



March 20, 2012

HONORABLE MAYOR AND CITY COUNCIL
City of Long Beach
California

RECOMMENDATION:

Receive and file the attached report, "Elevation Changes in the City of Long Beach, May 2011 through October 2011." (Citywide)

DISCUSSION

The City of Long Beach, through the Long Beach Gas and Oil Department (LBGO), supervises oil production and subsidence control operations in the Wilmington Oil Field. LBGO conducts elevation surveys every six months to monitor elevation changes in the oil fields and adjacent city areas. This report focuses on elevation changes that have occurred from May 2011 through October 2011. The LBGO survey includes the following areas: Civic Center, Central City, Alamitos Bay, Naples, Harbor District, and an offshore area encompassing the four oil islands.

The results of the six-month survey show that elevations were stable in the Civic Center, Central City, Alamitos Bay, Naples, Harbor District, and the offshore areas.

The LBGO survey uses a series of benchmarks to determine elevation changes. Studies by the Department's engineers and geologists show that the benchmarks may rise and fall in such a manner as to make a survey either optimistic (slightly up in elevation) or pessimistic (slightly down in elevation). These changes in elevations may be associated with tidal cycles, temperature changes, and/or deep earth tectonic changes or re-pressuring operations. Surface elevations in a rebounded area can be expected to fluctuate under changing water flood conditions.

This matter was reviewed by Deputy City Attorney Richard Anthony on February 22, 2012 and Budget Management Officer Victoria Bell on February 24, 2012.

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TIMING CONSIDERATIONS

City Council action on this matter is not time critical.

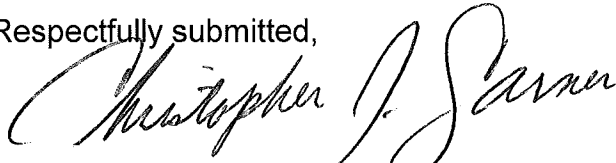
FISCAL IMPACT

There is no fiscal impact or local job impact associated with this action.

SUGGESTED ACTION:

Approve recommendation.

Respectfully submitted,



CHRISTOPHER J. GARNER
DIRECTOR OF LONG BEACH GAS AND OIL

CJG:JJ:lld

Attachment

APPROVED:



PATRICK H. WEST
CITY MANAGER

**ELEVATION CHANGES
IN THE
CITY OF LONG BEACH
MAY 2011 THROUGH OCTOBER 2011**

**PREPARED
FOR
LONG BEACH CITY COUNCIL
BY THE
LONG BEACH GAS AND OIL
DEPARTMENT**

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ELEVATION SURVEY ANALYSIS

The City of Long Beach semi-annual elevation survey of the Civic Center, Central City, Harbor District, Alamitos Bay, Naples, and offshore areas was conducted during November 2011. Changes in elevation that have occurred since the last two surveys, May 2011 and November 2010, are discussed in this report. The results in this report reflect elevation changes both within and beyond the scope of oilfield operations. Some changes are due to natural geologic factors.

Elevation Change – May 2011 through October 2011 (Figure 1)

Elevations throughout the Civic Center, Alamitos Bay, Naples, and offshore areas were stable during the six-month period. The Harbor District elevations were also stable during the six-month period.

Elevations in the City of Long Beach beyond the boundaries of the Wilmington Oil Field were stable.

Elevation Change – November 2010 through October 2011 (Figure 2)

Elevations in the Central City and offshore areas near Island Grissom continued to increase during the 12-month period by as much as 0.07 foot (0.8 inch). The elevation change was minor and attributed to regional geologic factors. Elevations throughout the Alamitos Bay and Naples areas remained stable during the 12-month period.

Elevations throughout the Harbor District slightly increased during the 12-month period. Portions of the Piers A and T experienced an elevation increase of up to 0.09 foot (1.1 inch). There is no reason for concern as the increase was minor. Analysis of reservoir pressure data, water injection requirements, and fluid production indicate the elevation

increase was due to regional geologic factors outside the boundaries of the Wilmington Oil Field.

Use of Global Positioning System (GPS)

This report is based solely upon computer processed data utilizing the Long Beach Deformation Network (LBDN). The LBDN consists of twelve (12) permanent, reference GPS base stations, communication equipment, computer server, monitoring software and five mobile GPS receivers. The Public Works Department's Bureau of Engineering surveyors utilize the mobile GPS receivers linked to the reference base stations to measure approximately 240 City and Harbor bench marks.

APPENDIX

Brief History of Long Beach Subsidence

Long Beach and the general vicinity have a history of regional subsidence (losses of elevation) since 1929. Elevation changes were minor amounting to an average of about -0.036 foot (-0.43 inch) per year until about 1939. Geologic movement such as the Long Beach Earthquake of March 1933 altered this average rate at times. Contributing causes of the subsidence were groundwater withdrawal from aquifers in the Long Beach area, regional basin sediment compaction, and tectonic effects of local faulting.

Development of the Wilmington Oil Field began in 1932. Oil operations accelerated subsidence and created a 29-foot deep subsidence bowl centered in the Wilmington-Long Beach Harbor area near Bench Mark 8772 (Figure 6). Development of the Ranger Zone west of Pine Avenue and its extension seaward in 1947 started the first definitive subsidence in the Central Business District that could be attributed to oil production.

Repressuring operations began in the 1950s. By 1965, subsidence stopped throughout the Long Beach portion of the Wilmington Oil Field. Several bench marks recovered over one foot in elevation, due to waterflood repressuring. As an example, from 1960 to 1970, Bench Mark 1735 near the corner of Ocean Boulevard and Magnolia Avenue recovered approximately one foot of elevation. The recovery of bench mark elevations is known as rebound.

In the 1990s, a large Harbor redevelopment project on Pier A destroyed several bench marks that overlaid the now curtailed steamflood project. Elevation losses in the area were suspected, and the destruction of these bench marks made it difficult to monitor any changes. In 1998, after the bench marks were replaced, additional well bore investigations determined that subsurface compaction of the deep shale intervals was

occurring above the steam flooded zones due to high temperatures. The Fault Block II Tar Zone Steamflood was terminated in 1999, and cold-water injection was initiated. The forced cooling of the deep formations has remedied the subsidence problem.

The Alamos Bay and Naples area had losses in elevation prior to development of the adjacent oil operations. These original small losses were most likely due to the regional effects of basin sediment compaction and tectonic movements along the Newport-Inglewood Fault Zone. Later, the coastal strip from the Civic Center eastward to the Alamos Bay Peninsula lost elevation due to oil and gas production from the West Wilmington Oil Field and possibly the adjacent oil fields. The coastal strip rebounded slightly due to water injection from the offshore Oil Islands that began in 1965.

Survey Accuracy

The May 2002 Elevation Leveling Campaign marked the conversion from spirit, first and second order rod leveling, to GPS surveying of bench mark elevations.

Through statistical analysis of satellite, base station, mobile instrument geometries, a coincident spirit leveling and GPS bench mark elevation survey, City surveyors estimate the accuracy of GPS elevations to be 8 to 10 millimeters (0.025 foot or 0.30 inch). Areas are considered to be stable where elevation change is less than 0.025 foot (0.30 inch).

