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Sustainable Spatial Architecture for Geo Engineering Data and Workflows

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Abstract

Spatial attributes are pervasive in petroleum engineering data. Solutions that create a competitive advantage by effectively using this data require a sustainable architecture with documented workflows to increase user confidence and alleviate engineering risk. The components of a sustainable spatial architecture are; data accessibility, a standard data model, portal consumption and Geographic Information System (GIS) access, and data maintenance and business rules. A full lifecycle solution for management of spatial attributes includes collection from field and public domain sources, quality assessment and control, storage in standardized data models, distribution to analysis applications, and capture in knowledge management and audit systems. Each component and lifecycle stage can impact financial performance of the organization using the geotechnical data. Site assessments and a standard methodology for documentation of processes and components were used to compare solutions and value statements for multiple domestic and international operators.

The assessments found that accessibility by end-users impacts quality, accuracy, and confidence related to spatial data. The economic impact of this component is lack of end-user confidence in data tools, and the cost of re-acquiring data. The data model provides feature class intelligence, naming conventions, and attribute accessibility, a standard taxonomy, and a method to move petroleum engineering data into a world of points, lines and polygons. The utility of this component is measured in lost opportunity costs of incomplete analysis, and inconsistent data causing poor drilling decisions. Portal access through service oriented architectures delivers visual and automated quality control of multiple data sources and is documented to save engineering time spent on data discovery and manipulation. Business rules serve to formalize data ownership and governance and support an intelligent synchronization process that maintains validated corporate spatial data, providing a single source of truth that reduces risk for engineering decisions.

Successful solutions require all described components plus repeatable and auditable workflows for extracting well, reservoir and seismic spatial attributes from robust industry standard models. This study allows petroleum engineers to determine the maturity of their current and legacy solutions, and plan for goals of mitigating risk, improving workflows, and lowering costs within a scalable, sustainable Spatial Data Architecture.

Introduction

In standardized data management site assessments, spatial data is one of the eight standard Data Services that is evaluated in a formal data hierarchy. This hierarchy is the basis for both a working taxonomy of data types used for classification during the assessment, and for a formal description of the "Information Management Landscape" using proprietary data modeling tools (Hawtin, 2006). The Spatial Data Service at assessed organizations contains the Spatial Data Cluster which can contain Data Streams such as culture data, boundaries of licenses or leases and their history, bathymetry for offshore data, gravity and magnetic survey location data, the definition of coordinate systems, the geographic extent of stratigraphic columns, and the spatial coordinates of geo-referenced images. In addition almost every other Data Service that impacts petroleum and geo-engineering projects has a spatial component. International oil and gas organizations already recognize the value and potential costs associated with maintaining this and other geotechnical data (Bouffard and Bayne, 2006). The standardized site assessment methodology provides a snapshot and benchmark of how this type of data is being used within an organization, and a quantitative measurement of the maturity of the systems and processes in place (Kozman and Hawtin, 2008). The same methodology can reveal a quantified financial impact of changing the methods for managing spatial data, or the costs of maintaining a current system.

Theory and Definitions

The result of analysis of multiple site assessments is that a sustainable architecture for spatial data with documented workflows is required to increase user confidence and alleviate risk. User confidence can be measured with surveys that collect information on the accessibility of data. A compilation of such surveys for more than 20 international oil and gas organizations shows that on average, less than half of the geo-technical and engineering staff in an organization who need specific spatial data types to perform their jobs both know where it is located in the organization and how to access it. These surveys have assessed not only spatial data but other geo-engineering data with spatial components (Fig. 1).

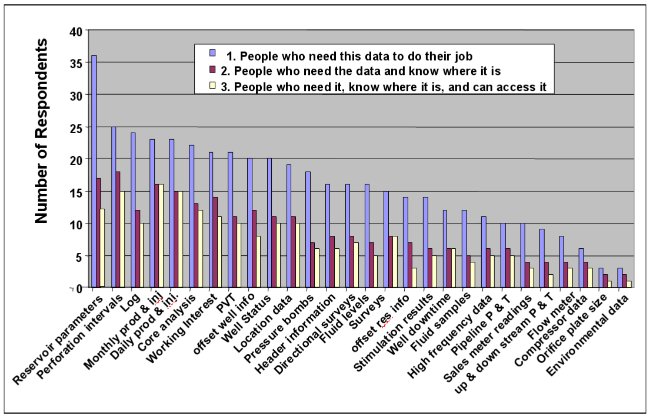


Fig. 1 – Example typical survey responses for some spatial data types from production engineers at a large independent oil and gas operator with international operations.

The obvious risks associated with this situation are the financial costs of time spent by geotechnical engineers looking for data rather than performing analysis, and the costs associated with re-purchasing, re-acquiring, or re-creating information already owned by the organization but not accessible to the technician needing it. In addition, financial impacts have been documented and used to develop business cases for spatial data management by citing the reduction in quality of geo-engineering decisions in the form of lost production, dry holes, or the time value of non-produced assets (Kozman, 2005). Any sustainable architecture that allows an organization to reduce or eliminate these risks will be reflected in an associated progression on the Data Management Maturity Model (DMMM). This model is based on the Capability Maturity Model (CMM) first developed for software programs (Humphry, 1989) has been extensively used, extended and modified for the petroleum industry and other technology driven industries and for different aspects of data management (Dyche and Levy, 2007). It should be noted that partly because of this application to other industries, the original CMM has been superseded by a variant identified most recently as the CMMI (Capability Maturity Model Integration). This model includes classes of appraisal and guidelines for publishing level ratings similar to those proposed for the oil and gas industry (SEI, 2008).

Description and Application of Processes

An analysis of the responses from standardized interviews of geo-technical professionals at international oil and gas organizations identifies perceived shortcomings and opportunities for increased efficiency in four distinct areas of spatial data management. This industry analysis indicates that the four components of a sustainable spatial architecture required are; data accessibility, an intelligent, scaleable architecture, map-based consumption, and business rules. Each of these components impacts a stage of the spatial data lifecycle identified during standardized data management site assessments. In the standardized Information Management landscape, there are seven Workflow Stages and six Data Store Roles for each Data Stream, and a process and work instruction associated with each combination (Fig. 2).

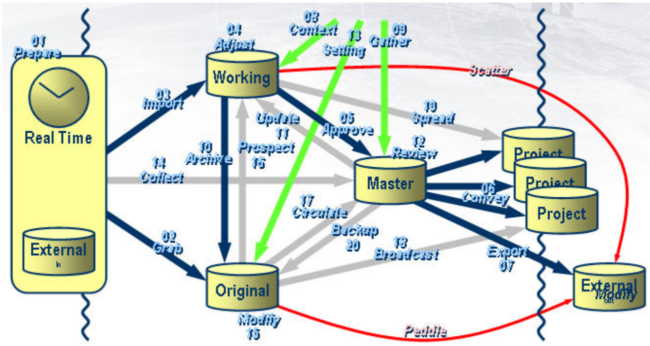


Fig. 2 – Standardized description of links and data flows for Workflow Stages and Data Store Roles

In general, the number of data stores for a given data type is related to its value to the organization, and the number of geotechnical users who require access to it for analysis and interpretation. For the four generalized Work Stages captured during standard interviews and assessments, spatial data overall in the assessed organizations is received from almost 50% more External Feeds than other data types (Fig. 3).

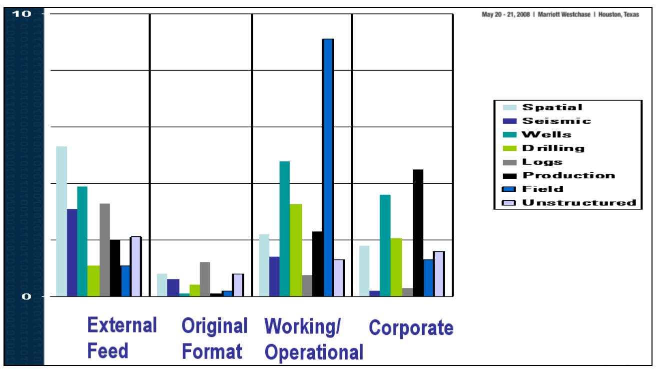


Fig. 3 – Average number of Data Stores at the four basic workflow stages for the standard data types in a site assessment (from Kozman, 2008).

