# M E M O R A N D U M

TO: Ms. Jing Song, Ecology

DATE: December 7, 2018
PROJECT: 2004-004.002

FROM: Dan Landry, Environmental Technologies Group, Inc.

RE: Groundwater Flow Direction Rose Diagram, Former Provisioners Express Facility, 2102 West Valley Highway North, Auburn, Washington, Ecology Facility ID 91612121, Cleanup Site ID 6847, VCP Project No. 3206

As requested by the Washington Department of Ecology (Ecology), Environmental Technologies Group Inc. (ETG) has prepared this memorandum to present the results of a groundwater flow direction evaluation for the Former Provisioners Express Facility in Auburn, Washington. A rose diagram was developed utilizing groundwater elevation data collected from August 12, 2011 through November 15, 2018 to determine the predominant groundwater flow direction for the site.

The following process was used to generate the rose diagram:

1. Historic groundwater monitoring well elevations data (Table 1) was imported into Surfer® 13 software;
2. Individual groundwater contour maps were generated using Surfer® 13 for each monitoring event (Attachment A);
3. The predominant groundwater flow direction for each contour map was identified and assigned a direction angle (north equaling zero (0) degrees with the angle increasing in a clockwise direction to 360 degrees) and tabulated with the corresponding data of the monitoring event (Table 2);
4. The results were then assigned to one of eight general directions (north, northeast, east, southeast, south, southwest, west, and northwest) with each section consisting of 45 degrees. For example, the angle range for north is from 337.5° to 22.5°, northeast is 22.5° to 67.5°, east 67.5° to 112.5°, etc.; and
5. The predominant flow directions were totaled in each of the eight (8) general directions (Table 3) and a rose diagram (Figure 1) was generated with the totals from Table 3.

Based on groundwater data collected from August 12, 2011 through November 15, 2018, the predominant flow direction for the site is east-southeast.

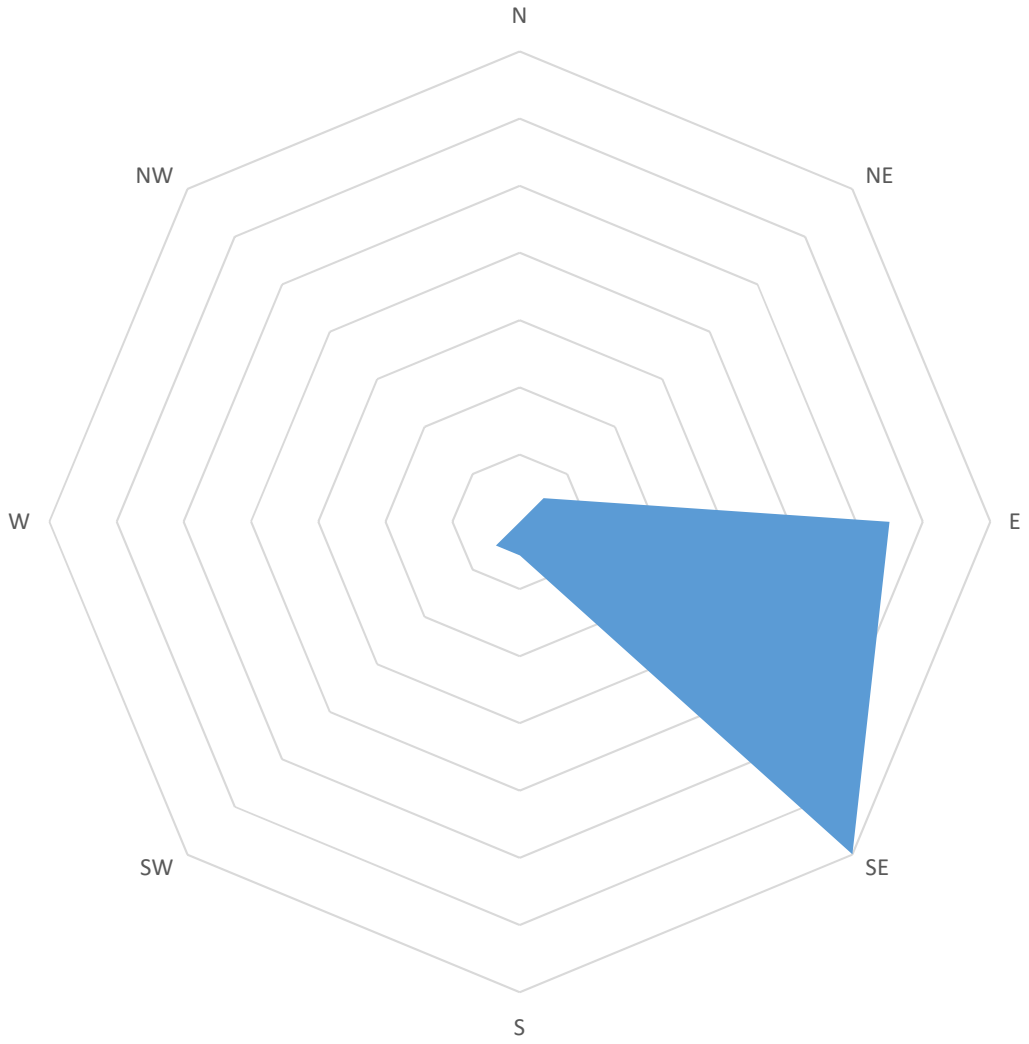
Attachments: Figure 1
Tables 1, 2, and 3
Attachment A

cc: Angela Maidment, Commerce Road Terminals, LLC

**Figure 1**

**FORMER PROVISIONERS EXPRESS FACILITY**

**Groundwater Directional Frequency Rose Diagram Using 28 Historic Measurement Events**



# Table 1
## Groundwater Elevation Summary

| Well Number/ TOC Elevation | Date of Measurement | SWL (feet) |
|---|---|---|
| MW-1 | | |
| 60.77 | 08/12/11 | 54.65 |
| | 11/11/11 | 55.35 |
| | 02/10/12 | 56.01 |
| | 05/17/12 | 55.42 |
| | 08/28/12 | 54.49 |
| | 11/15/12 | 55.78 |
| | 02/14/13 | 55.55 |
| | 05/16/13 | 55.35 |
| | 08/14/13 | 54.60 |
| | 11/25/13 | 55.71 |
| | 02/20/14 | 57.15 |
| | 05/15/14 | 56.01 |
| | 08/14/14 | 53.45 |
| | 11/24/14 | 55.55 |
| | 03/31/15 | 55.78 |
| | 06/29/15 | 54.54 |
| | 09/28/15 | 54.40 |
| | 03/03/16 | 58.59 |
| | 06/21/16 | 54.95 |
| | 09/16/16 | 54.78 |
| | 12/20/16 | 55.85 |
| | 03/24/17 | 57.44 |
| | 06/16/17 | 56.52 |
| | 09/05/17 | 54.60 |
| | 12/20/17 | 56.32 |
| | 05/17/18 | 55.27 |
| | 08/23/18 | 54.23 |
| | 11/15/18 | 55.37 |
| MW-2 | | |
| 60.85 | 08/12/11 | 55.34 |
| | 11/11/11 | 55.72 |
| | 02/10/12 | 55.91 |
| | 05/17/12 | 55.43 |
| | 08/28/12 | 54.45 |
| | 11/15/12 | 55.73 |
| | 02/14/13 | 55.53 |
| | 05/16/13 | 55.37 |
| | 08/14/13 | 54.52 |
| | 11/25/13 | 55.71 |
| | 02/20/14 | 58.62 |
| | 05/15/14 | 55.99 |
| | 08/14/14 | 55.92 |
| | 11/24/14 | 57.15 |
| | 03/31/15 | 55.83 |
| | 06/29/15 | 54.49 |
| | 09/28/15 | 54.35 |
| | 03/03/16 | 58.21 |
| | 06/21/16 | 54.90 |
| | 09/16/16 | 54.72 |
| | 12/20/16 | 56.14 |
| | 03/24/17 | 57.76 |
| | 06/16/17 | 56.10 |
| | 09/05/17 | 54.53 |
| | 12/20/17 | 56.64 |
| | 05/17/18 | 55.25 |
| | 08/23/18 | 54.17 |
| | 11/15/18 | 55.41 |

# Table 1
## Groundwater Elevation Summary

| Well Number/ TOC Elevation | Date of Measurement | SWL (feet) |
|---|---|---|
| MW-3 | | |
| 60.80 | 08/12/11 | 55.26 |
| | 11/11/11 | 51.90 |
| | 02/10/12 | 55.75 |
| | 05/17/12 | 55.20 |
| | 08/28/12 | 54.40 |
| | 11/15/12 | 55.55 |
| | 02/14/13 | 55.42 |
| | 05/16/13 | 55.24 |
| | 08/14/18 | 54.49 |
| | 11/25/13 | 55.58 |
| | 02/20/14 | 56.46 |
| | 05/15/14 | 55.77 |
| | 08/14/14 | 54.52 |
| | 11/24/14 | 55.59 |
| | 03/31/15 | 55.65 |
| | 06/29/15 | 54.43 |
| | 09/28/15 | 54.29 |
| | 03/03/16 | 56.25 |
| | 06/21/16 | 54.87 |
| | 09/16/16 | 54.71 |
| | 12/20/16 | 55.42 |
| | 03/24/17 | 56.23 |
| | 06/16/17 | 55.57 |
| | 09/05/17 | 54.50 |
| | 12/20/17 | 55.89 |
| | 05/17/18 | 55.17 |
| | 08/23/18 | 54.17 |
| | 11/15/18 | 55.32 |
| MW-4 | | |
| 60.93 | 08/12/11 | 54.56 |
| | 11/11/11 | 55.28 |
| | 02/10/12 | 55.73 |
| | 05/17/12 | 55.30 |
| | 08/28/12 | 54.43 |
| | 11/15/12 | 55.57 |
| | 02/14/13 | 55.43 |
| | 05/16/13 | 55.26 |
| | 08/14/13 | 54.51 |
| | 11/25/13 | 55.62 |
| | 02/20/14 | 56.48 |
| | 05/15/14 | 55.79 |
| | 08/14/14 | 54.60 |
| | 11/24/14 | 55.66 |
| | 03/31/15 | 55.66 |
| | 06/29/15 | 54.48 |
| | 09/28/15 | 54.31 |
| | 03/03/16 | 57.73 |
| | 06/21/16 | 54.82 |
| | 09/16/16 | 54.53 |
| | 12/20/16 | 54.61 |
| | 03/24/17 | 56.24 |
| | 06/16/17 | 55.57 |
| | 09/05/17 | 54.54 |
| | 12/20/17 | 55.93 |
| | 01/02/18 | 55.93 |
| | 05/17/18 | 55.19 |
| | 08/23/18 | 54.20 |
| | 11/15/18 | 55.38 |

# Table 1
## Groundwater Elevation Summary

| Well Number/ TOC Elevation | Date of Measurement | SWL (feet) |
|---|---|---|
| MW-5 | | |
| 60.90 | 08/14/13 | 54.59 |
| | 11/25/13 | 55.66 |
| | 02/20/14 | 56.52 |
| | 05/15/14 | 55.84 |
| | 08/14/14 | 54.59 |
| | 11/24/14 | 55.66 |
| | 03/31/15 | 55.73 |
| | 06/29/15 | 54.55 |
| | 09/28/15 | 54.39 |
| | 03/03/16 | 56.31 |
| | 06/21/16 | 54.94 |
| | 09/16/16 | 54.79 |
| | 12/20/16 | 55.74 |
| | 03/24/17 | 56.29 |
| | 06/16/17 | 55.63 |
| | 09/05/17 | 54.63 |
| | 12/20/17 | 55.98 |
| | 01/02/18 | 55.98 |
| | 05/17/18 | 55.25 |
| | 08/23/18 | 54.32 |
| | 11/15/18 | 55.46 |
| MW-6 | | |
| 60.76 | 08/14/13 | 54.55 |
| | 11/25/13 | 55.63 |
| | 02/20/14 | 56.49 |
| | 05/15/14 | 55.79 |
| | 08/14/14 | 54.63 |
| | 11/24/14 | 55.68 |
| | 03/31/15 | 55.66 |
| | 06/29/15 | 54.49 |
| | 09/28/15 | 54.34 |
| | 03/03/16 | 56.23 |
| | 06/21/16 | 54.85 |
| | 09/16/16 | 54.75 |
| | 12/20/16 | 55.62 |
| | 03/24/17 | 56.24 |
| | 06/16/17 | 55.58 |
| | 09/05/17 | 54.53 |
| | 12/20/17 | 55.96 |
| | 01/02/18 | 55.96 |
| | 05/17/18 | 55.19 |
| | 08/23/18 | 54.25 |
| | 11/15/18 | 55.37 |
| MW-7 | | |
| 59.87 | 09/16/16 | 54.72 |
| | 12/20/16 | 54.60 |
| | 03/24/17 | 56.19 |
| | 06/16/17 | 55.54 |
| | 09/05/17 | 54.44 |
| | 12/20/17 | 55.92 |
| | 05/17/18 | 55.16 |
| | 08/23/18 | 54.20 |
| | 11/15/18 | 55.38 |
| MW-8 | | |
| 59.70 | 09/16/16 | 54.61 |
| | 12/20/16 | 55.08 |
| | 03/24/17 | 56.03 |

## Table 1
## Groundwater Elevation Summary

| Well Number/ TOC Elevation | Date of Measurement | SWL (feet) |
|---|---|---|
| MW-8 Continued | 06/16/17 | 55.49 |
| | 09/05/17 | 54.39 |
| | 12/20/17 | 55.92 |
| | 05/17/18 | 55.04 |
| | 06/05/18 | 53.80 |
| | 08/23/18 | 54.14 |
| | 11/15/18 | 55.26 |
| MW-9 60.91 | 09/05/17 | 54.58 |
| | 12/20/17 | 56.18 |
| | 05/17/18 | 55.27 |
| | 08/23/18 | 54.22 |
| | 11/15/18 | 55.41 |

Notes:
TOC - Top of casing
SWL - Standing Water Level
Wells surveyed to the North American Vertical Datum of 1988 (NAVD 88) on September 19, 2017.

**Table 2**
**Predominant Groundwater Flow Direction**

| Date | GW Flow Angle | Notes |
|---|---|---|
| 2011-08-12 | 232 | |
| 2011-11-11 | 110 | |
| 2012-02-10 | 120 | |
| 2012-05-17 | 110 | |
| 2012-08-28 | 100 | |
| 2012-11-15 | 120 | |
| 2013-02-14 | 120 | |
| 2013-05-16 | 120 | |
| 2013-08-14 | 80 | |
| 2013-11-25 | 120 | |
| 2014-02-20 | 150 | |
| 2014-05-15 | 120 | |
| 2014-08-14 | 140 | |
| 2014-11-24 | 175 | |
| 2015-03-31 | 130 | |
| 2015-06-29 | 90 | |
| 2015-09-28 | 90 | |
| 2016-03-03 | 135 | Water levels possibly affected by air injection sys. |
| 2016-06-21 | 90 | |
| 2016-09-16 | 85 | Water levels possibly affected by air injection sys. |
| 2016-12-20 | 120 | Water levels possibly affected by air injection sys. |
| 2017-03-24 | 120 | |
| 2017-06-16 | 120 | |
| 2017-09-05 | 90 | |
| 2017-12-20 | 120 | |
| 2018-05-17 | 90 | |
| 2018-08-23 | 60 | |
| 2018-11-15 | 90 | |

Note: GW Fflow angles established from groundwater contour maps.

