Appendix A. Climate Data.

The climate data for the NCDC cooperative observers and NDAWN have days of missing data. Some sites have considerable missing data including consecutive months of missing data.To create complete daily datasets for this study, the missing daily data for climate station was infilled with days from nearby stations. Tables A-1 through A-12 list the primary station in the first row and the stations that were used to infill missing data in the subsequent rows. The program used to infill the data, if it does not find data for the primary station for that day, moves down through the listed stations until it finds data for that day.

Figures A-2, A-4, A-6, A-8, A-10, A-12, A-14, A-16, A-18, A-20, A-22, and A-24 provide a graphical display of the infill process. If a bar occurs for mx tmp, mn tmp, or precip in the top half of the graph (positive y-axis), then no data was found for that day. A bar in the lower half of the graph (negative y-axis) indicates that an alternate station in the table was used to infill the data for precip, mn tmp, and/or mx tmp. As an example, if the bar is plotted on the precip line, then the precipitation is infilled with a value from the second table. If the bar is half the bar length up, then it is from the third station in the list. Each station, as one moves down the table, plots a half bar up. Therefore, the amount the bar is shifted upward on the plot shows the source of the infilled data.

The other figures show annual water precipitation (October to September) and potential evapotranspiration (PET) estimated from minimum and maximum temperature using the Penman-Monteith method (Allen and others, 1998).

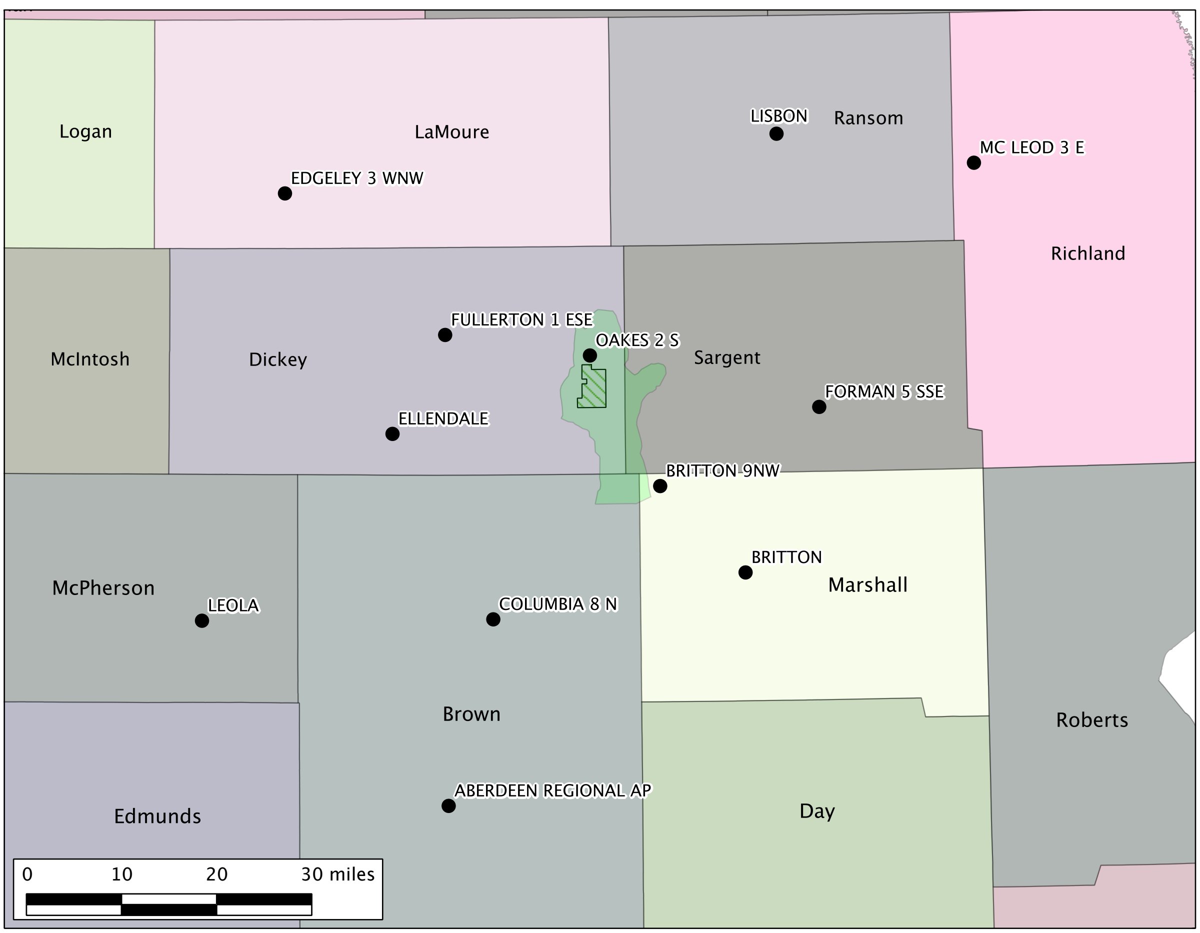


Figure A-1. Location of NOAA Cooperative observer sites presented in figures A-1 to A-25. North Dakota and South Dakota counties are shown.

Table A-1. List of NOAA Cooperative observer stations used to create Aberdeen, SD climate dataset.

Station	Start of Record	End of Record
ABERDEEN.NCD	01/01/1932	12/31/2009
COLUMB8N.NCD	09/01/1949	12/31/2009
LEOLA.NCD	01/01/1948	06/30/2007
BRITTON.NCD	01/01/1913	12/31/2009
BRITT9NW.NCD	04/01/2002	12/31/2009
Fullertn1894.daily2	01/02/1894	12/31/2005

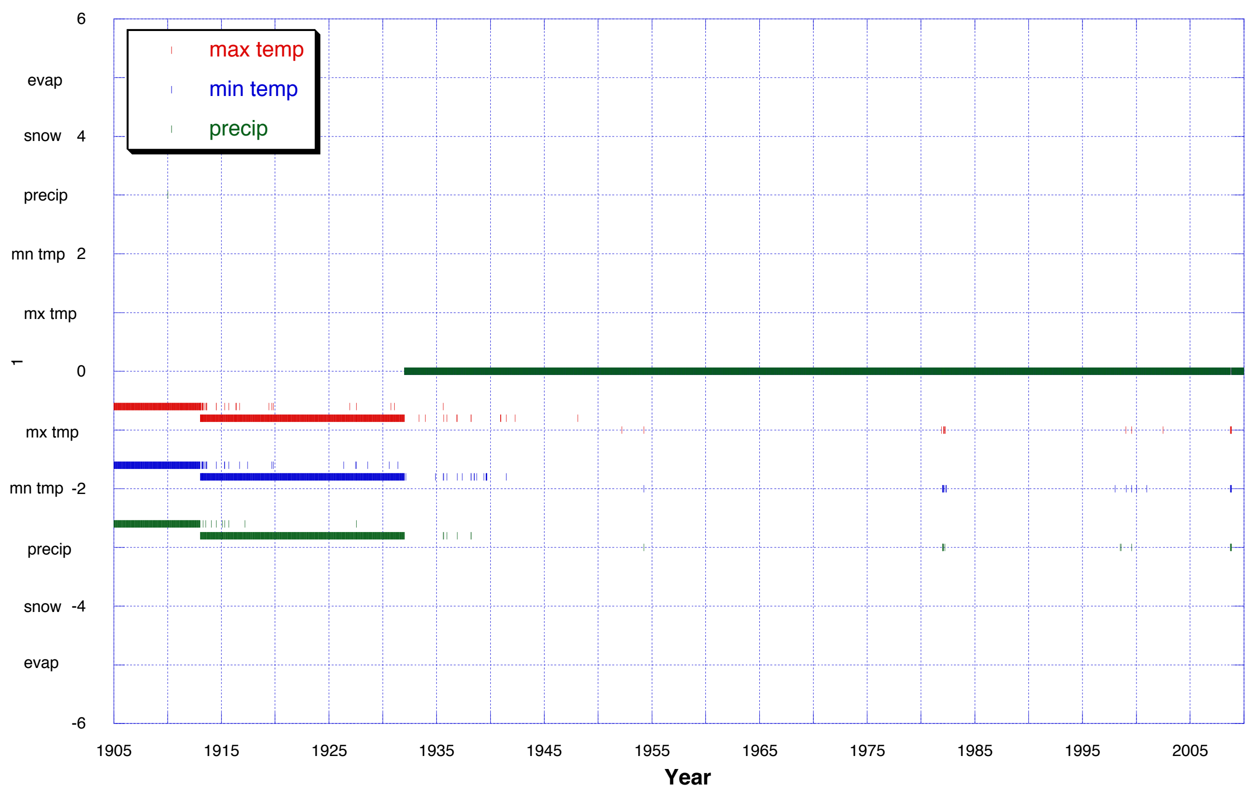


Figure A-2. Plot showing days with missing data at Aberdeen and stations used to fill in missing days.

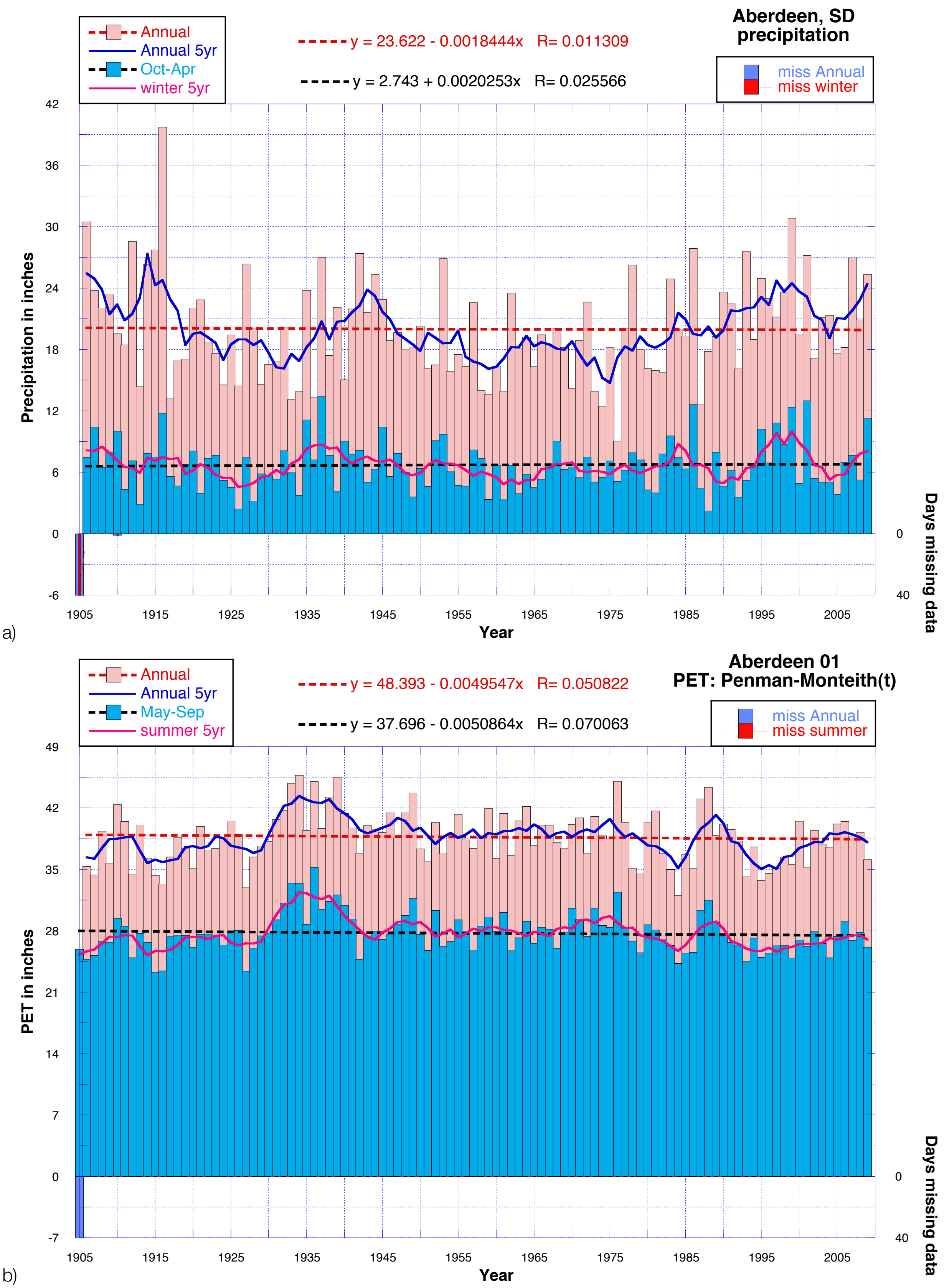


Figure A-3. Water year annual and winter a) precipitation and b) PET for Aberdeen, SD (dataset 01).

Table A-2. List of NOAA Cooperative observer stations used to create Britton, SD climate dataset.

Station	Start of Record	End of Record
BRITT9NW.NCD	04/01/2002	12/31/2009
BRITTON.NCD	01/01/1913	12/31/2009
COLUMB8N.NCD	09/01/1949	12/31/2009
Oakes1929.daily2	01/02/1929	12/31/2005
VERONA.NCD	08/01/1948	12/31/2009
FULLERTN.NCD	07/01/1948	12/31/2009
ELLENDA.NCD	07/01/1948	12/31/2009

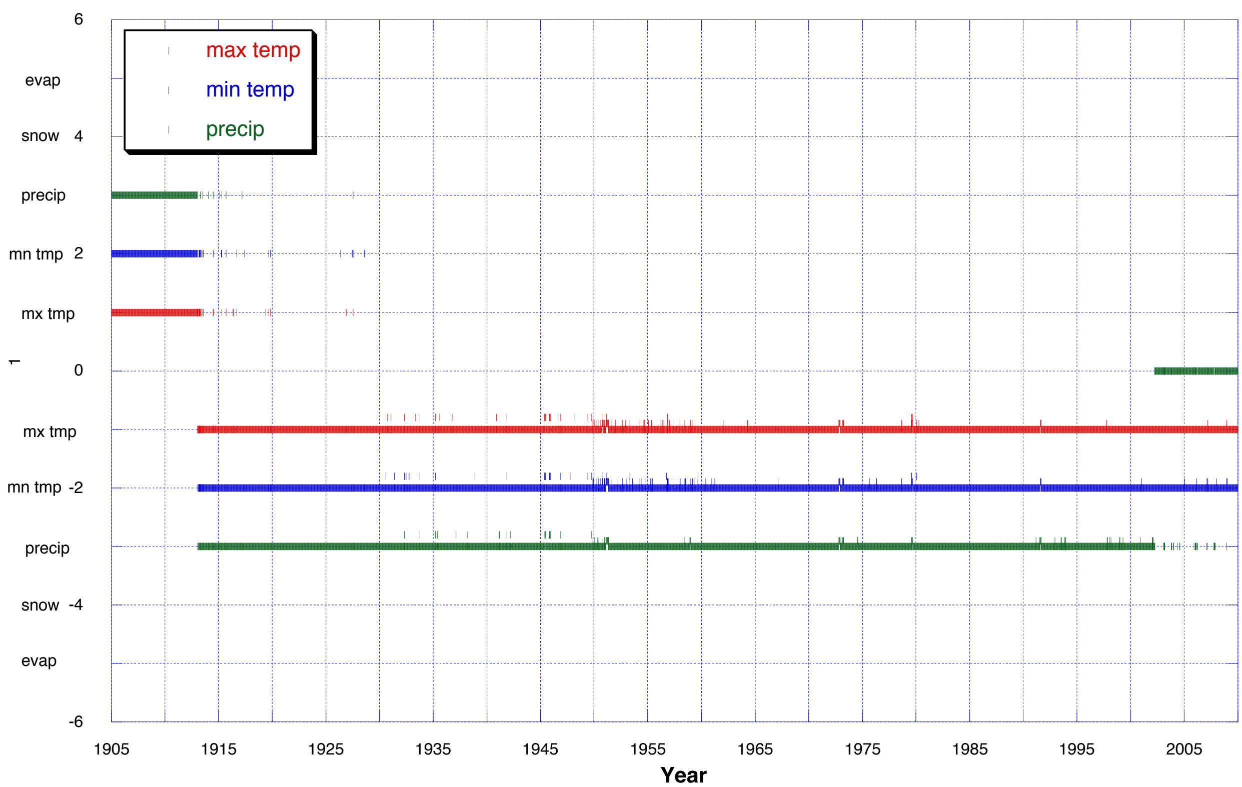
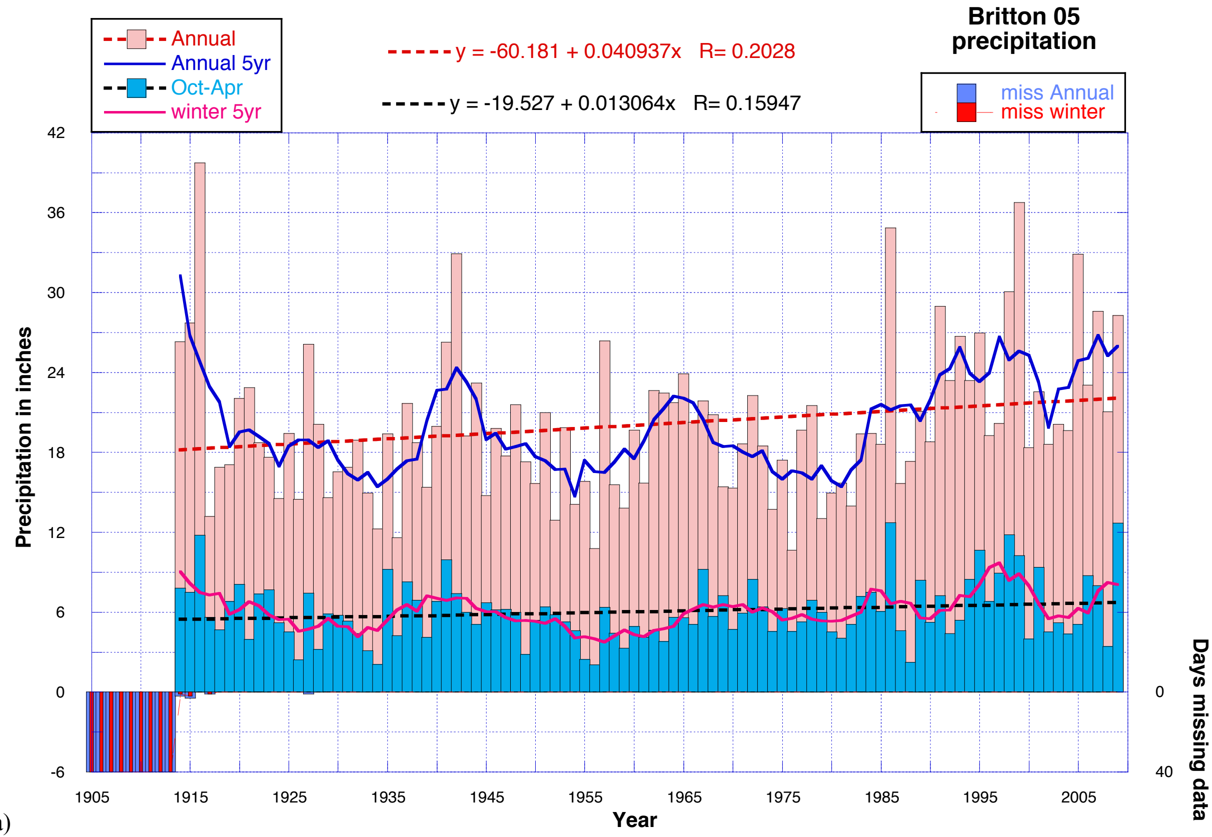
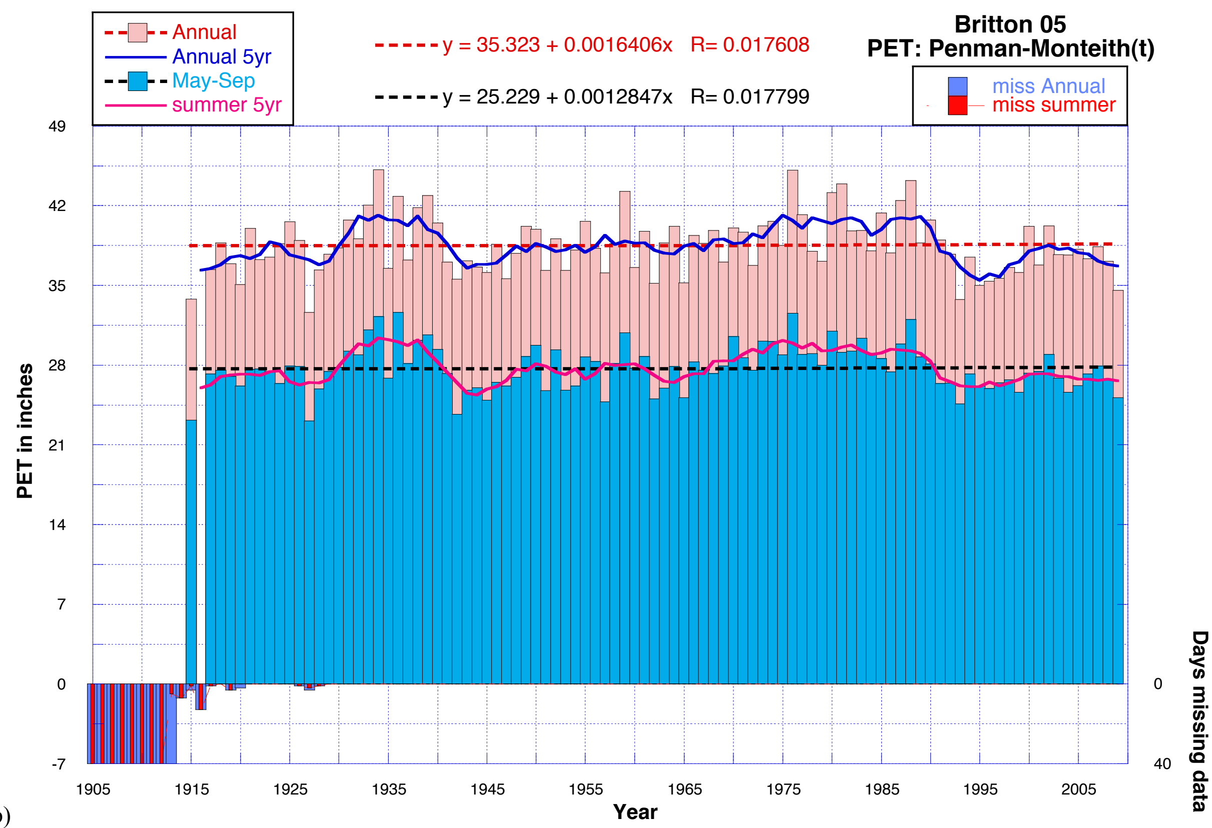


Figure A-4. Plot showing days with missing data at Britton and stations used to fill in missing days.



a)



b)

Figure A-5. Water year annual and winter a) precipitation and b) PET for Britton and Britton 9NW, SD (dataset 05).

Table A-3. List of NOAA Cooperative observer stations used to create Columbia 8N, SD climate dataset.

Station	Start of Record	End of Record
COLUMB8N.NCD	09/01/1949	12/31/2009
ABERDEEN.NCD	01/01/1932	12/31/2009
LEOLA.NCD	01/01/1948	06/30/2007
Oakes1929.daily2	01/02/1929	12/31/2005

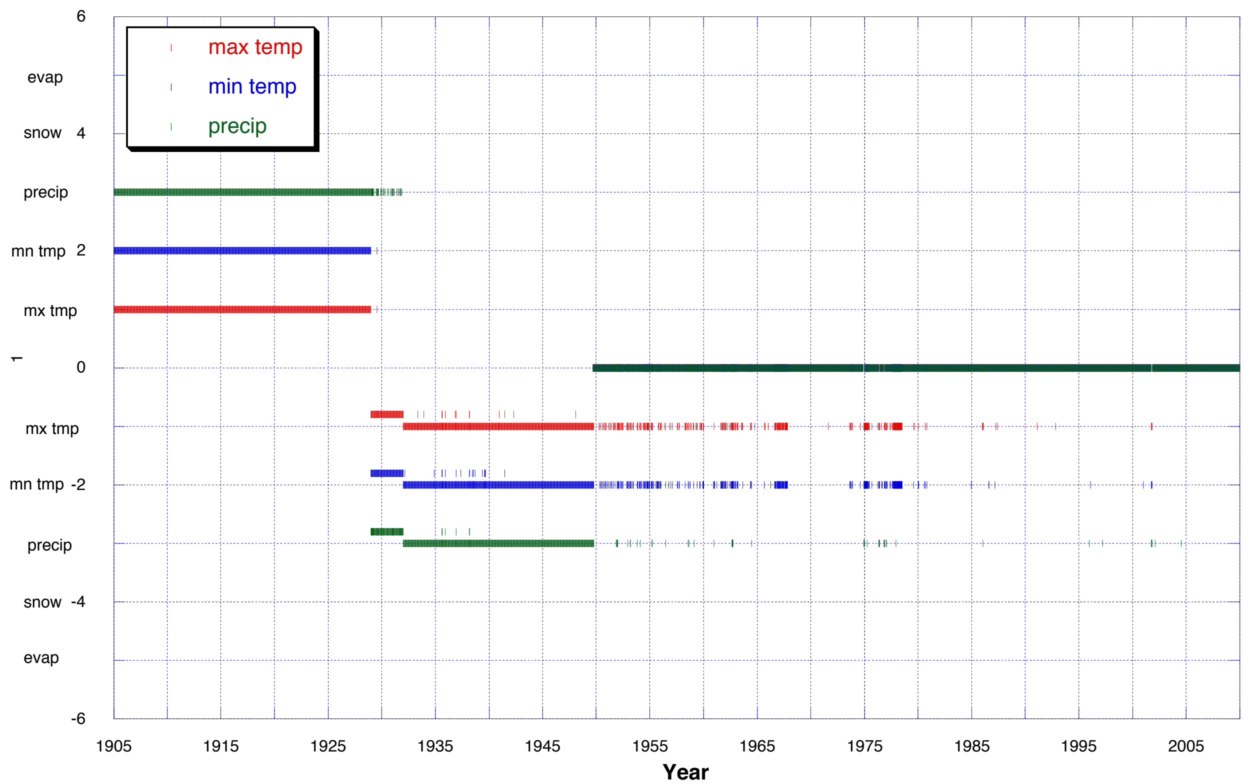
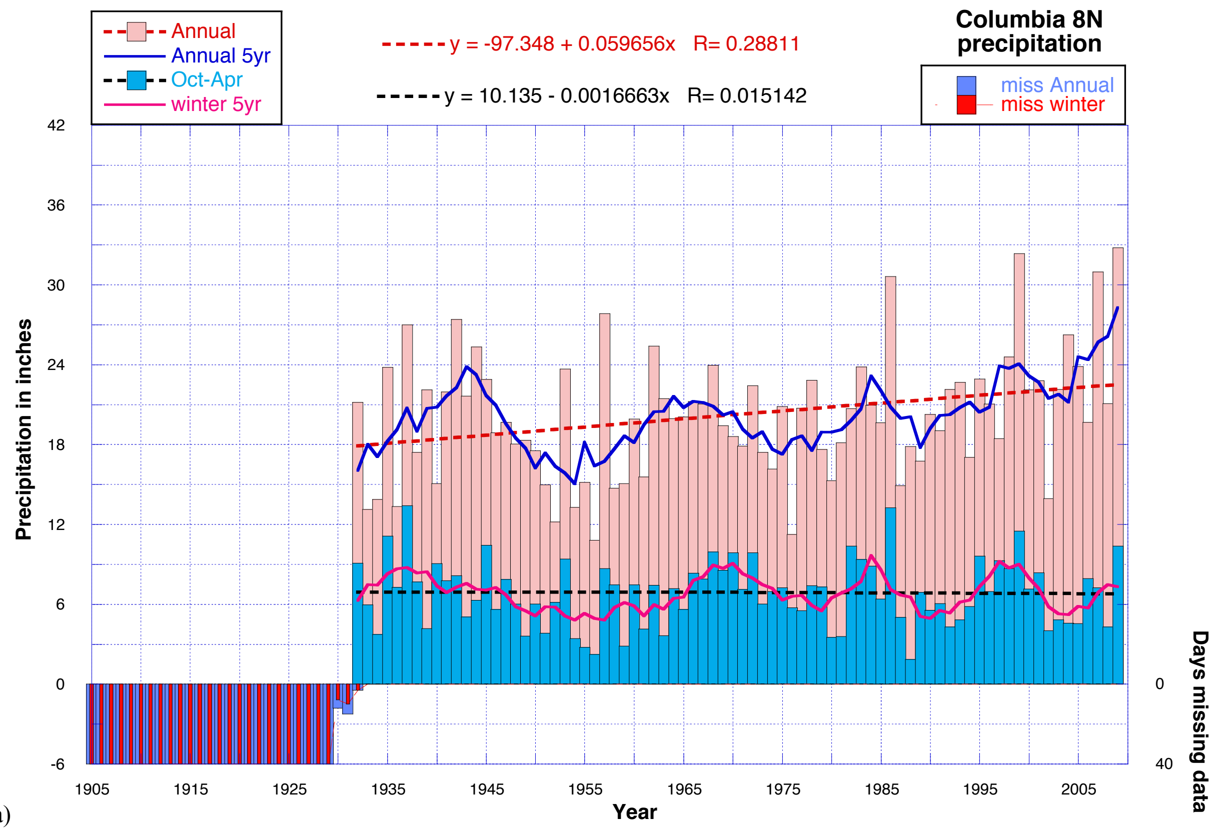
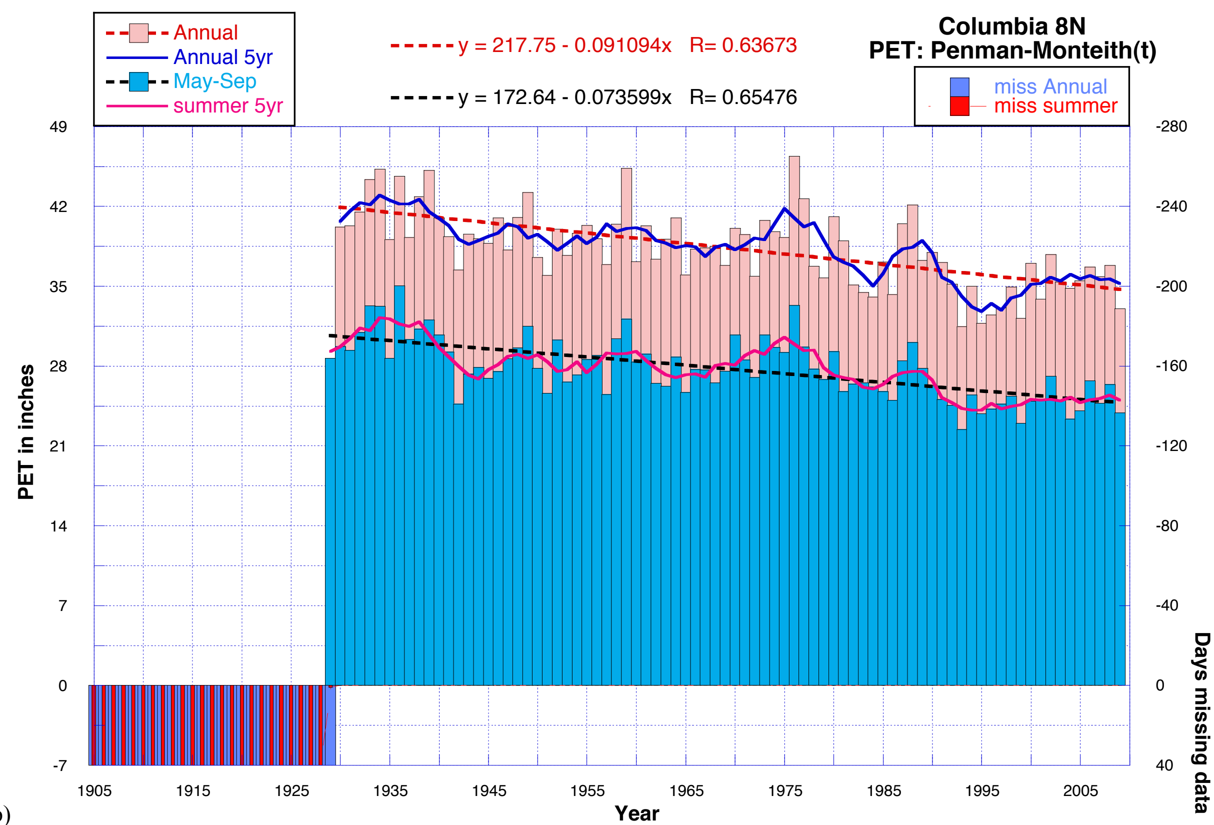


Figure A-6. Plot showing days with missing data at Columbia 8N and stations used to fill in missing days.



a)



b)

Figure A-7. Water year annual and winter a) precipitation and b) PET for Columbia 8N, SD.

Table A-4. List of NOAA Cooperative observer stations used to create Edgeley, ND climate dataset.

Station	Start of Record	End of Record
EDGELEY.NCD	05/01/1901	12/31/2009
FULLERTN.NCD	07/01/1948	12/31/2009
Fullertn1894.daily2	01/02/1894	12/31/2005
LISBON.NCD	01/01/1932	08/31/2009
Lisbon1903.daily2	01/02/1903	12/31/2005
VERONA.NCD	08/01/1948	12/31/2009
LAMOURE.NCD	07/01/1948	12/31/2009
MCLEOD.NCD	07/01/1948	12/31/2009
LITCHVIL.NCD	05/01/1951	12/31/2009
Mcleod1912.daily2	01/02/1912	12/31/2005
OAKES.NCD	09/01/1922	12/31/2009
Oakes1929.daily2	01/02/1929	12/31/2005
VALLEYCT.NCD	07/01/1948	12/31/2009
Vallcity1893.daily2	01/02/1893	12/31/2005

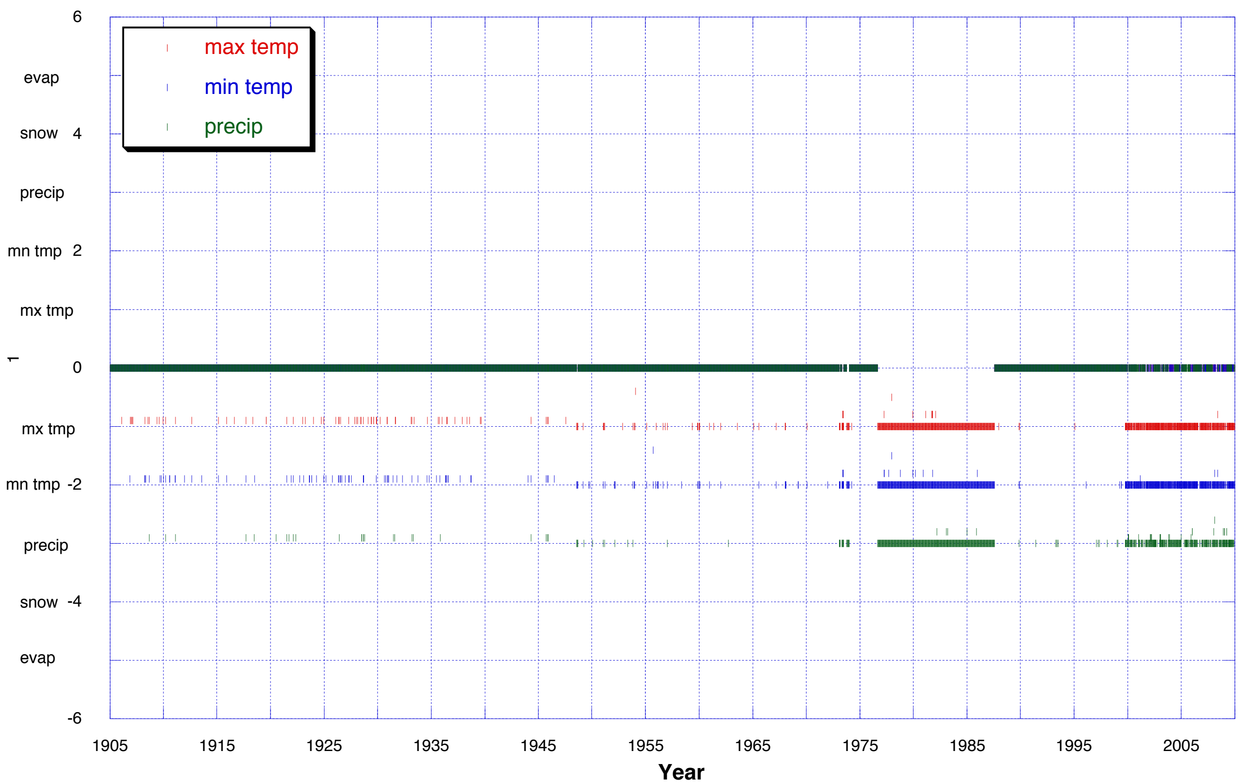
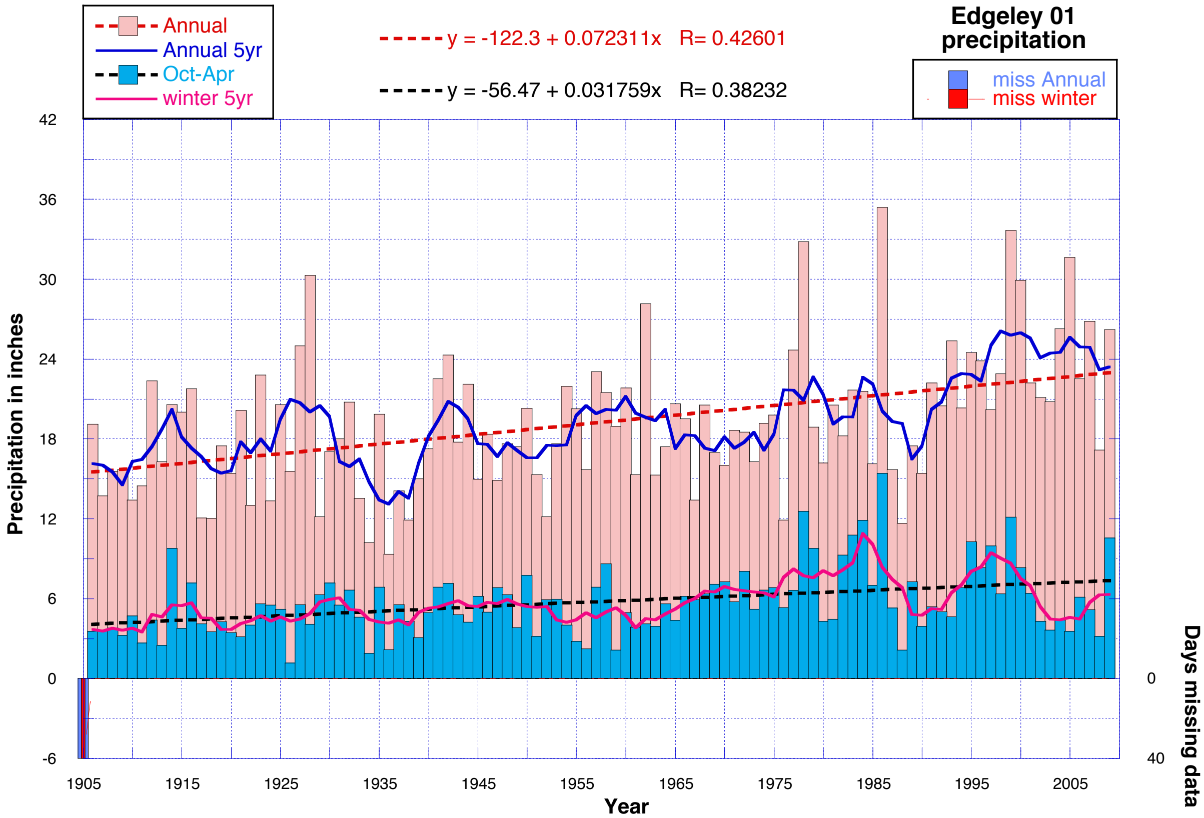
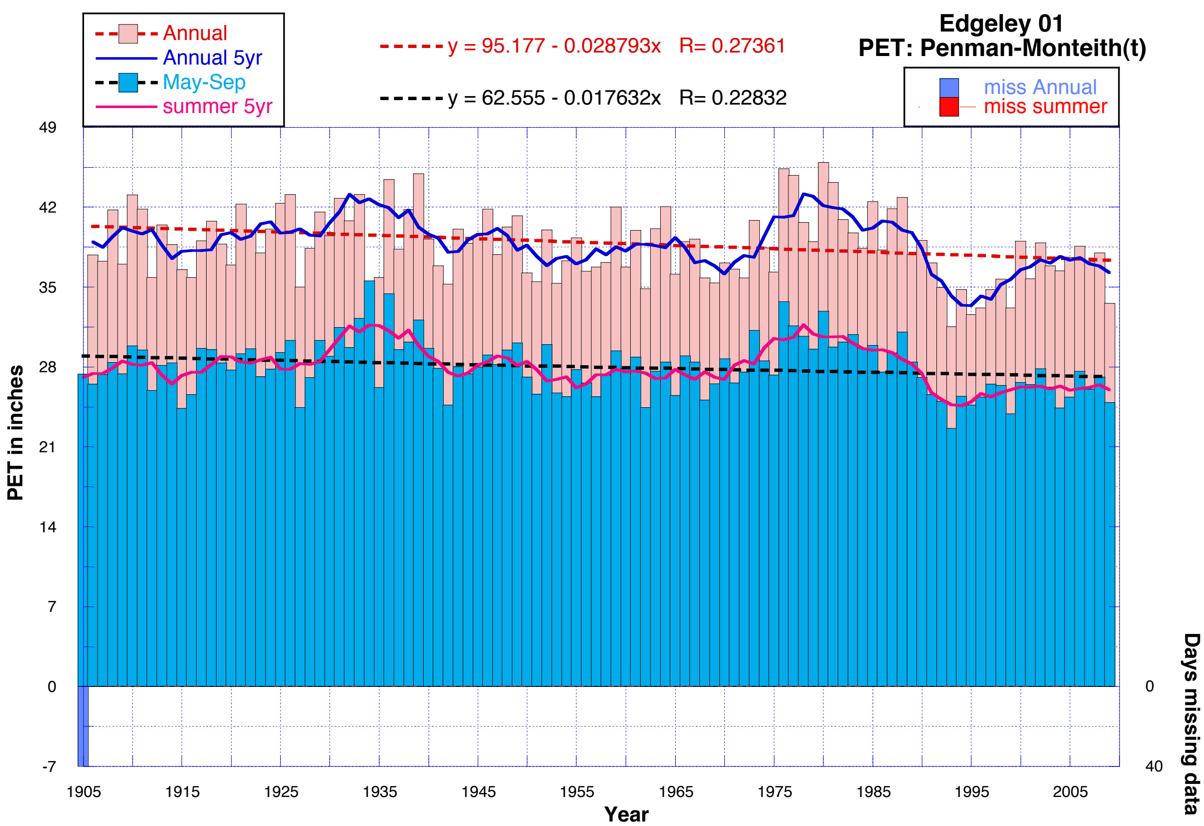


Figure A-8. Plot showing days with missing data at Edgeley, ND and stations used to fill in missing days.



a)



b)

Figure A-9. Water year annual and winter a) precipitation and b) PET for Edgeley, ND.

Table A-5. List of NOAA Cooperative observer stations used to create Ellendale, ND climate dataset.

Station	Start of Record	End of Record
ELLENDA.NCD	07/01/1948	12/31/2009
ELMRIVER.NCD	10/01/1999	12/31/2009
COLUMB8N.NCD	09/01/1949	12/31/2009
FORBES.NCD	05/01/1951	12/31/2009
LEOLA.NCD	01/01/1948	06/30/2007
Fullertn1894.daily2	01/02/1894	12/31/2005
EDGELEY.NCD	05/01/1901	12/31/2009

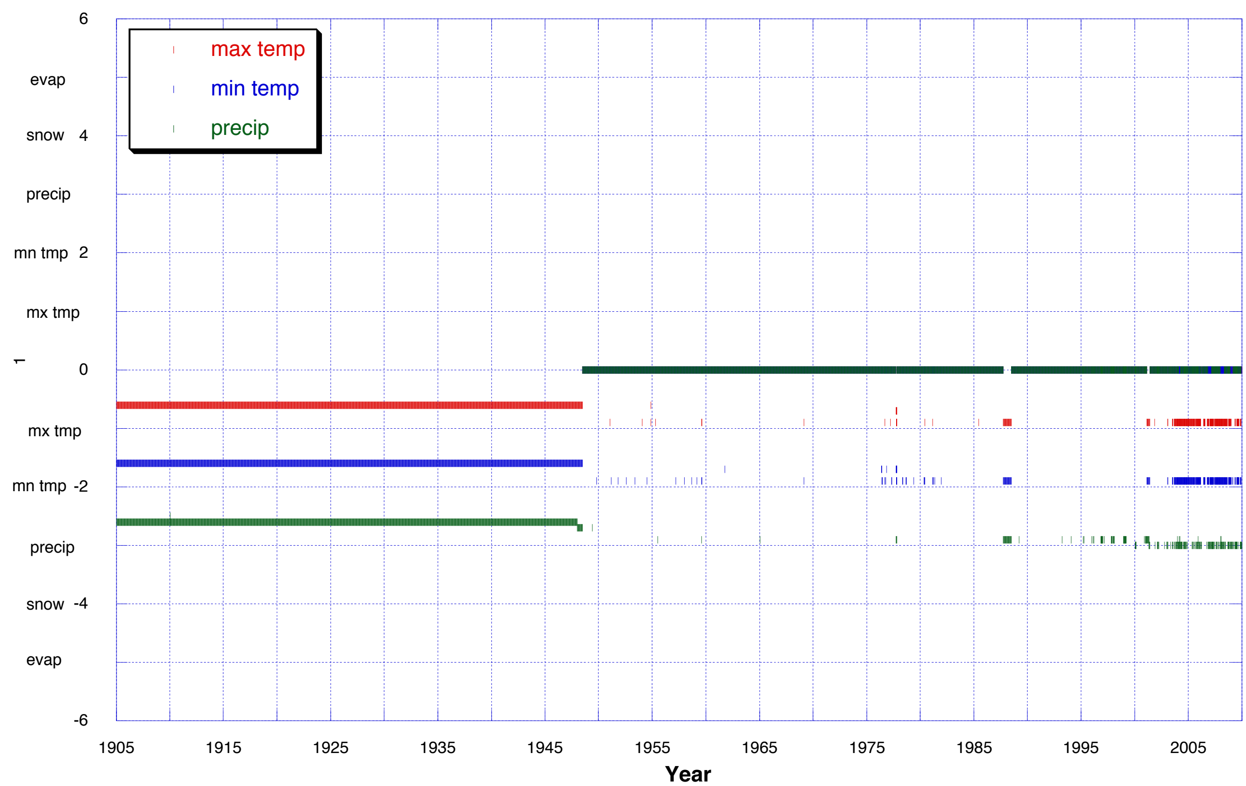
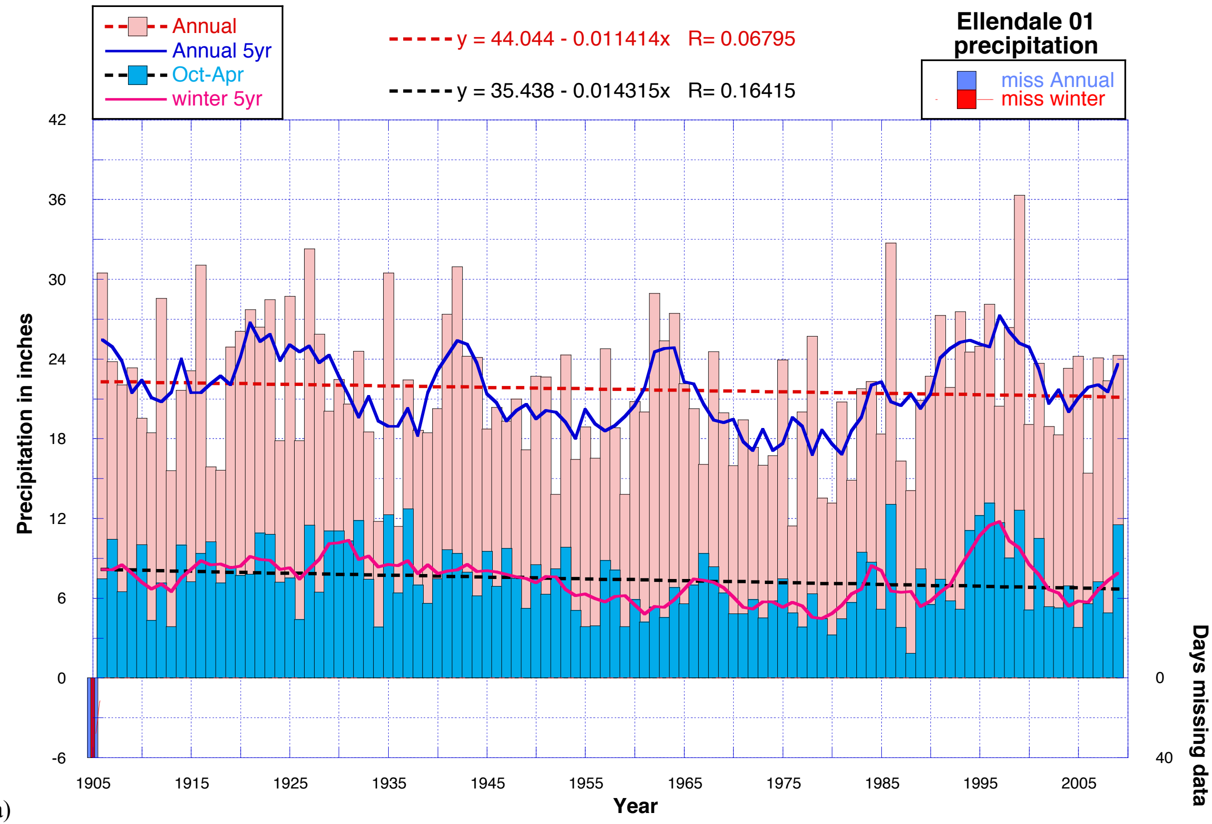


Figure A-10. Plot showing days with missing data at Ellendale, ND and stations used to fill in missing days.



a)

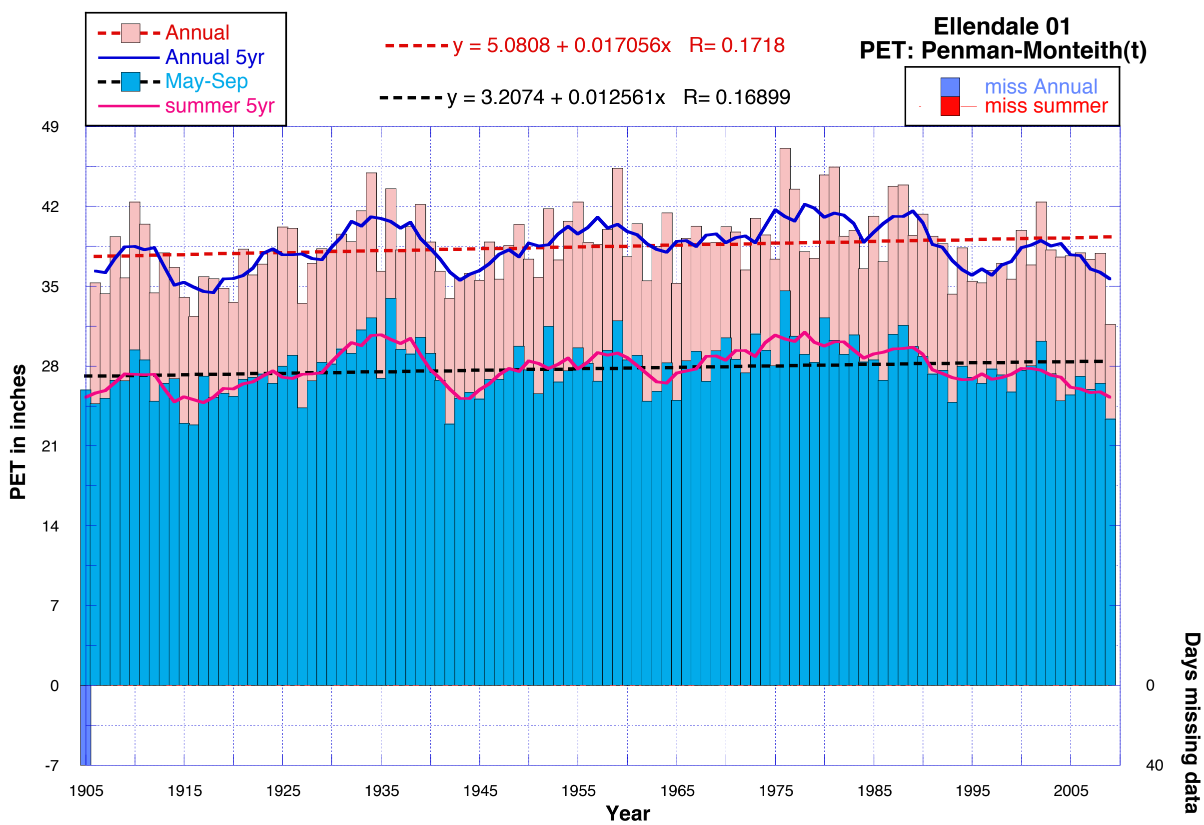


Figure A-11. Water year annual and winter a) precipitation and b) PET for Ellendale, ND.

