# *EFFECTS OF DEICING SALTS ON THE CHLORIDE LEVELS IN WATER AND SOIL ADJACENT TO ROADWAYS*

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**16. Abstract**
In 1971, the Michigan Department of Transportation began a study of the effects of roadway deicing salts on the chloride levels in roadside soils and groundwater.  Monitoring included sampling of surface water from ponds, streams, and drains, as well as from shallow groundwater wells that received recharge from surface water drainage from the roadways containing chlorides from winter maintenance deicing applications.  Monitor well arrays were situated on roadway segments along a north-south trunkline system extending from the northern Lower Peninsula to the south-central region of the State.  Chloride levels were monitored during the period from 1976 through 2006 at which time the investigation was ended.  Results of the monitoring showed that the chlorides applied to the roadways are diluted by precipitation which prevents chloride build-up in the roadside soils and groundwater.  The levels of chloride in the roadside surface waters also were found to be within acceptable limits.  Caution is recommended regarding the use of alternative organic deicers that may result in biodegradation of the roadway infrastructure by bacteria and other organisms known to be in the roadway environment.



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**MICHIGAN DEPARTMENT OF TRANSPORTATION**
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# Effects of Deicing Salts on the Chloride Levels in Water and Soil Adjacent to Roadways

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# INTRODUCTION

In 1971, the Michigan Department of Transportation began a study of the effects of roadway deicing salts on the chloride levels in roadside soils and groundwater. Sampling locations were established along a major north-south state trunkline system to monitor deicing salt infiltration in areas experiencing winter conditions ranging from heavy snow accumulations in the northern region of the Lower Peninsula, to sleet and freezing rain in the southern region.

The pilot phase of the study, conducted during the 1971-72 period, involved selection of suitable sampling locations, placement of groundwater observation wells, and development of sample testing procedures. From the initial test findings a format for routine sampling was established. Preliminary sampling proceeded into 1973 at which time the study was temporarily suspended due to loss of qualified personnel.

In 1975, increased concern over the harmful effects of deicing salts led to reactivation of the study. In addition to the monitoring of chloride levels at selected field locations, the study included a literature search for possible alternatives to the use of chloride deicers, and for recommended procedures to be followed to minimize the harmful effects of chlorides. A progress report, Research Report No. R-1022 issued in 1976, presented the scope of the study, locations of the groundwater monitor wells, and the results of a literature search(1). Figure A-1 of the appendix shows the locations of the groundwater monitor well arrays.

The intensive monitoring phase of this investigation involved the biweekly sampling of groundwater, streams, and ponds adjacent to roadways, and biweekly sampling of shoulder gravels from statewide monitor sites along I-69, US-27 (now US-127), US-10 and I-75 on a year round basis from 1976 through 1984 at which time the project was again temporarily suspended. The results of the monitoring were presented in an interim progress report, Research Report No. R-1279 issued in 1986(2). The report included an additional literature search. Recommendations of the report included resumption of less intensive roadside chloride monitoring.

In 1986, the statewide chloride monitoring project was resumed with biannual spring and fall samplings. Results of the samplings from 1986 through 1992 were presented in interim Research Report No. R-1322 issued in 1993(3). The results indicated a continuation of the low chloride levels in the roadside environment. The report included an action item for adding an additional groundwater monitoring location on a new roadway in the Lansing vicinity.

In 1998, after opening of a new section of US-127 north of Lansing, a seven-well array of groundwater monitoring wells was established, including a sub-grade drain sampling location. Biannual samplings in spring and fall from the statewide monitoring locations continued through 2006 at which time the statewide roadside chloride monitoring project was ended.

This final report presents a long-term overview of the roadside monitoring from the well arrays and associated drain locations, expressed as biannual spring and fall chloride levels measured at the groundwater monitoring arrays. For the overview, the chloride levels are shown as averages for each well array. The average chloride levels for the well arrays show the overall effect of the deicing salt in the roadside environment at the monitoring locations.

## SAMPLING AND ANALYSIS

Sampling for this study was structured to monitor the migration of roadway deicing salt into the roadside environment. The intensive phase of the study from 1980 through 1984 included monitoring of ponds and streams, shoulder gravels along the roadways, and roadside groundwater wells.

Shallow groundwater wells were established in areas of permeable soils that furnish direct groundwater recharge. Monitoring from the groundwater wells resumed in 1986 with a biannual sampling frequency in spring after frost melt and in fall before resumption of winter maintenance deicing. Samples were obtained from the groundwater wells at three of the four statewide locations originally established for the project (Figure A-1).

In 1984, monitoring from the well array along I-75 south of Grayling was discontinued due to poor recovery from the groundwater at approximately 30 feet below ground level. Chlorides from roadway deicing were not evident in the groundwater at this location. In 1998, an array of groundwater monitoring wells was established along a newly-opened segment of US-127 at Dewitt. Figures A-2 through A-6 of the appendix show the locations of the groundwater observation well arrays at the subject monitor locations.

In addition to the groundwater wells, a roadside sub-grade drain near the US-10 array of monitor wells at Clare was included in the study for the monitoring of chloride levels in drainage from the roadway. An additional sub-grade drain sampling site was included at the new US-127 location at Dewitt to monitor chloride levels in run-off before dilution in the groundwater.

