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DEPARTMENT

OIL OPERATIONS • OIL PRODUCTION / SUBSIDENCE

February 13, 2007

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 2006 to November 2006." (Citywide)

**DISCUSSION**

The City of Long Beach (City), 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 2006 to November 2006. The LBGO survey includes the following areas: Civic Center, Central City, Alamitos Bay, Naples, Harbor District, and an offshore area encompassing the four offshore oil islands.

The results of the six-month survey show that elevations were stable in the Civic Center, Central City, Alamitos Bay, Naples, and offshore areas. Harbor District elevations were stable except in two areas. An elevation gain of up to 0.072 feet (0.86 inches) was observed on Pier D and an elevation loss of up to 0.069 feet (0.83 inches) occurred on the northern edge of Pier S adjacent to the Cerritos Channel. There is no immediate reason for concern as these two areas had minor elevation changes due to ongoing waterflood adjustments corresponding to oil field development programs. Additionally, the area located below Pier A, which had shown persistent elevation losses in the past, has slowed significantly.

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. Repressuring operations will result in the rebound of the affected areas.

Surface elevations in a rebounded area can be expected to fluctuate under changing water flood conditions.

Principal Deputy City Attorney Charles Parkin reviewed this item on January 25, 2007.

TIMING CONSIDERATIONS

City Council action on this matter is not time critical.

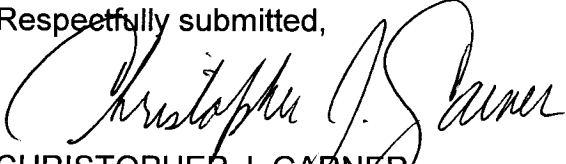
FISCAL IMPACT

There is no fiscal impact associated with this action.

SUGGESTED ACTION:

Approve recommendation.

Respectfully submitted,



CHRISTOPHER J. GARNER  
DIRECTOR OF LONG BEACH GAS AND OIL

CJG:jdj

Attachment

APPROVED:


GERALD R. MILLER  
CITY MANAGER

**ELEVATION CHANGES  
IN THE  
CITY OF LONG BEACH  
MAY 2006 TO NOVEMBER 2006**

**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, Alamitos Bay, Naples, and offshore areas was conducted during November 2006. Changes in elevation that have occurred since the last two surveys, May 2006 and November 2005 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 2006 to November 2006 (Figure 1)**

Elevations throughout the Civic Center, Central City, Alamitos Bay, and Naples areas were stable during the six-month period. Elevations in the City of Long Beach beyond the boundaries of the Wilmington Oil Field were also stable for the period. Minor elevation changes in geologically active areas outside the Wilmington Oil Field indicate that this six-month period was a slightly “down” period, semi-regionally.

The Harbor District elevations were stable except in two areas. An elevation gain of up to 0.072 feet (0.86 inches) was observed on Pier D and an elevation loss of up to 0.069 feet (0.83 inches) occurred on the northern edge of Pier S adjacent to the Cerritos Channel. There is no immediate reason for concern as these two areas had minor elevation changes due to ongoing waterflood adjustments corresponding to oil field development programs.

Over the curtailed Tar II streamflood on Pier A West and adjacent Henry Ford Avenue, elevation decline slowed significantly to within the 0.025-foot resolution of the GPS survey. The steamflood, initiated by Union Pacific Resources Company in the late 1980s, was terminated by Long Beach Gas and Oil Department (LBGO) in February 1999 because of negative surface elevation impact caused by extremely high oil reservoir temperatures heating and compacting shale layers between the reservoirs. LBGO

implemented increased water injection and production rates to hasten heat withdrawal and maintain reservoir pressure.

The Oil Islands in the offshore area were stable for the period.

**Elevation Change – November 2005 to November 2006** (Figure 2)

Elevations throughout the Civic Center, Central City, Alamitos Bay, and Naples areas remained stable during the 12-month period. Geologically active zones outside the oil-impacted areas indicate the one-year period to have been a “down” elevation period (see Appendix).

The Harbor District remained stable during the 12-month period except in the same two areas described in the previous section. Due to increasing water injection, an elevation gain of up to 0.141 feet (1.69 inches) occurred on Piers D, E, and H overlying Fault Blocks IV and V. Water injection is currently being adjusted.

Elevation losses continued through the 12-month period on Piers A, S, and T overlying Fault Blocks II and III. A one-year maximum elevation loss of 0.144 feet (1.73 inches) is attributed to both the continuing Tar II shale compaction caused by prior steamflood overheating, and the increased Fault Block III oil production that is coupled with loss of rebound. Water injection is currently being increased and realigned in the oil reservoirs of concern.

All four of the Oil Islands were stable for this year.

### **Use of Global Positioning System (GPS)**

LBGO operates the Long Beach Deformation Network (LBDN) consisting of thirteen (13) permanent, reference GPS base stations. This report is based solely upon computer processed LBDN bench mark elevation data generated from GPS satellites. GPS elevation measurements have been demonstrated to be reliable and can be more accurate than the spirit leveling which it replaced. The field data collection time has been reduced by more than 65 percent and the 800 spirit leveled bench marks have been reduced to approximately 240 GPS bench marks.

(Reference: Appendix, Survey Accuracy, pg. 5)

## **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 feet (-0.43 inches) per year until about 1939. Geologic movement such as the Long Beach Earthquake of March 1933 altered this average rate at times. The reason for this slight regional subsidence or slight elevation loss is not fully understood. Contributing causes appear to be groundwater withdrawal from aquifers in the Long Beach area, regional basin sediment compaction, and tectonic effects.

Development of the Wilmington Oil Field began in 1936. 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 5). 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. Some bench marks have actually recovered over one foot in elevation. This is known as rebound. As an example, from 1960 to 1970, Bench Mark No. 1735 near the corner of Ocean Boulevard and Magnolia Avenue recovered approximately one foot of elevation.

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 will be a long term project.



The Alamitos 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 affects of basin sediment compaction and tectonic movements along the Newport-Inglewood Fault Zone. Later, the coastal strip from the Civic Center eastward to the Alamitos 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 measurement of City and Harbor bench mark elevations. Through the GPS contractor, Condor Earth Technologies, Inc. (Condor), a network of thirteen permanent real-time GPS base stations and a central data collection and processing center were installed within the City of Long Beach. Several existing non-City operated stations were integrated into the new network. The Public Works Department's Bureau of Engineering surveyors utilize mobile GPS equipment linked to the base stations to measure approximately 240 City and Harbor bench marks, down from the previous 800 bench marks.

Through statistical analysis of satellite, base station, and mobile instrument geometries, and a coincident spirit leveling and GPS bench mark elevation survey, City surveyors and Condor estimate the accuracy of GPS elevations to be 6 - 8 millimeters (0.02 feet or 0.24 inches) that is equal to or better than the prior spirit leveling. Areas are considered to be stable where elevation change is less than 0.02 feet (0.24 inches).

