

FINAL REPORT

ANALYSIS OF EXISTING SEISMIC REFLECTION DATA IN SOUTH FLORIDA FOR ASR REGIONAL STUDY

Prepared for

Department of the Army
Jacksonville District
United States Army Corps of Engineers
Geotechnical Branch
701 San Marco Blvd., 3 West
Jacksonville, Florida 32207

and

South Florida Water Management District
P.O. Box 24680
West Palm Beach, Florida 33416

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URS

URS Group, Inc.
8181 East Tufts Avenue
Denver, Colorado 80237

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1.1 GENERAL

This report presents an assessment of reprocessing existing seismic reflection data in south Florida. The assessment was conducted by URS Group, Inc. (URS) under contract to the U.S. Army Corps of Engineers – Jacksonville District (USACE). The USACE is teamed with the South Florida Water Management District (SFWMD) on review of this assessment, as part of the Comprehensive Everglades Restoration Plan (CERP).

The primary objective of this work was to assess the viability of reprocessing existing seismic reflection data to resolve shallow subsurface structure. Specifically, this project seeks to determine if existing seismic reflection data collected originally for oil exploration purposes can be reprocessed to help characterize the subsurface shallow stratigraphy in an area south of Lake Okeechobee, Florida. Completion of this project can be used to assess whether reprocessing of additional selected seismic reflection data would benefit subsurface characterization.

The final negotiated scope of this project precluded completing an interpretation of these data, and thus a full assessment of the results is not prudent. A thorough interpretation of these data should be completed, including correlation to the geology and other information obtained from intrusive activities, to fully assess these results and determine the ultimate effectiveness of this data reprocessing effort

1.2 PROJECT BACKGROUND

The CERP identified many specific projects in south Florida to help restore the ecosystem. Several of these projects include various aquifer storage and recovery (ASR) studies. For example, the ASR Regional Study, which may include up to 333 ASR wells, is principally a feasibility project designed to evaluate the viability and potential effects of full-scale CERP ASR implementation on existing users of the Floridan Aquifer System (FAS), agri-business, utilities, and the environment. Better subsurface characterization, to help in optimizing placement and effectiveness of the ASR wells, is one issue that has been raised by parties interested in the restoration.

Numerous multi-channel seismic reflection geophysical surveys were performed in southern Florida by oil companies since 1960, with most of the surveys being run in the 1970s, 1980s and 1990s. These seismic surveys targeted potential oil producing zones at approximately 10,000 to 14,000 feet below ground surface (bgs). Advances in the field of geophysical data processing make it possible to reprocess and reanalyze some of this existing seismic data to provide geologic and potentially hydrogeologic information for the lower portion of the Hawthorn Group and underlying FAS occurring at depths of approximately 500 to 2,500 bgs. Given the many seismic lines that traverse areas for which no FAS data is available, it was deemed prudent to investigate the possibility of reprocessing selected portions of the available seismic reflection data.

1.3 REPORT ORGANIZATION

This report is organized into three main sections including:

- 1.0 – Introduction

- 2.0 – Preliminary Data Evaluation,
- 3.0 – Reprocessing and Analysis.

2.1 ASSESSMENT OF EXISTING DATA

A significant number of seismic reflection lines are known to exist near and south of Lake Okeechobee, in south Florida. In an attempt to adequately limit the scope of this assessment, available data reviewed were limited to one seismic data brokerage firm.

A seismic data coverage map was obtained from Seismic Exchange, Inc. (SEI) for a large area of Florida, extending from 70 miles north of Lake Okeechobee to the southern tip of Florida. A senior geophysicist with URS assessed general data parameters of several of the existing lines for further review. After discussions with USACE, an area just south of Lake Okeechobee was selected for further data evaluation.

URS selected thirteen lines, based on general proximity to Lake Okeechobee and line orientation, for further assessment. Data acquisition parameters for each line was obtained from SEI for comparison and assessment. Evaluated for each line was the geophone interval, shot interval, fold, and cost to lease. From this review, five lines were chosen for visual review of sample sections from SEI.

After securing the data samples from their Houston office, SEI met with URS for data review. The review consisted of examination of one hard copy section of each line. Such a review is limited to what SEI provides. One cannot obtain multiple copies with various display parameters unless the data are leased. As a result, some experience was required in projecting what value additional processing is likely to produce for a given data set. Based on review of the hard copy seismic sections, two seismic lines were chosen by URS to be recommended for lease. One of these lines utilized dynamite as the seismic source with an east-west orientation, and the other line used a vibroseis source also with an east-west orientation. URS opined that both of these lines had favorable data acquisition parameters that could be processed to enhance shallow resolution. For potential future consideration, the lines chosen in this feasibility assessment represent some of the better seismic data that are available in the investigation area.

After discussions with USACE, and details of the required lease arrangement were resolved, URS chose one 5-mile section for each of the two selected lines. Although specific locations of leased line segments cannot be discussed herein due to the negotiated lease agreement with SEI, results of the reprocessing effort and any future interpretations made by URS are available for review by USACE.