Water samples were obtained for this investigation using several methods of retrieval including a centrifugal pump, pitcher pump, and dip-tube sampler. The water samples and shoulder gravel samples obtained for this investigation were analyzed in the laboratory for chloride ion content by titration according to the Mohr method using silver nitrate reagent and potassium chromate indicator.

## FINDINGS

Results of the groundwater monitoring conducted from 1976 through 2006 at the US-10 location indicated that the roadside groundwater chlorides increased slightly after the start of winter maintenance deicing treatment on the newly-opened roadway, with no long-term build-up of chlorides over the years. Records of annual winter maintenance salt usage on the trunklines monitored for this investigation were obtained for 13 winter maintenance periods. The records indicated that an average of 20 tons of salt was used per lane-mile for each winter maintenance period[(2)]. National Oceanic and Atmospheric (NOAA) records of total annual precipitation obtained for the same years indicated that the monitoring locations received an average 32 inches of precipitation[(ibid)]. The amount of water in the total annual precipitation has adequately diluted the deicing chlorides to prevent build-up in the groundwater. Table A-1 of the appendix shows the average spring and fall chloride levels in groundwater sampled from the roadside wells.

Monitoring of roadside groundwater observation wells on I-75 south of Grayling, I-75 south of West Branch, and I-69 at Kinderhook indicated the same lack of long-term chloride build-up in the groundwater as annual precipitation has provided adequate dilution of the deicing salt. Tables A-2, A-3 and A-4 of the appendix show the average spring and fall chloride levels in the groundwater sampled from the roadside wells in these monitor arrays.

The results of groundwater monitoring at the US-127 location at Dewitt showed groundwater chloride levels in some of the wells that were uncharacteristically higher than those at the other statewide locations, indicating possible chloride intrusion from a source outside of the roadway right-of-way. Table A-5 of the appendix shows the average spring and fall chloride levels in the groundwater sampled from the wells at this location.

A literature search conducted for this project found that salt has been the least expensive deicing agent available(1). As an essential mineral for living organisms, common salt is one of the least harmful agents to release into the environment. Complex chemical deicers, which are considerably more expensive than salt, may contribute to presently unknown types of pavement and structure deterioration, as well as environmental distress. Organic deicing agents contain compounds that are nutrients for bacteria and other organisms in the roadside environment which may excrete acidic residues that will attack the Portland cement concrete and bituminous components of the roadway infrastructure. The literature search also found that the chloride levels measured in the roadside environment were within tolerable limits for pond life and roadside vegetation(ibid).

## CONCLUSIONS AND RECOMMENDATIONS

The results of monitoring of the groundwater chlorides at the selected statewide roadside locations from 1976 through 2006 show that the annual precipitation can provide adequate dilution of the winter maintenance deicing salt applications to prevent a build-up of chlorides in the groundwater. It is apparent that increased winter precipitation that requires increased deicing salt application for safe roads also provides increased water for the dilution of the additional salt, preventing accumulation of the salt in the roadside environment.

Alternative organic deicers, known to cause imbalances in aquatic environments due to nutrient properties which promote uncontrolled growth of undesirable organisms such as algae, should be used with caution. Calcium magnesium acetate (CMA) and other organic deicers, although less corrosive than salt, can also contain constituents which may be nutrients for organisms such as bacteria which are known to be active in the roadway environment. Such organisms may release acidic residues that cause deterioration of the Portland cement concrete and bituminous pavement infrastructure.

Major improvements in corrosion-resistance have been implemented by vehicle manufacturers, resulting in protection against the rusting problems that were previously prevalent due to the corrosive effects of deicing salt. Construction of new bridges and pavements now feature corrosion-resistant reinforcement components to eliminate the previous deterioration caused by rusting of corrosion-susceptible reinforcing steel.

Conservative use of salt for winter maintenance deicing appears to be the most economical procedure for maintaining safe roads.

# REFERENCES

1. Muethel, R. W. (1976), "Effects of Deicing Salts on the Chloride Levels in Water and Soil Adjacent to Roadways," Michigan Department of Transportation Interim Research Report No. R-1022.

2. Muethel, R. W. (1986), "Effects of Deicing Salts on the Chloride Levels in Water and Soil Adjacent to Roadways," Michigan Department of Transportation Interim Research Report No. R-1279.

3. Muethel, R. W. (1993), "Effects of Deicing Salts on the Chloride Levels in Water and Soil Adjacent to Roadways," Michigan Department of Transportation Interim Research Report No. R-1322.

