# Pilot Scale $CO_2$-EOR Project in the Mississippian: Decline Curve Analysis and Costs Associated with Mississippian Pilot $CO_2$ Flood

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## Introduction

For the pilot-scale $CO_2$-Enhanced Oil Recovery (EOR) project, a total of 21,783.71 U.S. tons, equivalent to 19,803.35 metric tons or 374,462.05 MCF, of $CO_2$ was injected into KGS well 2-32 in the Mississippian reservoir from January 2016 through June 2016. The injector well is shown in fig. 1. The $CO_2$ injection was followed by water injection after the end of $CO_2$ injection for a better sweep efficiency. The $CO_2$ flood did not result in an increase in oil production until February 1, 2016. Figure 2 depicts this effect and the increased oil production as a result of $CO_2$ flood in the East Nelson tank battery. Figure 3 shows the volume of injected water and $CO_2$ from January 2016 through September 2017. Waterflood data and tubing pressures are not available after September 2017.

## Decline Curve Analysis

Production rates versus time for individual wells were not available. However, monthly production rates for four tank batteries were available, so decline curve analyses were performed on tank batteries. Three tank batteries (West Nelson, Peasel, and Erker) have not shown an increase in oil production either during or after $CO_2$ flood (figs. 4, 5, and 6). Moreover, there is no $CO_2$ flood effect on the production of the wells connected to these tank batteries. Only the East Nelson tank battery has shown an increase in oil production as a result of $CO_2$ flood. Wells that are connected to the East Nelson tank battery are shown in purple circles in figs. 7 and 8.

A decline curve analysis and production forecast was performed on production rates for the East Nelson tank battery (fig. 2). Production rates have been updated for the East Nelson tank battery to August 2018 in Fekete Associates IHS Harmony. Decline curves were modified after updating the production rates. Decline curve by means of waterflood was modified to capture all data points except for the two lowest production rates (277 bbl/month and 243 bbl/month). The slope by waterflood is changed slightly from the last report and the slope by $CO_2$ flood is also changed after adding the new rates. The analysis shows a decline rate of 6.28% per year for the waterflood curve and continuation of production to January 2025 when the economic limit of 200 bbl/month is reached. The decline rate for the $CO_2$ plus waterflood curve is 18.93% per year with continuation of production to October 2024.

IHS Harmony calculated the cumulative oil production for each curve in table 1 from the start of forecast to the end of forecast. The difference between the two cumulative oil productions is the cumulative additional oil attributed only to the effect of $CO_2$ flood (the area between the two curves) (fig. 2). The area between the curves is 53.70 – 29.27 = **24.43 Mstb,** which is the cumulative additional oil production attributed only to $CO_2$ flood. Cumulative oil production attributed to $CO_2$ plus waterflood from the start of $CO_2$ response to October 2024 is **53.70Mstb** (table 1). Early production history is subject to change. Therefore, the next month's history may change the slope.

374,462 MCF of $CO_2$ was injected in the Mississippian reservoir. Therefore, the utilization efficiency would be 374,462 ÷ 24,430 bbl oil = 15.33 MCF/bbl. If ~62,385 MCF of vented $CO_2$ is considered, efficiency would be 12.78 MCF/bbl, excluding the vented $CO_2$. This efficiency is not bad for a pilot-scale $CO_2$ injection. The SACROC in the Permian Basin had an efficiency of 3.2 MCF/bbl for a full-scale $CO_2$ flood retrieved from http://petrowiki.org/CO2_miscible_flooding_case_studies.

