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Reservoir Characterization from Seismic and Well Control with Intelligent Computing Software

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The Intelligent Computing System (ICS) is a set of tools for reservoir characterization from 3D or 2D seismic data and conventional well information. The software uses clustering, artificial neural networks and classical regression methods to combine seismic, geologic and engineering data for predictions of reservoir potential. The software tools have been written by Luff Exploration Company, a Denver-based independent operator, under a cooperative project with the National Petroleum Technology Office of the U.S. Department of Energy. The project team is applying these tools for analysis of carbonate reservoirs in the Red River Formation (Williston Basin). However, the software should be applicable in any reservoir setting that yields seismic attribute variation (i.e. amplitude, frequency, etc.) with reservoir changes of porosity, thickness and fluid saturation. The software is available without cost and will run on modern personal computers with Windows operating systems.

The tools are used to transform seismic attributes to reservoir characteristics such as thickness, porosity, permeability, and entrapment pressure. Data from wells are used as training control to transform the seismic attributes to conventional reservoir attributes. Lastly, the seismic-transformed reservoir characteristics are combined with production data through a neural network solver to describe oil-water contacts, oil-cut and producibility. Luff Exploration Company is using these tools to quantify reservoir parameters for forming waterflood units, targeting drilling locations and orientation of horizontal drill holes. Output from the software is also used for construction of computer reservoir simulation models.

The Intelligent Computing System is a collection of tools and utilities that are accessed from a menu screen shown in Figure 1. Individual tools are selected to evaluate geological data or transform seismic data within a particular strategy for reservoir characterization such as shown in Figure 2. The first level of characterization consists of data collection, regional-setting study and seismic-attribute study. ICS tools for clustering and multiple-linear regression are used to find depositional setting relationships from well logs for rock quality (such as storage or phi-h) and seismic attributes for depositional setting (such as depositional cycle thickness) and storage (such as thickness or phi-h).

The second level of characterization consists of applying knowledge from regional geologic study and forward seismic modeling to a data set of seismic attributes. In this characterization level, the seismic attributes are transformed to pseudo reservoir attributes such as depth, storage, rock quality and entrapment potential. Each well location then is used to capture the seismic-reservoir attributes.

The third level of characterization comes from a training file of production attributes and seismic-reservoir attributes at well locations. Production attributes that we have been using consist of oil-cut and oil production rates. These have been peak values and normalized values over a consistent time frame, such as first 24 months. The training file is applied with a neural-network solver to a transformed seismic-reservoir attribute file. The training files we have been using are composed of well and seismic data from multiple seismic surveys. The seismic data from each survey are processed in the same manner and then normalized. We have been working with transformed seismic attributes that describe Red River dolomite reservoirs. For this we have identified structure, depositional-thickness setting, rock-quality, entrapment and structural growth as general categories of reservoir attributes.

Successful application of the Intelligent Computing System requires a sufficient population of wells and fields producing from a target reservoir from which conclusions and predictions may be made for an area that is under evaluation. It is not easy to say what constitutes a sufficient population. We have been using data from over 400 wells for evaluation and analogy of depositional setting and reservoir development (porosity and permeability) in upper Red River oil reservoirs. Also, we have been using data from 10 Red River fields with more than five wells for evaluation and analogy regarding oil entrapment (oil-water contact and oil-water transition column). Seismic data from six 3D surveys and

three areas with 2D seismic grids have been used for correlation of seismic attribute with reservoir attributes and subsequent transforms. Figure 3 is a map view showing locations of six 3D seismic surveys in portions of Bowman County, North Dakota and Harding County, South Dakota. The figure is intended to show that seismic and well data from multiple 3D seismic surveys are used to predict reservoir and production attributes at a particular seismic survey.

The reservoir characterization example prepared for the poster session is from porosity zones in the upper Red River Formation at depths from 9300 feet. The field is located in Bowman County, North Dakota, Williston Basin. The characterization problems are determining productive limits and identifying areas with maximum production potential for a waterflood unit with existing and new wells. Our goal is to produce production attribute maps from reservoir attributes. The reservoir attributes are transforms of seismic attributes.