Table A-6. List of NOAA Cooperative observer stations used to create Forman, ND climate dataset.

Station	Start of Record	End of Record
Forman1893.daily2	01/02/1893	12/31/2005
FORMAN.NCD	07/01/1948	12/31/2009
BRITT9NW.NCD	04/01/2002	12/31/2009
VERONA.NCD	08/01/1948	12/31/2009
BRITTON.NCD	01/01/1913	12/31/2009
Oakes1929.daily2	01/02/1929	12/31/2005
Lisbon1903.daily2	01/02/1903	12/31/2005
Mcleod1912.daily2	01/02/1912	12/31/2005
COLUMB8N.NCD	09/01/1949	12/31/2009

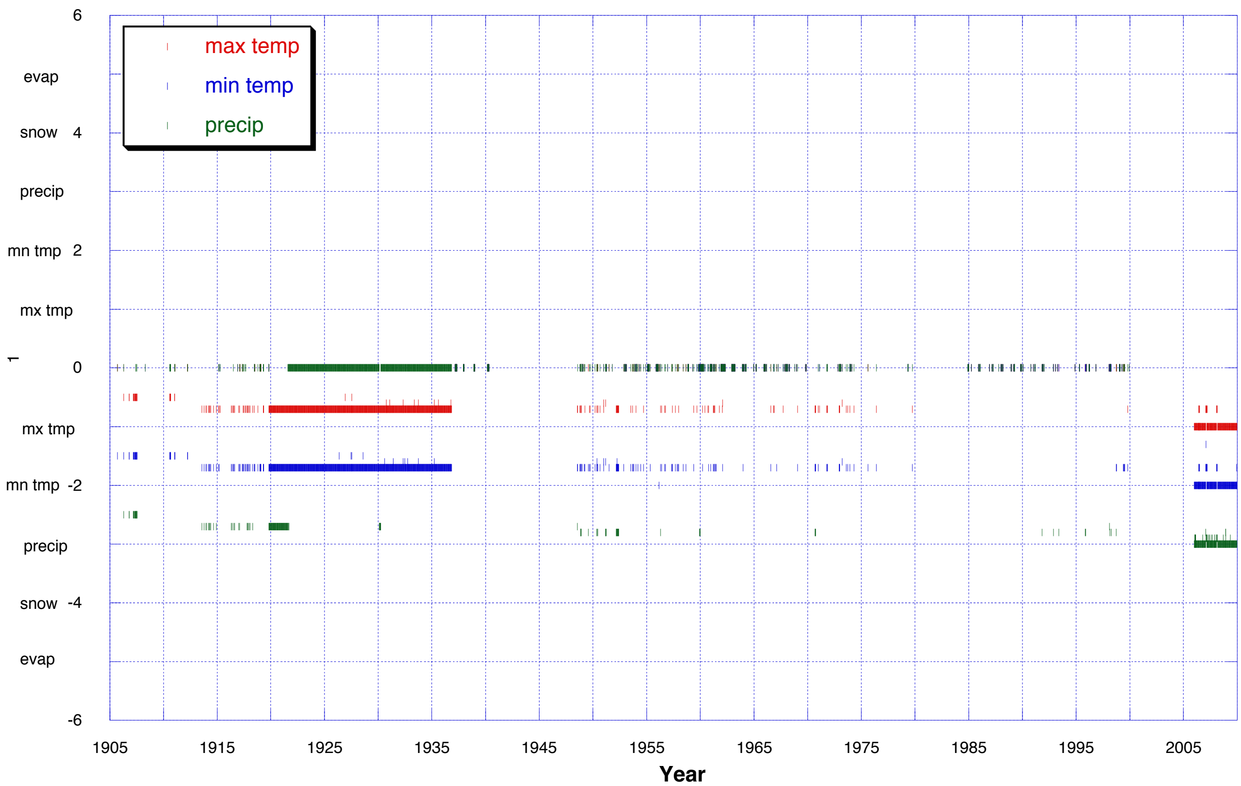
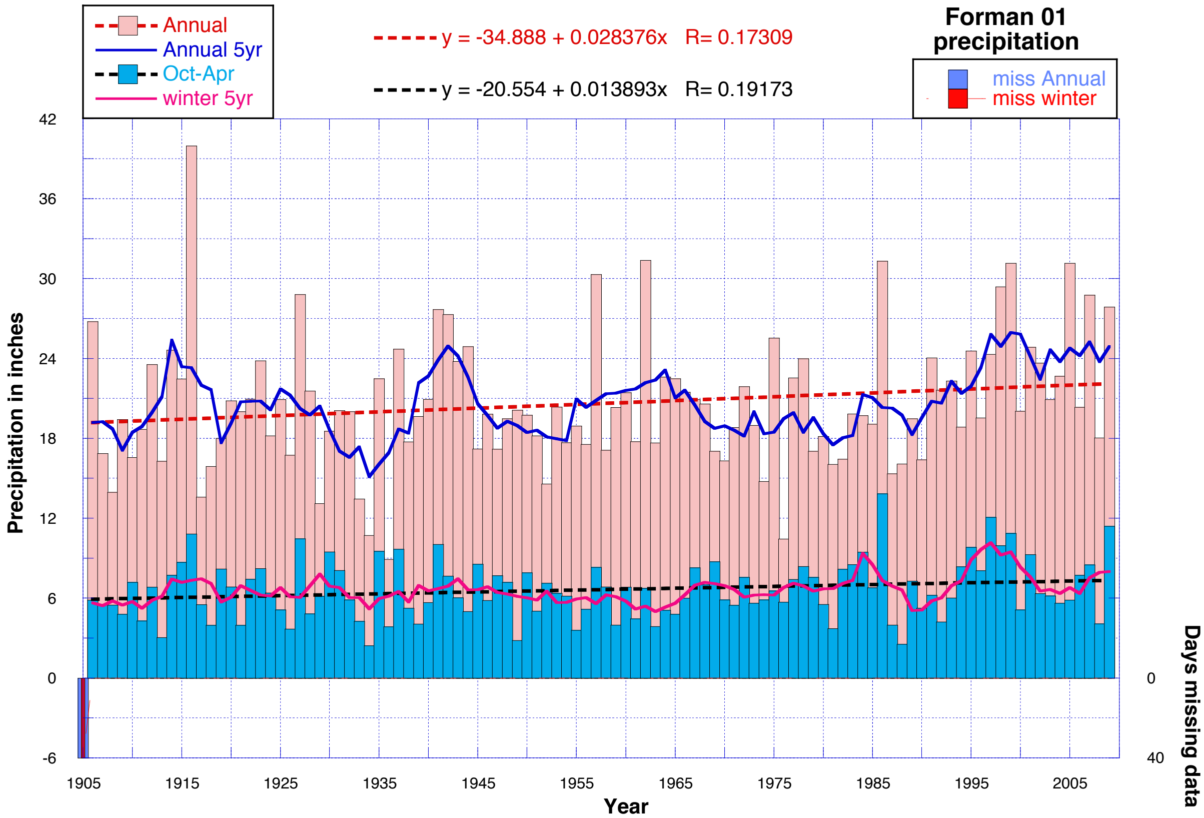
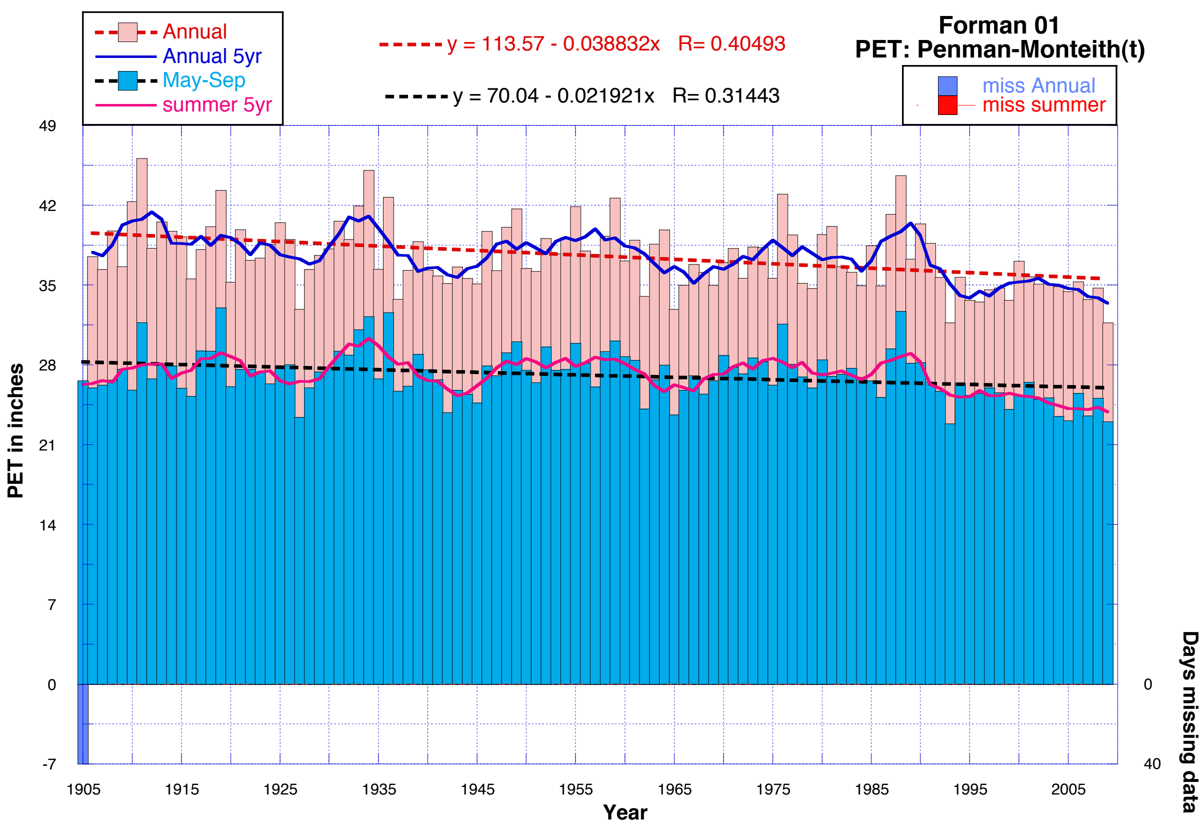


Figure A-12. Plot showing days with missing data at Forman, ND and stations used to fill in missing days.



a)



b)

Figure A-13. Water year annual and winter a) precipitation and b) PET for Forman, ND.

Table A-7. List of NOAA Cooperative observer stations used to create Fullerton, ND climate dataset.

Station	Start of Record	End of Record
FULLERTN.NCD	07/01/1948	12/31/2009
ELLENDA.NCD	07/01/1948	12/31/2009
Oakes1929.daily2	01/02/1929	12/31/2005
VERONA.NCD	08/01/1948	12/31/2009
BRITT9NW.NCD	04/01/2002	12/31/2009
BRITTON.NCD	01/01/1913	12/31/2009
COLUMB8N.NCD	09/01/1949	12/31/2009
EDGELEY.NCD	05/01/1901	12/31/2009

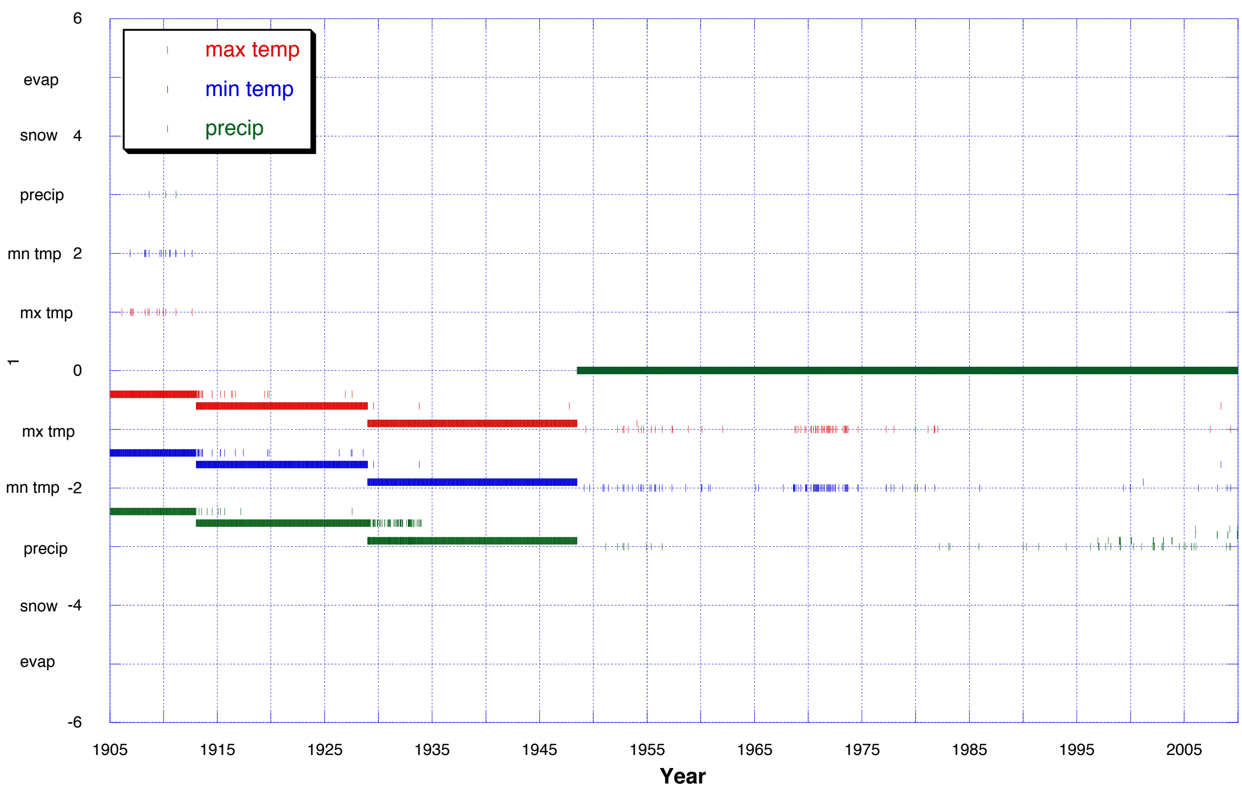
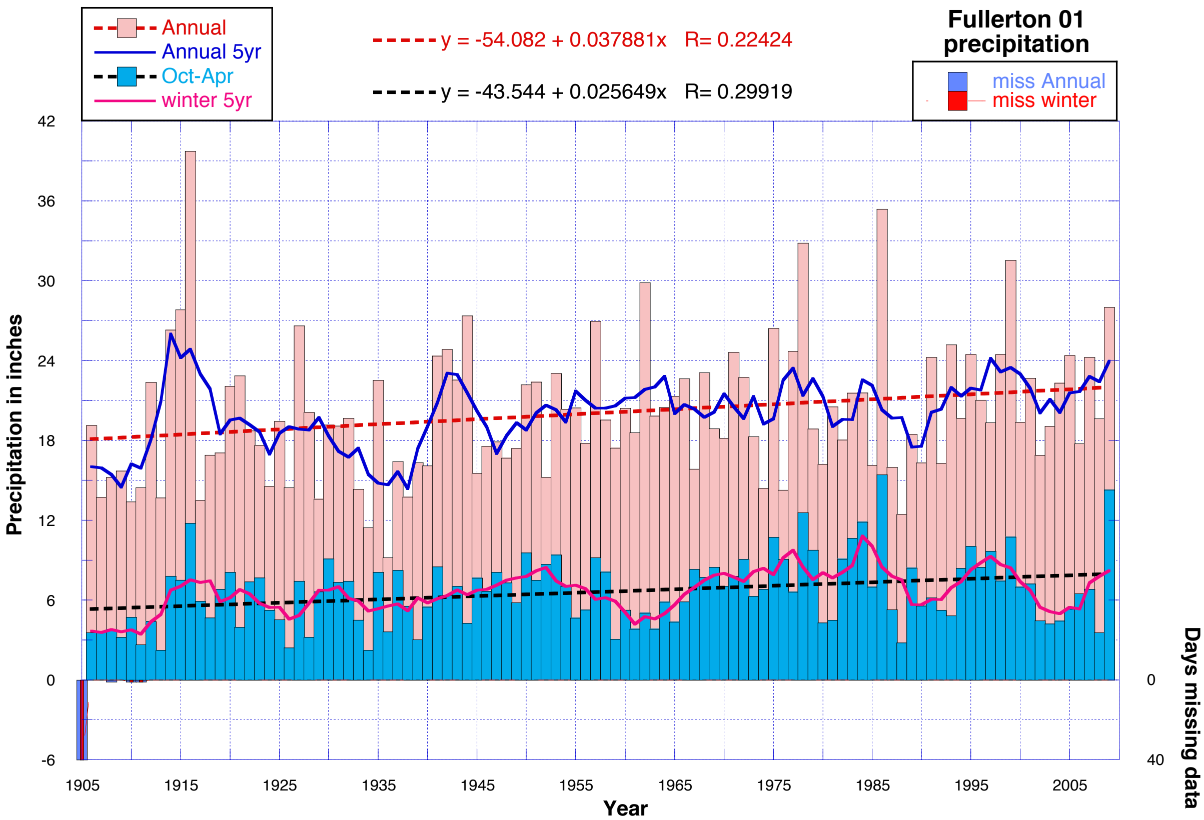
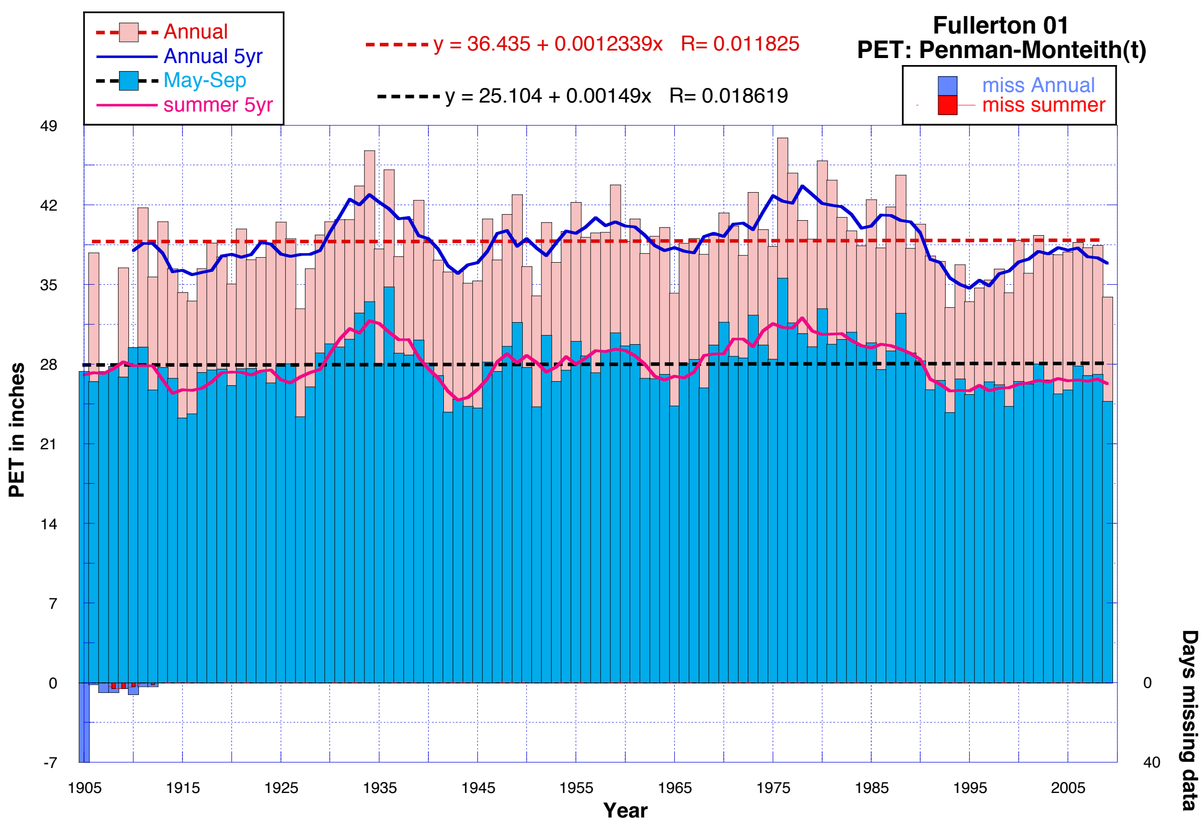


Figure A-14. Plot showing days with missing data at Fullerton, ND and stations used to fill in missing days.



a)



b)

Figure A-15. Water year annual and winter a) precipitation and b) PET for Fullerton, ND.

Table A-8. List of NOAA Cooperative observer stations used to create Leola, SD climate dataset.

Station	Start of Record	End of Record
LEOLA.NCD	01/01/1948	06/30/2007
COLUMB8N.NCD	09/01/1949	12/31/2009
ABERDEEN.NCD	01/01/1932	12/31/2009
Oakes1929.daily2	01/02/1929	12/31/2005

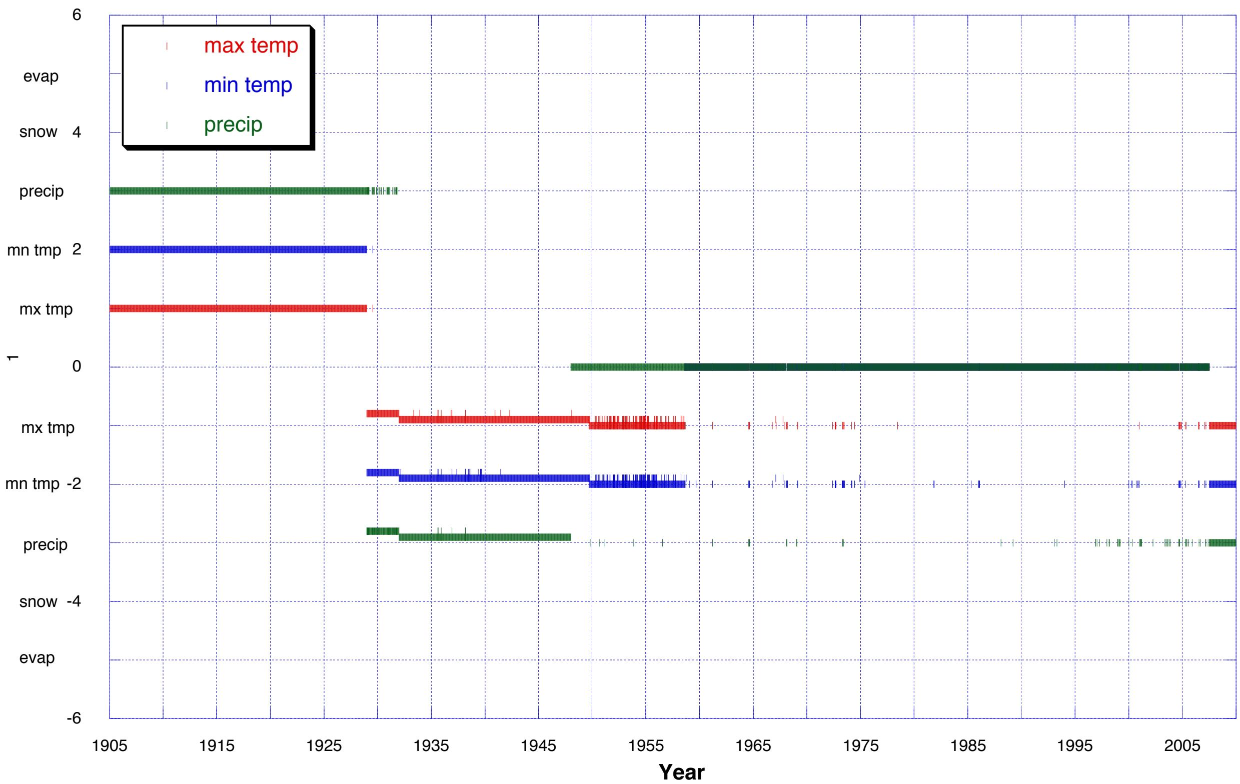
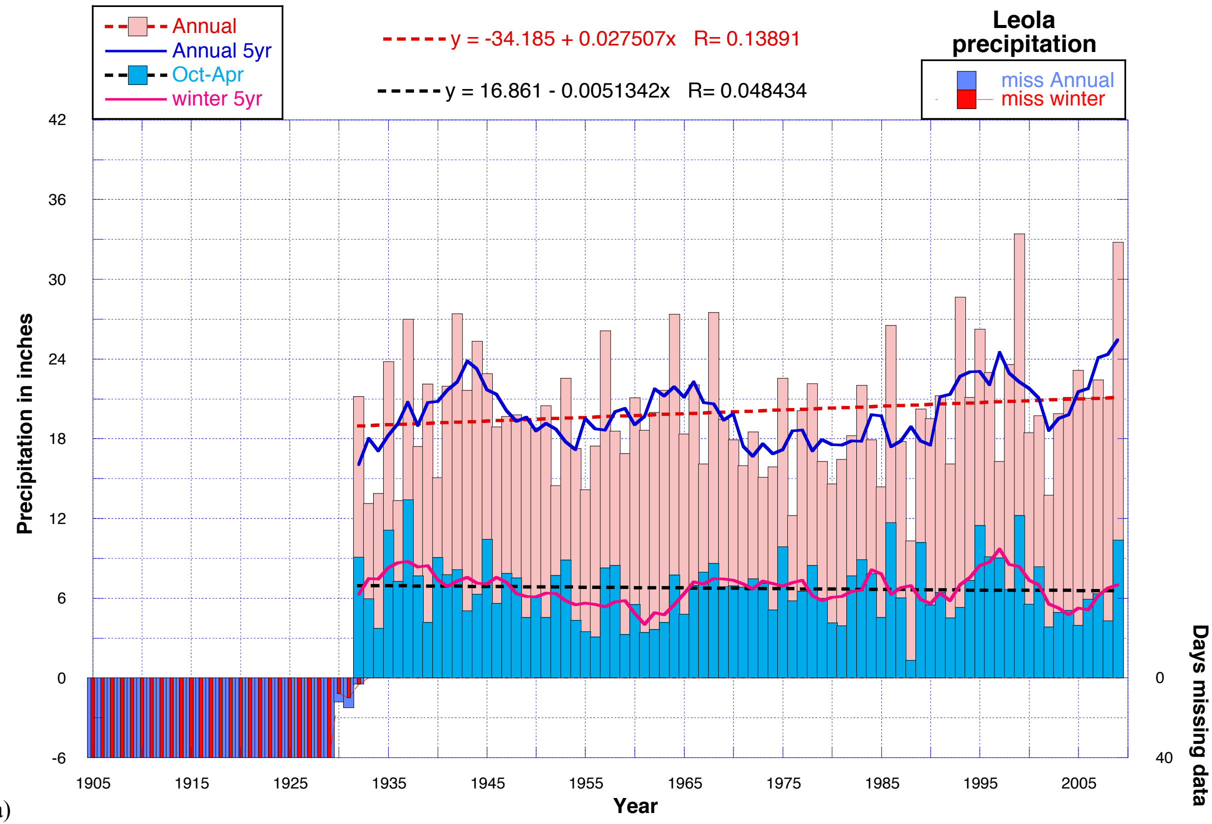
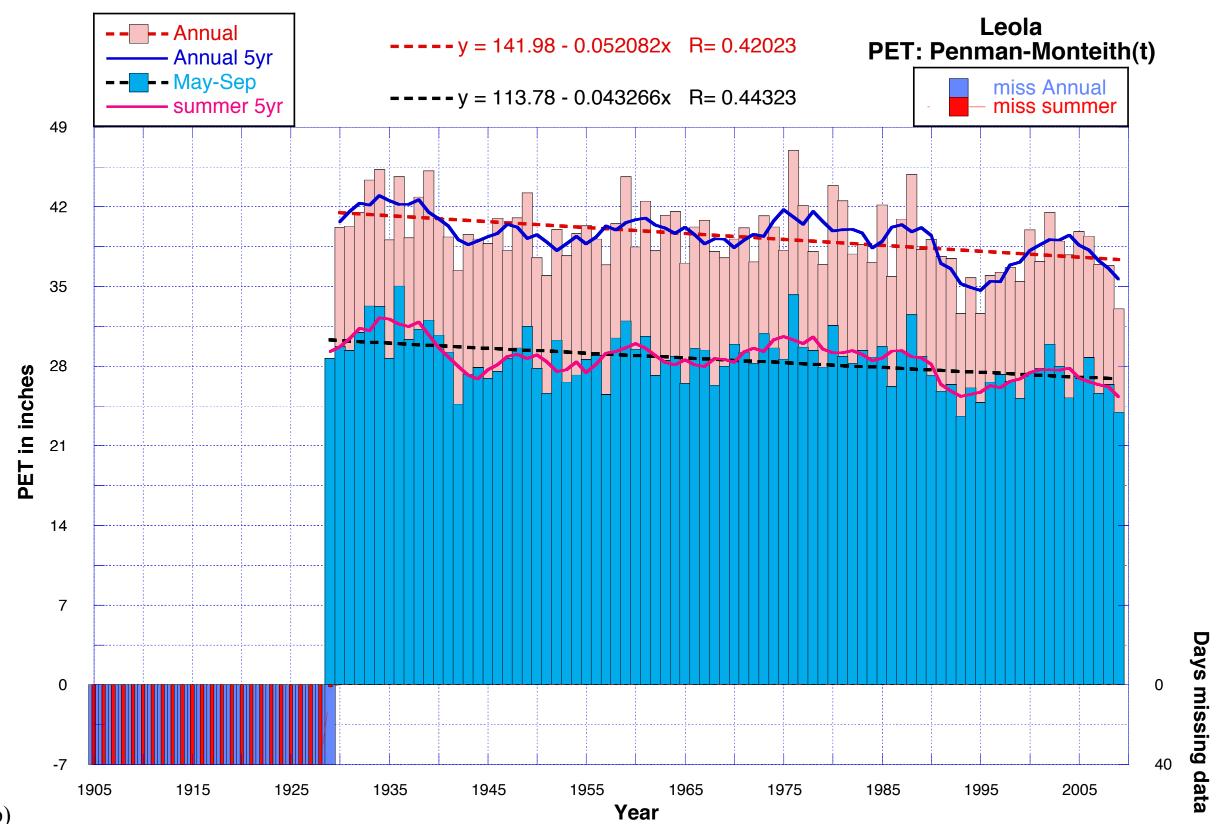


Figure A-16. Plot showing days with missing data at Leola, SD and stations used to fill in missing days.



a)



b)

Figure A-17. Water year annual and winter a) precipitation and b) PET for Leola, SD.

Table A-9. List of NOAA Cooperative observer stations used to create Lisbon, ND climate dataset.

Station	Start of Record	End of Record
Lisbon1903.daily2	01/02/1903	12/31/2005
LISBON.NCD	01/01/1932	08/31/2009
VERONA.NCD	08/01/1948	12/31/2009
Forman1893.daily2	01/02/1893	12/31/2005
FORMAN.NCD	07/01/1948	12/31/2009
BRITT9NW.NCD	04/01/2002	12/31/2009
BRITTON.NCD	01/01/1913	12/31/2009
Oakes1929.daily2	01/02/1929	12/31/2005
Mcleod1912.daily2	01/02/1912	12/31/2005
MCLEOD.NCD	07/01/1948	12/31/2009

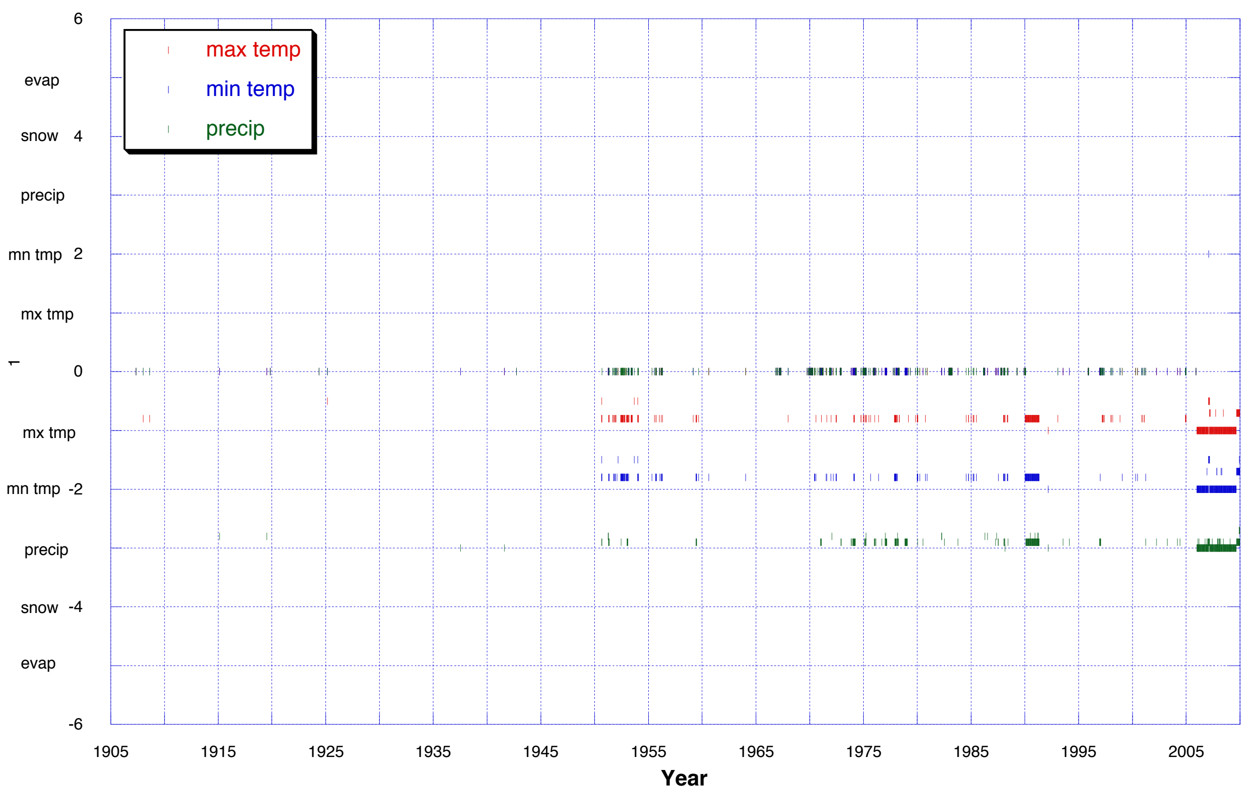
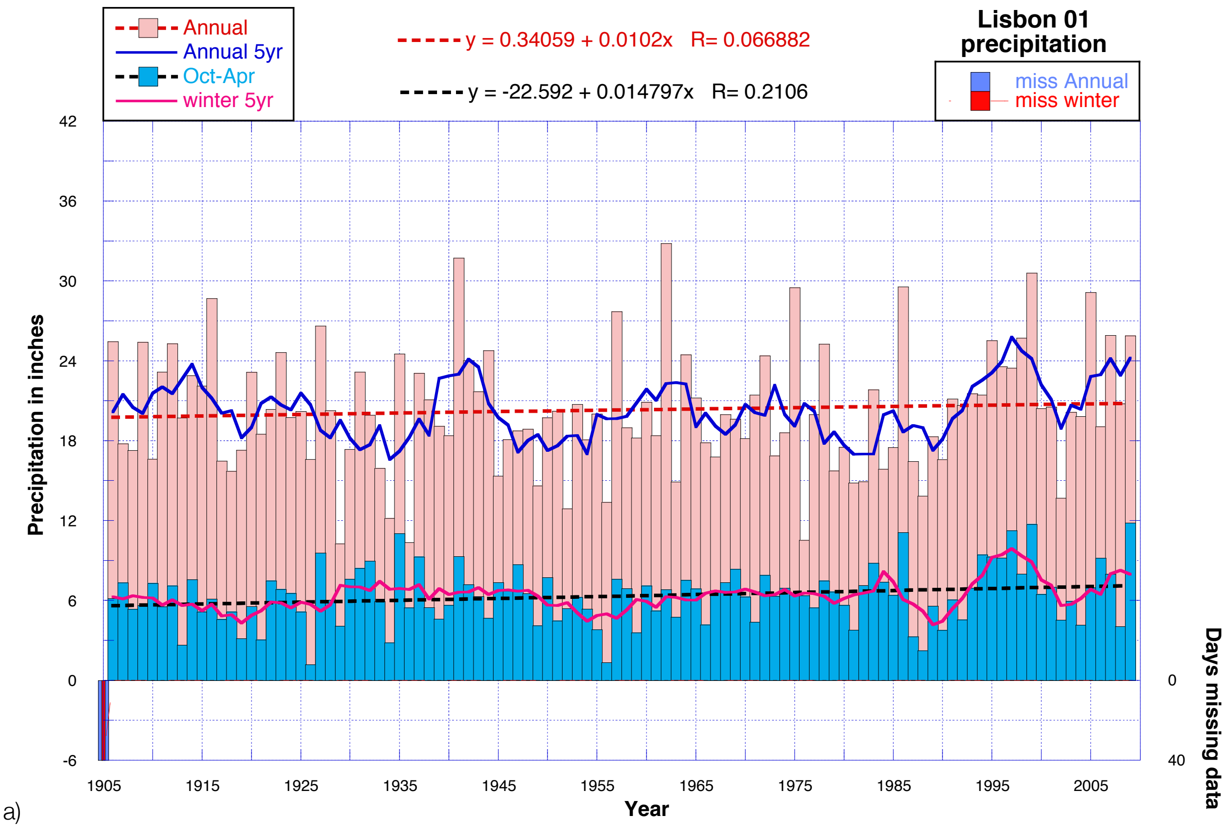


Figure A-18. Plot showing days with missing data at Lisbon, ND and stations used to fill in missing days.



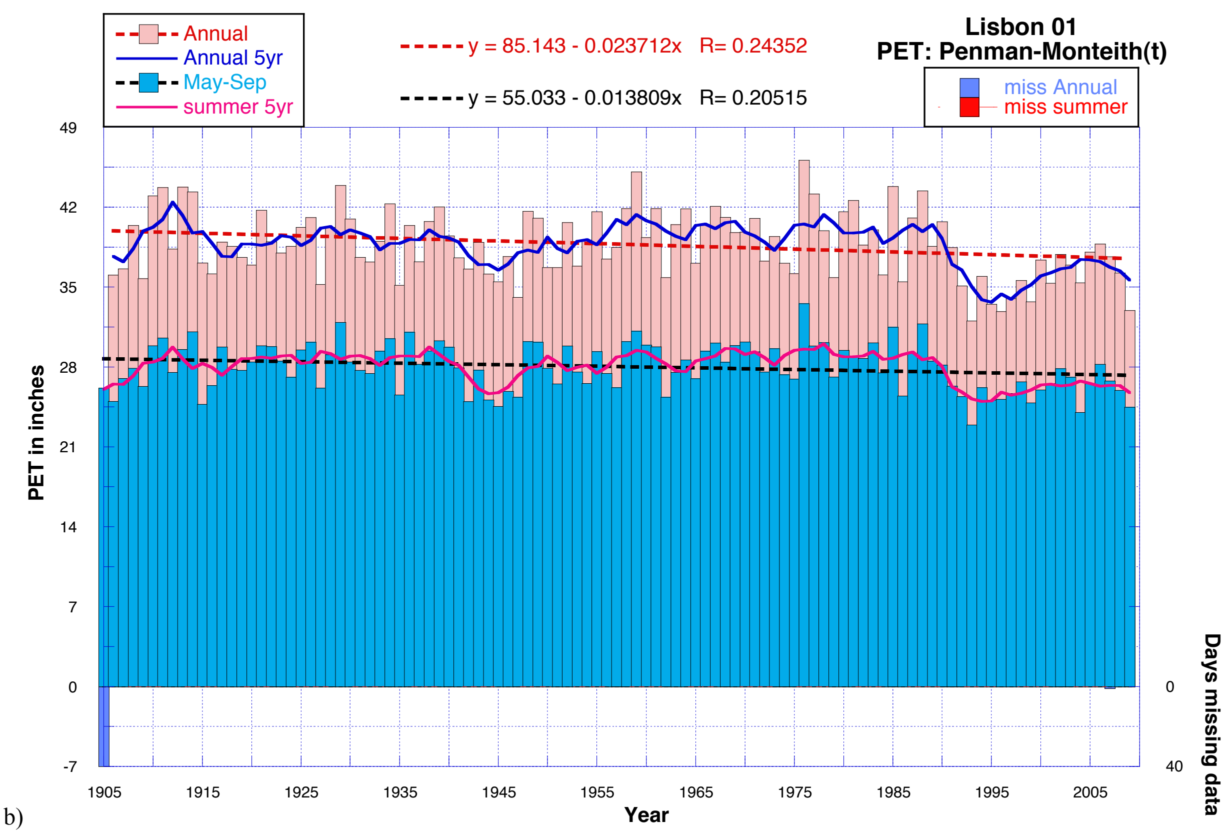


Figure A-19. Water year annual and winter a) precipitation and b) PET for Lisbon, ND.

Table A-10. List of NOAA Cooperative observer stations used to create McLeod 3E, ND climate dataset.

Station	Start of Record	End of Record
Mcleod1912.daily2	01/02/1912	12/31/2005
MCLEOD.NCD	07/01/1948	12/31/2009
Lisbon1903.daily2	01/02/1903	12/31/2005
LISBON.NCD	01/01/1932	08/31/2009
Forman1893.daily2	01/02/1893	12/31/2005
FORMAN.NCD	07/01/1948	12/31/2009
Hankinsn19291993.daily2	01/02/1929	12/31/1993
LIDGERWD.NCD	01/01/1979	12/31/2009
CHAFFEE.NCD	12/01/1962	12/31/2009
VICTOR.NCD	01/01/1932	12/31/2009

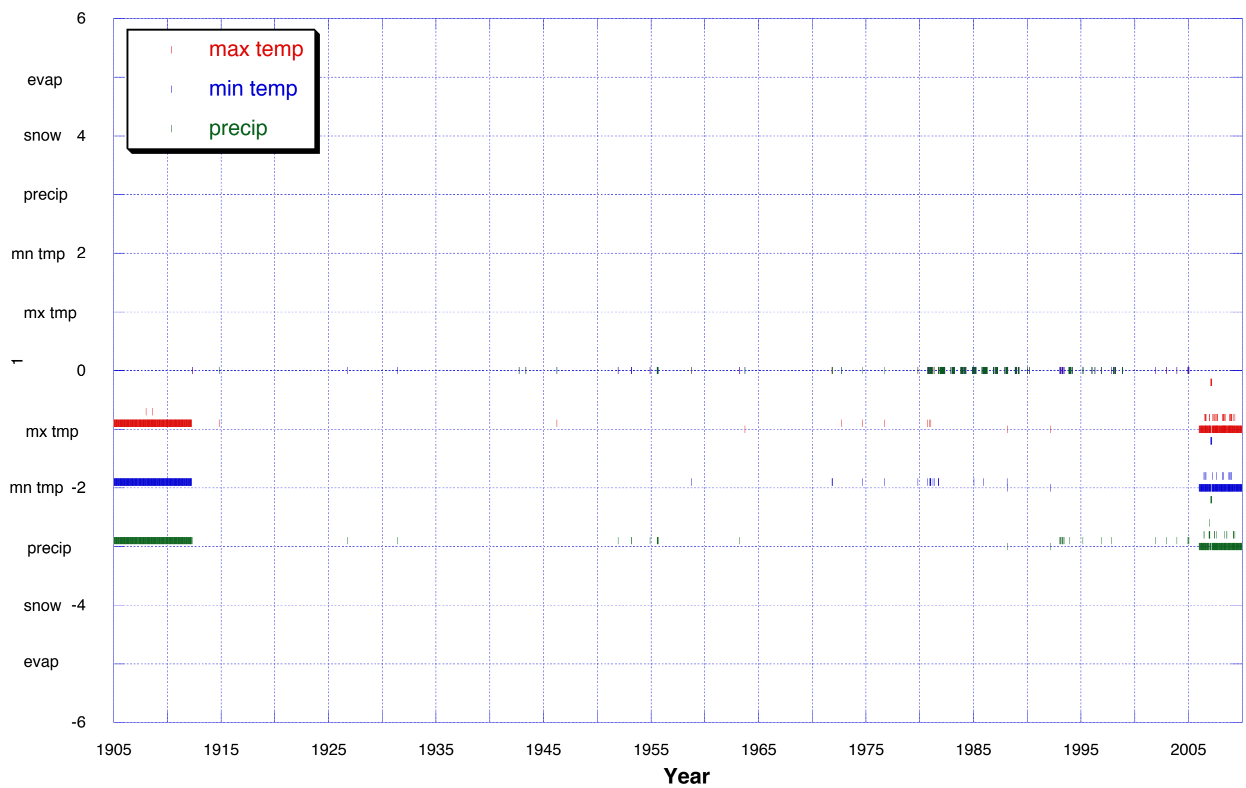
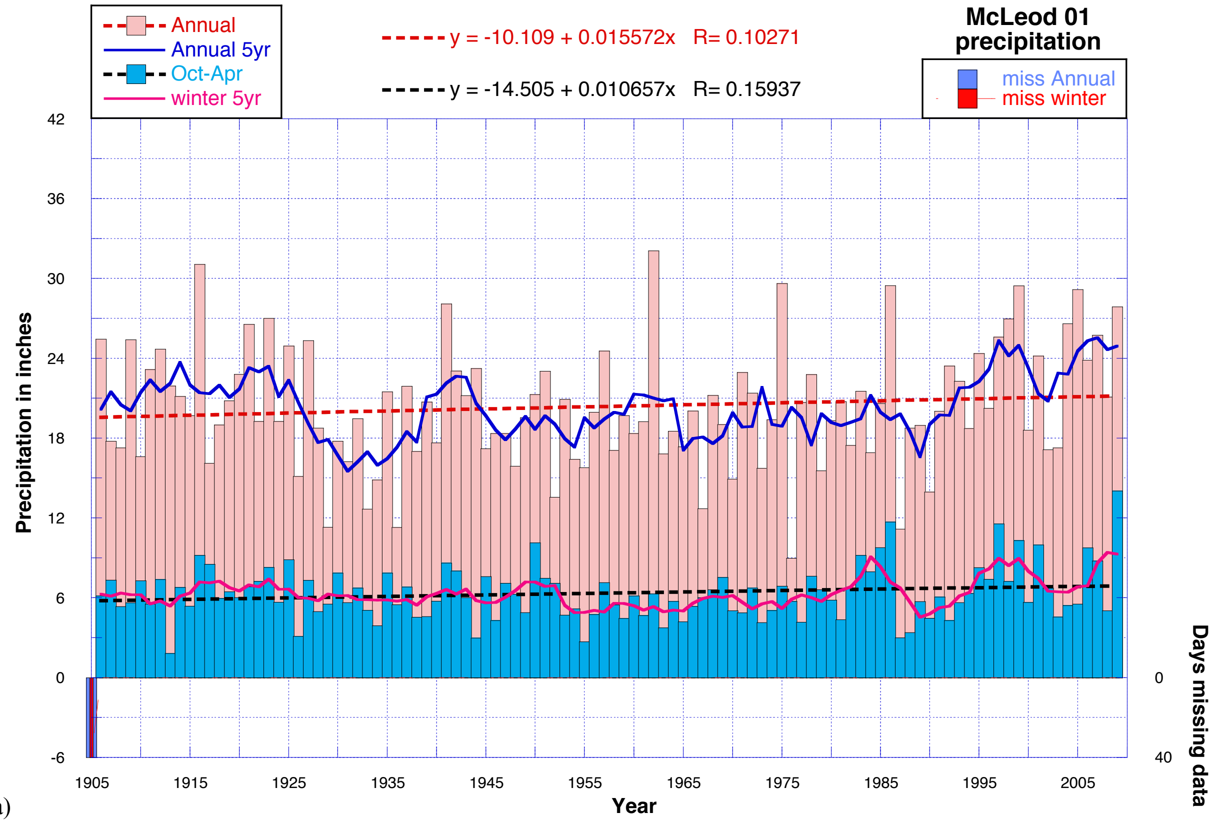
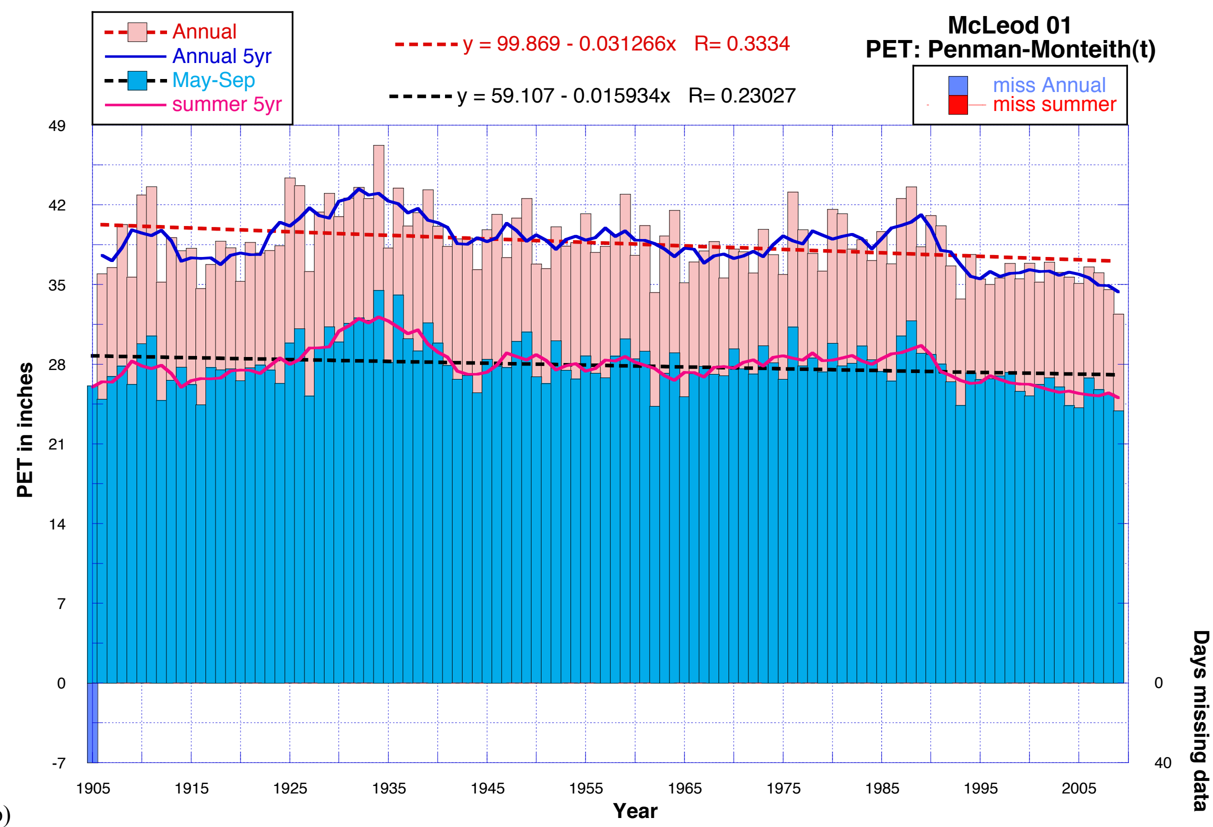


Figure A-20. Plot showing days with missing data at McLeod 3E, ND and stations used to fill in missing days.



a)



b)

Figure A-21. Water year annual and winter a) precipitation and b) PET for McLeod 3E, ND.