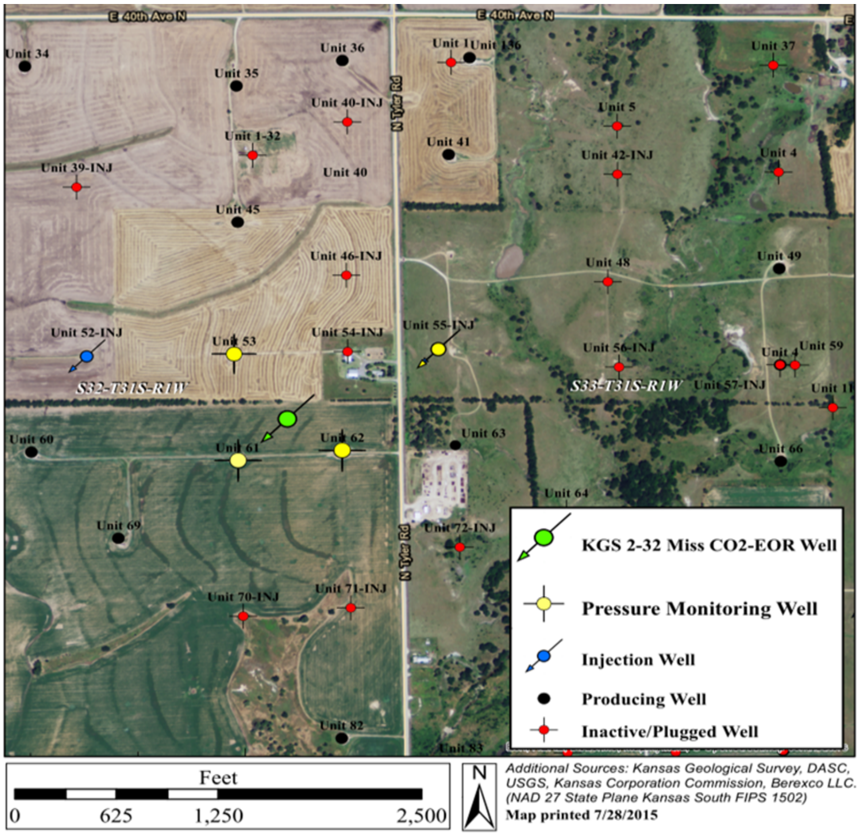


**Figure 1: Injector well (KGS 2-32) and producing wells in the study area.**

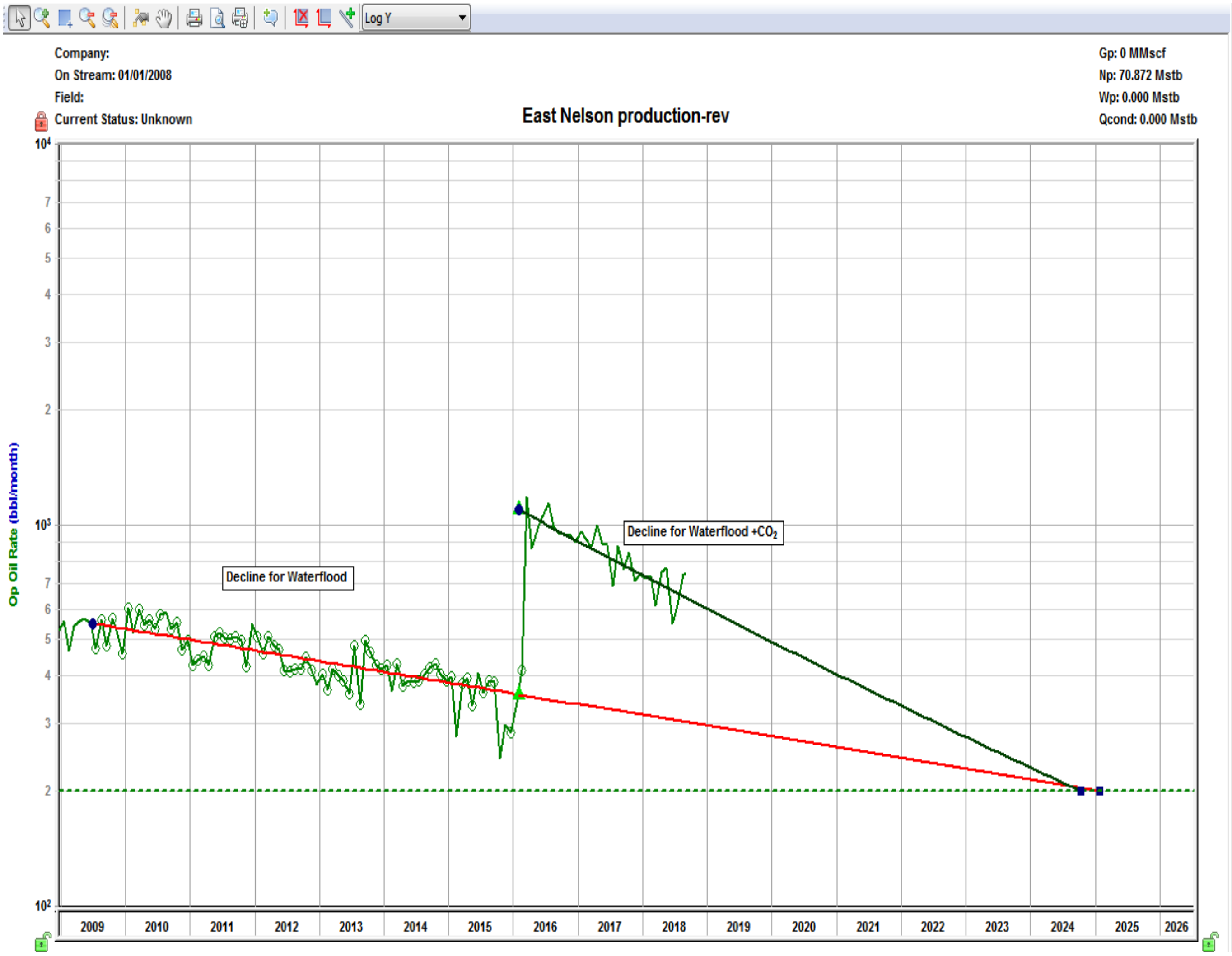


**Figure 2: Decline curve forecast for $CO_2$ plus waterflood and waterflood