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 (Figure 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 feet (0.60 inches) on an Elevation Change Map gained an elevation of one-twentieth of a foot or six-tenths of an inch during that period. The small hachures along contour lines point towards a loss in elevation.

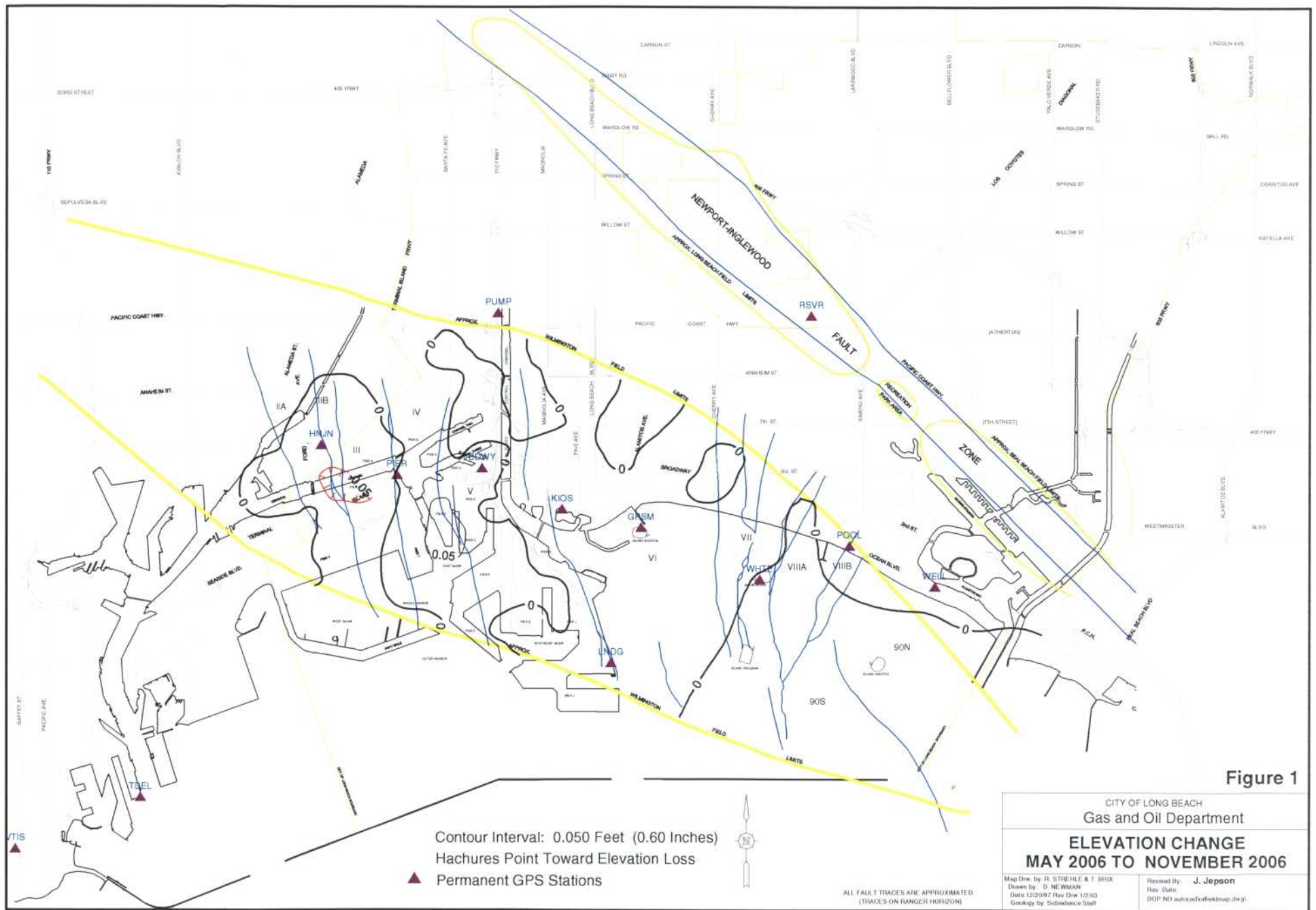
### **Bench Mark and Net Injection Graphs, Harbor District (Figures 3 - 8)**

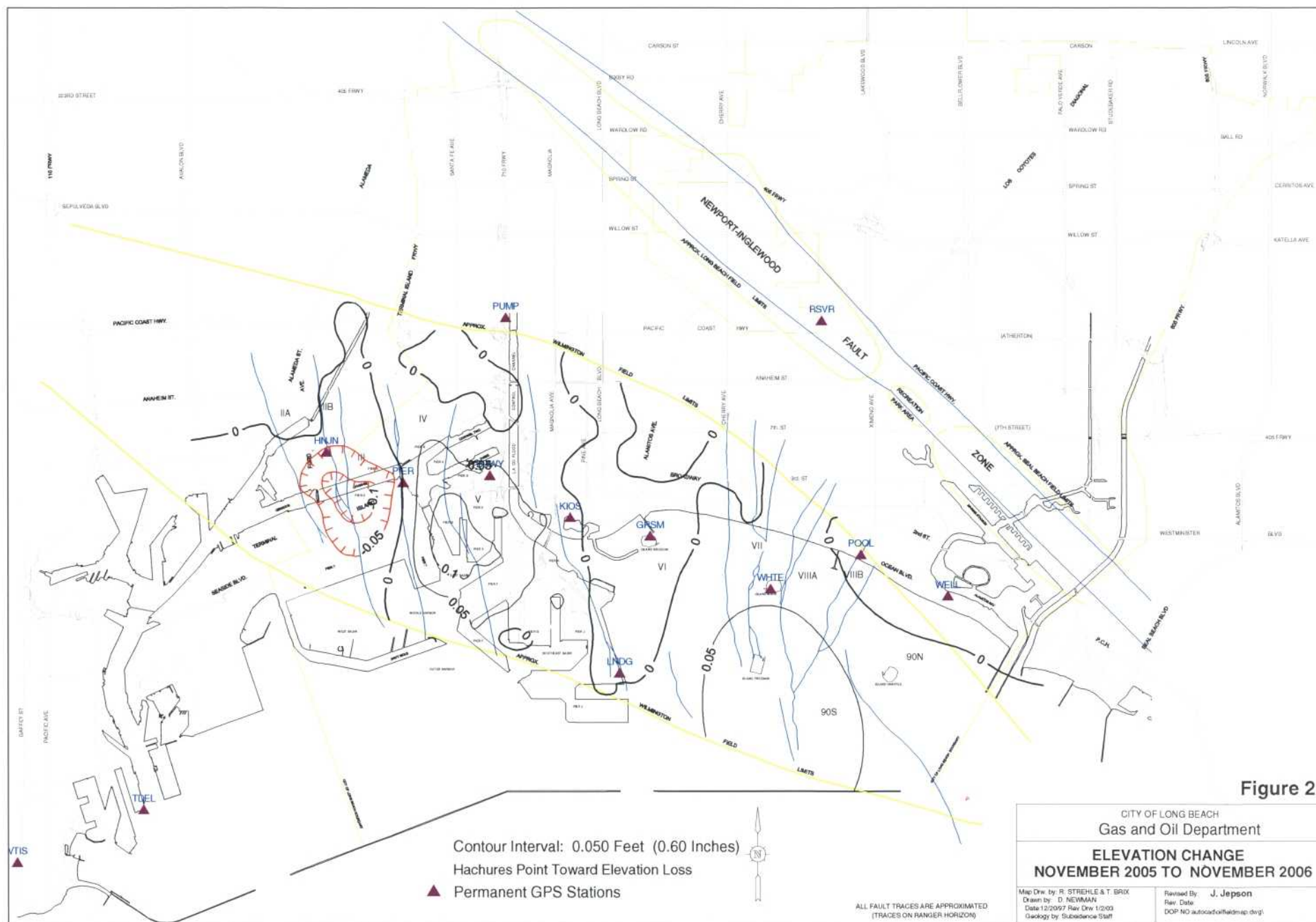
The benchmarks are normalized to mean sea level. Bench marks are plotted each time they are surveyed and are shown on a graph with a history of net injection for that same area and time. The net injection is the amount of water injected into the reservoirs that underlie that particular bench mark minus the gross fluid produced from the reservoirs in barrels per day. The graphs only cover the last 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 benchmarks on Figures 3 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 9 – 13)**