**Table 3**
**Total Count of Groundwater Flow in Each Direction**

| Angle Min (Degrees) | Angle Max. (Degrees) | Direction | Total |
|---|---|---|---|
| 337.5 | 22.5 | N | 0 |
| 22.5 | 67.5 | NE | 1 |
| 67.5 | 112.5 | E | 11 |
| 112.5 | 157.5 | SE | 14 |
| 157.5 | 202.5 | S | 1 |
| 202.5 | 247.5 | SW | 1 |
| 247.5 | 292.5 | W | 0 |
| 292.5 | 337.5 | NW | 0 |

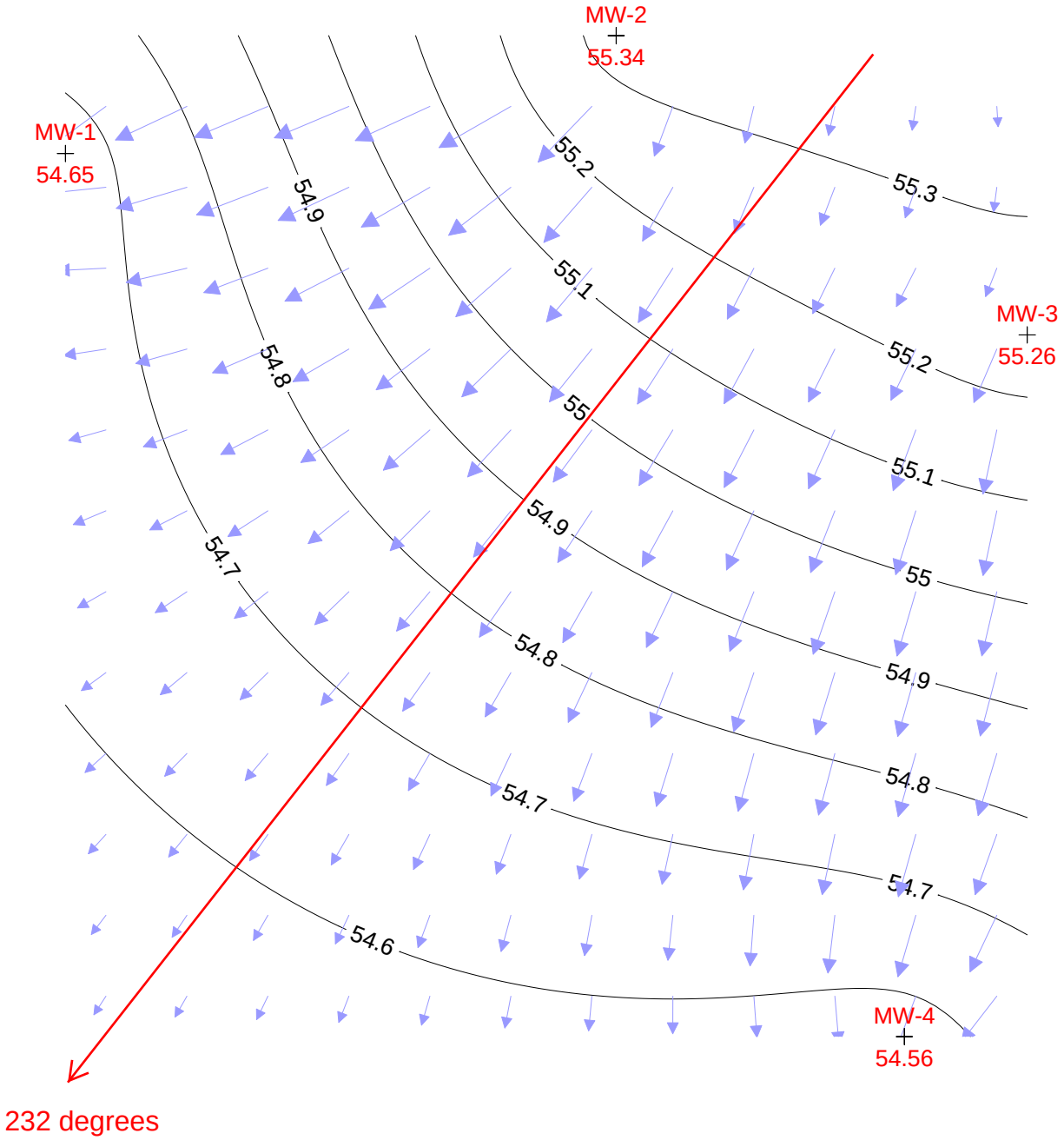
# ATTACHMENT A

# GROUNDWATER CONTOUR MAPS

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 8/12/11

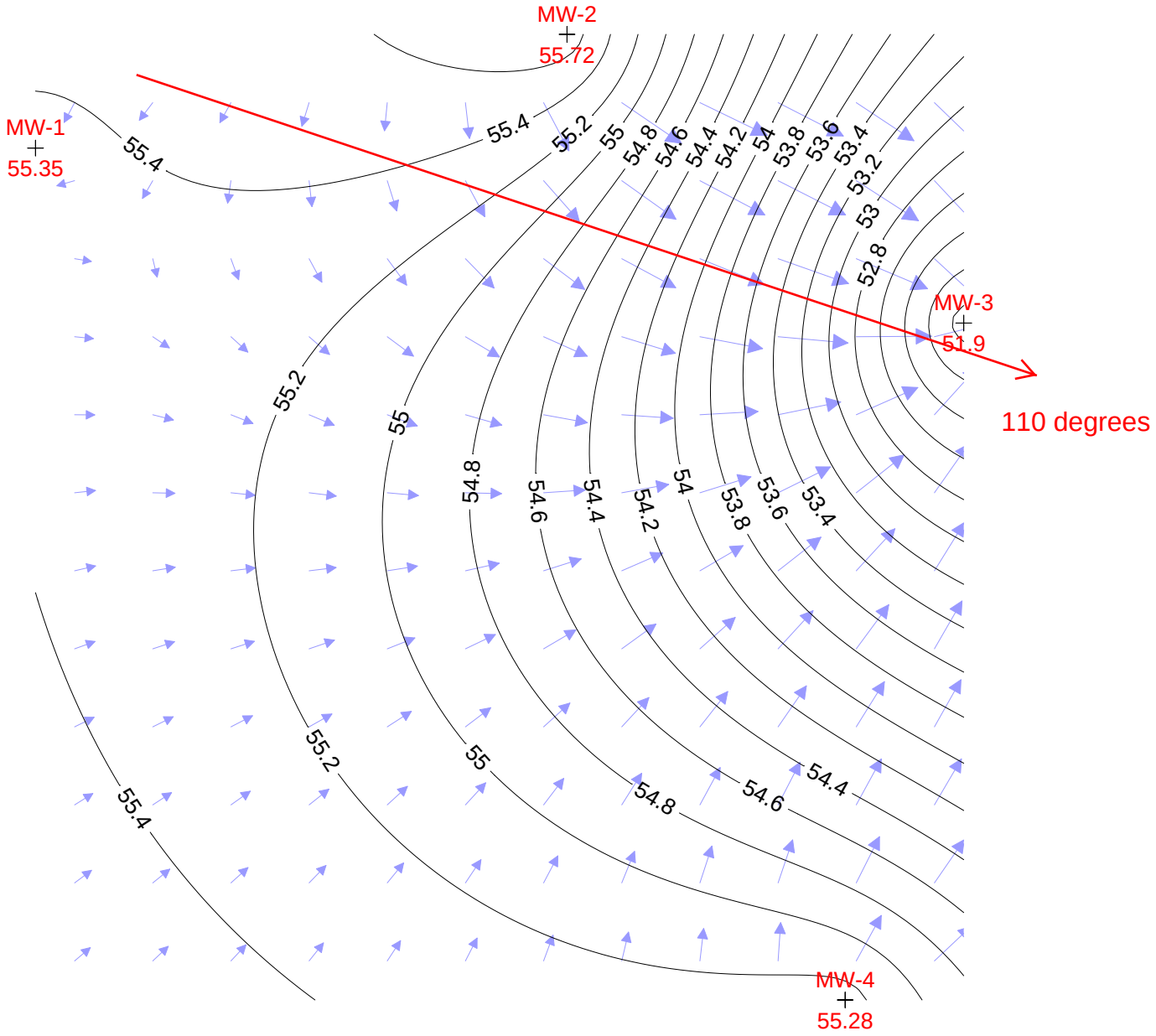