Studies by the City's subsidence control engineers, geologists, and consultants show that the bench marks may at times rise and fall somewhat rhythmically city-wide in such a manner as to make an entire survey either optimistic or pessimistic. These elevation changes are random and not well understood. Repressuring operations and the resulting rebound can mask the rise or fall pattern. Surface elevations in a rebounded area can be expected to fluctuate under changing water flood conditions. Because of these fluctuations, conclusions based upon short-term survey data should be viewed with caution. Short-term survey data are useful for possible early detection and confirmation of subsidence trends or relative elevation changes but should not be accepted without

consideration of the above factors. Annual survey data tend to average these fluctuations and depict a more dependable picture of the relative movements of bench marks.

Elevation Change Map Construction (Figures 1 and 2)

All data are presented as contour lines showing the average change in surface elevation during a particular time period. For example, any point along a line reading 0.05 foot (0.60 inch) on an Elevation Change Map gained an elevation of one-twentieth of a foot or six-tenth of an inch during that period. The small hachures along contour lines point towards a loss in elevation.

Bench Mark Location Map (Figure 3)

This map shows the location of bench marks used for the Bench Mark and Net Injection Graphs.

Bench Mark and Net Injection Graphs, Harbor District (Figures 4 – 7)

The bench marks are normalized to mean sea level. Bench marks are plotted each time they are surveyed and are shown on a graph with a history of net injection for that same area and time. The net injection is the amount of water injected into the reservoirs that underlie that particular bench mark minus the gross fluid produced from the reservoirs in barrels per day. The graphs cover 20 years of net injection and bench mark monitoring.

In general, these graphs show a good correlation between the net injection and elevation change. For example, an increase in net injection is usually followed by an increase in elevation. There tends to be a lag time of months and sometimes years between the net injection change and the subsequent elevation change. The elevation plots of bench marks on Figures 4 through 7 in the Harbor District illustrate surface elevation fluctuations that can be expected to occur under the dynamic reservoir conditions experienced in extremely mature waterflooding operations.

Bench Mark and Net Injection Graphs, Ocean Boulevard and the Offshore Drilling Islands (Figures 8 – 13)

The last 20 years of elevation changes and accompanying net injection histories are shown on Figures 8 through 13 for bench marks located along Ocean Boulevard and on the offshore drilling islands. The elevation changes at Ocean Boulevard near Magnolia Avenue are shown by the graph of Bench Mark 1735 and Bench Mark 1215 on Figure 8. Permanent GPS Station WELL on Figure 12 shows surface elevation changes on the Alamitos Bay Peninsula. Bench Mark 938 monitors elevation on Naples Island.



Figure 1

CITY OF LONG BEACH
GAS AND OIL DEPARTMENT

**ELEVATION CHANGE
MAY THROUGH OCTOBER 2011**

Map Drawn by: D. HEWMAN
Reviewed by: John Johnson
Checked by: Subsurface Staff
Date: 11/18/11

Contour Interval: 0.05 0 Foot (0.60 Inch)

▲ GPS Reference Stations

ALL DATA TRACKS ARE UNCORRECTED
(TRACKED ON NAVSTAR HORIZON)

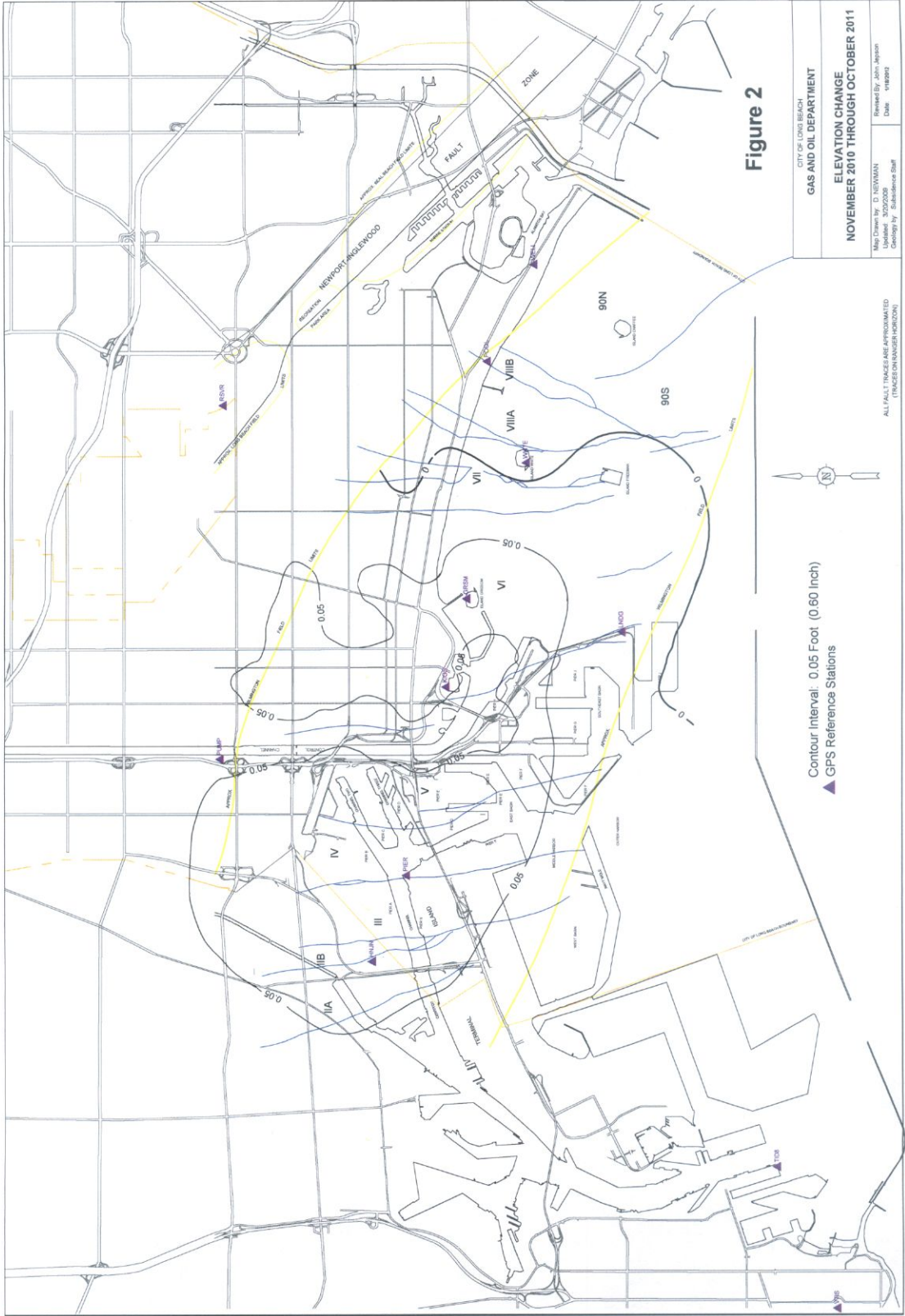


Figure 2

CITY OF LONG BEACH
 GAS AND OIL DEPARTMENT
 ELEVATION CHANGE
 NOVEMBER 2010 THROUGH OCTOBER 2011

Contour Interval: 0.05 Foot (0.60 Inch)
 ▲ GPS Reference Stations

Map Created by: D. NEVANS
 Updated: 10/20/2011
 Geology by: Surveillance Staff

Revised by: John Jensen
 Date: 11/20/11

ALL FAULT TRACES ARE APPROXIMATED
 (TRACES ON NUMBER HORNS)