**APPENDIX**

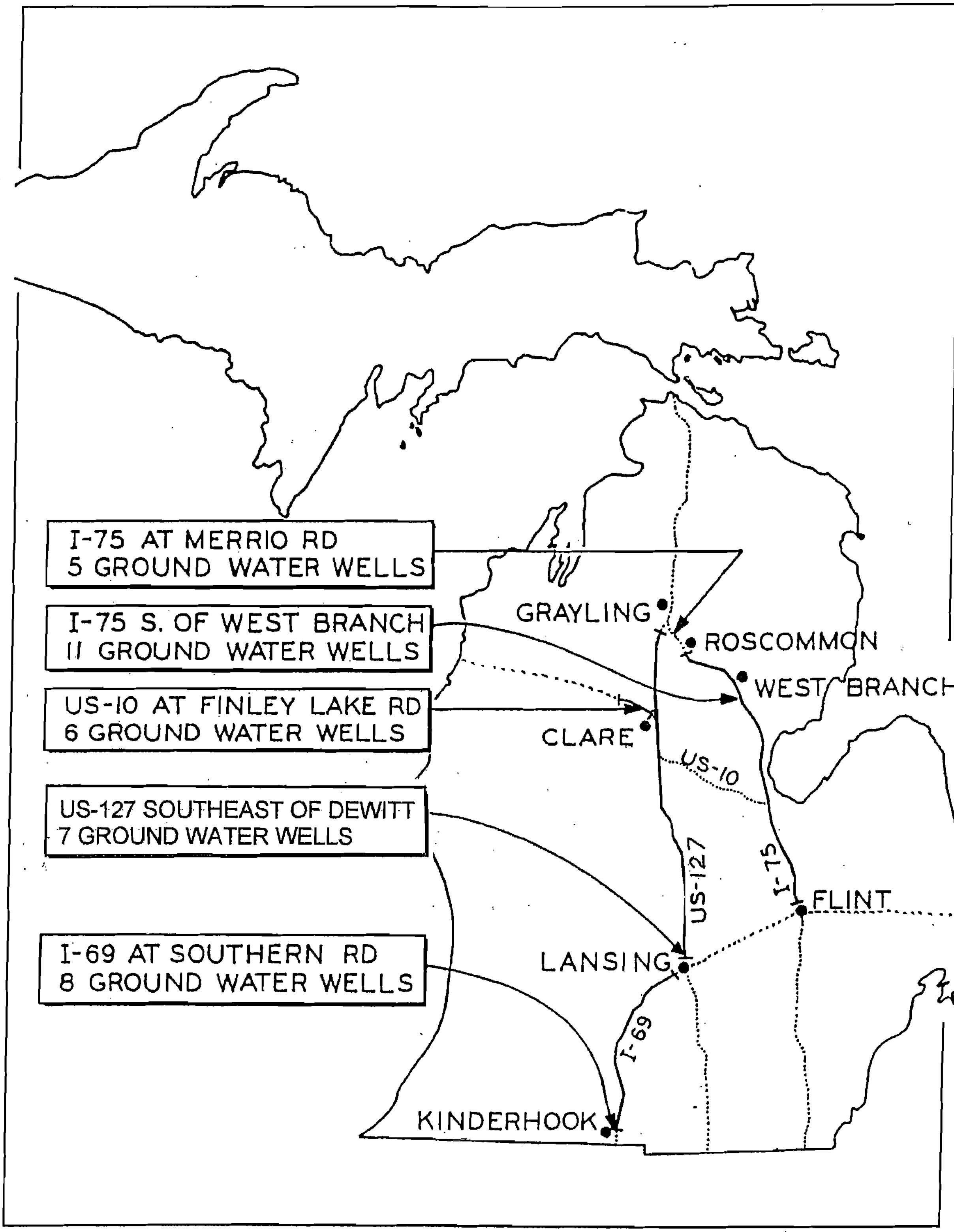


Figure A-1. Locations of ground water wells and state trunkline segments monitored.

