated good thermal stability and are less prone to adsorb to sandstone. This modified tracer also remained in the water phase when mixed with oil and water, and passed through a sandstone column without delay and in quantitative manner under simulated reservoir conditions.

3.3.2. Setting Cement for Sealing off Layers of Reservoir

The most suitable subsurface formation for storage of oil can be developed for an efficient reservoir. To prepare required size of reservoir for the needed capacity layers can be cemented to make impervious boundaries. The cementing details are prepared based on current practices for cementing wellbore.

(i) Slurry Density

The slurry should be designed on density at least one-half pound per gallon heavier than reservoir fluids. A higher density cement (reducing mixing water) plugging is required for high porosity strata and for inclined plugging to increase compressive strength. For appreciable increase, addition of dispersant will be required to maintain fluidity needed for proper mixing, pumping and penetration of slurry. Increase in density above 17.5 pounds/gallon requires weighting material be added to slurry, iron ore materials (*hematite* and *ilmenite)* are effective.

(ii) **Thickening Time**

The thickening time is period of fluidity between cement solids and slurry attaining consistency of 70 Bearden units (Bc's). The slurry is designed to have thickening and strengthening time plus reasonable safety factor, and not be excessive to allow cement to remain fluid.
The thickening time can be extended, as desired, by adding materials to blend that retard the setting of slurry, i.e. *lignosulfonate* materials or accelerative additives (i.e. *potassium chloride, sodium chloride, or calcium chloride*). Offshore, sea water is substitution for *sodium chloride,* with caution in combination with additives.

(iii) **Fluid Loss Control**

Slurries can dehydrate if being flown and injected at resistance to flow encountered, creates pressure-drop and differential pressure is exerted across the barrier cause separate solids from fluid phase. Slurry *gelation* is increase in viscosity due to attraction between the hydrating cement particles and controlled by checking fluid loss. The "*flash set*" is slurry becoming too viscous to pump at allowable pressures. Gelation and premature dehydration can be two main reasons for inappropriate, insufficient sealing and/or fluid loss.

(iv) **Free Water**

Free water might be present in reservoir or may result from increased volume of mixing, cause problem in plugging for low density slurries and in angled strata. Slurry should exhibit zero water when measured at 45^0 angle after subjecting slurry to downhole conditions of temperature and pressure.

(v) **Compressive Strength**

Rapid compressive strength development after expiration of thickening time is important. Fault and inclined plugging require rapid and high strength development, that should have greater strength than formation. Strength development of about 3000-5000 psi is usually sufficient.

3.3.3. Downhole Conditions

(i) **Washouts**

Excessive washout over a short section is usually reflected by such indicators as geological/offset data, a change in penetration/injection rate, volume and type of solids washed out. The most effective in dealing with washouts in high pervious sections is to use more slurry volume than calculated.

(ii) **Lost Circulation**

High loss rate of cement slurry is remedy, as *Gilsonite*, that enters the loss zone and plugs the voids. When potential for lost circulation is present, both slurry design and placement procedure selected carefully. A little or no fluid loss acceptable but high differential will allow rapid dehydration even with low resistance.

(iii) Slurry Contamination

The formation mud and different fluids can commingle into slurry, affects setting and strength development of plugging through contamination. The extent of interface is contingent upon difference in fluid densities, yield point relationships of fluids, rate if displacement, geometry, and angle of formation. Slurry with *cellulose* material would be used in strata with *lignosulfonate* mud for contamination tolerance but not for *carboxymethyl* mud.

(iv) Geological Consideration

The permeability influence major in cementing rate then geology. Usually cement solids plug pore throats at face of formation toward which they are being pumped. This plugging effect creates filter cake as liquid is squeezed from the solids-laden fluid into interconnection system.

Carbonates (limestone and dolomites) typically have a less porous matrix and, unless fractured, have permeability can easily be squeezed so long as fracture gradient is not exceeded. A massive shale section (regarded as impermeable as can massive salt) have very little or no interconnected pore spaces and allow only negligible fluid leak-off into actual rock.

(v) Injection Rates / Pressure

At bottom hole static temperature "two-rate" injection profile yields most important data for any squeeze job. Squeeze job can be obtained from properly executed injection profile. This physical measurement made at site; whereby well fluid in injected into formation at controlled rates, and corresponding pressure are recorded. The two rates to record are lowest rate at which formation will take fluid, and minimum rate anticipated to displace slurry to the first hesitation cycle.

The safe injection rate is the pump rate with pressure below formation fracture gradient. When properly attained, high injection rate will have low pump pressure, high pump pressure have low injection rate. The slurry should be designed for a particular job for long enough thickening time to allow pumping it below squeeze packer at suitable rate. The system of injecting slurry in strata can be simple as injecting in wellbores. A casing and packers are fixed in well and then pressurized pumping can be applied. The concerning pressures calculation;

$$\mathbf{PE = P_{sq} + (0.052 \times D_1 \times p_1) - (0.052 \times D_2 \times p_2)} \qquad \text{(eqn- 3.5)}$$

P_1= fluid density (ppg), P_2= fluid density during squeeze (ppg)

D_1= depth surface to packer (ft), D_2= distance packer to squeeze zone (ft)

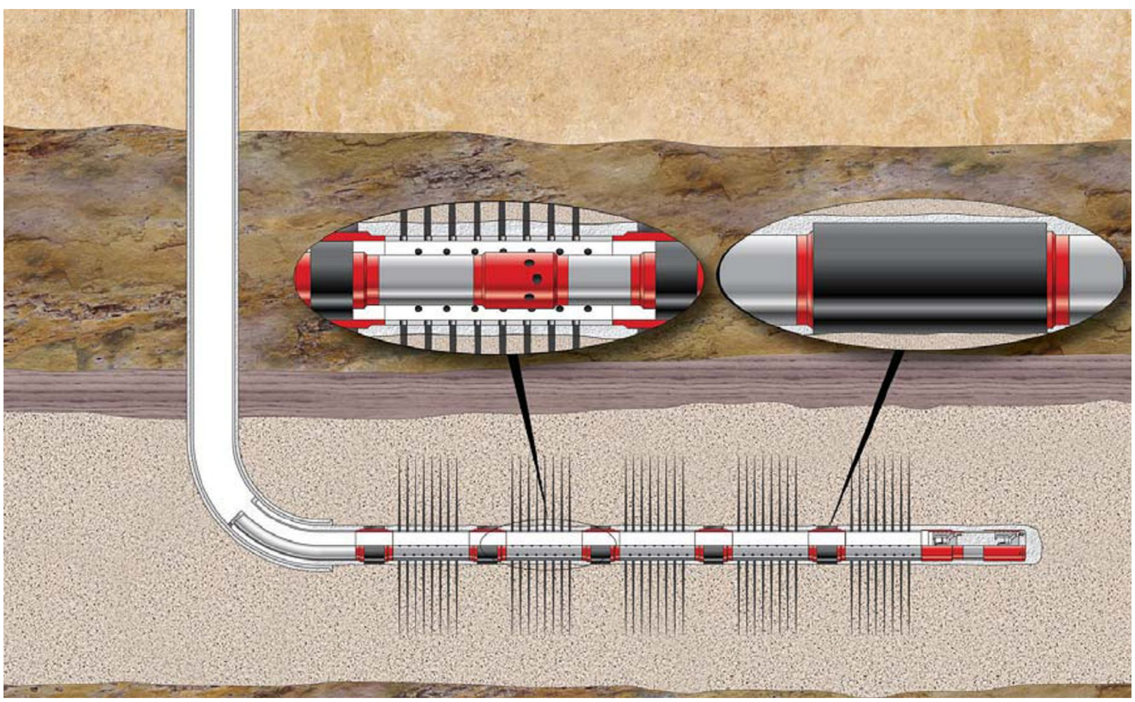
P_{sq}= pressure applied to squeeze, PE= sum of pressures applied with hydrostatic pressure of fluid.

3.3.4. Reservoir Compartmentalization

The horizontal drilling technique would provide maximum exposure to reservoir for sealing. Compartmentalized reservoir can control early gas/water breakthrough, inter-connected faults, and reservoir compaction. Horizontal wells can provide significant cement slurry placement opportunity, less bled-off cement, mud treatment, solids removal and inability to create fractures to create ideal isolation.

Challenges

- Horizontal/circular wellbore
- Ensure no leak paths in sealing
- No delays to next part of program
- Compartmentalization may restrict future production-operation options.



(fig- 3.5)

3.4. Reproduction of Oil from Geological Storage

Production covers subsurface and surface facilities and treatment capabilities (chemical, physical and technical) to achieve optimum performance. The main disciplines involved are as following:

(i) **Engineering** related to;

- Fluids' flow
- Reservoir dynamics
- Equipment design, installation, operation and fault treatment.

(ii) **Production Chemistry**

- Fluids - produced, injected and treatment fluids
- Rock - mineralogy, physical/chemical properties and strength.

(iii) **Cashflow**

The overall objectives would ideally be to maximize both cash flow and recoverable reserves by;

- Maximum reproduction rate
- Maximum economic longevity

(iv) **Costs**

Fixed/direct costs, and production would be based on:

- Minimize capital costs
- Minimize production costs
- Minimize treatment costs

- Minimize workover costs

(v) Key Areas in Production

- Well Productivity
- Well Completion
- Well Stimulation
- Surface Processing

- Injectivity/Productivity Enhancement
- Production Problems and Workover Techniques.

