A Holistic Approach to Shale Field Development

By Dale Blue, Ron Dusterhoft, and Jennifer Hohman
Presented at Petroleum Network Education Conference (PNEC) 2012
**Introduction**

Economic production of hydrocarbons from shale or source rock reservoirs (SRR) has transformed the petroleum industry in North America by creating an abundant, local supply of low-cost energy. Drilling and completion of these very low-quality reservoirs has proven to be highly service intensive and could easily become commoditized, but the complexity within these reservoirs, combined with economic pressure, is dictating that there is a need to “work smarter” to maximize hydrocarbon recovery and realize the maximum value from the asset. In late 2010, Halliburton’s Integrated Workflow Team initiated a project focusing on shale field development (SFD) to define a multi-product service line (PSL) offering. This offering will enable Halliburton to offer a full-lifecycle solution to its customers that will help them to lower exploitation costs while maximizing production efficiency.

At the beginning of this project, it was recognized that data management was a central element to developing such a solution. To better define the requirements for a data management system for the SFD project, the Integrated Workflow Team kicked off a data management assessment to analyze the current state of data management around shale field activities within Halliburton, understand the data requirements for a complete shale field solution, and define a data management solution that would enable the SFD workflow.

This data management assessment took place from July to September 2011 and involved interviewing a number of key personnel from Halliburton Business Development Technical Teams (Tech Teams) and product service lines (PSLs). This was a high-level assessment that was intended to identify current workflows, understand how those workflows would be improved in a new system, and identify ways to easily address current data management problems.

In summary, the assessment identified a number of potential improvements in the current processes used by the Tech Teams as well as several immediate solutions that are currently being implemented. One of the more challenging issues found was that engineers and geoscientists do not have an easy way to access the data they need to do their work. By deploying data federation tools to make it easier to access data from disparate sources, users will more easily find the information they need. In addition, end users have a difficult time formatting data and loading it into their technical applications. One solution for this is to provide a centralized data management team that specializes in data loading activities on behalf of users in multiple regions. Creating a centralized, managed repository of technical data in shared application databases will make it easier find reliable information and support a new integrated application framework.

**Integrated Asset Approach to Shale Field Development**

Taking a holistic approach to optimizing shale field exploitation incorporates a full range of products and services throughout the asset lifecycle, from appraisal to brown field recovery. Tech Teams currently support specialized activities within the SFD lifecycle; however, operators tend to be focused on the services provided by a single PSL, usually well stimulation services. Going forward, the Tech Teams will be one primary point of delivery for full-lifecycle SFD workflows.
The high-level processes for SFD have been defined as the result of an Integrated Solution Shale Field Development workshop that took place in December 2010. The central concept that came out of this workshop was that there should be a shared integrated asset model accessible to, and updated by, all applications in the workflow. By having an integrated asset model that is continually improving, it is easier to provide more effective and more efficient field optimization plans. A high-level diagram of this workflow is shown in Figure 1.

The workflow has several key components, but can be broken into two distinct areas:

- Petroleum Systems Analysis
- Drilling and Completions Optimization

**Petroleum Systems Analysis**

Petroleum systems analysis begins with basin modeling to determine the presence of suitable conditions to generate and retain hydrocarbon. For shale, this is more aligned with source rock modeling rather than conventional reservoir modeling. During this phase, all available information from existing sources is gathered, including logs, core analyses, seismic, and reports, that may contain vital information regarding
the zone of interest. This information is then used to generate basin models and maps to evaluate the opportunity. The next step is to drill appraisal wells to validate the basin modeling and more accurately assess the initial analysis by providing more detailed information. Critical steps here include determining the best locations for appraisal wells and determining the information that must be gathered from these wells to improve the models.

If things look good and there is no detailed 3-D seismic available, it would be a good plan to collect this information after the appraisal project so that the model resolution can be improved significantly and the area between the wells can be integrated with good information. For shale, the use of wide azimuth seismic provides more information on natural fracture density, stress anisotropy, mechanical properties, and key reservoir parameters, making it a preferred solution for evaluating shale assets.