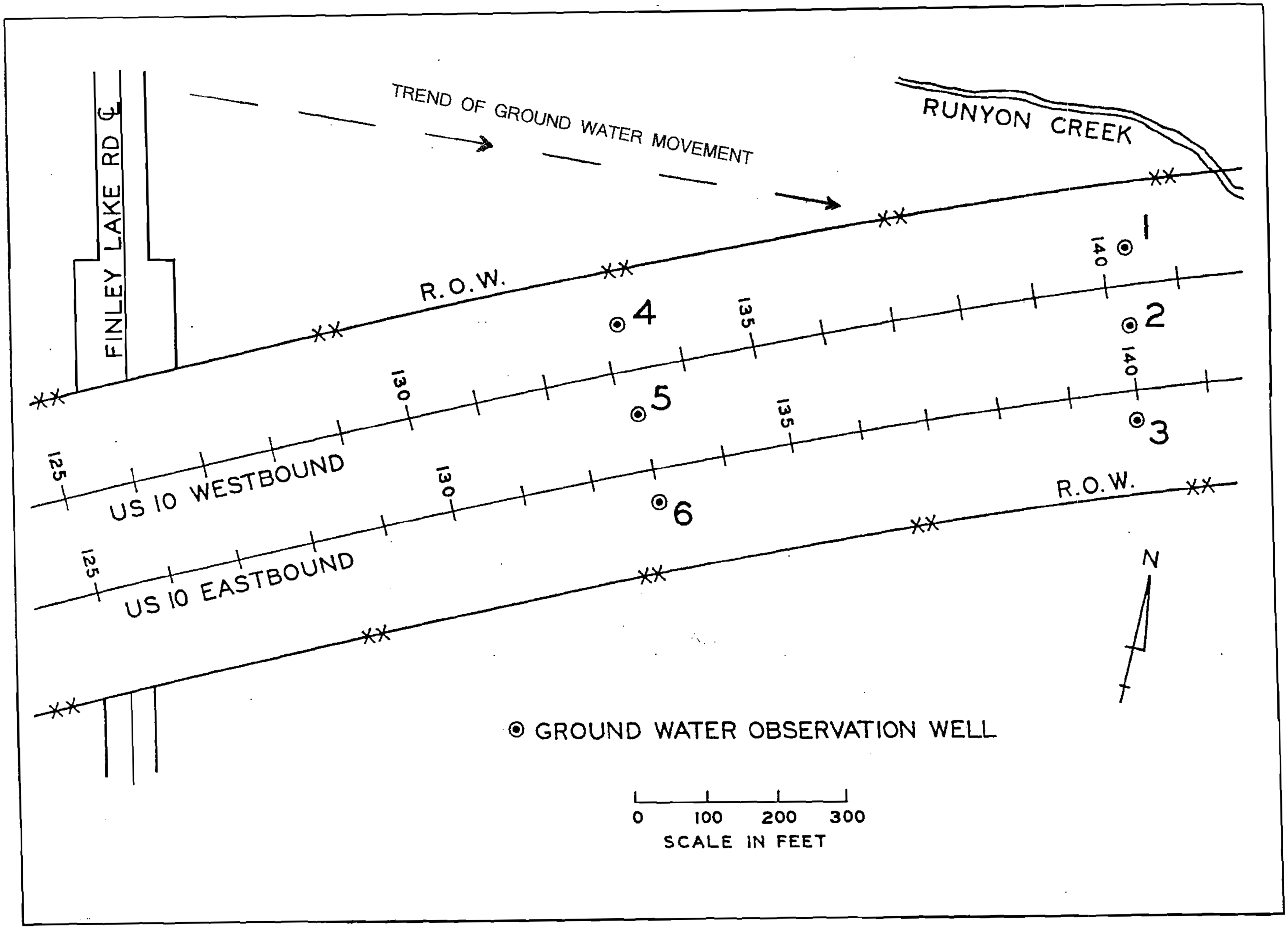


Figure A-2. US 10 well locations, vicinity of Finley Lake Road. Roadway opened to traffic in 1975.