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 11/11/11

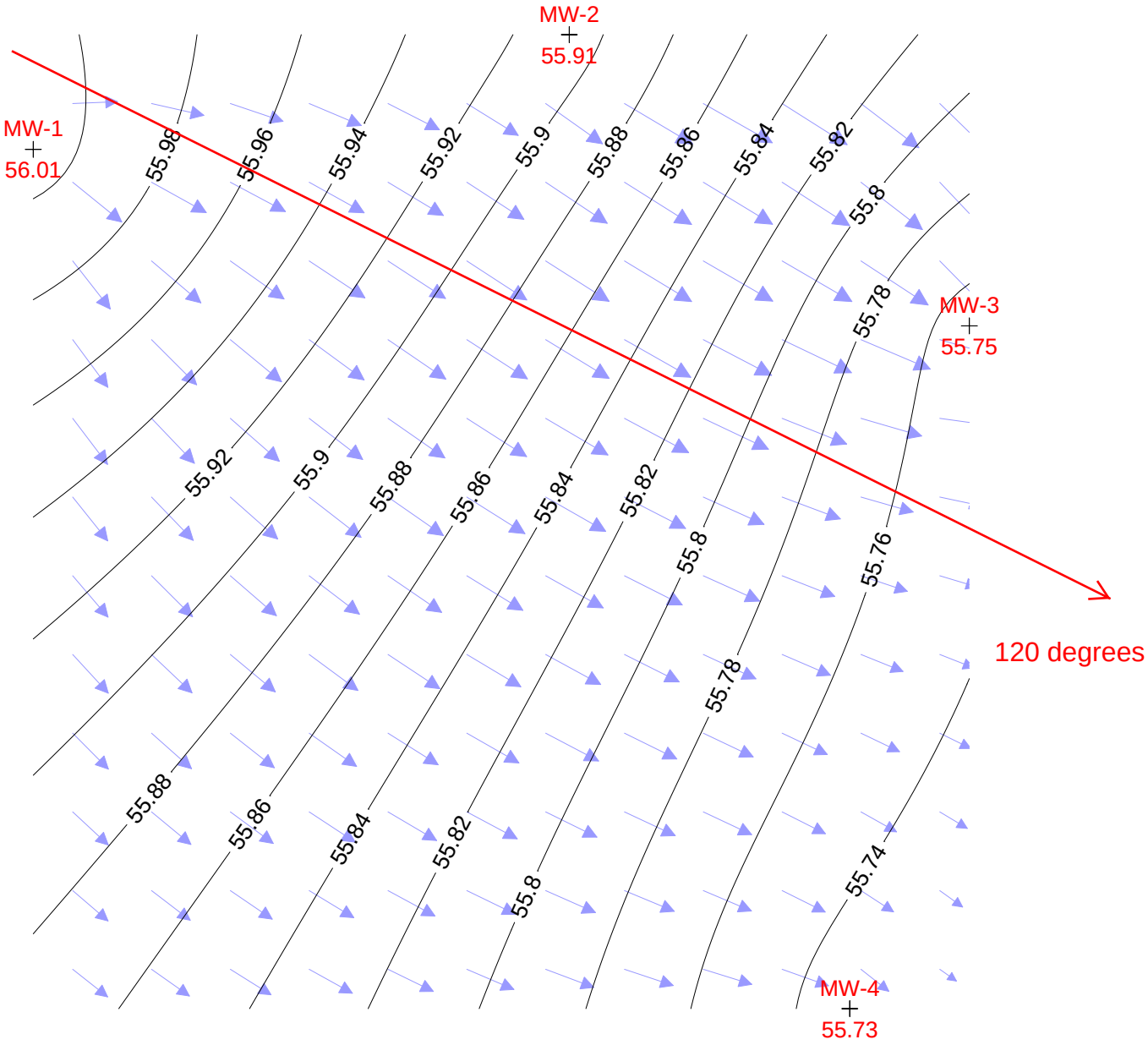



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 2/10/12

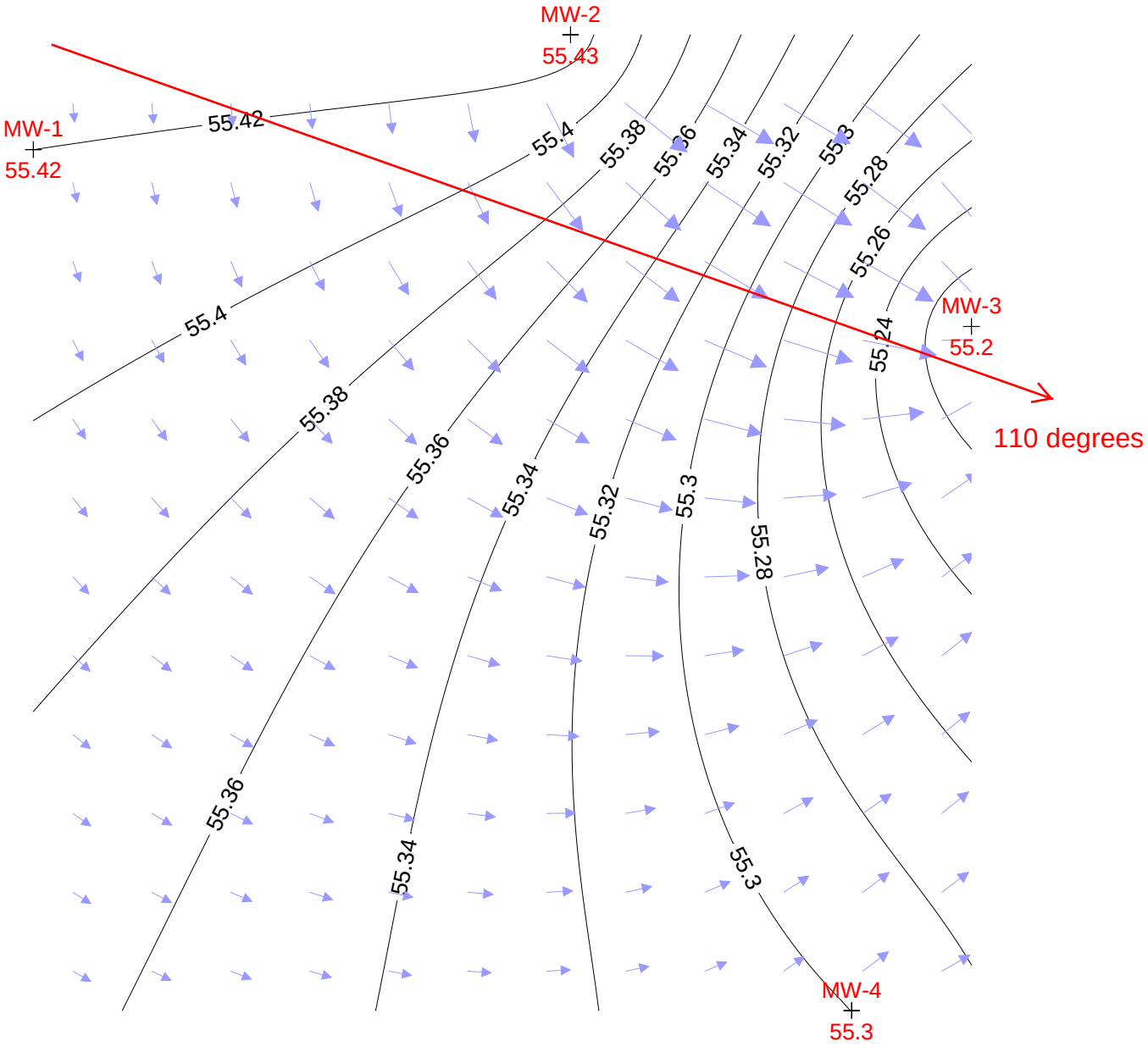



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 5/17/12

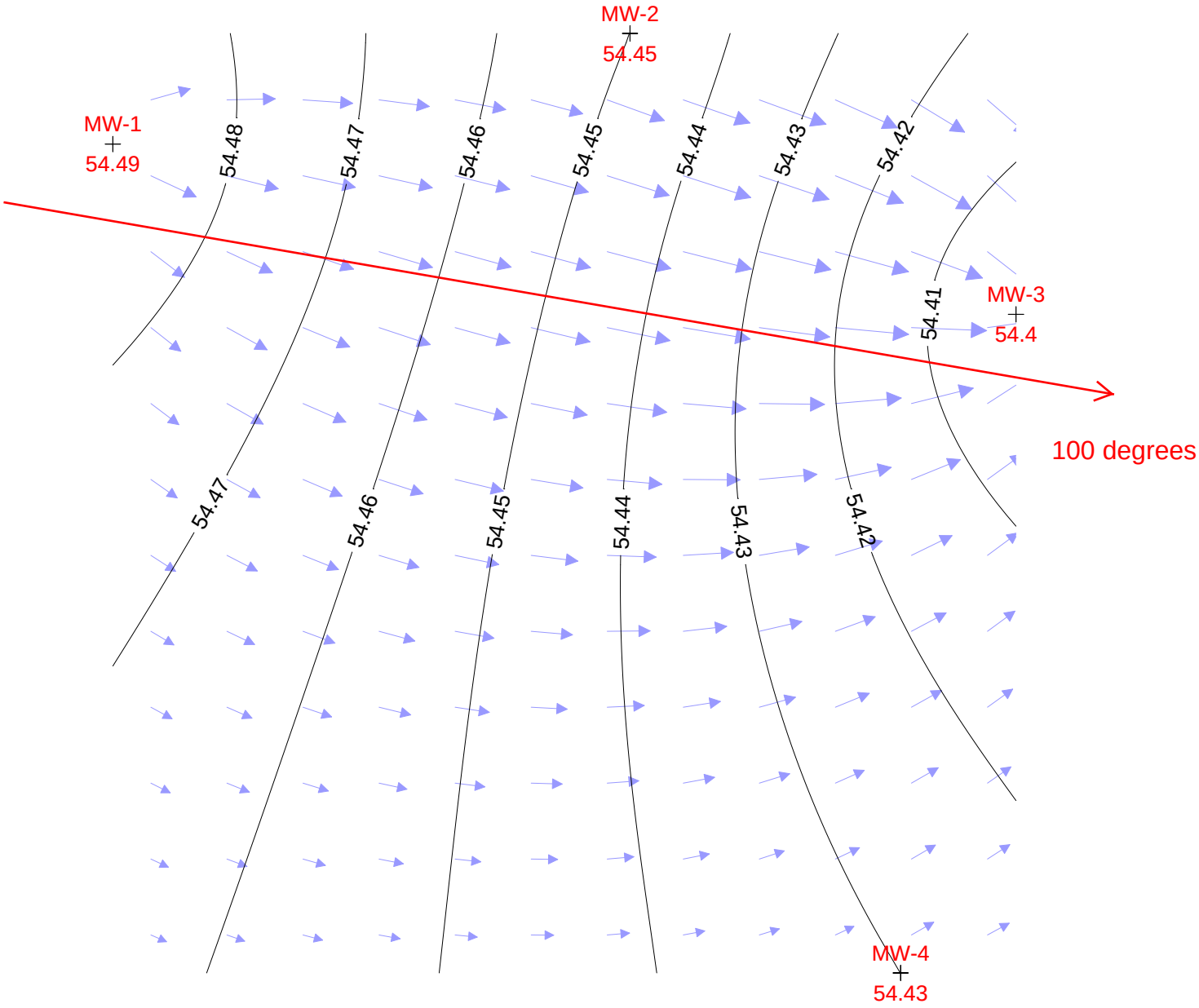



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 8/28/12

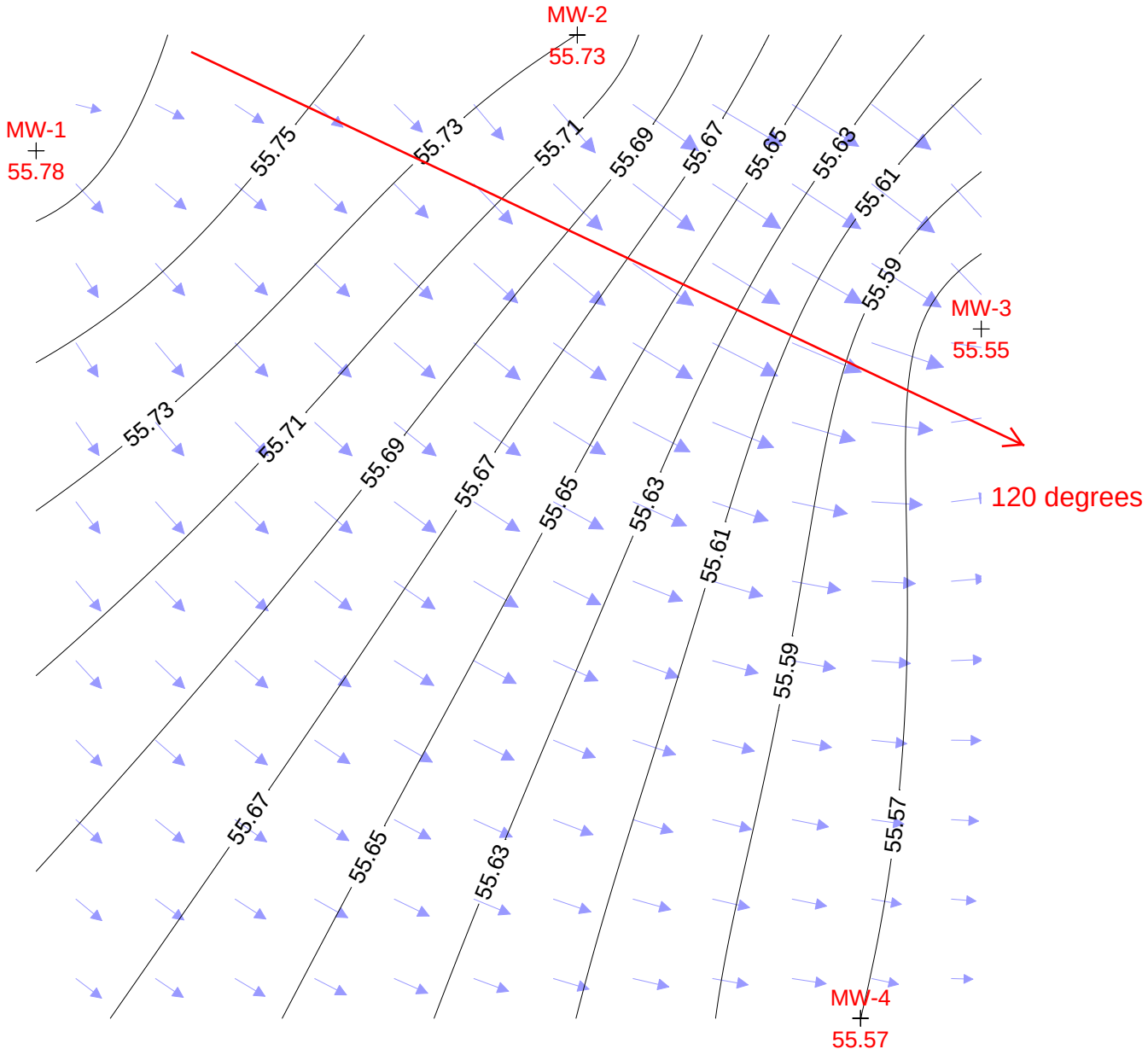



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 11/15/12

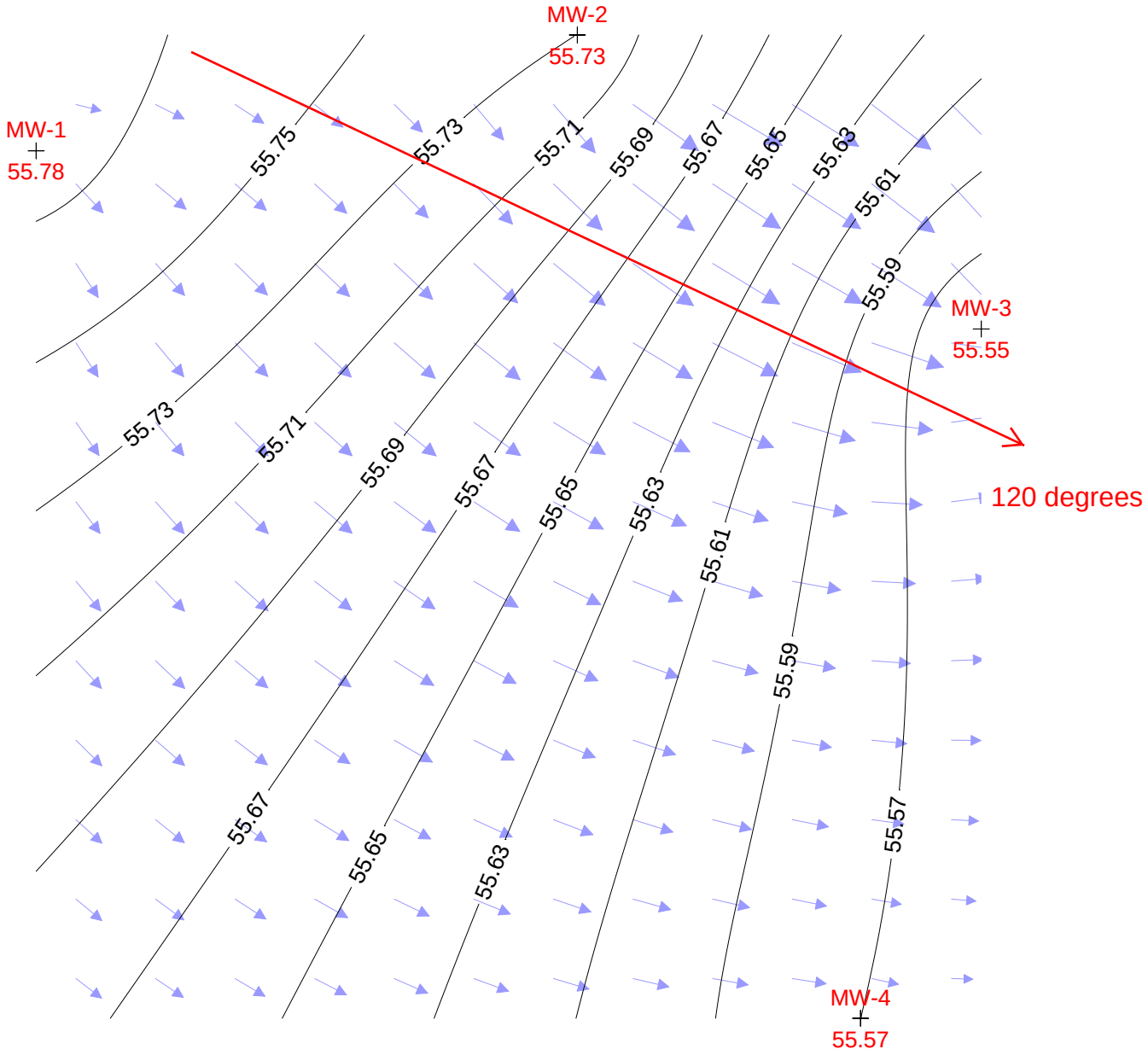