Table A-11. List of NOAA Cooperative observer stations used to create Oakes, ND climate dataset 03.

Station	Start of Record	End of Record
Oakes1929.daily2	01/02/1929	12/31/2005
OAKES.NCD	09/01/1922	12/31/2009
FULLERTN.NCD	07/01/1948	12/31/2009
COLUMB8N.NCD	09/01/1949	12/31/2009
VERONA.NCD	08/01/1948	12/31/2009
BRITTON.NCD	01/01/1913	12/31/2009
ELLENDA.NCD	07/01/1948	12/31/2009
EDGELEY.NCD	05/01/1901	12/31/2009

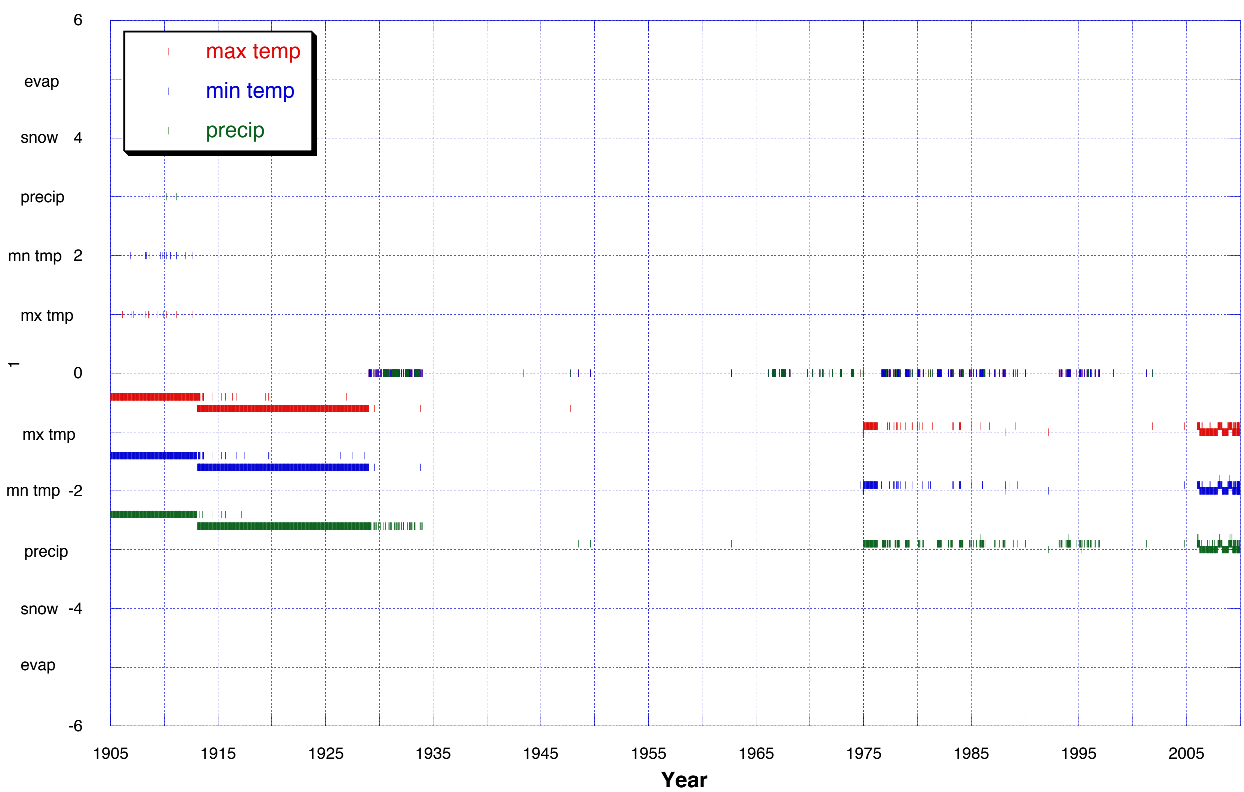
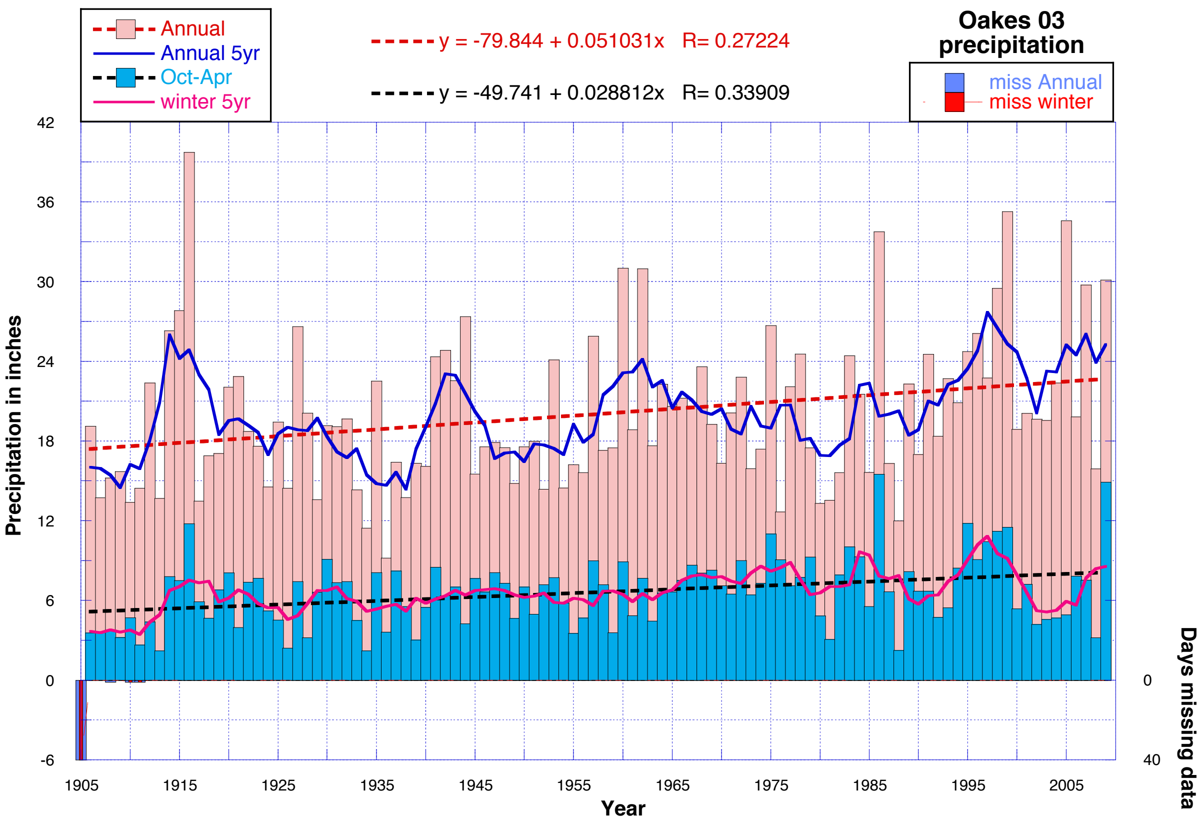
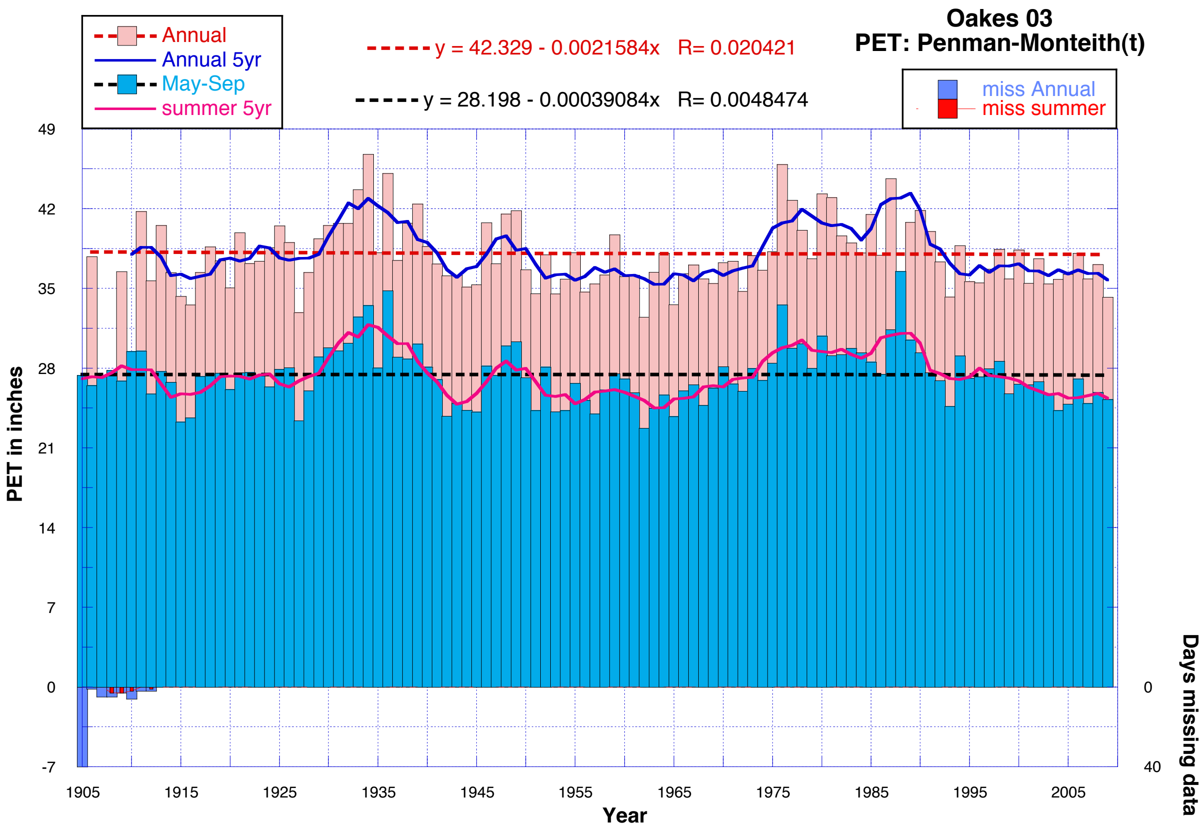


Figure A-22. Plot showing days with missing data at Oakes, ND and stations used to fill in missing days.



a)



b)

Figure A-23. Water year annual and winter a) precipitation and b) PET for Oakes, ND.

Table A-12. List of NOAA Cooperative observer stations used to create Oakes, ND climate dataset 04. This adds the Oakes NDAWN data to dataset 03.

Station	Start of Record	End of Record
oakes.csv	04/24/1990	01/02/2010
Oakes1929.daily2	01/02/1929	12/31/2005
OAKES.NCD	09/01/1922	12/31/2009
BRITT9NW.NCD	04/01/2002	12/31/2009
COLUMB8N.NCD	09/01/1949	12/31/2009
VERONA.NCD	08/01/1948	12/31/2009
BRITTON.NCD	01/01/1913	12/31/2009
ELLENDA.NCD	07/01/1948	12/31/2009
EDGELEY.NCD	05/01/1901	12/31/2009

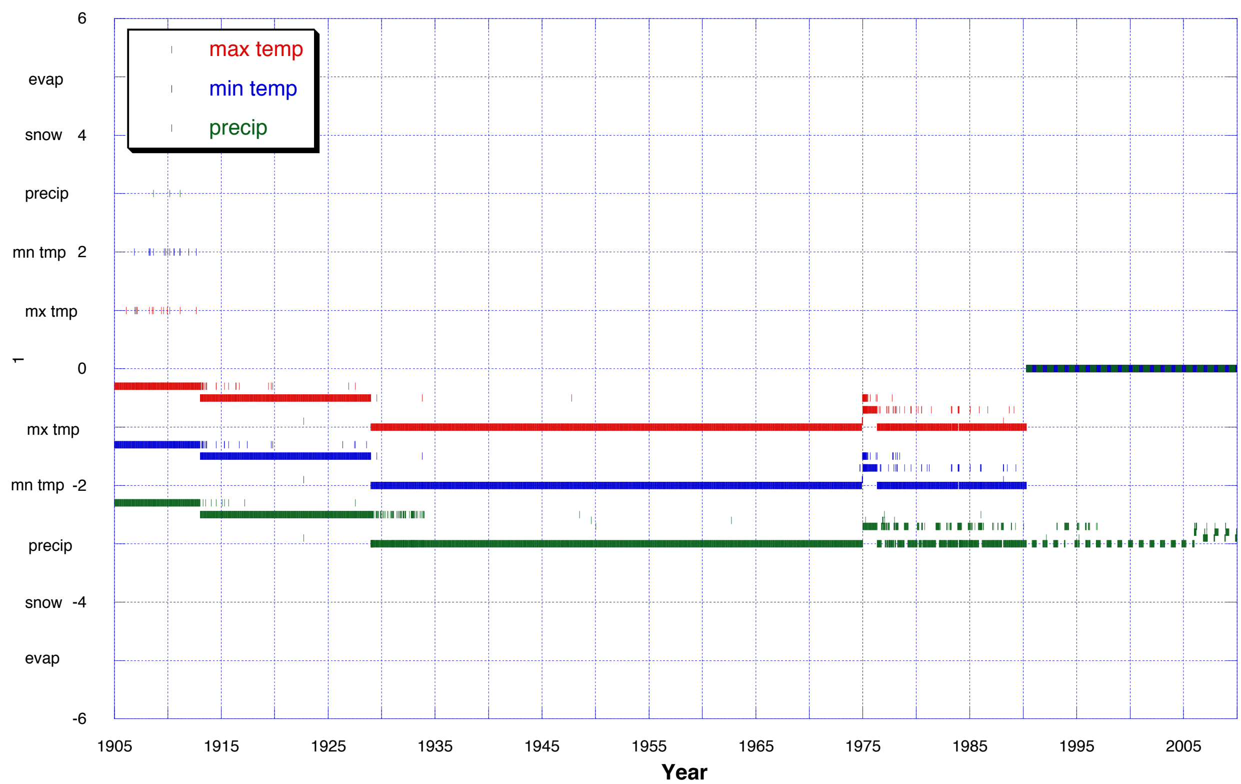
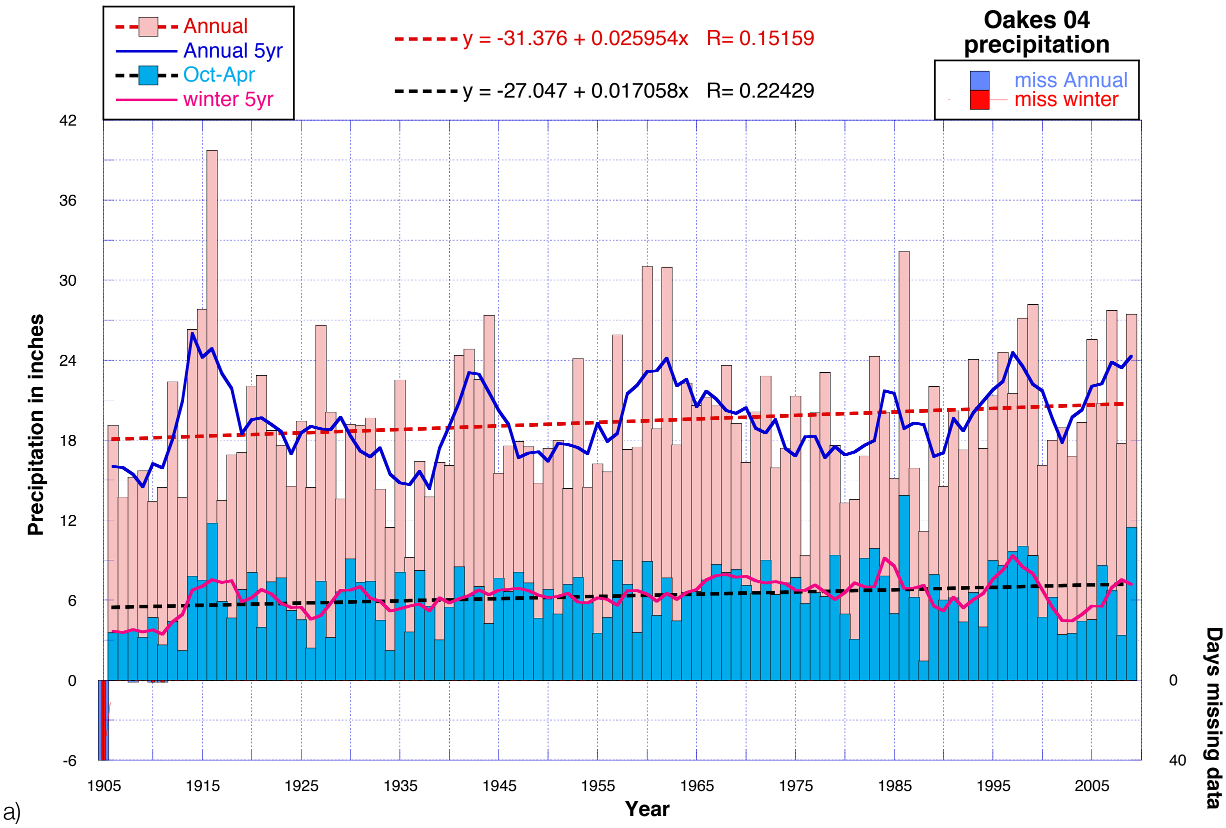
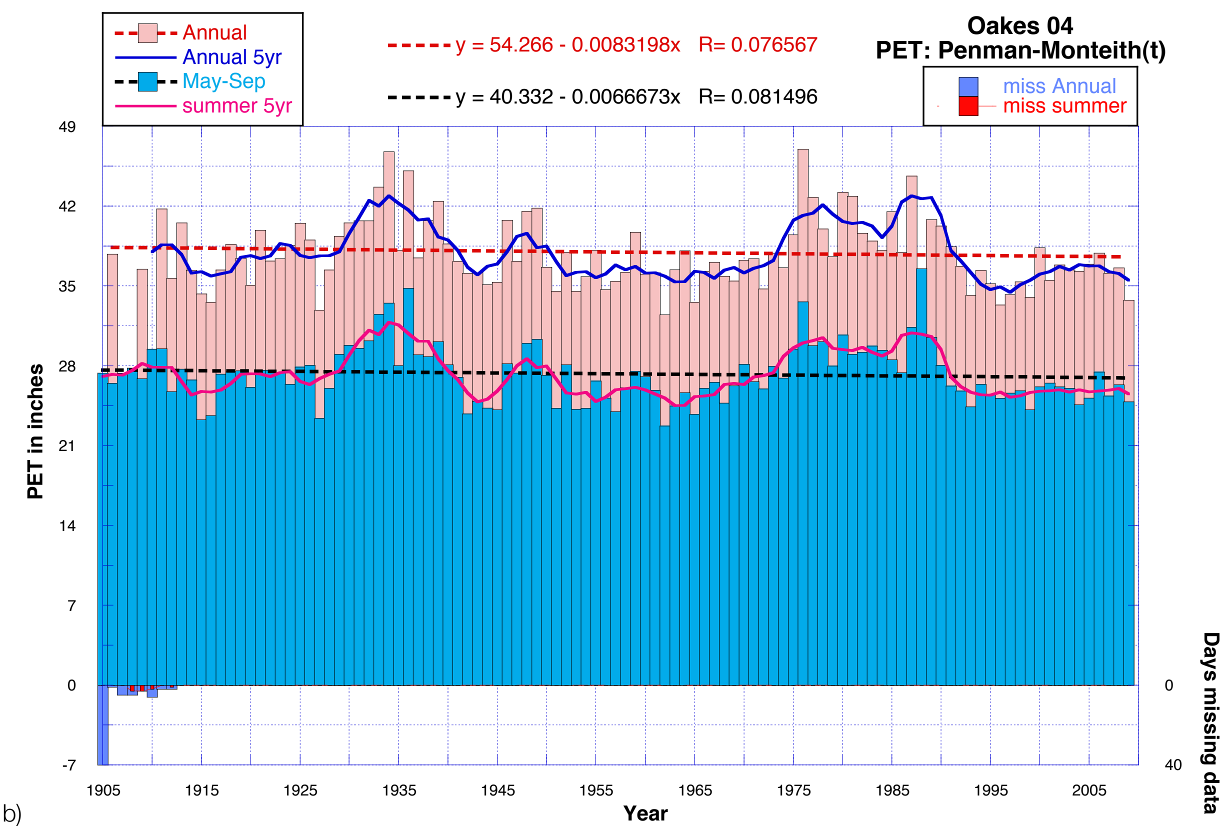


Figure A-24. Plot showing days with missing data at Oakes, ND and stations used to fill in missing days in NDAWN site near Oakes, ND.



a)



b)

Figure A-25. Water year annual and winter a) precipitation and b) PET for NDAWN site near Oakes, ND.

Appendix B. Water Level Hydrographs.

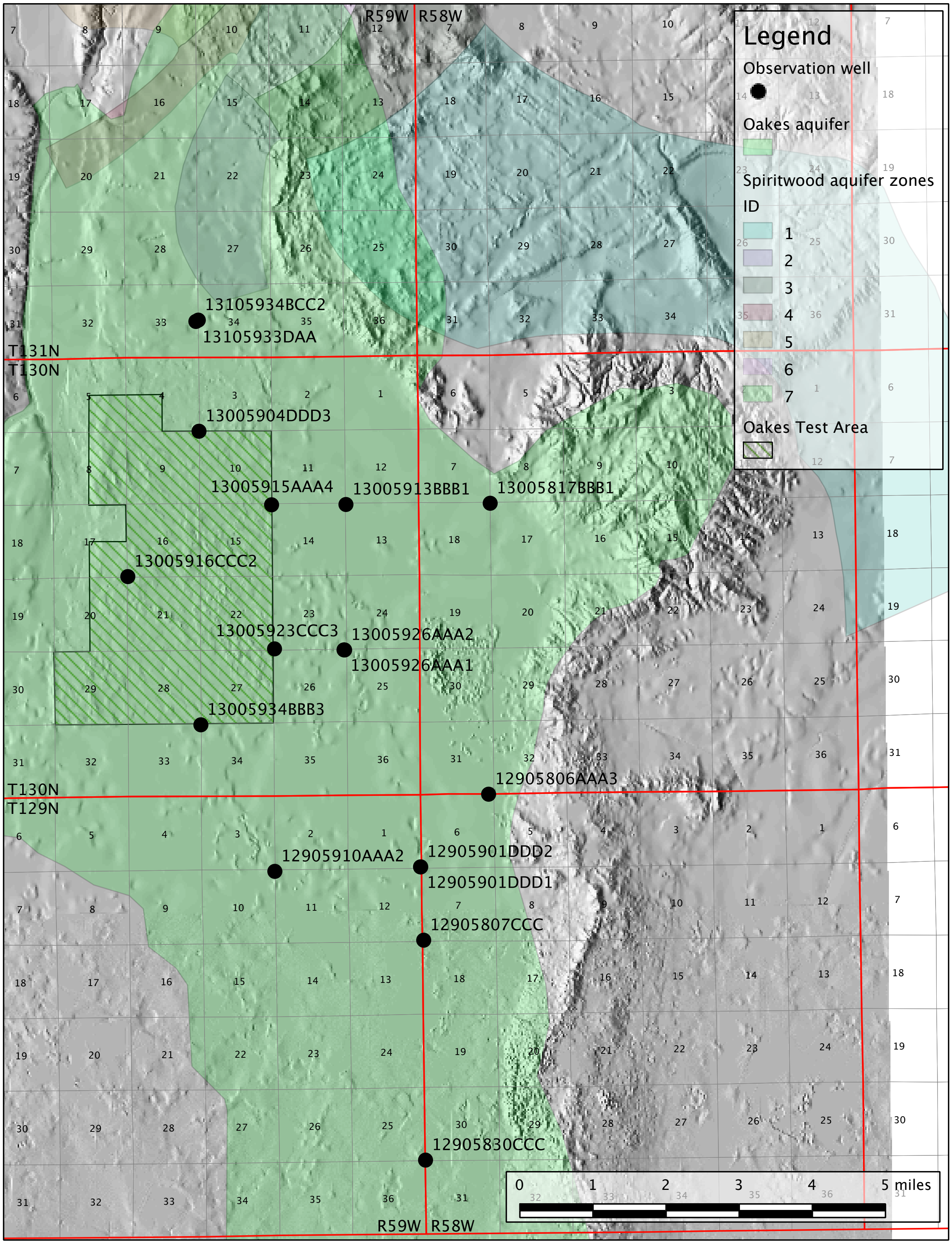


Figure B-1. Location of observation wells shown in figures B-2 to B-14.

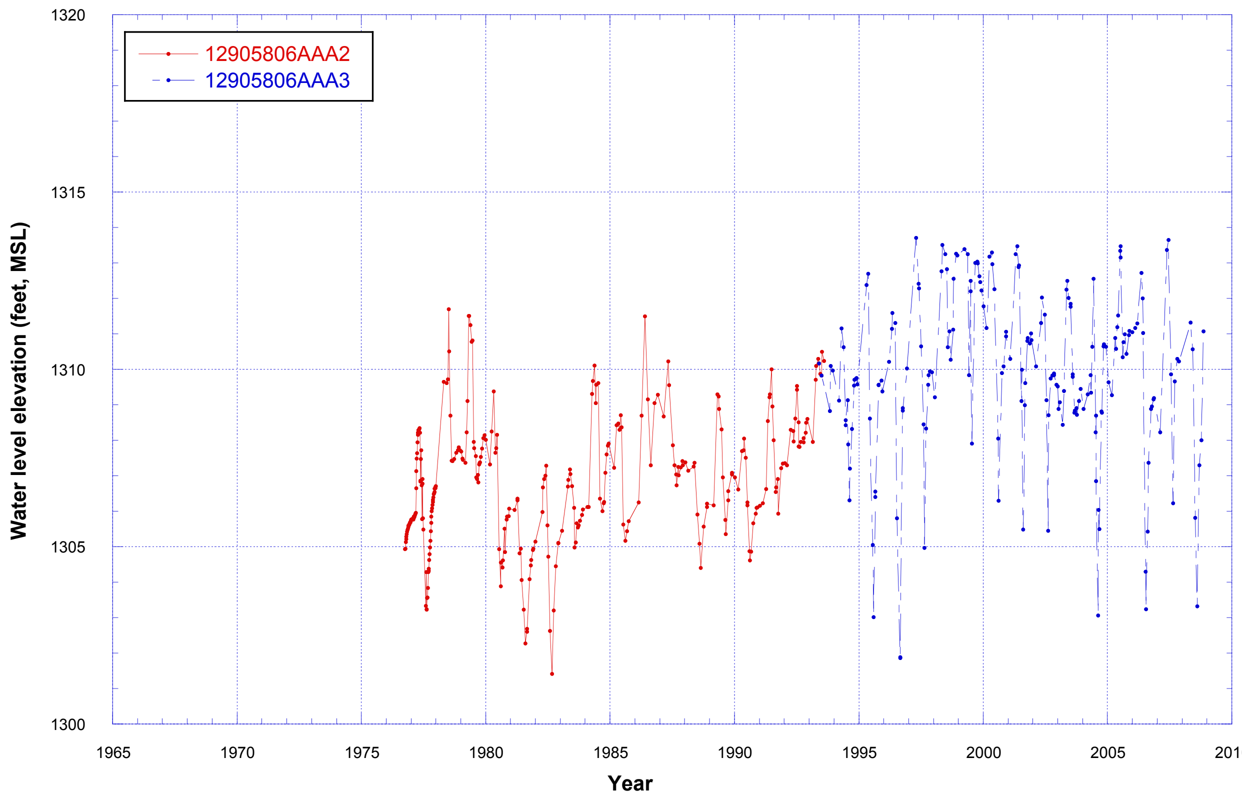


Figure B-2. Hydrograph of observation wells 129-058-06AAA2 and 129-058-06AAA3.

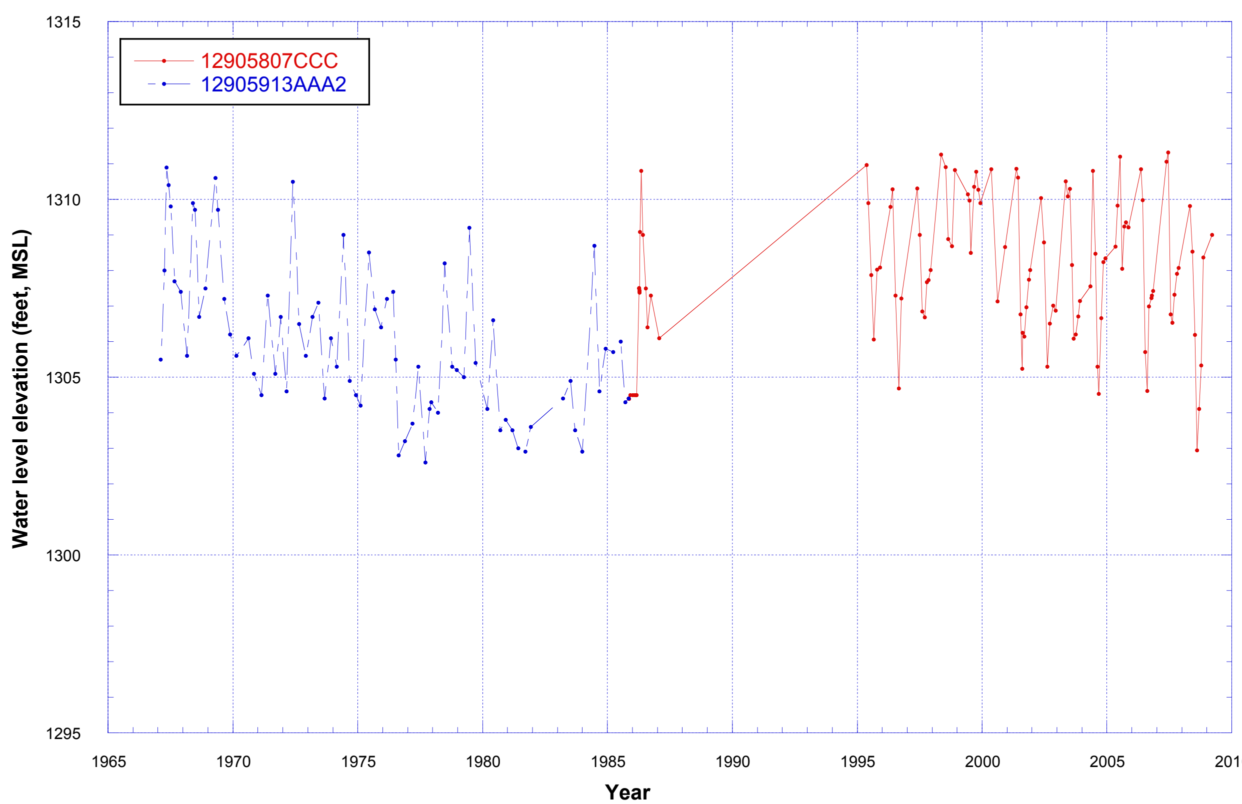


Figure B-3. Hydrograph of observation wells 129-058-07CCC and 129-059-13AAA2.

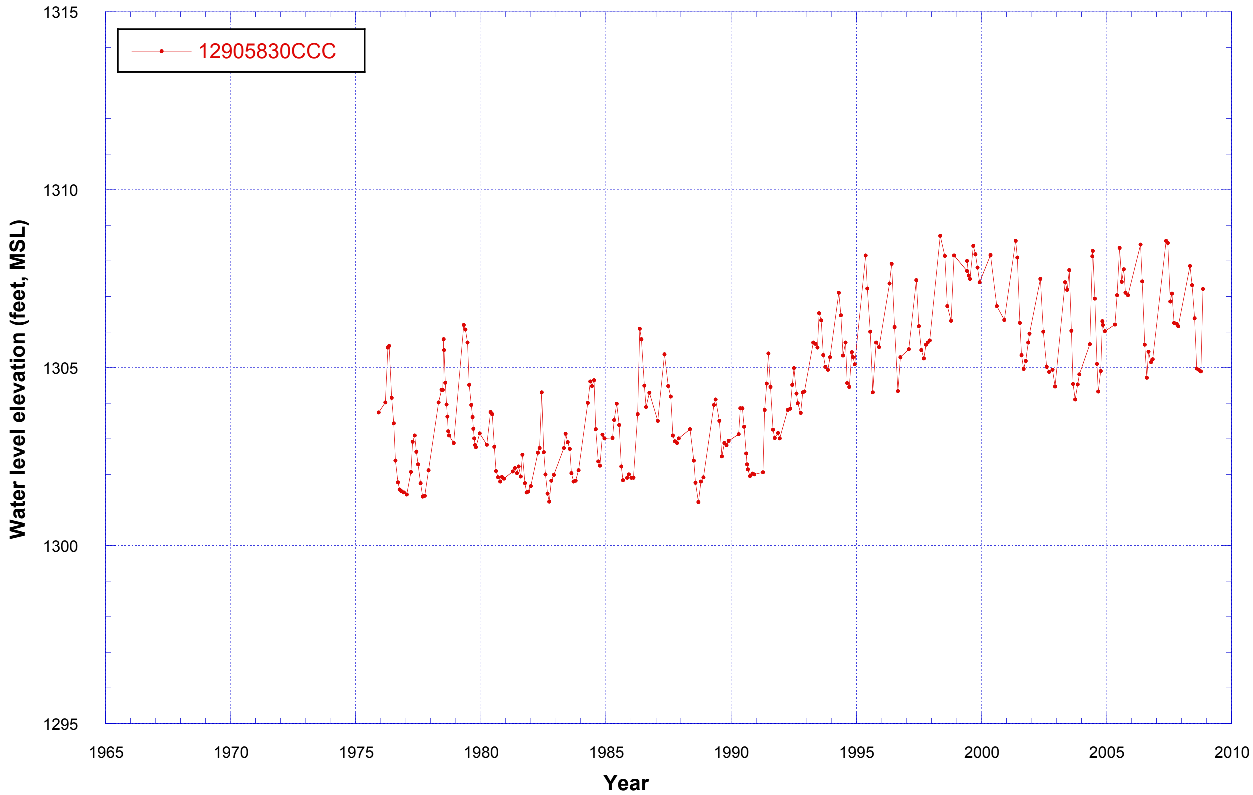


Figure B-4. Hydrograph of observation well 129-058-30CCC.

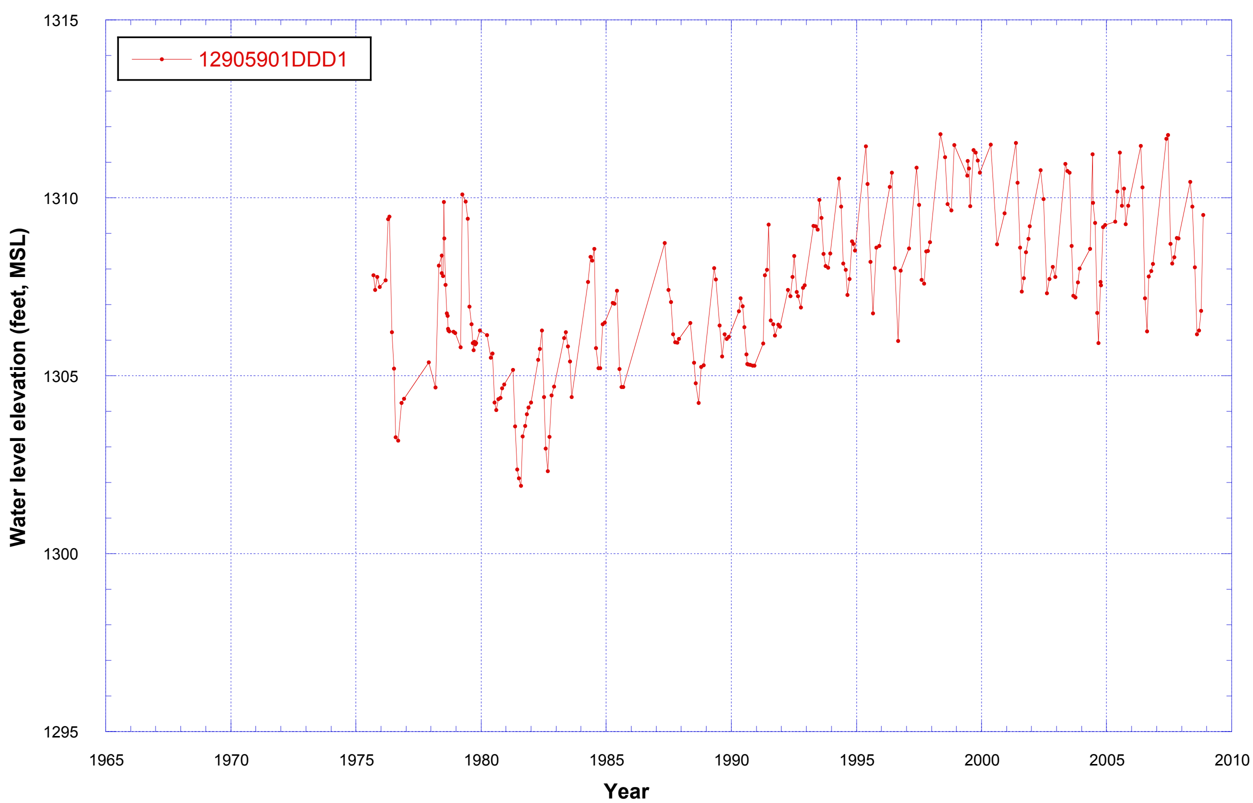


Figure B-5. Hydrograph of observation well 129-059-01DDD1.

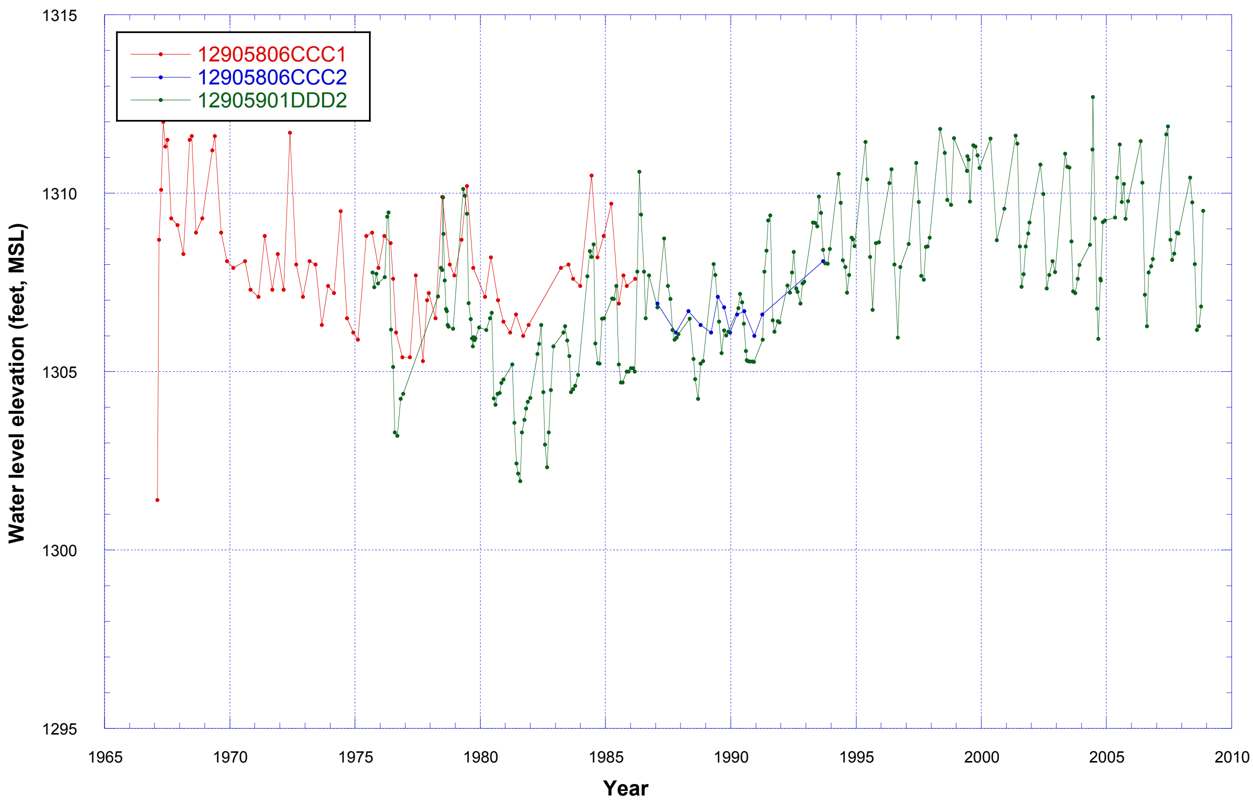


Figure B-6. Hydrograph of observation wells 129-050-06CCC1, 129-058-06CCC2, and 129-059-01DDD2.

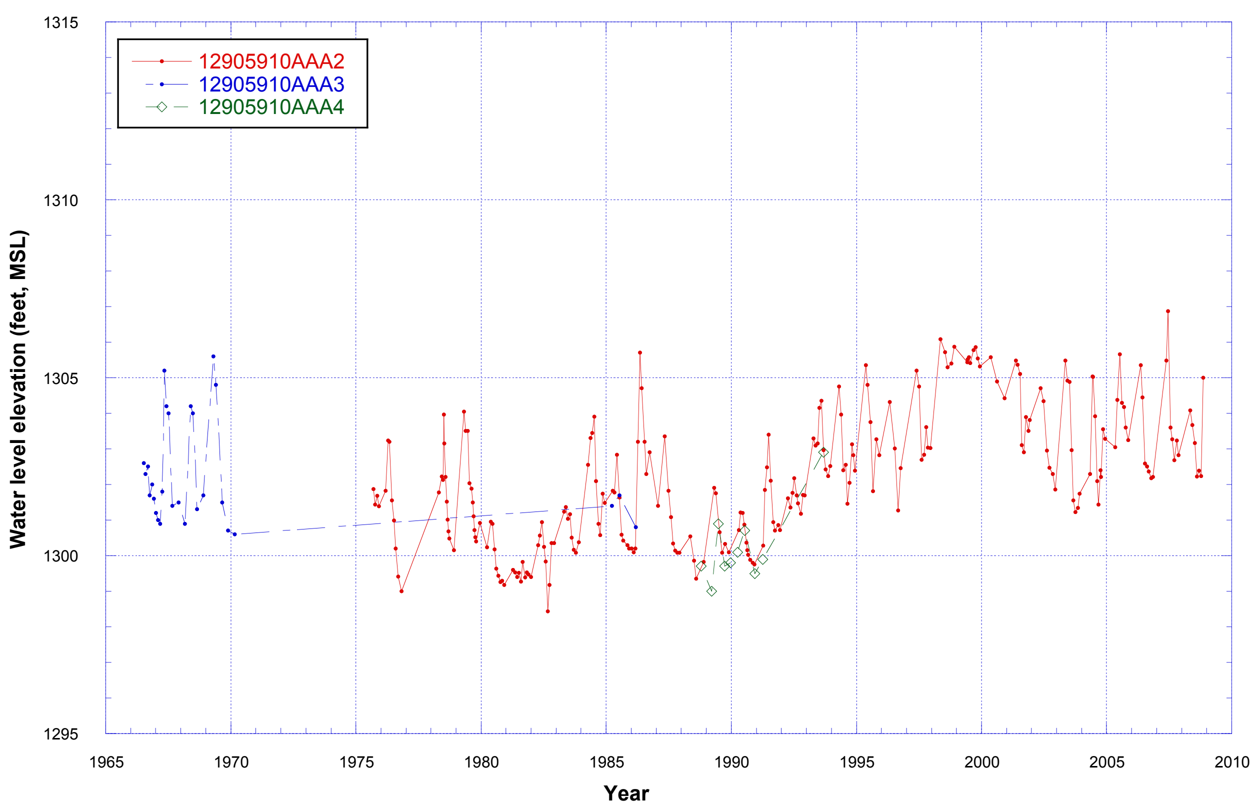


Figure B-7. Hydrograph of observation wells 129-059-10AAA2, 10AAA3, and 10AAA4.