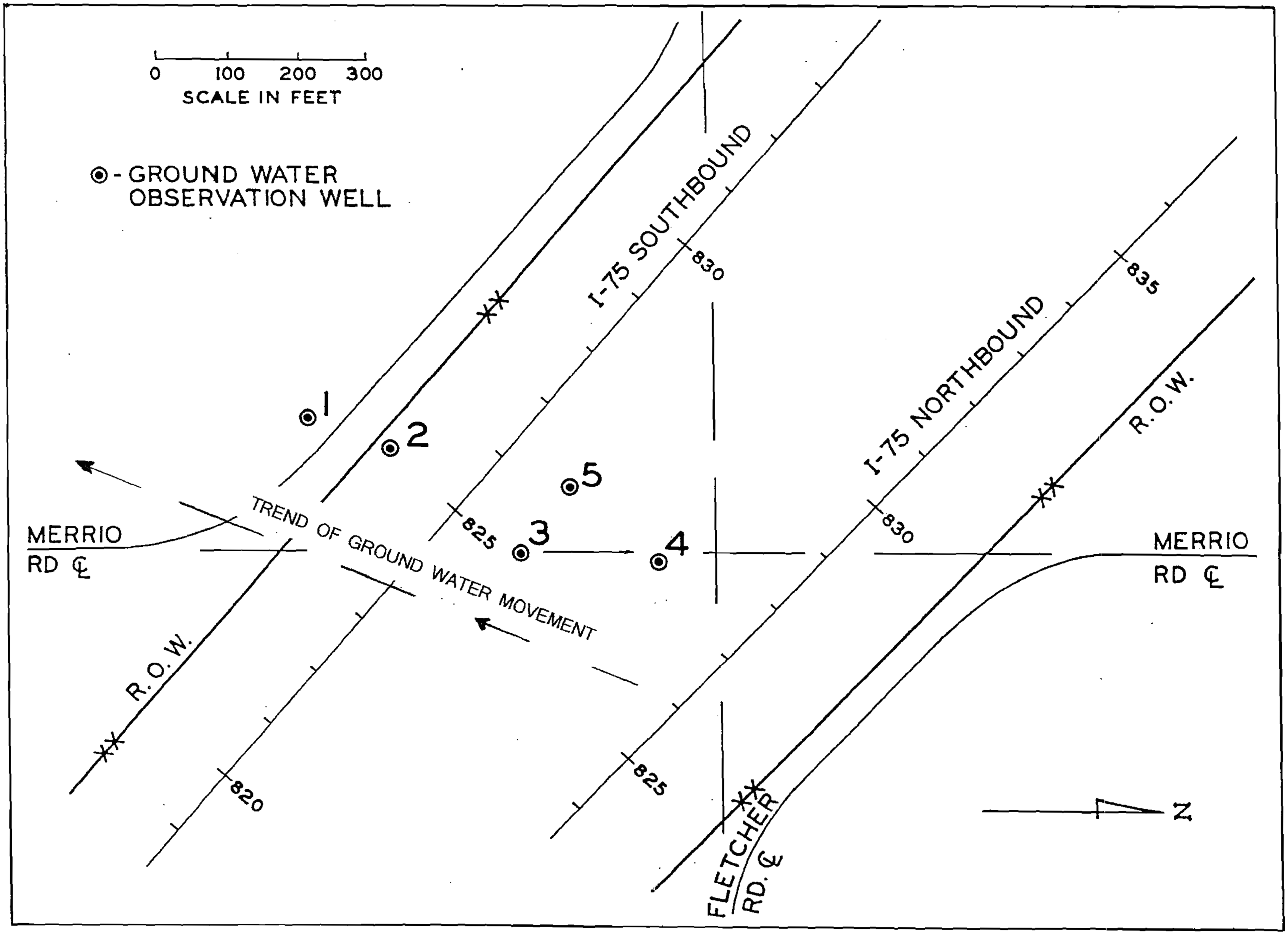


Figure A-3. I 75 well locations, south of Grayling. Roadway opened to traffic in 1971.

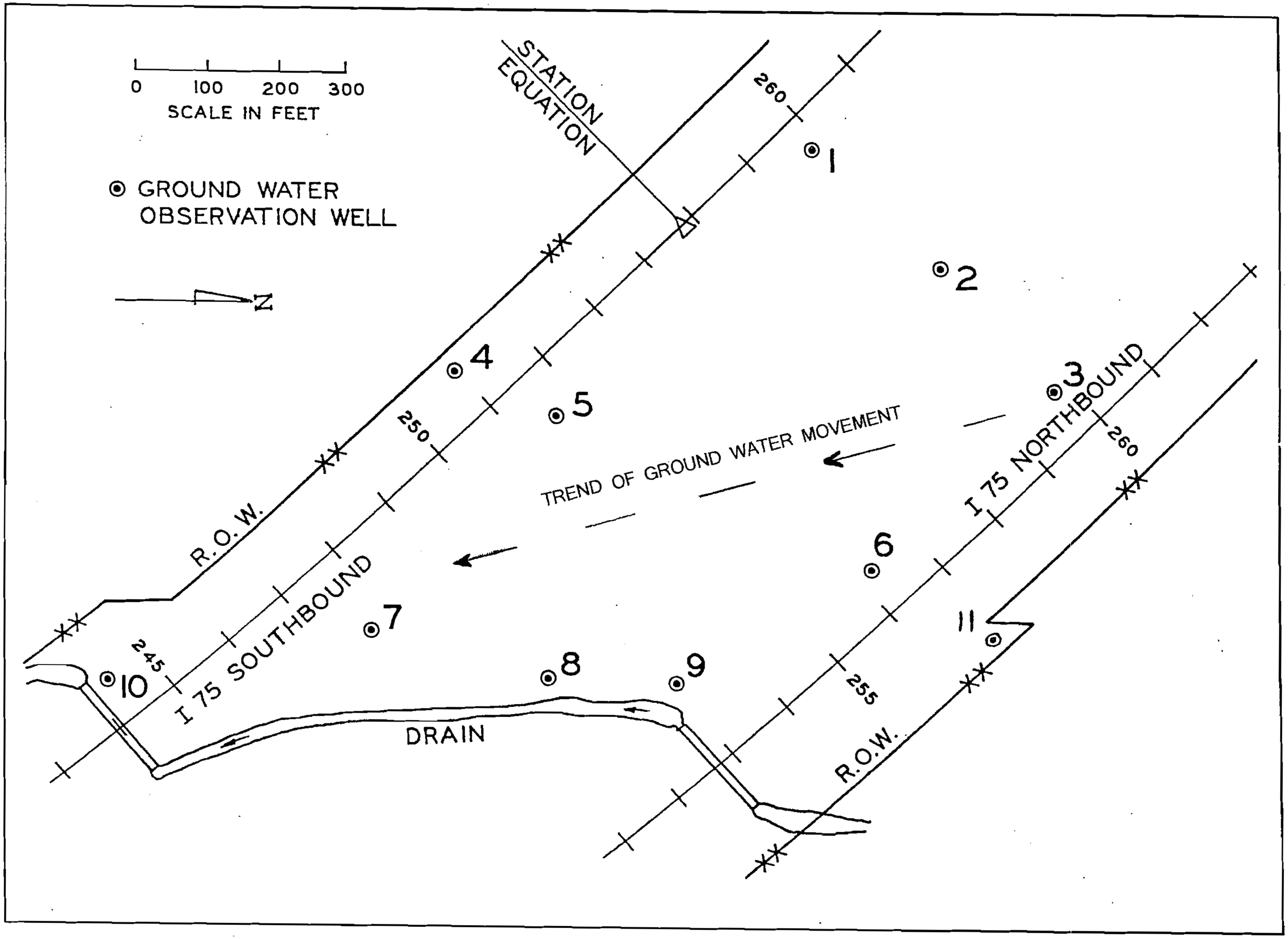


Figure A-4. I 75 well locations, south of West Branch. Roadway opened to traffic in 1971.