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 11/15/12

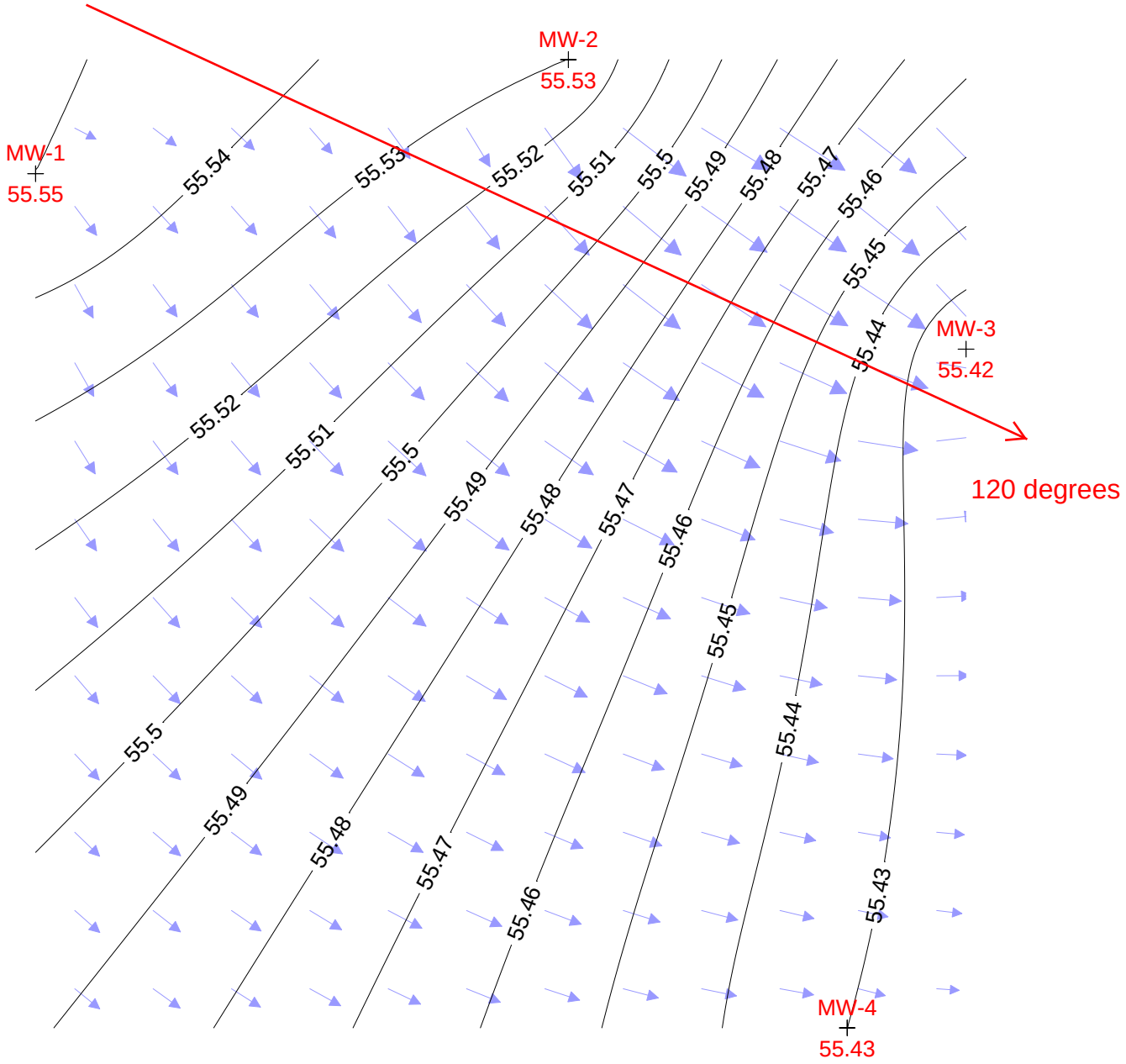



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 2/14/13

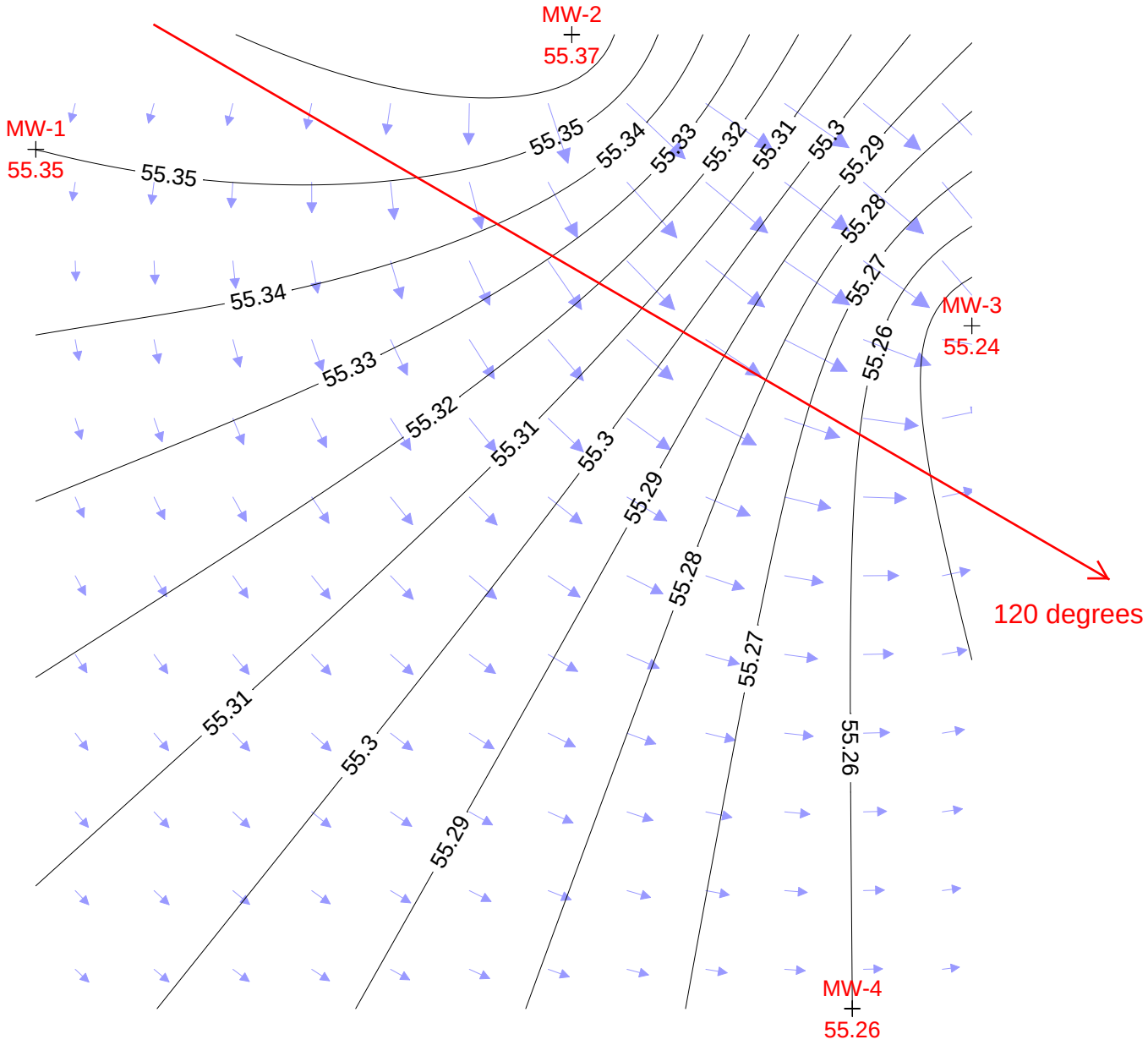



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 5/16/13

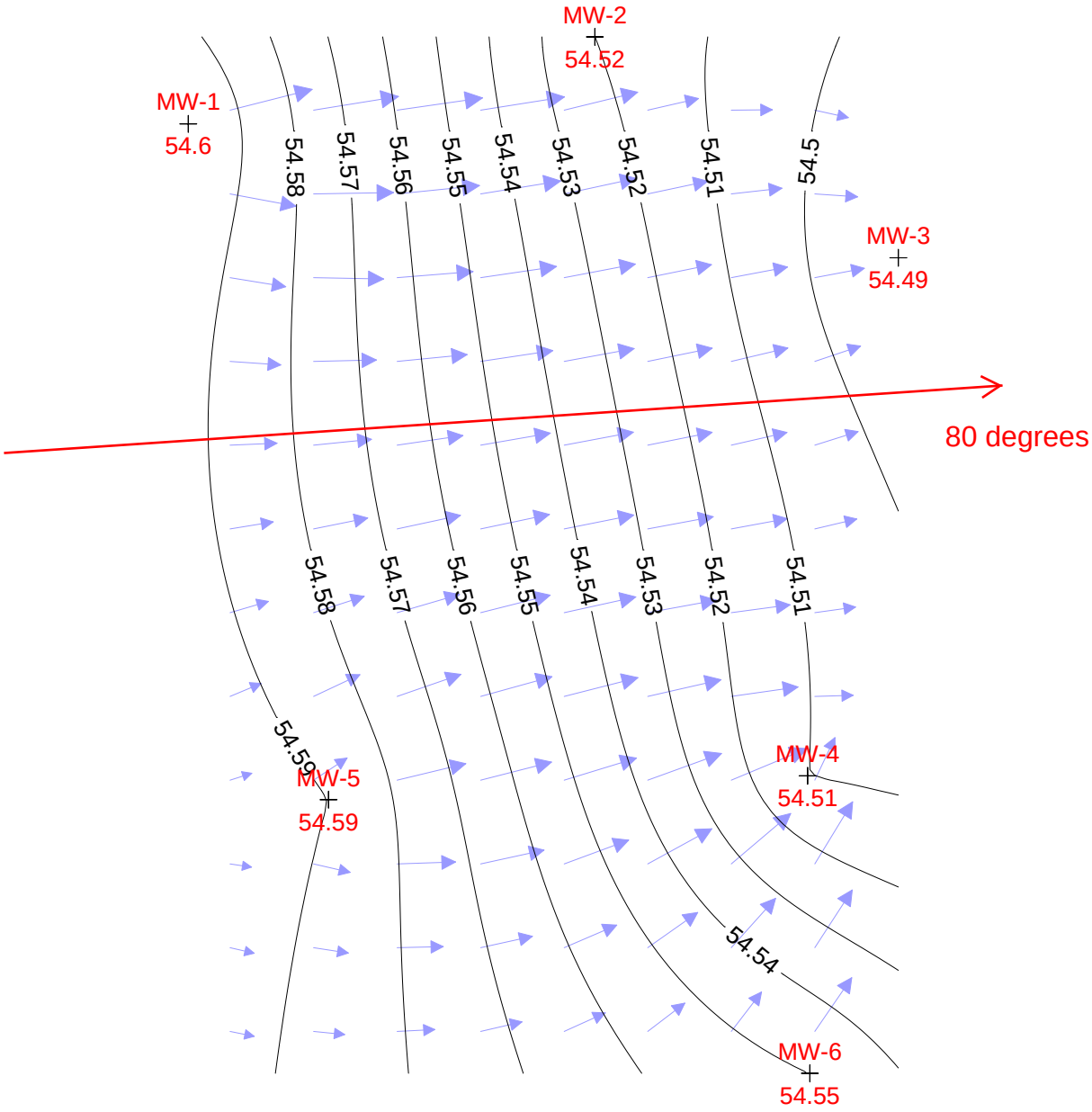



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 8/14/13

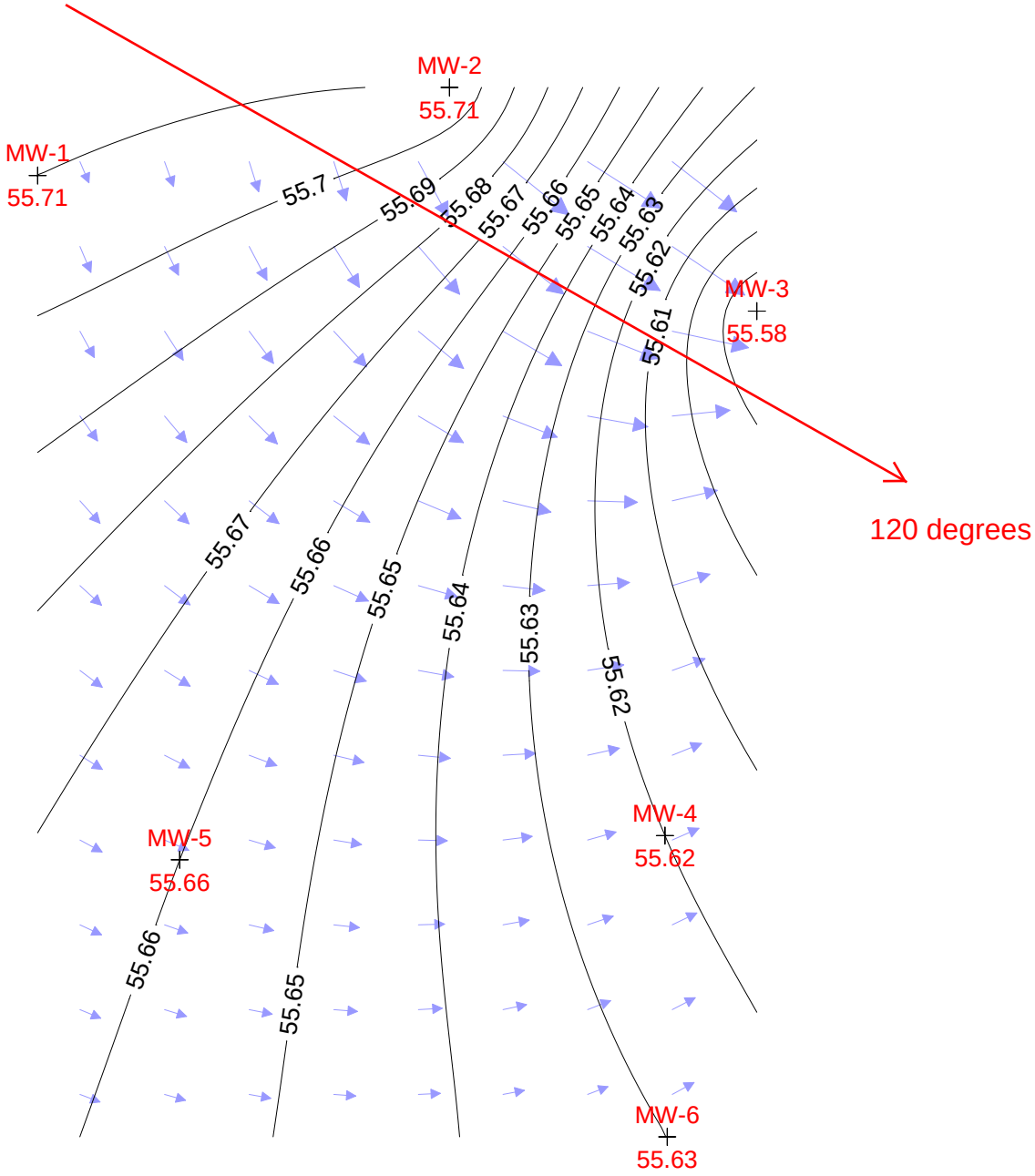



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 11/25/13

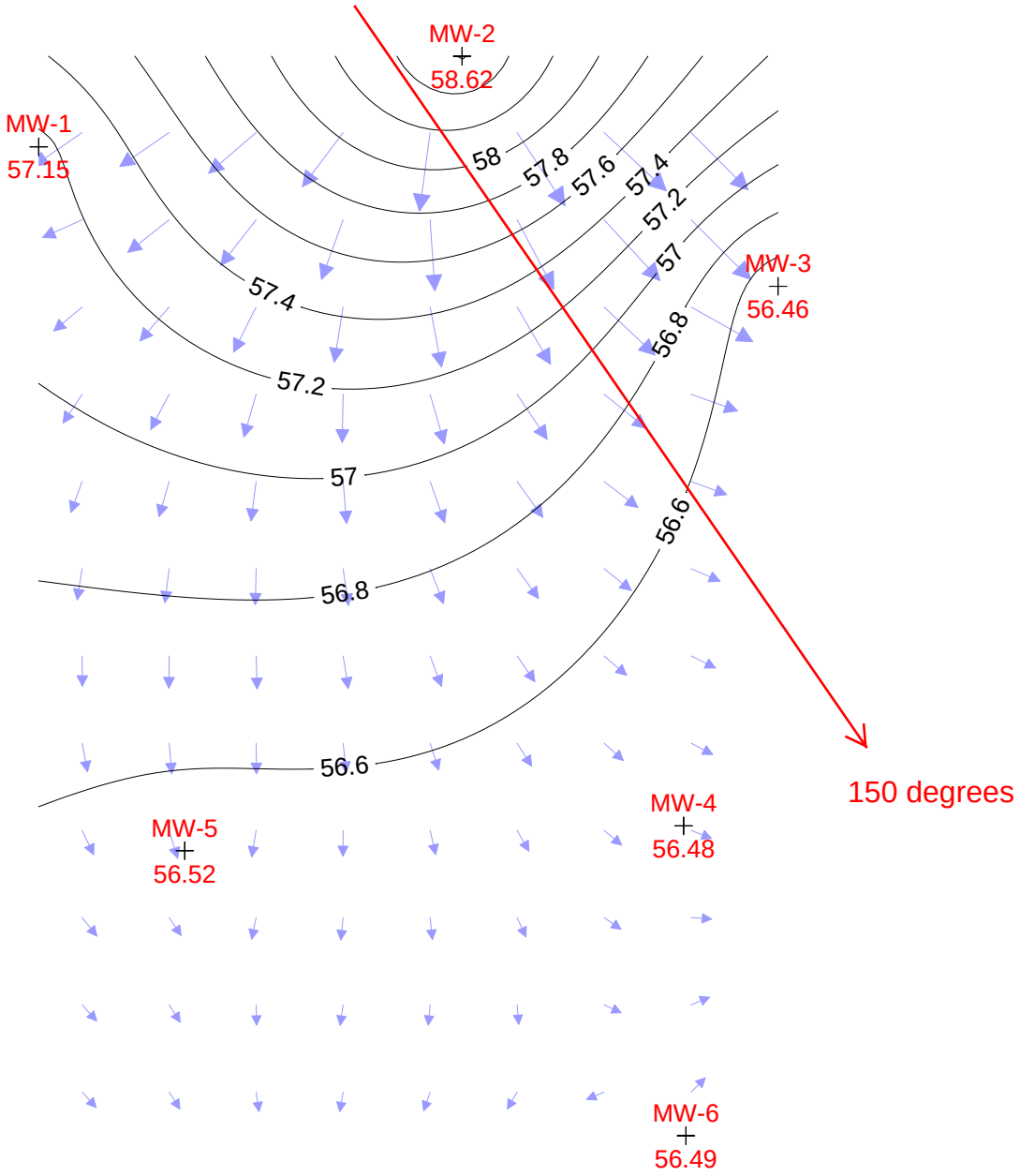