The last 20 years of elevation changes and accompanying net injection histories are shown on Figures 7 through 12 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 7. Bench Mark 225 on Figure 11 shows surface elevation changes on the Alamitos Bay Peninsula. Bench Mark 938 monitors elevation changes on Naples Island.

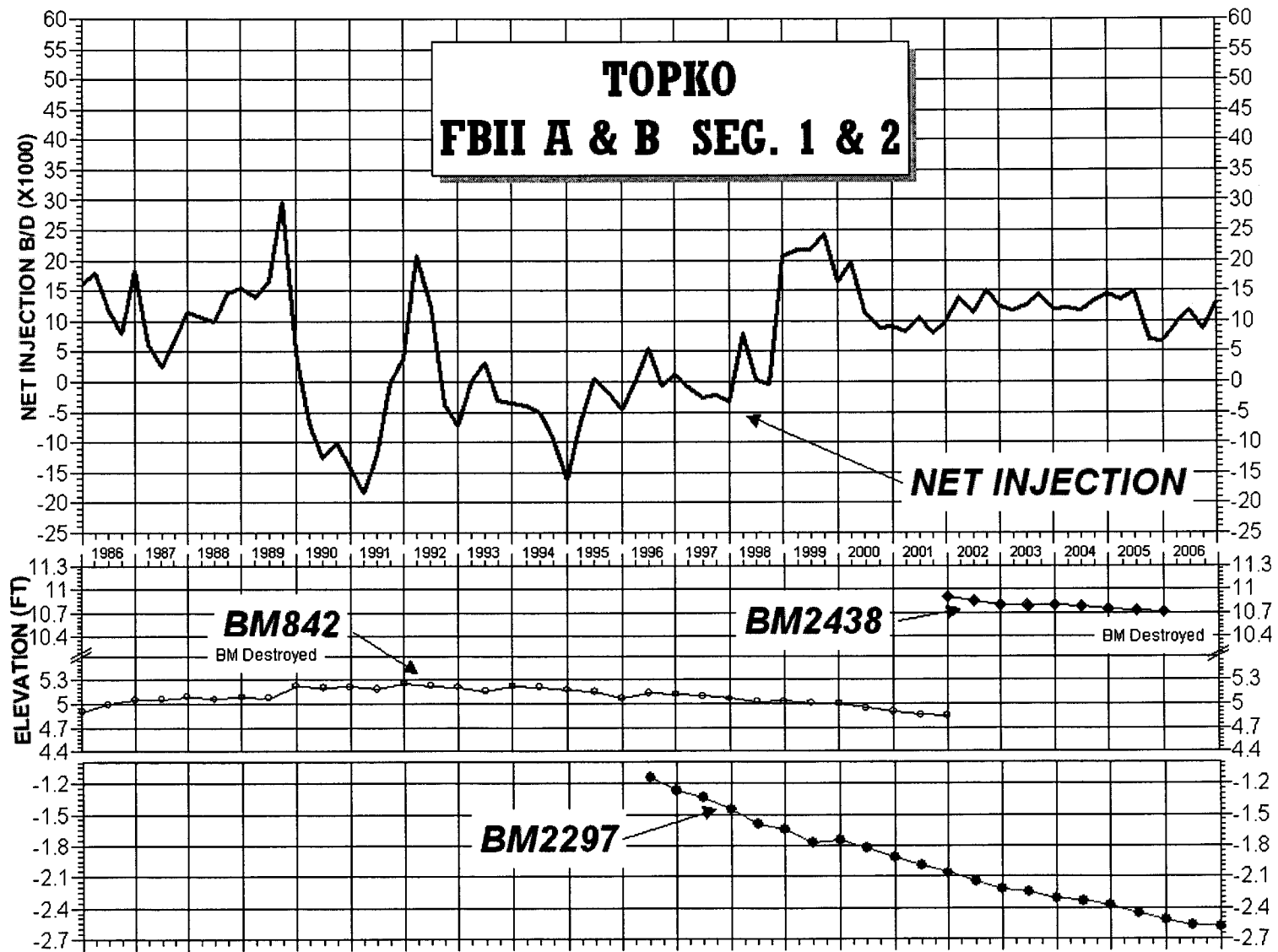