in the East Nelson tank battery production area at the study site.**

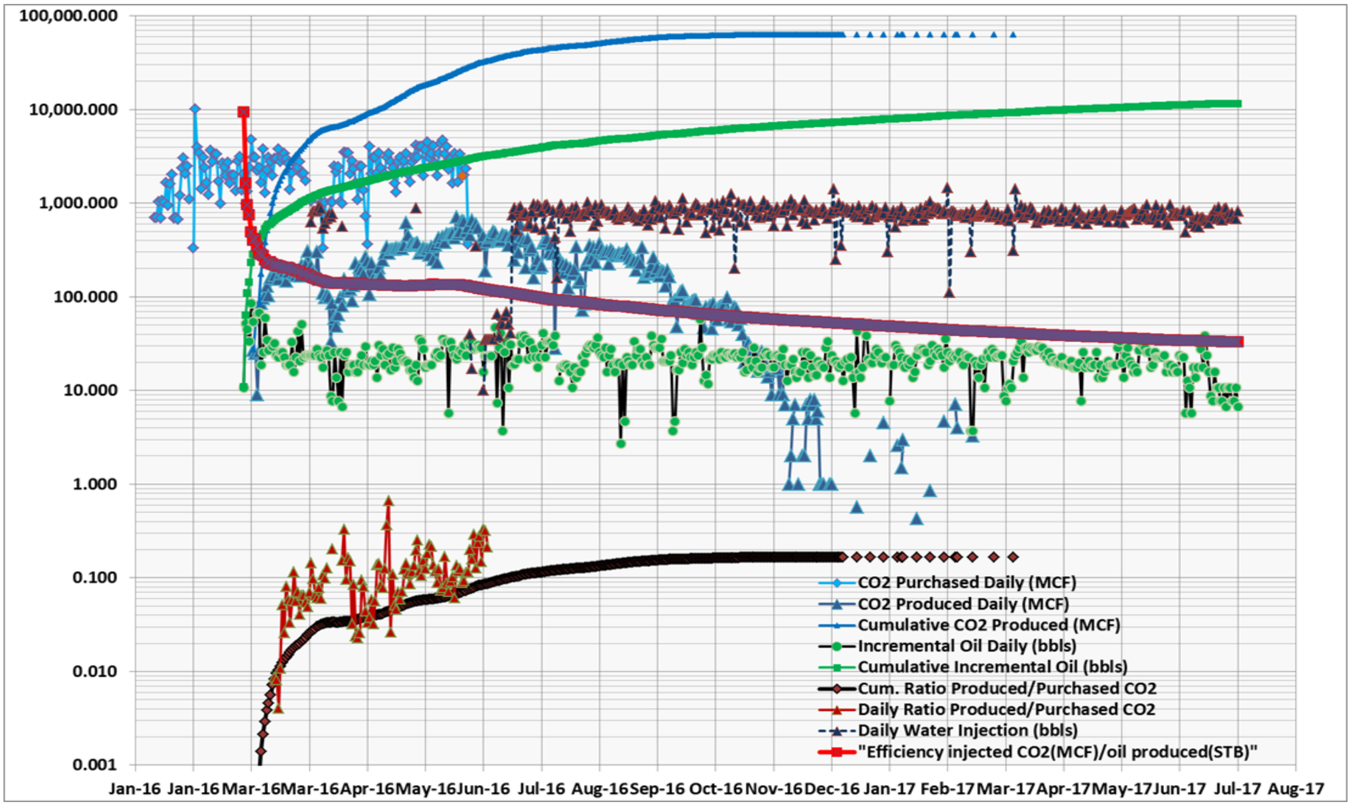


**Figure 3: The volume of injected $CO_2$ and water, efficiency (MCF/bbl), and vented $CO_2$ from January 2016 to August 2017.**