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 2/20/14

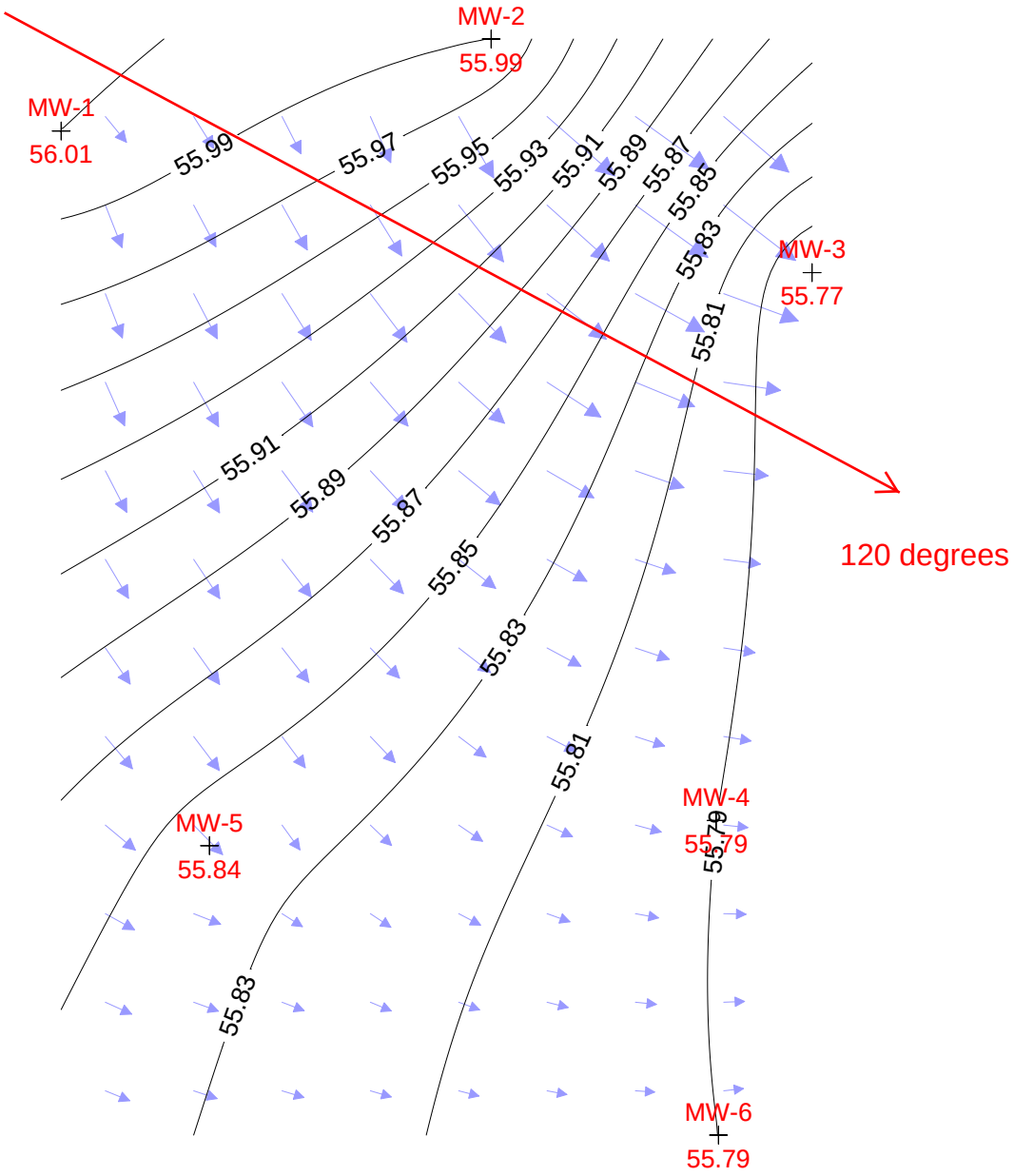



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 5/15/14

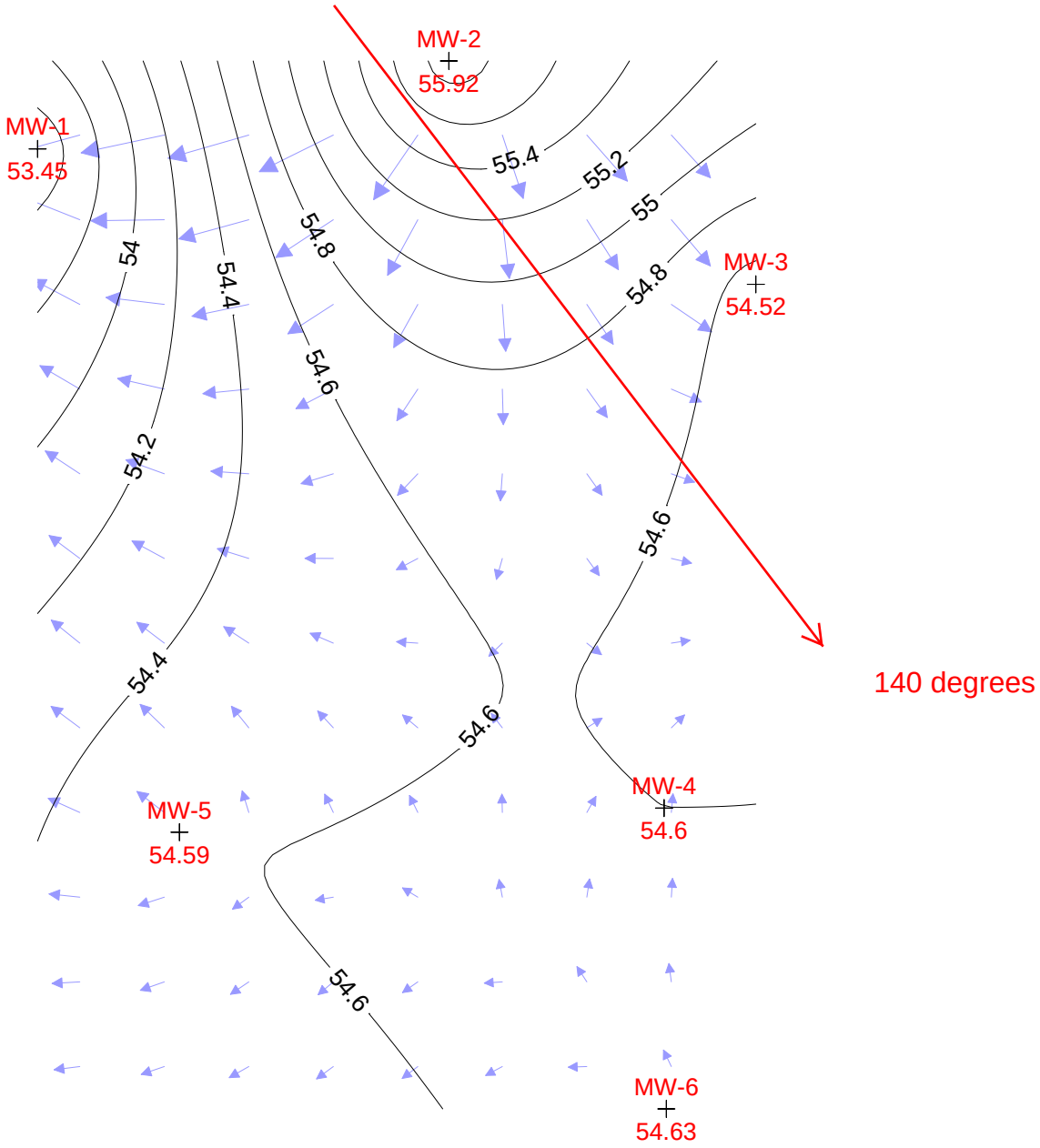



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 8/14/14

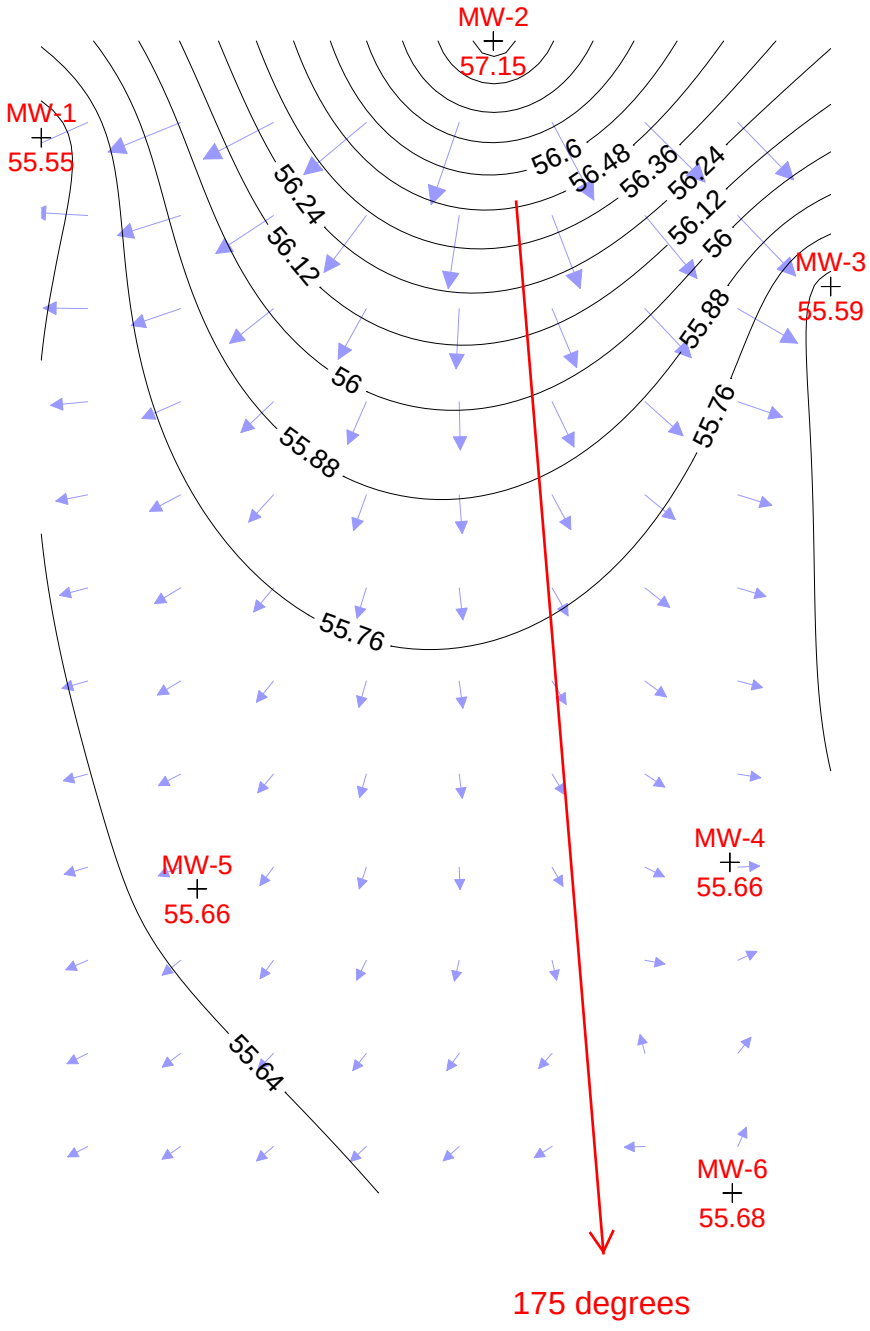



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 11/24/14

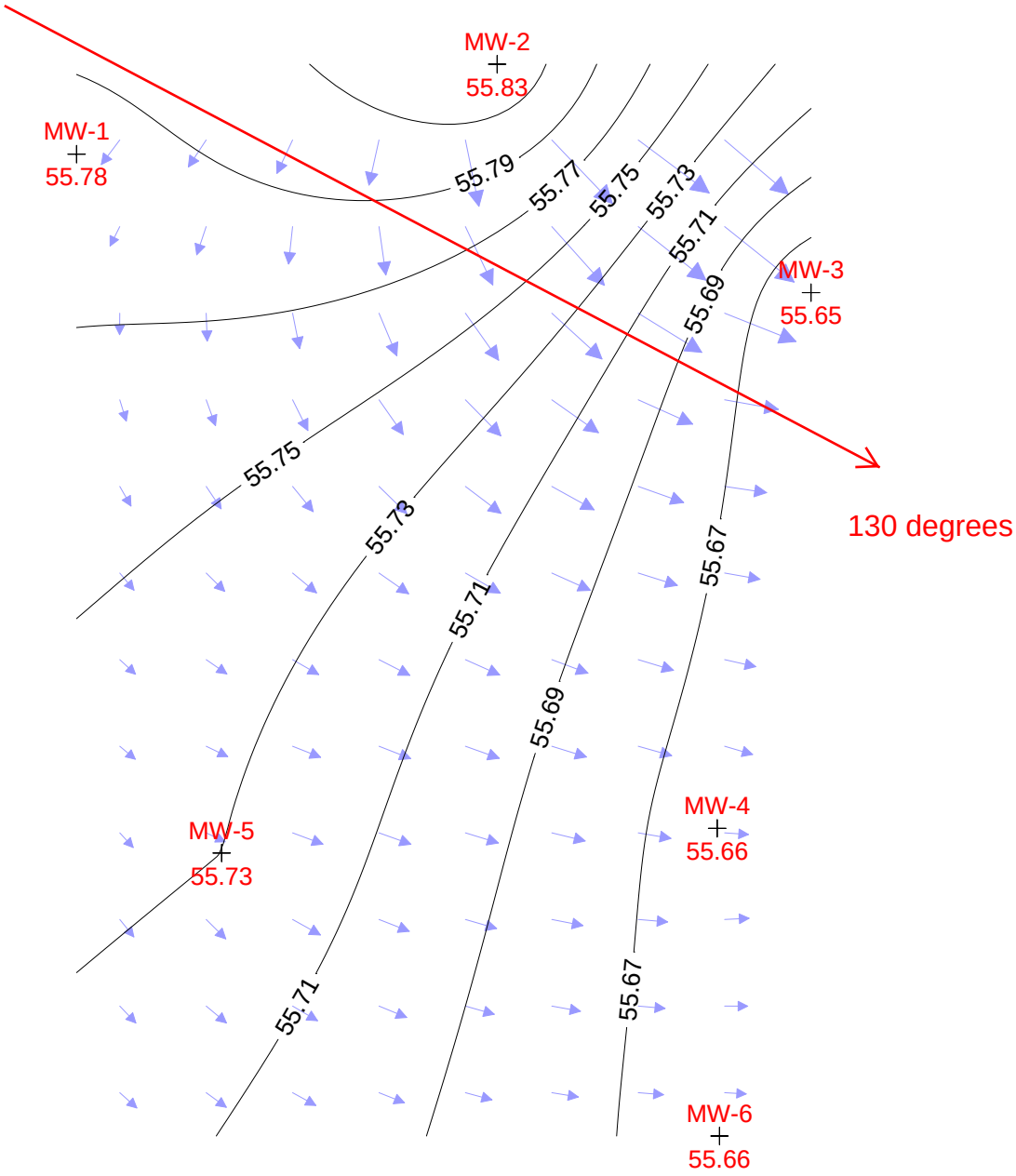



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 3/31/15

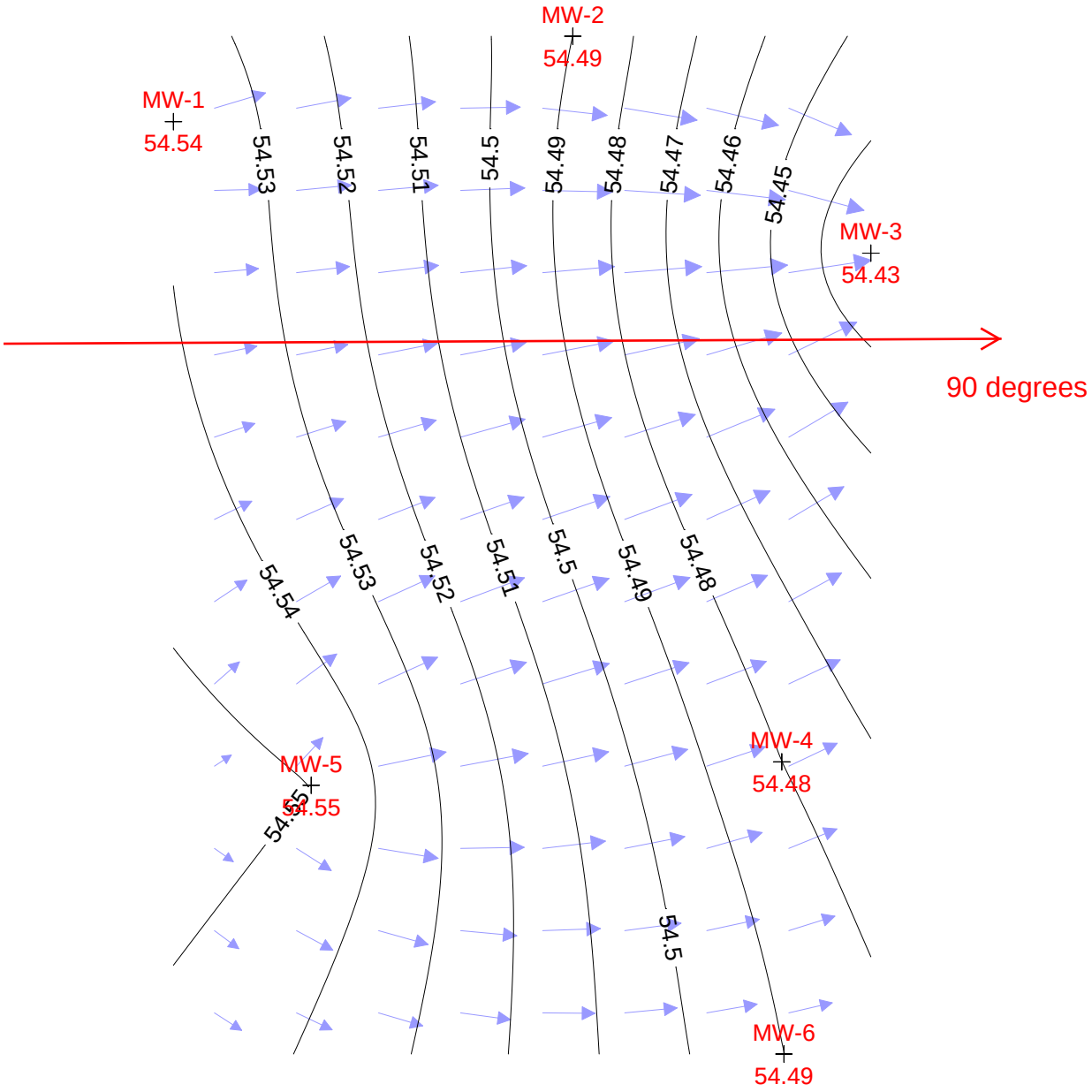