**Figure 2**

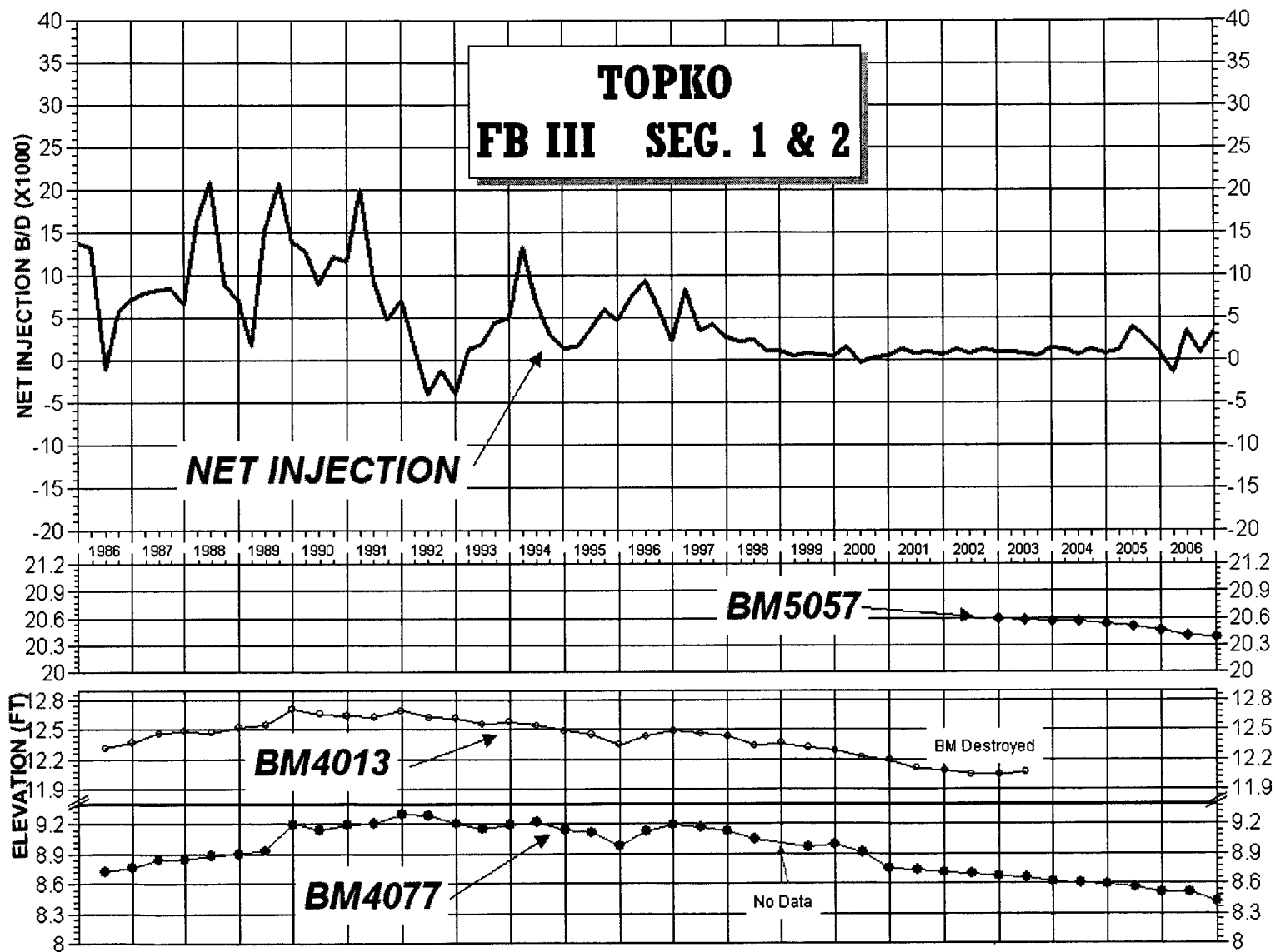




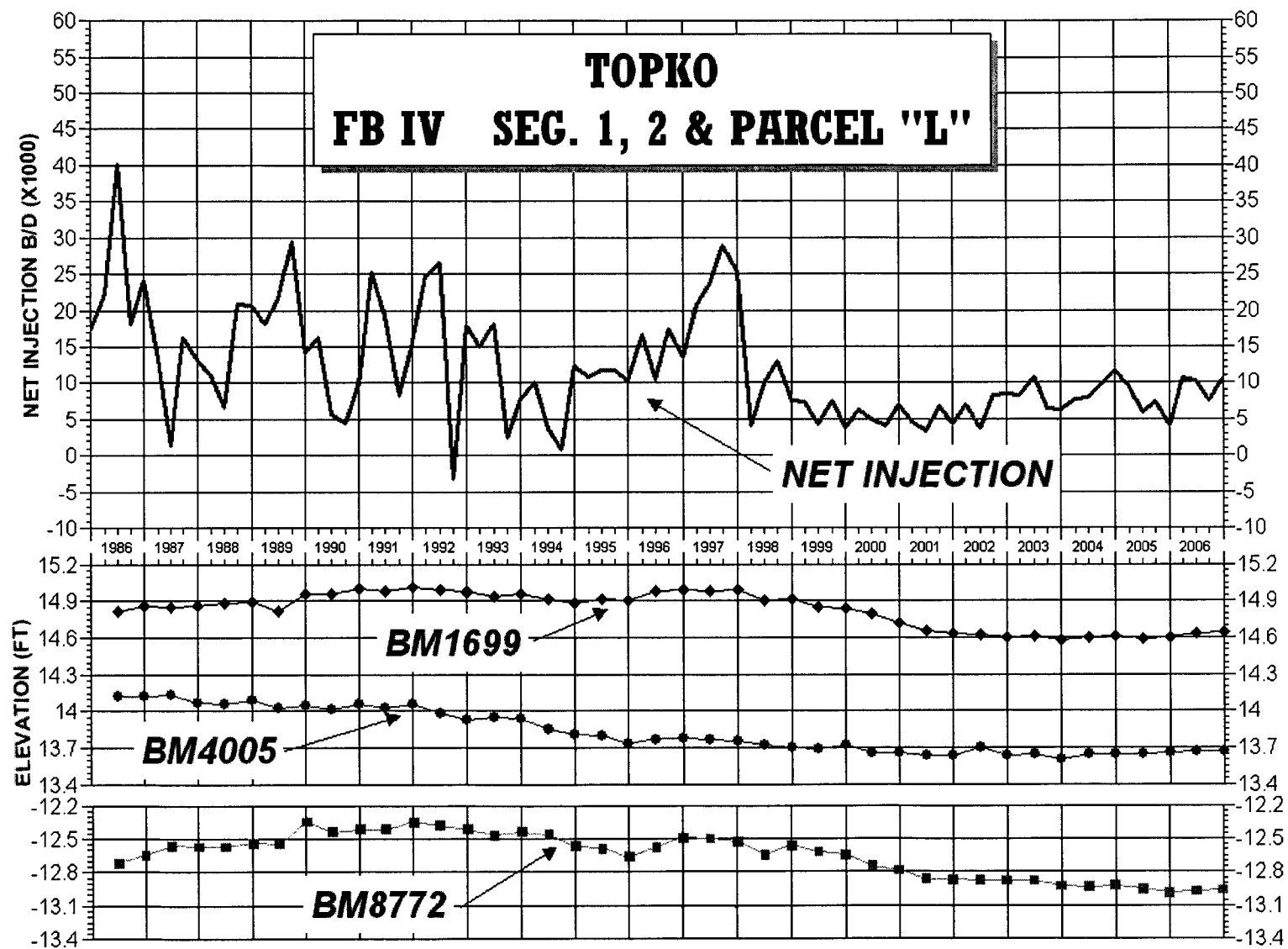


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Figure 4