The end product from this portion of the workflow is the creation of a geo-cellular earth model that contains mechanical property information as well as reservoir characteristics. This model is the deliverable that is moved forward into the Drilling and Completions Optimization cycle.

**Drilling and Completions Design**

In shale, stimulation is a critical component to achieve economic production rates. As a result, the completion must drive the ultimate well design by determining the best portions of the reservoir with the best stimulation characteristics. A stimulation design process has been identified where the fracture simulator, reservoir simulator and an uncertainty analysis tool are linked together to optimize the fracture design, fracture spacing, lateral length and number of fracture stages per well to allow the operator to factor in uncertainty to make better decisions.

Collaborative well planning then allows the operator to integrate the surface restrictions regarding pad size and pad locations with the subsurface needs to create a full field plan optimized for well spacing, lateral lengths, and stimulation designs. Using the earth model during this stage will allow the operator to identify and target the best portions of the reservoir to more effectively exploit the reserves.

During drilling, completion, and production, the goal is to follow best practices and capture vital reservoir information to update the asset model. The asset model captures critical reservoir information from logs, cuttings analysis, surface data logging, fracture injection tests, microseismic fracture mapping, and production, which can be used to continuously calibrate and improve the reservoir model. The ultimate goal is an optimized well placement plan.

By continuing this cycle over the full life of the asset, the data and knowledge are continuously captured and kept current to provide the engineers with the best possible data and history to make the most informed and best decisions throughout the life of the asset.

**Current State Assessment**
To define the data management requirements for this new SFD workflow, as well as try to resolve some of the data management issues currently encountered by the Tech Teams when designing well completion and stimulation plans, a current-state data management assessment was conducted by a team of internal consultants in 2011.

The assessment’s objectives were to:
- Gain an understanding of the overall data management and work processes currently used.
- Identify immediate areas of improvement for operational efficiencies.
- Make recommendations to enable tech teams to spend more time on higher-value-added activities related to improving production and design well treatments.
- Define the data services and technology required to implement full-lifecycle workflows.

The main activities for this phase of the project involved interviewing a wide range of people who are currently involved in delivering specific services and who are involved in developing new solutions for SFD.

The various individuals interviewed have experience in geology, geophysics, production, reservoir engineering, drilling, completions, stimulation, and software development from the following service lines:
- Well Stimulation
- Fracture Mapping and Diagnostics
- Technology Development
- Formation and Reservoir Solutions
- Software Solutions
- Integrated Solutions
- Regional Tech Teams

Findings
As a result of the assessment, the project team gained a clear understanding of the current workflows, applications, and data that are currently employed when planning shale field activities. While current activities within the various service teams tend to be focused on single well design, it is still critical to understand the current situation to develop a solution for full field optimization. It is also necessary to identify the current data management challenges to improve existing processes and to avoid introducing inefficiencies into the new solution.

Current Workflows
Detailed completion and stimulation workflow analyses were conducted with the Tech Teams from several regions. In general, the workflows for designing a well completion and stimulation plan in each of these regions or Natural Working Areas (NWAs) are very similar, but each team or technical advisor may use customized tools or processes based on their personal experience or preference and based on the data that is available for each job. A high-level overview of the common processes performed in each NWA is shown in Figure 2.
High Level Overview of Current Workflows

To understand the requirements for a data management solution to support this workflow, it is essential to know what types and formats of data are required and produced by each step in the workflow. The data flow determined from the analysis is shown in Figure 3.
Data Flow for Current Stimulation Workflows

Figure 3

Basically, the workflow to design a well stimulation plan can be described as follows:

- A technical advisor will acquire as much information about a well and its neighboring offsets as possible.
- Core tests and open-hole well logs are primary data that must be available to determine the petrophysical properties of a well and produce a rock-properties model. These properties are derived from logs and core tests using petrophysical analysis software.
- New stimulation plans are generally based on previous stimulation plans for neighboring wells, provided those stimulations had good results.
- Petrophysical properties for a well and a base stimulation plan are fed into a fracture simulator, and the plan is modified to obtain ideal simulated results.
- Microseismic data and historical production data from offset wells may be used to calibrate the petrophysical parameters used in the fracture simulator.
- If sufficient subsurface data is available, the tech team may build a reservoir model based on known geophysical and geological data. Otherwise, the reservoir model will be based on the rock properties of the target well.
- The fracture simulation results and reservoir model are fed into a reservoir simulator, and stimulation parameters are further refined to obtain optimized production results.
Current Data Management Challenges