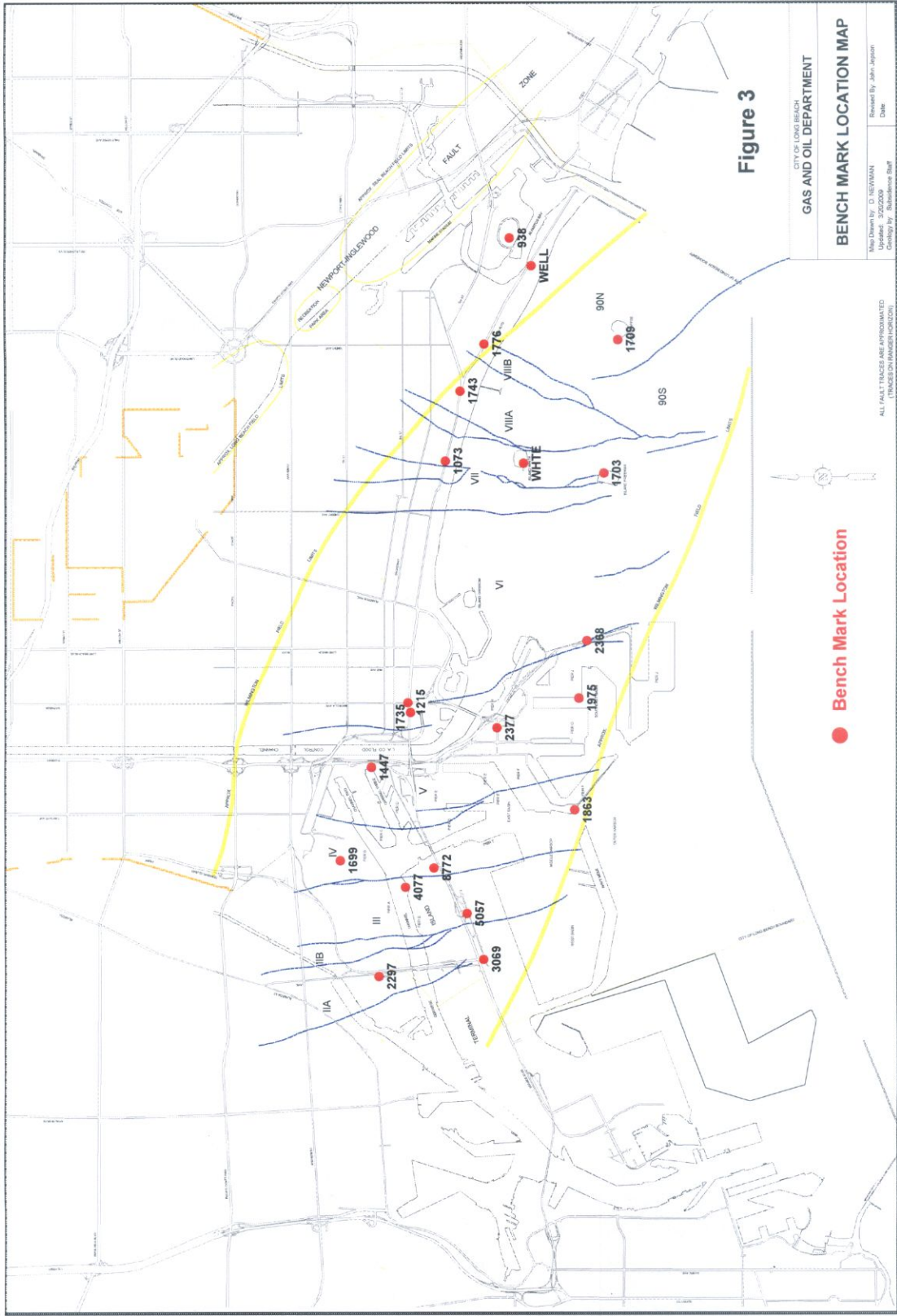


Figure 3

CITY OF OAK BENCH
 GAS AND OIL DEPARTMENT
BENCH MARK LOCATION MAP

Map Drawn By: D. NEWMAN
 Updated: 2/20/2009
 Created by: [unclear]
 Revised By: John Johnson
 Date: [unclear]

ALL FAULT TRACES ARE APPROXIMATED
 (FRANCOIS HANSEN FOUNDATION)