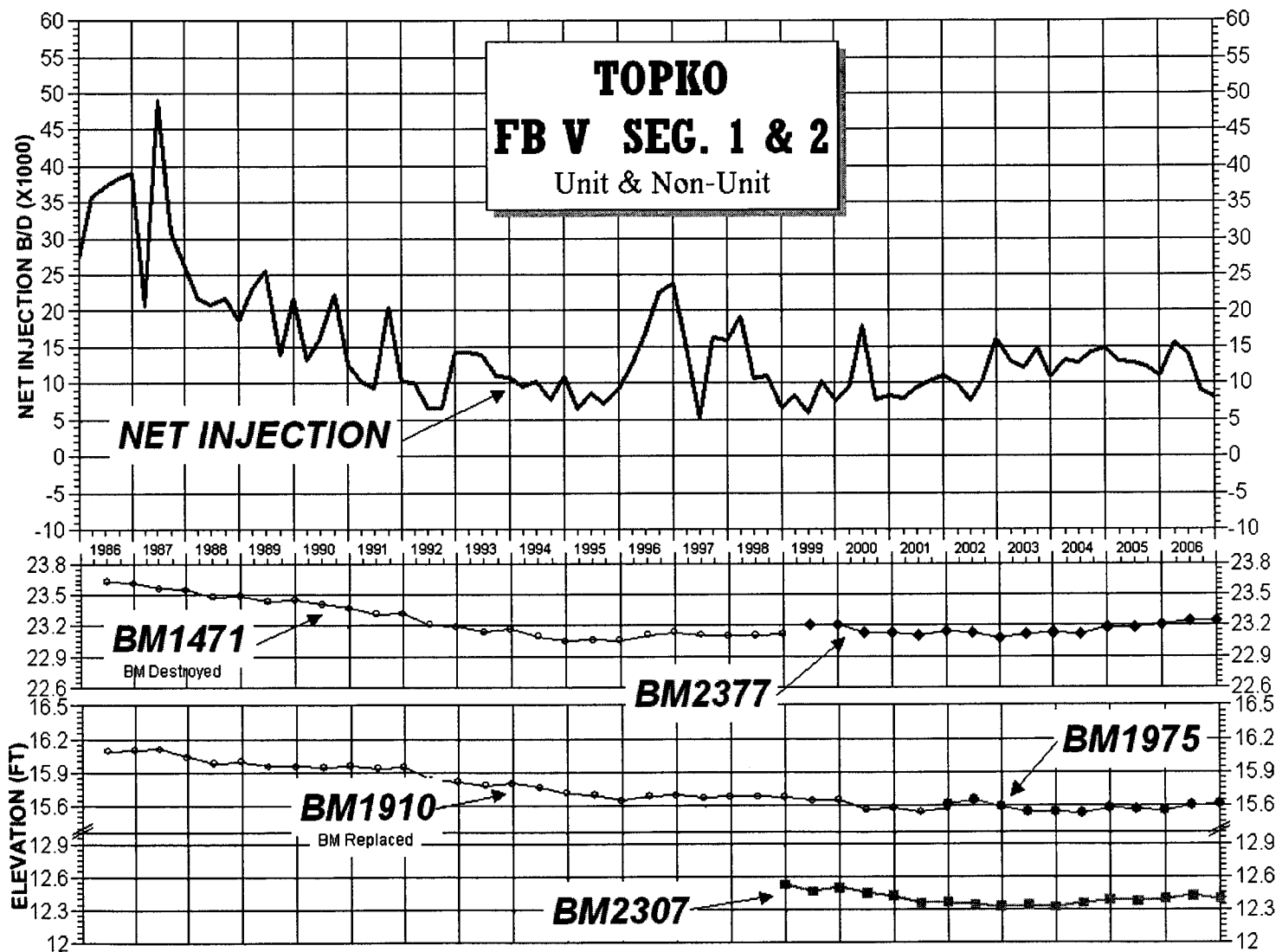


Figure 7

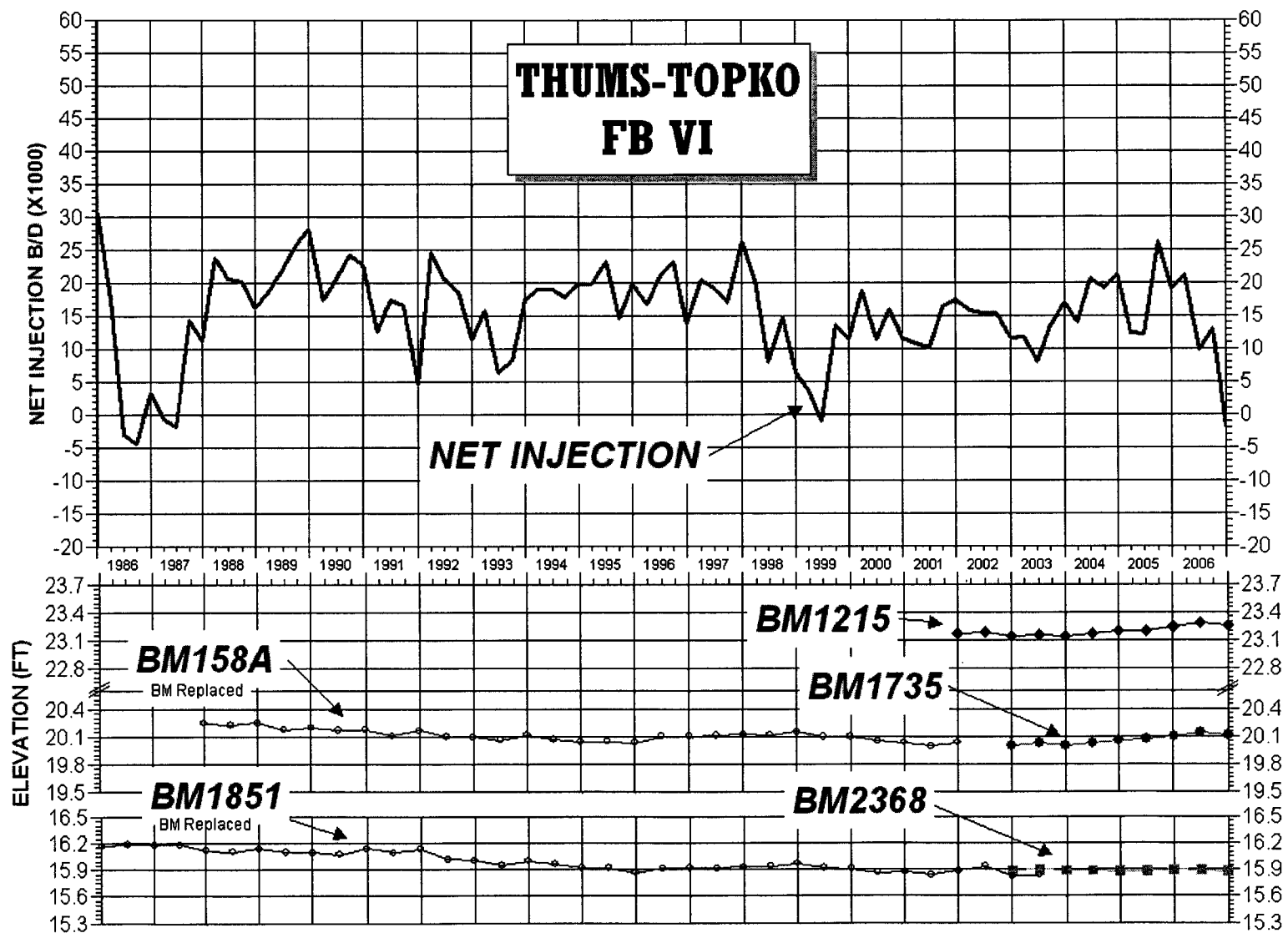
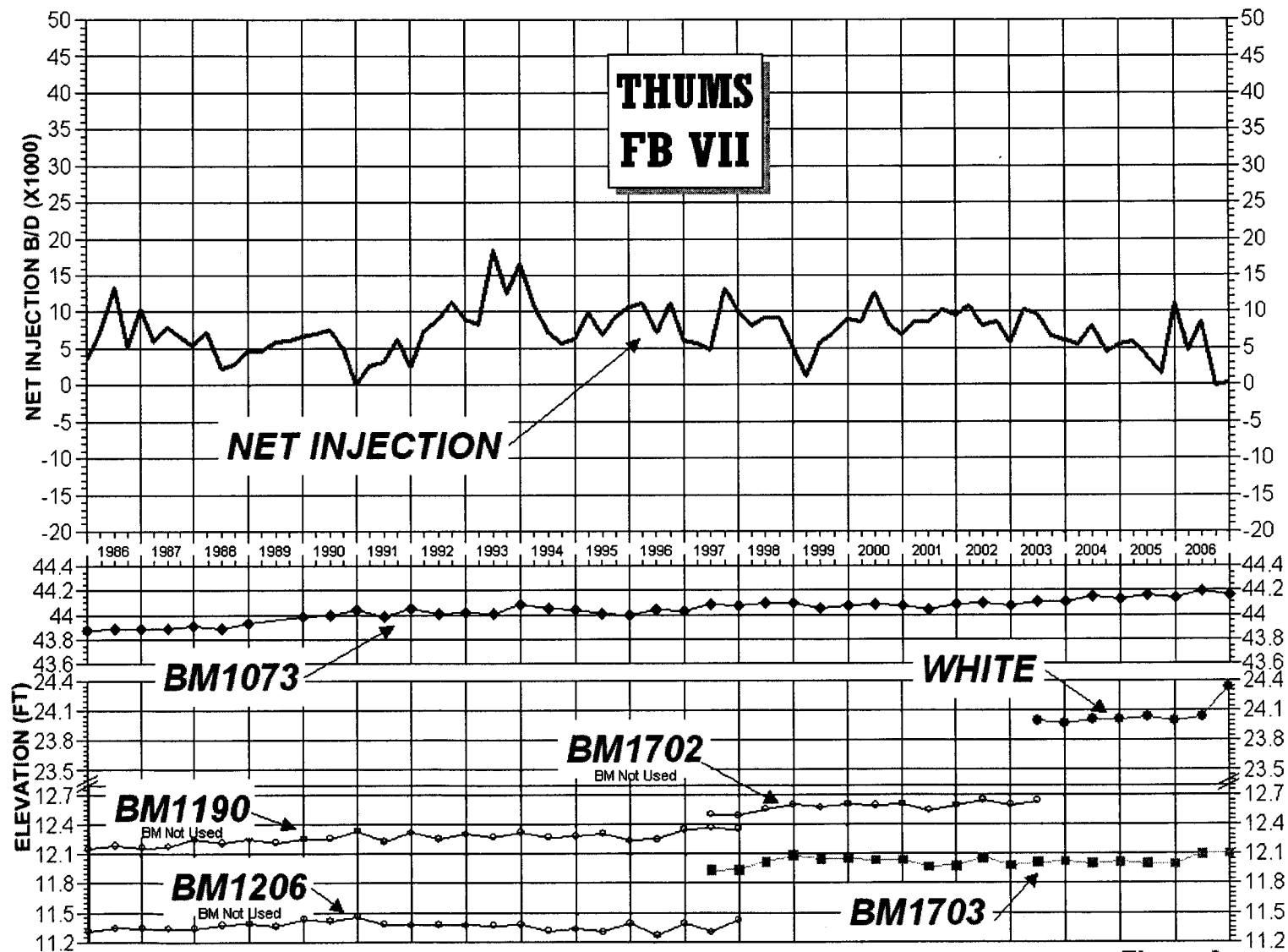
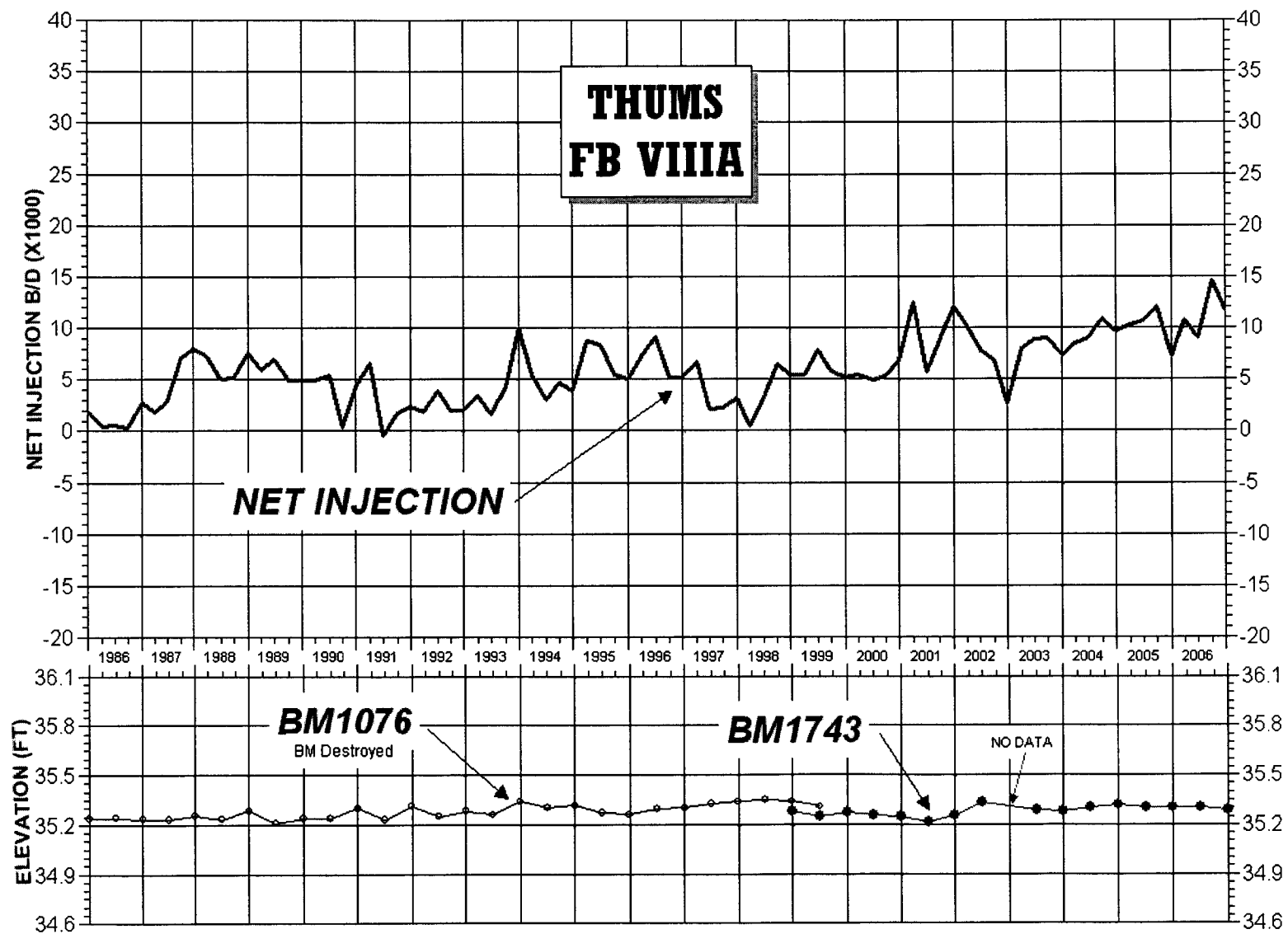