Figure 4 is an example of seismic reservoir attribute transform of porosity-thickness for the Red River D Zone reservoir. Multiple seismic attributes and digitized log data from six 3D seismic surveys were used to produce this transform. Porosity thickness is but one of several reservoir attributes used in the reservoir characterization process and final prediction of production attributes. The porosity-thickness prediction is also useful for reservoir simulation studies.

Figure 5 shows a production-attribute map of predicted initial producing oil-cut for the Red River B Zone reservoir. Maps such as this and maps of other production-attribute transforms are used to highlight areas of maximum oil reserves and productivity. The correlation of predicted oil-cut and actual production is shown in Figure 6. Data used from other 3D seismic surveys and wells produce a good prediction with a R-squared correlation of about 0.75 at this reservoir. Reservoir characterization with ICS tools and the outlined strategy have been used successfully for targeting horizontal wells, either new or re-entry, at other fields. The characterization results for reservoir size and limits have created confidence to re-develop several old fields. Marginal and abandoned wells have been re-entered for lateral drilling with results exceeding the initial producing rate of the original vertical completion.

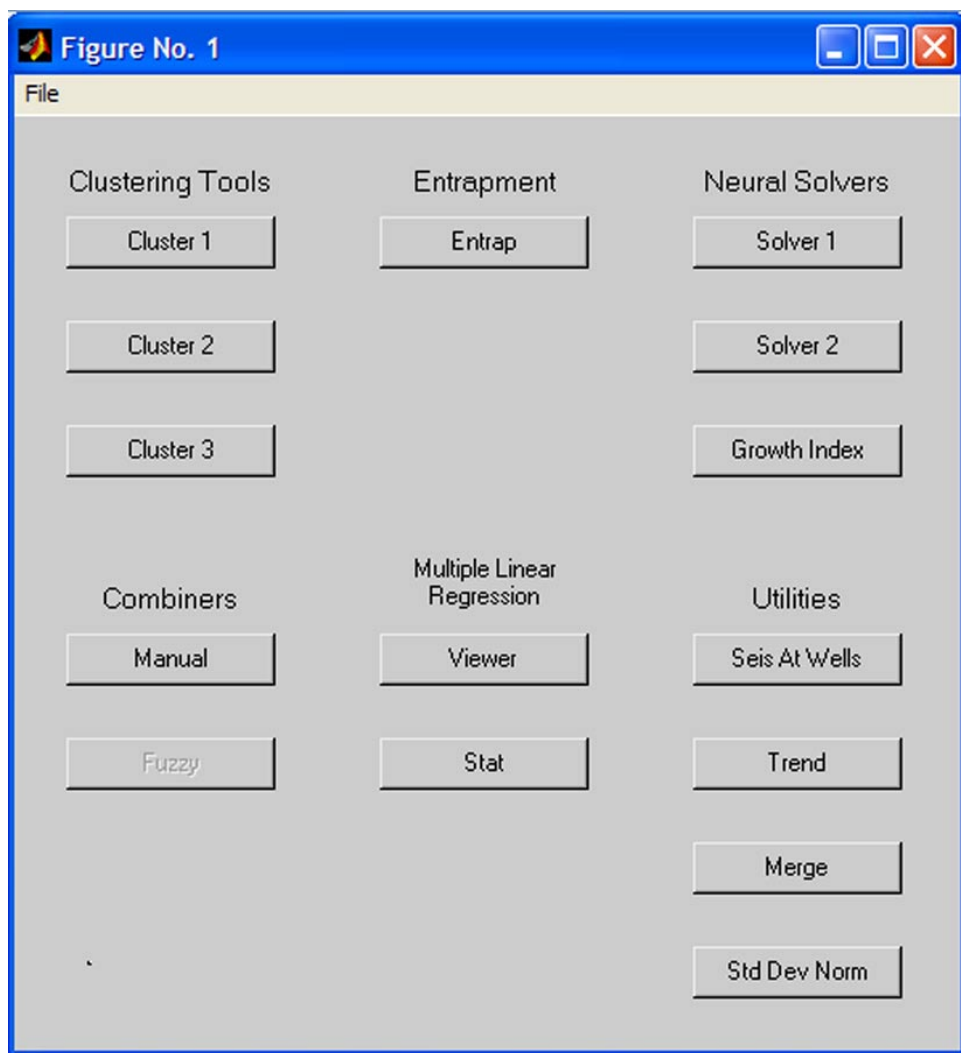


Figure 1. Menu screen for access to tools and utilities for the Intelligent Computing System.