(vi) **Natural Flow*;*** operates under reservoir pressure and must be compensated for the loss of the produced fluid by one or more of the following mechanisms:

i. Compaction of reservoir rock matrix, (compaction drive)
ii. Expansion of the connate water
iii. Expansion of hydrocarbon phases in reservoir; (solution gas drive);

- Reservoir, above bubble point, then expansion of oil in place
- Reservoir, below bubble point then expansion of co-existing oil/gas.

iv. Encroachment of an underlying aquifer (water drive)
v. Expansion of overlying gas cap, (gas cap drive).

3.4.1 Utilisation of Reservoir Pressure

The energy stored up within the compressed state of reservoir fluids should be provided the pressure loss in the producing system. The pressure loss distribution as follows:

$$\mathbf{P_{res} = \Delta P_{res} + \Delta P_{bh} + \Delta P_{vl} + \Delta P_{surf} + \Delta P_{chok} + P_{sep}} \quad \text{(eqn- 3.6)}$$

$$\mathbf{\Delta P_{vl} = \Delta P_{fri} + \Delta P_{hhd} + \Delta P_{ke}} \quad \text{(eqn- 3.7)}$$

P_{res} = initial pressure reservoir, ΔP_{res} = pressure loss due to production

ΔP_{bh} = well bore pressure loss, ΔP_{vl} = vertical lift pressure,

ΔP_{fri} = frictional pressure drop, ΔP_{hhd} = hydrostatic head pressure drop,

ΔP_{ke} = kinetic energy pressure drop, ΔP_{chok} = pressure loss across choke,

ΔP_{surf} = pressure loss at surface (Xmas tree),

P_{sep} = operating pressure for separator.

Available pressure drop for the system = $\Delta P_{sys} = (P_{res} - P_{sep})$

$= \Delta P_{res} + \Delta P_{bh} + \Delta P_{vl} + \Delta P_{surf} + \Delta P_{chok}$ ———— (eqn- 3.8)

Total system pressure drop = ΔP_{tot} =

$= [\Delta P_{res} + \Delta P_{bh} + \Delta P_{vl} + \Delta P_{surf} + \Delta P_{chok}]Q$ ———— (eqn- 3.9)

Artificial Lift; assists to pressure by applying technical means, where reservoir pressure is insufficient to lift fluid to surface or at an economic rate with:

- Rreducing flowing pressure
- Fluid injection into reservoir
- Additional power by using pumps.

Each lift system has a preferred operating and economic envelope influenced by factors such as fluid gravity, gas/oil ratio, production rate, development factors such as well type, location and availability of power.

1.4.2. Fluid Injection into Reservoir

Water injection; is applied either by produced water or sea water (offshore), requires minimal repressurisation and treatment. Water is slightly compressible and not an ideal fluid for compression energy storage but, alternatively comparison cost is low.

Gas injection; is more compressible and suitable to maintain reservoir pressure.

Gas Lift Process; involves the injection of gas into the annulus between the production tubing and casing. The gas is subsequently allowed to enter the flow stream within the production tubing at some specific depths through a series of gas lift valves.

Downhole Pumping; allows a higher production rate to be attained by the well:

$$P_{res} + \Delta P_{pump} = [\Delta P_{res} + \Delta P_{bh} + \Delta P_{vl} + \Delta P_{surf} + \Delta P_{chok}]\, Q + P_{sep} \quad \text{——} \quad \text{(eqn- 3.10)}$$

3.5. Problems in Reproduction (Oil Trapping)

3.5.1. Oil Trapping Mechanisms

The subsurface flow behavior of fluids and reservoir lithology influence ultimate GSRO mechanism. There are different mechanisms for GSRO, which include:

- structural/ stratigraphic trapping
- hydrodynamic trapping
- residual trapping
- dissolubility trapping
- mineral trapping
- adsorption trapping

(i) Structural / Stratigraphic Trapping

Structural/ stratigraphic trapping relates to free-phase (immiscible) oil that is not associated with formation. When petroleum rises upwards by buoyancy it can be physically trapped in structural/ stratigraphic traps. The nature of physical trap depends on geometric arrangement of reservoir and seal units. Common structural traps include anticlinal folds or tilted fault blocks and typical stratigraphic traps include lateral change in facies up-dip or depositional pinch-out.

There are various structural/ stratigraphic traps, plus combinations of both structural and stratigraphic elements, that provide physical traps for GSRO. In dipping formation with no defined structural closure, small bumps in seal geometry behave like small anticlinal structural traps.

(ii) Hydrodynamic Trapping

The flow of oil depends on dip of sealing horizon, flow velocity and direction of formation fluid. The stored oil would travel with moving formation fluid. Saline aquifers have low flow velocities (tens of cm/year).
During injection phase migration involves both gravity override and viscous fingering. At high injection rates, viscous forces dominate and plume develops rapidly along permeable paths. At lower injection rates gravity forces dominate and buoyancy causes rise upwards. The heterogeneity in permeability distribution has significant impact on flow behavior. If degree of heterogeneity is large (comparing horizontal and vertical permeability) then channeling along permeable paths dominants flow behavior. After cessation of injection, migration plume continues during relaxation of

pressure gradient driving lateral migration under influence of gravity (buoyancy) and natural formation water flow. The oil moves with formation water and relationship between these two phases determines which storage mechanism dominates and how far will migrate from injection site.

The longer migration pathway and slower migration rate, more oil will become trapped residually or mixed with formation fluids, that eventually no mobile and free-phase oil will exist in system, as modeled in various numerical simulations. The length of migration pathway is controlled by geological parameters such as stratigraphic heterogeneities (i.e. intra-formational siltstones, shales and impervious rocks) which play crucial role in determining tortuosity of flow path. The intra-formational seals act as barriers or baffles to buoyancy-driven upward flow and induce lateral migration until able to breach barrier or get past it.

(iii) **Residual Trapping**

Residual trapping occurs when oil becomes trapped in pore space as residual immobile phase by capillary forces. At tail of migrating plume, imbibition processes are dominant as formation water (wetting-phase) imbibes behind migrating (non-wetting phase), and oil becomes trapped by capillary pressure forces and ceases to flow. Therefore, trail of residual, immobile quantity is left behind plume as it migrates to production well.

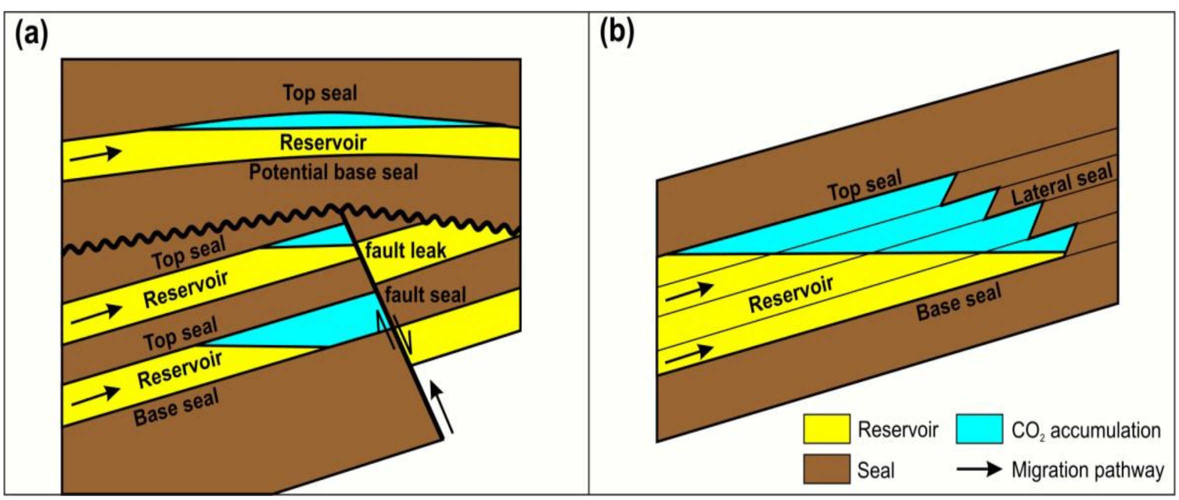
(iv) **Dissolubility Trapping**

Dissolubility trapping relates to oil dissolves into HC gas in formation, increases with decreasing pressure, increases with increase in temperature plus higher porosity. With increasing time, HC gas disassociates from oil and absorb into formation, in result density/viscosity of oil increases. The dense or saturated oil (or water mix) overlying less dense unsaturated, creates density instability and plumes of oil (or water mix) flow downward. The time-scale for dissolution is critically dependent on vertical permeability and geometry of top seal, aided by flow velocities of *in situ* formation fluid.