While the workflows seem relatively straightforward, data management was unanimously identified as the biggest impediment to efficiently producing a stimulation design. The main points can be summarized as follows:

- Accessing data is the most challenging task reported by all of the Business Development Tech Teams – advisors claimed that anywhere from 50-90% of their time was spent looking for data.
- In most areas, customers do not readily provide a sufficient amount of ancillary data to produce accurate subsurface models.
- Data management is performed by individual users, each with their own process.
- Finding previous job data for a well is difficult because each PSL uses its own independent data management system, and there is often no common identifier for a well across different systems.
- Accessing some systems is difficult because many data systems are designed for specific application purposes and not general data access or querying.
- Capturing knowledge and results from a completed job is ad hoc, inconsistent across PSLs and regional teams with limited effectiveness.

Data Management Solution for SFD

To define a standard workflow for shale field development, there are four main aspects that must be addressed: Subject matter experts (SMEs) or people, processes (workflow) that are used by the SMEs, applications required to provide specific results or functionality to support those processes, and the data that is accessed and also produced by the applications.

The solution described here has been designed to address the current data-management issues faced by the Tech Teams, as outlined in the findings, as well as establish an advanced solution that will support the development of the SFD application environment. This solution is also divided into several discreet components or activities that are implemented independently to make the project more manageable and to maximize the benefits that can be achieved early in the project.

A high-level overview of the solution is shown in Figure 4 and explained in more detail in the following sections.
Data Management Solution for Integrated Shale Field Development Workflow

Figure 4

Standardized Application Set
To have a standard workflow that is common across regions, it is necessary to have a standard set of tools to perform the workflow. Having a standard set of applications to perform common tasks across service lines and regions reduces the chance of duplicating efforts when developing new tasks that need to be performed, such as creating new reports or analyses. It also makes it possible to define standard data formats for data exchange, and it enables a centralized support team to provide workflow assistance to any user.

For the SFD solution, the Integrated Workflow team has selected Landmark’s DecisionSpace® Desktop (DSD) framework as the primary foundation for software applications. DSD has a number of geophysical, geological, and engineering applications, including collaborative well planning, available as part of its standard suite, and it also supports the integration of custom applications as plug-ins. DSD uses Landmark’s OpenWorks® database as its primary data repository, which has coverage for most of the datatypes required in an integrated asset model. Additional databases can also be integrated as required to provide additional datatype support, such as engineering and operations data.
The current set of standardized applications for SFD support the following functionality:

- Geophysical Interpretation
- Geological Analysis
- Basin Modeling
- Petrophysical Analysis
- Microseismic Analysis
- Complex Fracture Modeling
- Production History Matching
- Collaborative Well Planning

Data Centralization

To fulfill the goal of having a shared earth model and shared access to field planning data, it is essential to keep certain data types in a shared data store that are easily accessed by a number of users and applications. The OpenWorks database, along with a complimentary database for engineering and operations data, fulfills this requirement for the intended set of application candidates. Having this data stored in a common set of database projects will make it easier to find and reuse on an ongoing basis. To date, the following datatypes have been loaded for two different basins, and additional datatypes and regions are being added on an ongoing basis:

- 3-D seismic data
- General well information
- Directional surveys
- Core tests
- Open-hole logs
- Stimulation logs
- Microseismic data
- Cultural data
- Well interpretations
- Structural interpretations
- Complex fracture models
- Reservoir models
- Depth referenced images
- Geo-referenced images

Data Services Team

Business Development Tech Teams reported that they spend anywhere between 50 and 90% of their time looking for and managing data. They also expressed difficulty with putting data into the correct formats for loading into their applications. Both of these findings are consistent with reports from asset teams in operating companies; therefore, an industry standard solution is applicable to resolve these issues for Halliburton. Most operators with more than a few users have a team of one or more data management specialists that perform these services so that engineers and geoscientists can concentrate on tasks that are more in line with their skill sets.