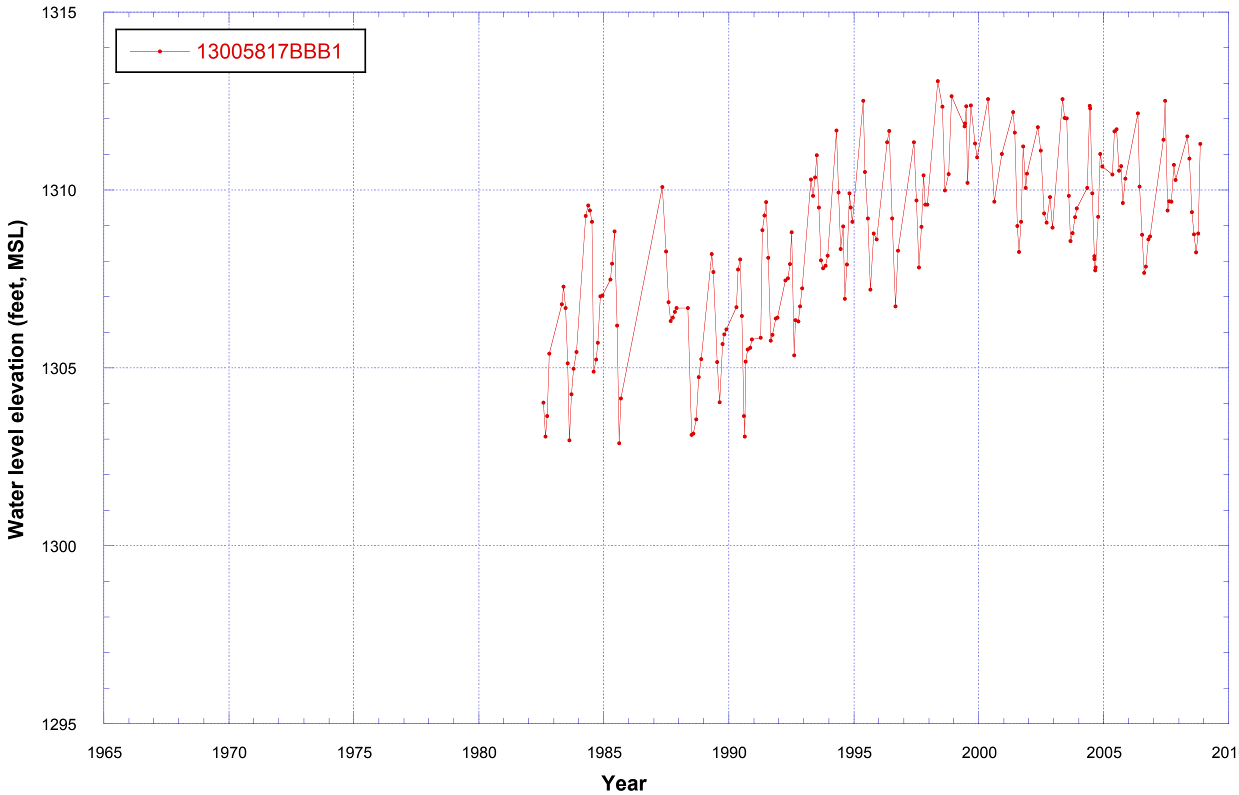


Figure B-8. Hydrograph of observation well 130-058-17BBB1

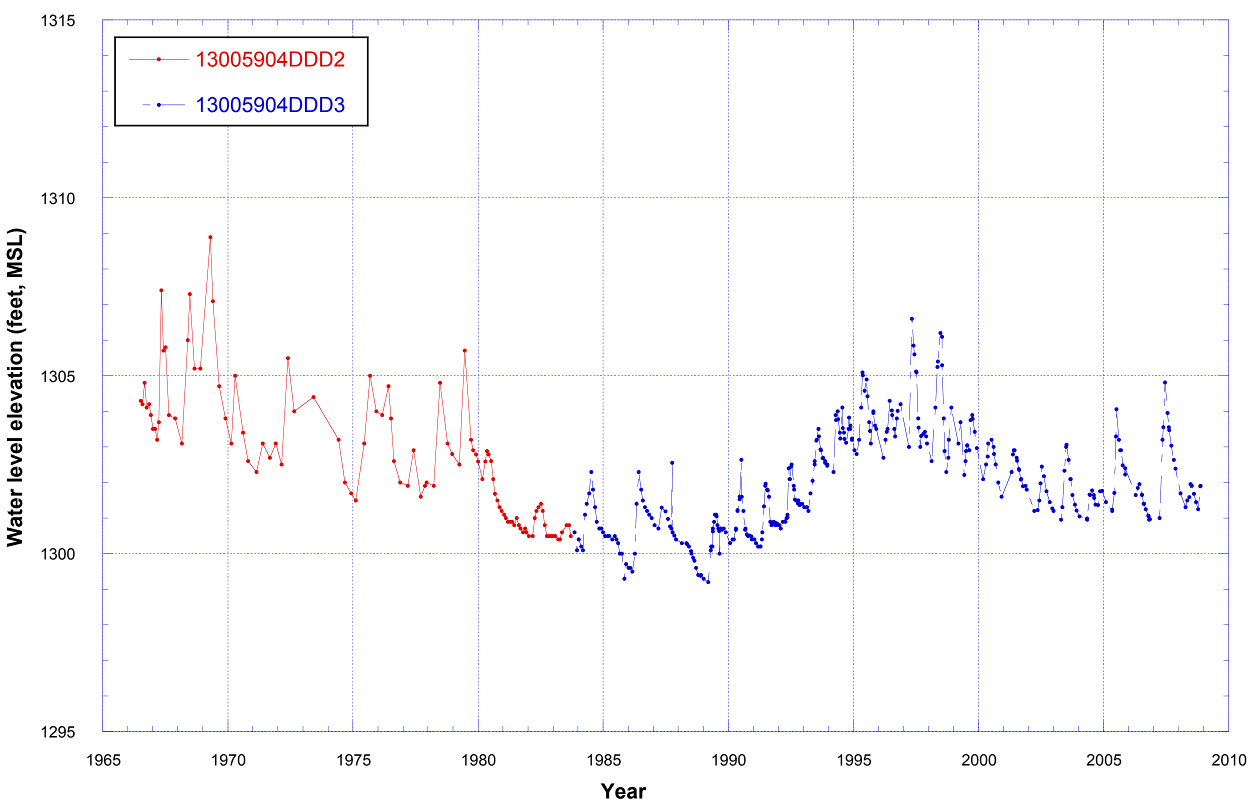


Figure B-9. Hydrograph of observation wells 130-059-04DDD2 and 04DDD3.

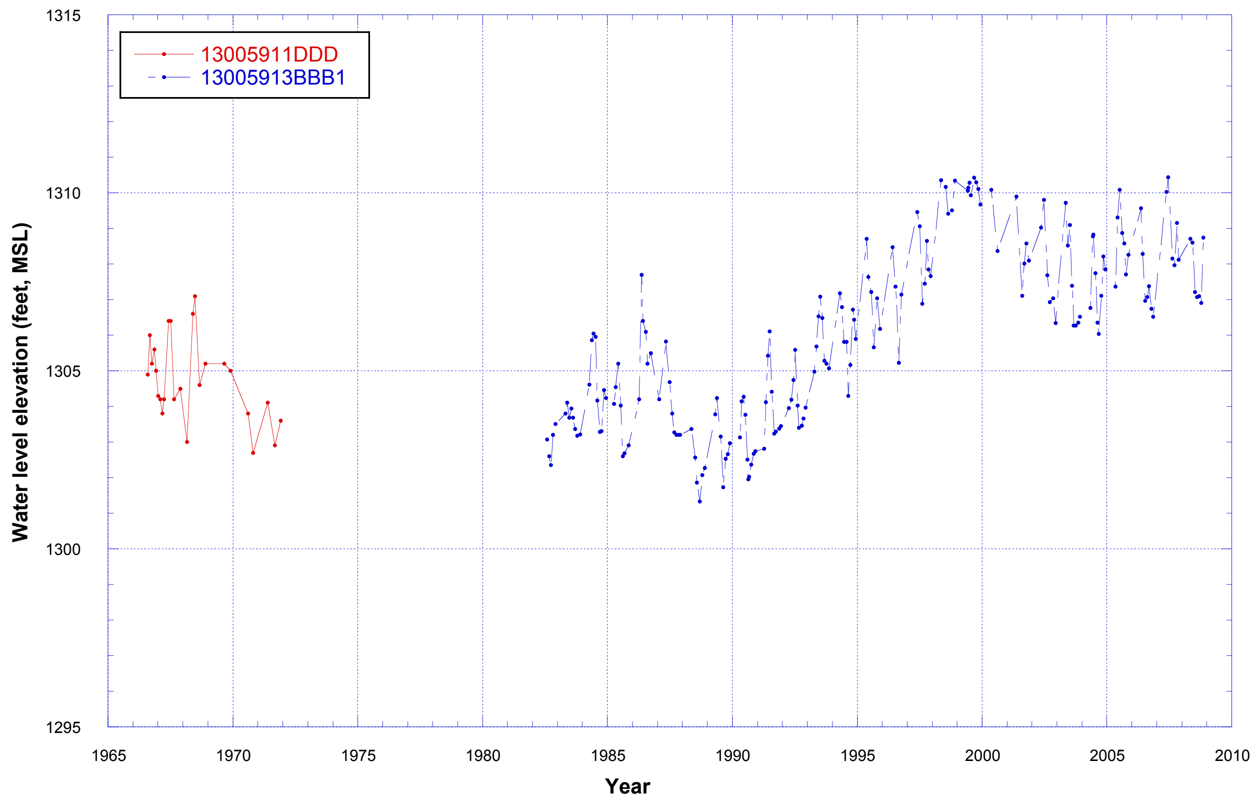


Figure B-10. Hydrograph of observation wells 130-059-11DDD and 13BBB1.

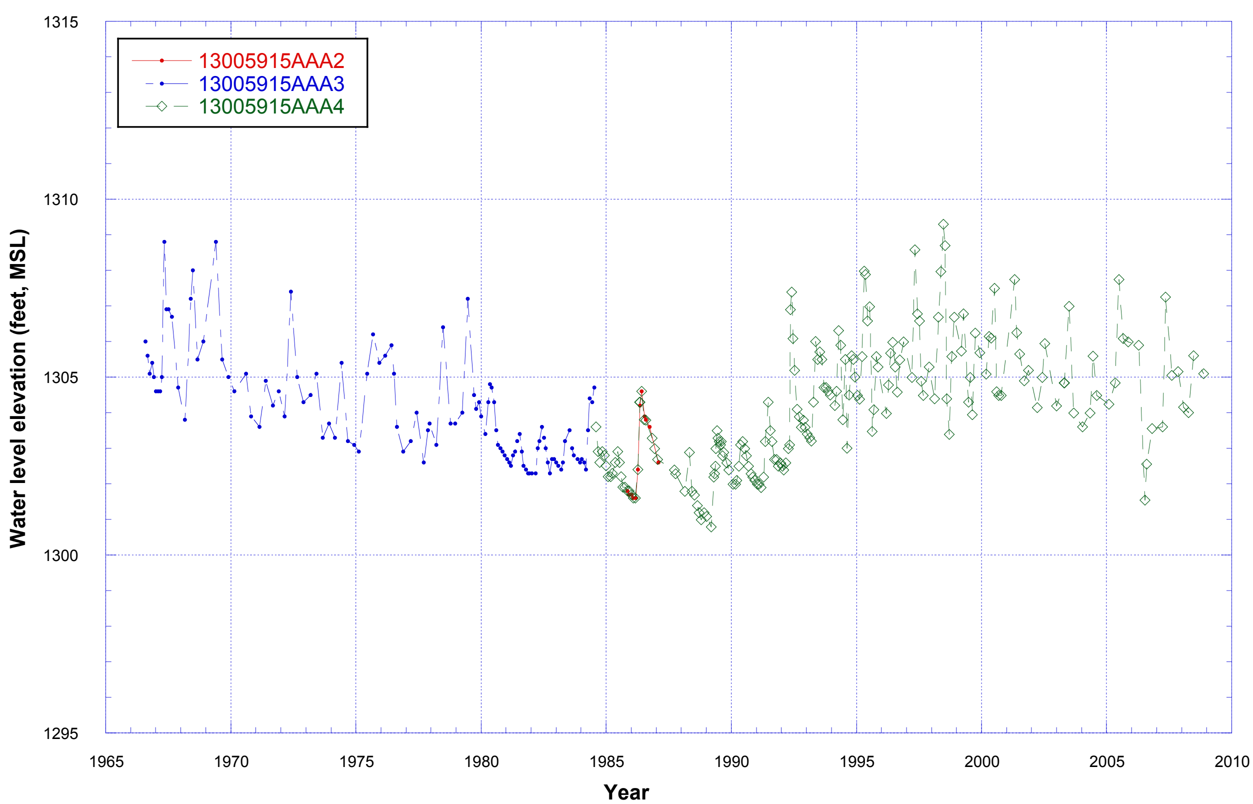


Figure B-11. Hydrograph of observation wells 130-059-15AAA2, 15AAA3, and 15AAA4.

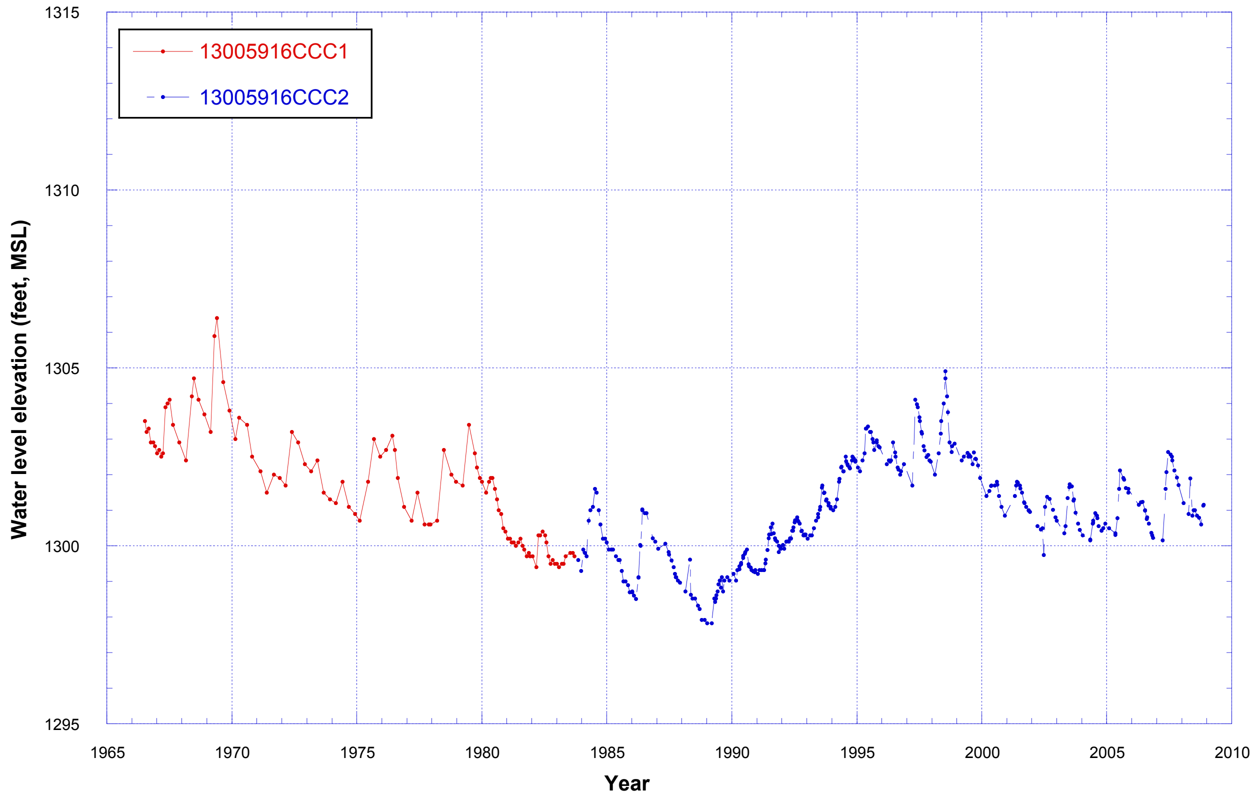


Figure B-12. Hydrograph of observation wells 130-059-16CCC1 and 16CCC2.

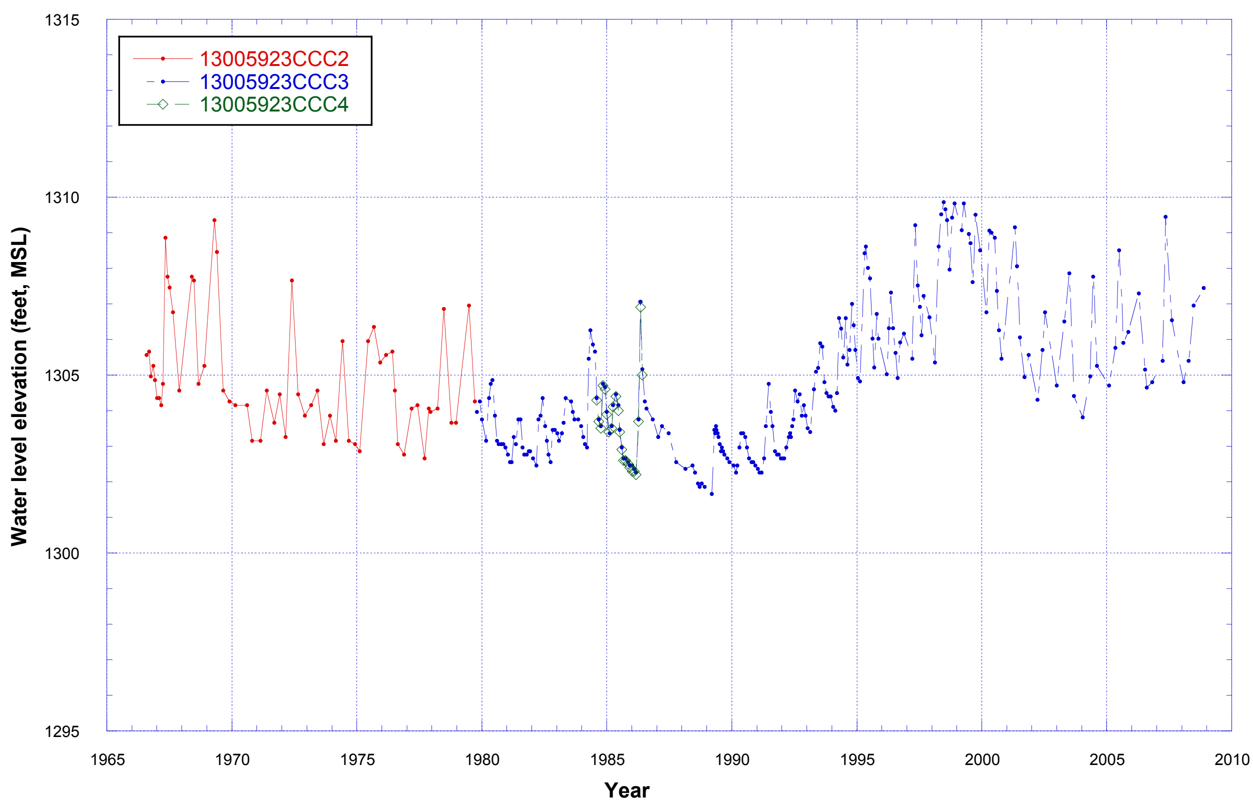


Figure B-13. Hydrograph of observation wells 130-059-23CCC2, 23CCC3, and 23CCC4.

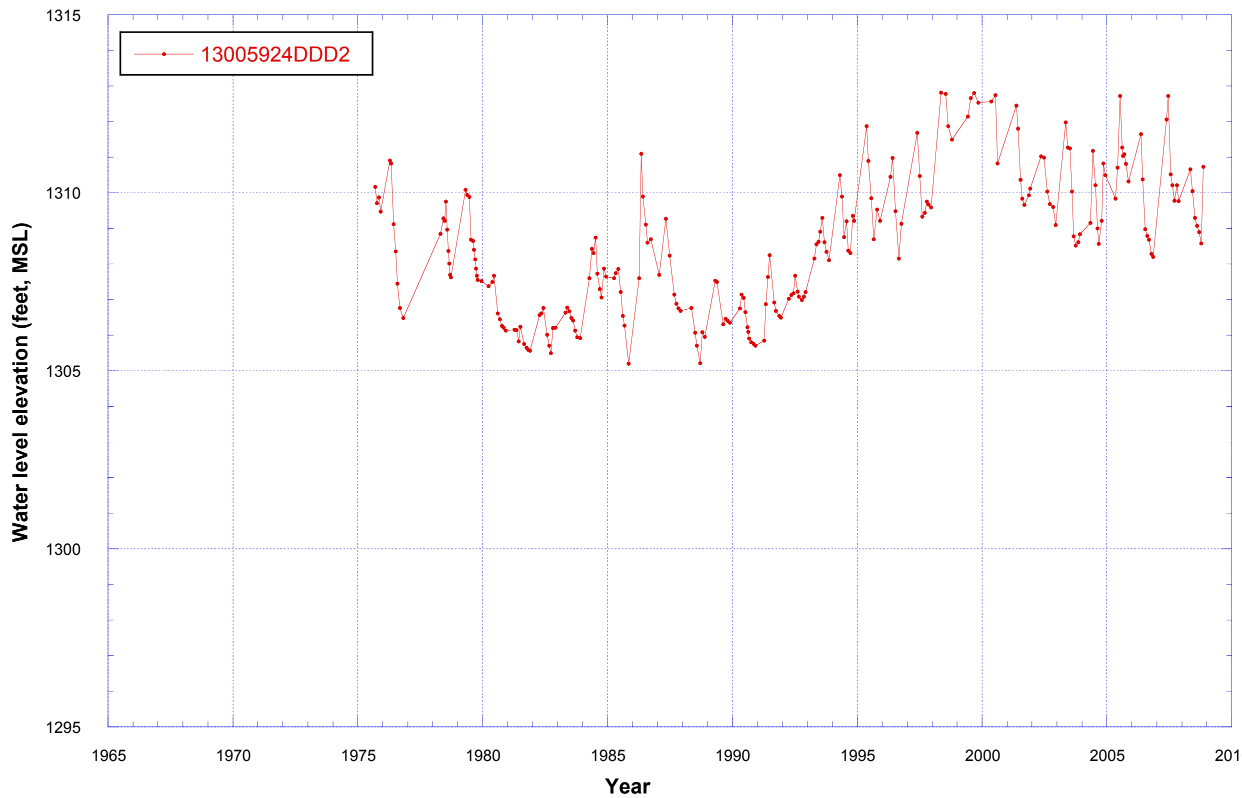


Figure B-13. Hydrograph of observation well 130-059-24DDD2.

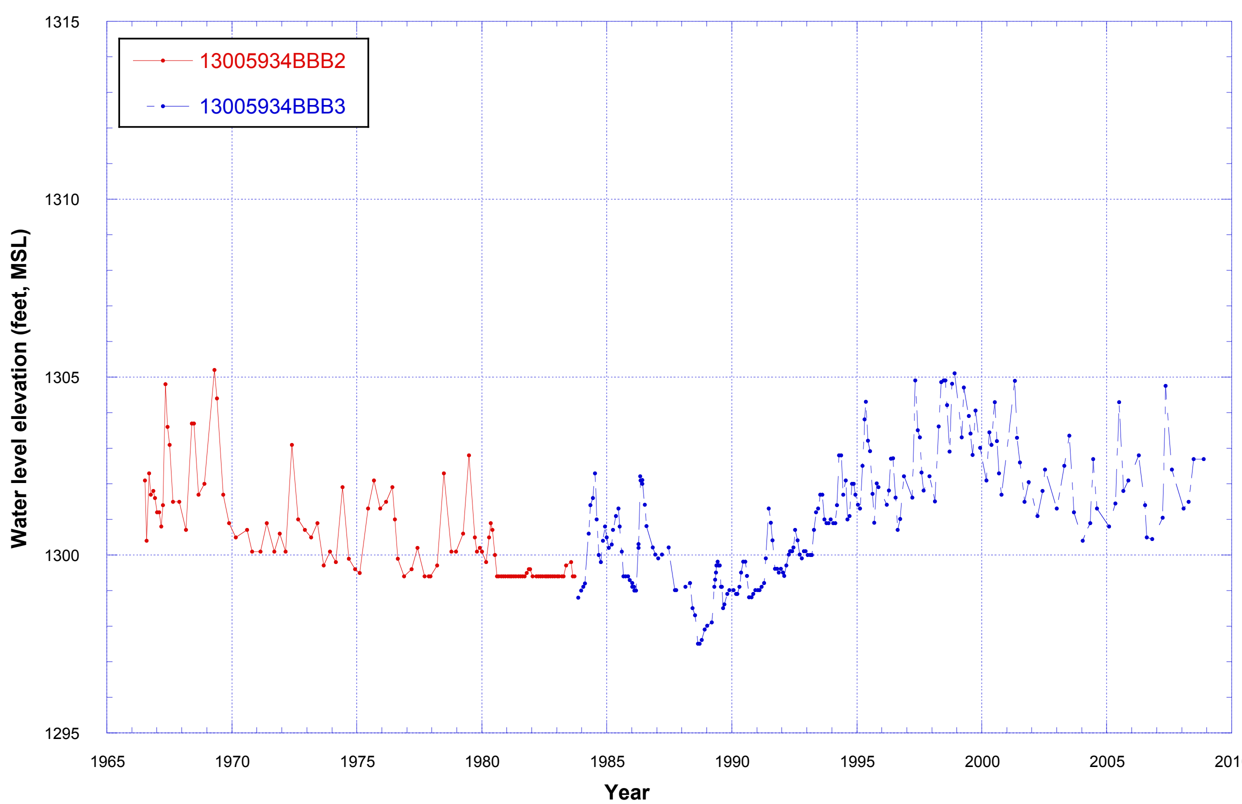


Figure B-14. Hydrograph of observation wells 130-059-34BBB2 and 34BBB3.

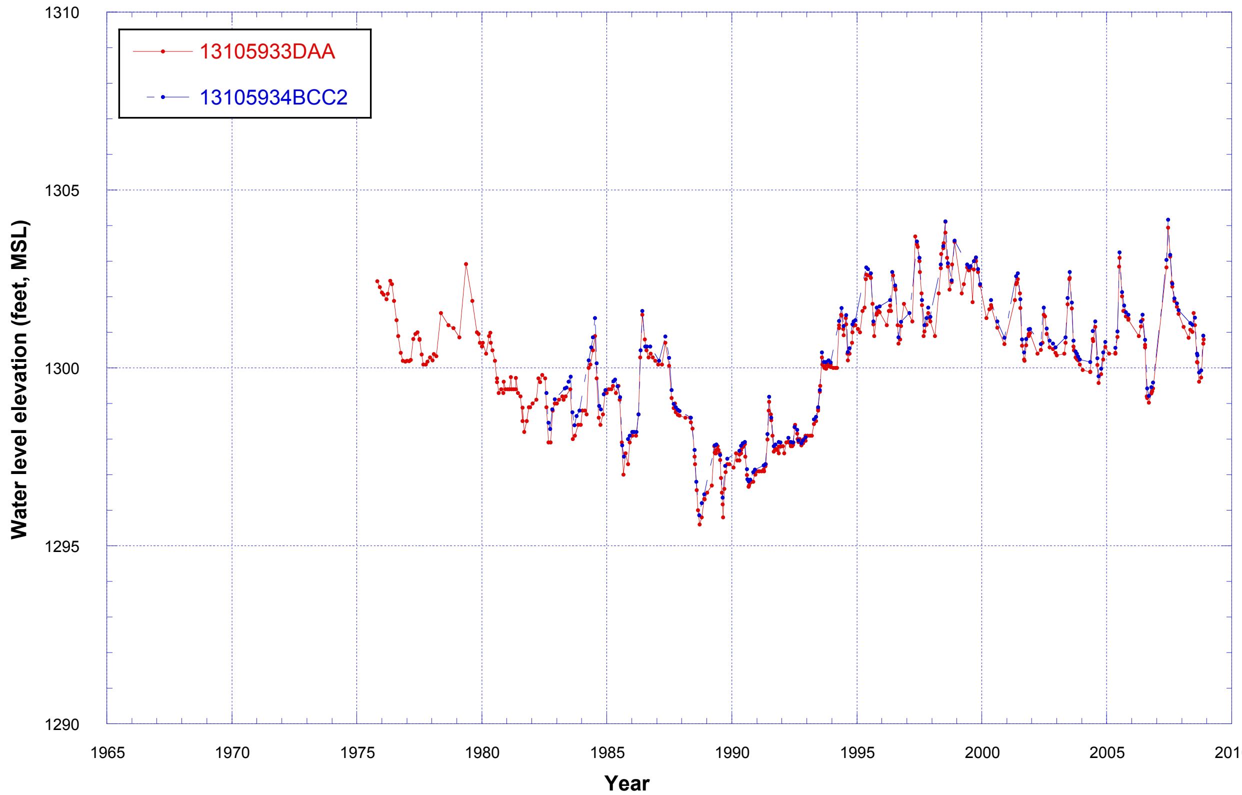


Figure B-15. Hydrograph of observation wells 131-059-33DDA and 34BCC2.

Appendix C. LANDSAT Images of Oakes Aquifer.

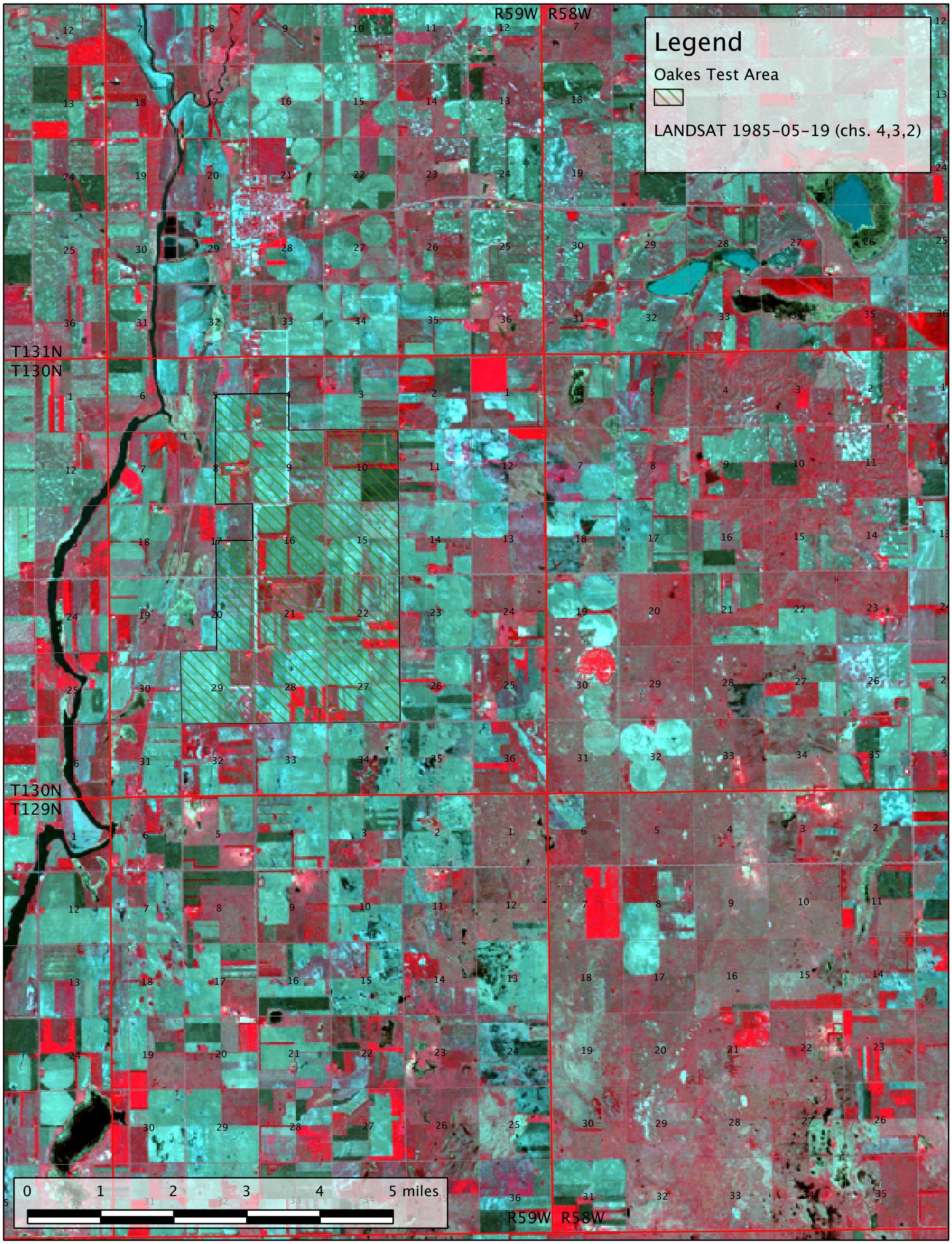


Figure C-1. LANDSAT image for May 19, 1985 bands 4,3,2.

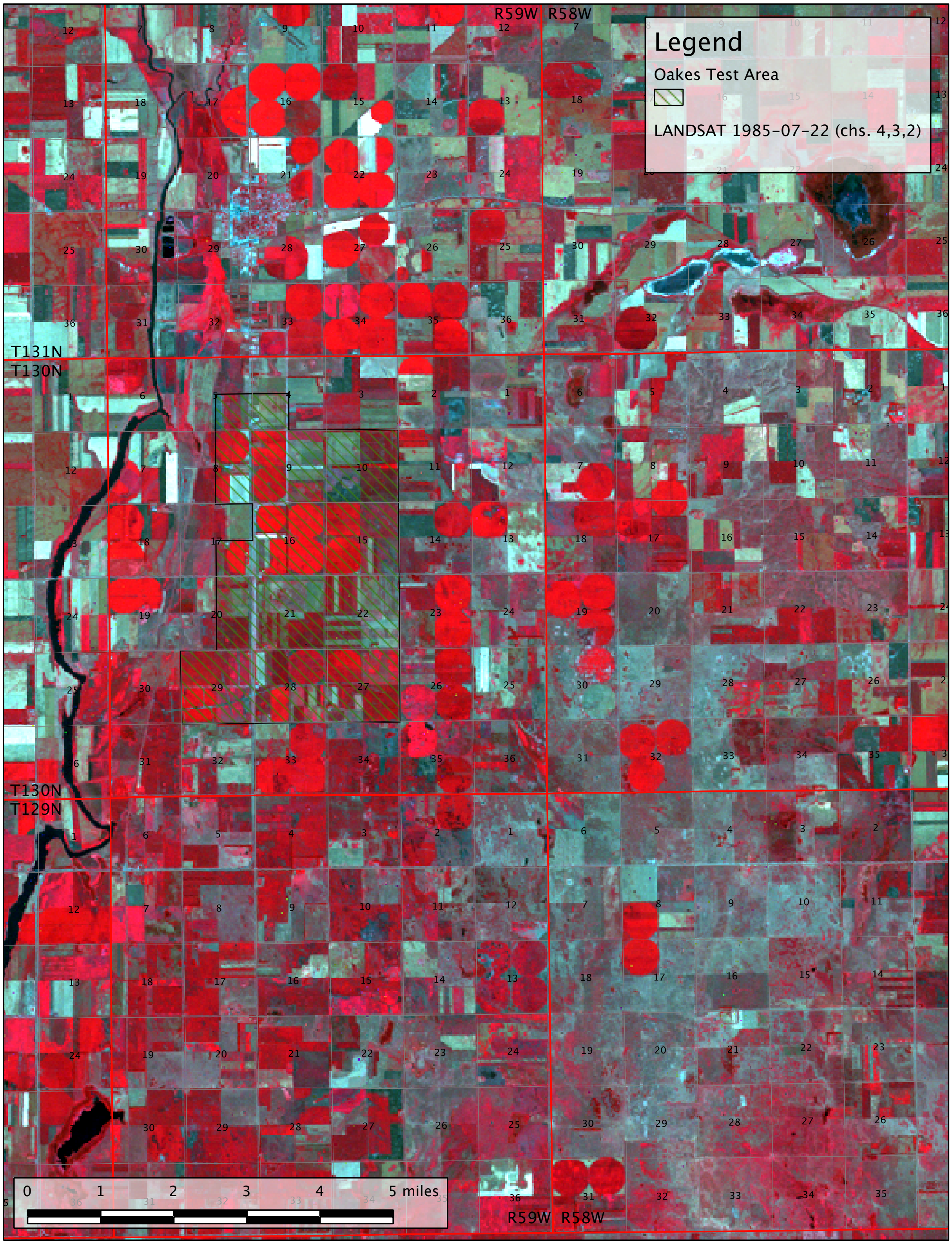


Figure C-2. LANDSAT image for July 22, 1985 bands 4,3,2.

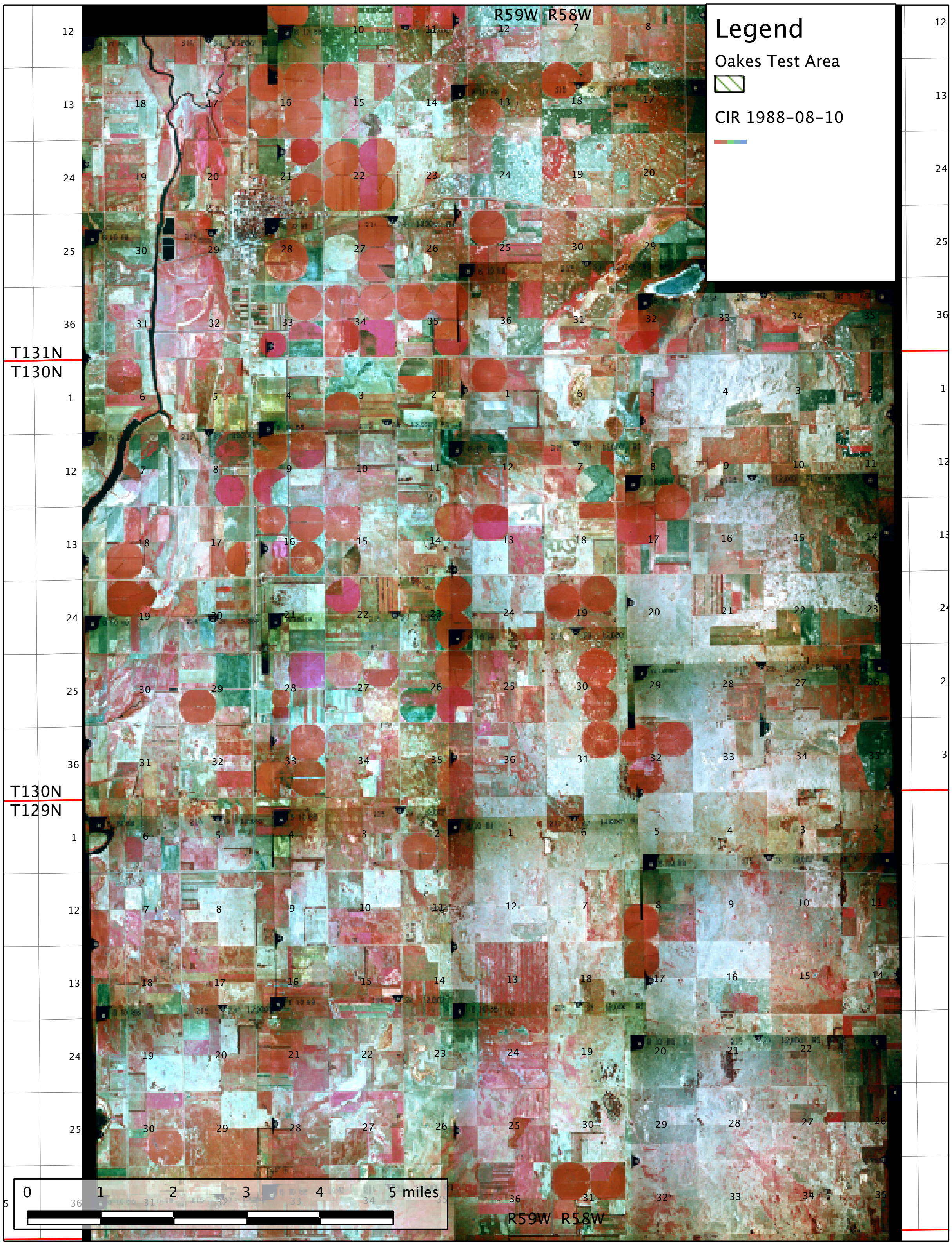


Figure C-3. NDSWC color infrared photography for August 10, 1988.

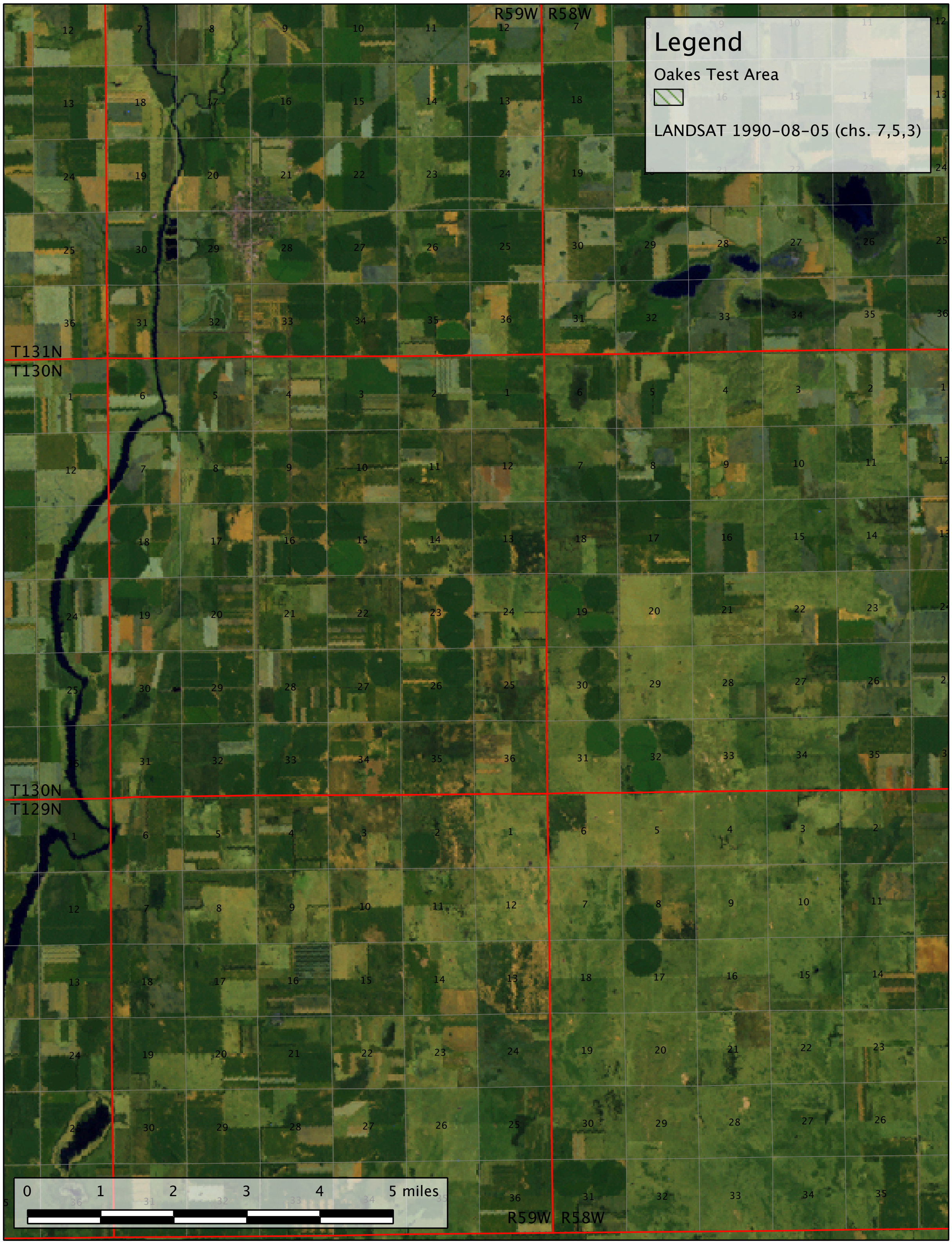


Figure C-4. LANDSAT image for August 5, 1990 bands 7,5,3.

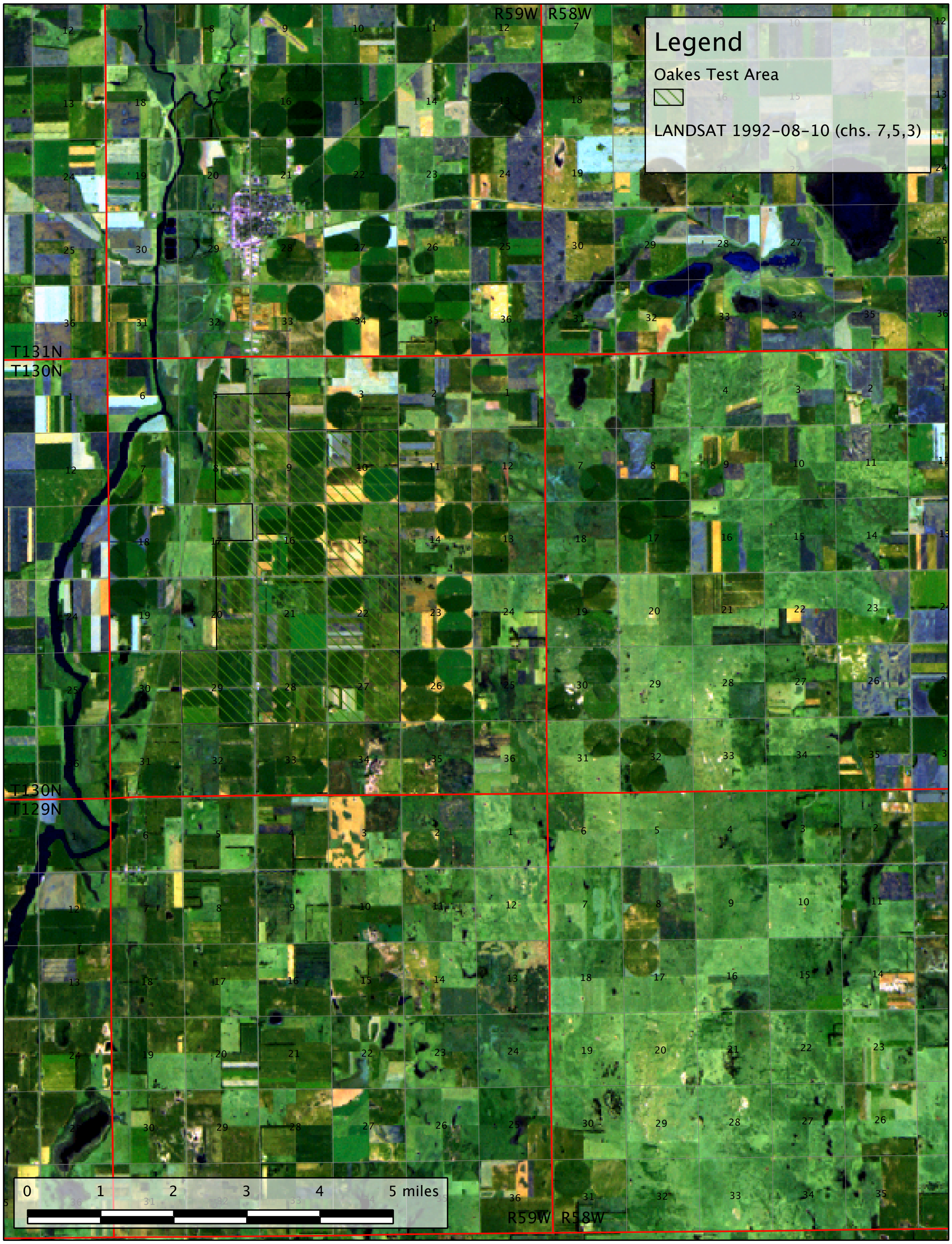


Figure C-5. LANDSAT image for August 10, 1992 bands 7,5,3.

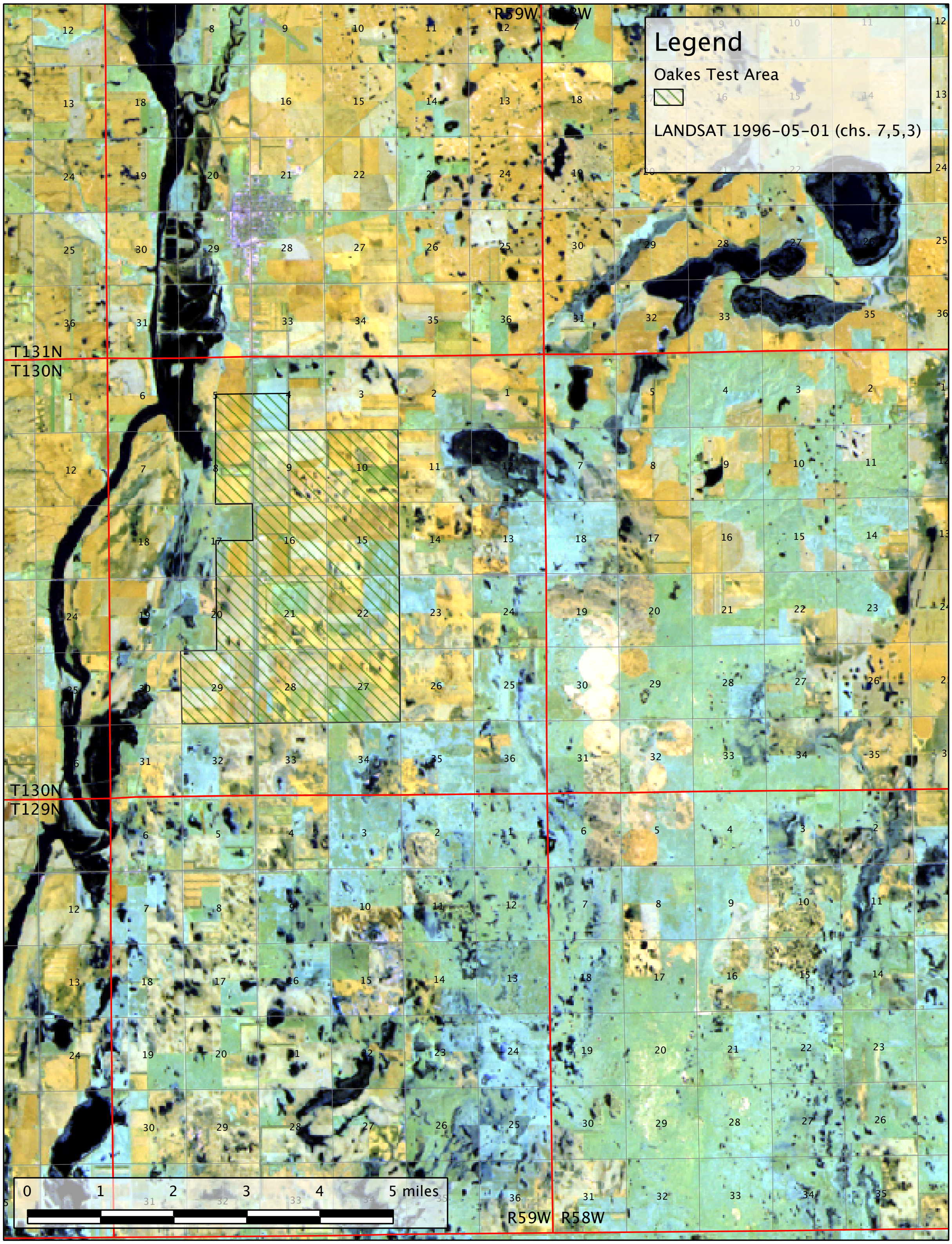


Figure C-6. LANDSAT image for May 01, 1996 bands 7,5,3.

Figure C-7. LANDSAT image for April 29, 2001 bands 7,5,3.