(v) **Mineral Trapping**

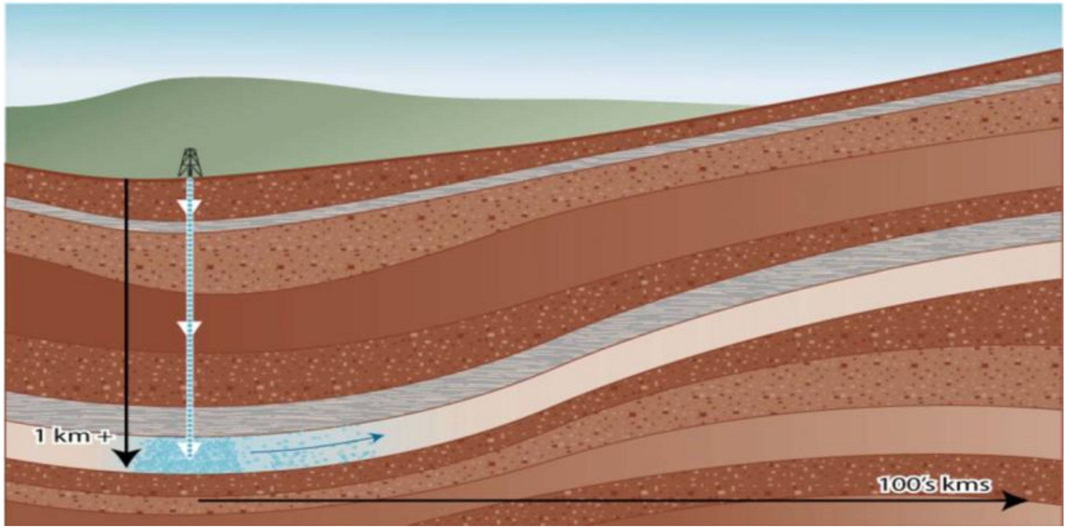
The mineral trapping depends on time-scale, formation chemical composition and fluid and formation temperature plus pressure. Siliciclastic reservoirs are unfavoured over carbonate reservoirs.

Structural and (b) stratigraphic physical traps



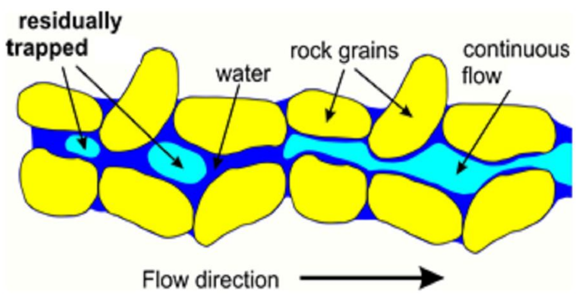
(fig- 3.6)

Hydrodynamic trapping of oil; migration pathway is 1 to 10s km long allowing for a long residence time.



(fig- 3.7)

Residual Trapping of Oil



(fig- 3.8)

Chapter 4

CRUDE OIL DAM (or BARRAGE) CONSTRUCTION

After studies of GSRO, another option is oil dam or barrage with minimum loss (near to 0%) of stocked. Decisions on dam building, once the province of governments and bureaucracies, are becoming a public process involving many stakeholders with different priorities. All stakeholders need a clear understanding of possible benefits and potential consequences of dams if they are to achieve rational solution.

Lifetime of capacity is varied in dam planning, but one hundred years is fixed recently through the establishment and prevalence of planning technical standards (Josuke Kashiwai, japan). The oil dam can work as water dam, and benefits or common purposes can be as follow:

Function	**Example**
Power generation	Electric power is major source and largely consumed
Assured supply	Metropolis are supplied with oil from far areas
Stabilize industry	Can ensure supply for longer period
Price control	Can control price by stocking for import and export
Supply diversion	Busy trade routes can be diverted with economy

(Table- 4.1)

Well designed and maintained oil dam comparatively cheap and reliable, with low escape risk and an alternative of GSRO. It would be less complex to operations and contractual dealings with extendibility.

4.1 Construction Aspects of Subsurface Reservoir

(i) **Site (location)**

The best place for building dam is narrow part of deep mountain valleys, as sides act as natural impervious walls and gap becomes minimum for the required storage capacity. The most economical arrangement is composite structure such as masonry dam flanked by concreted floor and embankments. The use of structure should be dispensable. Significant other engineering and geology considerations when building a dam include:

- Earthquake faults
- Environmental impacts
- Ecological impacts
- Land compensation
- Impact on human habitations
- Landslides and slope stability
- Imperviousity of floor and wall
- Settlements of impurities
- Removal of toxic materials

(ii) **Impact assessment**

Impact is assessed in several ways: the benefits to human society arising from dams (employment, economic strength, risk prevention and fuel energy), harm to nature, wildlife and geology of an area - whether the change to water quality and disruption to human lives (relocation, loss of archeological or cultural matters structure).

(iii) **Environmental impact**

Dams affect many ecological aspects of area under and around. Petroleum supply might be on constant fluctuation, so tolerance needs to be adjusted for strength of structure.

(iv) **Temperature**

Temperature creates risk of gases release and reservoir will have layered temperatures (warm on top and cold on bottom). It is oil from the colder (lower) layer which is released downstream, and so may have different dissolved gases content than before. System depending upon a regular cycle of temperatures may be unable to adapt and release operation can be complex by change of gas content. A large dam can cause loss of entire ecospheres, including endangered and undiscovered species in area, and replacement of the original environment.

(v) **Human social impact**

The impact on human society may or may not be significant. For example, a reservoir's, 6-10 km long and 1-3 km wide, construction can restrict people's activities and their mass movement while loss of many valuable archaeological and cultural sites might be possible.

(vi) **Economics**

Construction may take a long lead-time for site plus geological studies, supplies of materials, and environmental impact assessment etc, as a large scale project by comparison to traditional limited storage terminals or keeping reserves in natural reservoirs.

Assessment and Analysis Criteria

Location/ Option (sub/surface)	Engineering & Economic ($, bbl)			consturct. cost ($)		Operat. Cost		Environment	
	HoldingCost bbl/year	Intake / year	Outlet year	Reserv.	Route	Reserv.	Route	Area km^2	pollut. cost
Location – 1									
Location – 2									
Location –3									
Location – 4									

(table- 4.2)

4.2 Reservoir Selection by Scoring Matrix

Several diversified locations and routes can initially be selected by preliminary engineering, cost and environmental estimations. After first screening more in-depth data should be concluded:

Aspect	Weighted Scores			
	Case-1	**Case-2**	**Case-3**	**Case-4**
Engineering	30	30	40	25
Social	10	20	10	25
Economics	30	30	25	25
Environment	30	20	25	25
Total	100	100	100	100

(table-4.3)

Various factors are considered for weighing method i.e. volume of storage, pipeline system length, geological, geophysical, alignment, agriculture households, social acceptance, costs, and ecological environment, etc.

(Table- 4.4) For above chart Weight factor:1 - least important, 9- most important

No	**Factors**	**Factor's wt**	**Grading Criteria**	**priority**	**Total**
Engineering					

1	**Region's Oil demand / reservoir Capacity**	**9**	**> 0.5,** **0.3 – 0.5,** **< 0.3**	**3** **2** **1**	**27** **18** **9**
2	**Inflow vs outflow**	**7**	**> 20%** **20-40%** **<100%**	**3** **2** **1**	**21** **14** **7**
3	**Geological condition**	**9**	**Very suitable** **Moderate suitable** **Slight suitable**	**3** **2** **1**	**27** **18** **9**
4	**Length of pipelines**	**9**	**>100 km** **100-1000 km** **1000-10,000 km**	**3** **2** **1**	**27** **18** **9**
			Total =		
Social					
1	**Area affected**	**9**	**<100km^2** **100-1000km^2** **>1000km^2**	**3** **2** **1**	**-27** **-18** **-9**
2	**Acceptance of people**	**9**	**High** **Medium** **Low**	**3** **2** **1**	**27** **18** **9**
3	**People reaction management**	**9**	**Excellent** **Normal** **poor**	**3** **2** **1**	**27** **18** **9**
			Total =		
Economic					
1	**Net Present Value (based on 12% discount rate)**	**9**	**<100 million $** **100-1000 million $** **>1000 million $**	**3** **2** **1**	**27** **18** **9**
2	**Economic Internal Rate of Return**	**9**	**>12%** **10-12% - <10%**	**3** **2 - 1**	**27** **18 - 9**
			Total =		

Major environmental factors	**weight**	**lev**	**el-**	**of-**	**im**	**pa**	**ct**	**s**	**Scores**
		-3	**-2**	**1**	**0**	**1**	**2**	**3**	
Water quality affected	**7**								

Area of affected land	**7**								
Earthquake	**7**								
Geological strength or structure safety	**5**								
Management of pipeline Materials	**7**								
Ecology (aquatic & land animals spread)	**7**								
Forest area lost	**9**								
Air quality affect due to gas emissions	**9**								
other	**-**								

(Table-4.5)

Using of Score Matrix could be applied to several criteria i.e. selecting type of reservoir the most suitable, and technical, economic, social, comparative cost, environmental aspects. Decision can be made on total scores by desirable rating scale of many factors.

Actually this model is used by Royal Irrigation Department, (Thailand) and can equally be useful for oil reservoir development planning.

4.3. Checklist of Dam/Barrage Technology Issues

(i) **General**

- Report on any specific investigations and analyses carried out
- Report on design methods, standards and loads adopted and design data
- Report on proposed and actual construction methods (results of testing)
- Report on operational and maintenance intentions
- Describe the expected performance and condition of structure
- Describe the instrumentation and monitoring requirements for operations.

(ii) **Drawings**

- Plan of the dam and appurtenant works drawn on a contour plan of site
- Arrangements, elevations and sections showing details of structures, proposed foundation levels and sub-surface geological features.

(iii) **Summary of Principal Data**

- Type of dam
- Type of spillouts
- Elevations
- Height of dam
- Size of structure
- Filling volume / storage capacity
- Reports prepared by person/ organization in investigation and design.