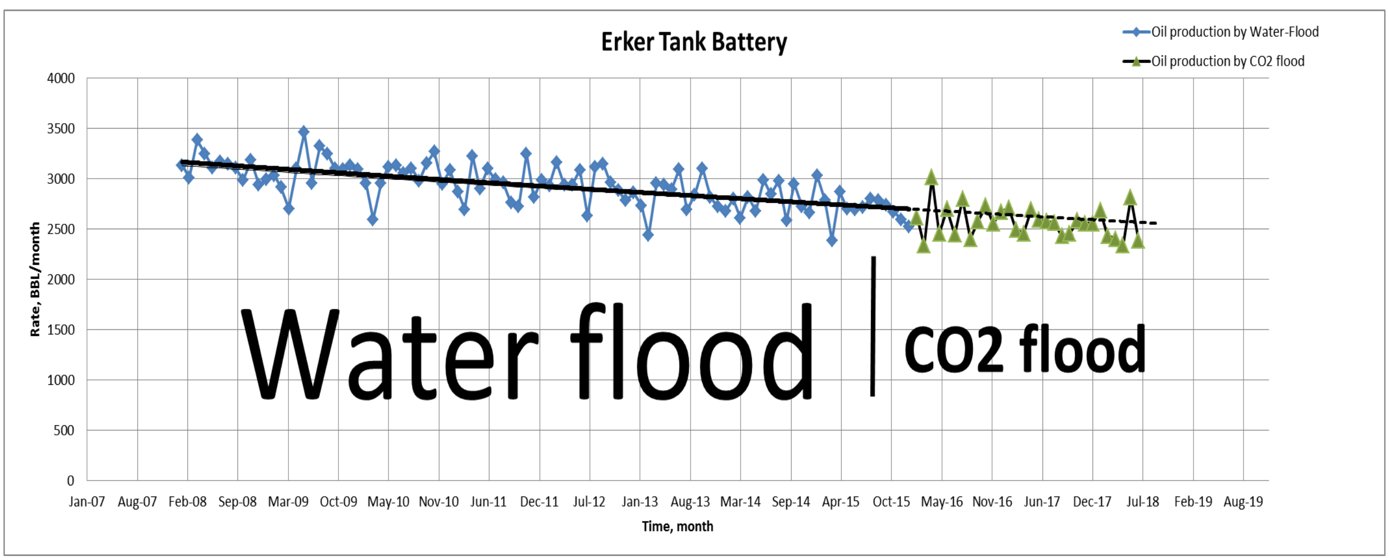


**Figure 4: The decline curve for the Erker tank battery shows no additional oil production as a result of $CO_2$ flood.**