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 6/29/15

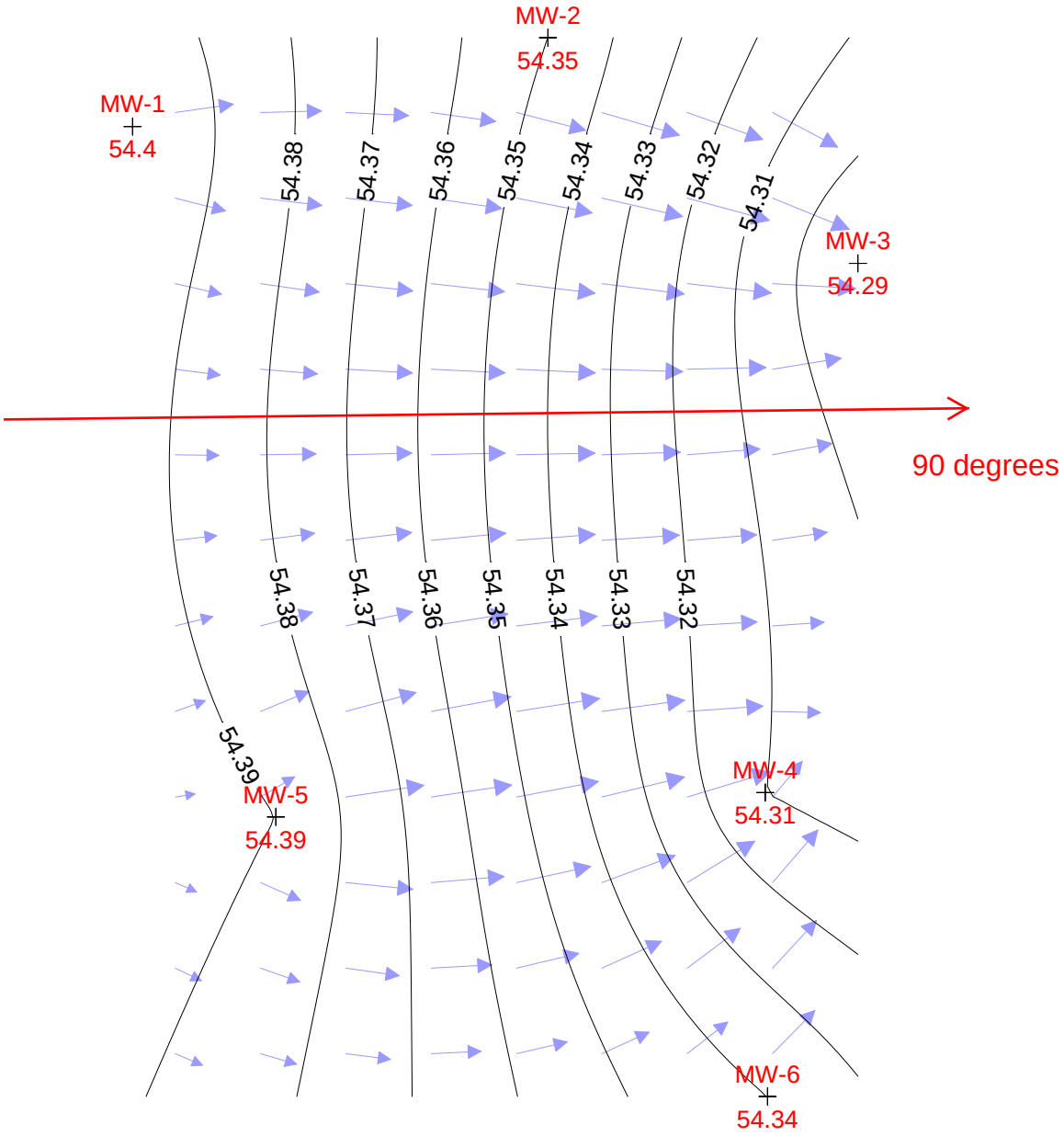



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 9/28/15

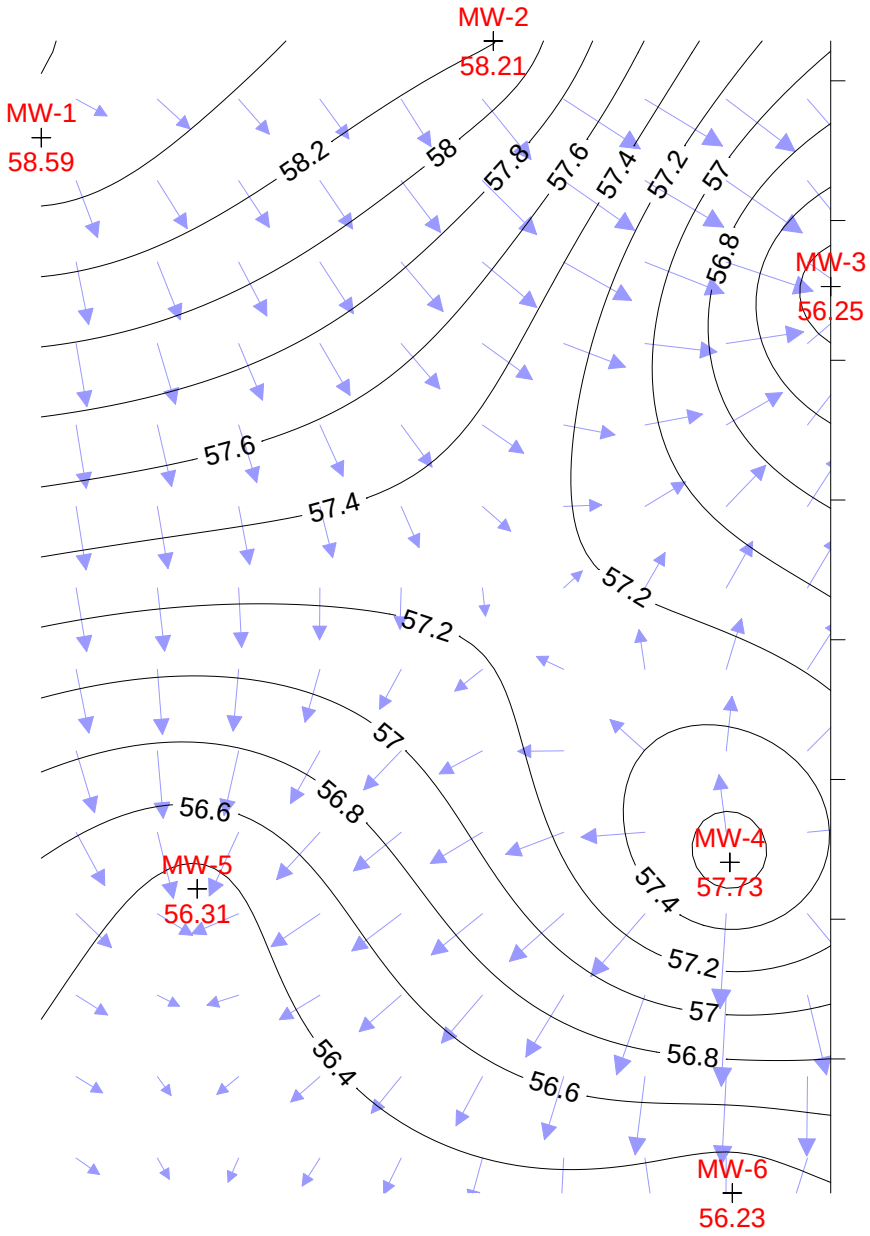



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 3/3/16




Not Used

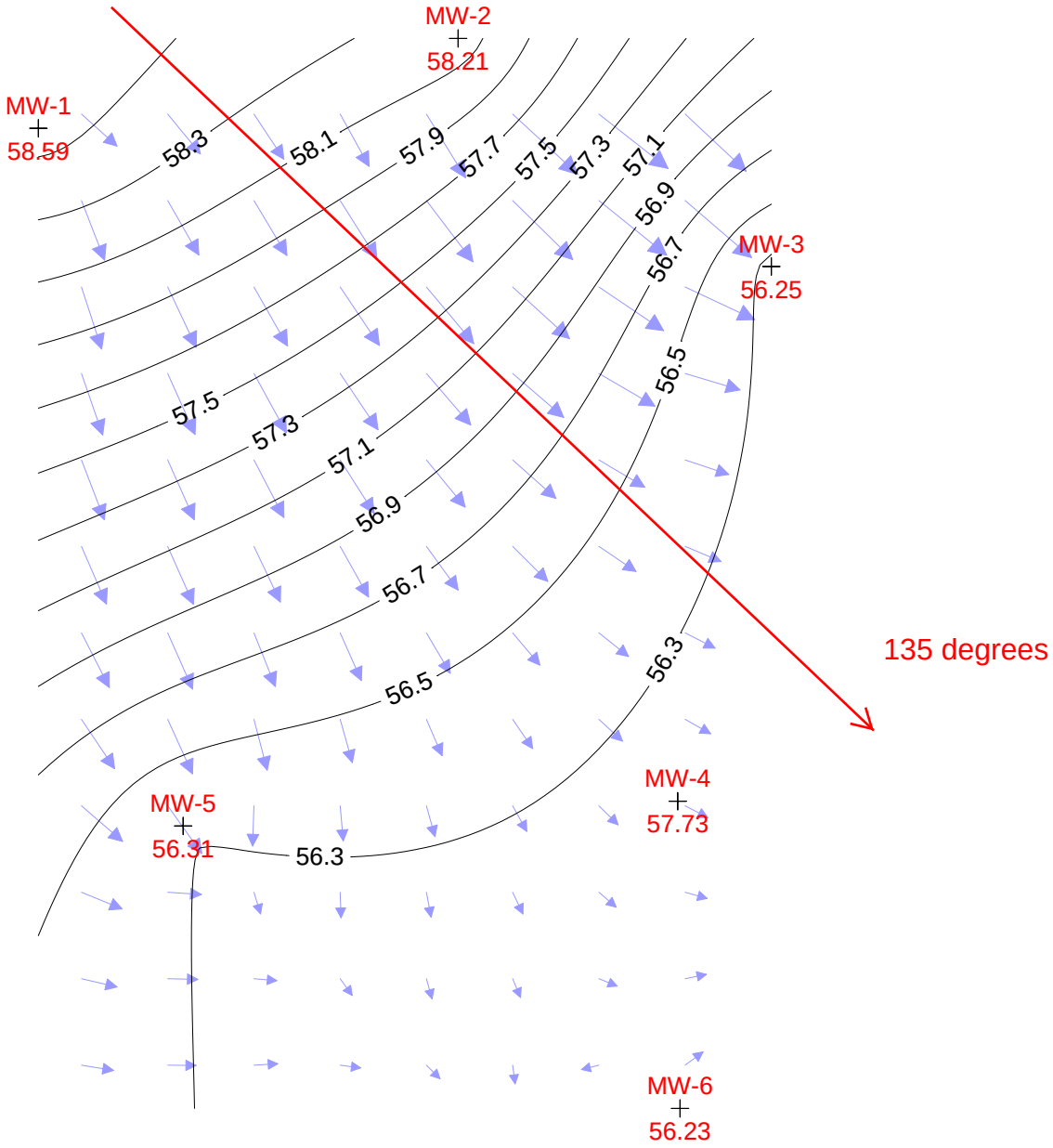
Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 3/3/16

**MW-4 elevation not used for this for this map since groundwater elevation likely affected by nearby air injection system.**