(iv) **Petrophysical and Fluid-dynamics Data and Analyses**

- Failure impact and consequence assessment (with dam break analysis)
- Topographic map of incoming pipes, description and elevations around

- Sub-area prospecting for other storages or leakages
- Data of flood flow, rainfall records, etc.
- Petrophysical data, formulae & coefficients for capacity and gasification
- Assumptions, methods to design, energy dissipaters for inflows and outlets
- Results of physical or numerical fluid-dynamics model studies.

(v) **Stress and Stability Analysis of Concrete Structures & structural components**

- Assumptions to loads, including combinations of live and dead weight, dynamics, uplift, earthquake and temperature changes
- Methods of analysis
- Description of maps and foundation of dam site
- Results of any structural model studies.

(vi) **Instrumentation**

- Layout and description of embedded instruments and devices installed to observe behavior of works including, as applicable, gas pressures and uplift, leakages, embankment settlements, foundation deformations, alignment, deflections, stresses, strains, temperatures, contraction joint openings, seismic and mechanical vibrations.

(vii) **Construction specifications**

- Clauses dealing with construction works
- Construction schedule and sequence of construction operations
- Supply diversion plan with respect to safety during repair or reconstruction.

4.3.1. Construction Costs

Civil engineering works are site-specific while initial cost evaluations are completed from map studies during appraisal /feasibility level analysis. Costs associated with access roads, relocations, property, designing, etc also need to be considered. At pre-appraisal, reconnaissance-level of project development, cost estimates are useful for rough comparison, screening, and evaluation of projects. Future phases of analysis generally include survey, geologic investigation, drilling, sampling, and testing of foundation and materials to assess feasibility of any project. Despite best engineering efforts, additional surprises can still occur during construction.

Thus, the design of dam is not completed until construction is completed and functioning satisfactorily.

(i) **Non-Field Costs**

Total costs for project implementation might be substantially larger than estimated field construction costs because siting and development projects are not common in today's political environment. Non-field costs related to permitting, documentation, mitigation, contract administration, land acquisition, etc are unknown at this time, but reclamation records and industry standards estimates up to 25% of field costs.

(ii) **Field Costs**

All field costs are indexed in dollars and include allowances as percentage of subtotal field construction cost, as follows:

- Mobilization at 5 percent
- Unlisted items at 10 percent
- Contingencies at 25 percent.

Specifically pump stations, pipelines, and storage is costed. The following sections describe the approach, assumptions, and unit costs used to prepare the estimates for these major components.

(iii) **Pump Stations**

Pump station costs can be extended from unit price of $2,000 per horsepower, representing a typical pre-appraisal-level cost for facilities consisting of structure, pumps, and other components, but no emergency generators or custom architectural treatments. Assumptions and approach for estimating horsepower were as follows:

- Static pumping head estimates, based on elevation difference between supply sources to reservoir, versus elevation of apparent high point along pipeline route
- Tunneling consideration as a means of reducing static lift
- Friction losses estimates, as pipeline part of total dynamic pumping head
- Costs based on multiple pump stations in series.

(iv) **Pipelines**

Pipeline costs extend from unit price of $10/inch diameter/ft length, representing typical open-trench installation of large-diameter pipe and appurtenances. Pipe would likely be welded steel with provisions for corrosion and/or cathodic protection.

Assumptions and approach for estimating horsepower were as follows:

- Pipeline lengths are estimated straight line from supply source to reservoir site, and approximate 25 percent allowance to cover deviations in alignment.
- Costs base on single large pipeline
- Tunneling is considered separately.

4.3.2 General Cost Construction of Dam

Generally cost per acre foot can be applied initially, for screening of which reflects assumption that all sites with volume of storage being the major discriminator. A collection of construction costs for projects constructed over past several decades by various companies can be used to develop cost table using 5 percent inflation per year. More information includes earth fill, rock fill, concrete, roller-compaction, concrete and suitable construction materials.

Summary of Field Cost Estimates by New "Area of Opportunity".

Area of Opportunity	**Reservoir Capacity Range Acre feet**	**Cost Range** $ million
South Fork Boise	100,000	410-600
North/Middle Fork Boise	100,000	150-380
Lower South Fork Payette	50,000-300,000	170-1,290
Lower North Fork Payette	50,000-300,000	170-1,200
Main stem Payette	50,000-300,000	190-1,200
Lower Payette	50,000-300,000	140-450

(table-4.6)

These ranges reflect the limited site-specific information available during the reappraisal / reconnaissance-level assessment.

3.3.3. Rueter-Hess Reservoir (Case Study)

An estimated 240,000 yd^3 of soil and cement used to complete about 50,000 yd^3 of floor. The 196 ft high dam created about 72,000 acre-feet of storage.
1 acre-foot = 1233.5 m^3 = 43,560 ft^3

It is built for Parker Water and Sanitation District, and will serve water needs and solve long-term supply and management challenges. The Rueter-Hess project consists of dam, water diversion structure on Cherry Creek and pump stations and pipeline to carry water from Cherry Creek to Rueter-Hess Reservoir.

Designed by RJH Consultants, Inc. of Englewood, Colorado, project originally was envisioned to build 135ft high, 5300 ft long dam that would impound approximately 16,200 acre-feet. Construction began in 2004, than increased surface area of lake from 470 to 1170 surface acres and height up to 196 ft.

At November, 2006, total cost of in-place soil-cement was \$38/yd^3, includes materials, mixing, transporting, placing and curing, while construction is expected to be completed by 2011.

3.3.4. Dam failure

Dam failures are catastrophic if structure is breached or significantly damaged. Routine deformation monitoring of seepage in and around dams is necessary to anticipate any problems and permit remedial action to be taken before structural failure occurs. Most dams incorporate mechanisms to permit reservoir to be lowered or even drained in the event of such problems, so precautionary/remedial measures must be prepared. Another solution can be rock grouting or pressure pumping cement slurry into weak fractured rock, area adjacent to accommodate spillage if happens.

During an armed conflict, dam is to be considered as an "*installation containing dangerous forces*" due to the massive impact of possible destruction on civilian population and environment. It is protected by rules of *International Humanitarian Law (IHL)* and shall not be made object of attack if that may cause severe losses among civilian population. To facilitate the identification, a protective sign consisting of three bright orange circles placed on same axis is defined by the rules of IHL.

The main causes of dam failure include:

- Design error
- Geological instability
- Exceed to storage levels
- Poor maintenance
- Extreme rainfall
- Human error.

3.3.5. Reservoir Safety Risk Treatment

The reduction in likelihood can be achieved by:

- Storage level telemetry
- Intake telemetry

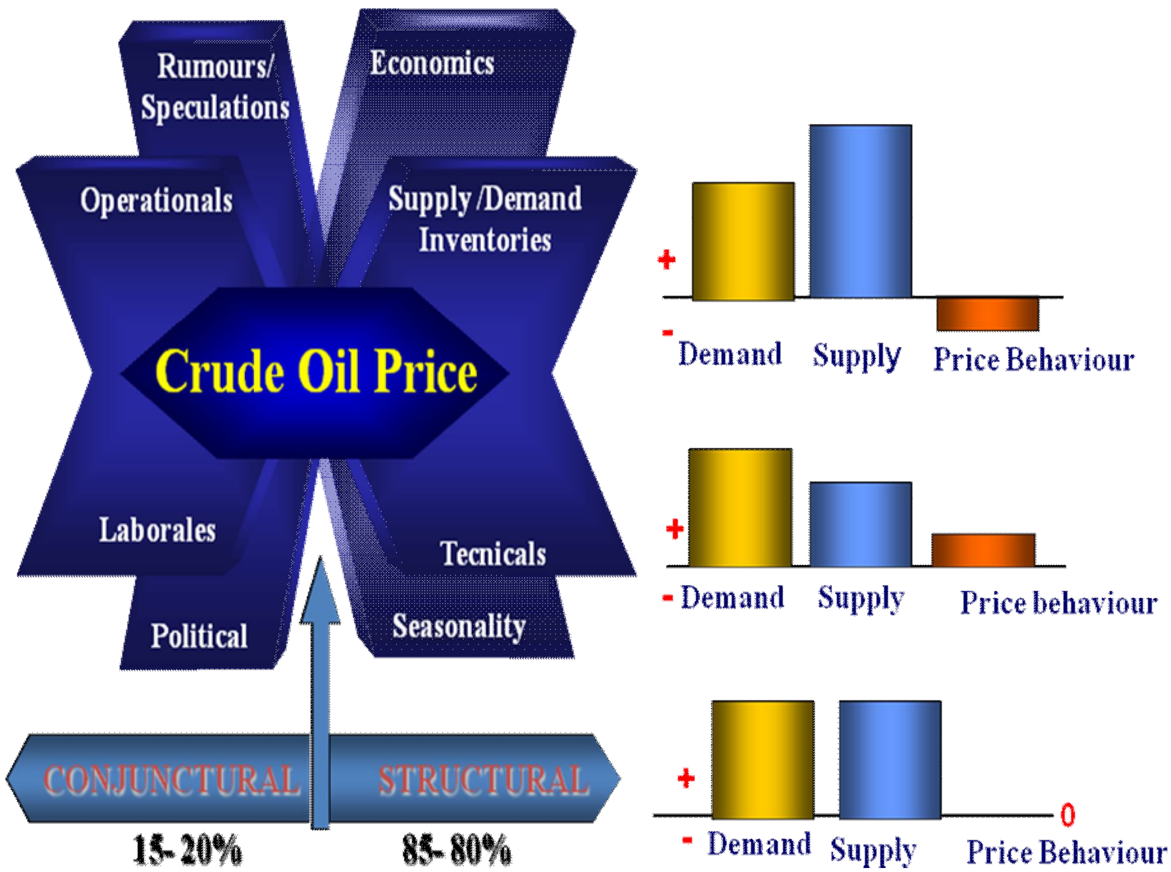
- Operational procedures
- Trainings
- Backup systems
- Maintenance
- Evacuation plans
- Warning systems
- Design, intake / spillout operation

Chapter 5

OIL as 'PRODUCT' STANDARDIZATION by PRICE STABLIZATION in PORTFOLIO ENVIRONEMENT

5.1. Economic Modeling of Oil Business

Factors influence oil Price and market mechanism. The behaviour of prices in market is strongly influenced by the fundamental forces of demand and supply.