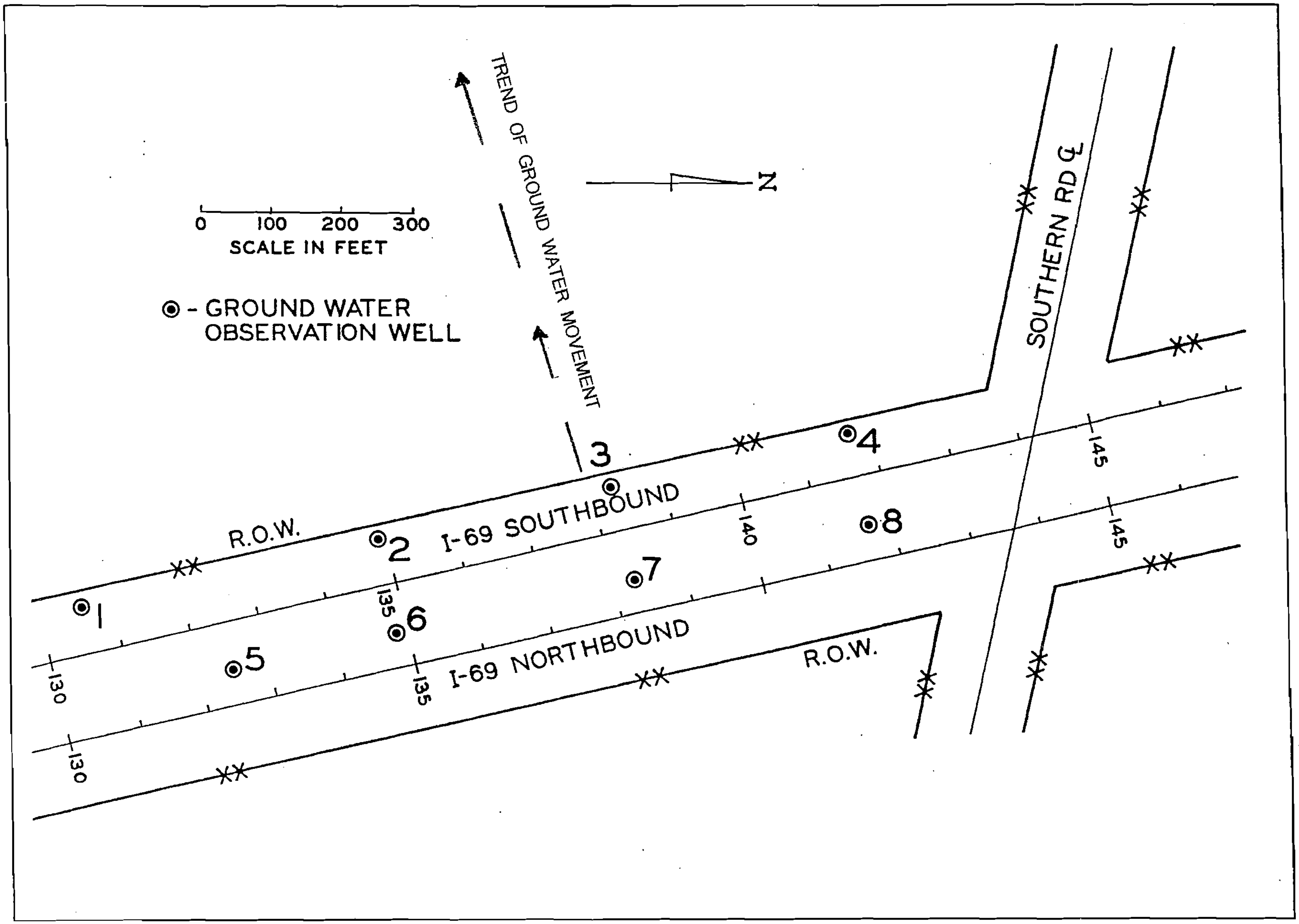


Figure A-5. I 69 well locations, vicinity of Southern Road. Roadway opened to traffic in 1967.