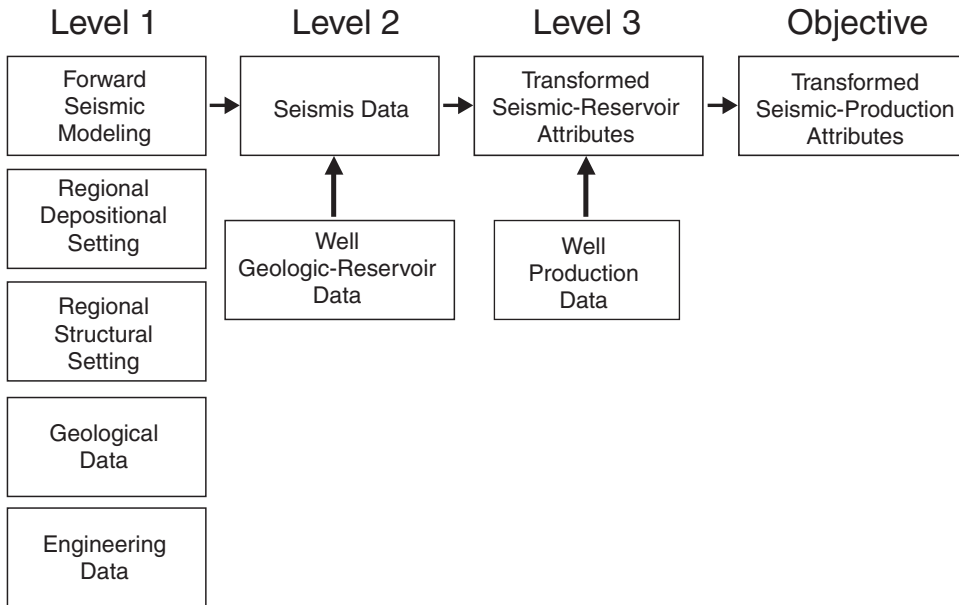


Figure 2. Schematic diagram for a reservoir characterization strategy used at Red River reservoirs in Bowman County, North Dakota, Williston Basin. This reservoir characterization strategy should be applicable for many reservoirs.