(fig- 5.1) Demand / Supply Behaviour Mechanism and factors influence.

Main elements in discounted cashflow model:

- Net Present Value
- Pay back time
- Break even oil price
- Cash flow (per Year)
- Internal rate of Return
- Expected Monetary Value
- Number of times return of inestments

(i) **Investment decisions**

NPV indicates value an investment or project adds to the value of firm.

If...	It means...	Then...
NPV > 0	investment adds value to firm	project may be accepted
NPV < 0	investment subtracts value from firm	project should be rejected
NPV = 0	investment neither gain / lose value	accept or reject projects, decision bases on other criteria e.g. strategic positioning or other calculations.

(table- 5.1)

NPV = 0 does not mean that project is only expected to break even, in sense of undiscounted profit or loss (earnings). It will show net total positive cash flow and earnings over its life.

(ii) Investment Criteria

Net Present Value (NPV's)

The sum of the present values of the profits (revenue minus operating costs) minus the initial investment costs.

$$\mathrm{NPV} = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} = 0 \qquad \text{———————} \qquad \text{(eqn- 5.1)}$$

A rate of return for which this function is zero is an internal rate of return.

t= time, C_t = cash flow, r = internal rate of return, NPV = net present value

Net cash flow = Income (inflow) – Costs (outflow)

$$NPV = \sum_{i=1}^{i=n} \frac{R_i - O_i}{(1+r)^i} - I_o \quad [r = \text{cost of capital}]$$

(eqn- 5.2)

Priority sector of CR system

- Restructuring of energy industry to utilize more efficiently natural hydrocarbon resources, Creating competitive environment and/or adjustment with national company's monopoly
- Energy sector's economic regulation improvement towards incentive for CRS trading, and tariffs
- Possible retail and wholesale trading.

5.1.1. Advantages of CRS Holding Countries

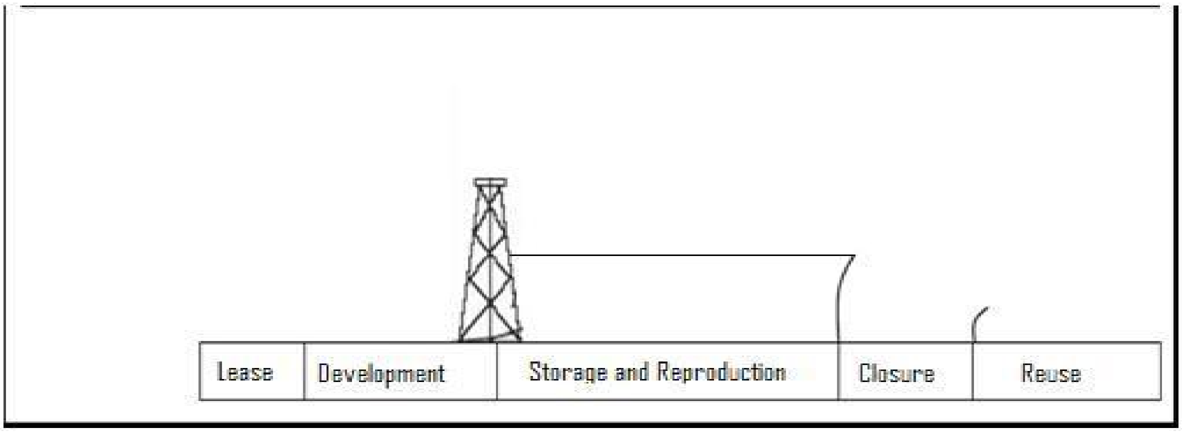
CRS can be developed in other third or transit (not importer /exporter) countries, and significant benefits can be availed, i.e.:

- Attract Foreign Direct Investment
- Dependent upon line off take
- Several alternatives possible
- Can be Competitive exporter.

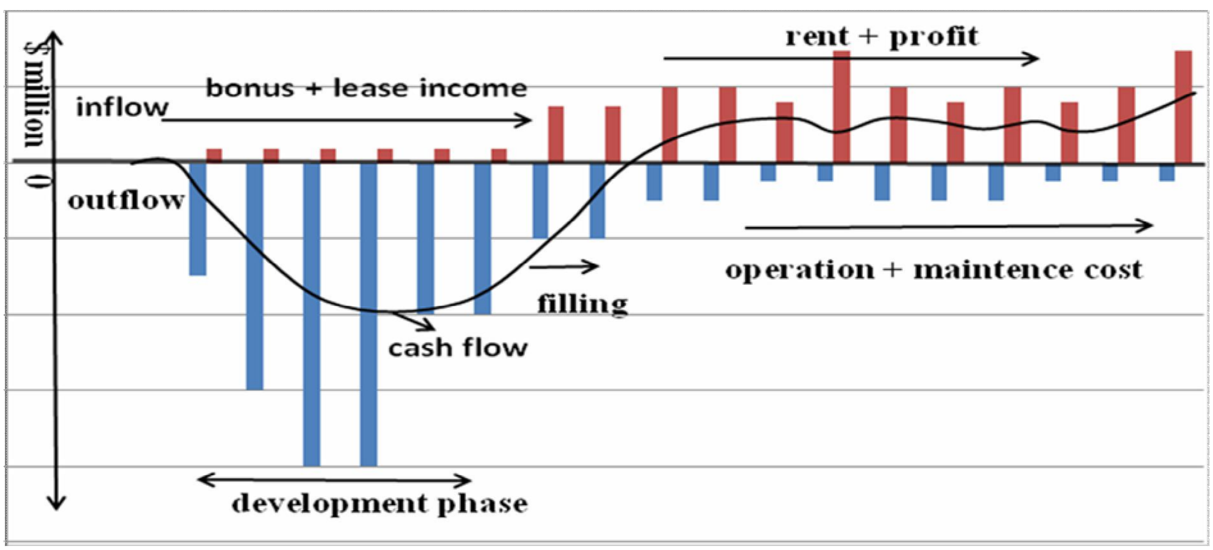
5.2.2. CRS Financial Management (Project Analysis)

The CR system has different life cycle to conventional/natural reservoirs, as after development the immediate change for commercial value can be positive or negative, without risk of zero value of investment at failure of recovery of hydrocarbons. The structure is not having zero value as abandonment of reservoir, due to possibility of alternative usage.

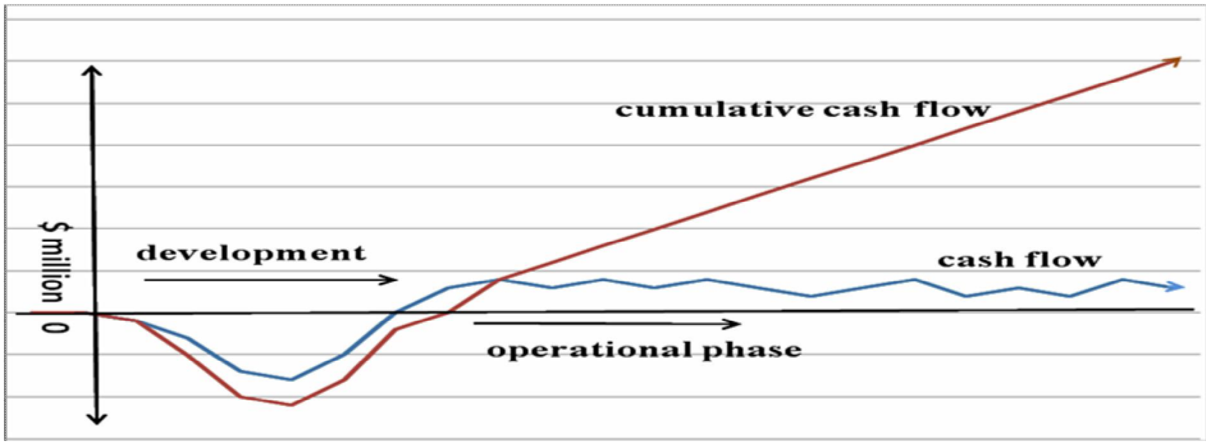
CRS Project Life Cycle (fig- 5.2)