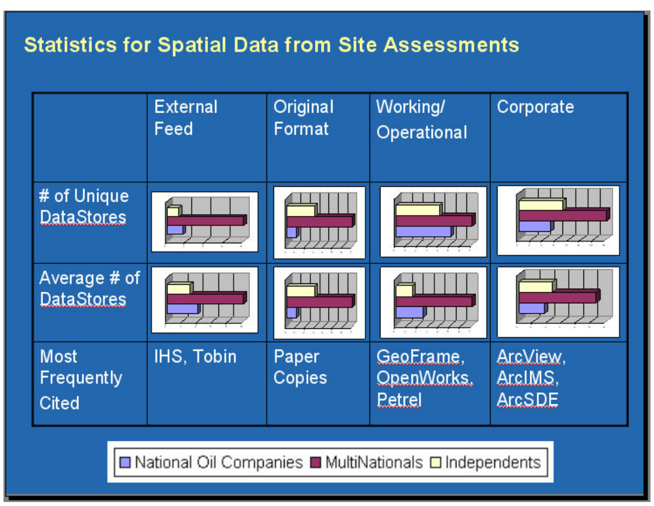


Fig. 4 – Selected statistics from a compiled subset of standardized site assessments show the differences in spatial data handling between categories of oil and gas

organizations. Note that in many cases the difference between working and corporate data stores for spatial data is not fully defined or understood.

The original format version of these same data types are found generally in only one original format Data Store, while the number of Working and Project Data Stores that contain spatial data types is approximately 30% less than the average of other Data Streams, although this varies by the type of client company (Fig. 4). There is remarkable consistency across the industry in the choice of Corporate Data Store for spatial data, with the Environmental Science Research Institute (ESRI) ArcSDE product being the most frequently referenced in site assessments. The lifecycle for spatial data can include collection from field and public domain sources, quality assessment and control, storage, distribution to applications, and capture in knowledge management and audit systems. Together each component and stage impact financial performance. In the following sections, a standardized methodology for documentation of the components and stages was used to compare solutions and financial impact at multiple domestic and international operators.

Spatial Data Quality Methodology

Some spatial data management initiatives focus solely on spatial data quality as a metric for measuring performance against a business case. This is well justified by the potential costs related to spatial data inaccuracy. For example, it is well documented and understood that datum conversion errors can result in positional errors of between 10 and 20 feet (Heggelund, 2008). But a quick calculation based on known average porosities, recovery factors, and producing zone thicknesses shows that such a positional error in the location of the bottom of a wellbore can result in missed reserves of over 500,000 barrels in a producing field. Furthermore, some applications use default values for International instead of U.S. feet and these differences can lead to positioning errors for wells and seismic navigation of up to 50 feet in the southern United States. Errors in calculating convergence angles and scale factors for deviation surveys can also result in positioning differences of 30 to 50 feet (Williamson and Wilson, 2000). These known problems are often only discovered when spatial data from multiple applications are combined in a single map view in enterprise spatial data architectures. This has led multiple organizations to implement Data Quality initiatives that focus on spatial data types in their exploration and production business units. Many of these initiatives were showcased at the 5th Annual InnerLogix User Group Meeting in Houston, TX on May 17, 2007.

DQM Case Study 1

At that meeting, Chevron (Underwood, 2007) described a Data Quality Methodology (DQM) for spatial data to provide professionals with spatial data access and quality improvement solutions, beginning with well header data, which dramatically increase productivity and confidence in the resulting analysis. Their approach uses corporate, business unit, and asset wide rules. The focus is on Well Header data stored in the Corporate Well Database (WPH). Rules are enabled by a DQM Team consisting of IT Management, WPH support team members, and Business Unit IT Information Management Data Analyst personnel. They create rules around well header data issues within WPH that are common to all business unit sites and organize areas of interest (AOI's) and automated Quality Control (QC) jobs. At the corporate level in Chevron, DQM tasks consist of defining data flows, reviewing loading procedures and standards, creating and accepting prioritized "Friction Points" and translating those "Friction Points" and standards into Rules. Tolerances for spatial data quality are defined at the corporate level, as are rules and AOI's. It is a corporate responsibility to run, review and rerun the accepted rules against spatial data types and analyze the results of the rule application. Spatial well data is evaluated for completeness, in which a well record must contain the Well name, Surface Latitude, Surface Longitude, Well Number, Operator, County, Lease Name, State, and Spud Date. A list of 23 validity rules focused around well header attributes is also applied. Examples are that measured depth is equal to or greater than TVD, ground level [if it exists], must be less than KB [if KB is present], and depth values must have a unit of measure and the unit of measure must be valid. Well headers are tested for uniqueness based on a combination of Operator, Well Number, and Lease. The corporate DQM organization plans on implementing correction rules for the same current well header data, expanding the AOI's for each business unit, building additional rules for well header data, production and other data types in the WPH, and rules for log curve data in the corporate data repository. There are also opportunities to incorporate new quality attributes in the data quality software currently implemented. At the business unit level, the focus on BU specific data quality issues, such as automating the monthly maintenance reconciliation and synchronization process between WPH and local interpretation projects for well header and well curve data, and consolidating local projects. Phase one of the spatial data DQM project was well defined to include find missing well data between local and corporate data stores, finding wells with incomplete information, loading data from external sources, validating standards, populating a Common Well Name among data stores with spatial content, truncating well numbers to a standard 10 characters, and loading the complete and validated wells to interpretation projects. Phase two includes a step to validate and correct Area Block, Lease, and Operator data contained in relational data stores against spatial data in the corporate database. In the Chevron Gulf of Mexico Business Unit (Underwood, 2008) more than 10 separate data stores for spatial data were identified and quality metrics were tracked for the duration of the project (Fig 5).

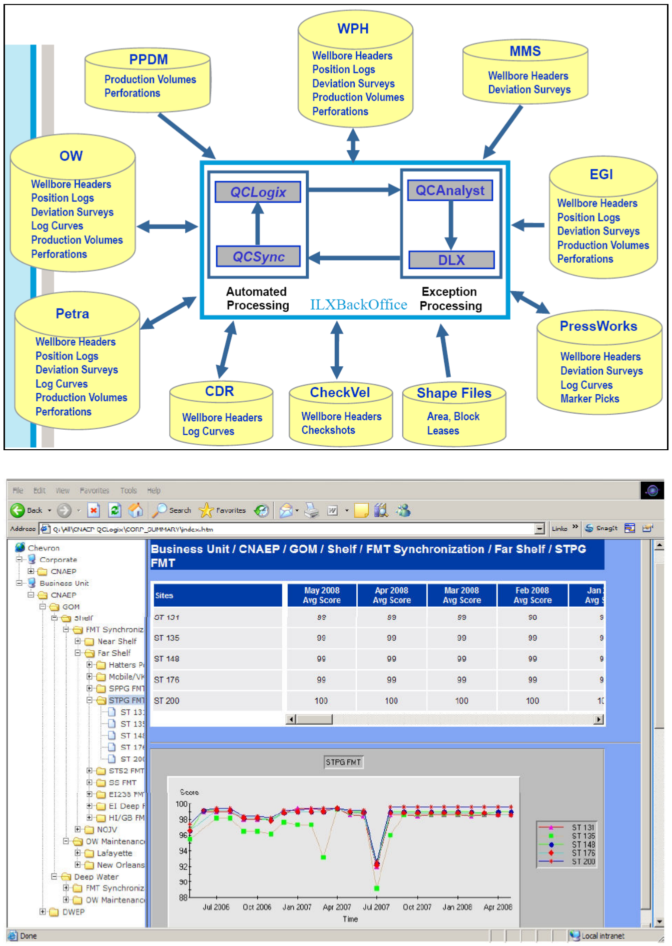


Fig. 5 – Data stores for spatial data involved in a DQM project in the Gulf of Mexico, and plot of quality metrics tracked for continuous process improvement in spatial data management (from Underwood, 2008)

In applying DQM methodologies to drilling data, Chevron sought to develop a tool to automate the process of checking the quality of large volumes of directional survey data and identify which wells needed manual review (Dalgliesh, 2008). The tool was run on a large data set which had been manually reviewed and contained known data quality issues for the Gulf of Thailand. The study attempted to answer the question in six-sigma terms, that is, if I have 2800 wells, how many do I need to look at manually to correct 70% of the problems? The inconsistency check did not necessarily identify “bad” data but it did indicate which wells contained suspect data and should be checked. The inconsistency tool measures the shift in Bottom Hole Location caused by removing any one survey station from a complete directional survey. The inconsistency is calculated as: *Change in bottom hole location / Measured depth interval x 100%.* In the first pilot, it was found that by looking at wells with a threshold inconsistency of 5 or greater, the number of defects could be reduced by 69% with a review of only 315 wells (11% of the data population). In a pilot study to compare DQM metrics in two working data stores, the data types with the most missing data were found to be those that related directly to spatial attributes (Fig. 6). Applying business rules increased completeness of the data by between 26% and 28%.