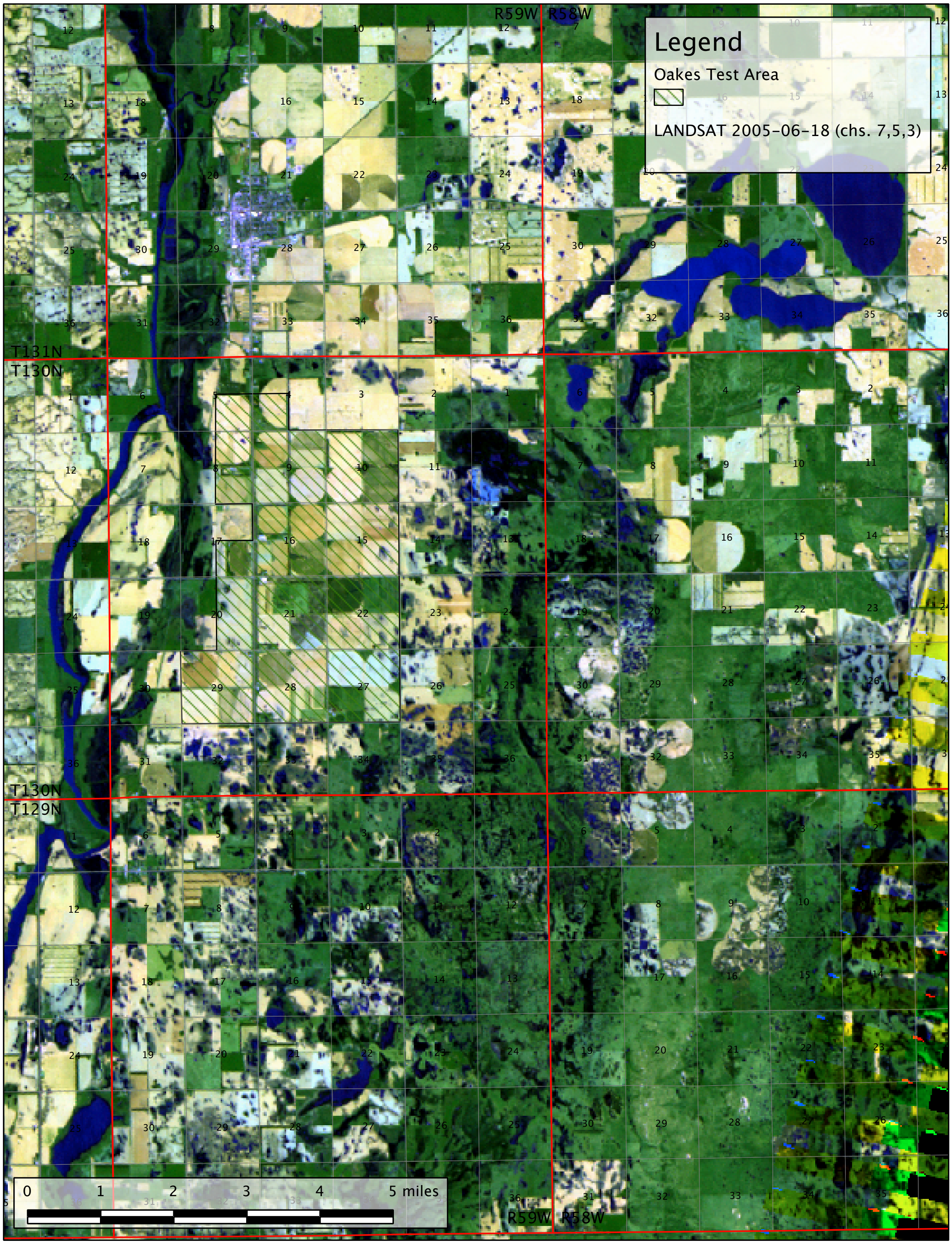


Figure C-8. LANDSAT image for June 18, 2005 bands 7,5,3.

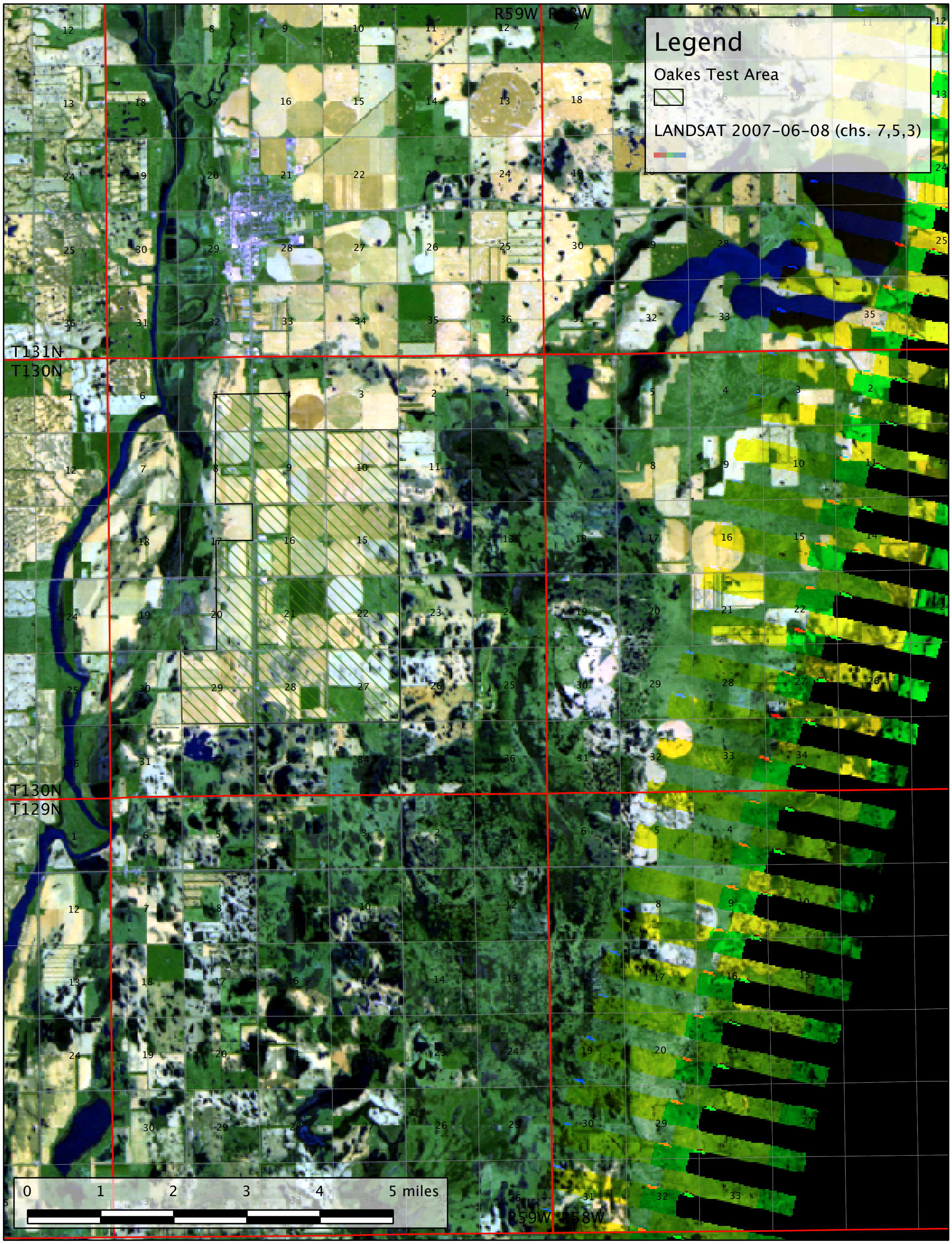


Figure C-9. LANDSAT image for June 8, 2007 bands 7,5,3.

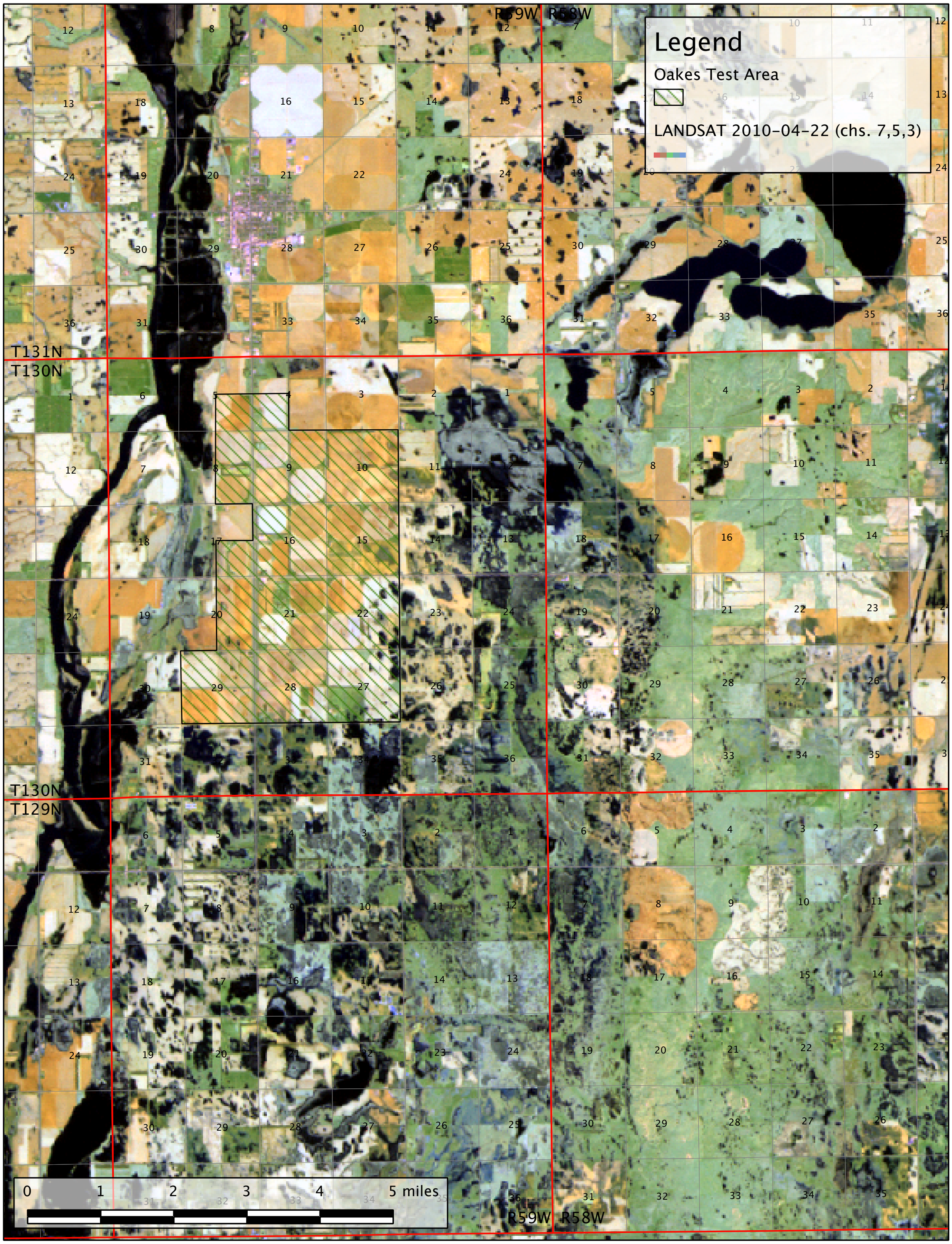


Figure C-10. LANDSAT image for April 22, 2010 bands 7,5,3.

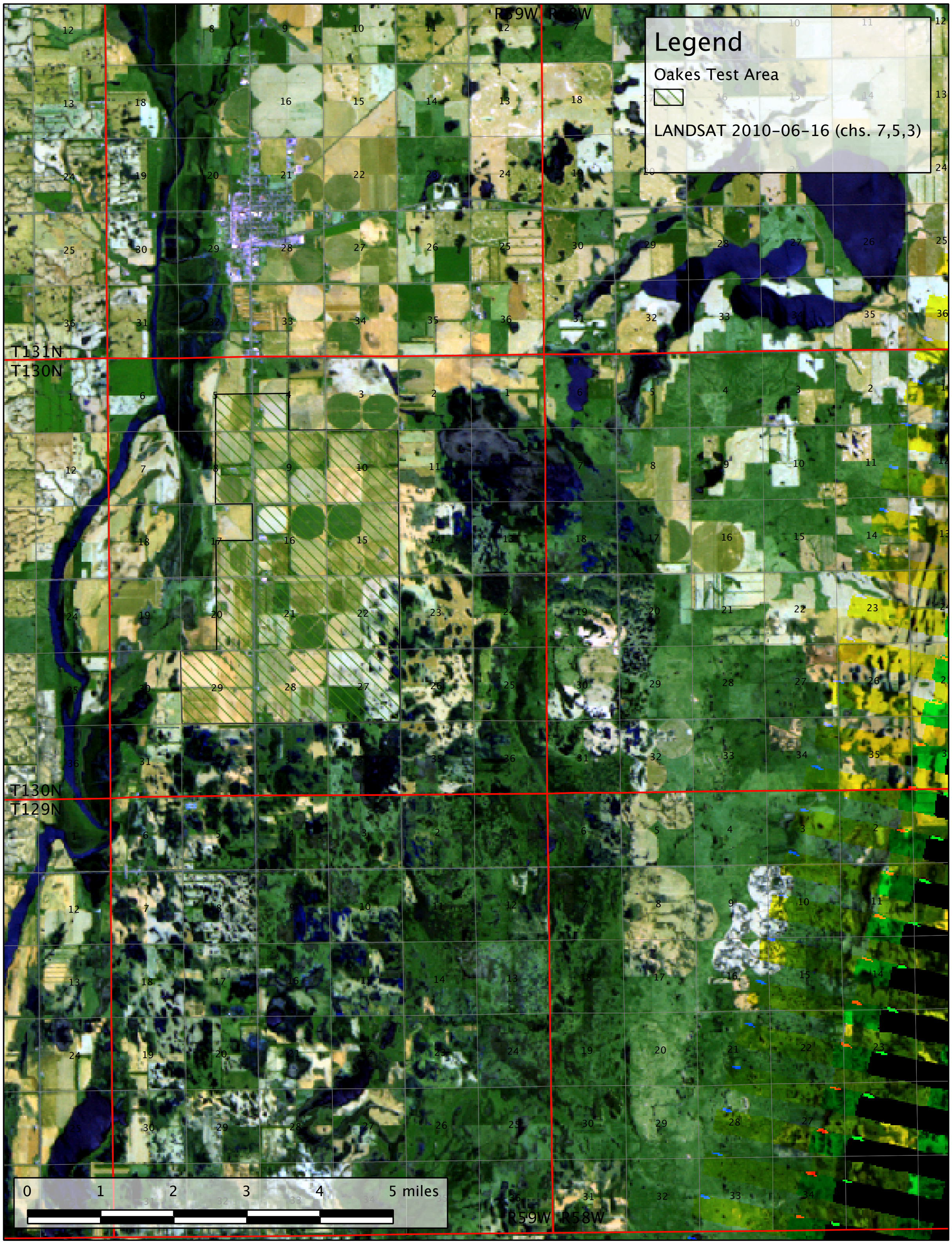


Figure C-11. LANDSAT image for June 16, 2010 bands 7,5,3.

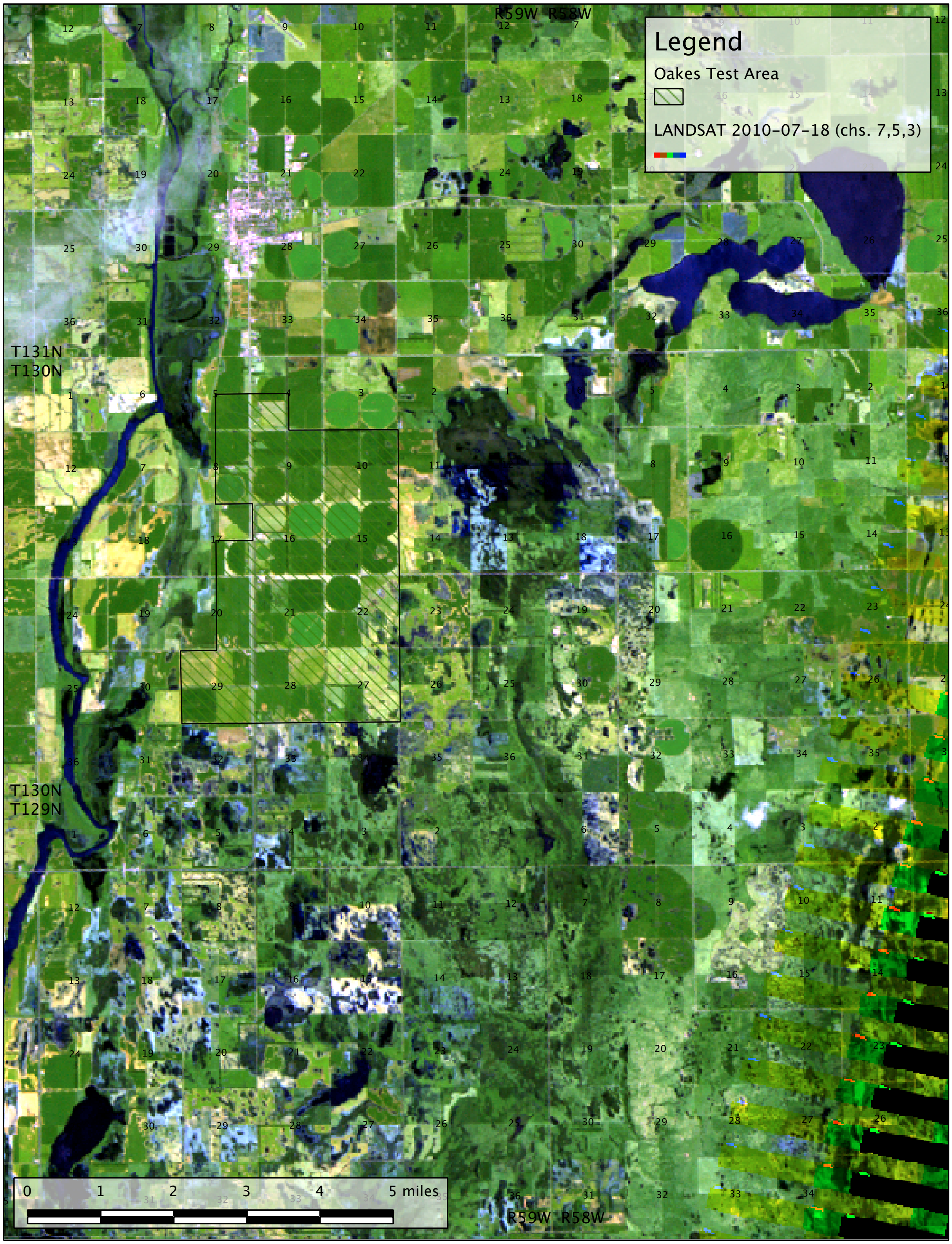


Figure C-12. LANDSAT image for July 18, 2010 bands 7,5,3.

Appendix D. Model Calibration: Observed vs. Simulated Water Levels.

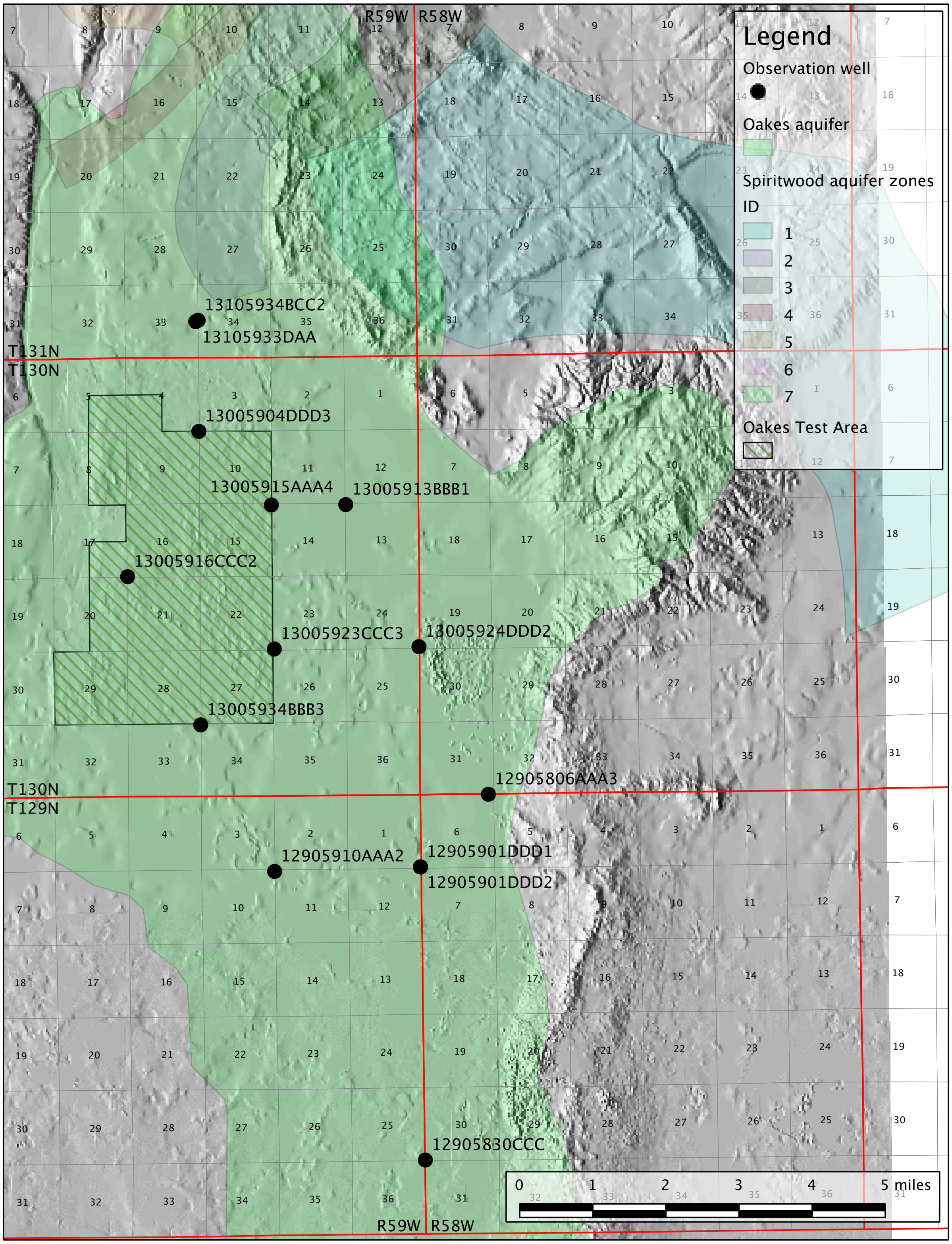


Figure D-1. Location of sites in figures D-2 to D-14 where comparison is shown between transient calibration water levels, run F23, to observed water levels at the observation wells.

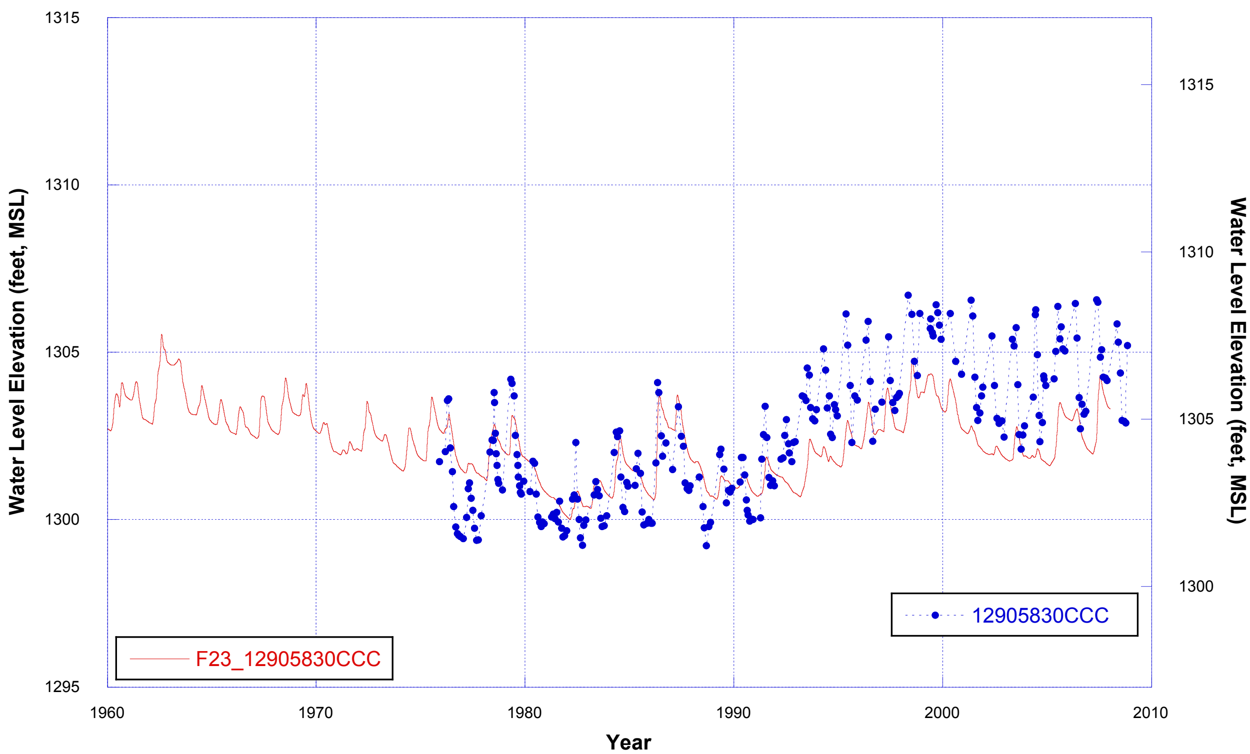


Figure D-2. Comparison of transient calibration water levels, run F23, to observed at observation well 129-058-30CCC.

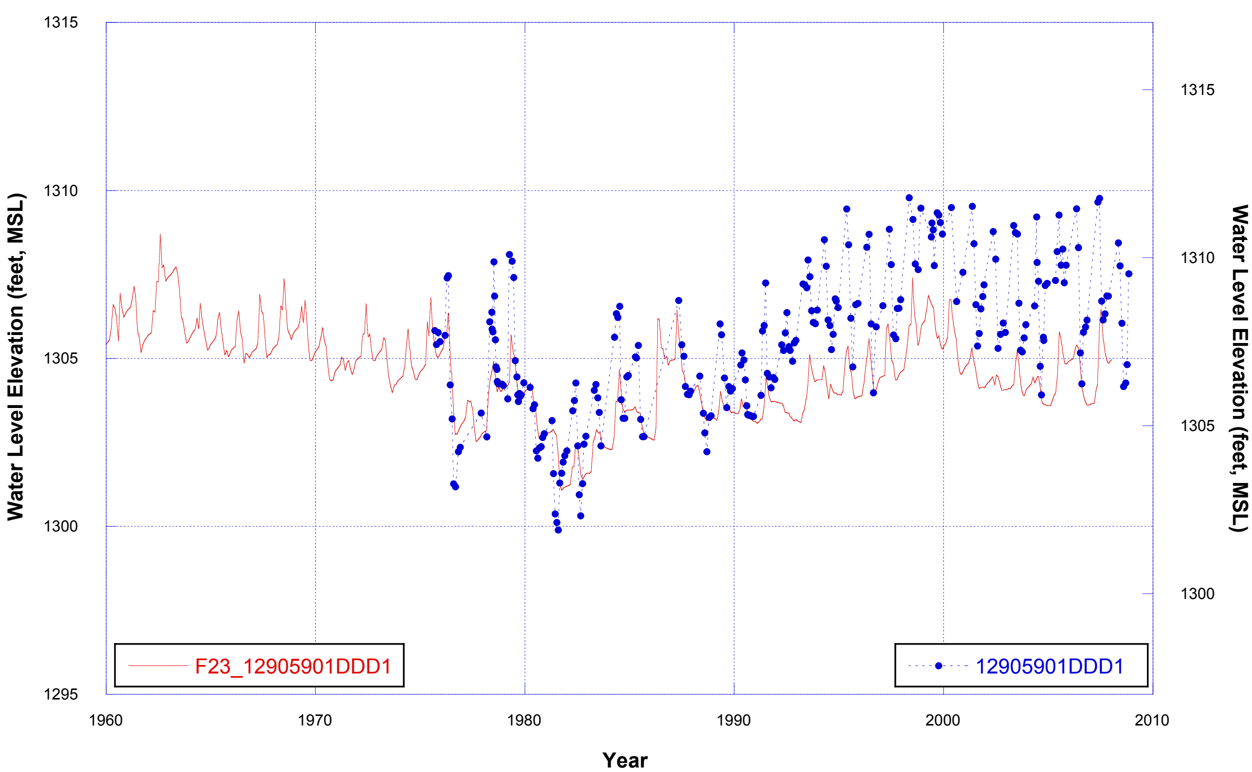


Figure D-3. Comparison of transient calibration water levels, run F23, to observed at observation well 129-059-01DDD1.

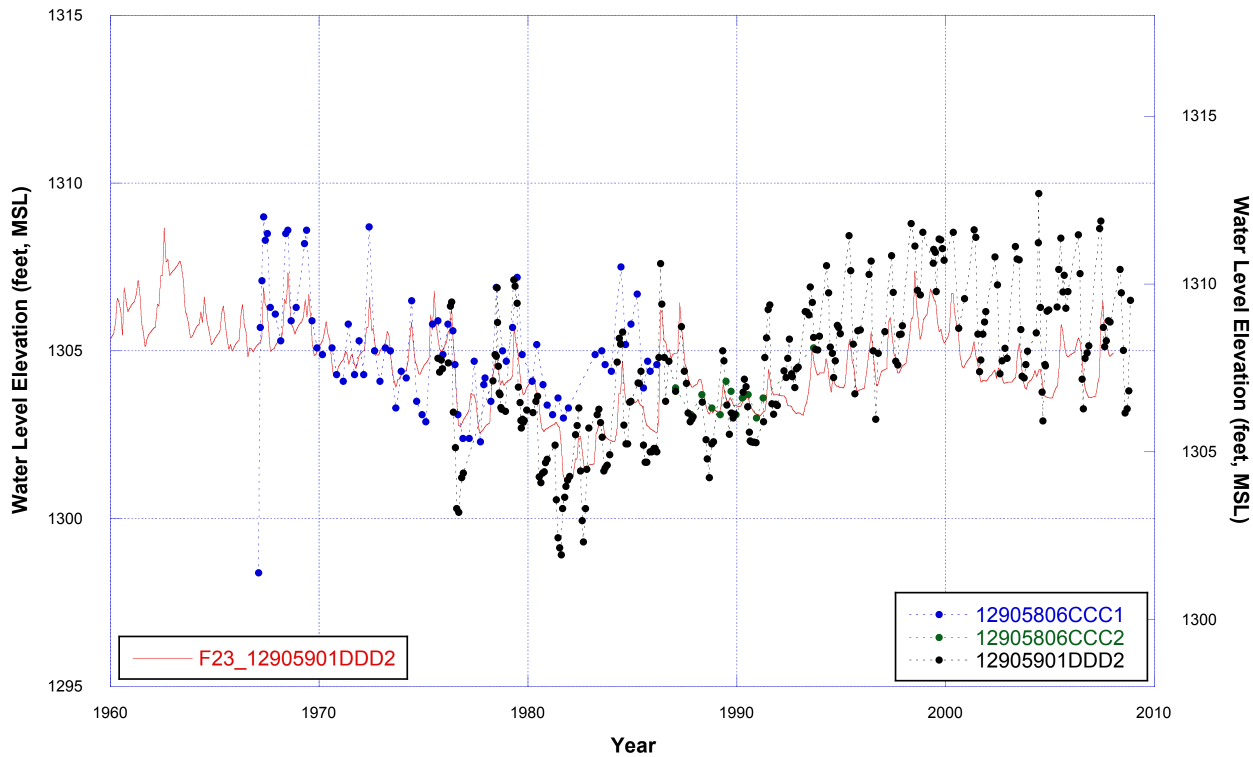


Figure D-4. Comparison of transient calibration water levels, run F23, to observed at observation wells 129-058-006CCC1 and 06CCC2 and 129-059-01DDD2.

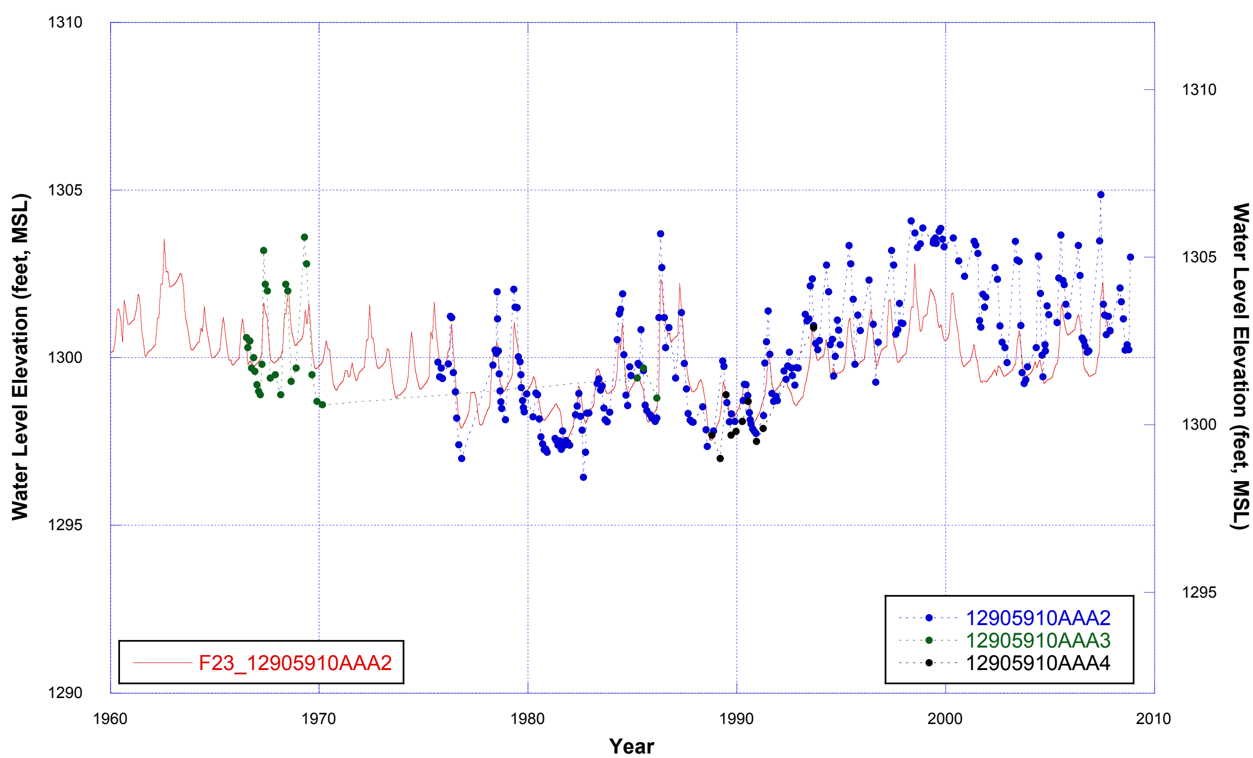


Figure D-5. Comparison of transient calibration water levels, run F23, to observed at observation wells 129-059-10AAA2, 10AAA3, and 10AAA4.

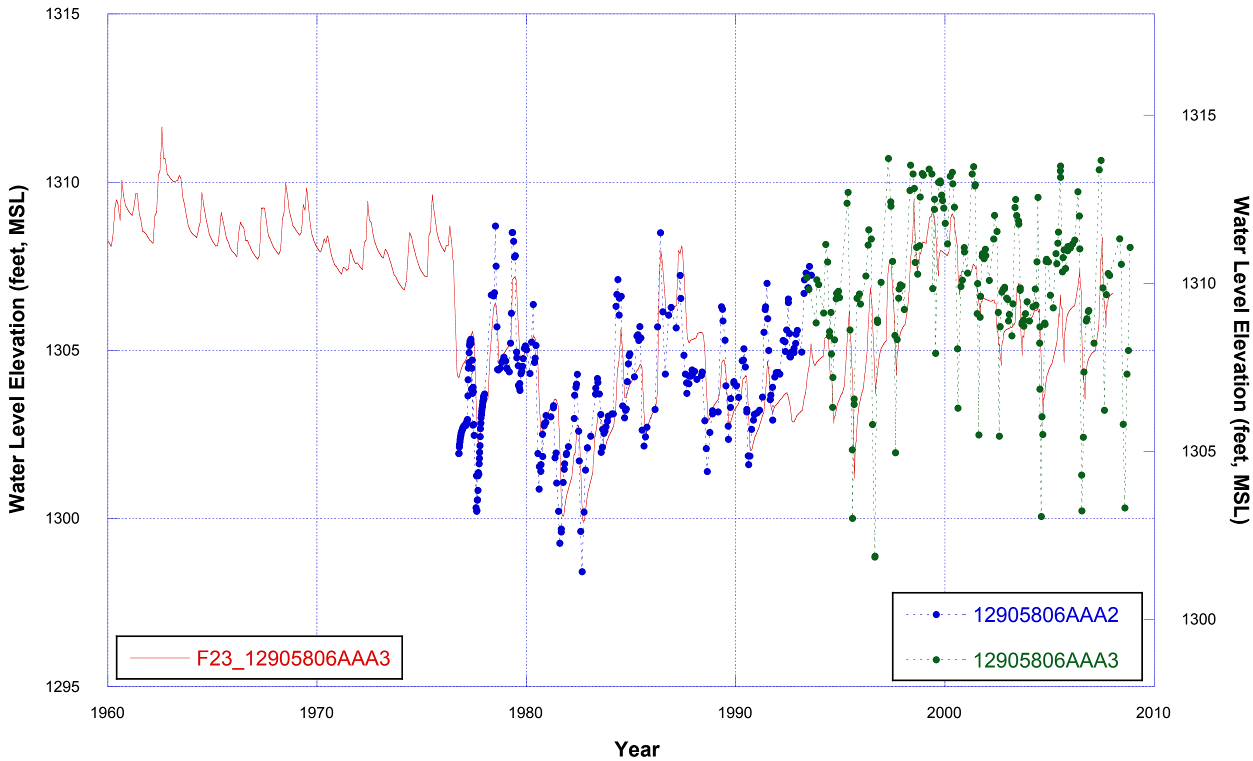


Figure D-6. Comparison of transient calibration water levels, run F23, to observed at observation wells 129-058-06AAA2 and 06AAA3.

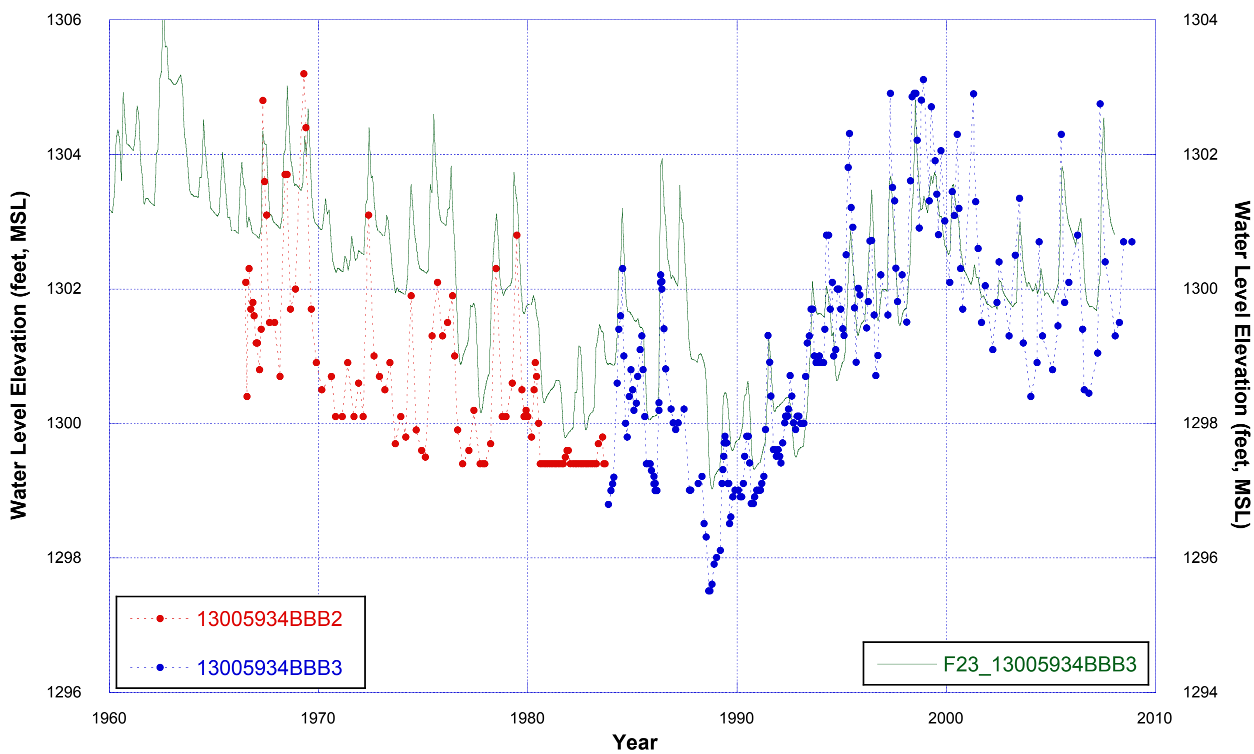


Figure D-7. Comparison of transient calibration water levels, run F23, to observed at observation wells 130-059-34BBB2 and 130-059-34BBB3.

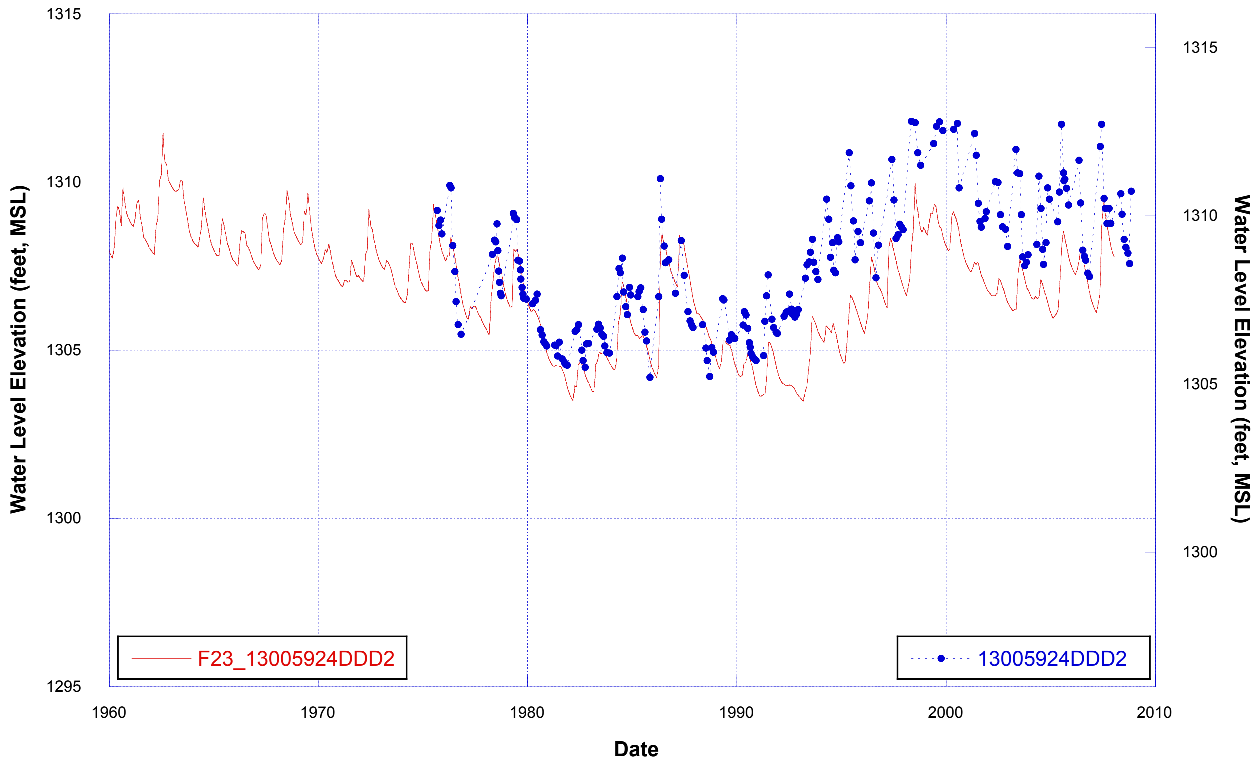


Figure D-8. Comparison of transient calibration water levels, run F23, to observed at observation well 130-059-24DDD2.

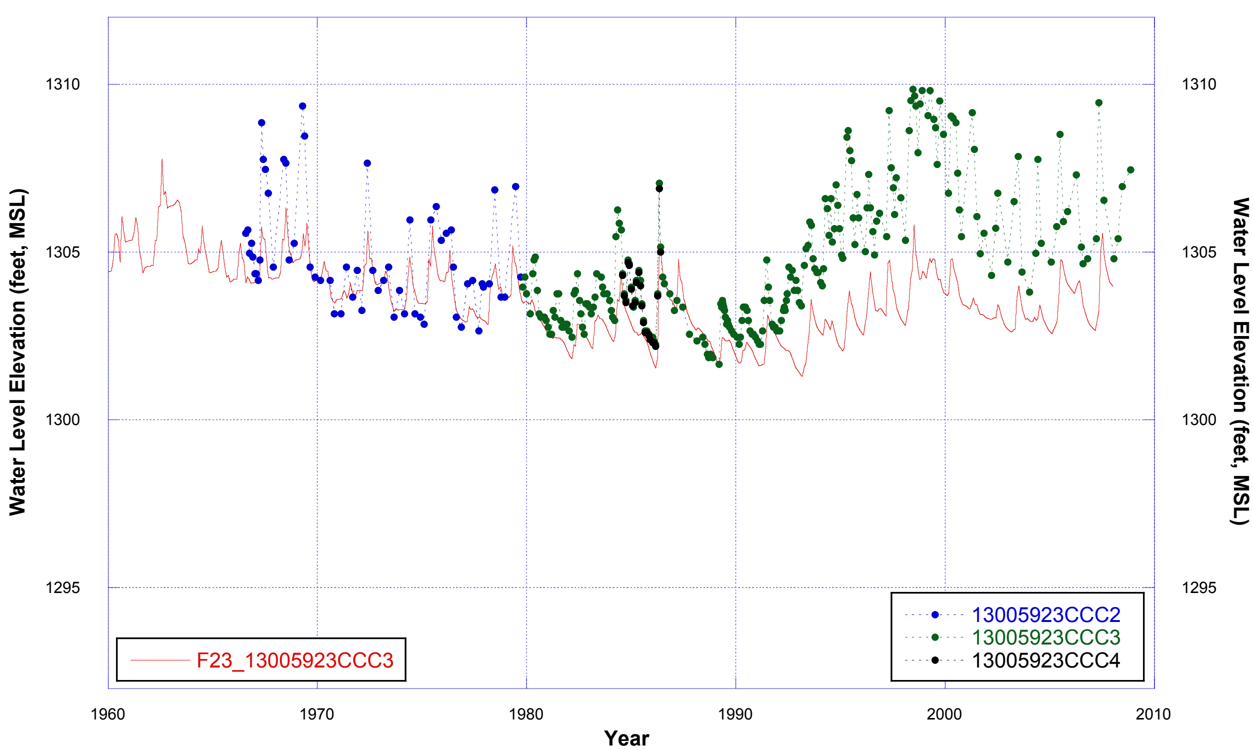


Figure D-9. Comparison of transient calibration water levels, run F23, to observed at observation wells 130-059-23CCC2, 23CCC3 and 23CCC4.

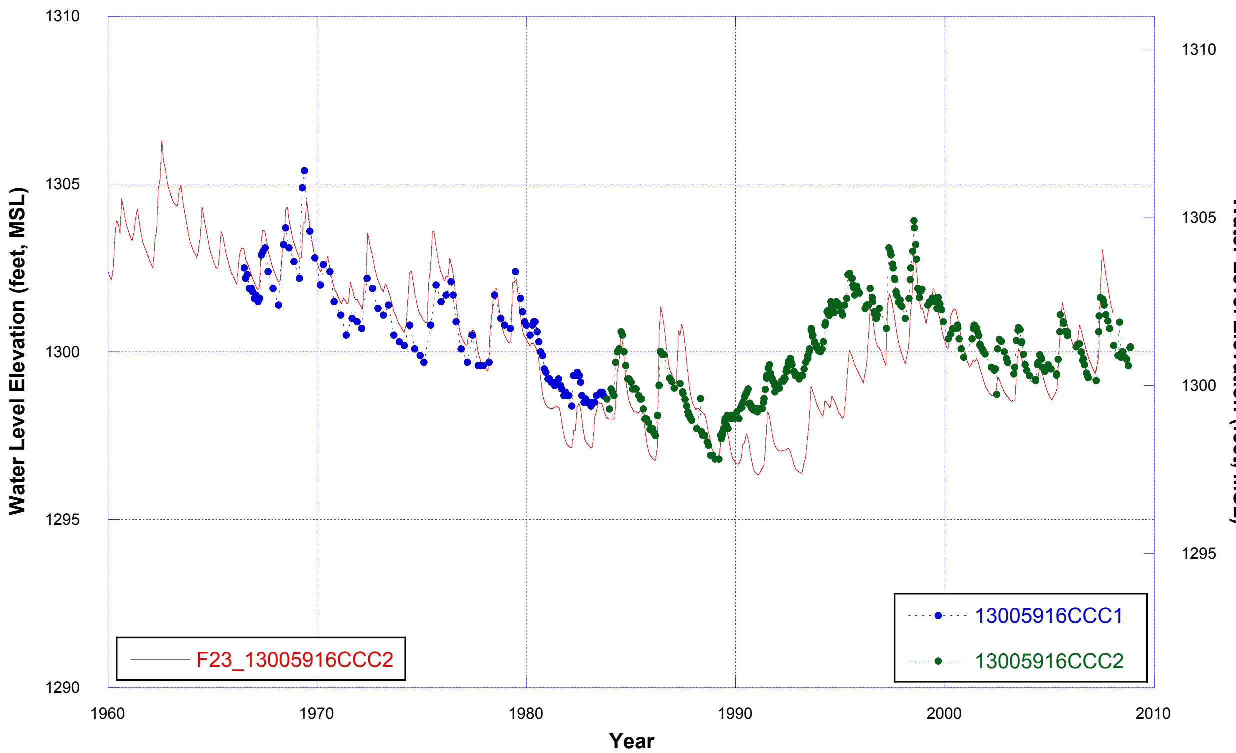


Figure D-10. Comparison of transient calibration water levels, run F23, to observed at observation wells 130-059-16CCC1 and 16CCC2.