● Bench Mark Location

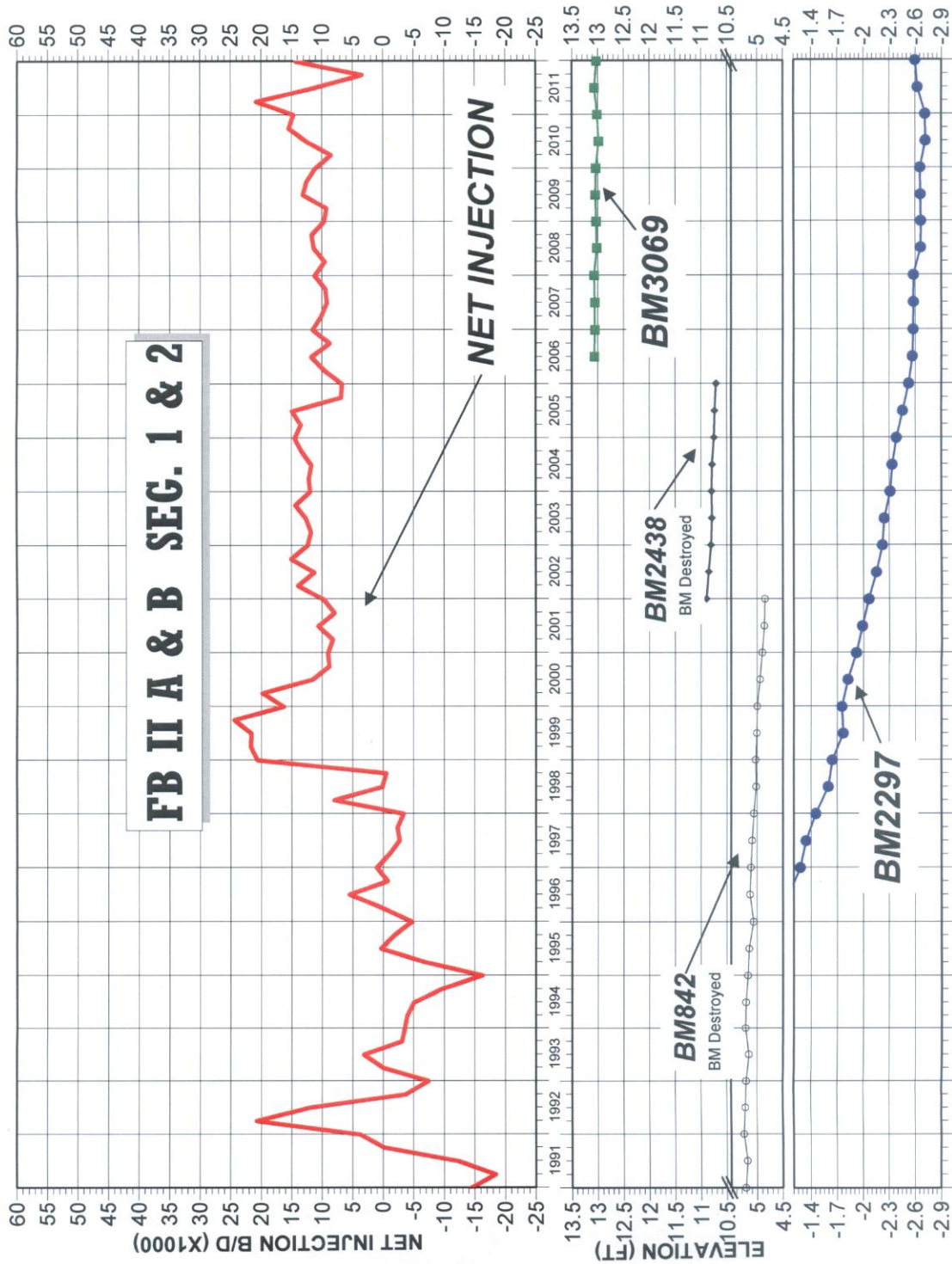


Figure 4

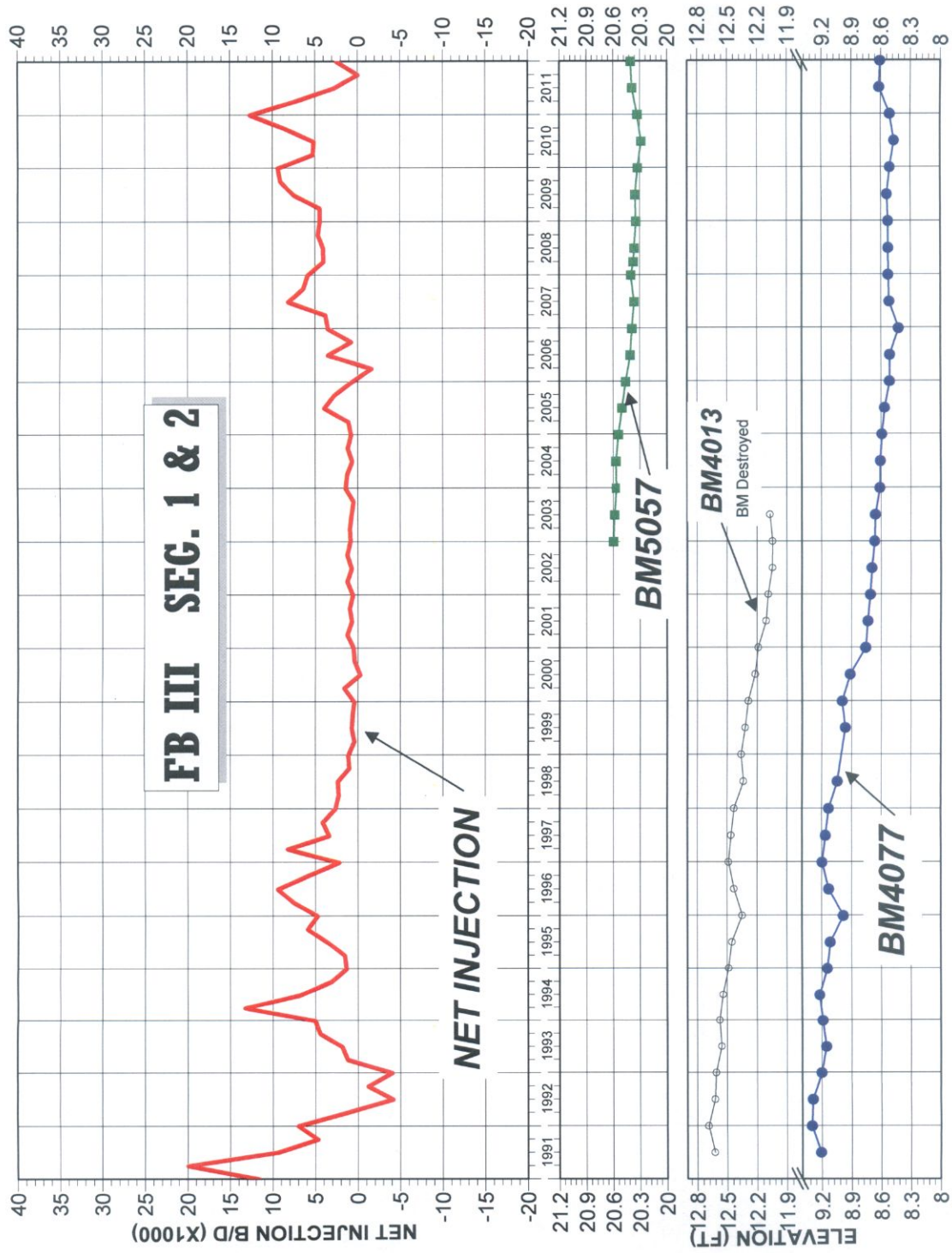