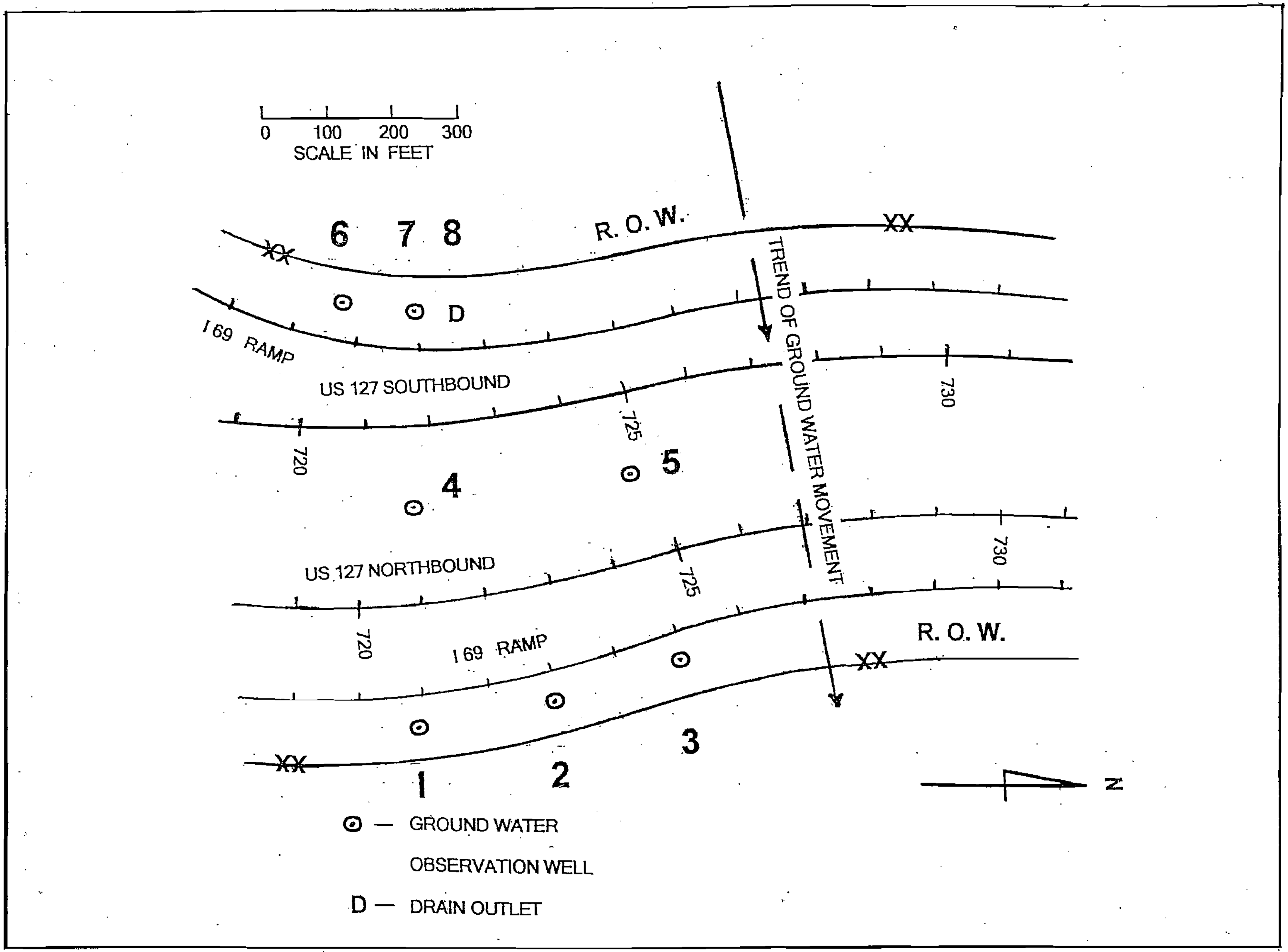


Figure A-6. US 127 well locations, southeast of Dewitt. Roadway opened to traffic in 1998.

| TABLE A-1<br>**Biannual Samplings from Clare US-10 Monitor Site** | | | | |
|---|---|---|---|---|
| | Groundwater Wells<br>Avg Chlorides, as ppm cl- | | Edge Drain, Sta 145 EB<br>Chlorides, as ppm cl- | |
| Year | Spring Sampling | Fall Sampling | Spring Sampling | Fall Sampling |
| 2006 | 47 | 40 | 156 | 78 |
| 2005 | 97 | 95 | 135 | 138 |
| 2004 | 64 | 42 | 181 | 35 |
| 2003 | 64 | 78 | 209 | 121 |
| 2002 | 52 | 41 | 103 | 67 |
| 2001 | 150 | 43 | 259 | 99 |
| 2000 | 124 | 55 | 135 | 78 |
| 1999 | 55 | 73 | 145 | 82 |
| 1998 | 44 | 88 | 100 | 52 |
| 1997 | 42 | 41 | 107 | 59 |
| 1996 | 42 | 16 | 103 | 63 |
| 1995 | 142 | 64 | 74 | 50 |
| 1994 | 27 | 46 | 110 | 43 |
| 1993 | 52 | 25 | 234 | 57 |
| 1992 | 15 | 22 | 164 | 82 |
| 1991 | 21 | 25 | 103 | 61 |
| 1990 | 26 | 32 | 154 | 46 |
| 1989 | 35 | 35 | 83 | 61 |
| 1988 | 32 | 22 | 117 | 60 |
| 1987 | ns | 61 | ns | ns |
| 1986 | ns | ns | ns | ns |
| 1985 | ns | ns | ns | ns |
| 1984 | 58 | 66 | 103 | 71 |
| 1983 | 45 | 35 | 99 | 57 |
| 1982 | 30 | 26 | 99 | 50 |
| 1981 | 43 | 38 | 113 | 50 |
| 1980 | 28 | 64 | 71 | 50 |
| 1979 | 38 | 33 | ns | ns |
| 1978 | 33 | 33 | ns | ns |
| 1977 | 24 | 9 | ns | ns |
| 1976 | 0 | 3 | ns | ns |