Financial Outlook of CRS



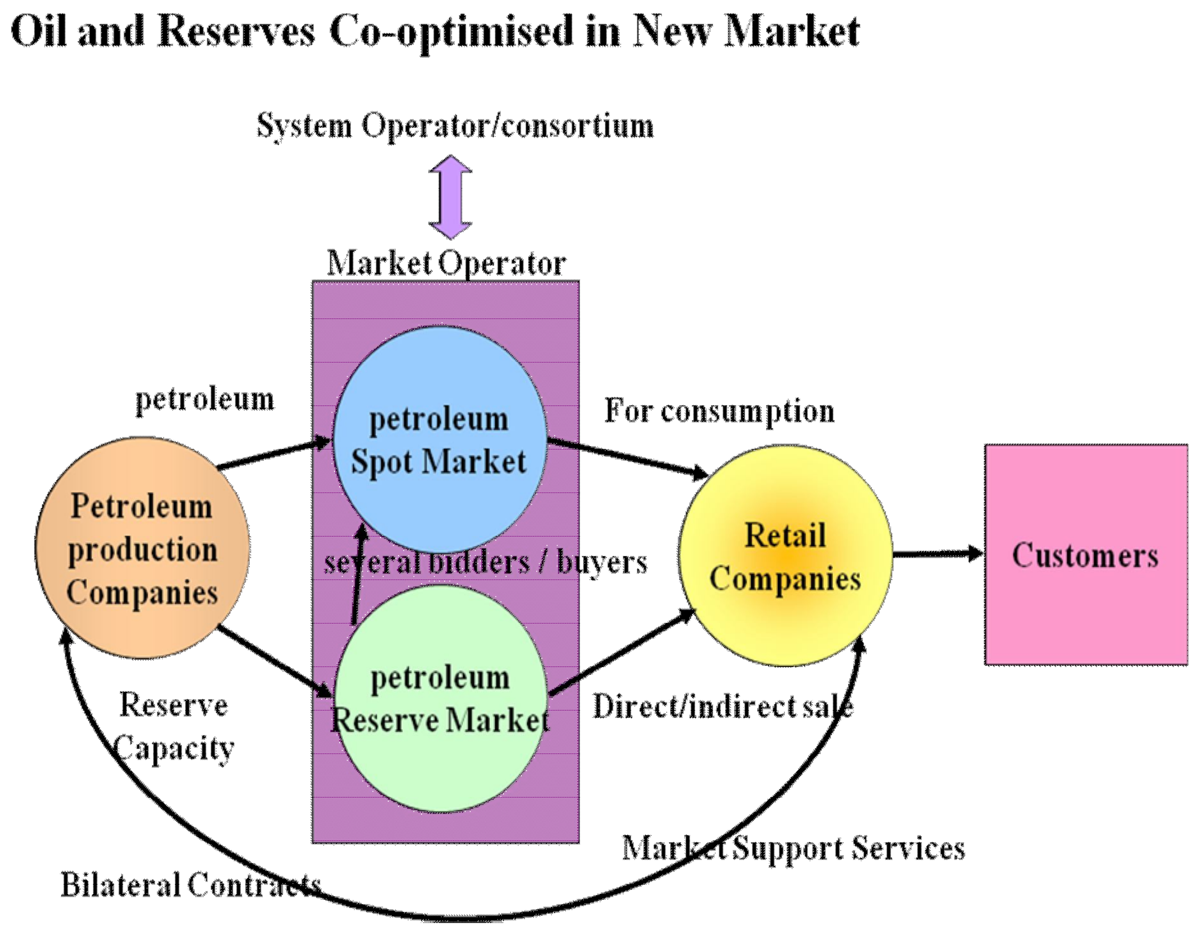
(fig-5.3)



(fig-5.4)

The financial aspects are normal and more stable compare to natural reservoir's performance. The graphical representation is generated speculative and analytically close to real behavior. The real values depend on business performance that relates to petroleum price at which bought-stored -sold, stored quantity, price on petroleum sold, administrational plus transport charges.

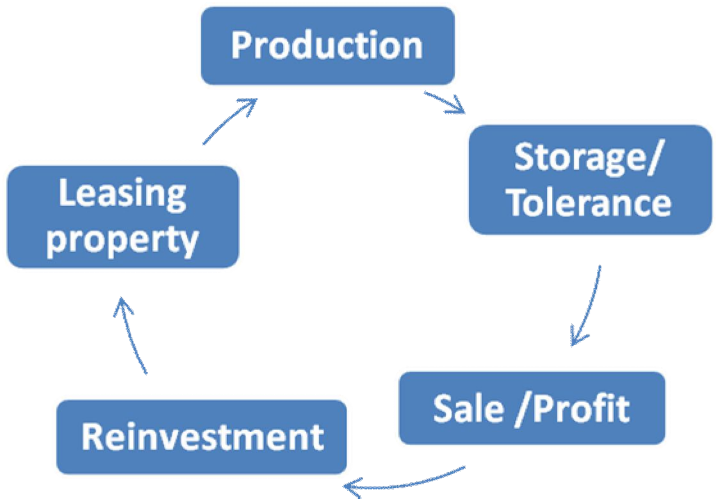
Components of Market system



(fig-5.5)

5.2. Portfolio Management in Oil / Gas Petroleum Industry

Oil companies make money based on their skills in identifying portfolio of properties and utilizing technologies to discover, produce and sell oil in optimal manner. The key ingredient to improve business performance is which allows companies to present performance of all its producing properties and business targets in normalized way i.e. *Business Metrics* such as earnings, production volumes, net cash flow, reserves additions and competitive advantages. Fluctuations in market are evaluated statistically so that hedges, trades, options and specially projects are evaluated in quantitative and comparative sense. Cash flow is vital, and true value of each property is interaction with all other properties in portfolio.



(fig- 5.6)

The efficient frontier (optimal risk/ reward position for business plan) of portfolio is long-term business strategies. A property producing critical cash for exploration plays may be valued considerably higher than "book value" determined by an audit of remaining proven and probable reserves. Correspondingly, a property of high audited value may be tremendous burden to overall portfolio, and consequently may carry a substantially lower valuation. Understanding how business operates from day to day, than forms foundation for improvements to business capabilities of individual properties. Superior business performance (not just production volume) rests in capability to know how, when, and in what order to execute technologies and investment-tactics within the overall business plan of oil company.

5.2.1. Exploration / Production Performance Oil Company

The exploration and production business is midst of major transformation, and emphasis on cost cutting to more diverse portfolio management practices, and industry has found that it's not easy to simultaneously optimize Net-Present-Value (NPV), Return-on-Capital Invested (ROCI) and long-term growth. In fact, companies have not much recent success in exploration/ exploitation growth. Though balance sheets of companies look fine for near term (as share prices are holding), they are neither booking sufficient new reserves to replace those being produced, nor they efficiently exploiting fields they own.

5.2.2. CRS and Portfolio Management

The oil management problem is decomposed into a hierarchy of decision making at different options of storages. Thesis exemplifies proposed approach through some models and case studies on multiple types of developed reservoirs with various behaviors, in which theoretical aspects of reservoir model are used as a virtual field. A model-predictive control (MPC) strategy is used to construct and regulate reservoirs at economically optimal set points to develop predictable and intelligent reservoir behavior, which capitalize on long term storage.

To optimize profitability, engineers traditionally have used mathematical models, field data, instrumental technologies and domain expertise in an effort to make decisions about the best operational scenario. To address the discussed issues, thesis proposes a framework with the following key features:

- It uses a mapped series of various developed reservoirs, level of production and sale decision making is performed over that, thus rendering a complex oil price problem solvable
- It continuously optimizes reservoir operations while satisfying all business and physical and technical (surface and subsurface) constraints

- It is an advanced financial and operational feedback and control strategy, which can work easily on price control
- Its multistage aspects can naturally host optimal levels of production from producing areas, multi-choice buying and sale origins, suitable locations, and portfolio expansion
- Environmental and political hazard risk control.

To bring into existence above framework, project is proposed MFO (Multiple Financing Opportunity) that underlies a consortium establishment among IOCs, NOCs, Government, and private sector, which can be the best operating association. Dynamic analysis leads to proposed strategy results in significant stability of oil price and optimize productions.

CRS proposes approach, based on petroleum system expansion, an MFO strategy, and a closed-loop program and constant production optimization up to specific level.

A common list of objectives includes the following:

- Decrease risk
- Maximize recovery
- Minimize operating costs
- Maximize profitability
- Increase HC production
- Minimize capital expenditures

In managing CRS, operators are concerned about the surrounding environment (oil price, market access, expenditures, etc), limitations of the current infrastructure and physical properties of subsurface/surface system, confidence in reservoir model on which decisions to be made and intrinsic risks of business.

5.2.3. Petroleum Fund, Dutch Disease and CRS

Strategy, Guidelines and Management

Investing into CRS can be new guideline for Petroleum Fund, benchmarking portfolio with investments in both equity i.e. issuing shares and fixed income (rent) instruments. The investment management aims at high long term returns within acceptable limits of risk exposure, and to induce general confidence, adequate risk controls and strong financial performance.

Usually petroleum funds are very large and inter-generational justice and economic policy considerations suggest for not to be spent risky. Such CRS serves can work as buffer in case companies are hit by political shocks, financial value can be split between storage (10%) and equity (30%) implies risk diversification fall in petroleum prices and to utilize stocks if hard to buy at high price. The rationale for having equities in portfolio for CRS can return higher than fixed income from financial institutes. Banks are managing the Petroleum Fund, it may become difficult for politicians to ensure safety for future, while CRS has such advantages:

- Global investment (regions can be chosen)
- Division of share and ownerships among various parties
- Product (oil) existing to management of equity investments
- Active mandates for sales and purchases

The owner(s) of CRS can set guidelines for investments and operations for dividends and oil reserve's values. On co-venture among several oil companies, weightings methods can be used based on importer's shares or customers' demand. With short term investment an independent party relevant to basic goal of maintaining international or local supply and renting can undergo.

