CHAPTER II

LITERATURE REVIEW

This chapter discusses some related works on PWI and PWRI. Some works on reservoir simulation and history matching are also discussed here.

2.1 PREVIOUS WORKS ON PWI

Water is producing with the production of oil and gas. This PW may be formation water or flood water previously injected into the formation. Due to government regulations and cleaner environment disposal of this PW is a great challenge for the petroleum industry. Among others disposal methods, direct discharge following treatment and PWI or PWRI are suitable for offshore operations. The following literatures discuss some related works on PW disposal.

Sirilumpen and Meyer (2002) discussed re-injection option, lessons learned, anticipated well characteristics, water management history and future considerations at the Erawan Field. They discussed the way they converted pressure-depleted wells into injectors and how some stimulation works, tests have had limited success. They also discussed the ways produced water is disposing either separator pressure or injection pump. They also told the exploring the possibility of injecting into shallow sands for areas do not have depleted sands and simulations are being run to determine the feasibility of using water disposal as a way to flood depleted gas reservoirs to increase recovery.

Singh (2002) described planning on operational aspects regarding daily activity for successful re-injection. The operational aspects especially included working pressure along the injection system, estimated formation fluid pressure as a function of cumulative injected water, estimated fracture pressure and its relation to proposed injection rate. He developed operational window to determine the range of allowable injection pressure and proposed injection rate. He also described a method to determine the life time of each proposed injection well. This study is very useful to make injection programs and scenarios to extent the injection lifetime.

Rubiandini, Fitnawan and Singh (2002) described evaluations and planning on operational aspects that are essential to successful water injection project. They discussed working pressure along the injection system, estimated formation fluid pressure as function of cumulative injected water, estimated fracture pressure and its relation to proposed injection rate. They developed an operational window to determine the range of injection pressure in relation to proposed injection rate. Using with the simulation results they determined the lifetime of the proposed injection well. They recommend that method is very useful to make injection programs and scenarios to extent the injection lifetime.

Weijermans and Warren (1997) described a method which permits produced water injection rate and volume prediction to be made based on historical measured gas production rates and volumes. They described how to convert an analytical gas productivity index solution for dual-porosity systems to a water injectivity index as well. The conversion was validate using rigorous dual-porosity simulations and sensitized to a broad range of matrix and fracture properties. They also described how the converted water injectivity index combined with other nonlinear repressurisation, relative permeability and water viscosity effects were combined with surface pump curve and wellbore head/friction calculations for predicting long term injectivity.

Russell and Hazlett (1996) showed the feasibility of using the Ojo Alamo Sandstone (OAS) aquifer of the San Juan Basin (SJB) to store produced water from oil and gas operations by using data analysis and reservoir modeling. To perform this study, they constructed a reservoir (aquifer) simulation model to estimate the effect of injecting low salinity produced water from oil and gas wells into the Ojo Alamo Sandstone. Then by simulation they selected sites for both the injection and discharge of water within the reservoir boundaries and predict water quality at any point in the aquifer. Finally they proposed that the gas operators be allowed to inject produced water into the OAS on case by case basis.

Furtado, Siqueira, Souza, Correa and Mendes (2005) presented an overview of the main PWRI project in Petrobras. Petrobras has been reinjecting water in their mature onshore fields for many years, and it is starting reinjection projects in offshore Campos Basin. They discussed technical, economical and environmental aspects of PWRI. Other related topics such as injectivity loss due to PWRI, injection above the fracture propagation pressure, PWRI effects on oil recovery and reservoir souring potential are also discussed.

Abou-Sayed et al. (2005) discussed technical approaches for addressing the production, separation and disposal/injection segments of water injection and reservoir waterflooding procedures and the basis for selecting strategy components and produced water management actions. They assessed fracture propagation during seawater and PW injection and its impact on injector performance. Physical phenomenon, namely matrix and fracture injection, and other associated issues (i.e. monitoring) with regard to injectivity and facility requirements are discussed. Several field cases, as well as water injection design and analysis tools for quantifying the impact on flood and well performance are also presented.

2.2 PREVIOUS WORKS ON RESERVOIR SIMULATION

As stated earlier, the selected method for PW disposal in the M field is to inject it into shallow aquifer. Reservoir simulation is used for this study to investigate the capacity and performance of the targeted aquifer. The reservoir simulation consists of data gathering, reservoir model construction, history matching and run the model for different cases. The following are some literatures that discuss reservoir simulation and history matching:

Sanchez, Martinez, and Rattia (1992) discussed the standardization of the procedures that are involved into a reservoir simulation study. They developed a methodology aimed to eliminate engineering and computing time waste during the model initialization, history match and predictions. Therefore work processes were established and documented including flow diagrams and forms were prepared to obtain information allowing to use statistic control to monitor each process performance. Besides the aforesaid application, the developed methodology allowed to optimize the studies execution process by reducing the risk of overlooking key aspects and variables. They also provide step by step procedures of model initialization and history matching process.