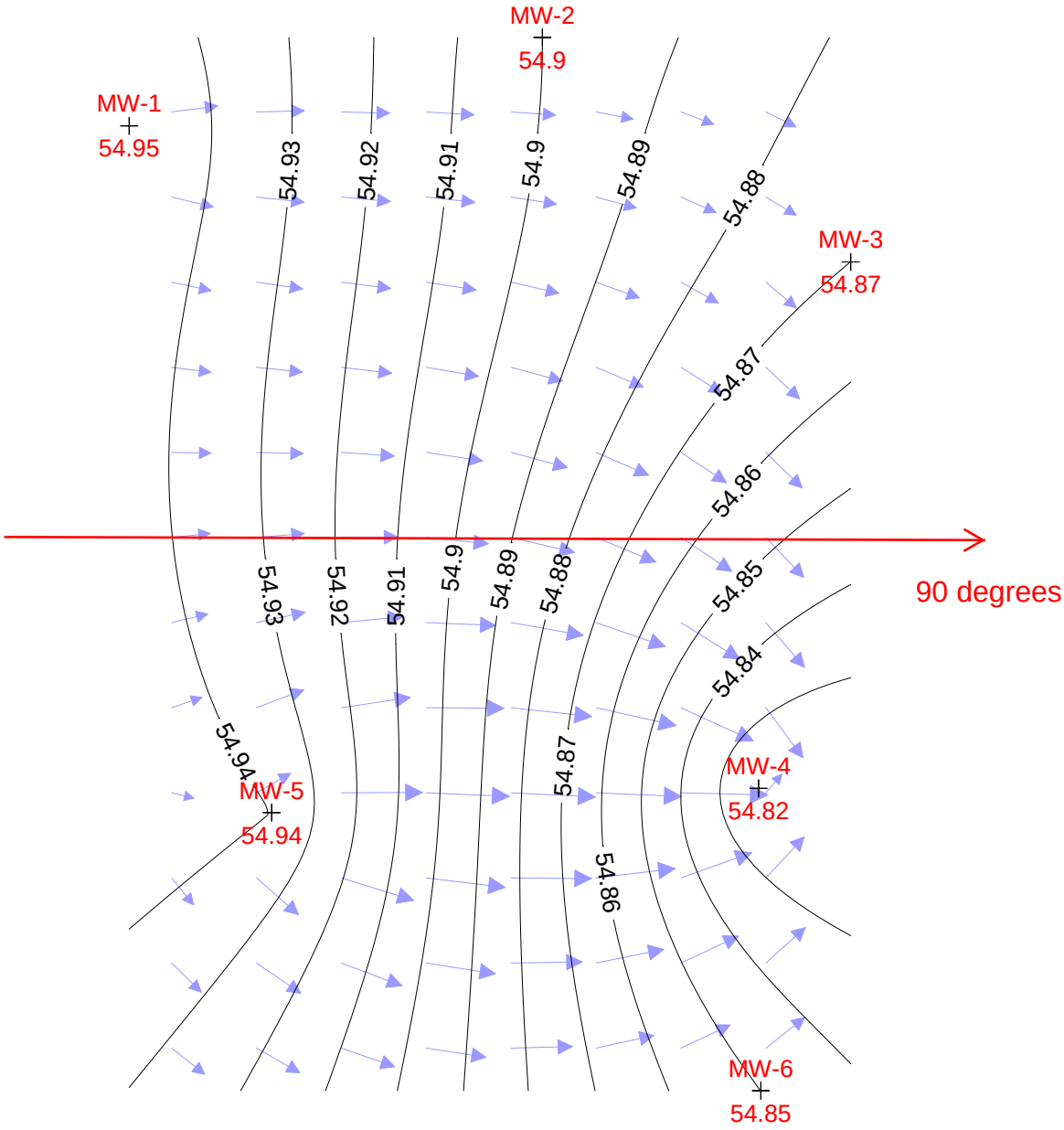



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 6/21/16



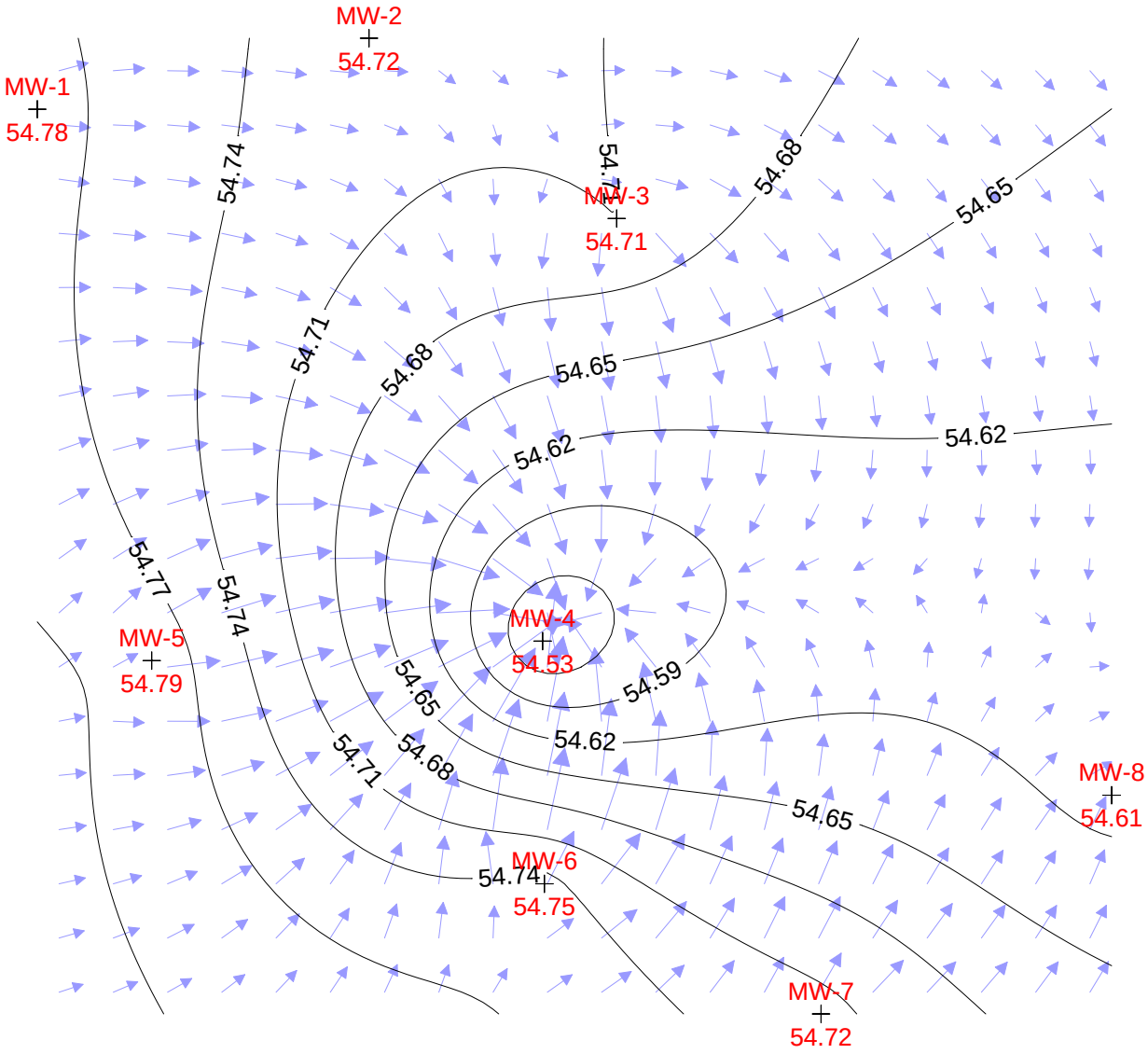

Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 9/16/16

Not Used



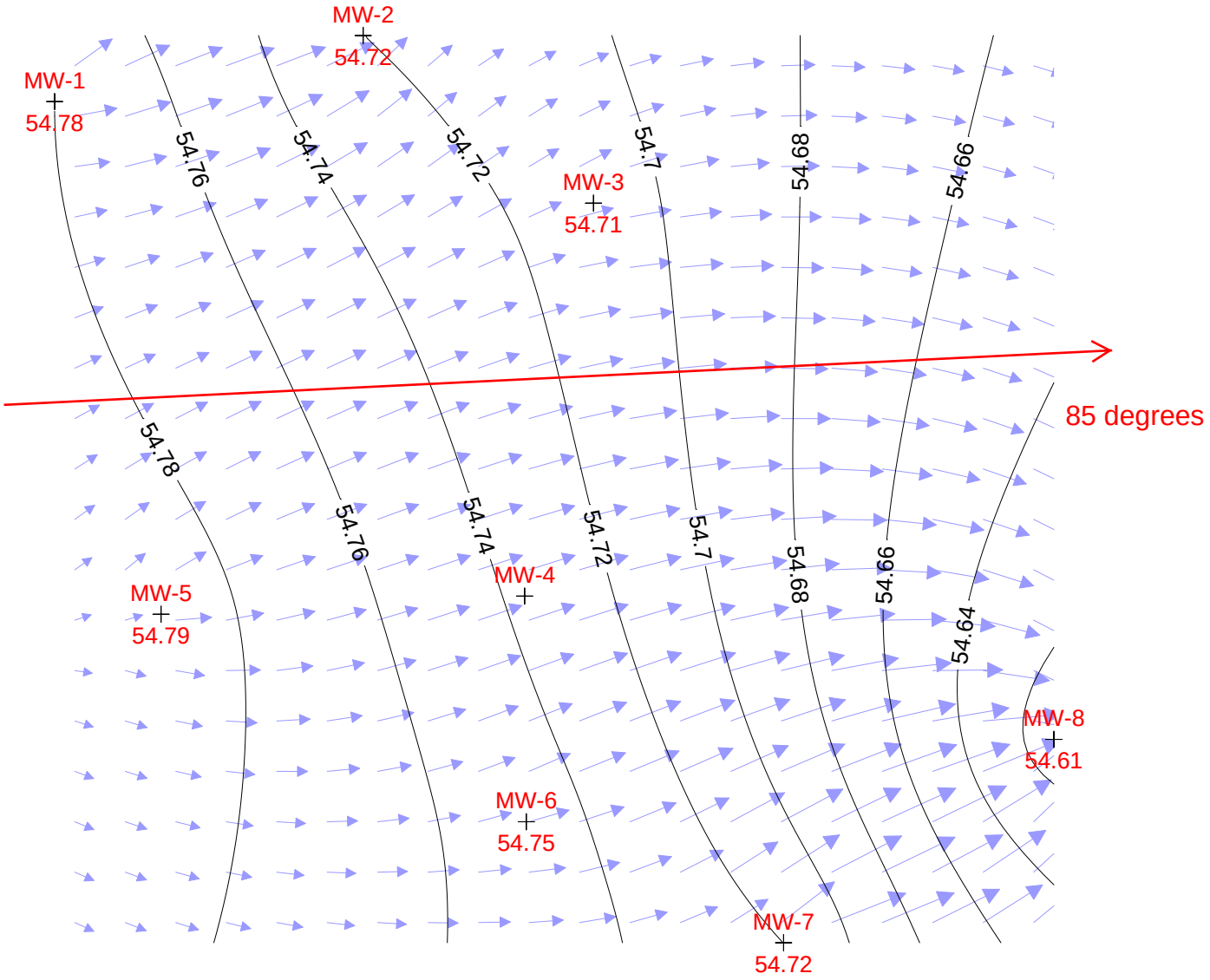

Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 9/16/16

**MW-4 elevation not used for this for this map since groundwater elevation likely affected by nearby air injection system.**

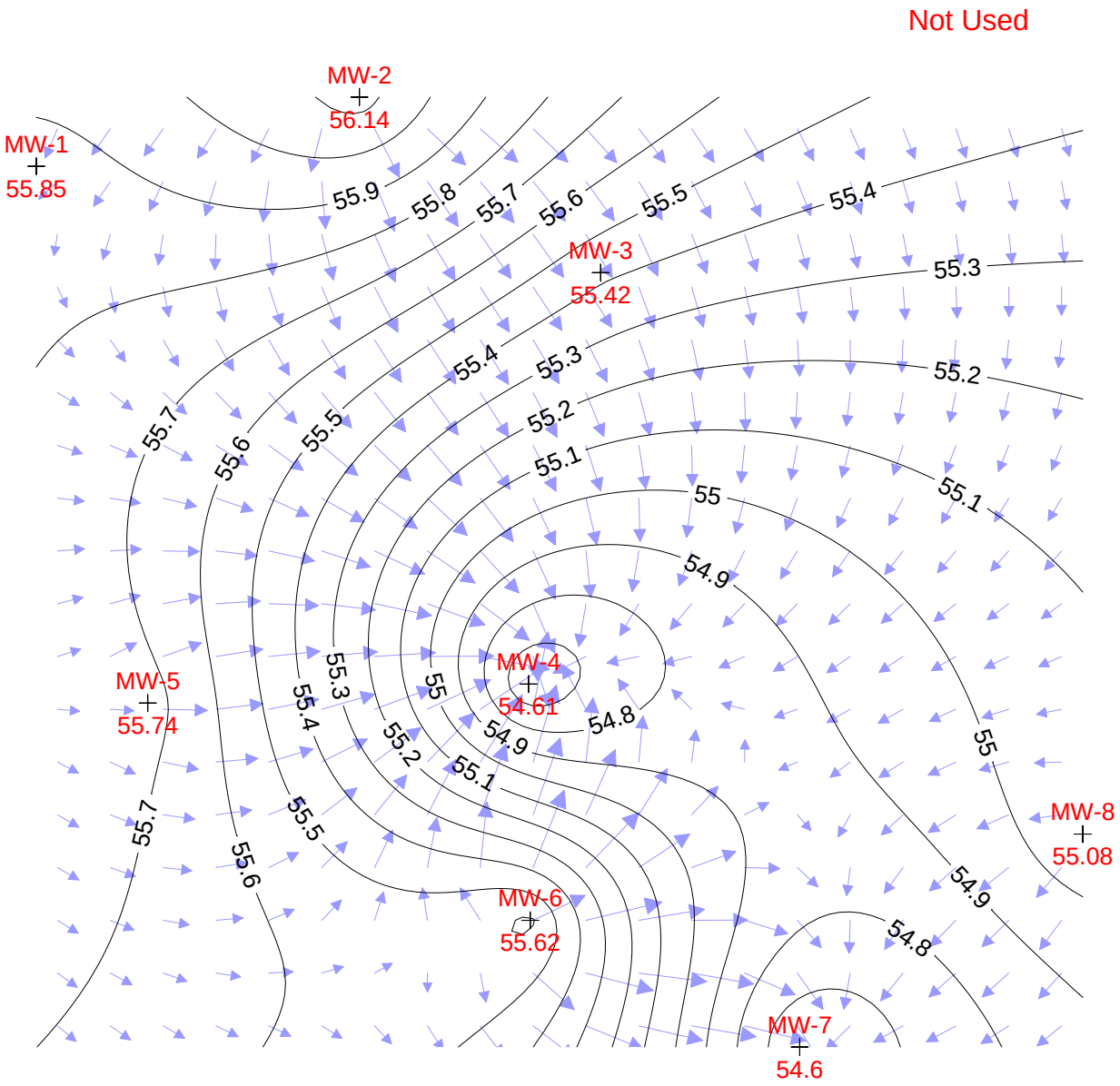



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 12/20/16



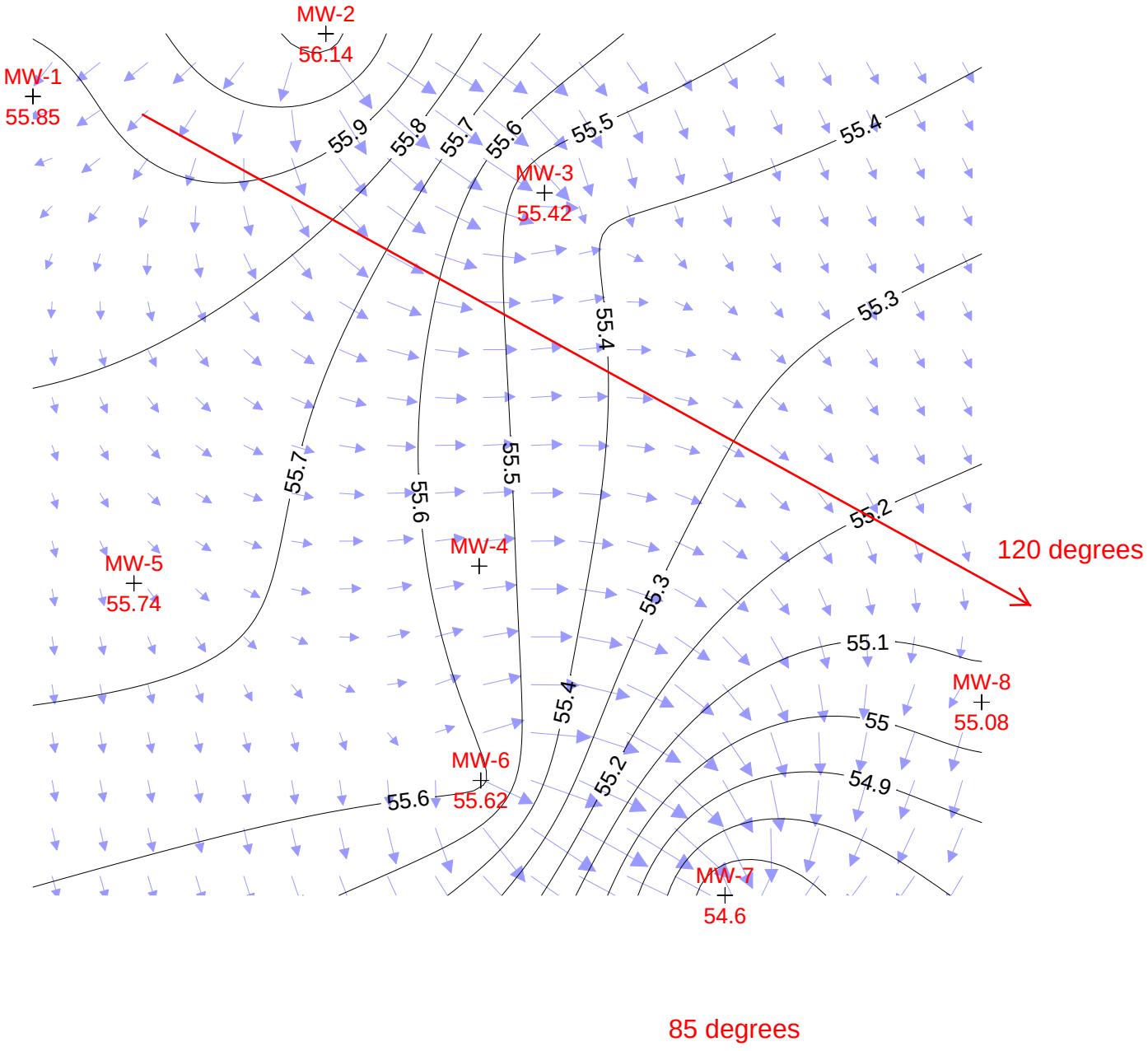

Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 12/20/16

**MW-4 elevation not used for this for this map since groundwater elevation likely affected by nearby air injection system.**