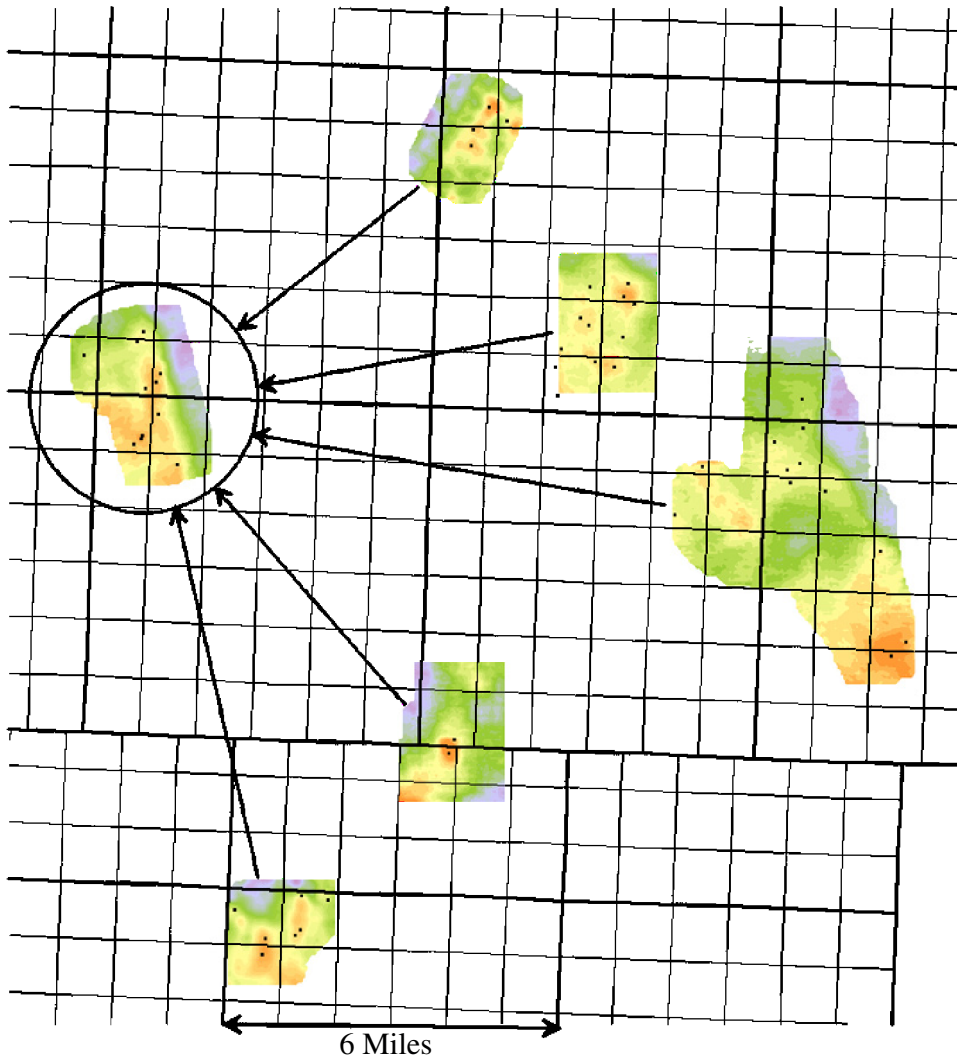


Figure 3. Map of 3D seismic surveys used for correlation and subsequent prediction of reservoir and production attributes. The seismic records are processed in the same manner with the same seismic attributes extracted for reservoir attribute transforms.