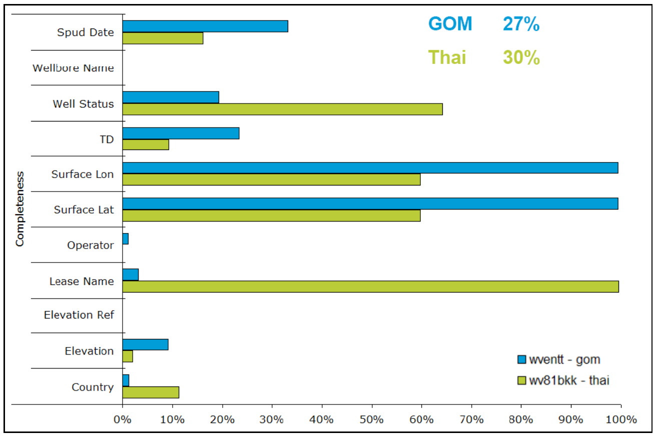


Fig. 6 – Percentage of missing spatial data types in wellbore data stores for two geographic AOI's (from Dalgliesh, 2008).

DQM Case Study 2

At the same meeting, Anadarko (Hopkins and Briggs, 2007) presented their DQM with a focus on the impact of spatial data quality on exploration geologists. They commendably addressed the natural communication barriers between the geologist and the IT group, discussed the impact of data quality issues on geologists, and tried to understand how to translate a problem from a geologist's spatial data quality issue into an IT task. They cited the now ubiquitous impacts on productivity and the decision making process of uncertainty and increased risk, the necessity of re-doing work, and questions about data reliability. Anadarko is specifically concerned with the impact of the validity of spatial data; that is, does data make sense and does it honor the science and your standards? Their methodology is designed to address questions such as, are your bottom hole locations correct, does the well name match your standards, and do your total depth ranges make sense? They gave examples of the impact on exploration of a directional survey missing a tie-in point, a directional survey not extending to the total depth of the well, and the potential impact on auditable reserve estimates (Fig 7).

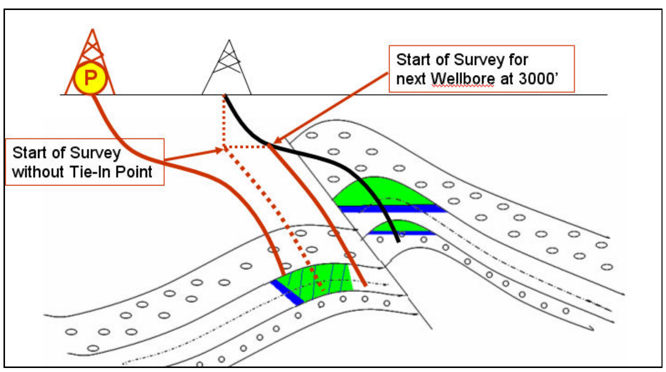


Fig. 7 – Example of a directional survey missing a tie-in point and the potential impact on reserve estimates (from Hopkins and Briggs, 2007).

To attempt to avoid erroneous reserve estimates, the DQM sets a rule to check the survey's first measured depth point. If it is greater than 100 ft, then a check is run for a valid tie-in point. Similarly, a rule is set to check if the survey extends to the wellbore TD. Reserve estimates are of particular interest since Sarbanes-Oxley legislation now requires all oil and gas operators to maintain the original geotechnical data on which reserve estimates were made for a period of seven years (SEC, 2003). This is clearly impossible without a sustainable architecture for the storage and retrieval of the spatial data associated with wells and reservoirs.

DQM at Anadarko is also concerned with consistency, namely if all team members are working on same data, and if the data is the same between various applications, especially if the surface locations & elevations are the same from one project to the next. They pointed out the impact of inconsistency in spatial well data on several geological workflows, including creation and viewing of structural or stratigraphic cross sections with fault gaps, display of log curves along deviated boreholes, multi-well time and depth functions, and display of seismic backdrop or horizon grids. The importance of 3-dimensional visualization and display was highlighted to discover errors introduced by export and import between applications.

Anadarko also required a user friendly front end to a non-relational log curve datastore (Davis, 2008) that would allow searching, viewing, reporting, and delivery of log curve data to project or *.LAS files. The non-relational nature of the datastore made searches slow and difficult to execute for spatial data types. The was a need for a catalog of the data in a searchable format with the ability to recognize new data in near real time, while synchronizing with corporate SDE spatial layers. The implemented solution utilized the ArcSDE corporate datastore as a master spatial data source (Fig 8).

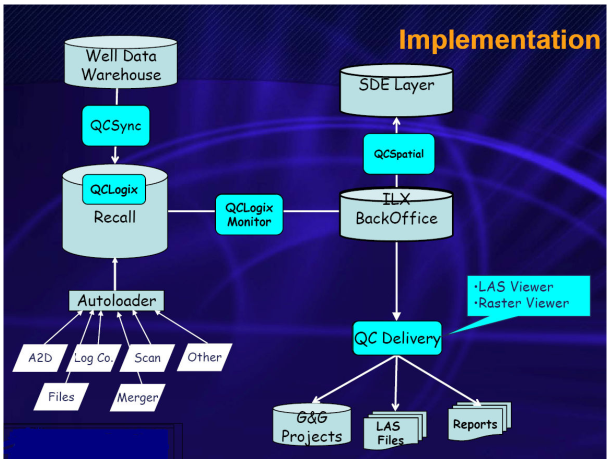


Fig. 8 – Implementation of a DQM system to synchronize project data with a corporate SDE data store (from Davis, 2008).

DQM Case Study 3

Dominion Energy's spatial data quality initiative (Warner, 2007) involves turning Dominion's PIDM database into an accessible, trusted corporate data repository and ensuring data integrity and synchronization between PIDM and all working projects. The PIDM data model is again a frequently cited external feed and working or operational data store for spatial data analyzed during site assessments. In the PIDM model, the UWI is the 14 digit API number for United States onshore wells, and over 2000 data integrity checks are built into the database. At Dominion, consistent and standard population rules and procedures are enforced for the 143 tables in the Well data model and the 25 tables in the Production data model (Fig. 9)

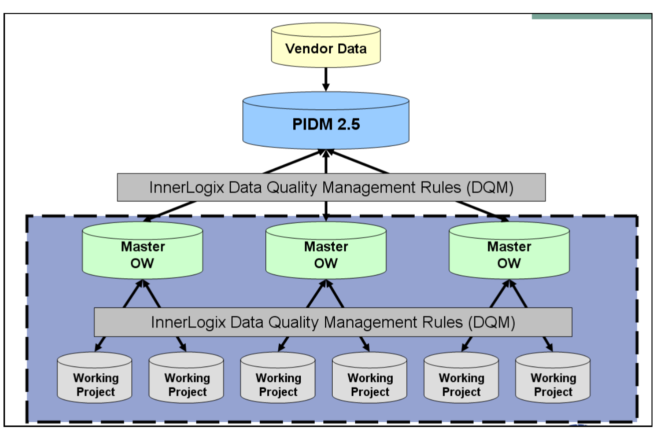
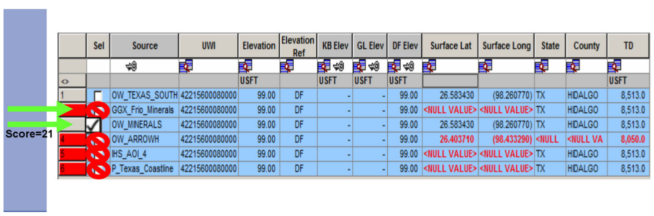


Fig. 9 - DQM processes at Dominion for populating master and working projects with spatial well data (from Warner, 2007).