Figure 5

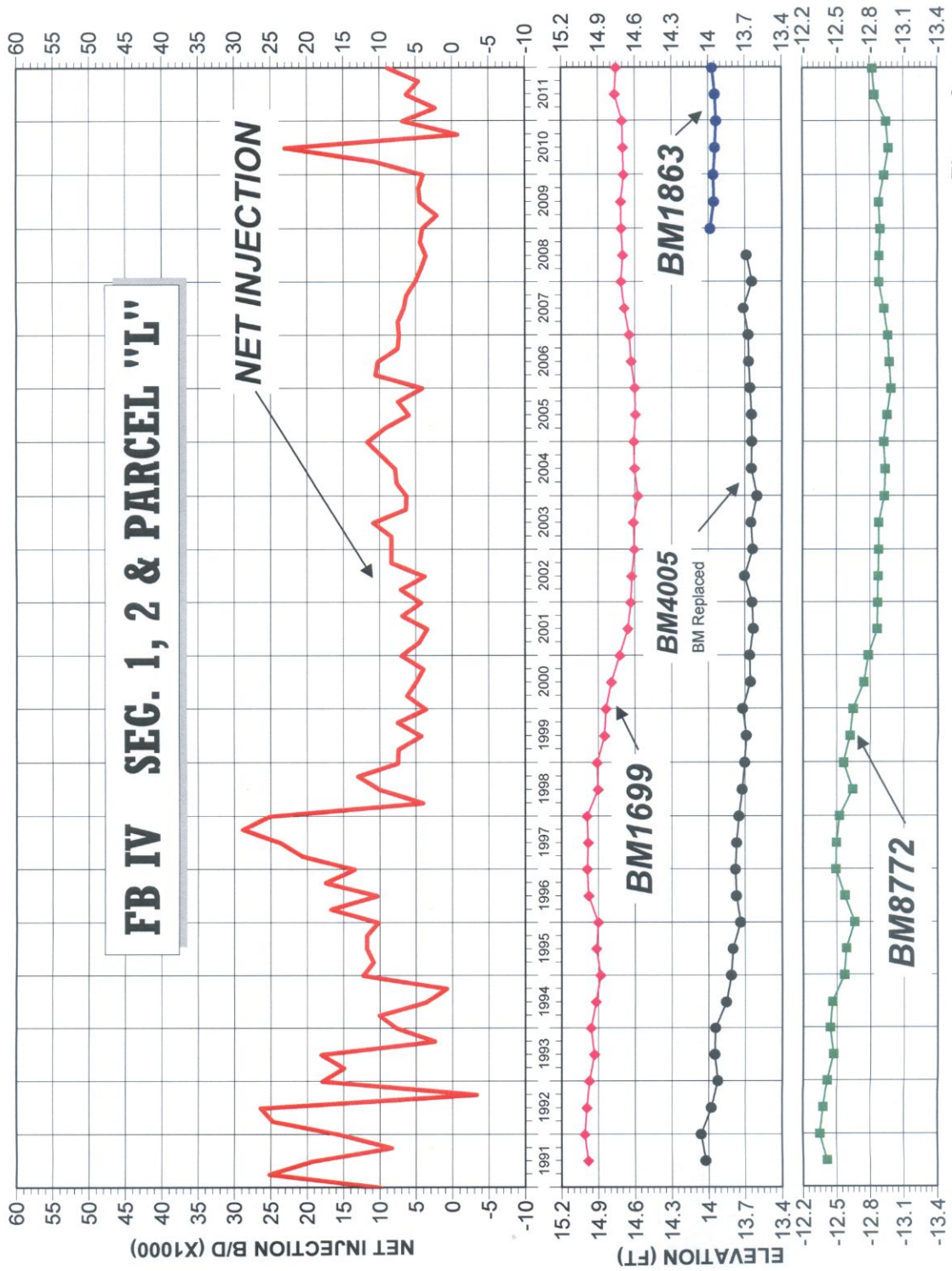


Figure 6

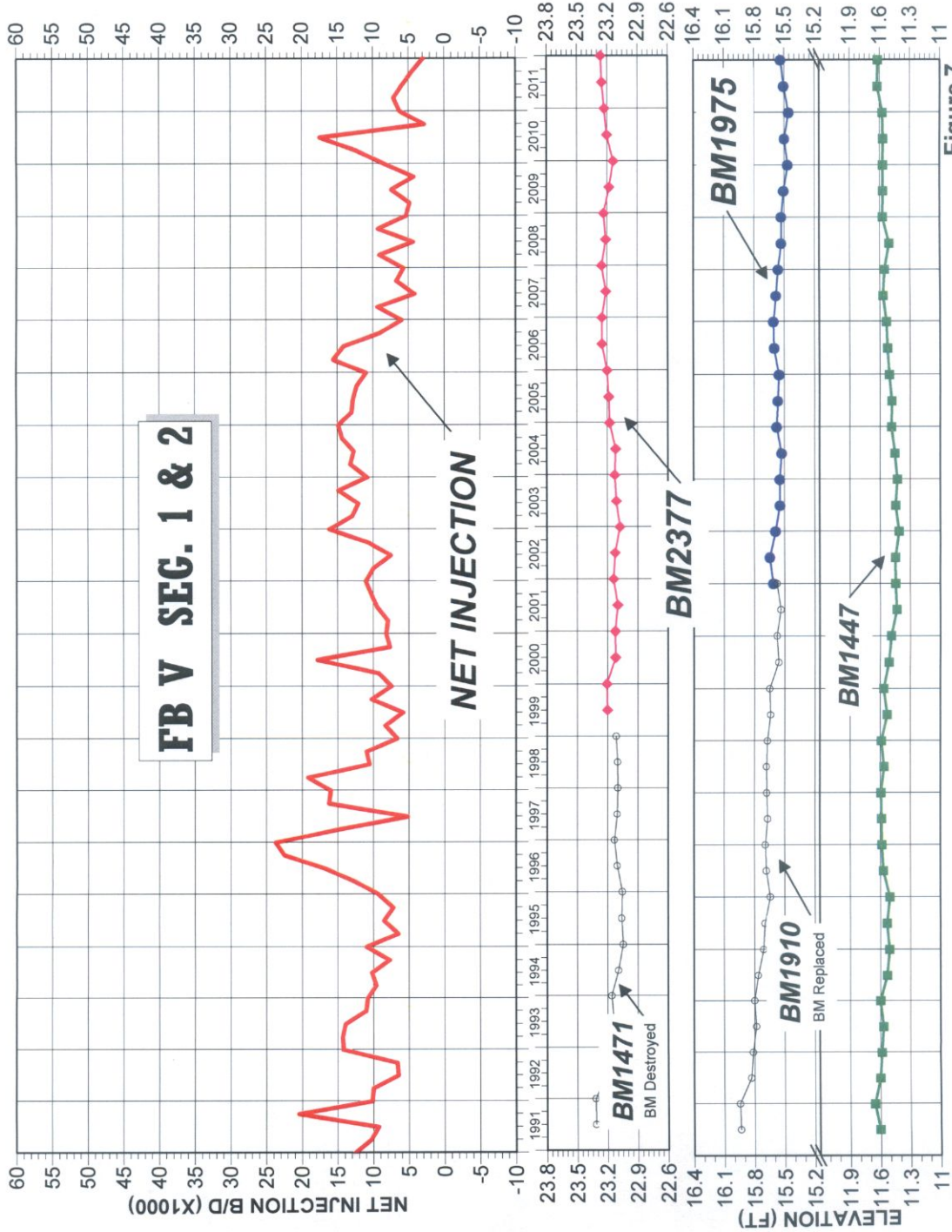