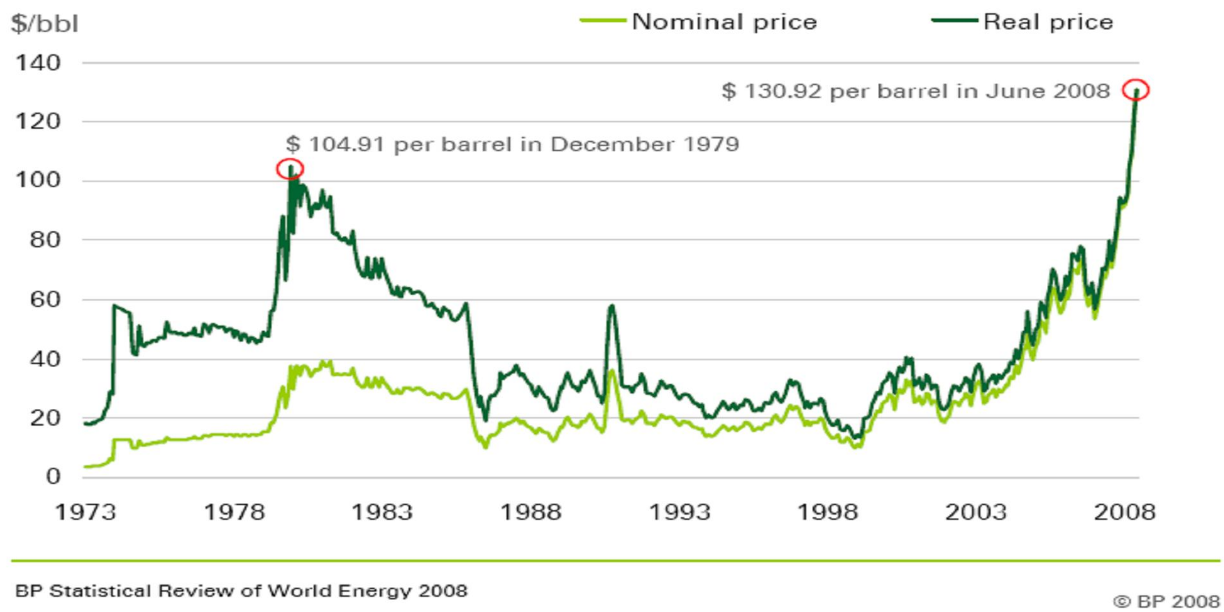
With larger and longer investment horizon, concentration of investments on five continents would expose to certain non-quantifiable risks (i.e. wars, natural disasters, political matters, etc) may involve several countries simultaneously. It's also realized that substitution and discoveries of HC could change import and export weights significantly over time, balance of production and supply activities around world need to locate suitable spots for CRS.

Analytical recommendation is to store oil for European region for 1-2 years, North America 2-4 years, Pacific Area 1-3 years and China/India 1-2 years. The reason is for risk mitigation at greater variability of oil prices, to secure returns in market, political exploitation of supply, but mainly to avoid capital loss without compromise on well developed structures or without high degree of liquidity from projects.

5.4. CRS Need and Global Oil Transport

The modern economy is termed '*Economy of Metropolis*' where big cities are '*economic engines*' and energy consuming giants. The oil value instability is permanent and dominant risk for business, investments on new projects is risky and decision making is difficult. Having a look on such issues by records emphasis the need of CRS.

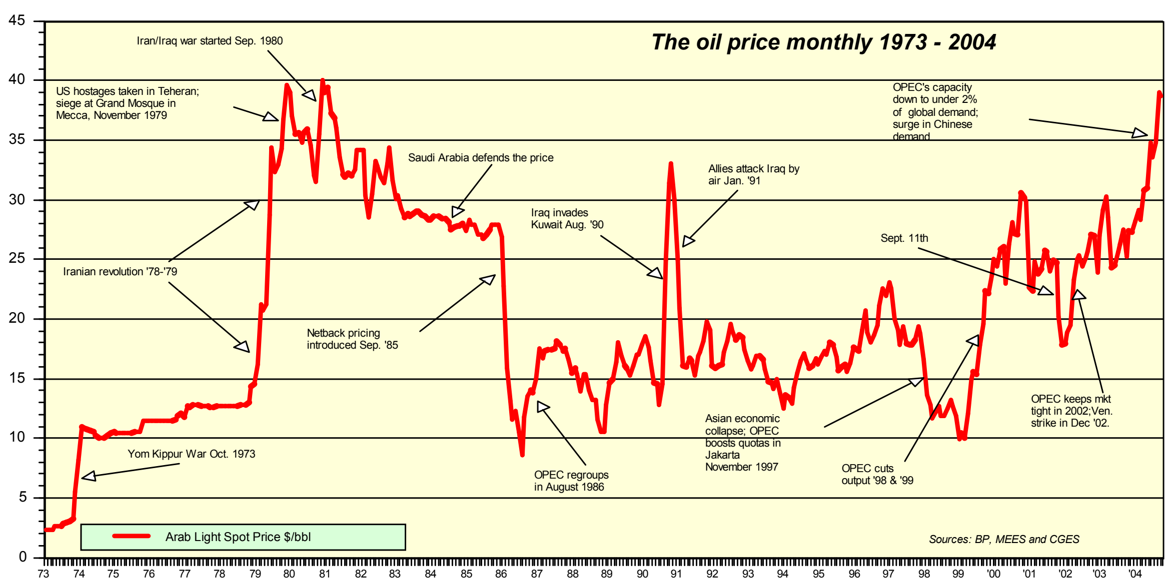
5.4.1. Real and Nominal Crude Oil Price



(fig-5.7)

Last three decades price graph showing the uncertain fluctuation of oil, situation needs the firm and steady trends of oil to emerge as 'Standard Product' for the business stabilization.

5.4.2. The impact of political events on oil price



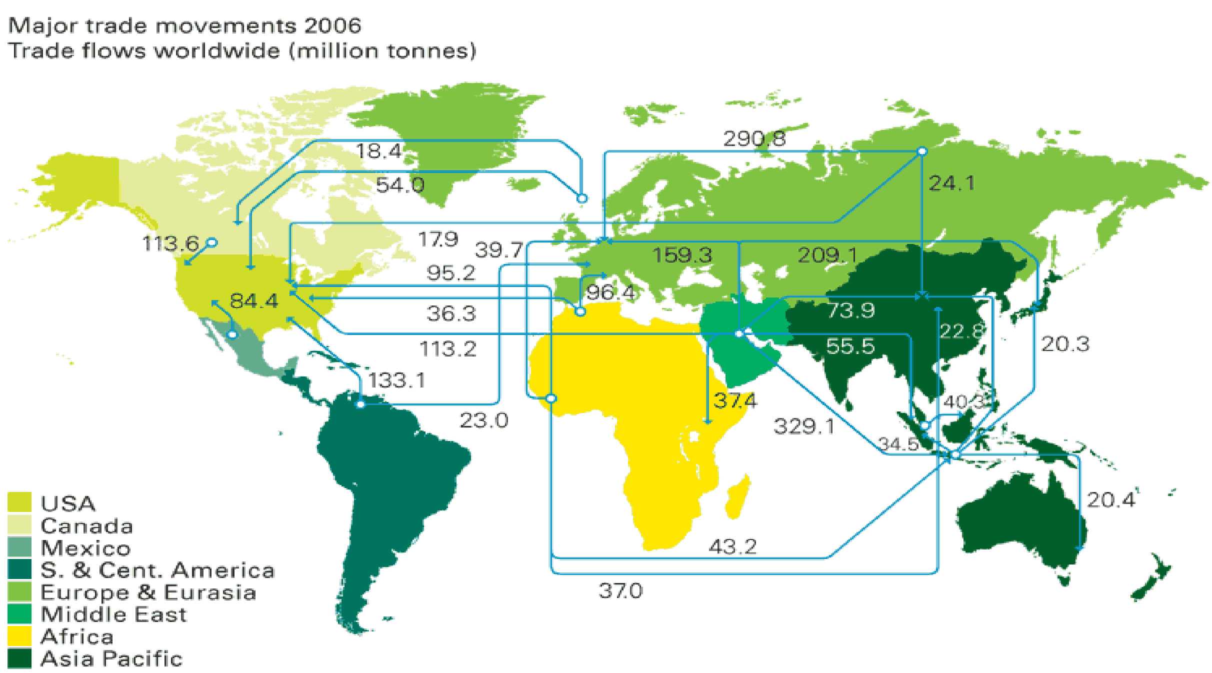
(fig- 5.8)

As continuous supply causes situation economically and politically critical, any change causes the price fluctuations dramatically.