An automated data loading process is in place to load well data nightly, with production data loaded as it becomes available. A node builder application promotes locations by their preferred source, and a composite Well Header promotes data by preferred source, with synchronization to SDE Well layers. An IT lead portion of the project provides PIDM database and master projects synchronization, with automated data loading into a master project from the PIDM, while maintaining value added data and populating PIDM with updated business unit information from the master projects. The business unit defines their AOI for master projects and determines area specific naming standards and IT helps determine if the AOI requires subdividing for performance. IT then actually runs the DQM software to apply the rules to the spatial data. A well data process flow is in place to enable additions and updates validated and captured from Master Projects to PIDM by IT. The data types currently supported are Well Headers, Directional Surveys, Perforations, Monthly Production, and Marker Picks. Data quality, movement and overwrite protection is handled by business rules with email notifications of exception to the rules. Together the business units and IT have established DQM Standards for master projects:

- The UWI will be the 12+”00” digit API number
- Upper Case well name, lease, operator, field, etc.
- No Special Characters well name, lease, operator, field, etc.
- Common Well Names standardized by teams
- Elevation reference can only be GR, KB, DF, SL or ES
- County name must be valid County name
- Deviation survey name will be flagged as “Preferred”
- Deviation survey and well paths must have at least 4 points
- Marker Picks must follow Consistent Standard Names
- All interpreters in OpenWorks must be <= 5 characters
- Production data by formation

A typical DQM project at Dominion involved 16 working project data sources with an AOI containing 5,239 unique wellbores. After applying DQM rules, 5,063 wellbores or 96.6% were promoted to the Master Project. A graphical display of the differences in spatial data types between sources shows how source priorities were used to populate the master project (Fig. 10)



	Sel	Source	UWI	Elevation	Elevation Ref	KB Elev	GL Elev	DF Elev	Surface Lat	Surface Long	State	County	TD
				USFT		USFT	USFT	USFT					USFT
1		OW_TEXAS_SOUTH	42215600080000	99.00	DF	-	-	99.00	26.583430	(98.260770)	TX	HIDALGO	8,513.0
		GGX_Frio_Minerals	42215600080000	99.00	DF	-	-	99.00	<NULL VALUE>	<NULL VALUE>	TX	HIDALGO	8,513.0
		OW_MINERALS	42215600080000	99.00	DF	-	-	99.00	26.583430	(98.260770)	TX	HIDALGO	8,513.0
4		OW_ARROWH	42215600080000	99.00	DF	-	-	99.00	26.403710	(98.433290)	<NULL	<NULL VA	8,050.0
5		IHS_AOI_4	42215600080000	99.00	DF	-	-	99.00	<NULL VALUE>	<NULL VALUE>	TX	HIDALGO	8,513.0
6		P_Texas_Coastline	42215600080000	99.00	DF	-	-	99.00	<NULL VALUE>	<NULL VALUE>	TX	HIDALGO	8,513.0

Fig. 10 – Graphic display of the use of source priorities for well location data (from Warner, 2007).

Dominion has identified savings attributed to their DQM project from reductions in:

- Data inconsistencies
- Cycle time in loading data
- Cycle time in finding, preparing, and moving data
- Risk of loading errors
- Risk of data becoming lost or unknown
- Data duplication
- Manual intervention for all data management processes

The acknowledged advantages for the organization are the ability to capture, retain, and manage value added interpretations, improved data access, an improved ability to share data across disciplines, an appropriate level of security, and the fact that will be recognized and treated as a corporate asset and that staff has confidence and trust in the data.

DQM Case Study 4

Newfield Exploration Company (Day and Potter, 2007) described a DQM project to support the drilling of over 400 wells in their domestic and international operations. It involved 150 “active” OpenWorks projects, over 1100 “active” SeisWorks projects, 15 GeoGraphix projects, 10 SMT projects, and 20 Petra projects. The goals were to load PIDM well data to active OpenWorks projects using 17 Well header data items and 4 other data items to construct well naming conventions. The 19 OpenWorks projects would be updated on a monthly basis, and directional surveys from PIDM would be loaded to active

OpenWorks projects. As part of the project custom scripts were delivered to support onshore and offshore well naming conventions, operator standards, data source, and directional surveys. As an example, well naming standards included:

- Offshore – BH block area, block #, well #
- Onshore – Lease name, well #
- Operator: First real word or combination of words: Newfield Exploration LLP; Newfield Midcontinent became NewField; El Paso LLP became El Paso not just El, etc.
- Data Source: hard coded to IHS to avoid confusion with PI as a source. This was changed to avoid conflict with another project

Directional Surveys:

- If there is no dir survey and the position log has greater than 2 pts
- Position log of 2 points only, replace with directional survey
- Validity rules (data loaded only when it passes these rules)
    - Tie-in > 500'
    - At least 4 points exist
    - Calculated bottom hole location = actual bottom hole location
    - Measured depth changes +.01 for each point

The project began in late December 2006. A single project was selected for the initial implementation. The rules for Consistency, Completeness and Validity were created around the 17 common header items. AOI's were determined from existing wells and project boundaries. The initial test was successful in that the project had 2,450 new wells added and 6,550 wells updated. The initial loads into the 19 projects started with 356,000 wells; added 155,000 new wells and updated 318,000 of the existing wells. Since the start of the project the DQM methodologies for spatial data have added 156,000 wells and updated 427,000 wells, an increase of 44 and 78% respectively. The project has also uncovered differences in definitions between content and software providers on what constitutes a directional survey vs. what constitutes a survey run.

Presentation of Data and Results

Case Study – Level 1

Organizations on the base level of the Data Management Maturity Model are identified by the use of general purpose tools for spatial data, and "people-centric" processes. Essentially, if a question is asked on a standardized interview template about the Data Store used for spatial data, and the answer from the organization includes the name of an individual (e.g. "that is in Alfred's desk", or "Kaye does that for us"), the organization is functioning at Level 1. The level on the DMMM can also be associated with a Six Sigma level of data quality, for spatial data this quality could be defined by quantifiable metrics of completeness, consistency, validity, and uniqueness (Radhay, 2008). Organizations at this level often store spatial data as latitude and longitude or x and y values in spreadsheets or other general purpose data stores, and have no defined processes for moving or quality checking that data even across the basic analysis tools used for spatial analysis and engineering (Fig. 11).

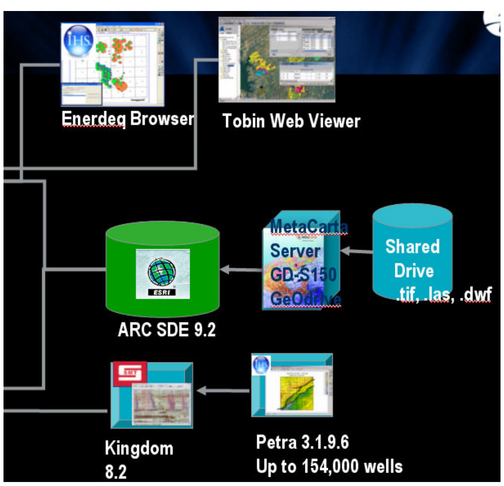


Fig. 11 – Example of the disparate data stores producing or consuming spatial data at a Level 1 organization.

Some assessments have seemed to indicate an even lower level of maturity for spatial data management, a Level 0 where the value of spatial data is not even recognized in the organization, or where problems and impacts are not acknowledged. A level

0 and even negative levels have been suggested for other Maturity Models (Schorsch, 1996 and Finkelstein, 1992).

Case Study – Level 2

Even an organization on the relatively "low" end of the Maturity Model can recognize value from the effective management of spatial data. For example, at a United States based seismic data marketing firm, the value of legacy seismic data is tied directly to business revenues, and that data has no value unless it can be properly located spatially. All sales are generated by customer interest in a particular geographic area. While this organization sees itself as necessarily "low-tech" and deliberately "low-profile", they interestingly have independently developed many of the same enabling technologies for spatial data that are now leveraged in mature information management initiatives at international oil and gas operations. With offices in 7 North American cities and an aggressive marketing presence in 4 others, this company was founded in 1975 to fill a growing demand in the market for quality seismic data. Over the years, the data library has expanded considerably and now comprises more than 2.5 million kilometers of onshore 2D seismic data and over 58,000 square kilometers of onshore, transition zone, and offshore proprietary data, making it one of the largest licensing data brokers in the business, and a prime broker for over 170 exploration companies. An internal physical asset management system uses many easily recognizable enabling technologies, including role based administration, GIS search engines, entitlements, and customized desktop order tracking.

The organization continues to focus its efforts on the effective management of 2D and 3D seismic databases to assist exploration companies in more accurately defining their geophysical evaluations and therefore maximizing their exploration budgets. They appear frequently in site assessments as an "external feed" of spatial data related to seismic surveys. Customers who wish to view seismic coverage in any part of the continental United States or Alaska can view the spatial location of the data graphically using a program developed by a local Data Services provider (Fig 12).

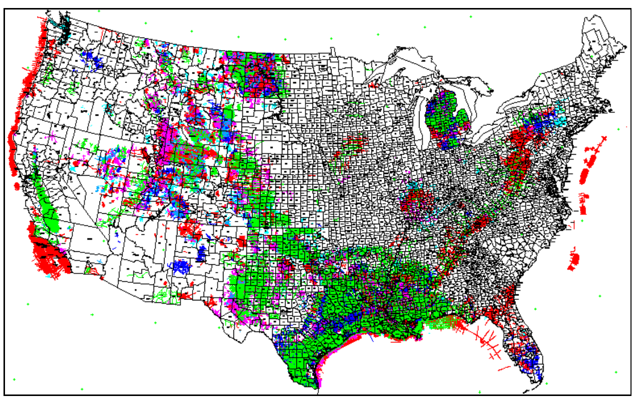


Fig. 12 – Example of Level 2 delivery of a large volume of spatial data for seismic surveys in the United States

The program provides selection of lines or surveys by clicking on their graphic display and invoking a pop-up specification window, which adds the line to a shopping list. Emailing the shopping list to a marketing representative can generate a further request for QC viewing or a local map of the area. This technology makes the search for seismic coverage faster and simpler, and places the organization in the Level II of the Maturity Model for spatial data, using "point solutions designed for specific tasks", but at Level 1 of the Master Data Management model, where list provisioning is the primary method of sharing between applications.