3.1 GENERAL

Upon executing the necessary lease agreement, URS instructed SEI to retrieve the leased data from their data archives. The digital field data were delivered to URS on 8 millimeter (mm) data tapes. Also included in the lease package were copies of relevant observer notes, survey position information, and a general location map. Upon receipt of these data, URS forwarded relevant portions of this package to the seismic data processing firm selected for this work, Tricon Geophysics, Inc. (Tricon).

3.2 FIELD DATA

The seismic data consisted of portions of two 2-Dimensional (2-D) seismic lines acquired in the mid to late 1980s by SEI. The original acquisition parameters were designed to target potential oil-producing zones from 10,000 to 14,000 feet bgs. One line was acquired using a dynamite source and recorded p-wave seismic data. The other line was acquired with vibroseis, using a truck-mounted controlled source vibrator, and recorded similarly to the dynamite data.

The vibroseis data were acquired with the following parameters:

- Number of Recording Channels – 480 channels
- Geophone Group Interval – 75 feet
- Source Point Interval – 150 feet
- Recording Geometry – balanced split spread (240-7-240)
- Data Sample Rate – 4 milliseconds
- Record Length – 6,000 milliseconds
- Maximum common – midpoint (CMP) fold – 120
- Low Filter – out
- Notch Filter – out
- Alias Filter – 93 Hz
- Sweep Start – 8 Hz
- Sweep Rate – 2 Hz/second
- Sweep Length – 24 seconds
- Taper – 0.5 second

The dynamite data were acquired with the following parameters:

- Number of Recording Channels – 480 channels
- Geophone Group Interval – 60 feet
- Source Point Interval – 60 feet
- Recording Geometry – balanced split spread (240-240)

- Data Sample Rate – 4 milliseconds
- Record Length – 6,000 milliseconds
- Maximum CMP fold – 240
- Low Filter – out
- Notch Filter – out
- Alias Filter – 93 Hz

The data were received on 8mm digital tape in SEG Y format (SEG, 1980). The vibroseis data already had been correlated with the pilot sweep.

3.3 DATA PROCESSING

The processing sequence (see Table 3-1) included a variety of programs that are normally applied to common midpoint (CMP) seismic data. After initial analysis the exact sequence was designed. During various steps the processing analyst reviewed the results to ensure optimum data quality. Processing programs have many functions including sorting data traces into CMP format, applying static and velocity functions, editing and removing unwanted noise, enhancing frequency content, scaling data for presentation, plotting data, and a variety of other data analysis techniques. Some description of the data processing programs used is found in Table 3-1. A detailed treatise or primer on seismic reflection or seismic reflection data processing is beyond the scope of this document. For further definitions the reader is directed to the Encyclopedic Dictionary of Exploration Geophysics (Sheriff, 1999). As an end result the data processing operations generated a 2D seismic profile, which upon interpretation represents a geologic cross-section through the earth.

The total number of input records was 399 for the dynamite line and 179 for the vibroseis line. The total number of CMPs for the dynamite line was 1,157 and for the vibroseis line was 1,055. After final stack, the data were migrated with finite difference algorithm to correct for imaging errors that can be caused by geologic structures.

There were no elevation data for the vibroseis line. An elevation profile from a previous stacked profile was available but the scale was not large enough to allow accurate elevations to be determined. Elevations were estimated to be 20 feet MSL everywhere. A scan of the profile did not show any major depressions. Residual static programs were used to make additional corrections to the seismic data in the CMP domain.

Three stacked sections were generated for each line, and are presented herein. The final stack, the migrated final stack, and a migrated final stack that has a frequency enhancement process are included. The final stack is the composite record combining the CMP trace results with appropriate statics and velocity analyses applied. The migrated section takes the final stack data and migrates, or rearranges, the seismic events so that reflections and diffractions are plotted at their true locations. This need arises since variable subsurface velocities or dipping interfaces can cause the events to be recorded at surface positions different from the subsurface positions. The enhanced section incorporates a process that increases the frequency content of the stacked seismic events, usually allowing for greater resolution.

The enhanced final migrated stack had Tricon's proprietary frequency enhancement technique, known as XFreq, applied. This is a series of programs designed to boost the amplitudes of the higher frequency range. The method is based on dipole filtering (see Colton and Nautiyal, 1996), which enhances the frequency content of the data.

Final sections are displayed with horizontal distance plotted (via CMP number) versus two-way travel time. Depths can be estimated by correlating a seismic velocity with a given two-way travel time. Presentation of the upper 700 milliseconds (ms) of data likely provides a depth coverage exceeding 2,600 feet.

Full conversion of the seismic section travel times to depth would be part of a complete interpretation of these data. However as stated above, depths can be approximated by estimating a seismic velocity and applying the appropriate travel time to convert a particular seismic event to depth. Although only an approximation, the seismic velocity used can be interpolated from the stacking velocities used in the final sections. These velocities are reported at the top of the seismic sections every 50 CMP's. One must keep in mind that the times are two-way travel times. So for example, at CMP 1735 of the dynamite line, a time of 200 ms would correspond to a depth of approximately 600 feet, and a time of 600 ms would correspond to a depth of approximately 2500 feet.