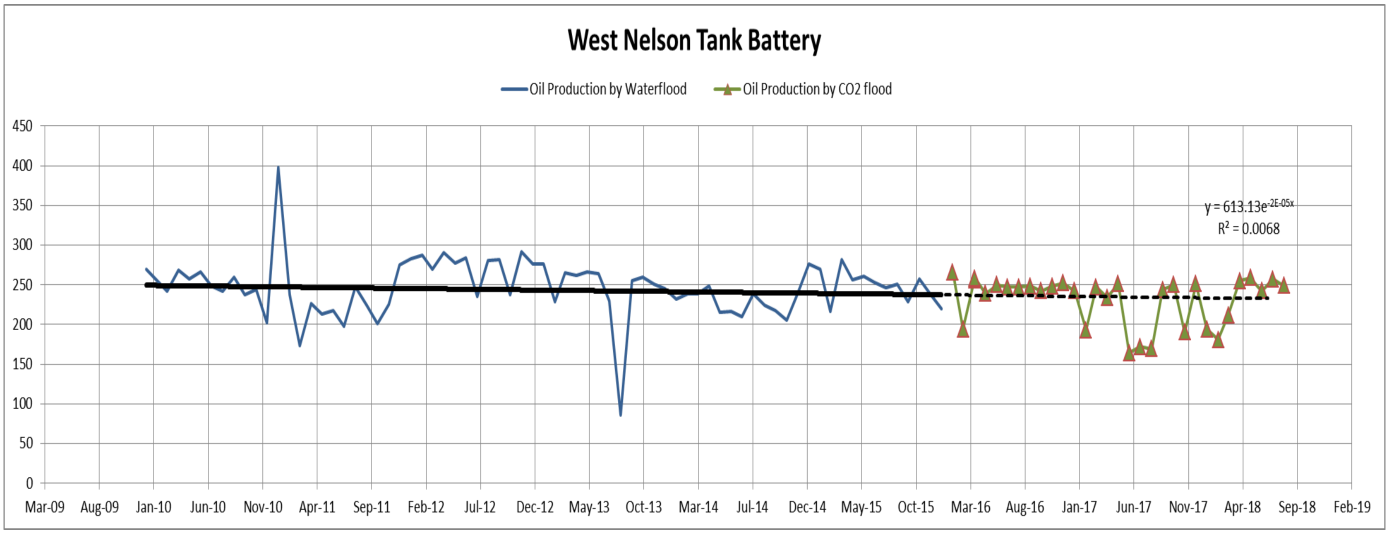


**Figure 5: The decline curve for the West Nelson tank battery shows no additional oil production as a result of $CO_2$ flood.**

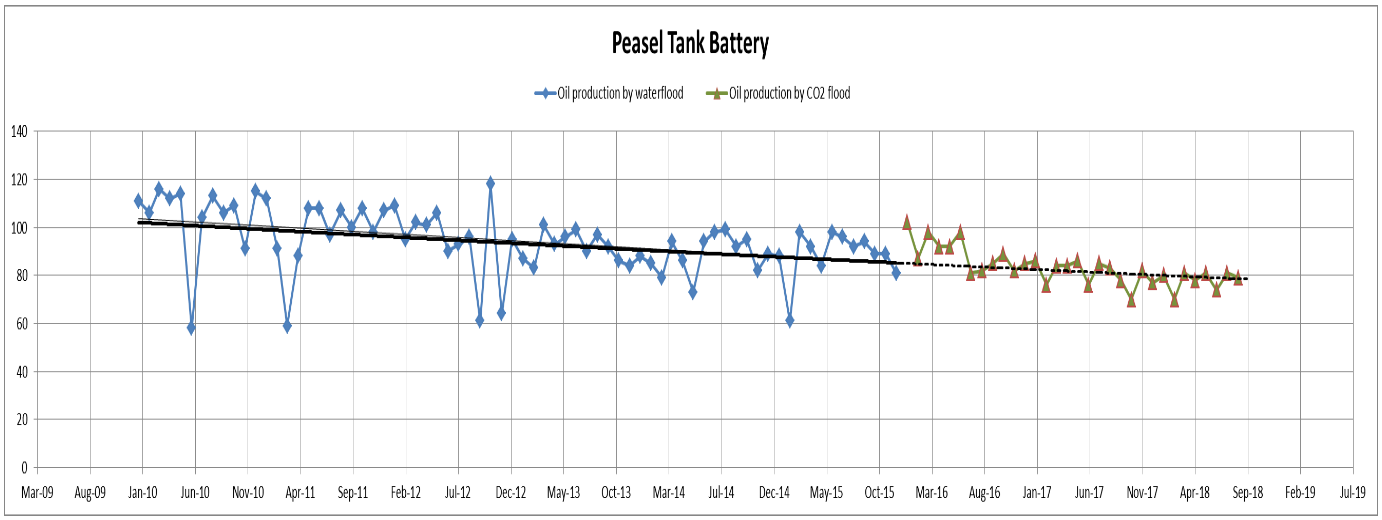


**Figure 6: The decline curve for the Peasel tank battery shows no additional oil production as a result of $CO_2$ flood.**