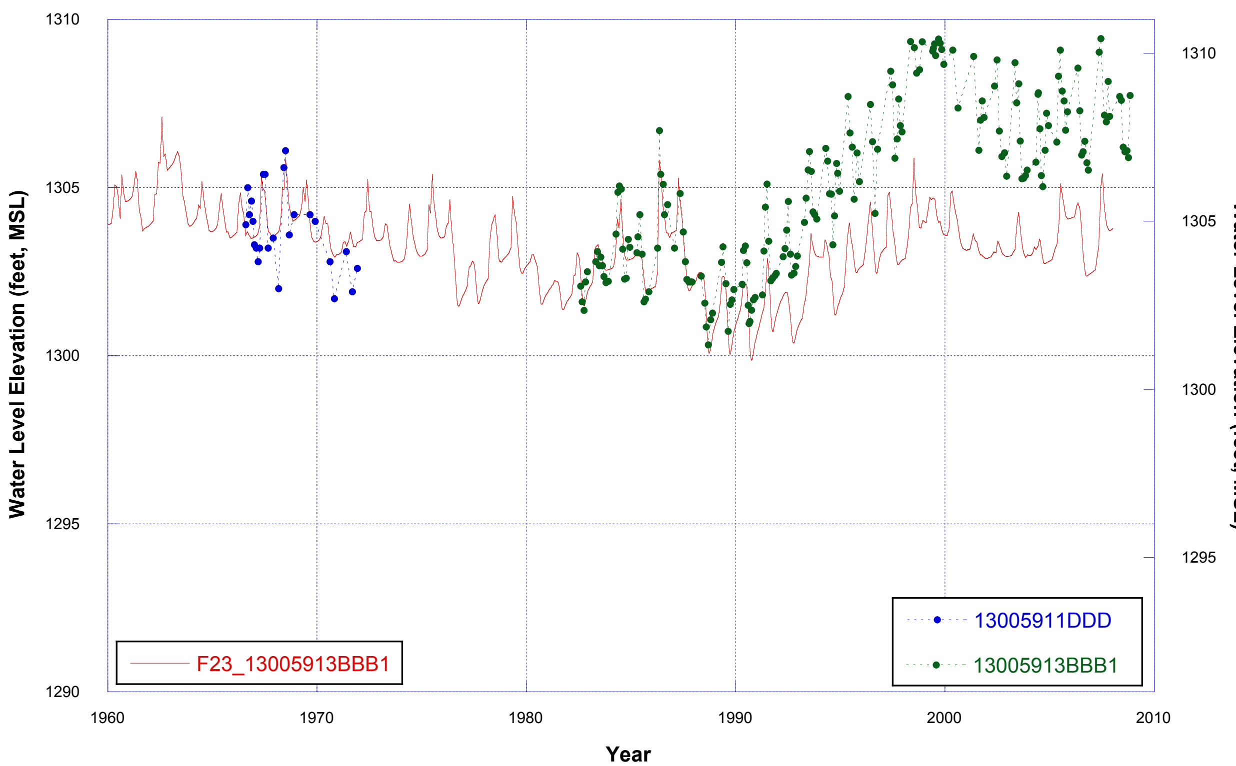


Figure D-11. Comparison of transient calibration water levels, run F23, to observed at observation wells 130-059-11DDD and 13BBB1.

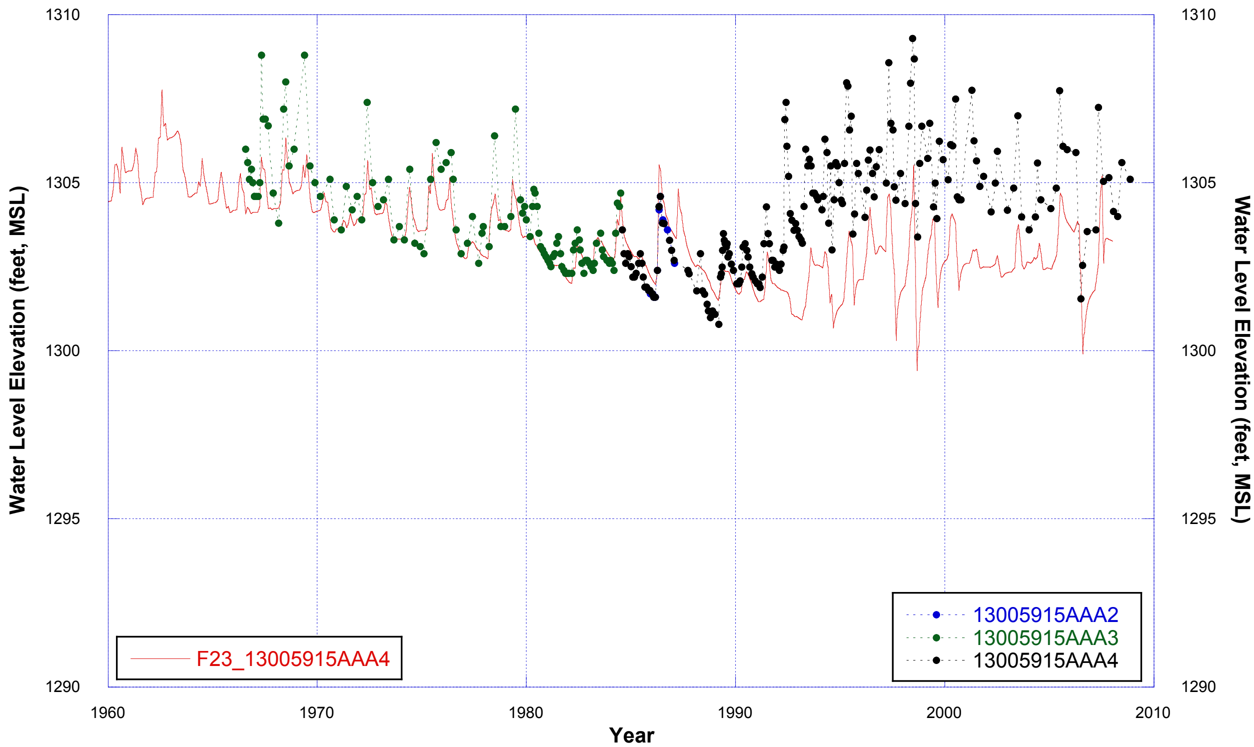


Figure D-12. Comparison of transient calibration water levels, run F23, to observed at observation wells 130-059-15AAA2, 15AAA3 and 15AAA4.

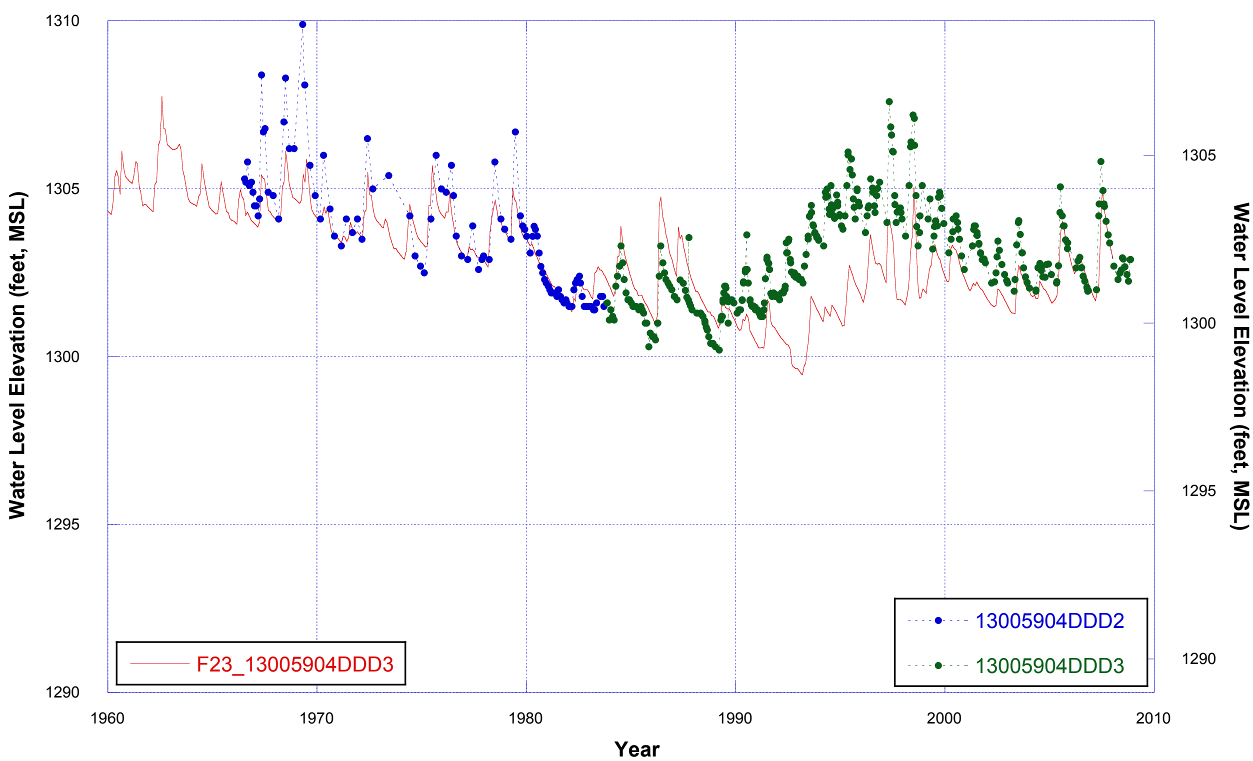


Figure D-13. Comparison of transient calibration water levels, run F23, to observed at observation wells 130-059-04DDD2 and 04DDD3.

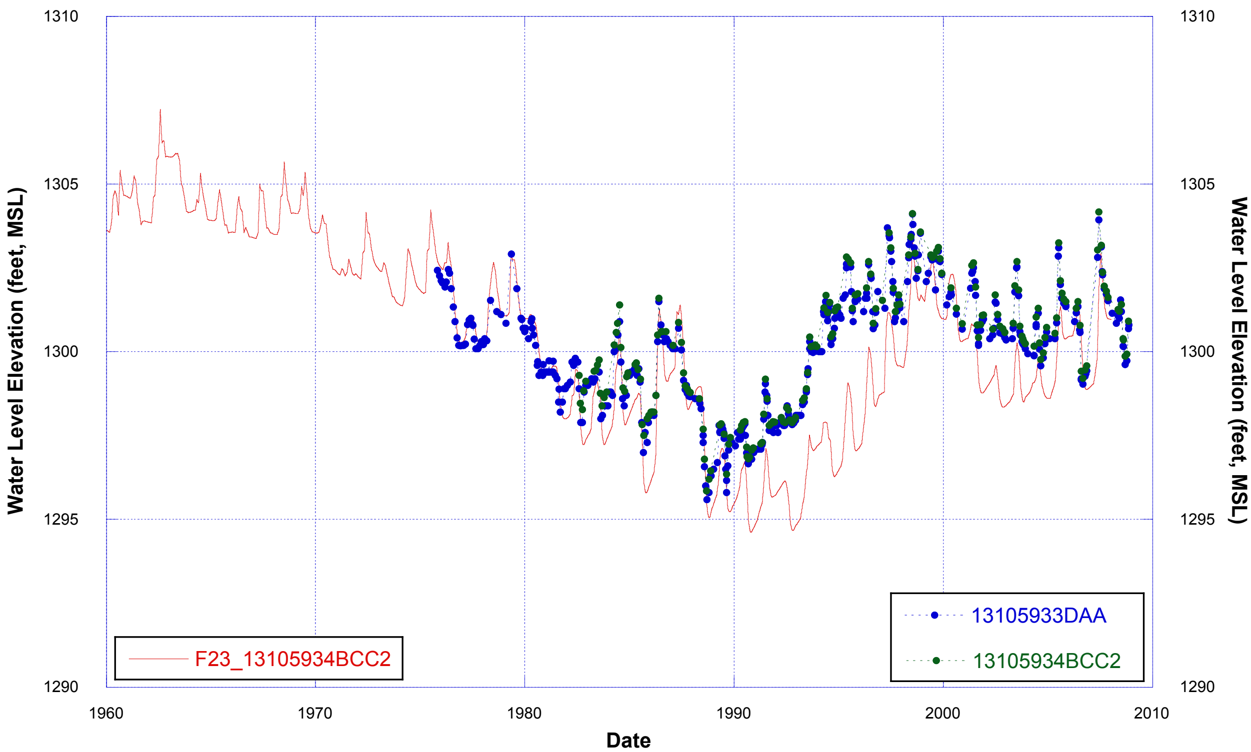


Figure D-14. Comparison of transient calibration water levels, run F23, to observed at observation wells 131-059-33DAA and 34BCC2.

Appendix E. VB2000 Estimates of Recharge, PET_{gw}, and Irrigation.

Table E-1. Summary of climate, groundwater ET, recharge, and irrigation water for Britton climate dataset britton_hecla_01c2a.

Britton	October - May			Water Year (Annual)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Precipitation	2.46	23.32	10.34	11.63	39.76	22.25
PET	7.38	14.15	10.62	27.91	38.11	32.53
AET	1.92	3.51	2.75	10.42	20.58	16.27
ET_{gw}	-0.58	11.97	4.40	6.33	26.81	16.26
Recharge	0.24	15.69	4.11	0.55	18.45	5.97
Irrigation				2.88	18.16	8.01

Table E-2. Summary of climate, groundwater ET, recharge, and irrigation water for Forman climate dataset forman01_hecla_01c2a.

Forman	October - May			Water Year (Annual)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Precipitation	2.85	17.33	17.33	8.94	39.99	20.60
PET	7.77	14.94	10.39	27.37	39.11	32.01
AET	1.85	3.47	2.62	8.50	19.85	15.63
ET_{gw}	0.65	11.84	4.16	5.69	29.32	16.39
Recharge	0.40	12.19	3.20	0.52	17.09	4.98
Irrigation				3.08	19.53	8.19

Table E-3. Summary of climate, groundwater ET, recharge, and irrigation water for Fullerton climate dataset fuller01_hecla_01c2a.

Fullerton	October - May			Water Year (Annual)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Precipitation	4.39	18.99	10.72	11.42	35.41	21.61
PET	7.38	14.39	10.64	27.37	41.14	32.71
AET	1.64	3.31	2.65	10.29	19.33	15.62
ET_{gw}	-0.31	11.30	4.2	6.33	29.66	17.11
Recharge	0.13	14.12	4.27	0.58	15.57	6.02
Irrigation				2.66	17.27	8.66

Table E-4. Summary of climate, groundwater ET, recharge, and irrigation water for Lisbon climate dataset lisbon01_hecla_01c2a.

Lisbon	October - May			Water Year (Annual)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Precipitation	3.32	15.00	9.00	10.28	32.83	20.19
PET	7.39	13.80	10.64	27.94	39.30	32.95
AET	1.91	3.34	2.62	9.59	19.86	15.75
ET_{gw}	0.28	9.81	4.50	8.61	29.73	17.22
Recharge	0.20	10.64	2.87	0.55	12.57	4.46
Irrigation				3.50	17.40	8.72

Table E-4. Summary of climate, groundwater ET, recharge, and irrigation water for Oakes climate dataset Oakes01_hecla_01c2a.

Oakes	October - May			Water Year (Annual)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Precipitation	2.65	18.78	10.06	9.22	35.26	20.94
PET	7.38	14.89	10.45	27.37	43.02	32.13
AET	1.81	3.81	2.61	9.47	19.21	15.28
ET_{gw}	-0.31	12.53	4.28	6.33	31.79	16.86
Recharge	0.29	14.12	3.89	0.50	15.80	5.67
Irrigation				2.66	20.89	8.55

Britton climate dataset

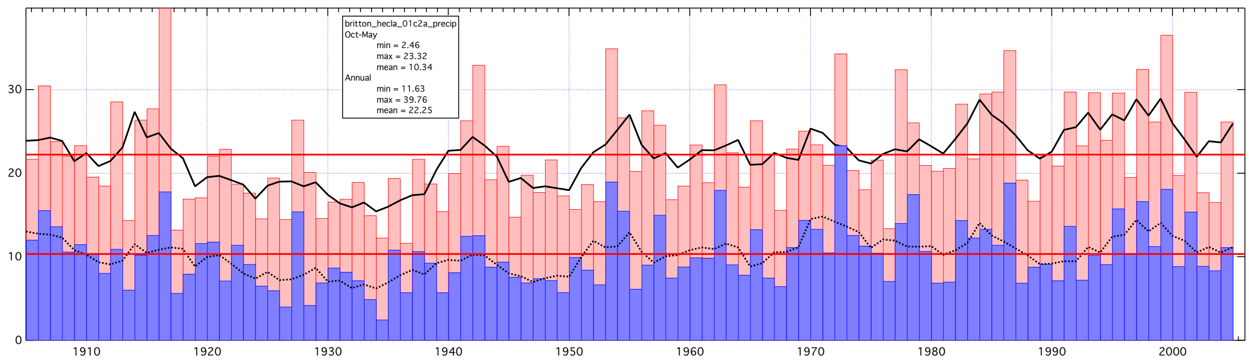


Figure E-1. Annual water year and winter precipitation (inches) 1905 through 2004 from VB2000 dataset britton_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

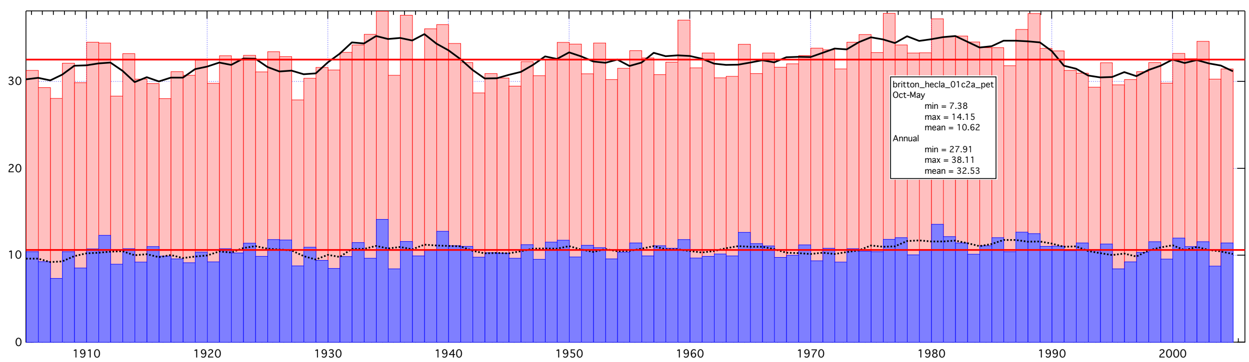


Figure E-2. Annual water year and winter PET (inches) 1905 through 2004 from VB2000 dataset britton_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

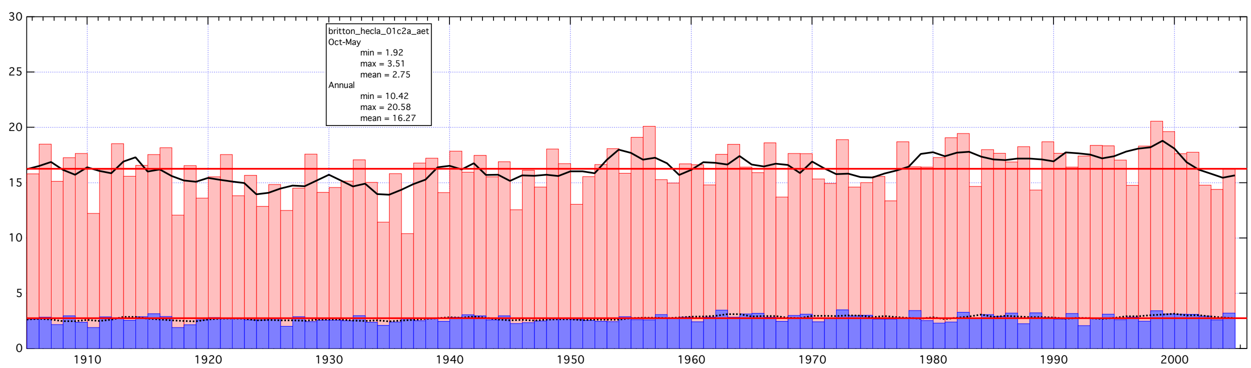


Figure E-3. Annual water year and winter actual evapotranspiration (AET) (inches) 1905 through 2004 from VB2000 dataset britton_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

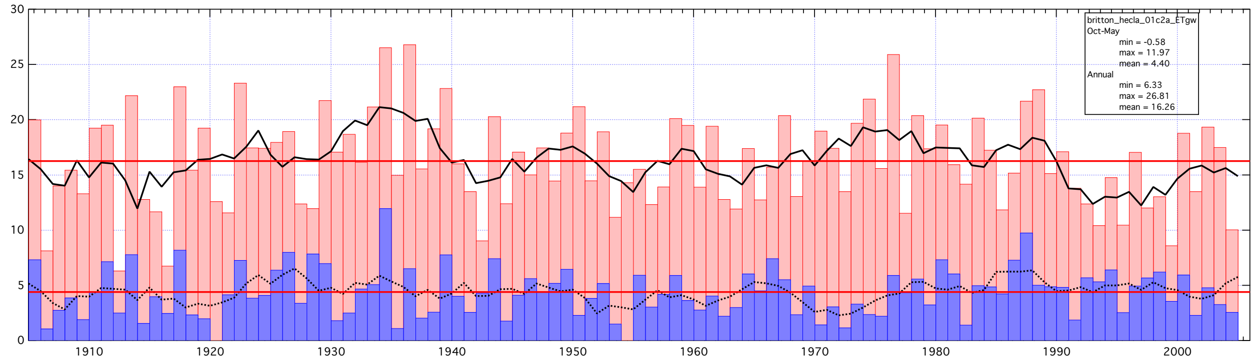


Figure E-4. Annual water year and winter ET from groundwater (inches) 1905 through 2004 from VB2000 dataset britton_hecla_01c2a. This is PET - precipitation + recharge. The solid and dashed lines show the five year moving average respectively.

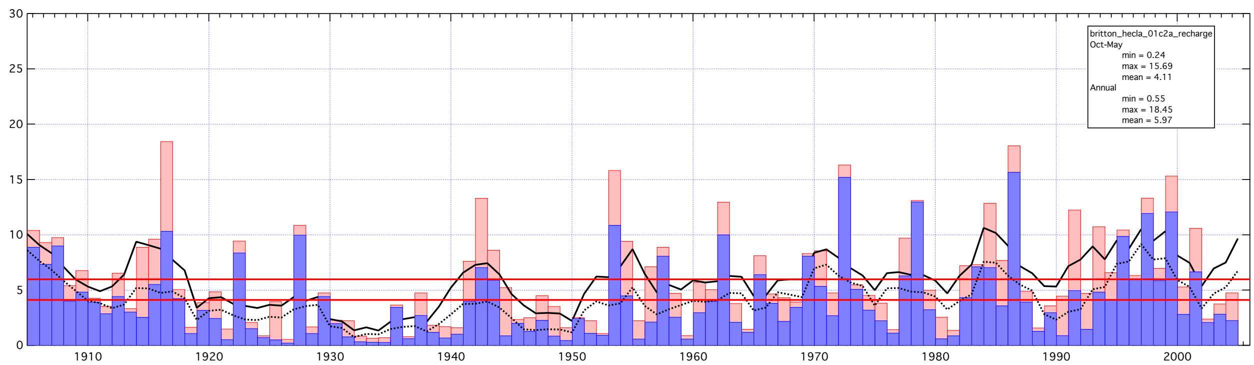


Figure E-5. Annual water year and winter recharge (inches) 1905 through 2004 from VB2000 dataset britton_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

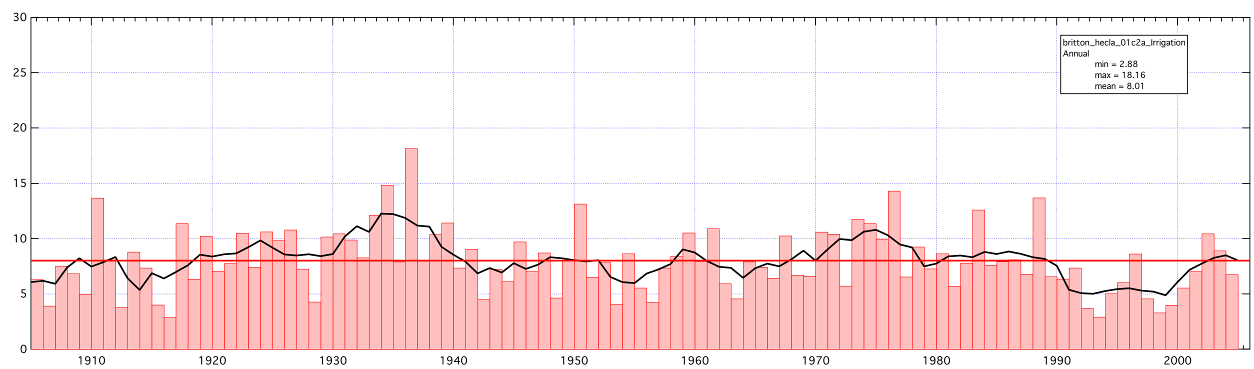


Figure E-6. Annual irrigation (inches) 1905 through 2004 from VB2000 dataset britton_hecla_01c2a. The solid line shows the five year moving average.

Forman climate dataset

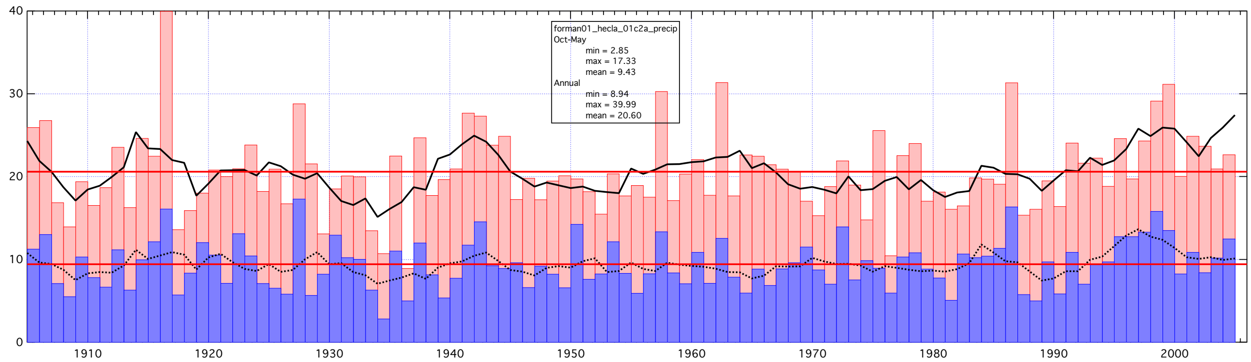


Figure E-7. Annual water year and winter precipitation (inches) 1905 through 2004 from VB2000 dataset forman01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

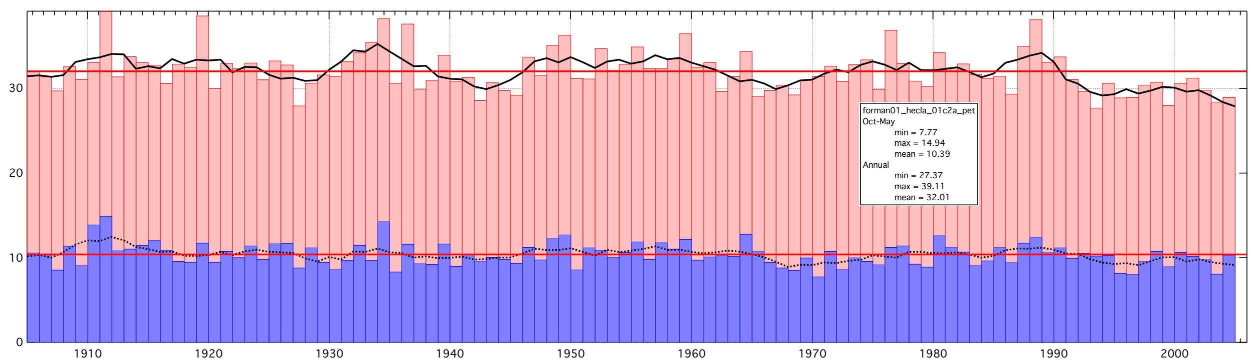


Figure E-8. Annual water year and winter PET (inches) 1905 through 2004 from VB2000 dataset forman01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

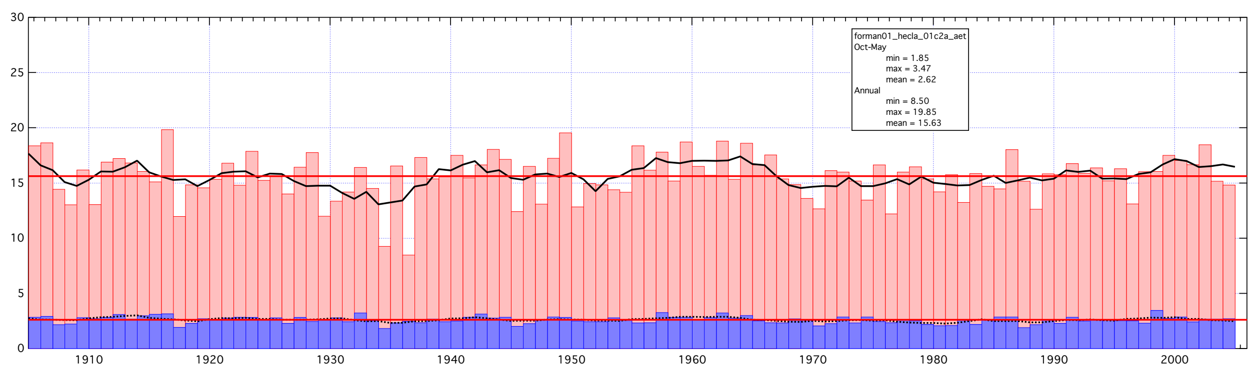


Figure E-9. Annual water year and winter actual evapotranspiration (AET) (inches) 1905 through 2004 from VB2000 dataset forman01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

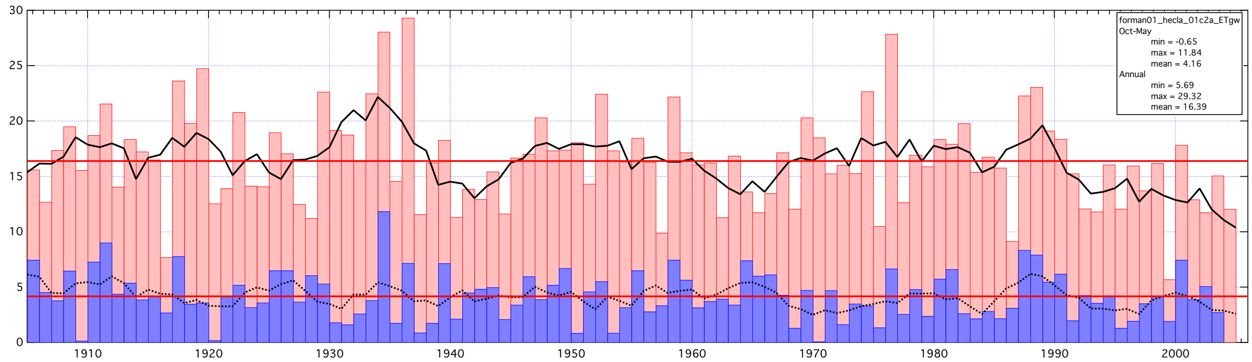


Figure E-10. Annual water year and winter ET from groundwater (inches) 1905 through 2004 from VB2000 dataset forman01_hecla_01c2a. This is PET - precipitation + recharge. The solid and dashed lines show the five year moving average respectively.

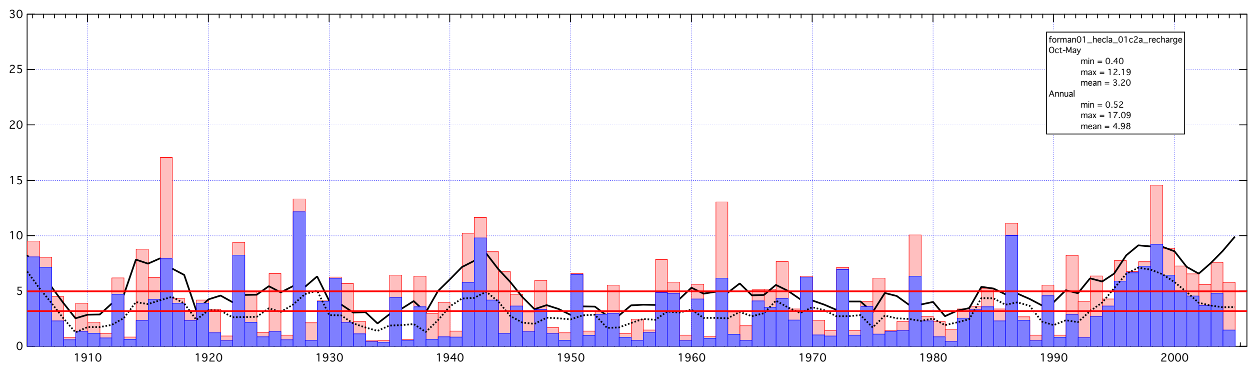


Figure E-11. Annual water year and winter recharge (inches) 1905 through 2004 from VB2000 dataset forman01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

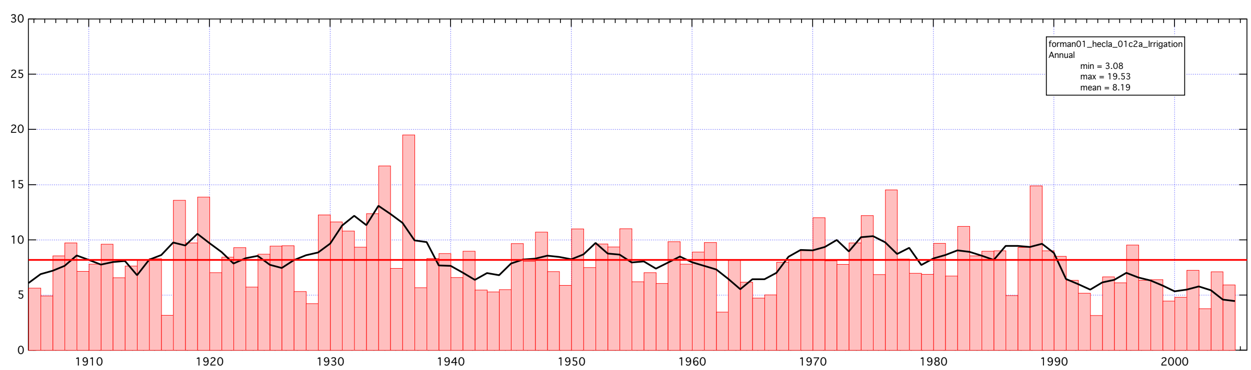


Figure E-12. Annual irrigation (inches) 1905 through 2004 from VB2000 dataset forman01_hecla_01c2a. The solid line shows the five year moving average.

Fullerton climate dataset

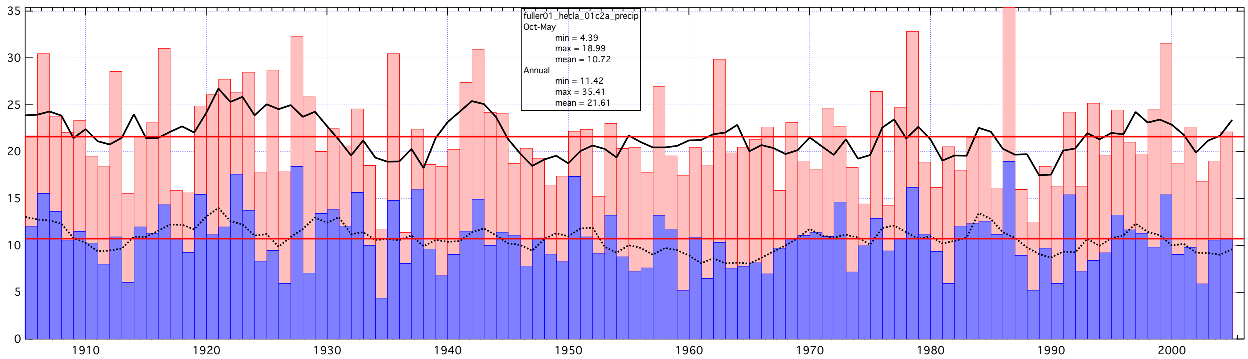


Figure E-13. Annual water year and winter precipitation (inches) 1905 through 2004 from VB2000 dataset fuller01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

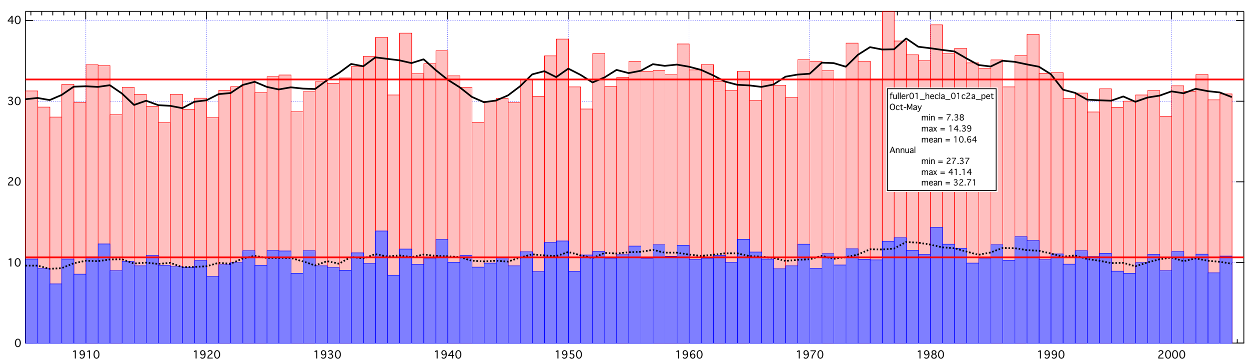


Figure E-14. Annual water year and winter PET (inches) 1905 through 2004 from VB2000 dataset fuller01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

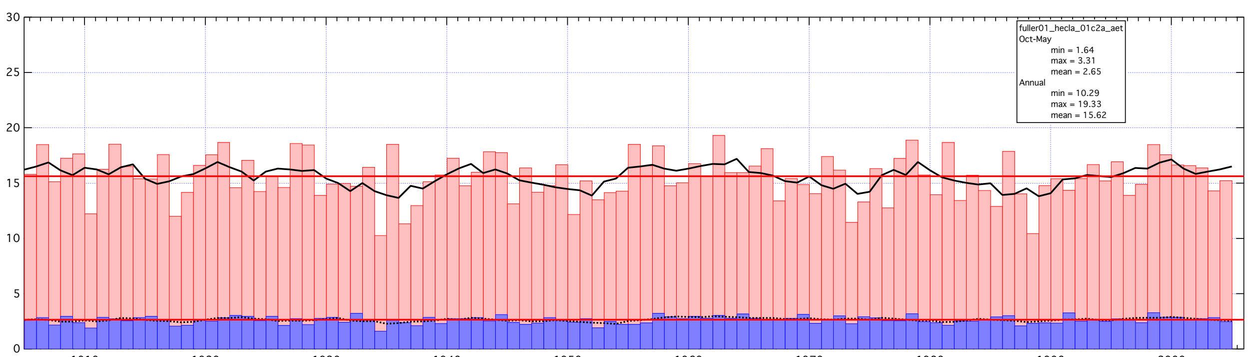


Figure E-15. Annual water year and winter actual evapotranspiration (AET) (inches) 1905 through 2004 from VB2000 dataset fuller01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

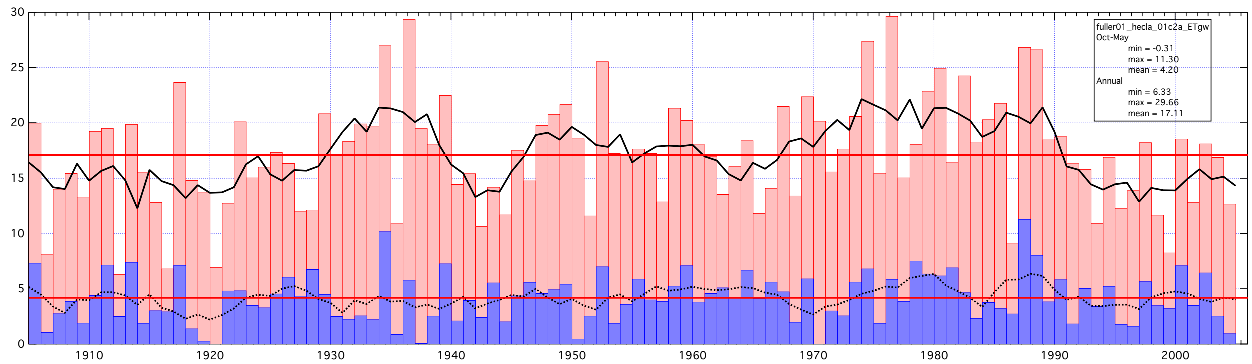


Figure E-16. Annual water year and winter ET from groundwater (inches) 1905 through 2004 from VB2000 dataset fuller01_hecla_01c2a. This is PET - precipitation + recharge. The solid and dashed lines show the five year moving average respectively.

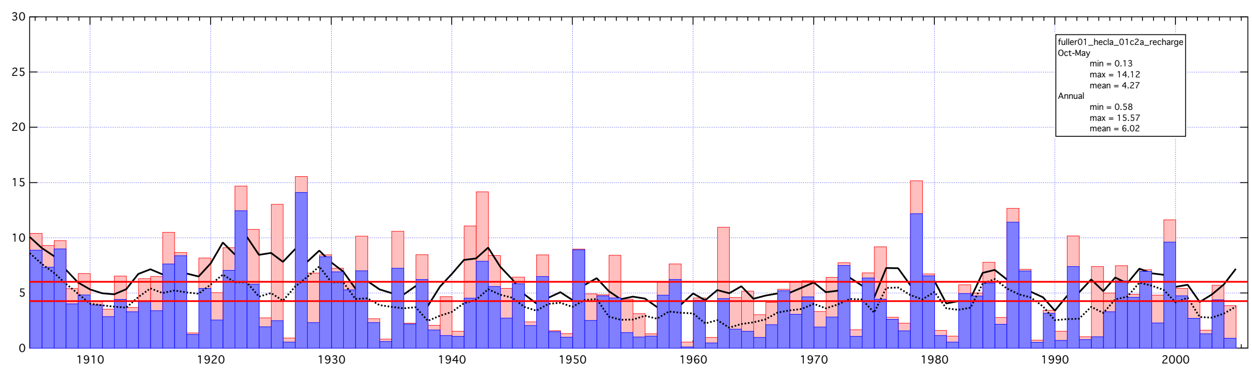


Figure E-17. Annual water year and winter recharge (inches) 1905 through 2004 from VB2000 dataset fuller01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

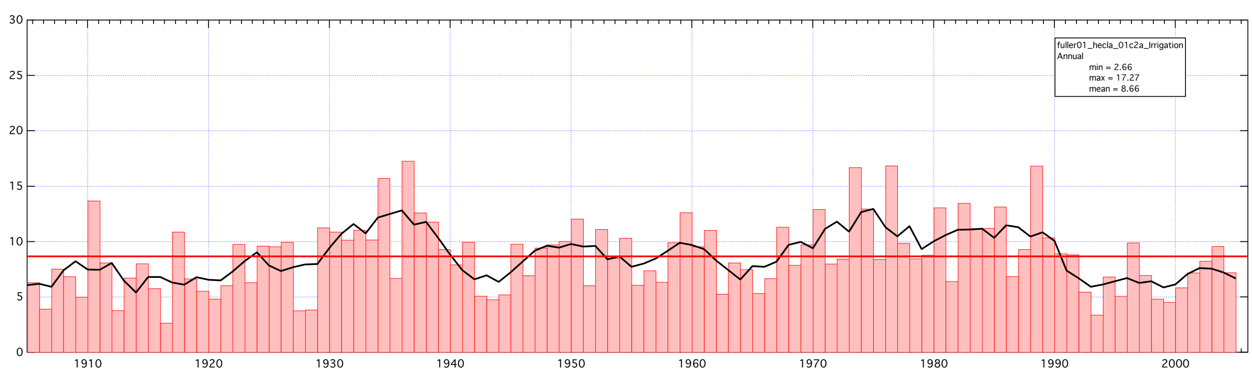


Figure E-18. Annual irrigation (inches) 1905 through 2004 from VB2000 dataset fuller01_hecla_01c2a. The solid line shows the five year moving average.

Lisbon climate dataset

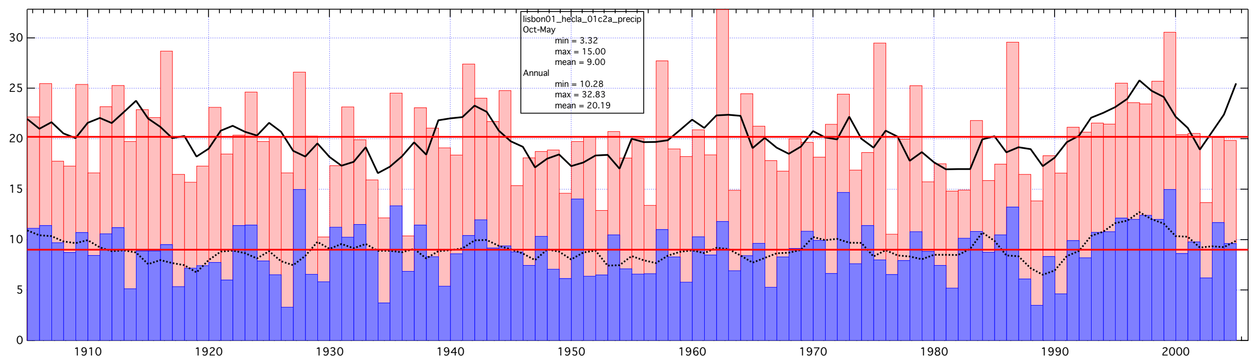


Figure E-19. Annual water year and winter precipitation (inches) 1905 through 2004 from VB2000 dataset lisbon01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

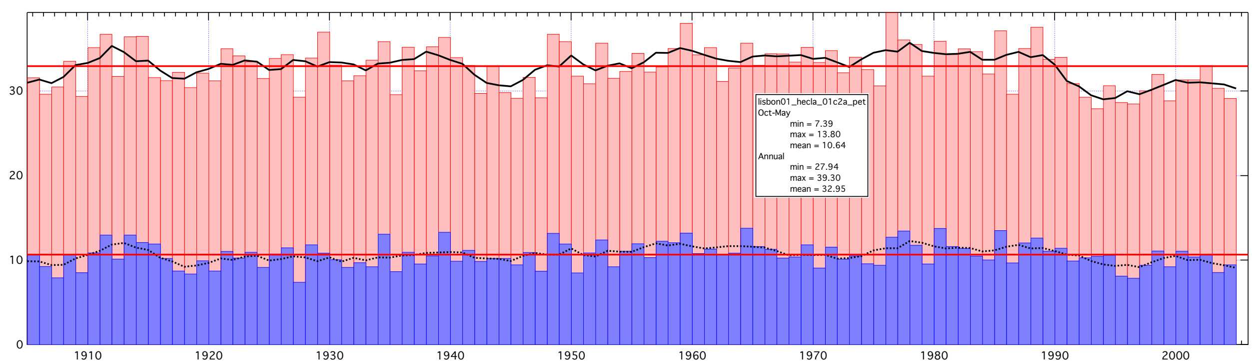


Figure E-20. Annual water year and winter PET (inches) 1905 through 2004 from VB2000 dataset lisbon01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

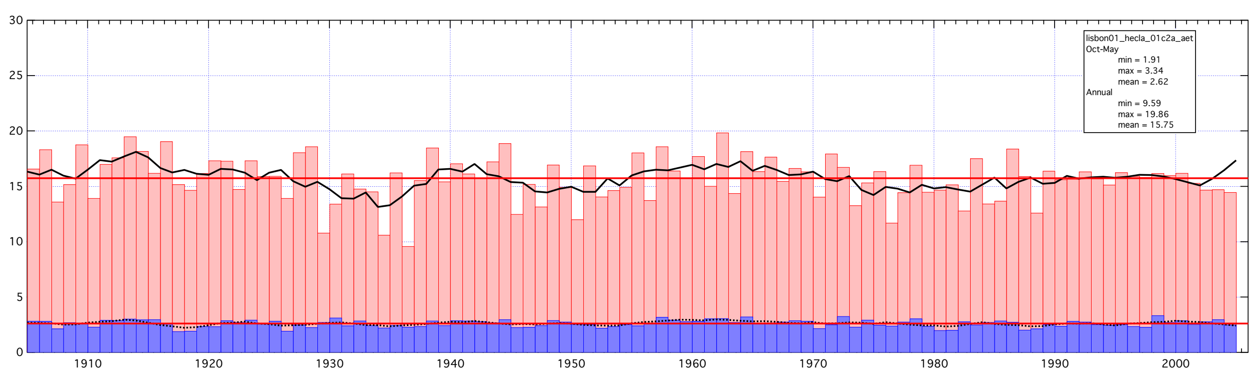


Figure E-21. Annual water year and winter actual evapotranspiration (AET) (inches) 1905 through 2004 from VB2000 dataset lisbon01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

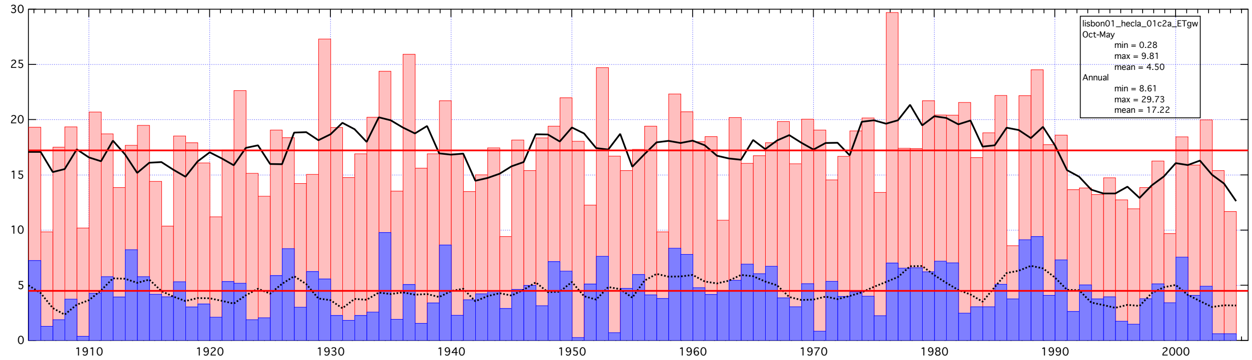


Figure E-22. Annual water year and winter ET from groundwater (inches) 1905 through 2004 from VB2000 dataset lisbon01_hecla_01c2a. This is PET - precipitation + recharge. The solid and dashed lines show the five year moving average respectively.