5.4.3. Supply/demand imbalance (oil trade flows 2006 mbpd). (fig-5.9)

From	To USA	Canada	Mexico	L. America	Europe	Africa	China	Japan	Other Asia	Rest of World	Total
USA	-	0.15	0.26	0.37	0.31	0.03	0.01	0.09	0.05	0.04	**1.32**
Canada	2.30	-	0.00	0.00	0.01	-	0.00	0.01	0.00	-	**2.33**
Mexico	1.70	0.04	-	0.13	0.20	-	-	-	0.04	0.00	**2.10**
L. America	2.71	0.09	0.05	-	0.47	0.02	0.26	0.00	0.08	-	**3.68**
Europe	1.12	0.37	0.08	0.06	-	0.25	0.01	0.00	0.13	0.15	**2.17**
FSU	0.37	-	0.00	0.06	5.89	0.01	0.49	0.05	0.11	0.19	**7.16**
Middle East	2.28	0.14	0.01	0.15	3.21	0.76	1.49	4.22	7.90	0.06	**20.20**
North Africa	0.74	0.18	0.01	0.08	1.95	0.06	0.07	0.00	0.11	0.01	**3.23**
West Africa	1.92	0.04	0.00	0.20	0.80	0.06	0.74	0.07	0.87	0.01	**4.70**
E. & S. Africa	-	-	-	-	0.00	-	0.11	0.11	0.03	-	**0.24**
China	0.03	-	0.00	0.09	0.00	0.00	-	0.04	0.31	0.01	**0.48**
Japan	-	-	0.00	-	0.01	-	0.07	-	0.03	-	**0.11**
Other Asia Pacific	0.21	0.00	0.01	0.02	0.14	0.04	0.63	0.52	2.25	0.01	**3.84**
Unidentified	0.24	0.12	-	0.01	0.47	-	0.01	0.08	0.07	-	**1.00**
TOTAL IMPORTS	**13.61**	**1.13**	**0.42**	**1.18**	**13.46**	**1.22**	**3.89**	**5.20**	**11.98**	**0.47**	**52.56**

Oil production and consumption in major region (2006). (fig-5.10)



The figures show enormous oil imbalance between production and consumption, so transported across the world.

Conclusion / Recommendation

A novel multilevel self-adaptive reservoir-management strategy has been developed. It entails two optimization levels: the *upper level* optimizes the NPV function subject to current reservoir-model and physical constraints by selecting optimal values for input variables such as production and injection flow settings. The upper level passes these optimal values as set points to the lower level, which uses model-based predictive control to ensure that controlled variables follow their set points.

This strategy is part of general field-operations hierarchy. Three-phase fluid transformation in multilayered reservoir can be optimized continuously using the sealing reservoir strategy. The proposed approach represents a distinct departure from conventional, in that:

- It uses multilevel optimization
- It is fact-driven as to maximize the production and supplies
- It is suitable for real-time business and supply operations
- It continuously optimizes price-supply performance while satisfying all business and physical surface and subsurface constraints
- It uses feedback corrections and planning aspects for future oil uses
- It provides framework for integration and reconciliation of diverse reservoir-management objectives.

I recommend that test of the proposed approach be attempted with real field to validate the outcomes of this research.

Further;

- The real options models provide rich framework to consider optimal investment under uncertainty in energy, recognizing the managerial flexibilities
- Traditional petroleum supplies are limited and induce serious errors in negotiations and decisions
- The difficulties for petroleum companies takes time and much training for such projects, but important results can be observed
- The CRS can be a strong option to workout for petroleum industry and several states to manage need
- Such model shows better project and financial status
- CRS would manage the petro-political exploitation and price stabilizations
- Such model has capabilities to make petroleum a standard product for business advantage purposes.

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Opinion of Supervisor

The thesis is written by Mr. Shoaib Jami, candidate for degree M.Sc. from Khazar University, under my continuous and strict supervision to achieve the excellence of research and objective work.

The research is done in effective and purposeful manners, while the essence of the most modern or current issues of petroleum engineering and industry are tried to encompassed to solve in swift and technical ways. The thesis's contents show the sequence of wider range of matters, discussed to achieve the targeted results.

Chapter 1, 2 and 3 researched for geological architectural behavior for the enhanced hydrocarbon recovery in an innovative way and to find the effective storage with reproduction capacity and development plan (both offshore and onshore aspects are discussed). Forth chapter discussed a unique plan of oil storage and supply geographically on the most suitable locations, in terms of constructing Oil Dam/Barrage for strategical, economical and business advantages. A mature conceptual and constructional plan is developed.

Chapter 5 is presenting the research and creative financial aspects for the hydrocarbon trades, supplies and price functioning. Sensitive and important matters (i.e. Dutch Disease, oil as 'product' standardization and geographically supplies stabilities) are provided solutions and effective discussions.

Overall the thesis is a genuine effort of candidate, and rated up to highly satisfying level of research, creation, managerial and engineering approach. My best wishes for his future efforts to continue such valuable work in petroleum engineering field.

My best wishes for future success of Mr. Shoaib Jami.

Supervisor:

Assoc. Prof. GASHAM A. ZEYNALOV (Ph.D) ____________________

Opinion of Expert

It is a nice opportunity and occasion for me to go through this experience responding the examination of M.Sc. Thesis and its defense.

This thesis is an attempt to work on combination of subjects related majorly to geological technicality of hydrocarbon recovery and storage, some other options to achieve the strategic advantages by constructing concrete reservoirs, and economic analysis for the hydrocarbon business. The candidate had tried to cover a wide range of subjects, having interlinks among the matters from engineering till administration via financial management.

The impressive work has been done regarding the geological reservoir architecture aspects for enhanced hydrocarbon recovery and financial management. The indirect approaches have been exercised for the business stability by establishing the price of oil.

The idea to make the oil a ‘business product’ can be successful concept for the benefit of economy of many countries, and for the engineering aspects of hydrocarbon business. Such act will give opportunity to non-producing countries to use hydrocarbon not only fuel-element but a research material for further development because of certainty of price and sustainable availability.

I suggest that more work in future should be done by candidate to refine and enhance the discussed matters. I comment that thesis is justifying the worth of research for Master level with significantly important creative works.

I congratulate to candidate on this work and wish success with good results on this thesis, as the research work is really impressive.

Mr. Ali Aliyev

Drilling (Reservoir) Engineer, British Petroleum, Azerbaijan.

Internal Expert Opinion

The thesis is an expression of research to combine the geological architectural aspects to develop the petroleum engineering tasks of enhanced hydrocarbon (HC) recovery and analysis for the HC storage.

The general overview of HC reservoir and explanation of methods used to analyze reservoirs, analysis of selected options of reservoir development, strategic and commercial analysis of reservoirs, and location suitable for commercial venture.

The thesis works for Objectives of understanding of reservoir performance, create additional value of firms, and provide international network for storage and supply. The Achievements of the thesis seems prediction of enhanced HC recovery and storage, development of reservoir on the most suitable geological/ geographical location (megalopolis), analysis of sealing reservoir for;

- oil recovery from thief zones
- blocked oil release.

I would like to comment that candidate has efforted for the excellence of research and objectivity, and thesis shows in depths analysis and beyond the conventional approaches. Overall it's the best combination of geological and engineering.

Gurbanov R.S.

Assistant Prof. Khazar University

CV

SHOAIB JAMI

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Secondary School	Government Arman School- 1987
High School	Government Malir Cantt College, Karachi, 1990
Graduation	Bachelor of Civil Engineering, 1998,
	N.E.D., University of Engineering & Technology, Karachi.

Skills: M.S. Project, Auto Cad, M.S. Office

Memberships of Professional Organizations

SPE - Member of Society of Petroleum Engineers

PEC - Pakistan Engineering Council (PAK)

RICS - Royal Institute of Charted Surveyors (UK)

PMA- Project Management Association (UK)

IPM - Institute of Project Management (USA)

WORK EXPERIENCE

Urazee & Partners. Jan. 1999 - Aug. 2001, Assistant Executive Engineer.

Responsibilities

- Responsible for monitoring and progress of work for infrastructure.
- Responsible for monitoring and progress of work for the systems installations, electrical and finishing work as per drawings and contract.
- Planning & design for structures.
- Visiting sites and liaison with client, visitors, trade men and sub-contractors, sub-contractors further giving instructions to contractors to make sure that all construction is carried out in accordance with contract.
- Arrangements for day-to-day running of site and implementation of health and safety measures.

Adnan Asdar & Associate. Sept. 2001 - Feb. 2002, Executive Engineer.

Responsibilities:

- Responsible to maintain the supply, storage, quality and safety of construction resources

- Responsible for construction as per drawings, schedules, standards, contracts and Project Engineer's directions
- Prepared costs and constructional schedules, minutes of meetings, daily works report and weekly and monthly progress reports
- Involved in preparations of presentations and documents for local authorities, govt. departments, clients and consultants
- Involved in surveying and estimations
- Day-to-day dealing and planning for works and issues.

Feb. 2002 - Jan. 2004. Associate Project Engineer.

Responsibilities:

- Maintaining daily records and setting out data to enable the accurate re-tracing of any relevant facts and figures
- Keeping adequate and correct measurement of work for cost and value purposes, for use by Section Engineer and Quantity Surveyor
- Ensure the works are constructed to quality and specification
- Organize the work in accordance with Method Statements and Risk Assessments so as to establish safe systems of work for all persons
- Ensure proper control is exercised over sub-contractors. Monitoring their performance carefully with regard to safe systems of work and health and safety matters. Report any non-compliance or safety problems to Senior Management
- Involved in planning and scheduling of project, supply of the materials and payments from client
- Quality checks and monitoring of civil works, materials, contractor's staff and work progress in respect of drawings, engineering codes and contract
- Presentation and correspondence with consultants, client, contractors
- Preparation of daily work reports, weekly and monthly progress reports.

Feb. 2004 - Oct. 2004. Associate Project Engineer

Responsibilities:

- Involved in project proposals, tendering, contract terms, work scheduling, and cash flow plans
- Reporting and assisting to the Project Manager
- Contract, drawing and standard applications
- Liaison with contractors, consultants, govt. authorities and client
- Preparation of Daily, weekly and monthly work-report.