REMARKS: ns = not sampled

| TABLE A-2<br>**Biannual Samplings from Grayling I-75 Monitor Site** | | |
|---|---|---|
| | Groundwater Wells<br>Avg Chlorides, as ppm cl- | |
| Year | Spring Sampling | Fall Sampling |
| 1984 | 10 | 14 |
| 1983 | 21 | 14 |
| 1982 | 16 | 16 |
| 1981 | 13 | 15 |
| 1980 | 11 | 12 |
| 1979 | 23 | 20 |
| 1978 | 21 | 23 |
| 1977 | 11 | 5 |
| 1976 | 7 | 14 |

| TABLE A-3<br>**Biannual Samplings from West Branch I-75 Monitor Site** | | | | |
|---|---|---|---|---|
| | Groundwater Wells<br>Avg Chlorides, as ppm cl- | | Background Well<br>Chlorides, as ppm cl- | |
| Year | Spring Sampling | Fall Sampling | Spring Sampling | Fall Sampling |
| 2006 | 45 | 105 | 11 | 11 |
| 2005 | 55 | 69 | 4 | 14 |
| 2004 | 44 | 104 | 18 | 4 |
| 2003 | 78 | 163 | 7 | 4 |
| 2002 | 66 | 91 | 11 | 0 |
| 2001 | 53 | 90 | 14 | 18 |
| 2000 | 121 | 121 | 11 | 0 |
| 1999 | 105 | 138 | 4 | 0 |
| 1998 | 100 | 173 | 0 | 4 |
| 1997 | 73 | 95 | 4 | 0 |
| 1996 | 89 | 82 | 7 | 0 |
| 1995 | 69 | 45 | 0 | 4 |
| 1994 | 78 | 68 | 4 | 4 |
| 1993 | 54 | 79 | 7 | 4 |
| 1992 | 52 | 71 | 4 | 4 |
| 1991 | 54 | 62 | 11 | 4 |
| 1990 | 46 | 64 | 21 | 4 |
| 1989 | 49 | 64 | 58 | 22 |
| 1988 | 48 | 66 | 4 | 11 |
| 1987 | ns | 68 | ns | 11 |
| 1986 | ns | ns | ns | ns |
| 1985 | ns | ns | ns | ns |
| 1984 | 54 | 62 | 11 | 4 |
| 1983 | 67 | 65 | 7 | 7 |
| 1982 | 72 | 88 | 11 | 11 |
| 1981 | 64 | 84 | 7 | 14 |
| 1980 | 66 | 84 | 14 | 7 |
| 1979 | 68 | 86 | 15 | 15 |
| 1978 | 78 | 91 | 15 | 23 |
| 1977 | 29 | 37 | 0 | 9 |
| 1976 | 19 | 20 | * | * |

REMARKS: ns = not sampled
* well not established

**TABLE A-4**
**Biannual Samplings from Kinderhook I-69 Monitor Site**

| Year | Groundwater Wells Avg Chlorides, as ppm cl- | |
|---|---|---|
| | Spring Sampling | Fall Sampling |
| 2006 | 291 | 98 |
| 2005 | 130 | 180 |
| 2004 | 134 | 124 |
| 2003 | 254 | 186 |
| 2002 | 89 | 95 |
| 2001 | 153 | 85 |
| 2000 | 186 | 148 |
| 1999 | 222 | 98 |
| 1998 | 156 | 101 |
| 1997 | 402 | 165 |
| 1996 | 126 | 94 |
| 1995 | 152 | 110 |
| 1994 | 141 | 117 |
| 1993 | 175 | 156 |
| 1992 | 88 | 136 |
| 1991 | 84 | 122 |
| 1990 | 187 | 99 |
| 1989 | 109 | 95 |
| 1988 | 107 | 119 |
| 1987 | ns | 171 |
| 1986 | 163 | 120 |
| 1985 | ns | ns |
| 1984 | 113 | 86 |
| 1983 | 107 | 92 |
| 1982 | 138 | 83 |
| 1981 | 114 | 101 |
| 1980 | 144 | 91 |
| 1979 | 192 | 115 |
| 1978 | 125 | 99 |
| 1977 | 61 | 44 |
| 1976 | 69 | 27 |

REMARKS: ns = not sampled

**TABLE A-5**
**Biannual Samplings from Dewitt US-127 Monitor Site**

| Year | Groundwater Wells Avg Chlorides, as ppm cl- | | Drain Chlorides, as ppm cl- | |
|---|---|---|---|---|
| | Spring Sampling | Fall Sampling | Spring Sampling | Fall Sampling |
| 2006 | 439 | 356 | 85 | 78 |
| 2005 | 410 | 518 | 1355 | 1156 |
| 2004 | 476 | 522 | 78 | 613 |
| 2003 | 393 | 703 | 571 | 518 |
| 2002 | 360 | 474 | 60 | 833 |
| 2001 | 341 | 424 | 57 | ns |
| 2000 | 235 | 292 | 28 | 121 |
| 1999 | 153 | 244 | 11 | 273 |
| 1998 | ns | 21 | ns | 15 |

REMARKS: ns = not sampled