Figure 7

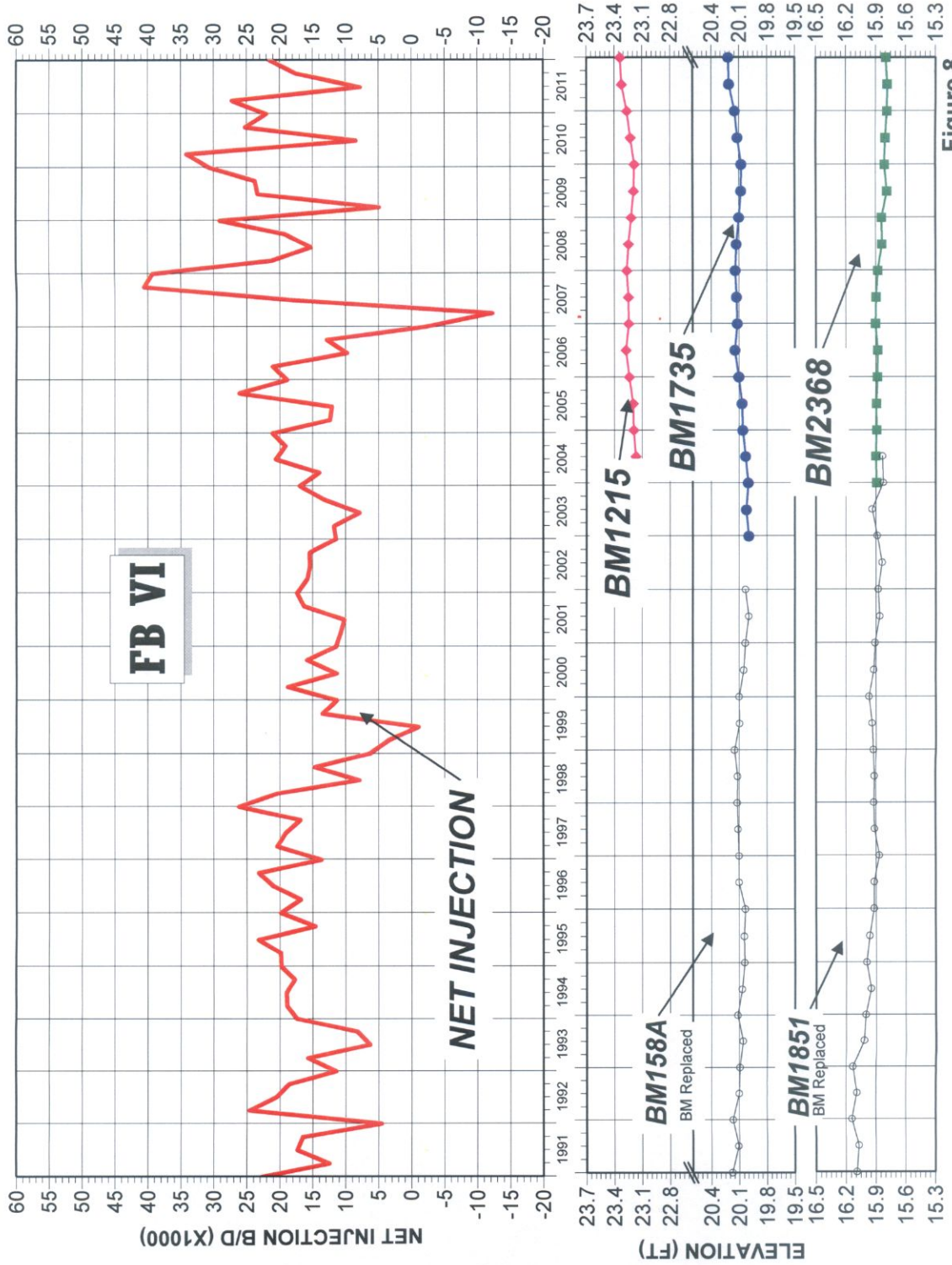


Figure 8

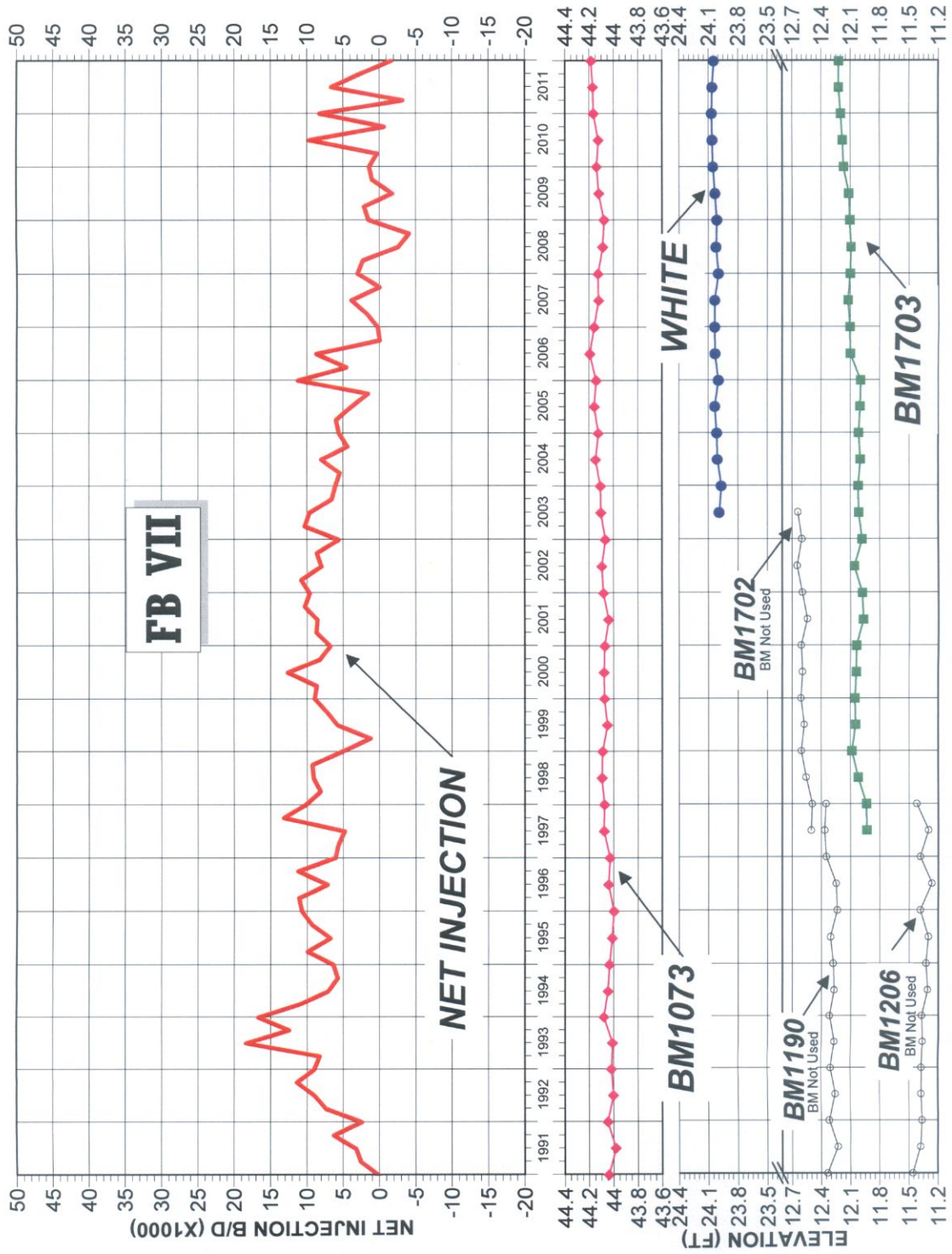