Case Study – Level 2

Another example of a Level 2 organization benefiting from advances in spatial data management comes from China National Offshore Oil Corporation (CNOOC), where Shenzhen engineers were tasked with compiling, validating, and distributing daily production data from 18 unique field operations in the South China Sea area (SIS, 2007). The data was compiled from six different operators in six different formats including the spatial locations of wells and producing facilities. Engineers in Shenzhen spent 2 hours a day just consolidating and correcting data and up to a full week each month preparing organizational reports tied to the locations of fields. The extra time CNOOC engineers spent on these burdensome tasks took away from the core responsibility of improving the efficiency of production operations.

To meet the spatial data demands created by this situation, CNOOC chose oilfield management and well and reservoir analysis software to improve and standardize spatial data management and analysis for production operations in Shenzhen. With the software in place, CNOOC engineers began a project to simplify production data management, automate spatial data integration, and standardize production analysis and reporting. The project team recognized the need for consistency in the various spatial data demands presented by the unique fields. With this in mind, they developed a standard software template to include historical data such as production history, geologic description, and well log curves tied to the spatial location of wells and fields. To ensure that the newly developed templates were populated with up-to-date information, the data consolidation process was automated using data-appending features. Even though CNOOC continued to use general purpose tools such as spreadsheets to capture production data with links to the spatial location of wells, each spreadsheet was dynamically linked to provide access to information as soon as the operator submitted it. This resulted in savings of more than 11 days of labor per month by eliminating manual input errors and improving data quality. As described by Yan Zheng He, a Reservoir Manager in the Production Department of CNOOC Ltd., Shenzhen, “the project has resulted in significant workflow improvements…it has reduced the daily data organization workload, enabling engineers to focus on business-critical problems” tied to spatially enabled data types, such as effective sidetrack analysis and forecast templates for re-perforation.

Standardization of production analysis and spatial data processing enabled expansion as new production data became available, and the template created with the help of spatially enabled oilfield analysis software established standards for production reports, plots, and forecasting formats. With easy access to quality production data, the CNOOC engineering team refocused on production analysis and reporting. The software’s analysis tools helped engineers quickly detect and correct spatial data errors and inconsistencies, saving both production time and money by addressing problems as they arose. Production analysis workflows were enhanced to quickly identify and qualify candidates for sidetracking, re-perforation, and stimulation. This rapidity allowed engineers to better evaluate the impact of well intervention using bubble maps and trend analysis techniques. The software improves the ability of engineers to identify evolving production problems, perform diagnostic analyses, and prevent serious downtime events. The design for back allocation of the automated oil field is based on well test data, and the spatial models of producing fields could enable in the future such analysis techniques as self-organizing maps to correlate the spatial location of data with reservoir performance characteristics (Fig. 13).

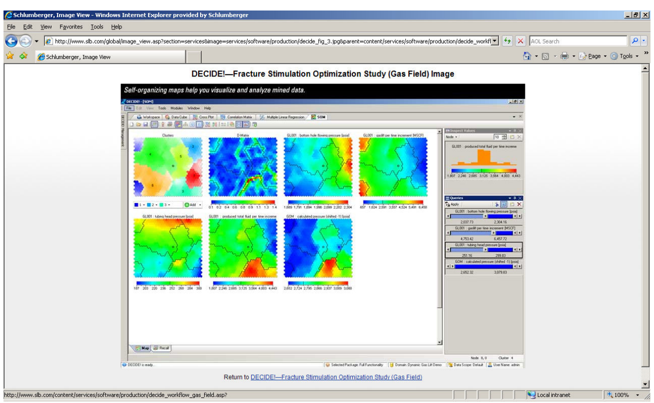


Fig. 13 - A fracture stimulation optimization study based on data mining of spatial gas field data.

Obviously such techniques are critically dependent on the correct location of spatial data and the production data associated with spatial elements of a producing field. The consistent use of exploration and production data mining techniques and expert systems is a hallmark of a Level 5, or fully optimized spatial data management solution, but there is no evidence in current site assessments of any oil and gas organizations fully functioning at this level.

Case Study – Level 2

In some cases, small advances in the sustainable management of spatial data can have a measurable impact on exploration projects, even in Level 2 organizations where point solutions are still in place. In Southeast Asia, VietSovPetro (VSP) VSP is the first international joint venture project in Vietnam for the exploration and production of oil and gas on the country’s continental shelf. Established in 1981, the first oil well was drilled in December 1983 at White Tiger geological structure, 120 km southeast of Vung Tau city. The initial oil was found in May 1984. Commercial operation of the oil field began two years later, in 1986. VSP had approximately 70 reservoir characterization projects, containing up to 300 wells and 200 well composites (SIS, 2007). A large amount of disk space was being used to duplicate well data in different projects. After evaluating an integrated reservoir characterization system with desired functionality in March 2002, VSP decided to upgrade to take advantage of new features, such as well sharing between projects. When VSP decided to upgrade all projects to the new version, the software provider and VSP worked closely to plan and implement the upgrade. The workflow included backing up the entire set of project data for safekeeping before all of the systems and software could be upgraded. The upgrade involved a change in the Oracle™ version, as well as an operating system upgrade. Therefore, it required careful planning and project management. Once the upgraded systems and software were in place, the data was restored to the new projects. Since VSP wanted to take advantage of the new well-sharing capabilities, the data was cleaned up and reorganized before being shared out to subprojects. Technical support staff created proper user accounts for each department so that spatial data security and multi-user features could be used to their fullest extent for improving asset team workflows. The upgrade was smooth and outstanding issues were resolved quickly. VSP saved disk space by sharing the spatial attributes of well data in the interpretation projects—the original goal for the project. Other benefits were realized from the upgrade, which offers more than 200 enhanced features to users, including the ease of use of geological workflow tools for the geologist, and faster surface gridding, available within advanced mapping and surface modeling applications. In this Level 2 project, spatial attributes of the shared well data were critical to the financial impact of reducing disk space, even without full enterprise-level spatial data architectures. Nguyen Nhi Thu, in the Reservoir Department of VietSovPetro, describes the benefits of the upgrade and spatial data sharing. “Our department has a lot of well data from Bach Ho, Rong, and Dai Hung fields. Now with this new release, we can manage our well data easily by using the share/subprojects structure. We do not need to load well data to separate projects for each user in our department anymore, which saves valuable disk space.”

Case Study – Level 2

Similarly in Latin America, a regional integration of 63 seismic interpreted grids, in time and depth, representing geology of Tertiary and Mesozoic of the South-East Gulf of Mexico basins, had been generated in different interpretation platforms. It covered an area of more than 60.000 km2 with 56 3D seismic surveys and numerous 2D lines, comprising the total of 89 projects (61 and 28 in each of the two industry leading interpretation applications at the time) generated during exploration studies from 2002 through 2007. Original data with non uniform scales, grid and contour intervals, symbols and color pallets were united in a single mega-project, selected as a standardization and integration platform, to deliver new insights into the regional geology. This diversity of input information forced a re-design of processes and workflows for integration, and necessitated special visualization techniques and criteria in order to achieve mapping of regular grids at standard scales. This integration facilitated the regional vision of the different geologically relevant levels of the area, those being Eocene, Miocene, Mid Cretaceous (KM) and Upper Jurassic reservoirs, in a south onshore and marine region. The structural model was tested and supported by geological picks from 1180 wells, and also includes relevant major fault polygons. Cultural elements like coast lines, hydrographic data and geopolitical borders were also included in the new application project.

The main challenge was in the search and restoration process for different interpretation projects executed during six (6) years. Projects were executed, stored and supported in several different software platforms and in different versions. Only with tedious attention to details and continuous support of the IT department was it possible to finish the process. The following spatial data were exported and loaded in the new model-centric application mega-project:

- Interpretation grids
- Wells
- picks
- faults polygons
- Cultural elements

Once data were loaded it was necessary to go through a complicated editing process, joining surfaces and faults from different interpreters, years and grid density. Only data coherent with the regional model were included, based on the controlled geological and interpretive criteria. Structural and velocity regional maps were prepared for the Exploration and Production units, and in future products can be generated in any spatial or graphical format adaptable to the needs of the user or client.