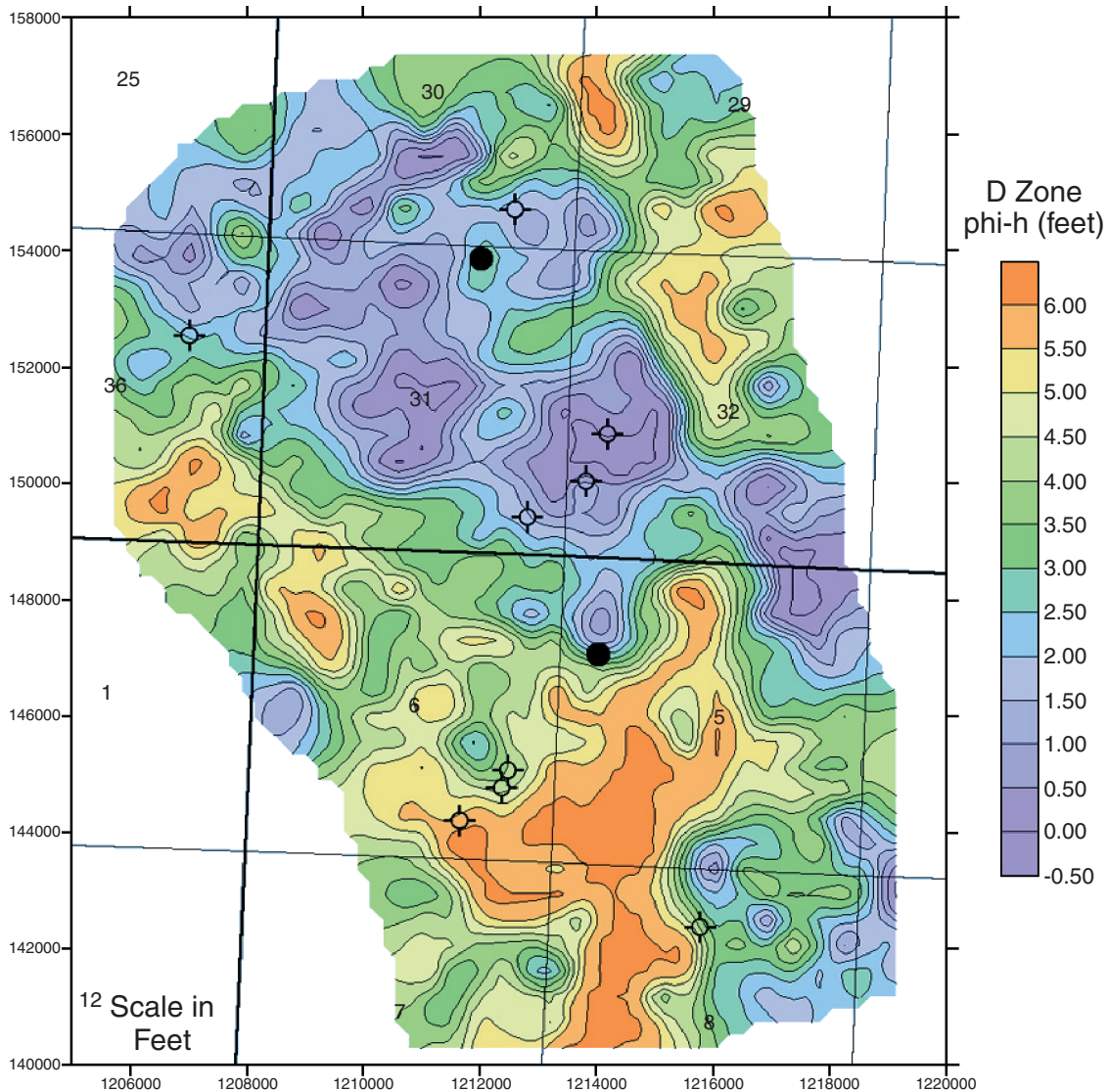


Figure 4. Map of predicted porosity-thickness from seismic transforms for the Red River D Zone. Multiple seismic attributes and digitized log data from six 3D seismic surveys were used to produce this transform.