Figure 9

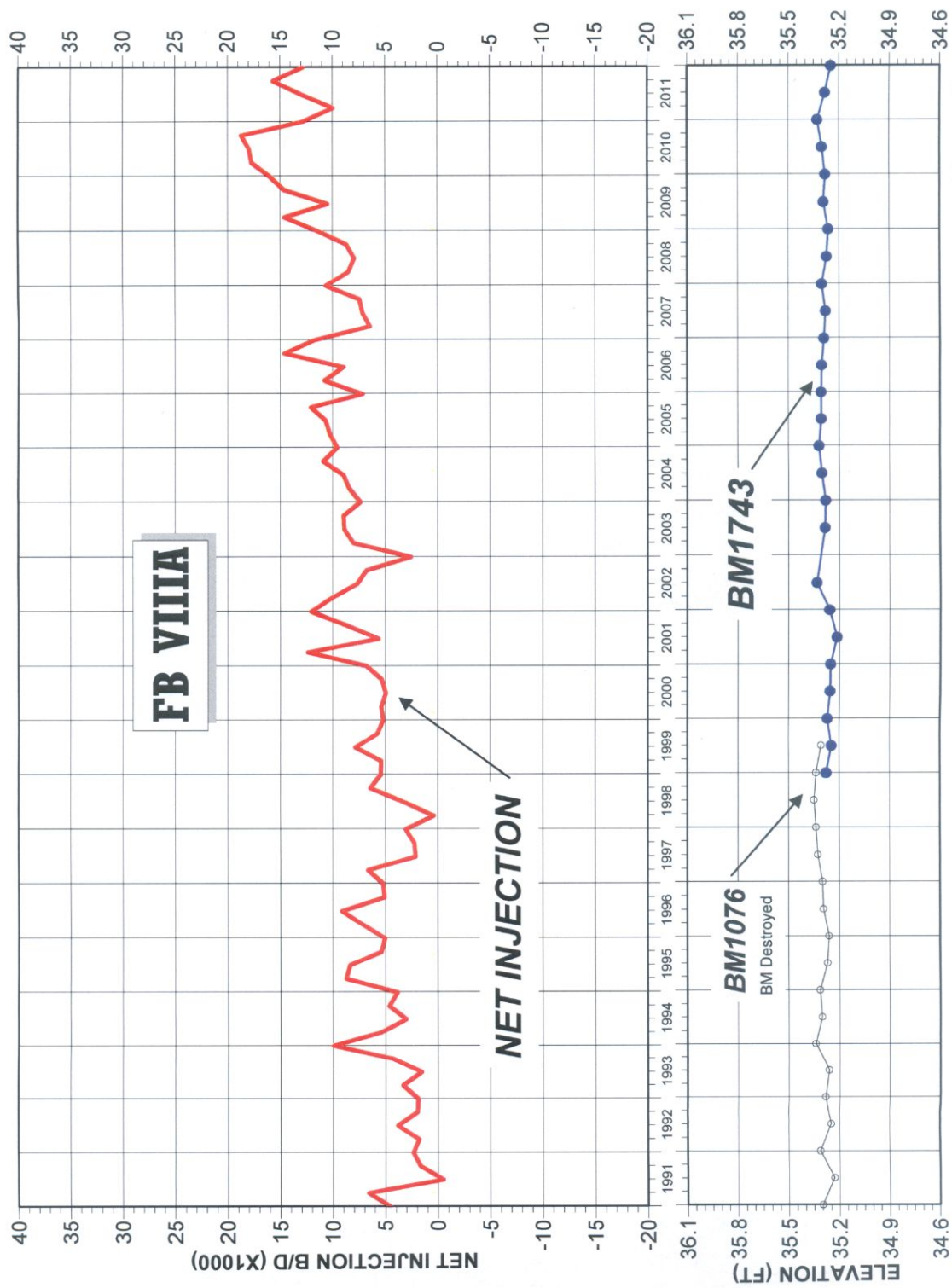


Figure 10

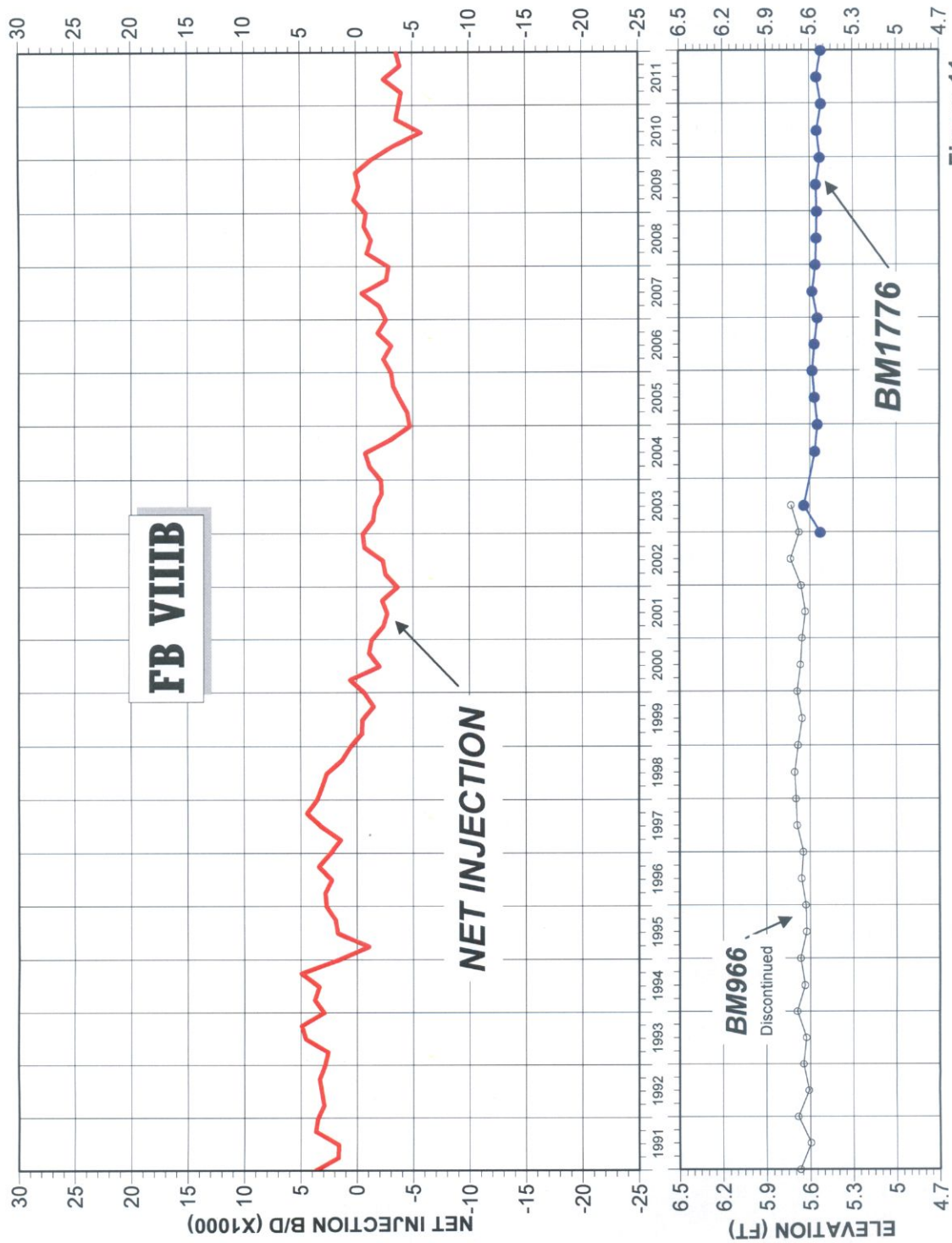


Figure 11