For the SFD project, we began with a team of two specialists who provide data management services to the Tech Teams. As the take-up of this project increases, additional data managers will be added to form a larger central organization. Optionally, regional organizations may be built to focus on the activities of one or two NWAs.
The responsibilities and functions of the Data Services Team include:
• Assisting Tech Team members to acquire and reformat data
• Loading data into the centralized databases
• Configuration and maintenance of the centralized database and data federation infrastructure
• Defining data quality standards and defining and implementing processes to maintain those standards
• Maintaining data security
• Developing and documenting data workflow standards
• Assisting and training the end users with the data management applications

Data Federation
One of the key findings from this project was that the Tech Teams are challenged by the time it takes to obtain information about wells that Halliburton has previously serviced. This is because typically, each PSL has its own historical job information database that is tailored to meet the needs of the PSL and not specifically designed to support general data access. To help facilitate this access, a data federation solution is being deployed, which will provide end user access to a number of existing databases inside the Halliburton environment.

The databases that are federated under this system include:
• OpenWorks
• Engineering databases
• Sales proposal systems
• Sales order information
• Stimulation job history details

PowerHub™ software is a Landmark product that can connect to SQL-based databases and Landmark application databases. PowerExplorer software is a client application that connects to the PowerHub application and provides an end user data management tools for searching, browsing, and modifying data in any of the aggregated data sources. PowerHub and PowerExplorer applications work on the data in situ; i.e., they do not copy the data into a local application repository.

Example workflows that are supported by this implementation include:
• Searching for wells using a map or attribute value and then finding the related sub-surface, engineering, sales, or historical job information for those wells from any of the connected databases
• Merging information from multiple databases or tables into a single view and exporting to Excel for further analysis
• Finding wells that exist in one database but not in another
• Copying well information from an internal database into the OpenWorks database
• Comparing well data attributes across databases or OpenWorks projects and producing a report of the differences
• Finding matching wells across different databases using attributes other than a unique identifier, such as operator and spud date, location, lease name, and well number, etc.

Progress
This SFD project is part of an ongoing process improvement strategy within Halliburton. To date, the following tasks have been completed:

• Validated the software application suite by performing a full workflow simulation from Early Appraisal and Evaluation to Mature “Brown” Field Opportunity Identification
• Initiated an Organizational Change Management Plan to centralize shared services and best practices
• Created a centralized data management team that is to be responsible for maintaining the necessary data management systems and performing shared data management services
• Deployed the data federation technology for access to internal data sources
• Developed best practices for data acquisition (public and internal), data loading, and basin modeling
• Loaded a wide range of subsurface data for two different basins into a centralized data repository
• Initiated ongoing internal technology development projects to provide differentiating functionality specific to unconventional reservoir characterization and modeling

Summary
One of the direct benefits of this assessment was the identification of duplicated, but inconsistent, workflows across PSLs and Regions. By bringing together the owners of the existing processes and technologies, it enabled the team to create a unified technical workflow, application suite, and data management solution. This effort also confirmed that a strong organizational change management plan was needed, especially as it relates to data management knowledge, expertise, and processes.

Analysis of the current stimulation planning process enabled the team to identify an opportunity in the existing workflow to improve operational efficiency by increasing visibility and streamlining access to internal and external data sources. Through better data access and standardized software applications, Tech Teams now have the ability to build an integrated asset model for entire shale field plays. This model has the capability to support a wide range of assessments, from simple analytical comparisons to complex interpretations and technical evaluations.

The process improvements that have been made have enabled technical specialists to become local basin level experts, service lines to identify solutions that most efficiently provide production value, and the organization as a whole to become a trusted industry advisor for the optimization of shale field development.

As a result of the collaborative effort to create a solid data management solution for a shale field development workflow, Halliburton will leverage their industry expertise, data management discipline, and an integrate asset model to provide a full-lifecycle solution to its customers and sustain its position as a leader in source rock reservoir expertise and service delivery.