Due to the variety of software applications, diversity of references and multi-users, one of the most complicated issues was to select the updated data, because standardization criteria were not established previously for file names, targets, and stratigraphic sequences. Nor were priorities and hierarchical structures set by the client. The IT person was in charge of restoring the projects in the same work platform in they were originally executed considering the size of the project and depending on the disk space available rather than the quality or value of the contained spatial data. In total, there were 89 seismic projects restored, representing approximately 250 GB of data. The next step was the evaluation and selection of the data, displaying all grid interpretations available, and selecting, with the consultation of geologists and geophysicists, the most coherent and updated, to finally export them in different formats such as:

- Grids in time and converted to depth: Grid (.grd), ASCII (.dat, .txt), binary (.svs), map set (.mcps), ZGF, and MFD.
- Fault polygons, polygon file (.ply), fault boundaries files (.flt), ASCII (.dat, .txt).
- Seismic surveys polygons, polygon file (.ply), ASCII (.dat, .txt).
- Wells, ASCII files (.dat, .txt).
- Cultural elements, border lines, coast line, polygon files (.ply), ASCII (.dat, .txt).

Editing was necessary for some files before loading. The binary files in *.svs and *.grd format were the easiest to load because they did not require any editing. For the rest of the data a tabular ASCII file format was used to evaluate and load the spatial content of the original projects. Files corresponding to grids available from other platforms were first converted into ASCII files X, Y, Z, inside the source application. This data was loaded as points and later, grids and surfaces were created in the target application. For the wells ASCII format was used and files were generated which included Well Name, UWI, Field, Surface X Coordinate., Surface Y Coordinate, Total Depth and KB.

In those cases where one or more interpreted surface existed in the same area, the one with a better fit to well picks was used. This procedure was used only for the surfaces converted to depth. Every surface was converted to line polygon and merged to create a unique file. This allowed application of a filter process to these surfaces to create an integrated grid representing an area of 60.000 km2 and constructed in the optimal and fastest way possible. Those filtered surfaces were validated with the original, although the size of the grid represented a limitation. It was created with a lower resolution (400x400m), and because of this, minor structural relief is missed in the interpretation of the spatial grid data. The editing process consisted of fitting those zones of intersection between different horizon interpretations, giving priority to the most recent or better quality ones that were adjusted to the well picks. In cases where there were not well data in the area, priority was given to the horizons best fitting general trends of the structural model. Zones with several interpretations and the results of integration and editing were then used to develop the same process to apply to fault polygons (Fig 14).

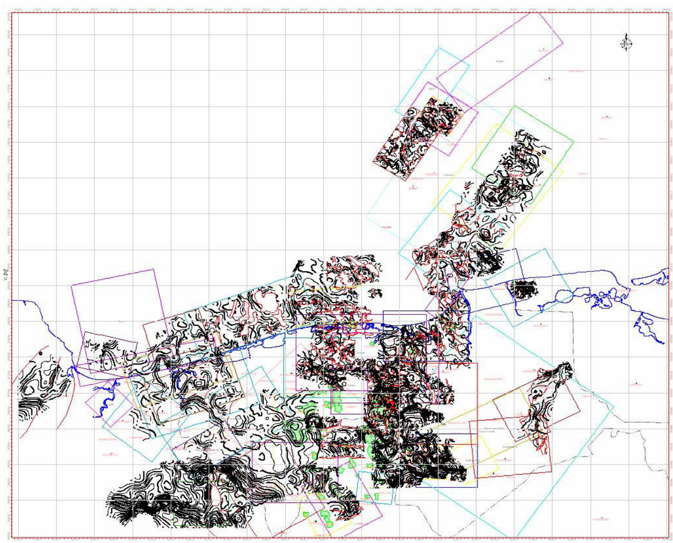


Fig. 14- Example of overlapping spatial content, in this case interpretation grids and contours, used in the merging of multiple source projects into a single mega-project.

Finally, a series of regional maps at 1:500.000 scale and some trial maps at 1:250.000 scales were created to quality control the data in the target application. A target project was constructed using digital format files allowing a continuous updating supported by printed maps in 1:250.000 and 1:500.000 scale, facilitating a periodic management review of the project progress. The result was a map that allows the visualization of detailed and relevant parameters that support corporate decisions in an exploration context, with the following spatial elements:

- Structural Elements
- Hydrocarbon Distribution / Limits / Reservoir fluid Contacts
- Prospective Areas
- Drilling status for geological levels selected
- Current well status
- Cultural elements

All of these data are now loaded following the official regulations and standards for the organization. The target application and its map interface are powerful integration tools, which allow standardizing the seismic regional interpretations and velocity models applied to depth conversion in areas with multiple surveys. Corporate management will have an executive and effective follow-up tool for cartographic processes that could be updated with new interpretations and used to highlight the areas that need re-evaluation, fine tuning of 2D/3D seismic interpretation or additional seismic data acquisition. The application of the spatial data to this mega-project shows an anecdotal value determination typical of a Level 2 implementation.

Case Study – Level 3

In January 1980, Kuwait Petroleum Corporation (KPC) was established to bring together the nationally owned companies operating in the areas of oil and gas production, processing, commercialization, and transportation. The Kuwait Oil Company (KOC) responsibilities under the KPC umbrella are to explore, drill, develop, and produce Kuwait's hydrocarbon reserves. KOC wanted to provide employees with fast, personalized access to a growing number of corporate E&P databases that contained spatial and other geotechnical petroleum engineering data (SIS, 2007). The company envisioned a Web portal solution that would allow users to personalize up-to-date spatial data views to fit their daily workflows, and would provide asset teams with a collaborative workspace.

One of KOC's immediate challenges was to encourage its geoscientists and engineers to move to a real-time information environment in which they would correlate data from disparate spatial repositories, analyze it in real- or near-real-time, and apply their decisions to on-going operations. A further objective was to provide a common point of spatial data access for users from petroleum engineers, reservoir engineers, and geoscientists to team leaders, supervisors, and managers. This would entail defining and providing data connectors for the spatial content of corporate data sources, and supplying GIS-based query and reporting tools beyond the conventional ones and "on-the-fly" report builders within a Web environment. Other technical challenges were created by the lack of a consistent spatial tool that would provide the capabilities required in the homogeneous environment of the corporate MyKOC portal, which was being developed using Microsoft® SharePoint® technology. In addition, the E&P Web portal solution would need to be fully integrated as a collection of Web components rather than as a simple chain of links to the MyKOC portal, supporting active directory authentication in a single sign-on environment. The final challenge for KOC was to find a partner with unique expertise in the E&P industry who was also knowledgeable and experienced worldwide in the spatial information management domain. An industry oilfield information solutions provider, through its Information Management segment, offered a portal solution that would enable users to personalize their workspaces. KOC initiated the GeoPortal project using global project team of experts with background in spatial E&P information management, and the project was divided into three stages.

Phase I included blending components of a commercial personalized Web portal solution into the Microsoft SharePoint environment. In Phase II, five commercial repositories and application databases utilizing spatial engineering data were connected and made accessible through the common Web interface (Fig. 15).

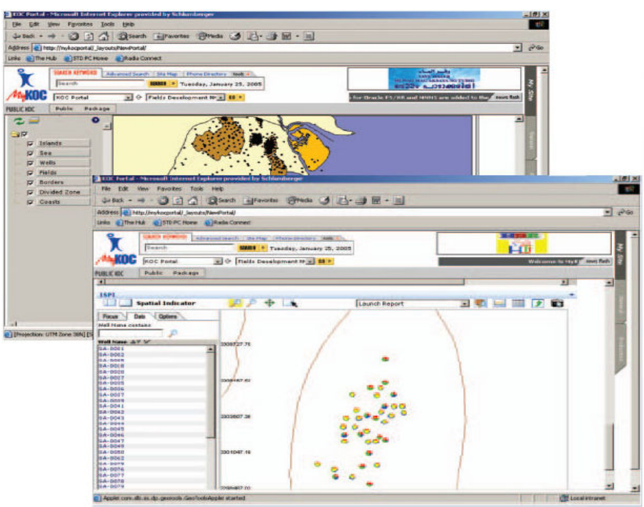


Fig. 15 - A sample spatial portal workflow at KOC for the Data Management Group, which encompasses views of spatial data for Drilling, Well Surveillance, and Production Operations.

In Phase III, the GeoPortal was integrated into MyKOC, the enterprise wide portal, with a unique user authentication mechanism. Phases II and III, carried out in parallel, included appointing KOC GeoPortal nominees from various divisions such as Data Management, Reservoir Management, Field Development, Drilling, Exploration, Production Operations, and Engineering. The GeoPortal was personalized and customized according to the nominees' specifications. Online user training material and full-day training sessions were provided to all nominees as part of the deployment stage of Phase III.