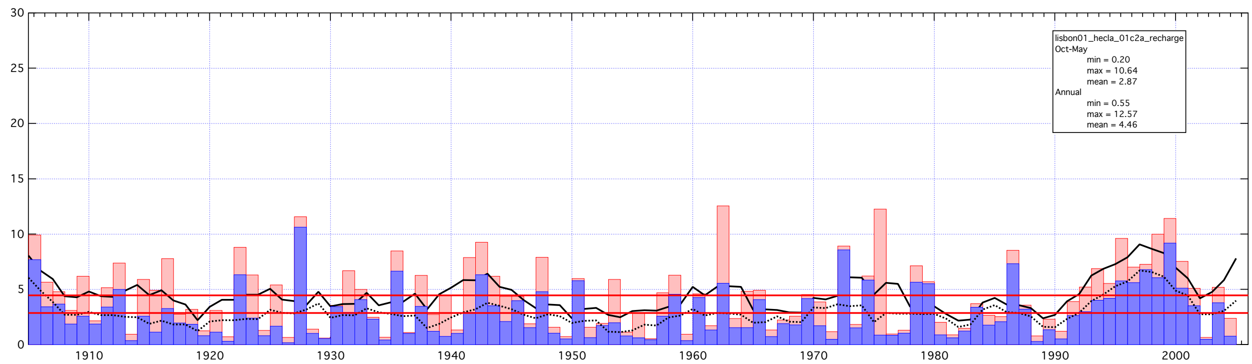


Figure E-23. Annual water year and winter recharge (inches) 1905 through 2004 from VB2000 dataset lisbon01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

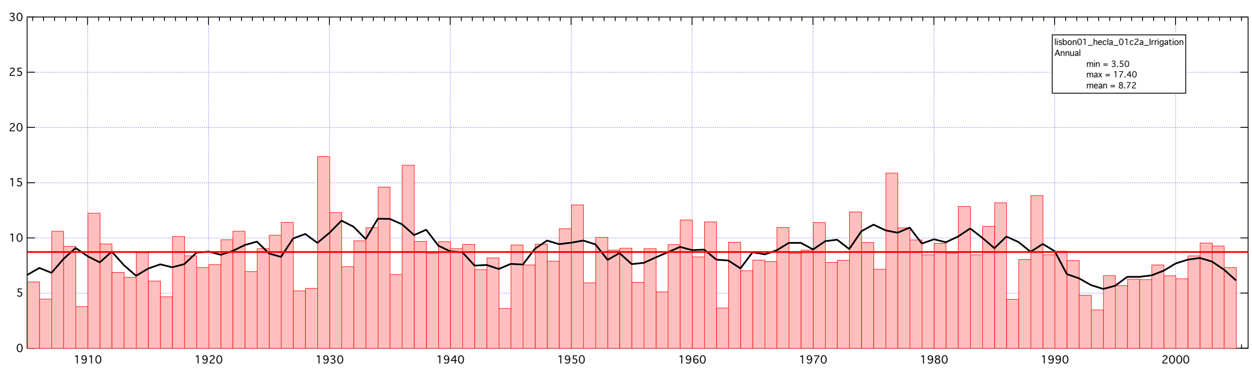


Figure E-25. Annual irrigation (inches) 1905 through 2004 from VB2000 dataset lisbon01_hecla_01c2a. The solid line shows the five year moving average.

Oakes climate dataset

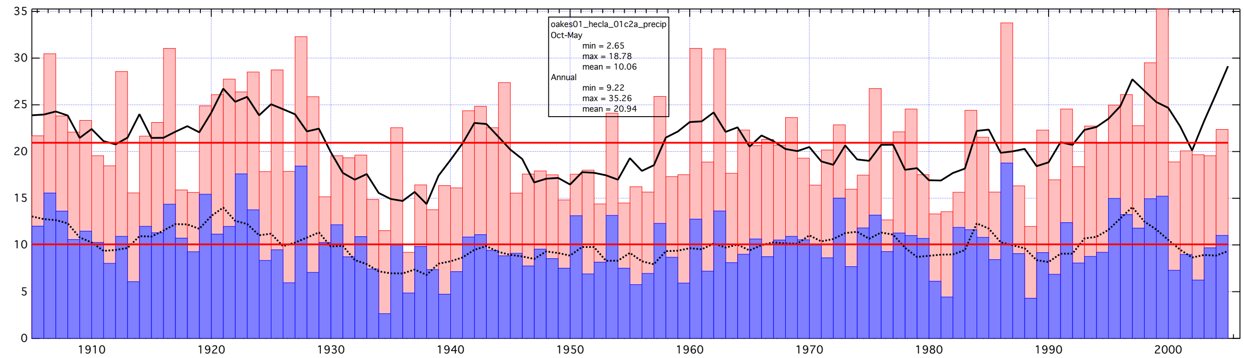


Figure E-25. Annual water year and winter precipitation (inches) 1905 through 2004 from VB2000 dataset oakes01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

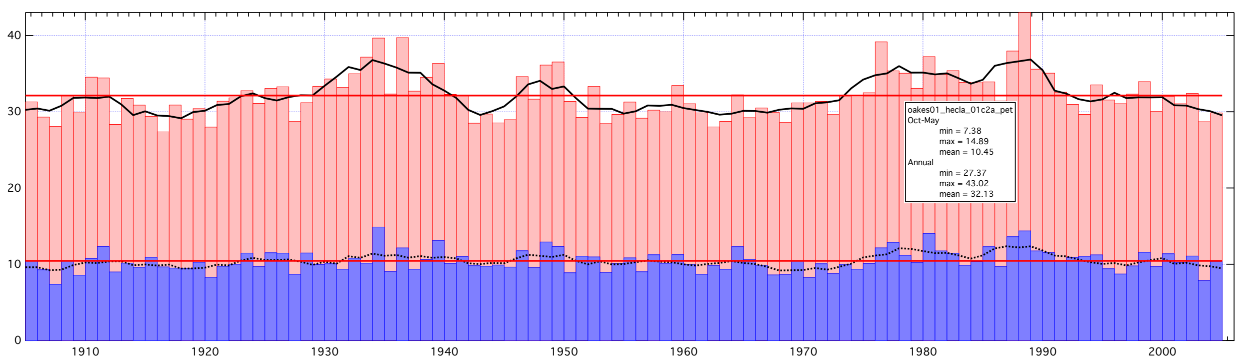


Figure E-26. Annual water year and winter PET (inches) 1905 through 2004 from VB2000 dataset oakes01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

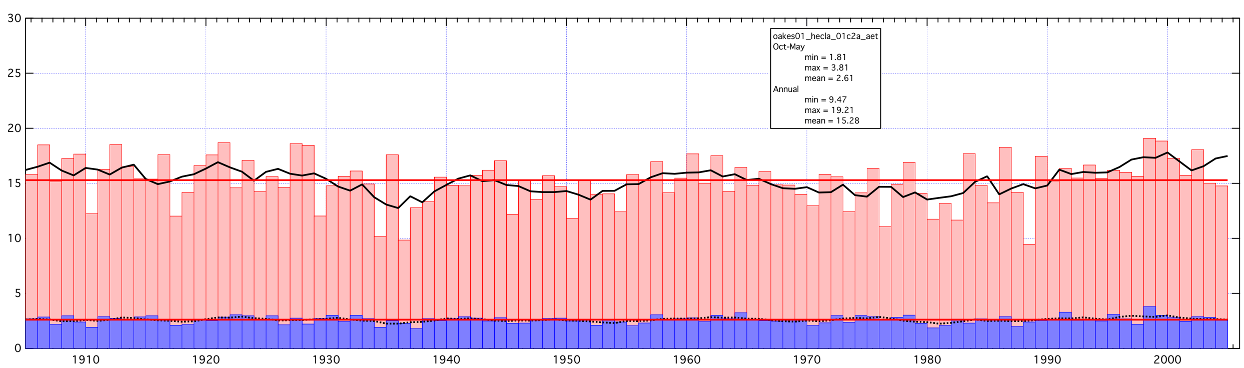


Figure E-27. Annual water year and winter actual evapotranspiration (AET) (inches) 1905 through 2004 from VB2000 dataset oakes01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

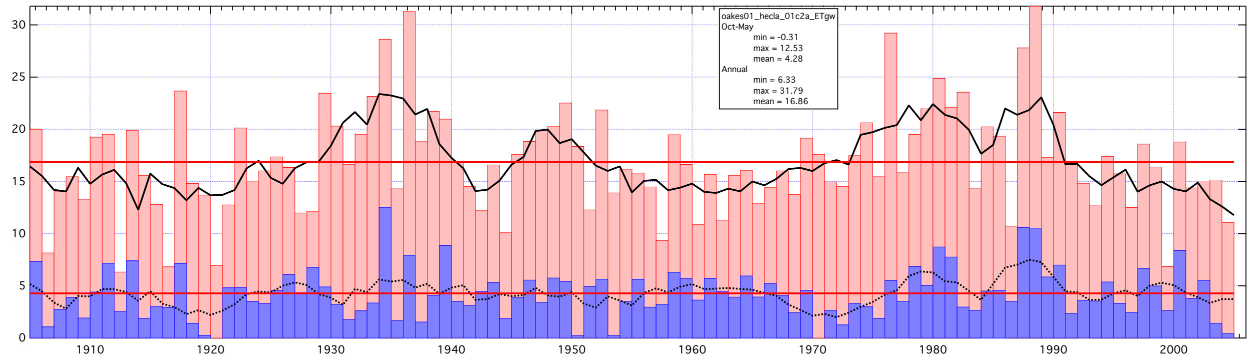


Figure E-28. Annual water year and winter ET from groundwater (inches) 1905 through 2004 from VB2000 dataset oakes01_hecla_01c2a. This is PET - precipitation + recharge. The solid and dashed lines show the five year moving average respectively.

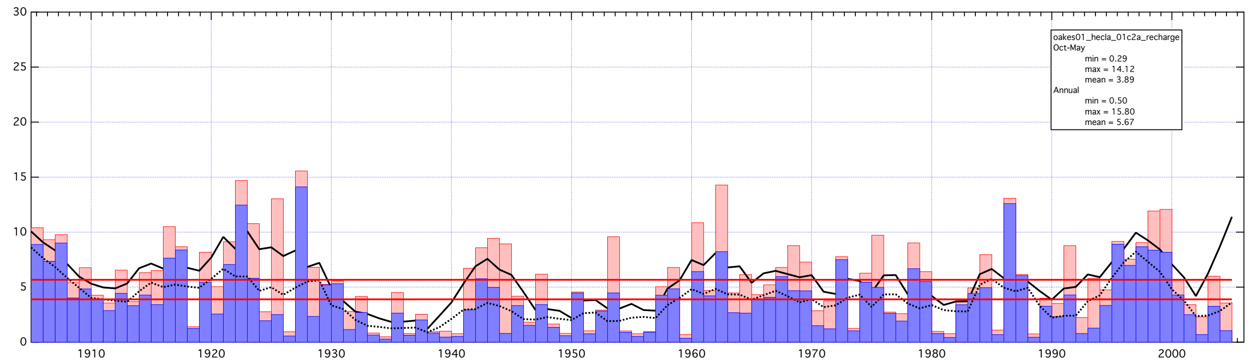


Figure E-29. Annual water year and winter recharge (inches) 1905 through 2004 from VB2000 dataset oakes01_hecla_01c2a. The solid and dashed lines show the five year moving average respectively.

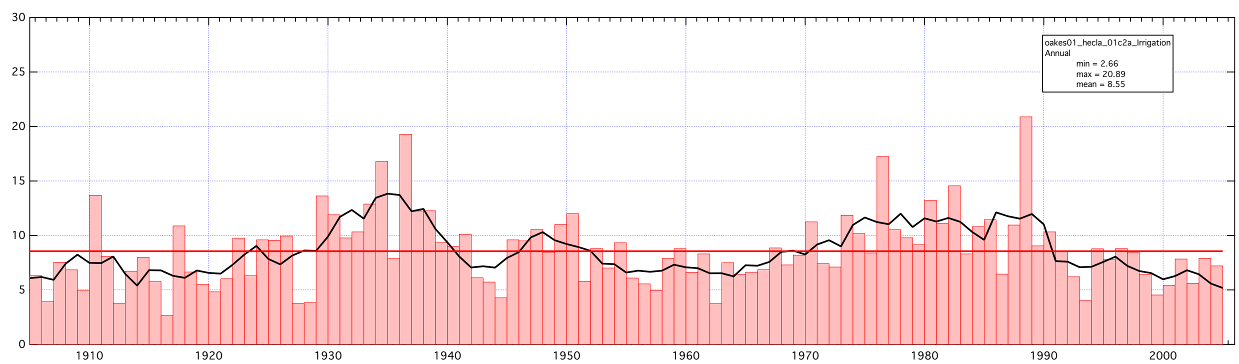


Figure E-30. Annual irrigation (inches) 1905 through 2004 from VB2000 dataset oakes01_hecla_01c2a. The solid line shows the five year moving average.

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Appendix F. Simulation Results for Permitted and Permitted + Pending Irrigation Using Oakes, Britton, Forman, Fullerton, and Lisbon Climate Datasets.

RUN F30, NO DRAINS, NO IRRIGATION

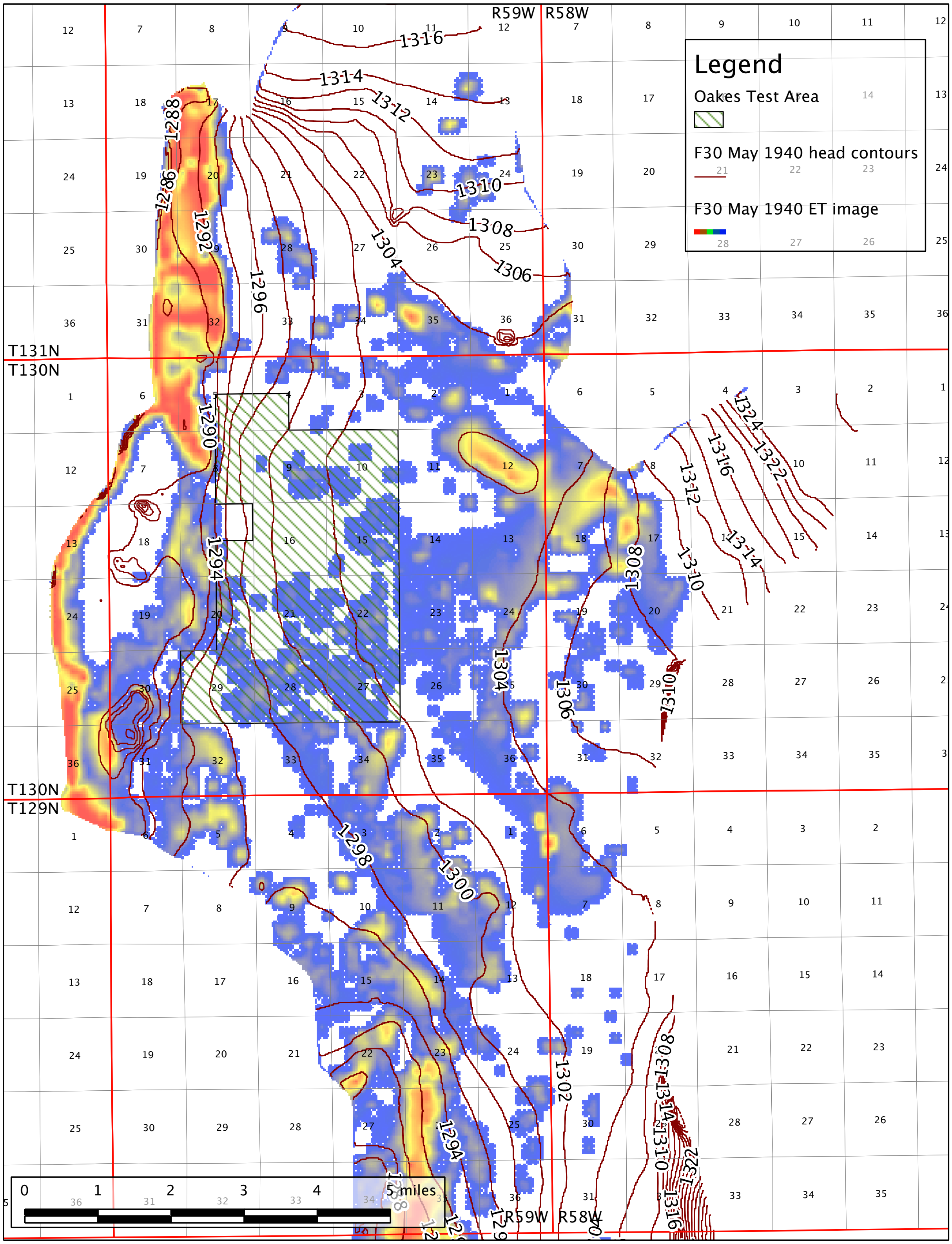

Figure F-1. Areas of evapotranspiration and water level contours for **May 31, 1940.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

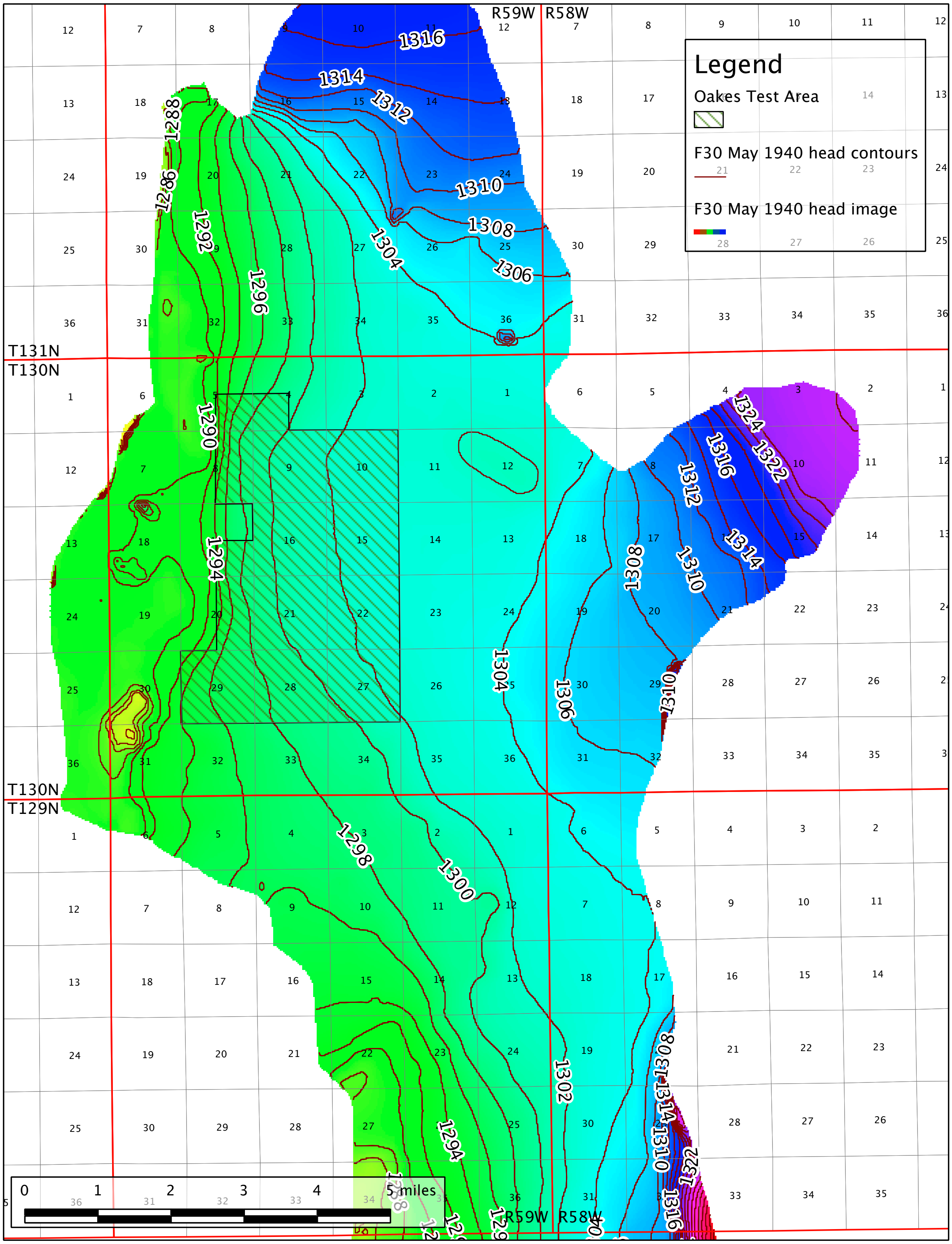

Figure F-2. Water level contours for **May 31, 1940. Run F30**, no drains, no irrigation.

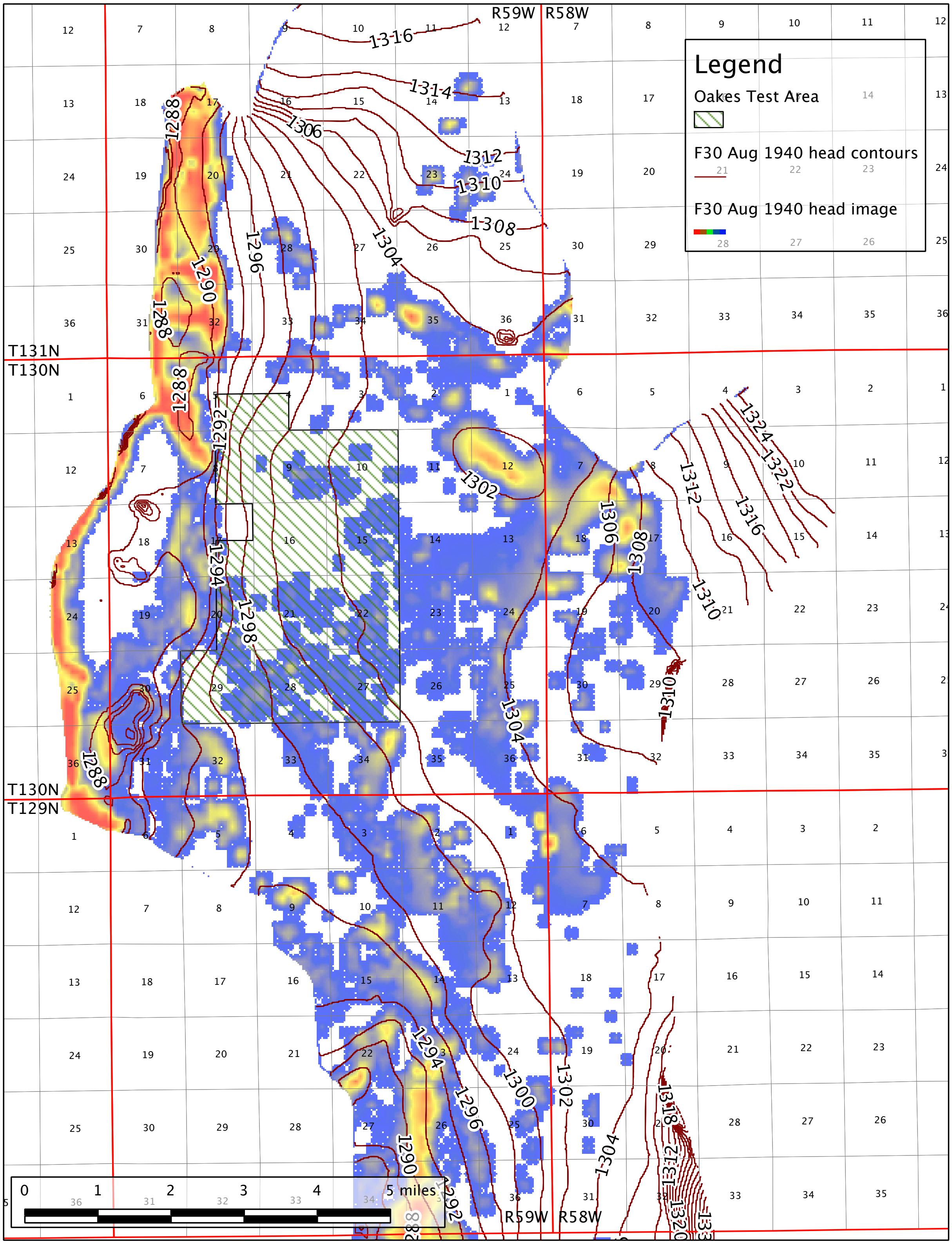

Figure F-3. Areas of evapotranspiration and water level contours for **August 31, 1940.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

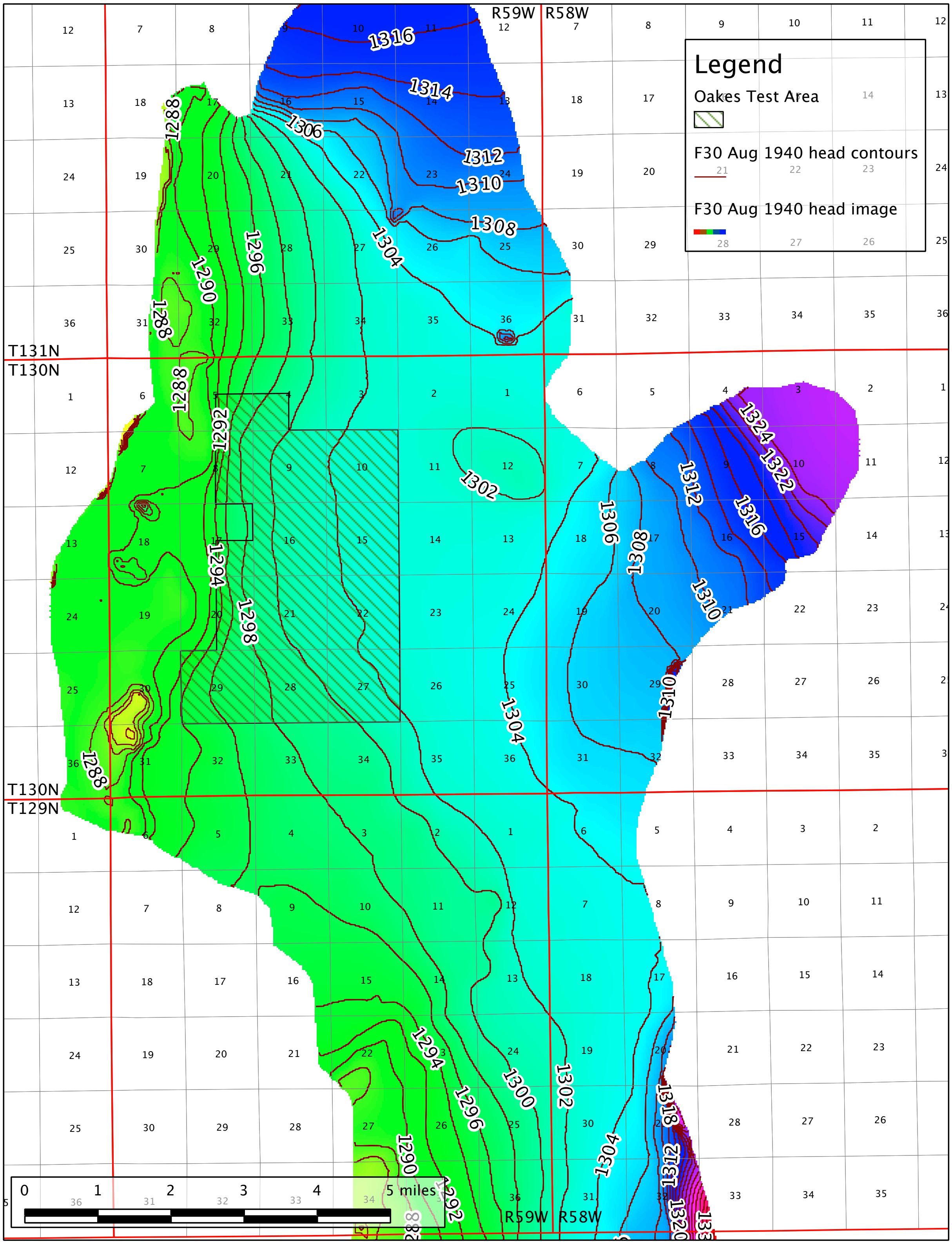

Figure F-4. Water level contours for **August 31, 1940. Run F30**, no drains, no irrigation.

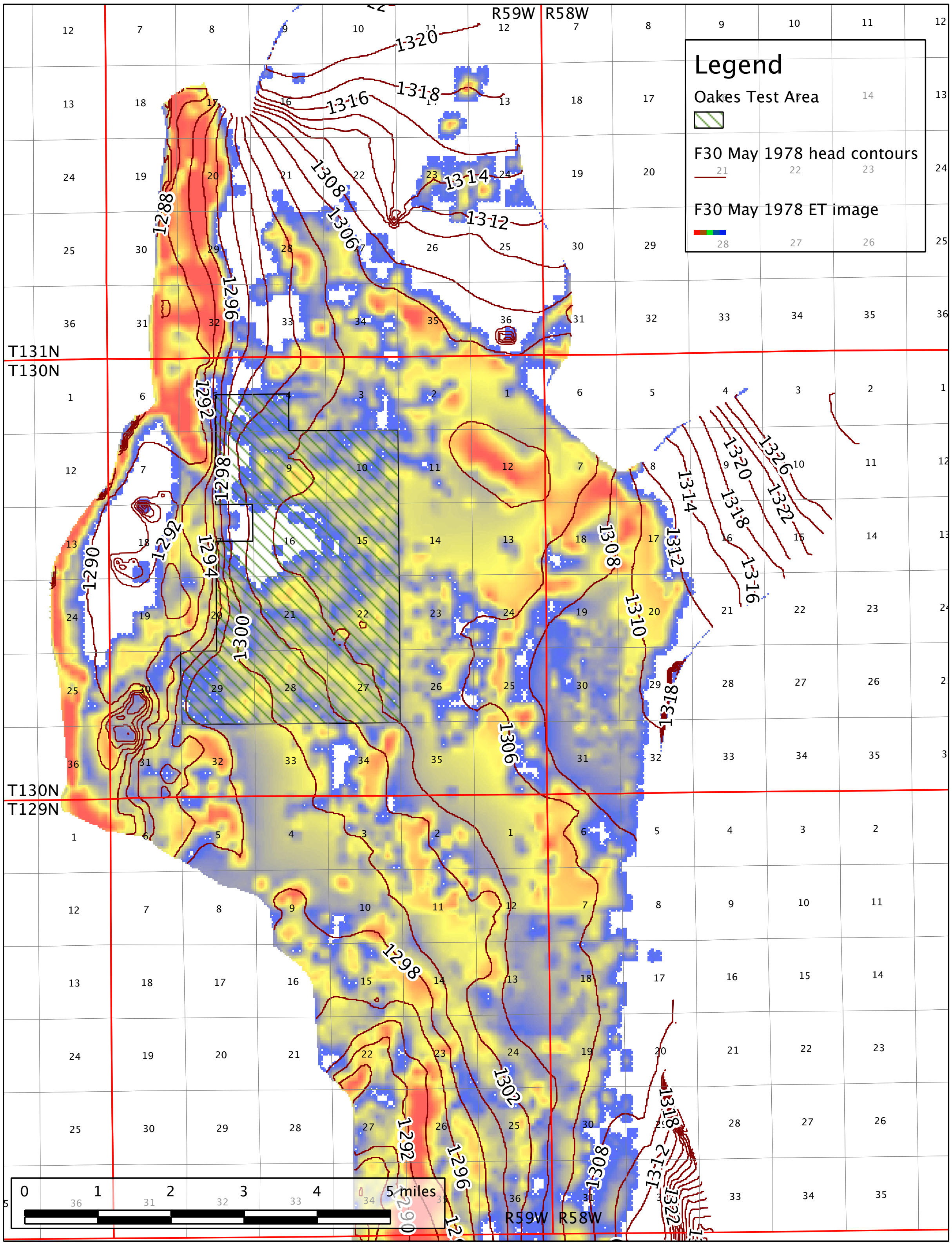

Figure F-5. Areas of evapotranspiration and water level contours for **May 31, 1978.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

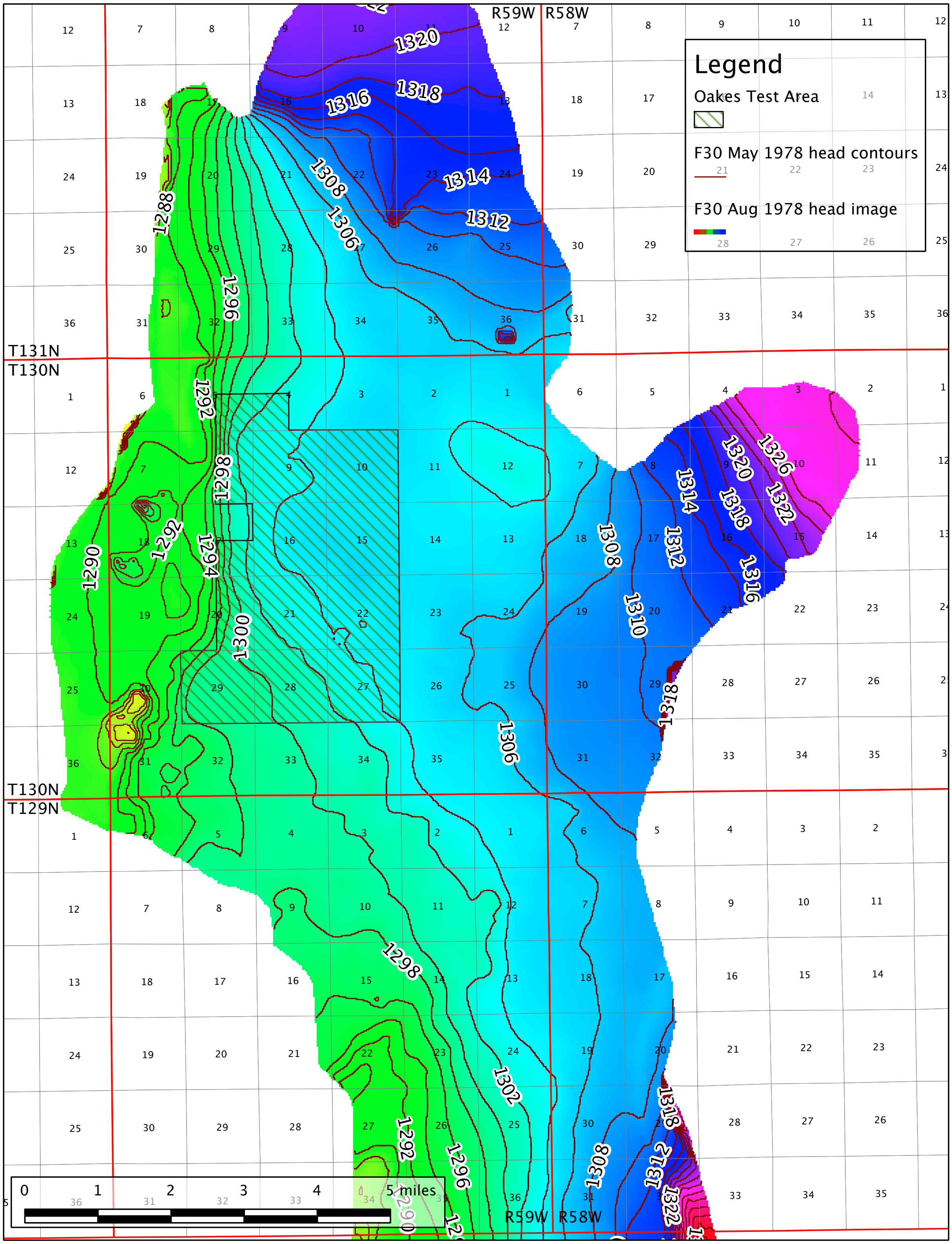

Figure F-6. Water level contours for **May 31, 1978. Run F30**, no drains, no irrigation.

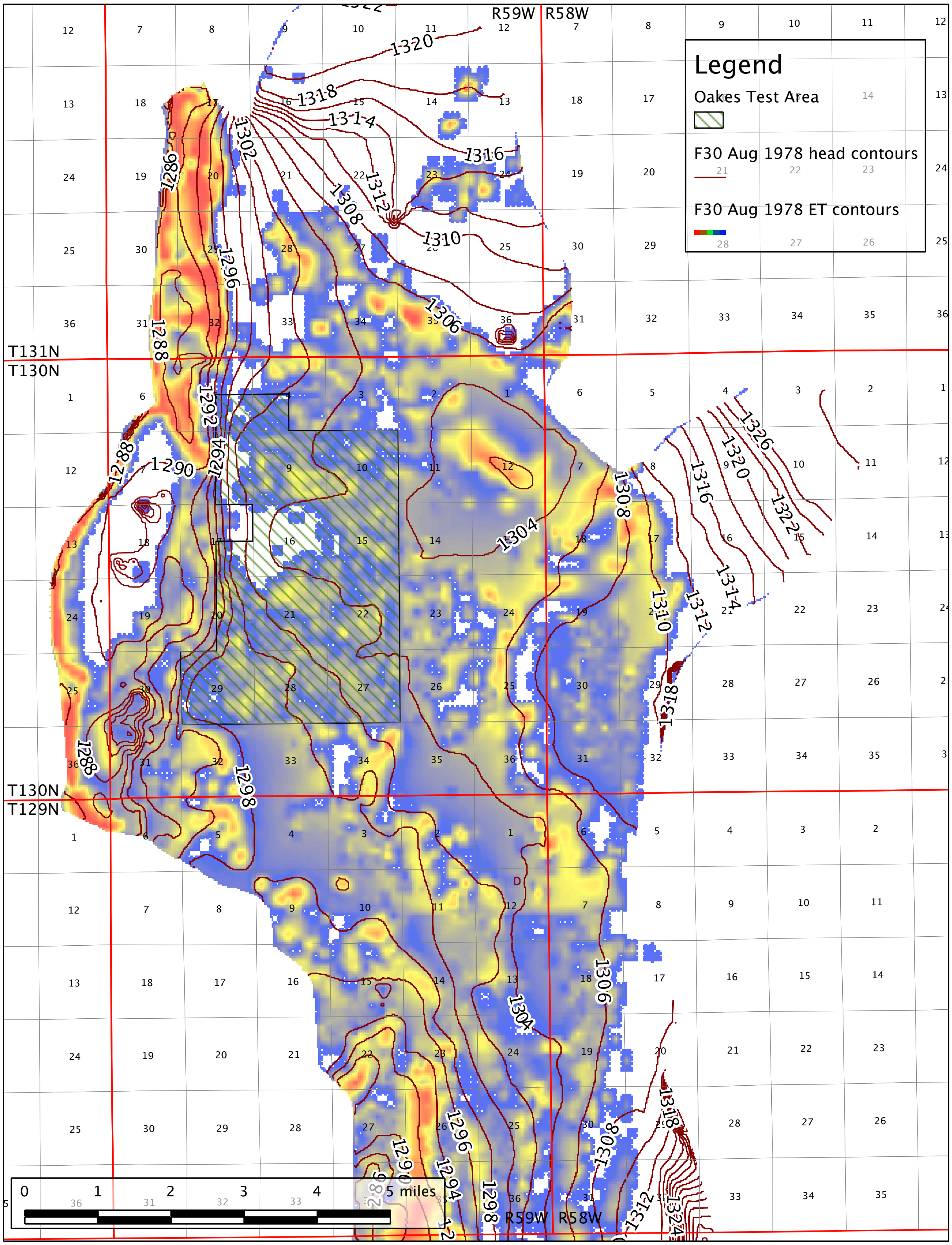

Figure F-7. Areas of evapotranspiration and water level contours for **August 31, 1978.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

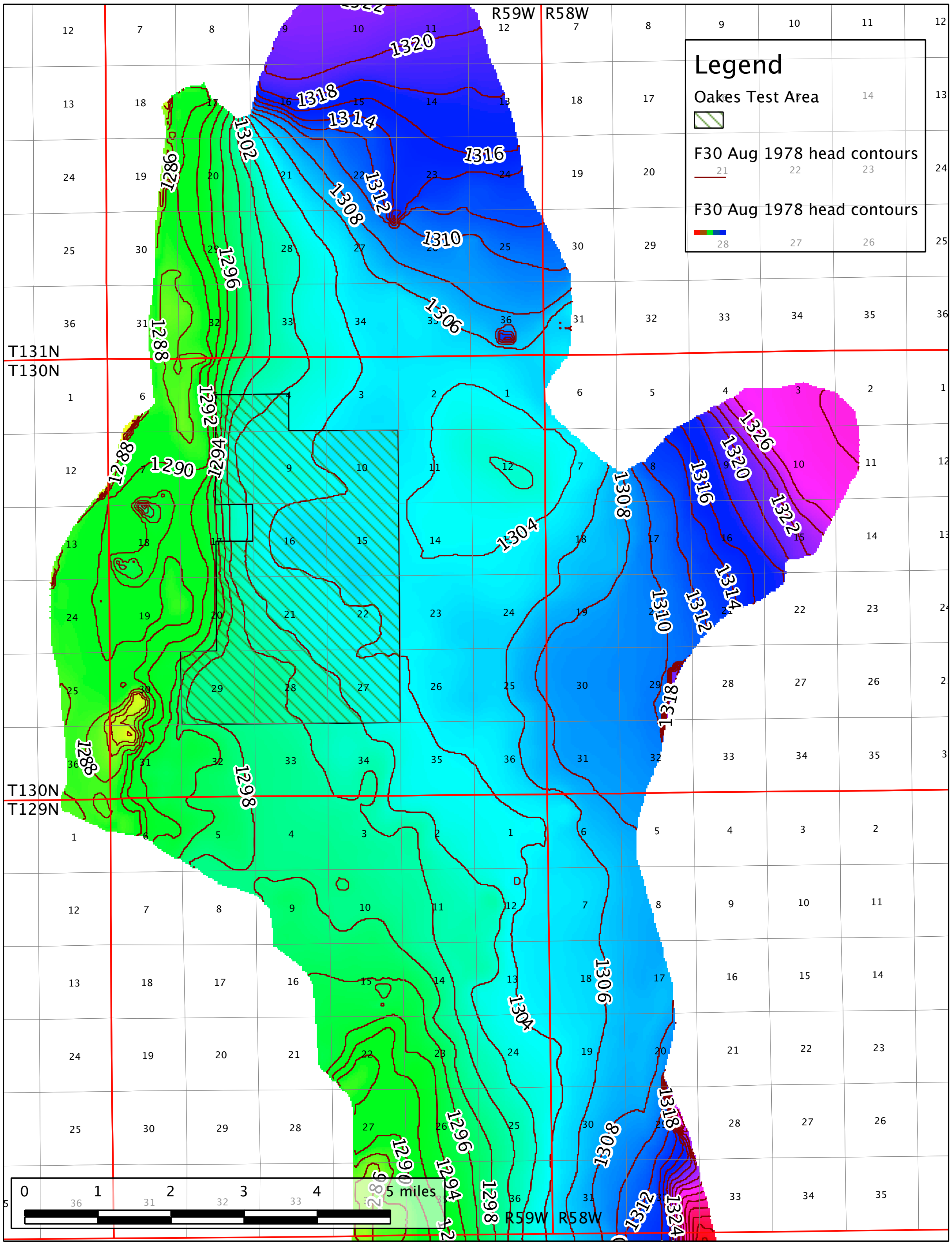

Figure F-8. Water level contours for **August 31, 1978. Run F30**, no drains, no irrigation.

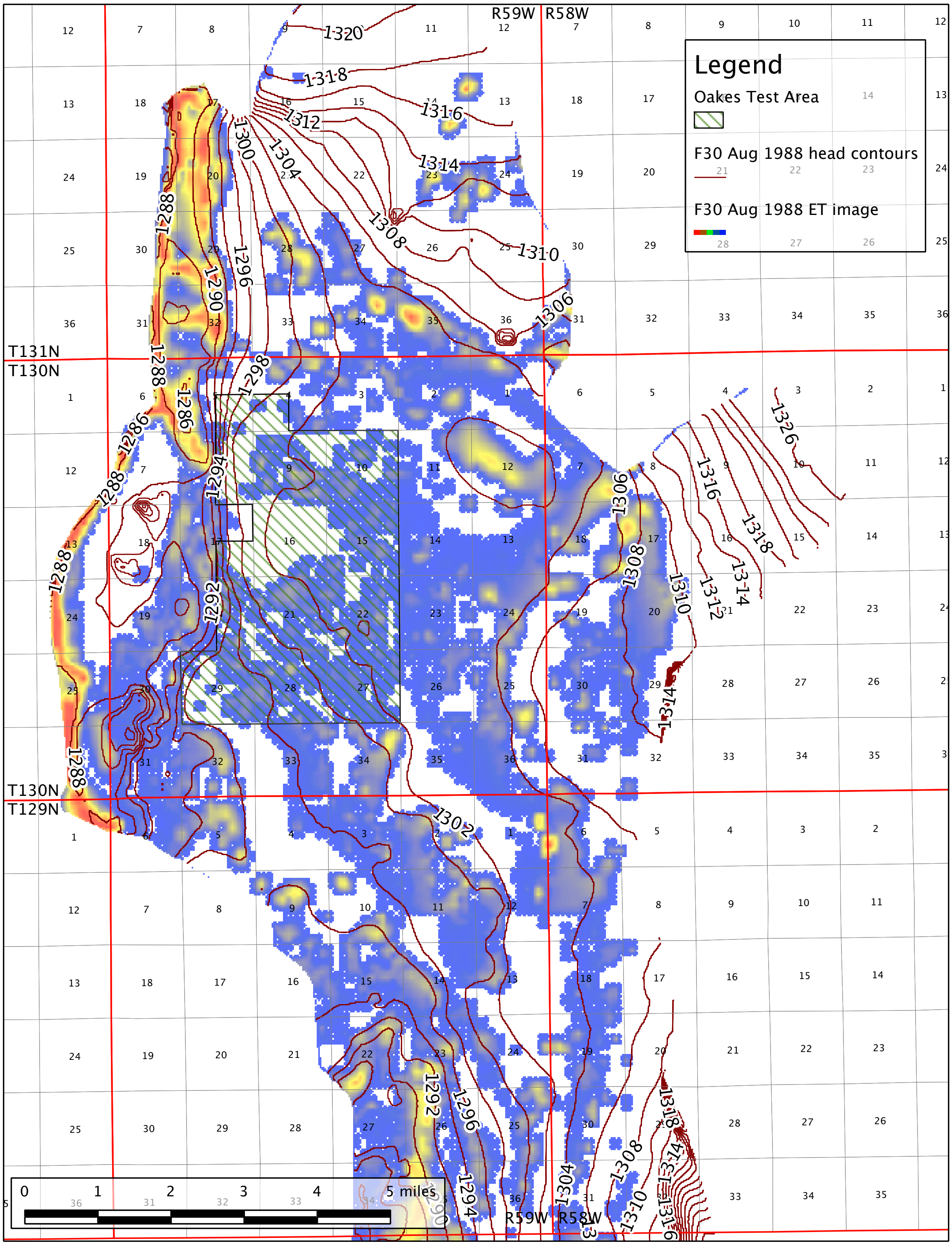

Figure F-9. Areas of evapotranspiration and water level contours for **August 31, 1988.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

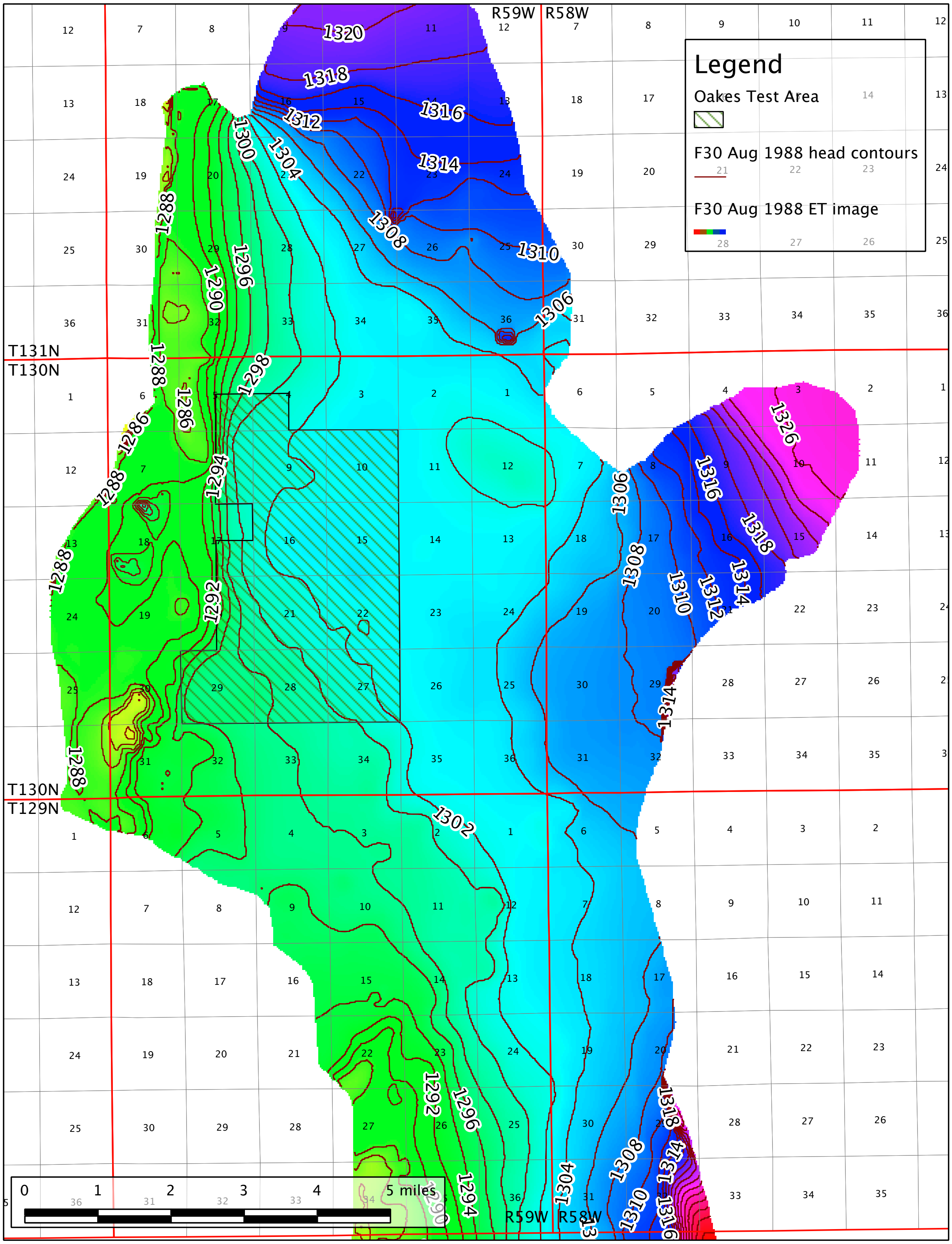

Figure F-10. Water level contours for **August 31, 1988. Run F30**, no drains, no irrigation.