Figure 8



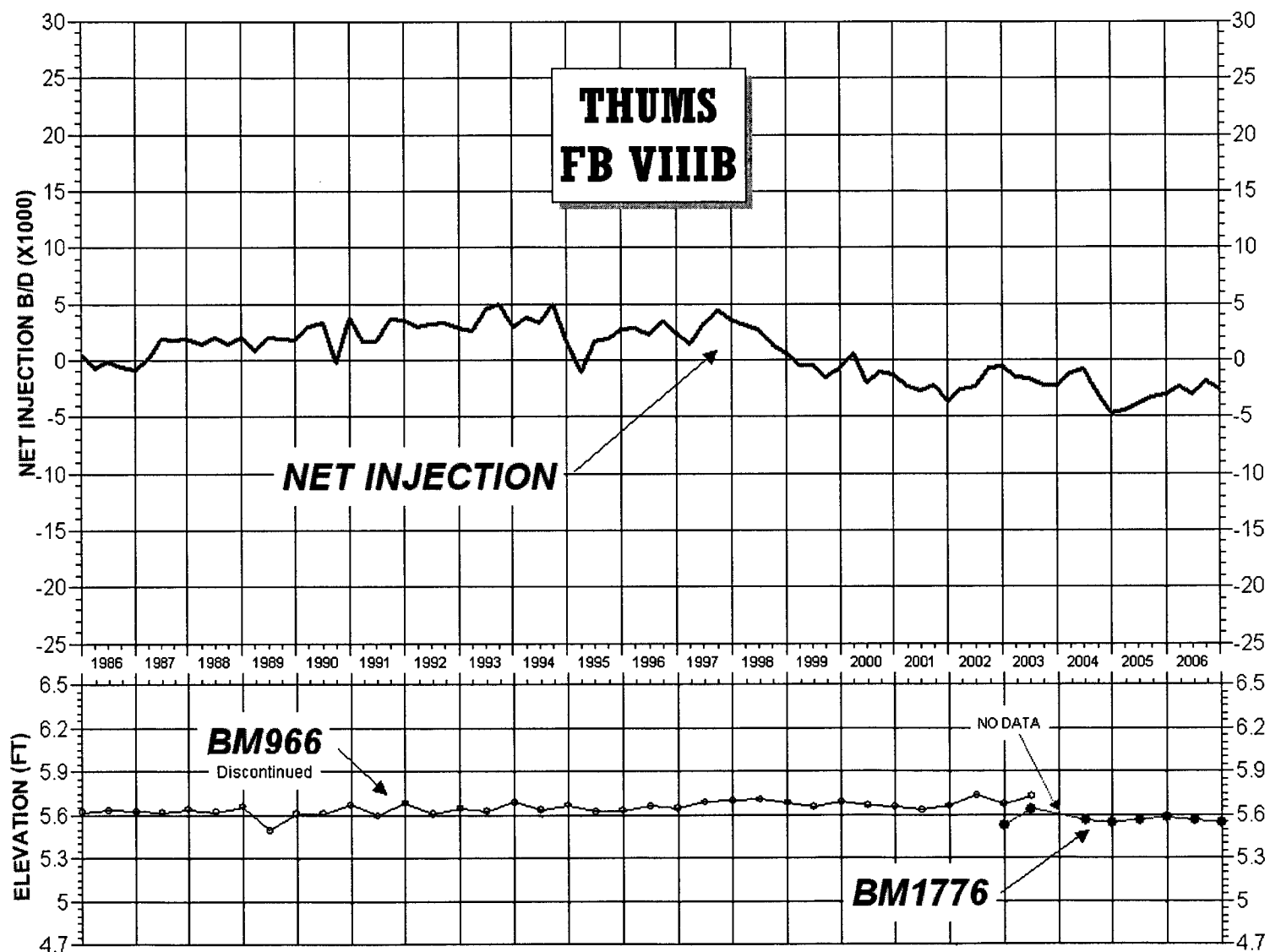
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**Figure 9**