An initial deployment group of 100 users, and a potentially wider population of over 1,500 spatial data users, gained a single point of access to a variety of spatial data types from the corporate data stores as well as user and project specific applications. In addition to accessing a default page created for each user community and based on their geographic area of interest, users are also able to create their own sites within the MyKOC portal utilizing the GeoPortal Web components of their choice, thus fulfilling the requirement of integrated personalized data access. The project has also led to publishing and enforcement of a KOC-wide naming convention to standardize the naming of spatial elements such as fields, wells, reservoirs, seismic lines, surface picks, gathering centers, production header, slots, storage tanks, de-salters, and booster stations (Harrison and Safar, 2004). This type of deployment places KOC on Level 3 of the DMMM, a level characterized by best practice and standardized processes and technologies, and the beginning of cost-benefit analyses.

The portal-within-a-portal solution also serves as a data validation checkpoint by supplying standard quality control indicators for spatial data types within the corporate data stores. In summary, the GeoPortal provides an integration framework and workspace for diverse KOC user communities, better collaboration between KOC communities, optimized personal productivity, spatial data browsing for all critical petroleum engineering information, the ability to monitor key business measures, and enhanced decision making based on spatial knowledge of producing reservoirs.

Case Study – Level 3

Another Level 3 DMMM example of enabling the components of sustainable spatial data management architecture also comes from the Middle East. The Kuwait/KSA (Kingdom of Saudi Arabia) Wafra Joint Operations (JO) Field Development Department's in-house production data application was facing difficulty in handling increasing spatial data volume and complexity (SIS, 2007). The Field Development Department lacked an adequate spatial data management structure. The data gathering and reporting system was deemed acceptable at the time the in-house application had been built, but it was having difficulty in handling the increasing volume and complexity of the recent data. It was a typical Level I organization in the Data Management Data Maturity Model for spatially enabled production data. Production data was entered daily, but the back allocation was run monthly, and the data was made available to users solely through a static version of well and reservoir analysis software. The important back-allocation process had reached the limit of the in-house application and could not handle more elaborate algorithms based on spatial relations in the producing network. The data model was slow and no longer properly maintained. It was not optimized, was using several disparate data sources for the same data, and did not apply relational database management system (RDBMS) constraints. There was no integration between spatial data classes coming from different divisions and no thorough validation process. The many data sources stored in general-purpose applications (Excel®, Access™) made it difficult to evaluate the quality of the data. The management of the data primarily relied on people rather than processes.

Based on the success of KOC in this geographic region, and their leadership in the field of E&P spatial data management, the same information solutions provider was asked to develop a solution for JO. The project management objectives were to implement the solution, synchronize the effort of the team members, and most importantly, make sure that the E&P Data Management (EPDM) division was accepted as part of the core business of managing spatial data in the Field Development Department. Many of the components of the solution were robust, industry-proven products that enabled components of a sustainable data architecture. The implementation of this solution had benefits including a gain in spatial data quality availability, confidence, integrity, and coherence, implementation of a corporate database for production data classes including spatial Data Streams, implementation of data management processes and a decision-centric interface utilizing map views of the data. In addition, JO foresaw the use of business intelligence tools, spatial integration across applications, and obsolescence of the in-house application with introduction of commercial spatial data applications using modern technology.

Numerous business processes were custom-designed and implemented. Workflows were created to channel the data from the originating source to a centralized spatial data store. Similarly, data validation workflows were implemented for consultants to make the best use of the applications by liaising with EPDM's users to ensure data quality, on-time spatial data uploading, and report development and applications that met user requirements. A field data capture software package was used to streamline the capture of production data classes, some of which are used for daily operations meetings. In parallel, components of daily reporting are captured with a daily reporting drilling/workover data capture application and transferred to a drilling operations performance analysis system with a GIS interface (Fig. 16).

The reporting contains most of the activities performed in a well on the equipment (production string) installed in the wellbore. At the end of the month, the integrated back allocation and production diagnostic and optimization solution is used to compute the monthly production and injection figures, which are then distributed across the organization. The software, which was already in use, was modified to obtain instantaneous access to the up-to-date data through a directly connected application. The intrinsic integration among these carefully chosen applications was a major differentiator in this holistic approach. Commercial software was installed to post incisive analytical reports through Web technology, while relational database software, in conjunction with an industry standard E&P datastore system, was used to build a powerful application that provides data entry and multilevel validation for well testing. The JO estimates the approximate time saved at 9 days per month for production data entry, 10 to 12 days for report generation, 6 days for well test validation, 2 days saved per month in time required to produce a shut-in priority list, and one day per month saved in back-allocation runs.

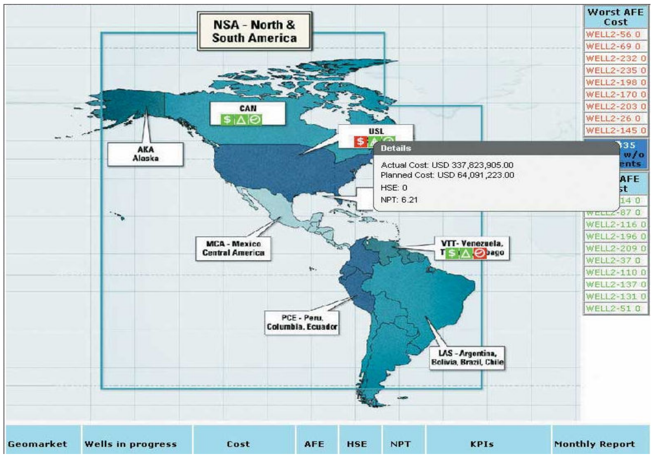


Fig. 16 – A drilling operations manager application with spatial upward aggregation and drill down capabilities.

Moayed Al-Bassam, a General Superintendent in the Field Development Department of Joint Operations, says "we see tremendous workflow efficiencies throughout the entire process of acquiring, processing, interpolating, storing, and accessing data." The implementation of this production data management solution allows JO to make faster and better-informed decisions regarding the daily operation of the field based on the spatial content of the field data. Gains in time and quality—the absolute metrics of any data management solution—were achieved by integrating purpose-built applications with workflows designed by experts (Fig 17), and by presenting a decision-centric map based interface to users. The experience, commitment, and dedication of the team were critical to securing a successful solution implementation. JO estimates that it has now reached Level III in the Data Management Data Maturity Model in the Field Development Department. Based upon this success, EPDM has been accepted as part of the core business. The legacy production database was phased out, and there is now a single source for all production data, which can be used concurrently by multiple users. Because procedures were designed and implemented both for data entry and validation as well as for better security, users have greatly enhanced confidence in the data. Using better analytical tools has raised awareness of information management practices and solutions.

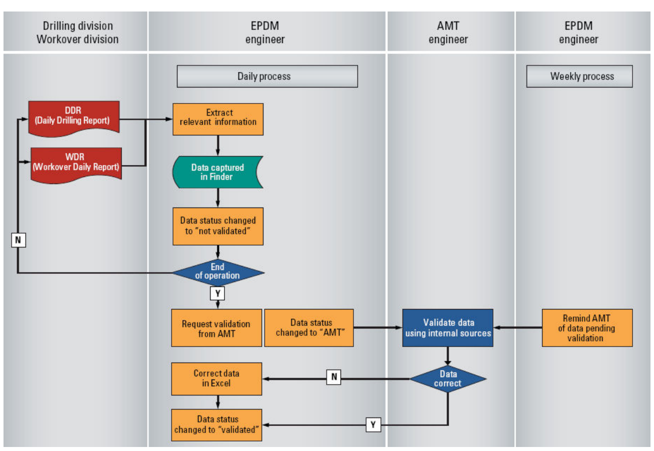


Fig. 17 – A portion of the spatial data workflow for well production data enabled at a Joint Operations organization

Case Studies – Level 4

A Level 4 organization on the DMMM is defined as having a proactive approach to spatial data management for geo-engineering data types. It uses automation of processes and tasks and decision support tools, and begins to routinely measure itself against industry standard metrics. Higher levels of six-sigma quality metrics are used not only to produce cost savings but also routinely to reduce uncertainty and risk in petroleum engineering processes. Finally, the most important distinction of organizations at this level is that spatial data management has become an embedded business process and not just a technological tool. While it cannot be documented that any organization has consistently maintained this level of spatial data management for an extended period of time across all business units, the argument can be made that some companies have for shorter periods developed characteristics of this level in individual projects or working groups.