Salwi and Toronyi (1988) presented broad critique of the current state of reservoir simulation and its application with an emphasis on its three key shortcomings: (1) lack of established industry standards for simulation (2) non-uniqueness, and (3) inherent uncertainties in reservoir modeling. Simulation can be very valuable and effective if (a) its acceptance and implementation by the user community as a probabilistic tool with inherent uncertainties and (b) the exercise of stringent & engineering and geologic control measures and a structured methodology in its utilization. They took a step in the direction of the two aforesaid principles. It forms the first leg of a three-part series: (I) A Critique of Current Practices, (II) Methodology, and (III) Examples. Part I presents a critique of the current state of simulation and its applications with an emphasis on the above three key shortcomings. Part II proposes a general methodology for conducting simulation study. The methodology allows a systematic approach to modal selection, construction, validation, and predictions thus reducing the potential for the commonly noted misuses. Included are steps for engineering and quality control. Part III presents three examples of Chevron studies where the methodology has been successfully used. They also provide step by step procedures of model construction, initialization and history matching process.

Ariadij, Suryanto and Mariani (2005) applied a single well numerical simulation model and accommodated geological data such as depth structure, net to gross ratio and distribution of petrophysical properties to a DST data. After incorporating the geological, reservoir engineering and production data they conducted history matching of pressures and rates of the DST data. In the history matching process they discussed the identification of less certain data and step by step adjustments of those data in a fantastic way. And those steps could explain and improve the understanding of reservoir characterization.

Williams and Keating (1997) discussed a structured approach to perform a history match on a complex and multilayered reservoir model. They recommended tools for interpreting data and simulation results, and discussed procedures for improving the quality and efficiency of the history matching process. They also reported the reservoir parameters that affect the matching observed reservoir performance most. The stratigraphic method (SM) is built on logic that a complex 3D system can be reduced to a series of simpler 2D systems and then the four hierarchical levels of model adjustments can be applied during history matching are (I) global or fieldwide, (II) flow units or layer groups, (III) individual layers, and (IV) individual wells. The seven steps history match plans are (I) gather data, (II) prepare analysis tools, (III) identify key wells, (IV) interpret reservoir behavior from observed data, (V) run model, (VI) compare model results to observed data, and (VII) adjust model parameters. This method has been successfully used on highly complex reservoirs.

Vark, Paardekam, Brint, Lieshout and George (1992) discussed the modeling of a fluvial reservoir system. At first step they constructed a detailed geological model by probabilistic techniques and then the model was converted into a coarser numerical model. At the geological modeling stage, they discussed detailed modeling of channels and crevasse splays. They used that later model for evaluating alternative development scenarios namely well spacing, completion strategy, etc. and matched it with field observations. Finally, they perform calibration of the simulation model to field performance.

Hoffman, Wen and Strebelle (2005) presented an innovative methodology to integrate geological information, well log data, seismic data and production data into a consistent 3D reservoir model. This method relies on probability perturbation method (PPM). Channels are modeled here and channel locations are perturbed in such a manner that the oil, water and gas rates from the reservoir match more accurately with the rates observed in the field. They used two different geologic scenarios and multiple history matched models were generated for each scenario. They also presented a practical method to integrate the dynamic data into reservoir models in a way that honors all other information that is known about the reservoir. Furthermore, they applied these methods to a channel reservoir from the African coast.

In the literatures reviewed in this study, several techniques such as direct discharge following treatment and PWI or PWRI, have been used to dispose the PW. As mentioned earlier, all those three methods are suitable for offshore fields also. Therefore, to dispose the PW in the M field, PWI into aquifer sand is selected, the reason is that harmful fluids are permanently removed from the environment. Moreover, no by product is generated by this method to create any impact on environment. The criteria for choosing the aquifer sand are adequate porosity-permeability and reservoir volume.

Reservoir simulation and history matching process were reviewed to obtain guidelines for this study, more specifically, model construction, channel modeling and history matching. Reservoir simulation starts with defining of the study objectives and then reservoir characterization, model construction, model testing, history matching and prediction are performed. After performing history matching, the history matched model is representation of the reservoir and the model is ready for prediction of future performance.