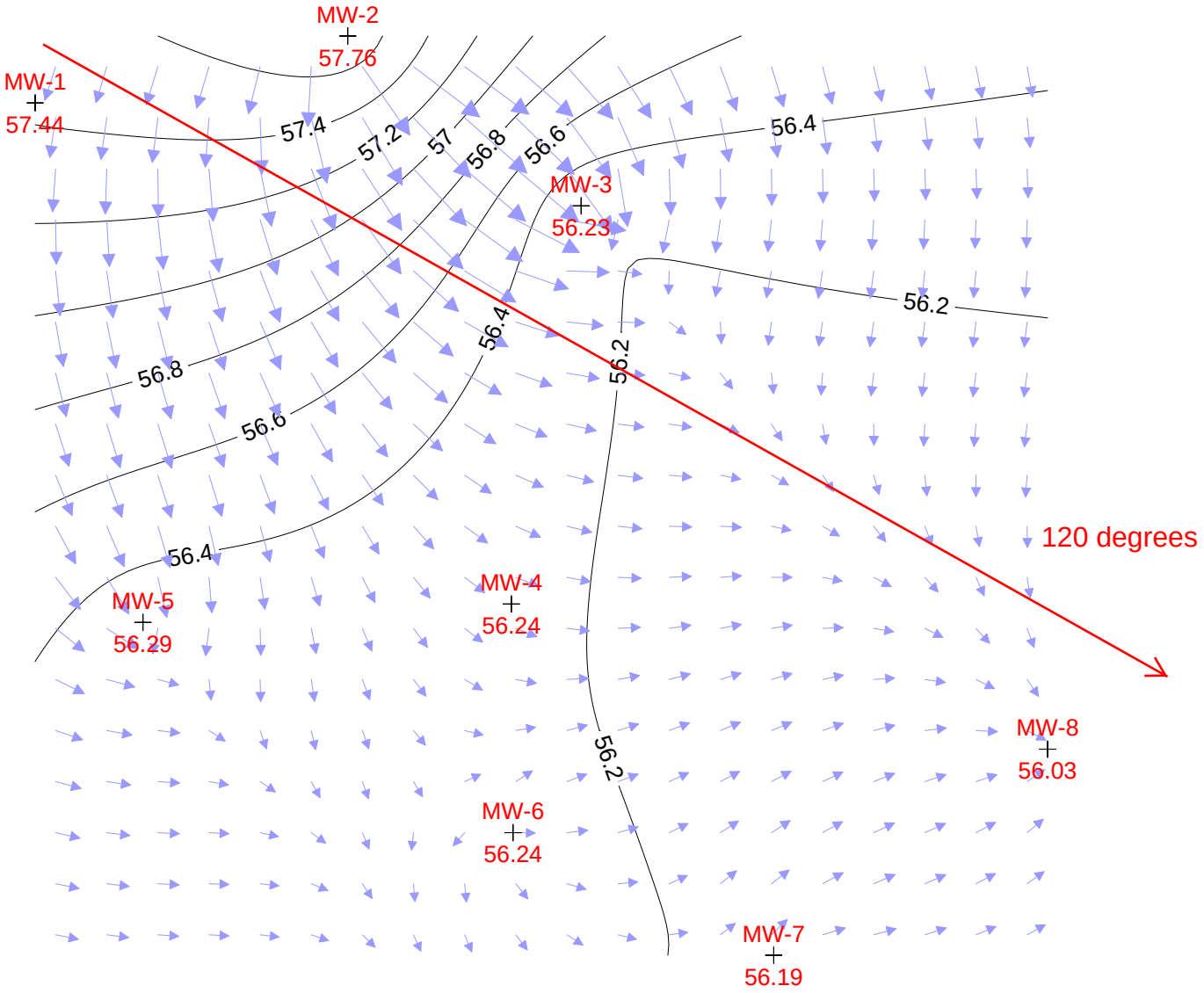



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 3/24/17

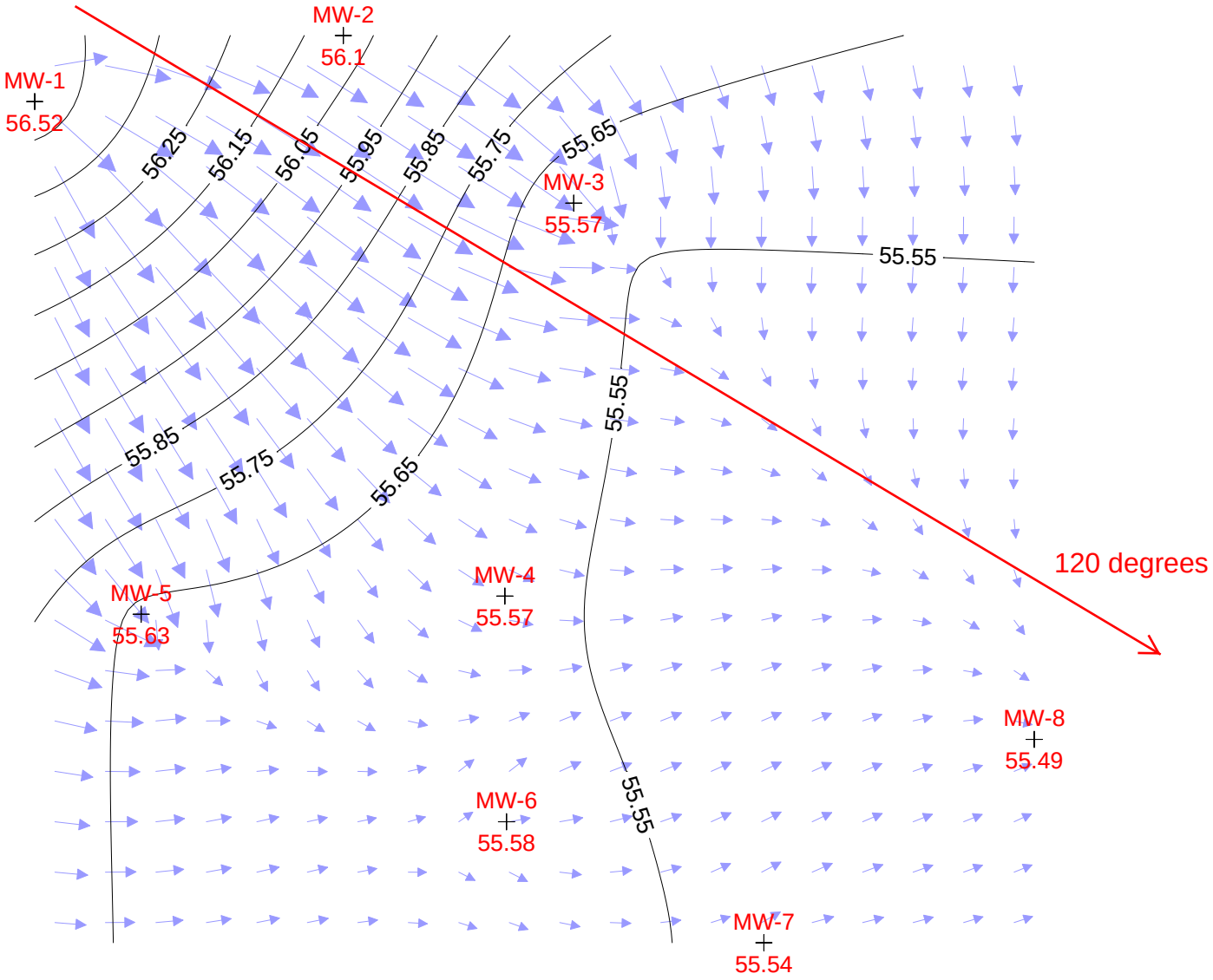



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 6/16/17

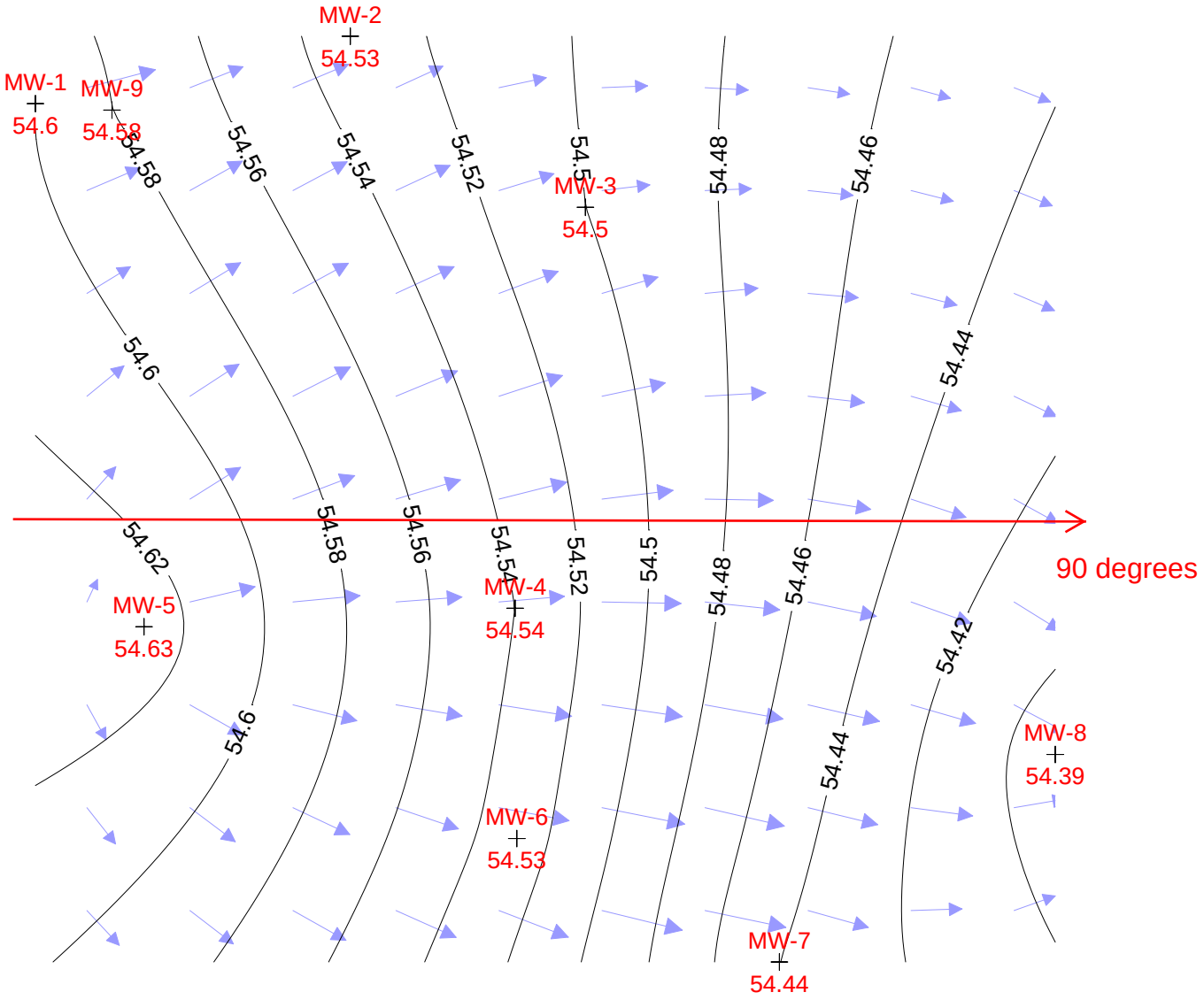



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

**9/5/17**

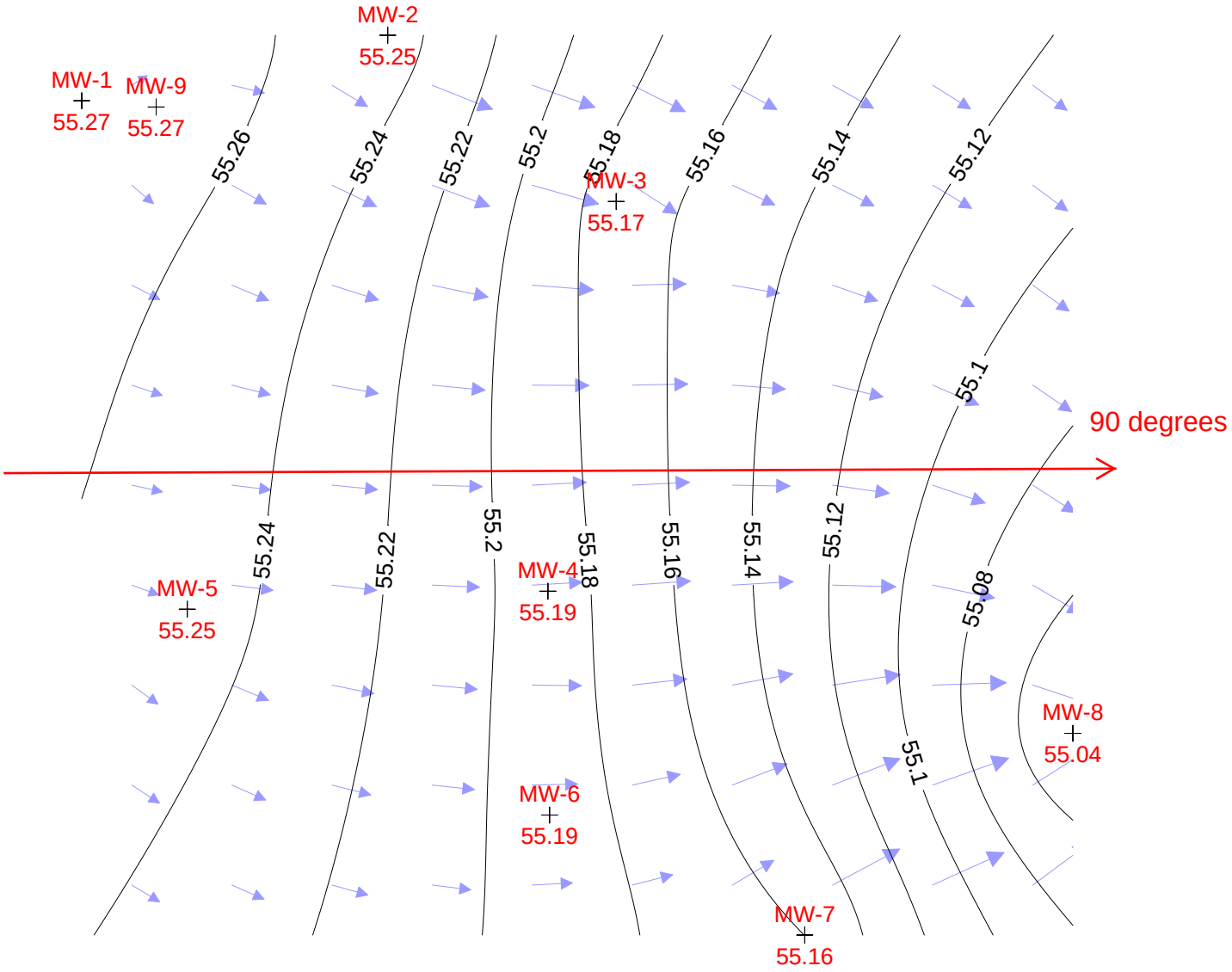



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 5/17/18

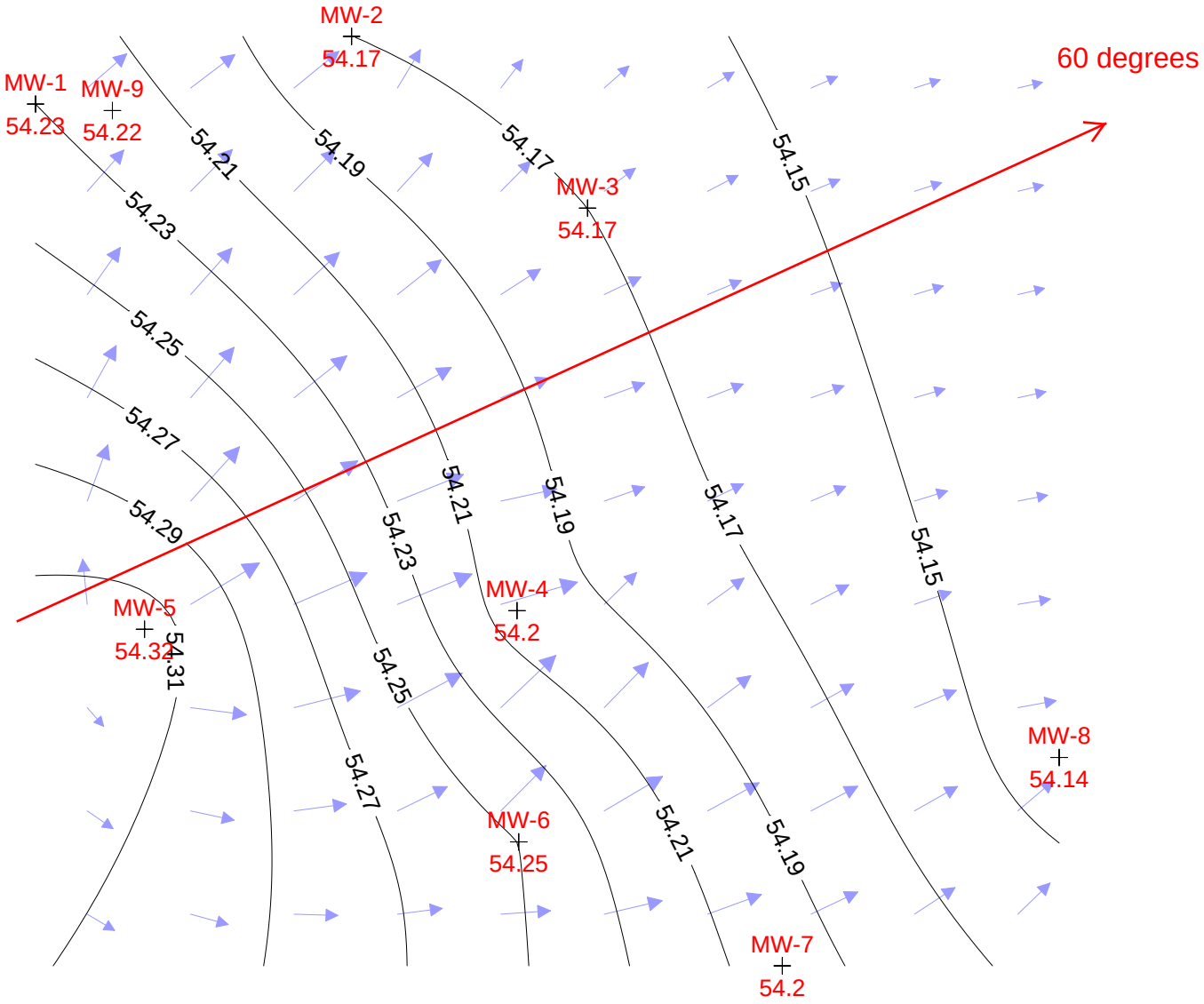



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

### 8/23/18

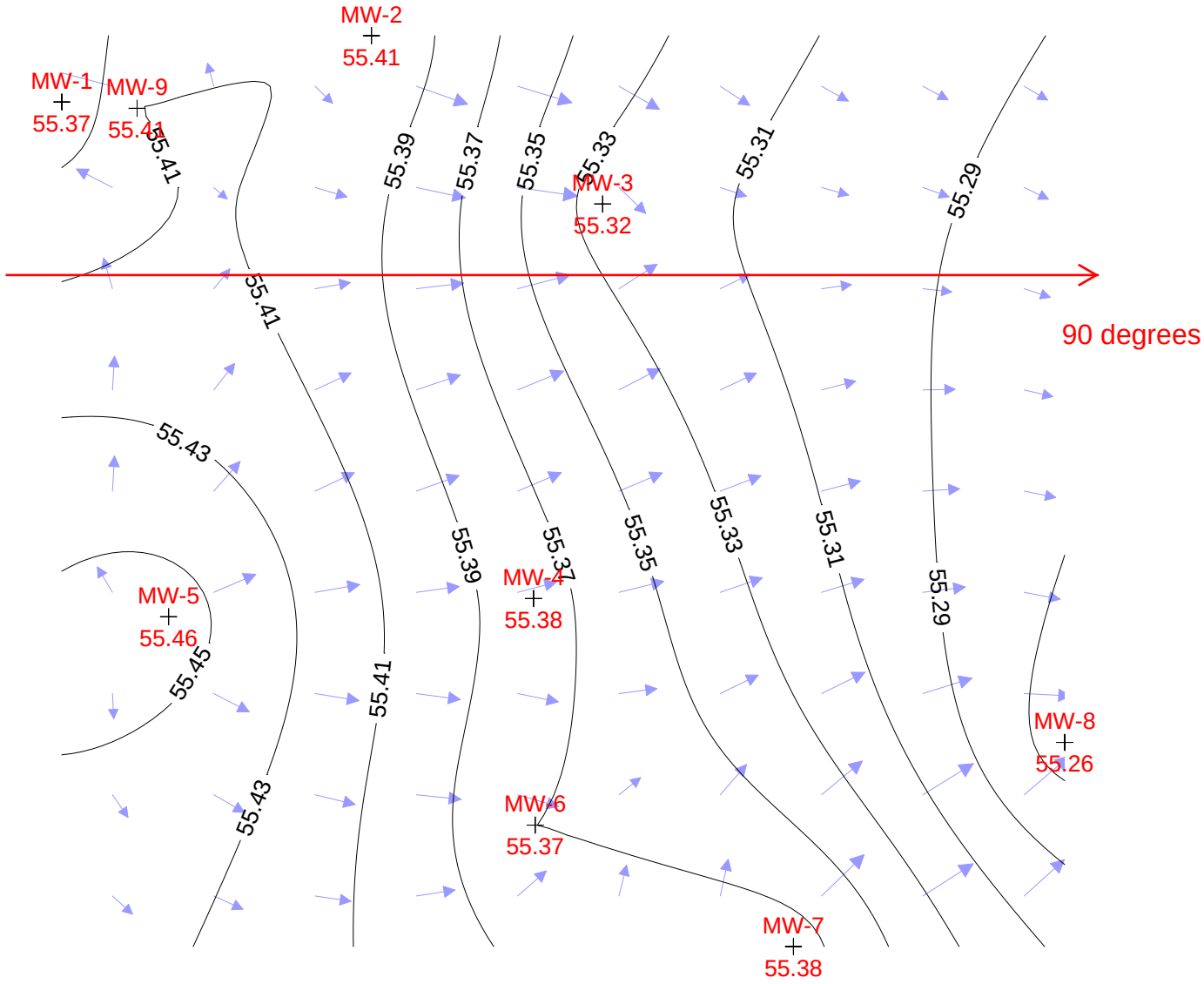



Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.

# FORMER PROVISIONERS EXPRESS FACILITY

## Groundwater Contour Map

**11/15/18**




Groundwater contour lines presented on this figure were generated by the Kriging method using Surfer® 13 software.