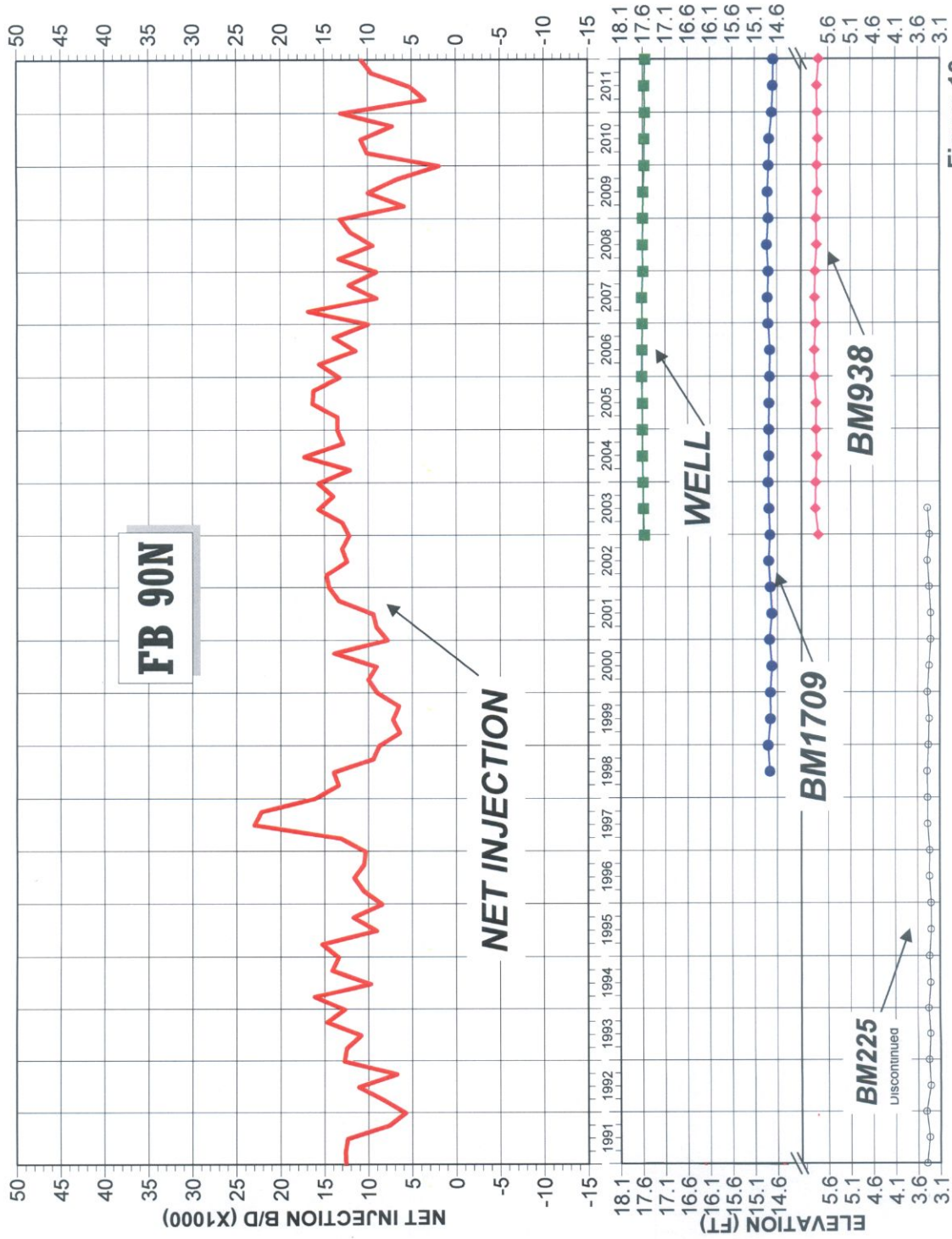


Figure 12

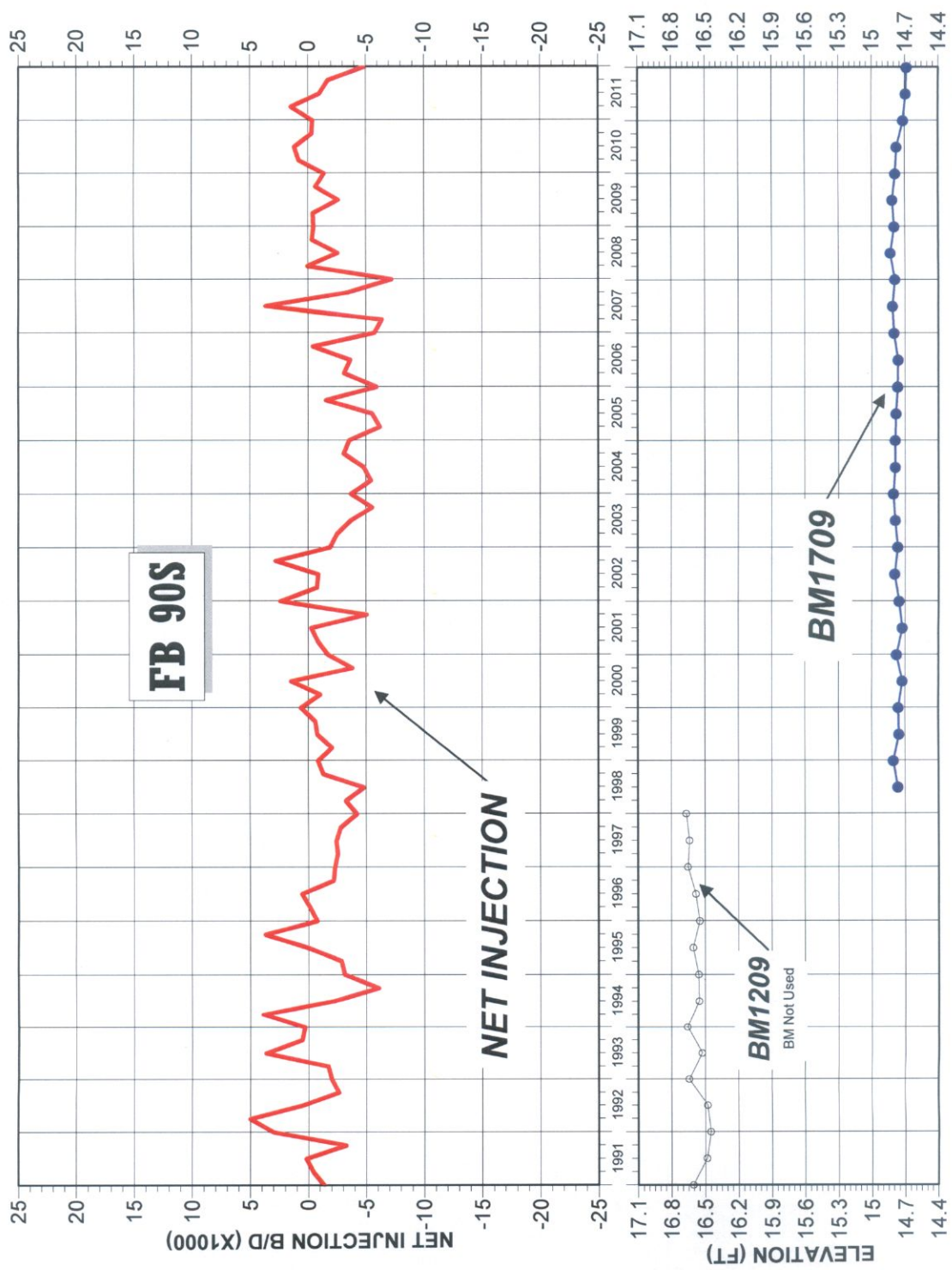


Figure 13