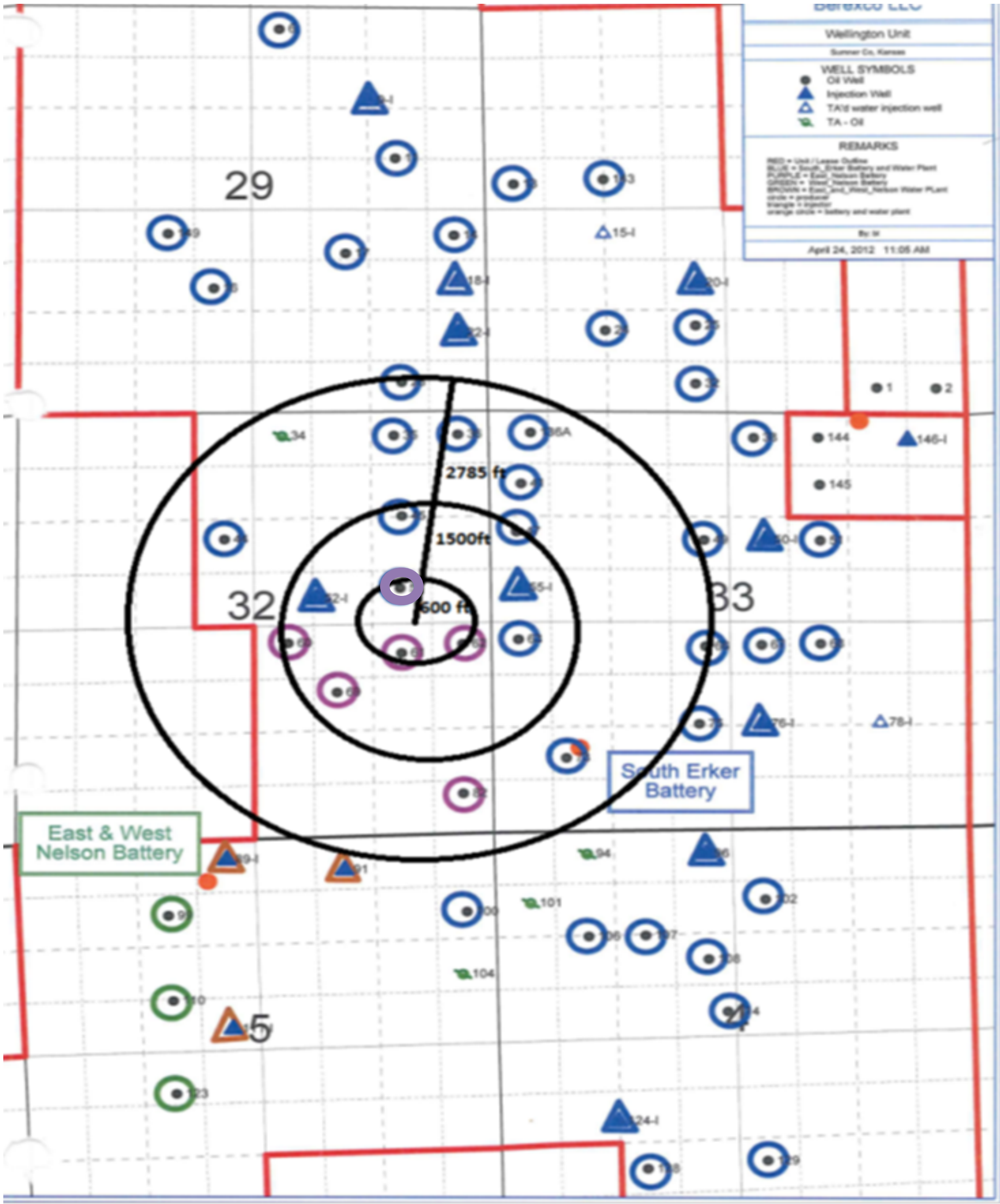


**Figure 7: Tank batteries map and wells connected to them. Wells circled in purple are connected to the East Nelson tank battery. Distance from the injector (2-32) to different producers are shown in black circles.**