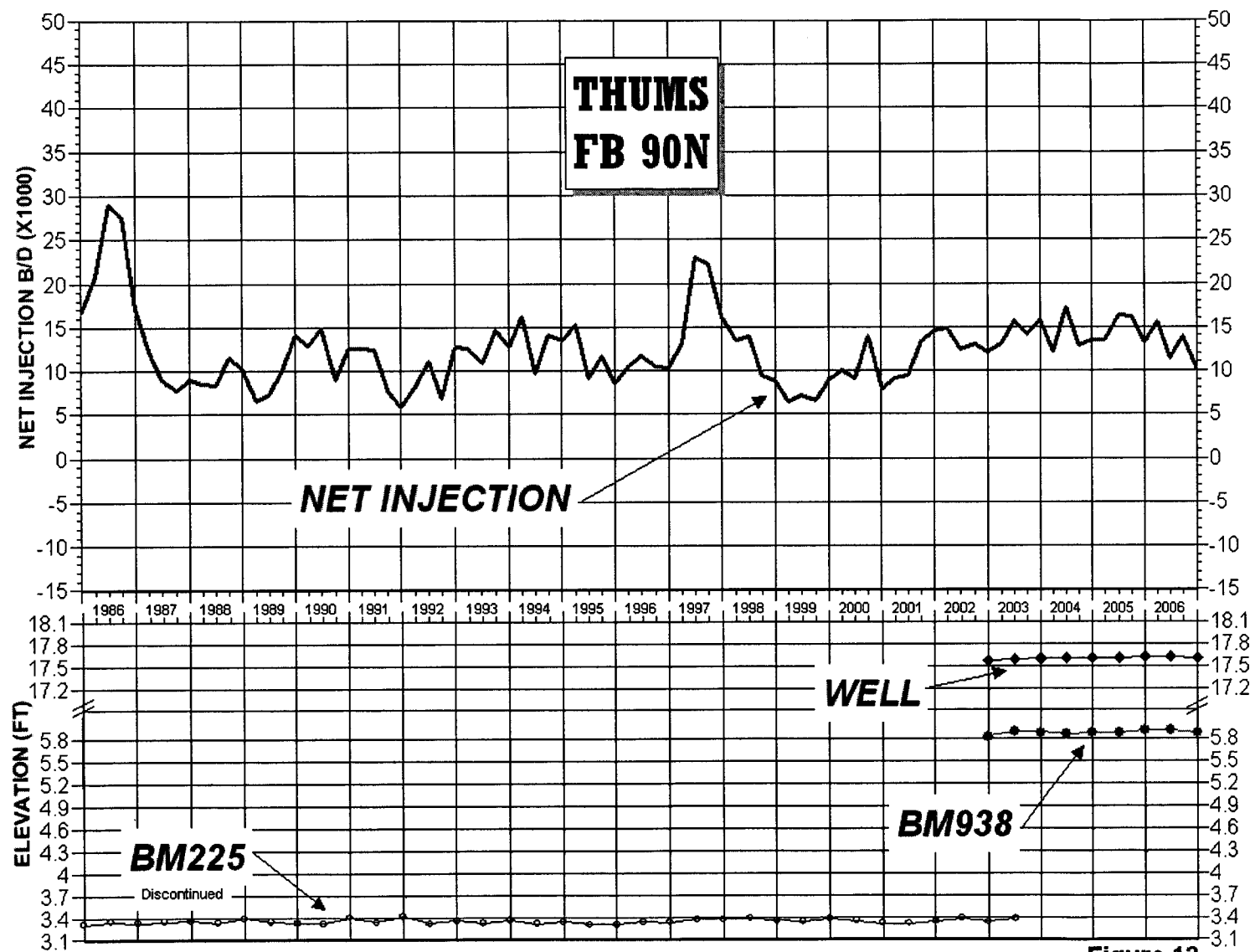
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**Figure 10**



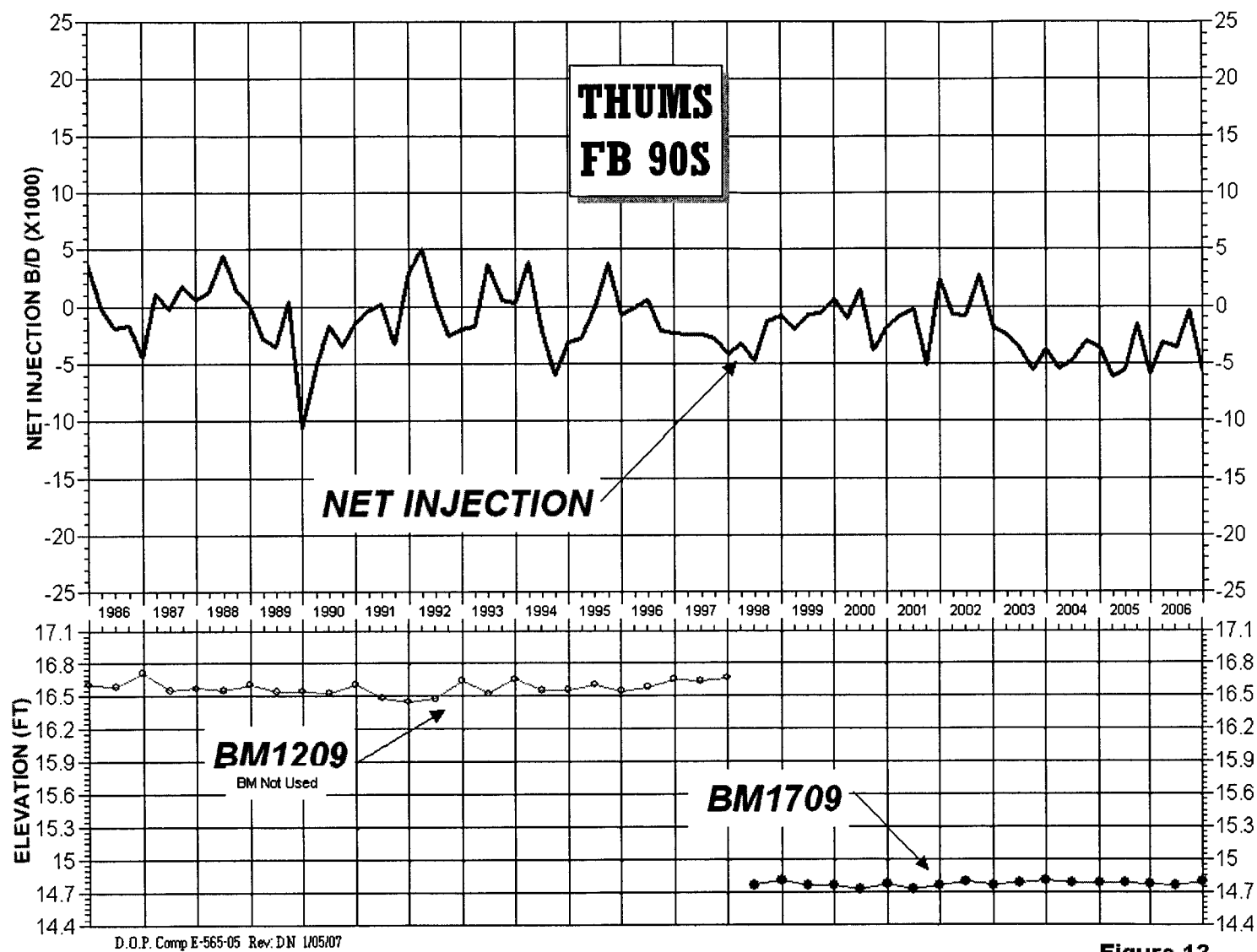
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**Figure 11**



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Figure 12



**Figure 13**