3.4 ANALYSIS

All three seismic sections presented herein could be examined, compared and correlated to form an interpretation. Any interpretation would also obviously include consideration of the geology, known faulting, fracturing or karst development, and would consider existing and relevant borehole information. For the purposes of this assessment however, a full interpretation will not be made but rather a few points of observation.

An obvious improvement can be seen in the stacked sections as one compares the final stack, the migration, and the enhanced-frequency stacks. With successive iterations, reflection continuity and resolution is increased. Scattering of reflection energy is reduced significantly by the migration, and the frequency-enhanced section suggests the presence of numerous thin bed units that are only marginally discernible in the final stack section. A classic example of this is between CMP 1660 and 1676 of the dynamite line at 0.305 seconds depth. The XFreq stack shows a small reflection here that is only marginally discernible in the other section. However, even the final stack and migrated sections are sufficient to see shallow stratigraphy that could be valuable characterizing the upper 2,500 feet useful to the ASR Regional Study. For the purposes of this assessment, additional comments will be limited to the XFreq stacked sections.

Higher frequencies are observed in the dynamite data, but this is largely because the vibroseis sweep was limited to 56 Hz whereas the dynamite raw data theoretically contains all frequencies. The vibroseis data does not have significant data gaps in the seismic section that can result from land access issues that the use of a dynamite source can create.

The dynamite line suggests good resolution of the reflection energy from 100 ms and deeper, and certainly over the key zone of interest for this project. Based on stacking velocities, the shallowest depth for resolution is likely about 400 feet bgs. Anomalous features suggesting potential buried channel-like sequences are suggested in several portions of the line including CMP 930 to 990, CMP 1100 to 1150, CMP 1250 to 1310, CMP 1430 to 1510, and CMP 1660 to

1700 to name a few. Fracturing and/or faulting is suggested at numerous locations as well. Examples include a easterly dipping feature at CMP 1090 (at 220 ms to 360 ms) and a westerly dipping feature at CMP 1726 (at 130 ms to 380 ms). Several potential collapse features are suggested. For example, one is potentially indicated between CMP 1150 and 1180 at a depth of 500 to 700 ms.

The vibroseis line suggests good resolution of the reflection energy from approximately 200 ms and deeper. Based on stacking velocities, this represents a minimum resolution depth of approximately 500 to 600 feet. This line delineates several shallow anomalous features as well. Most notable are several areas in which potential collapse features are suggested. By way of example, the zone between CMP 3015 and 3055 (at 240 ms) depicts a broad disrupted zone that narrows with depth (to between CMP 3030 and 3040 at 540 ms), suggestive of a collapse. Other anomalous features potentially suggesting a collapse or a buried channel include CMP 3130 to 3150 and CMP 3455 to 3485.

Results of this reprocessing effort clearly indicate that a complete interpretation of these data and findings is warranted to fully assess the ultimate success of this work. The final seismic sections suggest that a complete interpretation of these data could identify and clarify the value of additional reprocessing efforts on other data sets.

Table 3-1
Seismic Data Processing Flow Description

1. Reformat to Focus – Read data from SEG Y tape format and convert to internal Focus format
2. Trace Edit – Remove test and diagnostic records, and noisy and dead traces
3. Geometry Definition and QC – Describe the spatial relationship between the sources and receivers, insert geometry into trace headers, and display resultant shots to check consistency
4. Edit for Offsets – Remove traces with source offsets greater than 13,200 ft
5. Spherical Divergence Correction – Adjust amplitude values for spherical divergence to remove spatial effects
6. Surface Consistent Gain – Adjust amplitude values to remove surface effects at source and receiver
7. Surface Consistent Deconvolution – Apply Wiener deconvolution filter
8. Automatic Gain Control (AGC) – Adjust amplitude values within specified windows
9. Datum Statics – Correct for shot and receiver elevations
10. Velocity Analysis – Interactively pick CMP stacking velocities – 2 passes
11. Normal Moveout Correction – Apply normal moveout from stacking velocities
12. First Break Suppression – Apply mute function to suppress the first break event
13. Surface Consistent Residual Statics – Apply residual statics in the CMP domain. 2 passes
14. Signal Enhancement on Shots – Apply filters to reduce noise and increase frequency content
15. Surface Consistent Residual Statics – Apply residual statics the CMP domain
16. Common Mid-Point Gather – Sort into CMP and offset order
17. Stack – Sum traces within same CMP bin
18. Finite Difference Migration – Apply ray-path and imaging corrections
19. XFreq – Apply Tricon’s post-stack frequency enhancement suite (XFreq)
20. Automatic Gain Control (AGC) – Adjust amplitude values within specified windows
21. Bulk Shift to Final Datum – Shift the data values in time to the final elevation datum

Colton, Penny B. and Nautiyal, Atul. 1996. Cascaded Dipole Filters: Extending the Limits of Seismic Resolution, CSEG Recorder, October 1996, 8-19.

SEG (Society of Exploration Geophysics) Technical Standards Committee. 1980. Digital Tape Standards.

Sheriff, Robert E. 1999. Encyclopedic Dictionary of Exploration Geophysics, Third Edition, Society of Exploration Geophysicists.