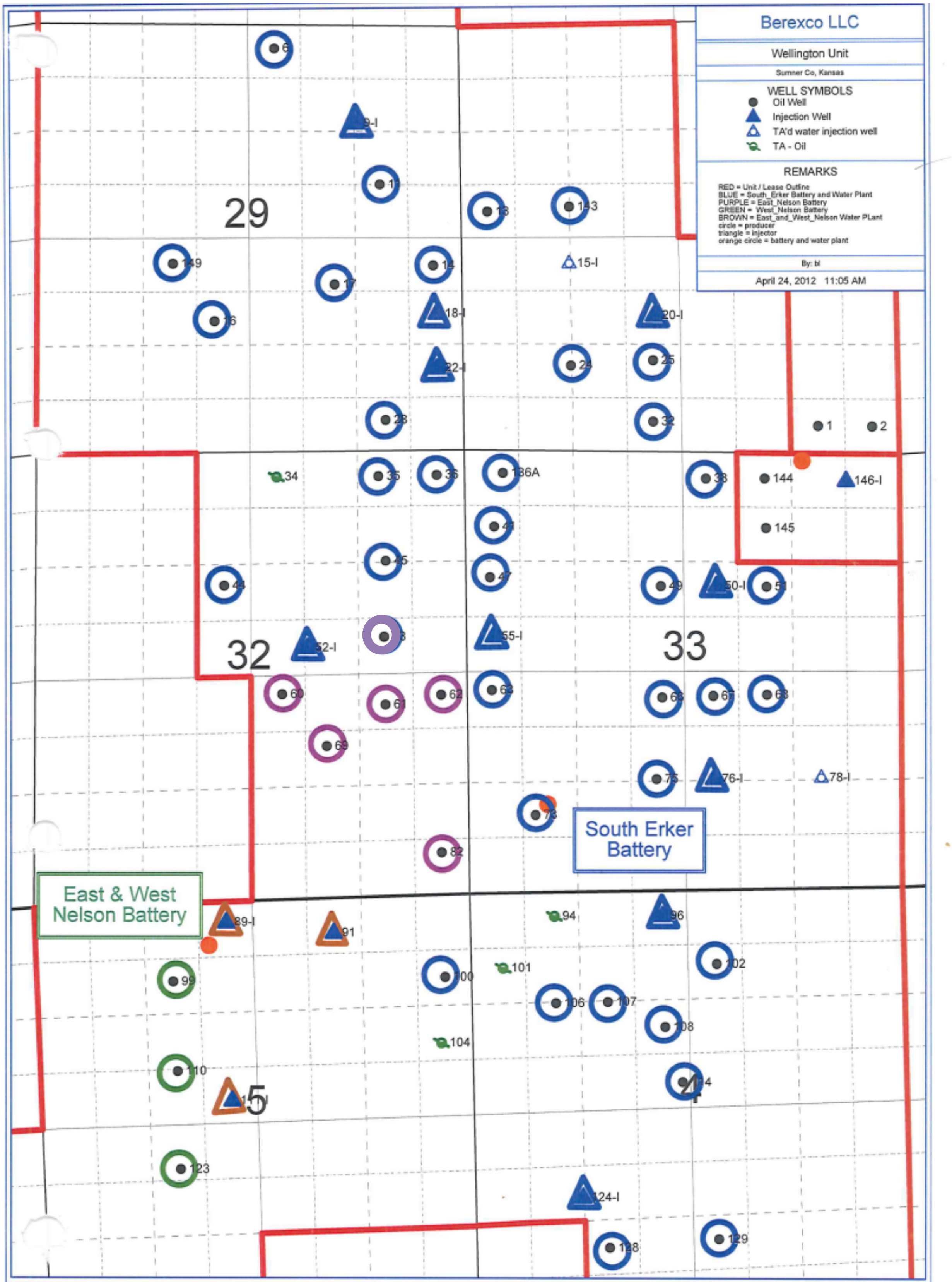


Figure 8: Wells associated with the $CO_2$-EOR project and their tank batteries. Wells circled in purple are connected to the East Nelson tank battery.

Table 1: Decline curve analysis results for waterflood and $CO_2$ flood integrated with waterflood for the East Nelson tank battery production area at the study site.

| | | | Oil Decline | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | From Start of Forecast | | | | | | |
| | Display Name | Analysis Name | Forecast Start Date | Initial Oil Rate | Initial Cumulative Oil Production | Effective Secant Decline Rate | Final Oil Rate | End Date | Delta Cumulative Oil Production |
| | | | MM/DD/YYYY | stb/d | Mstb | %/year | stb/d | MM/DD/YYYY | Mstb |
| 1 | East Nelson production-rev | Waterflood only | 02/01/2016 | 11.8 | 44.894 | 6.283 | 6.6 | 01/25/2025 | 29.270 |
| 2 | East Nelson production-rev | CO2 +Waterflood | 02/01/2016 | 35.9 | 44.894 | 18.929 | 6.6 | 10/11/2024 | 53.697 |

Note: stb/d = stock tank barrels/day; Mstb = thousand stock tank barrels