One recent example is the development of a workflow to improve the spatial data management and existing methods of production data management at the Pakistan-based Oil & Gas Development Company Ltd. (OGDCL). As-is methods were found in an assessment to be largely manual and inconsistent (SIS, 2007). Incomplete data had resulted in time-consuming and unreliable generation of reports and graphs. An efficient workflow for the spatial component of production data was required that included spatial network and facility visualization, data entry from field locations tied to spatial elements, data validation, standard back allocation methods, and reporting capabilities. In addition the solution needed a spatial interface to other applications and the system also needed to motivate personnel and train them in order to enhance governance systems and decision-making practices. These objectives corresponded to the country's regulatory framework and allowed OGDCL to stay abreast of the Global Depository Receipt (GDR) listing requirements for enrollment at the London Stock Exchange. In order to deliver solutions through proven technology and methodology, OGDCL awarded a contract for an enterprise-wide Production Data Management Solution—the first of its kind in Pakistan—to a global information solutions provider with experience in spatial data management solutions. The initial step was to enable direct data entry from field locations using third-party remote application-sharing software. A field-data capture system and data management production software were selected to model and graphically visualize the spatial context of field facilities (Fig. 18), load data, and set the stage for accurate reporting and back allocation. A quality control and validation system applied checks in different data entry fields in the form of thresholds.

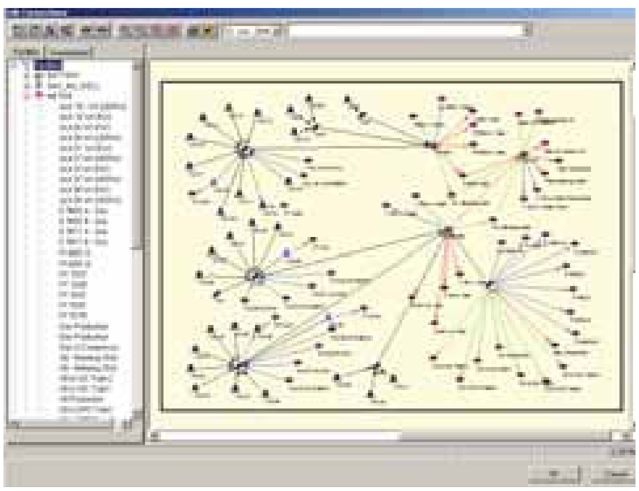


Fig. 18 – Spatial presentation and network visualization of OGDCL's fields for facility modeling and back allocation.

Amjad Yazdani, Manager of Production Surveillance in the Production Department at OGDCL, notes that "providing a road map for real-time decision making by bridging the gap between operations and management, adding value to the data generated, and assisting in optimizing production through effective monitoring are some of the key features of [the OGDCL] PDMS." Back-allocation processes across production workflows provided more accurate measures of actual versus estimated production and losses, and production reports were standardized for daily generation from the PDMS system. The production database with spatial locations for producing field elements enabled a painless querying and reporting process to identify and control costly issues such as downtime, production variances, and pressure anomalies. A central production datastore was provided by links to other production surveillance applications, well and reservoir analysis software, and planning, risk, and reserves software. The entire PDMS project was executed under PRINCE2™ professional project management methodology, which provided a framework for the wide variety of disciplines and activities required within the project. Project deliverables, quality expectations, and adherence to the plan and business case were monitored and documented throughout the project to assure success in the context of spatial data management.

The final deployed solution tying OGDCL's spatial data to the PDMS surpasses expectations and has reduced projected data collection and reporting costs by USD 2 million per year. More than 200 users were trained, and efficient project management enabled on-time and on-budget delivery. The system has been demonstrated to reduce by 50% data searching and reporting time, provide 99.5% data accuracy and confidence, and standardize improved workflows for spatially enabled production data across OGDCL. The solution also rectified years of inaccurate production data by standardizing reporting formats. Having surpassed expectations, a second phase is planned to include key i-field™ elements including real-time data access, production optimization, engineering, and further spatial portal integration. The new system solved production problems resulting from ineffective spatial data management, and continues to advance OGDCL's vision of becoming a leading oil company functioning at a Level 4 on the DMMM. Although the project business case aimed to reduce data search time for production data with spatial components by 50%, this target was exceeded by the gain that was actually achieved. According to Mohammad Kaleem, Deputy Chief Engineer of the Production Department, "raw data entered into the system was 97.5% accurate, which we further improved and now stands at approximately 99.99%. This is well above the objectives set forth in the project business case." This also places OGDCL's spatial production data at the 5 to 6 sigma level for data quality, another key aspect of Level 4 operations.

Conclusions

Varying levels of implementation of the required components of robust spatial data architectures are seen at the assessed oil and gas organizations included in this study. The first component; accessibility, addresses inventory, quality, accuracy, and confidence related to spatial data. The economic impact is the cost of re-acquiring data that cannot be accessed by end-users Fig. 19).

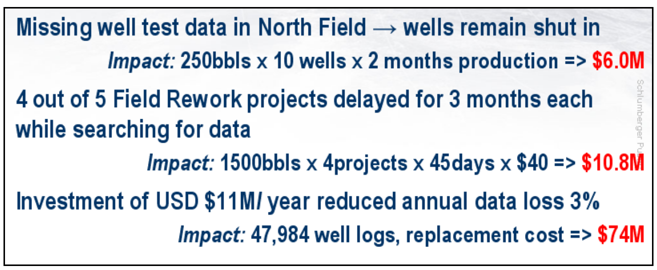


Fig. 19 – Example calculations of the financial impact of inefficient spatial data management from standardized information management case studies. These examples were presented to the assessed organization as part of the final report.

The spatially scaleable data architecture provides petroleum engineering data in a world of points, lines and polygons. It includes feature class intelligence, naming conventions, and a standard taxonomy. The impact of this component is measured in lost opportunity costs from unavailable or inconsistent spatial data. Map based access through service oriented architectures or client based systems, delivers visual and automated quality control for multiple data sources, typically via a Geographic Information System (GIS). Combining multiple accurate, confident spatial data layers with intelligent attribute linkages mitigates risk and increases decision making both in surface and subsurface analysis. Documented savings in time spent on data search are also attributed to this component. Finally, business rules serve to formalize data ownership and governance and support an intelligent synchronization process that maintains validated corporate spatial data. This leads to reduced risk in engineering decisions. Combined financial impact of moving between levels on the DMMM has been calculated in documented site assessments to range from less than USD $10M to over USD $100M for various sizes of assessments and organizations.

The site assessments also point out that despite a well managed spatial data model and architecture, success is still dependent on people. Legacy data collection methodologies can still allow inherent errors and the ability to recognize and cleanse these errors still resides in the domain of the Subject Matter Experts (SME's) or Data Stewards. The ability to find and fix these inconsistencies before the data flows into the realm of analysis and interpretation is one of the crucial components of the success of any project. In addition, the timely identification, access and involvement of these critical SME's must be ensured for any organization to go forward and improve their position on the Maturity Model for spatial data.

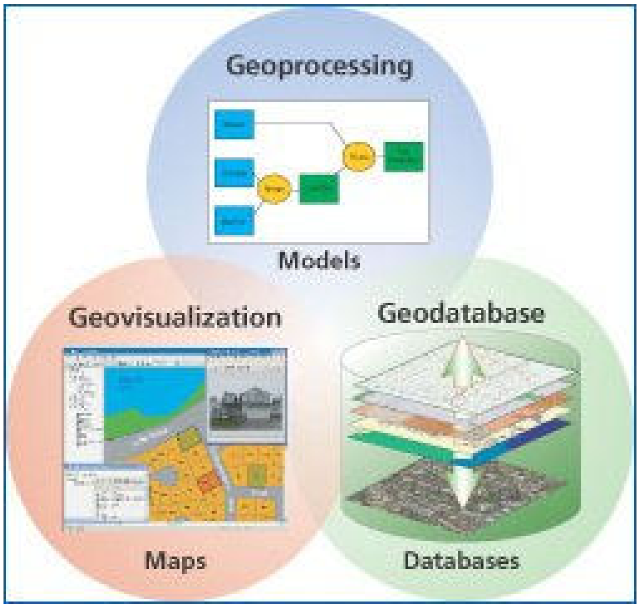


Fig. 20 – Best practice implementation of ESRI SDE™ for sustainable spatial data architecture.

Best practices in deploying spatial data architectures with all of these components are demonstrated by organizations functioning at the higher levels of the DMMM, as documented in standardized site assessments (Fig. 20). A full site assessment is recommended for any organization to understand the best systems and processes required to leverage their current investments and move forward on the Maturity Model. Such an assessment can determine the best way to implement solutions that incorporate all the described components plus repeatable and auditable workflows for well and reservoir spatial attributes. Analysis of existing solutions using the same methodology allows petroleum engineers to determine the maturity of their solutions, realizing a goal of mitigating risk, improving workflows, and lowering costs within scalable and sustainable spatial data architectures. At the same time there is a resource knowledge transfer associated with best practices that allows the most important "People" component to be recognized. The more individuals within an oil company that recognize the volumes, accuracy, cleanliness, accessibility and architecture of their spatial data, the more change processes can be improved and at the end of the day, more oil and gas can be found, extracted and delivered.

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