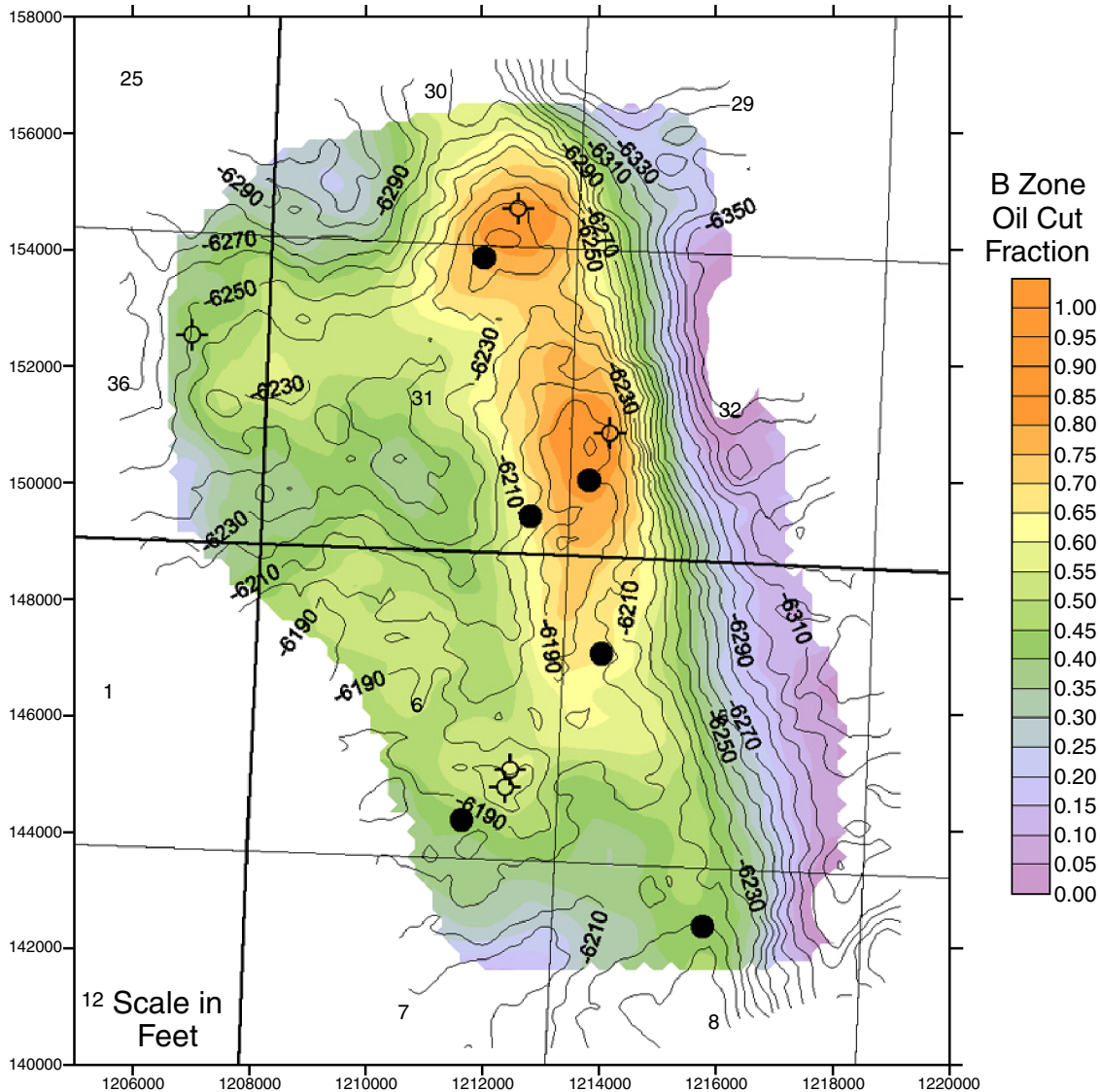


Figure 5. Map of predicted oil-cut from transformed seismic-reservoir attributes for the Red River B Zone. The predicted oil-cut was subsequently confirmed with horizontal drilling and production testing.

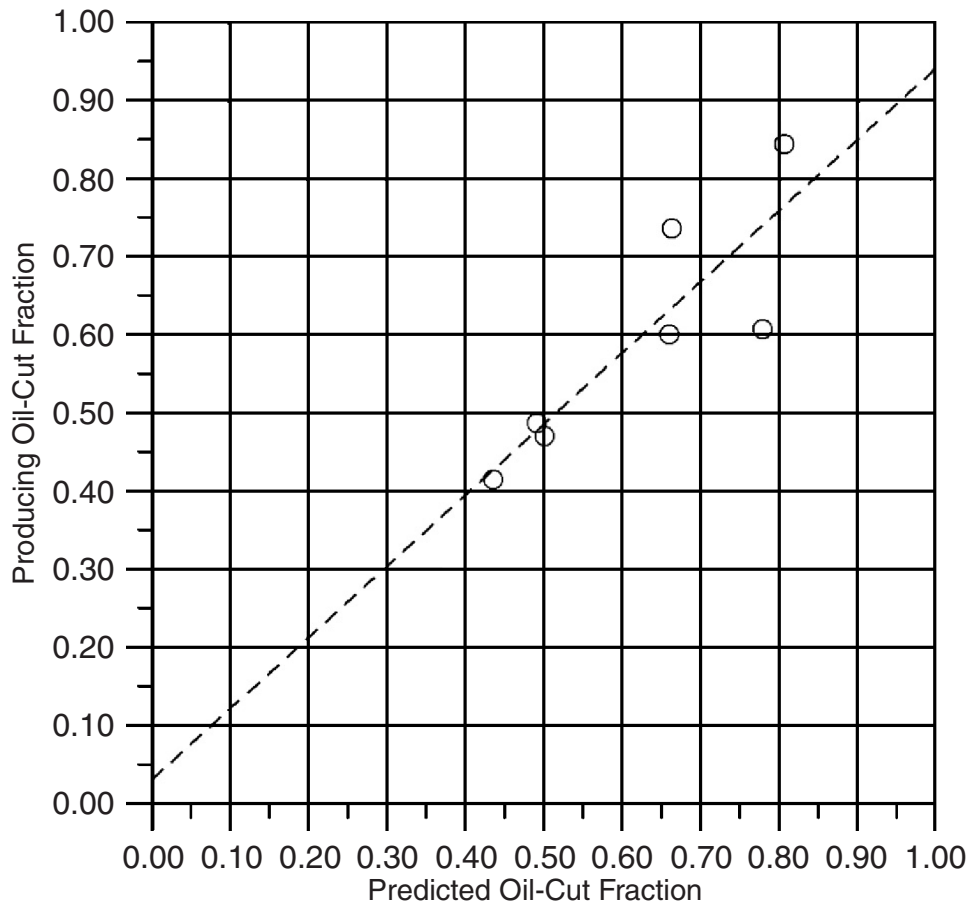


Figure 6. Graph showing correlation of predicted oil-cut from external training and oil-cut from actual well production at the example field.