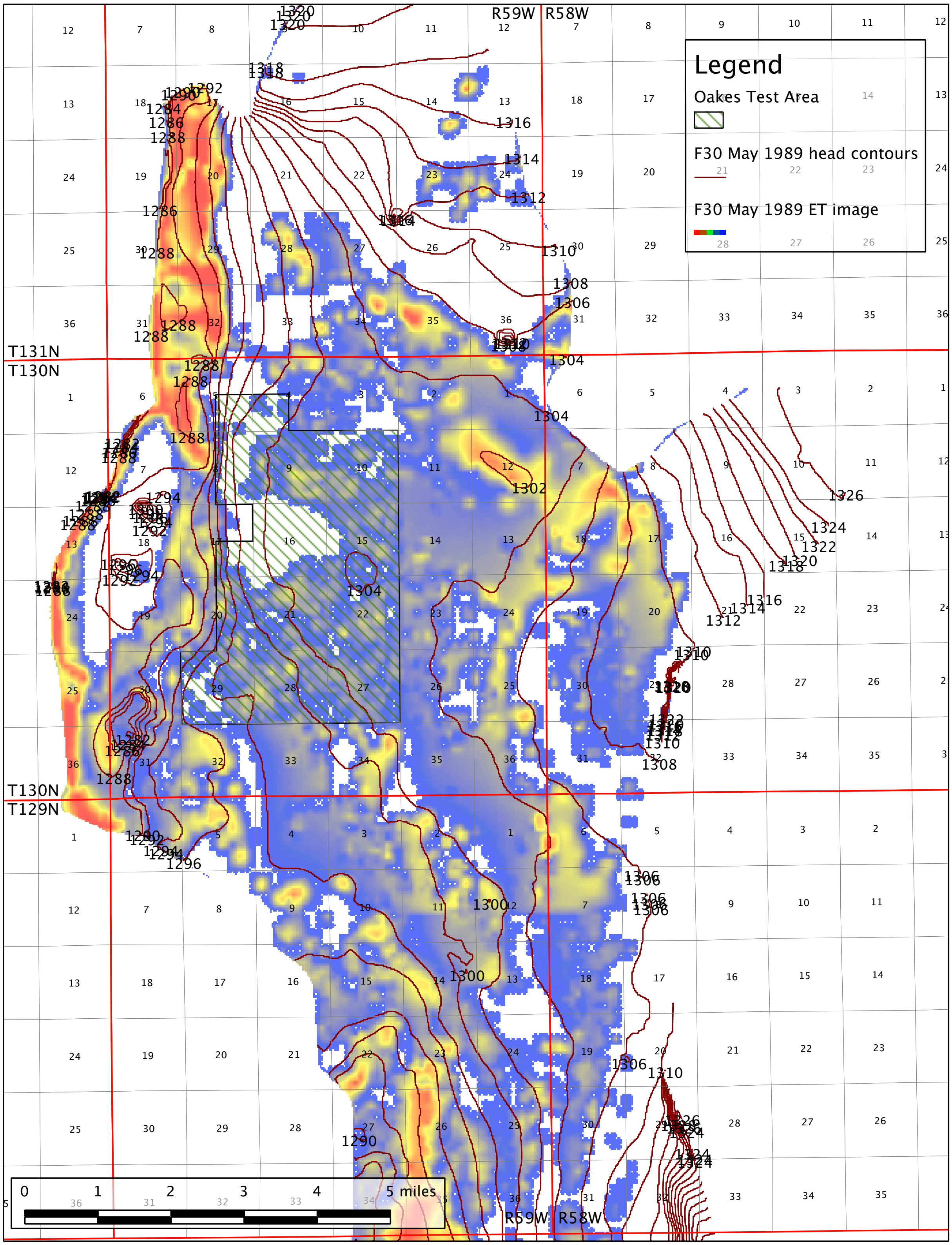

Figure F-11. Areas of evapotranspiration and water level contours for **May 31, 1989.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

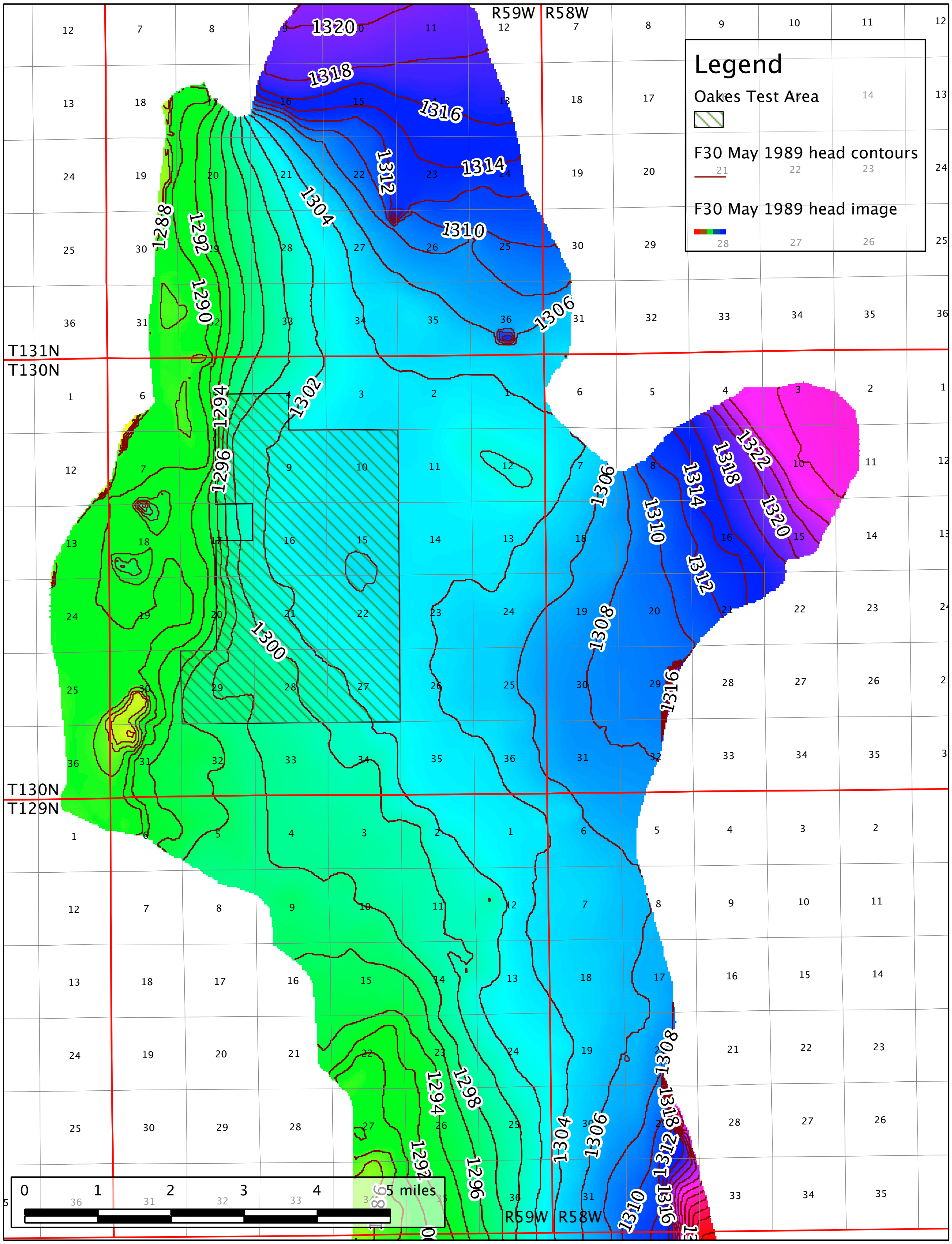

Figure F-12. Water level contours for **May 31, 1989. Run F30**, no drains, no irrigation.

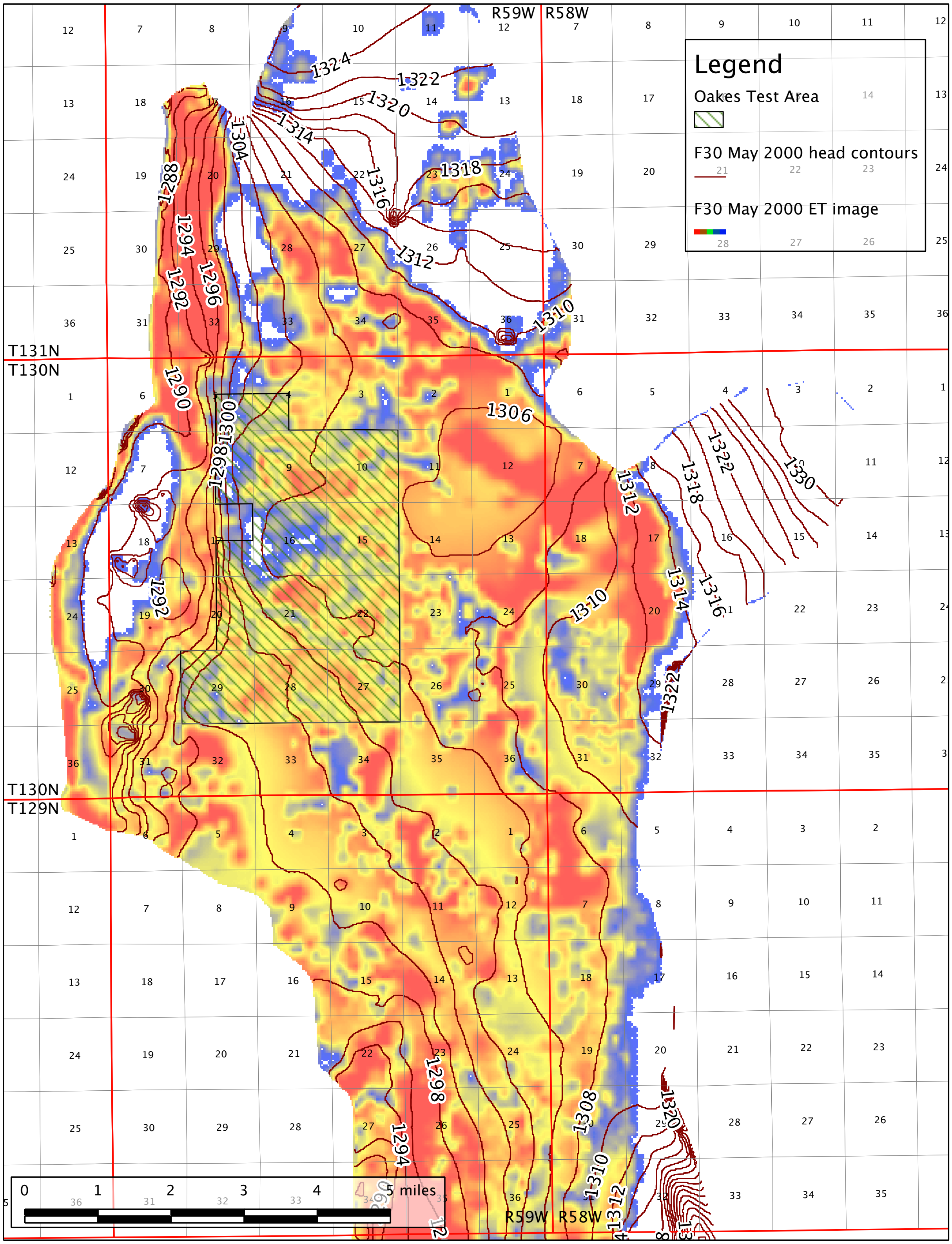

Figure F-13. Areas of evapotranspiration and water level contours for **May 31, 2000.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

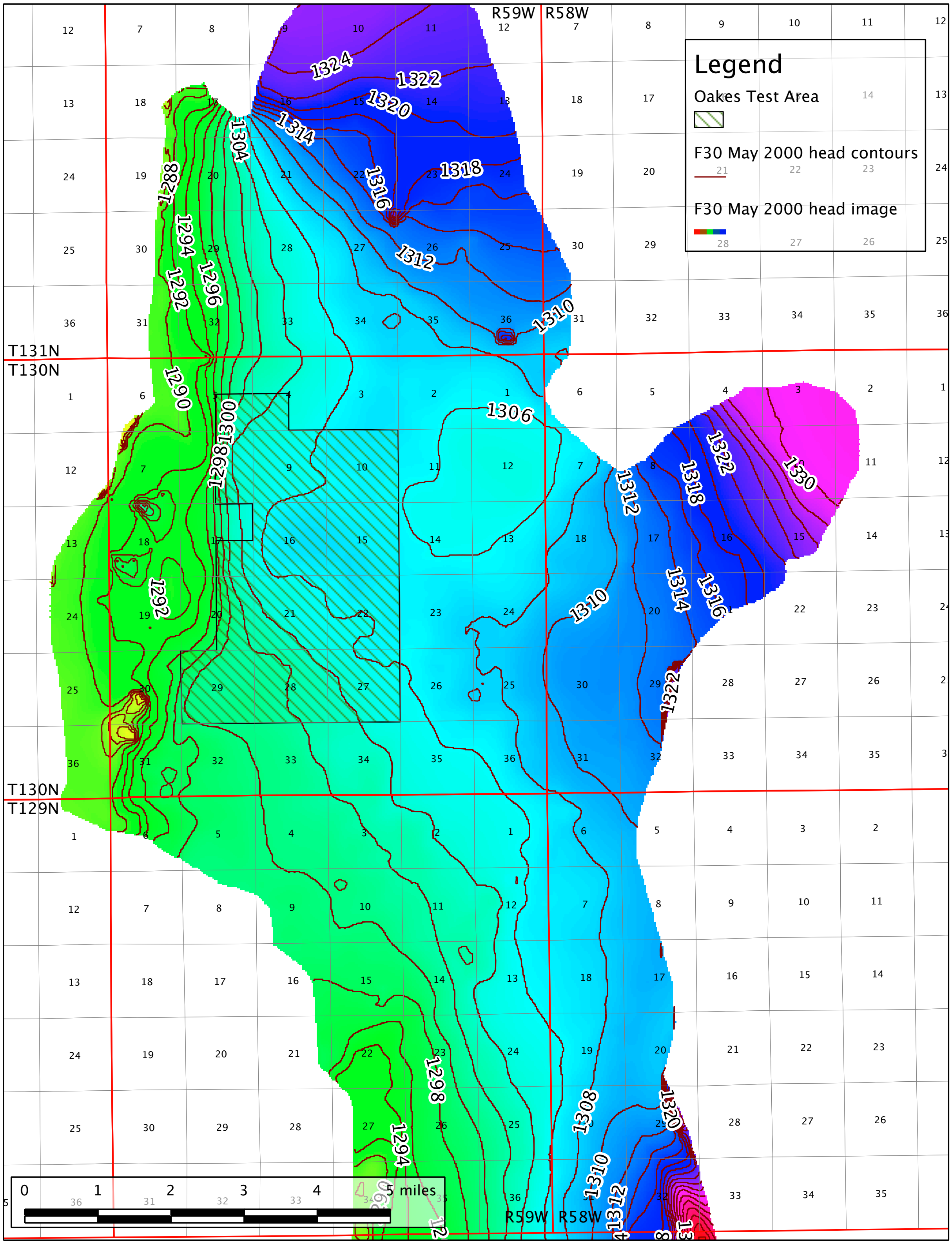

Figure F-14. Water level contours for **May 31, 2000. Run F30**, no drains, no irrigation.

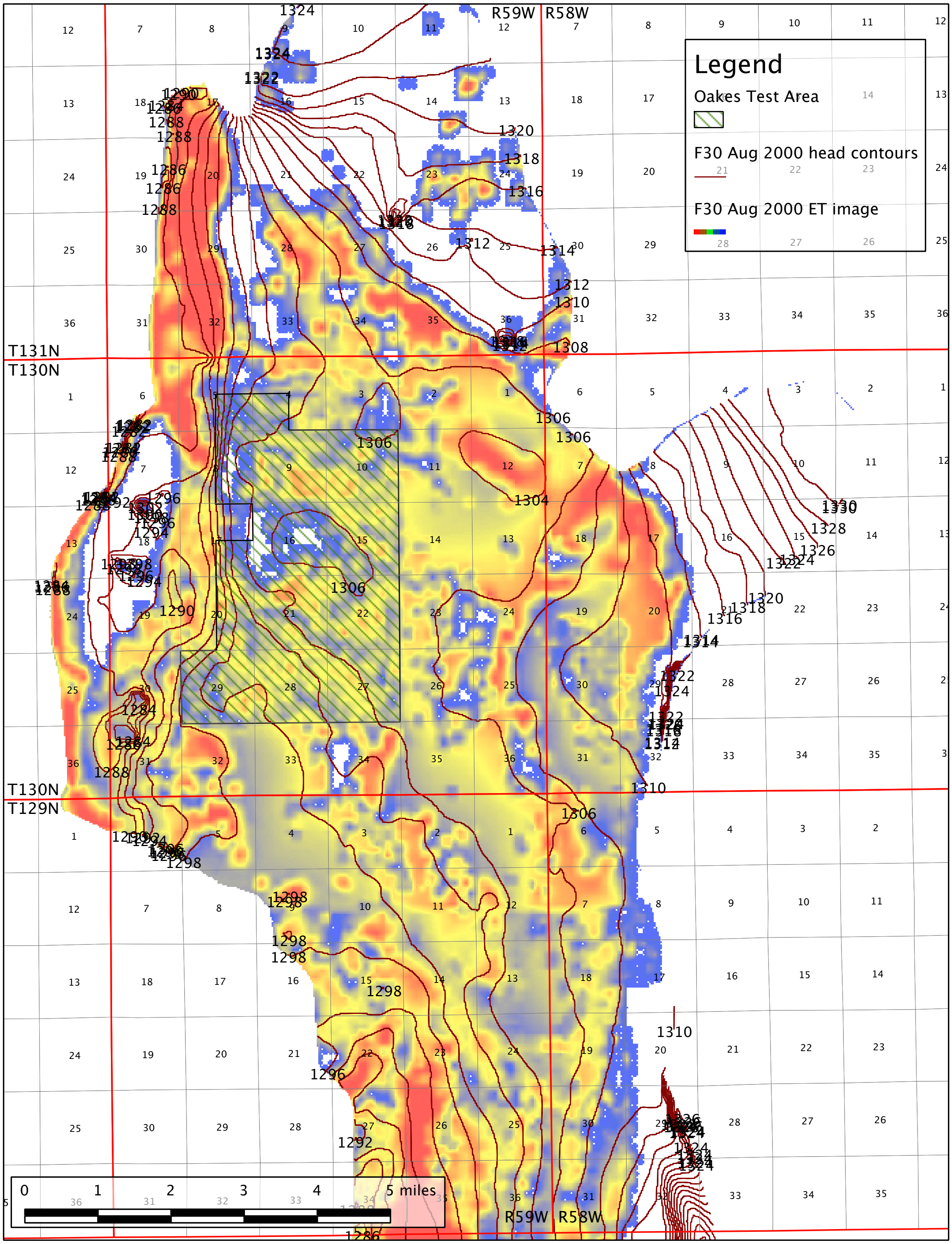

Figure F-15. Areas of evapotranspiration and water level contours for **August 31, 2000.** White is no ET. Red is maximum ET. **Run F30**, no drains, no irrigation.

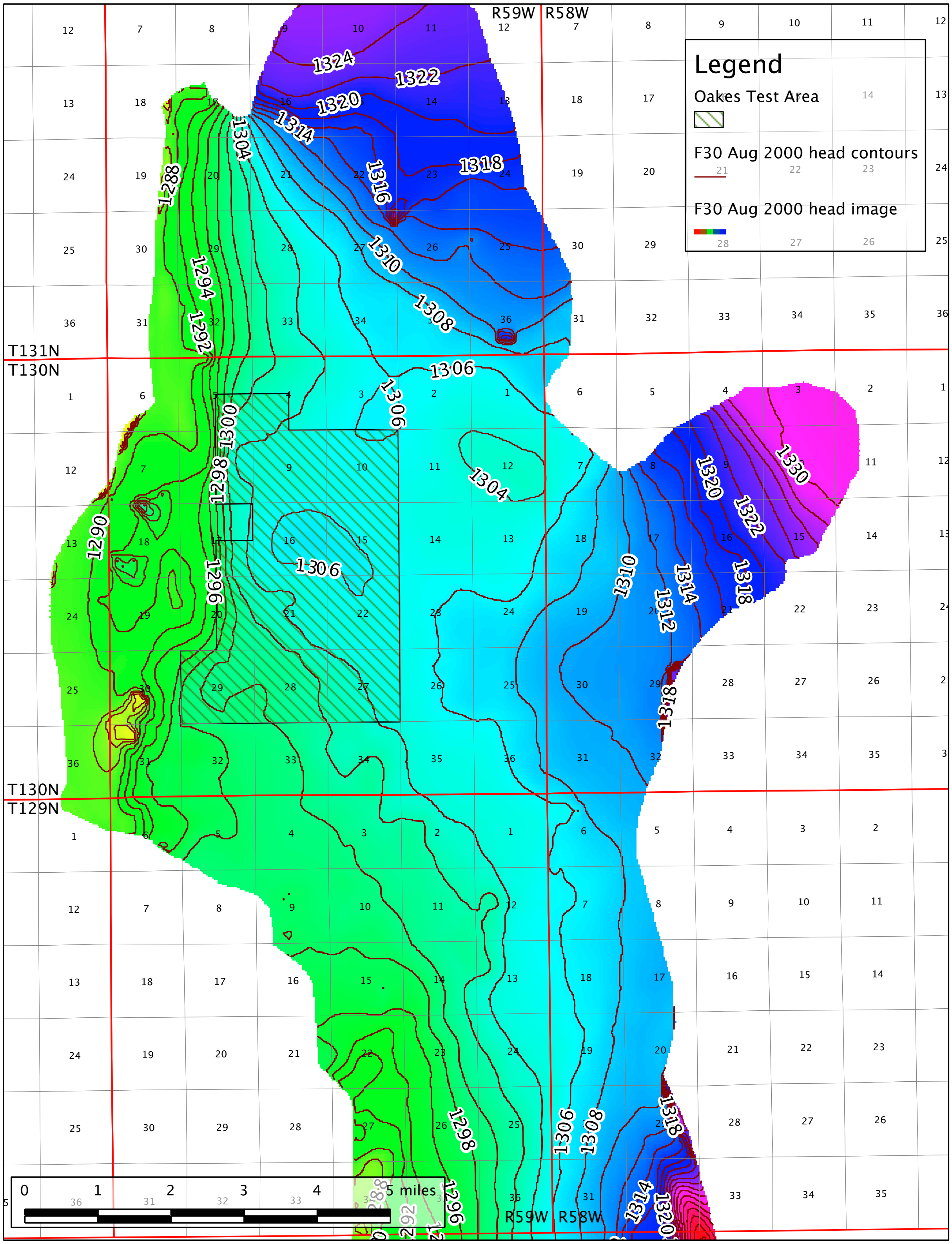

Figure F-16. Water level contours for **August 31, 2000. Run F30**, no drains, no irrigation.

RUN F32, DRAINS, PERMITTED IRRIGATION

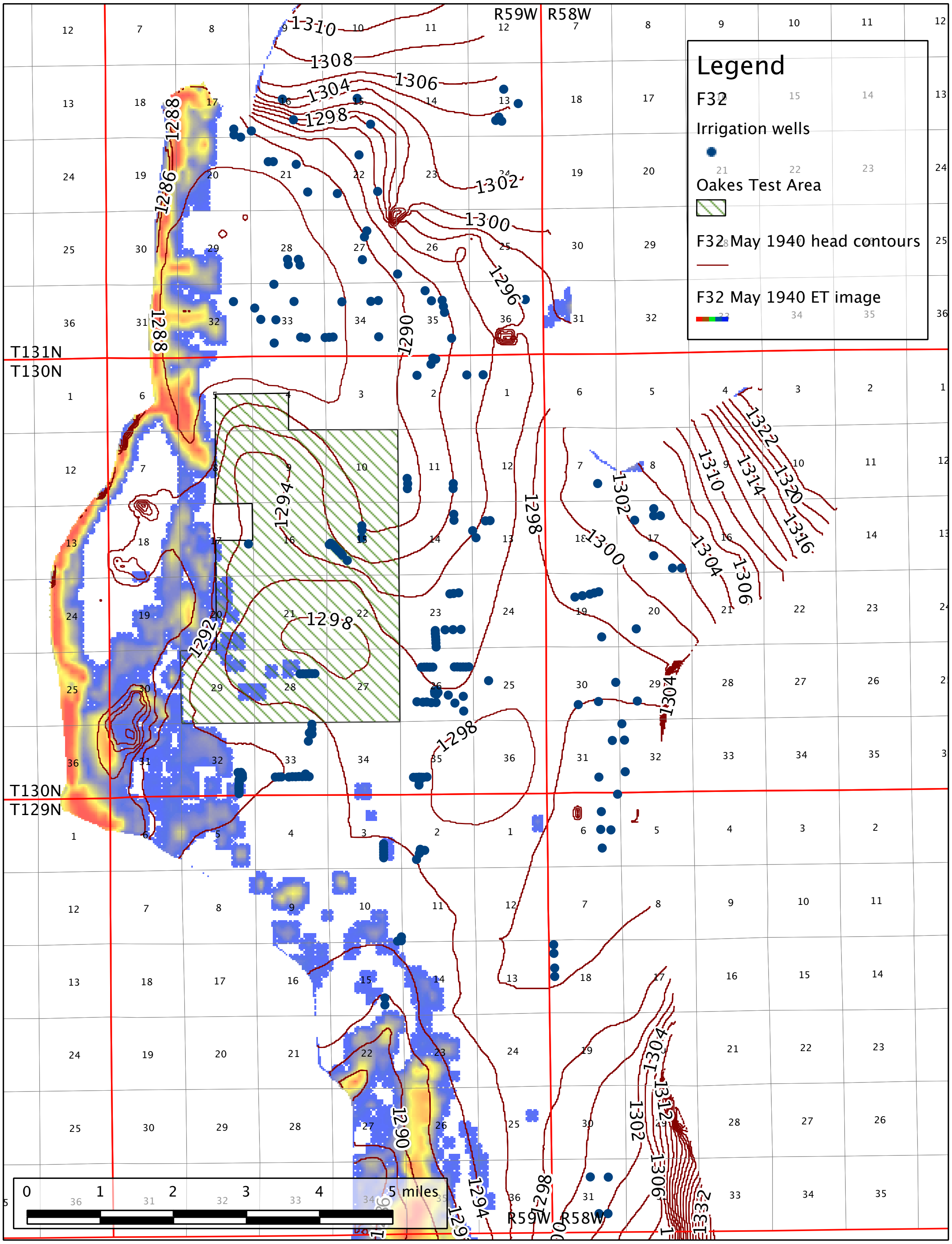

Figure F-17. Areas of evapotranspiration and water level contours for **May 31, 1940.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

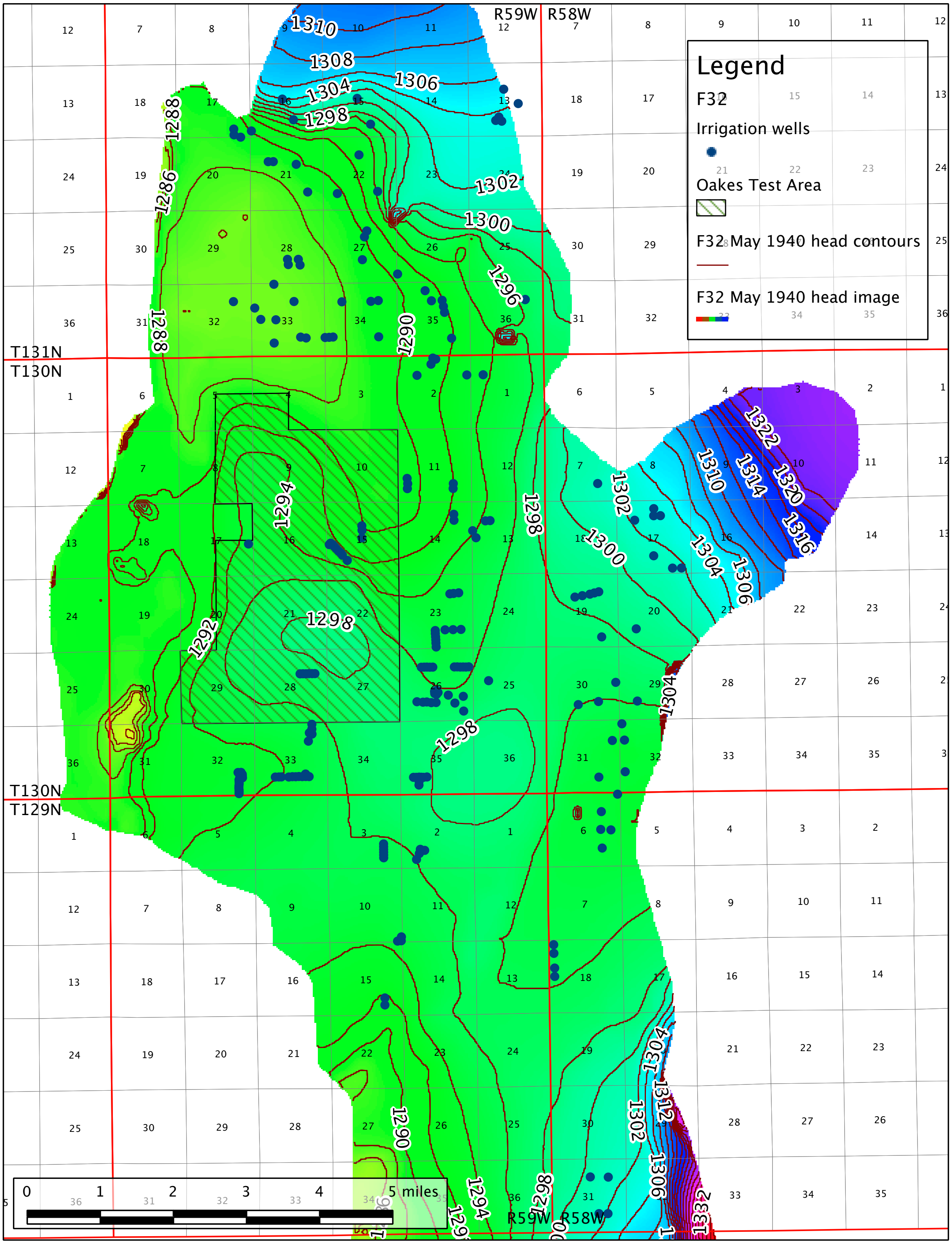

Figure F-18. Water level contours for **May 31, 1940. Run F32**, drains, permitted irrigation.

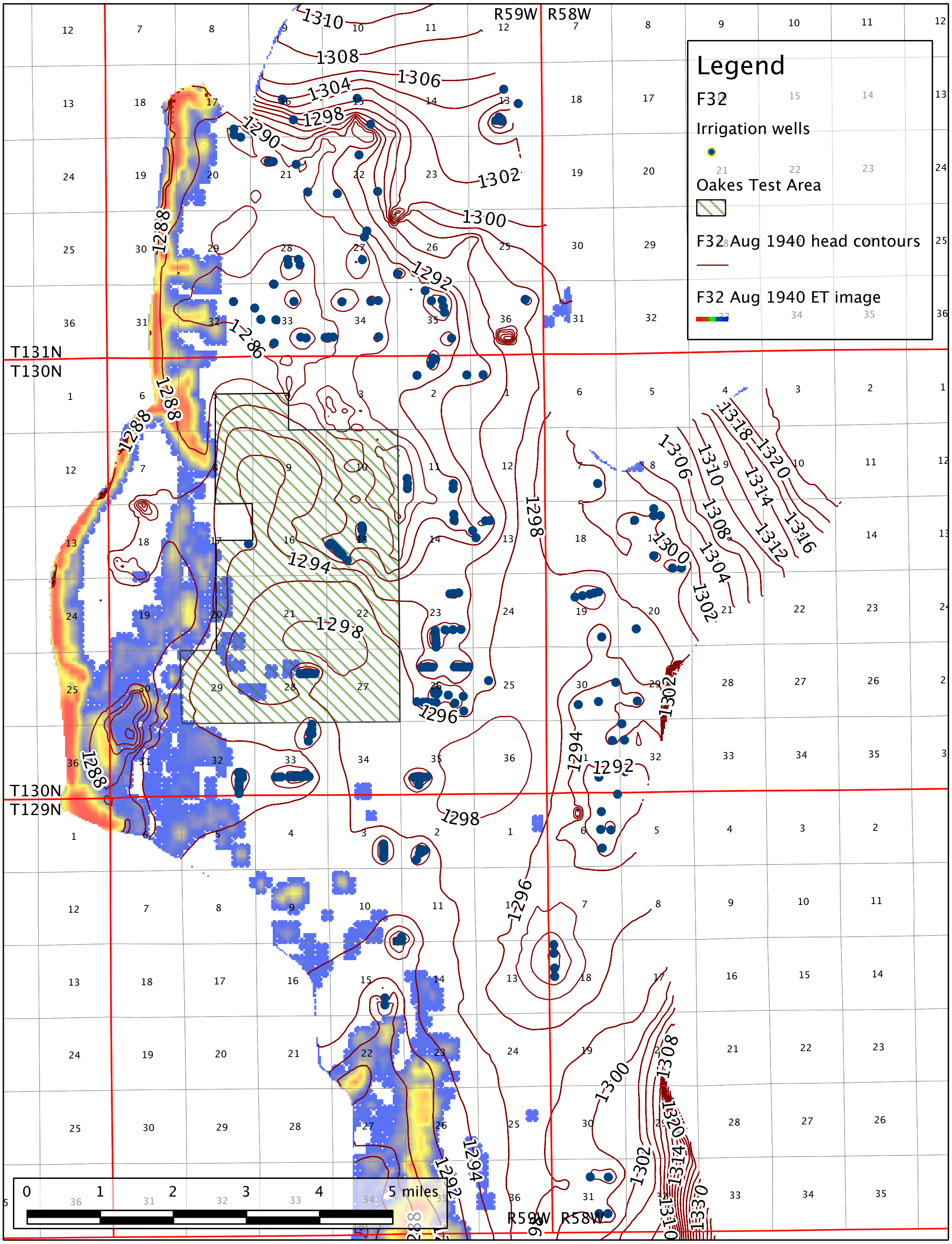

Figure F-19. Areas of evapotranspiration and water level contours for **August 31, 1940.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

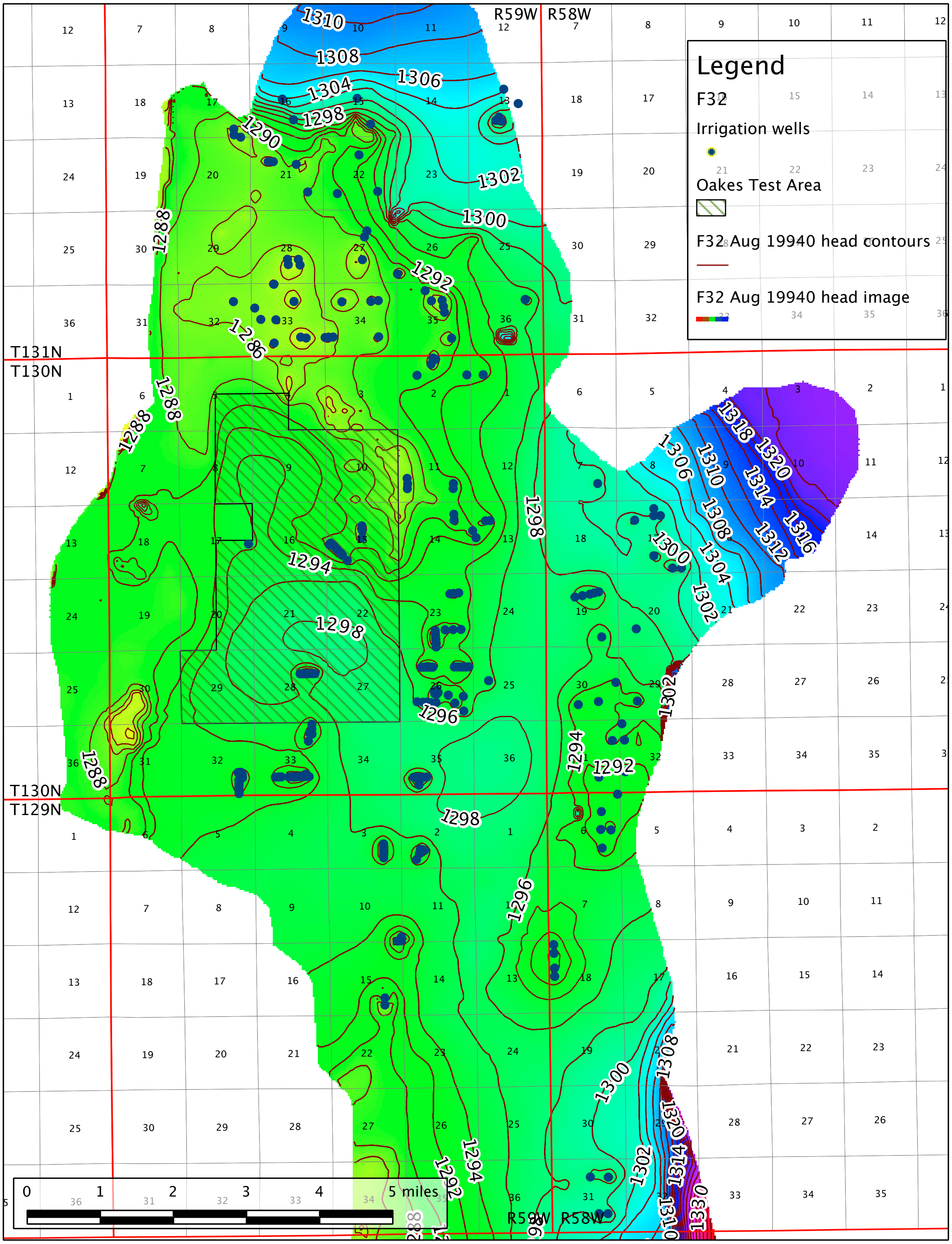

Figure F-20. Water level contours for **August 31, 1940. Run F32**, drains, permitted irrigation.

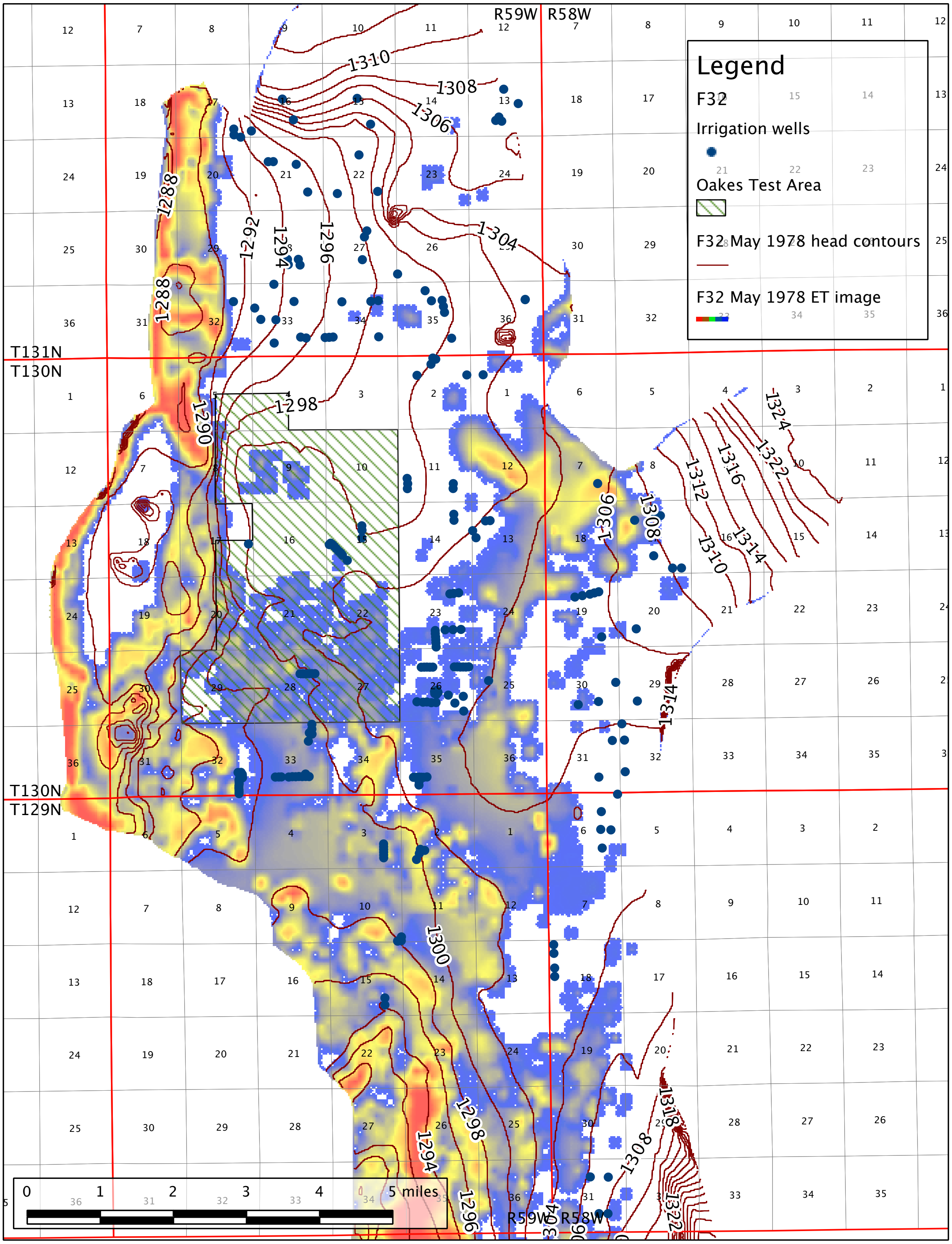

Figure F-21. Areas of evapotranspiration and water level contours for **May 31, 1978.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

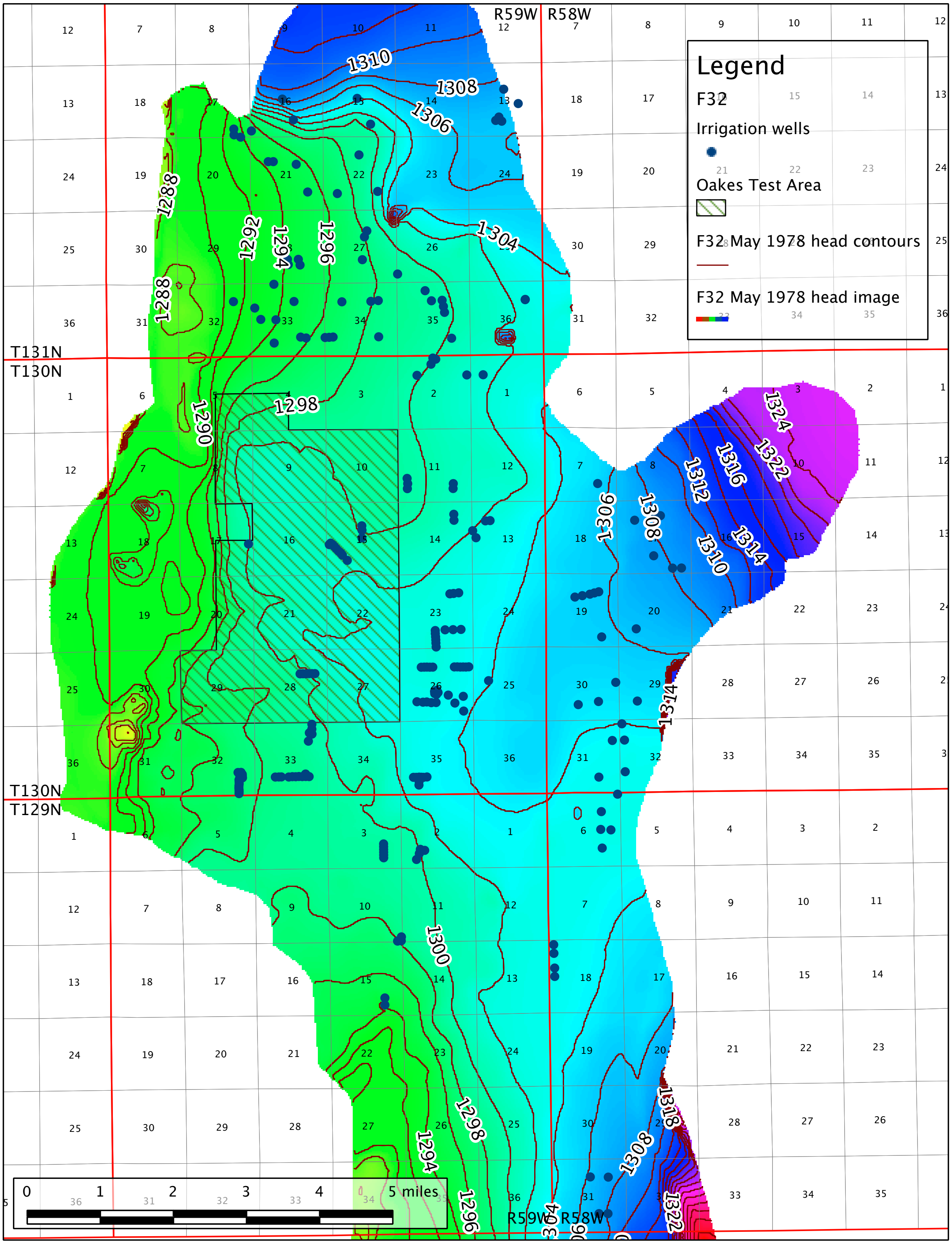

Figure F-22. Water level contours for **May 31, 1978. Run F32**, drains, permitted irrigation.

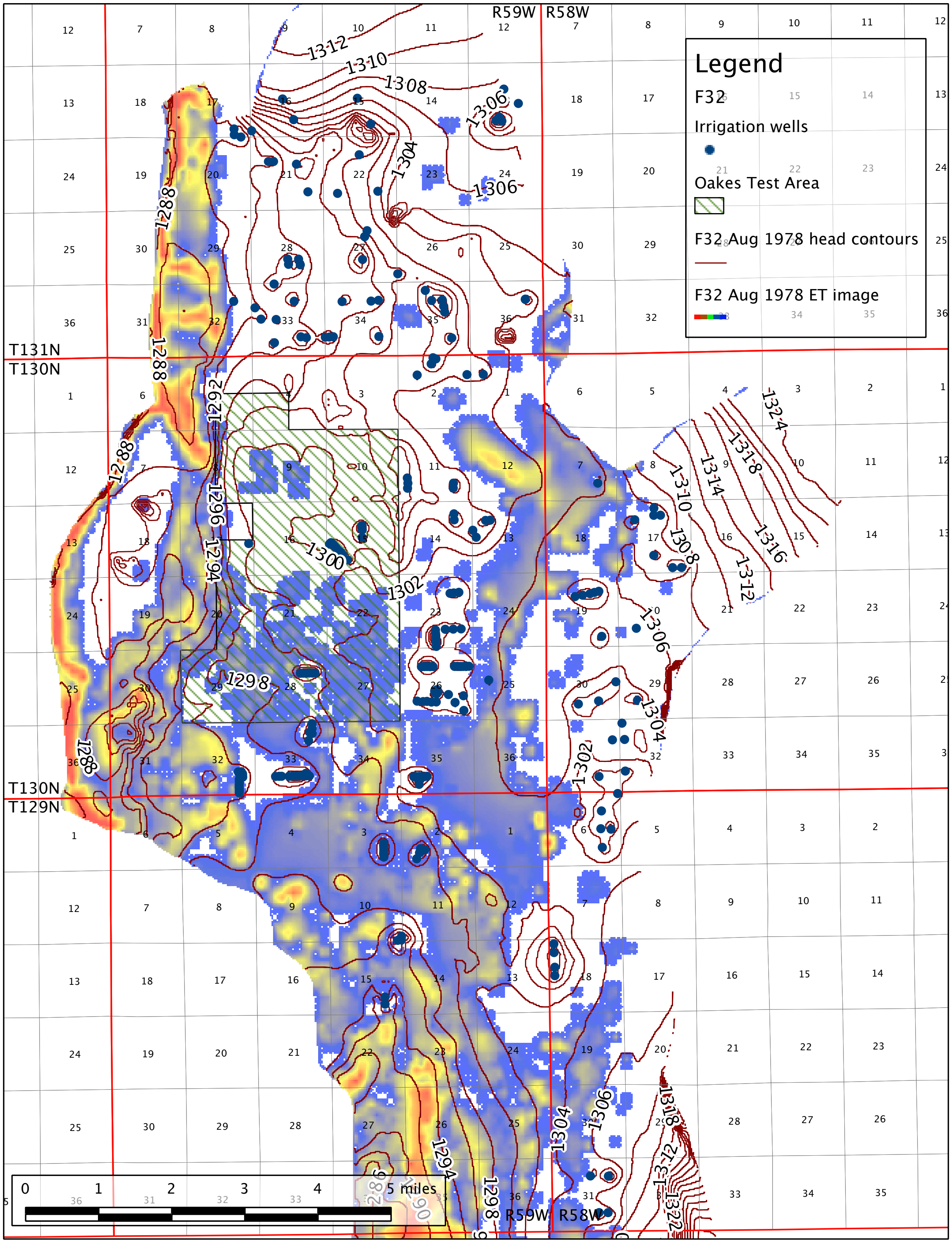

Figure F-23. Areas of evapotranspiration and water level contours for **August 31, 1978.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

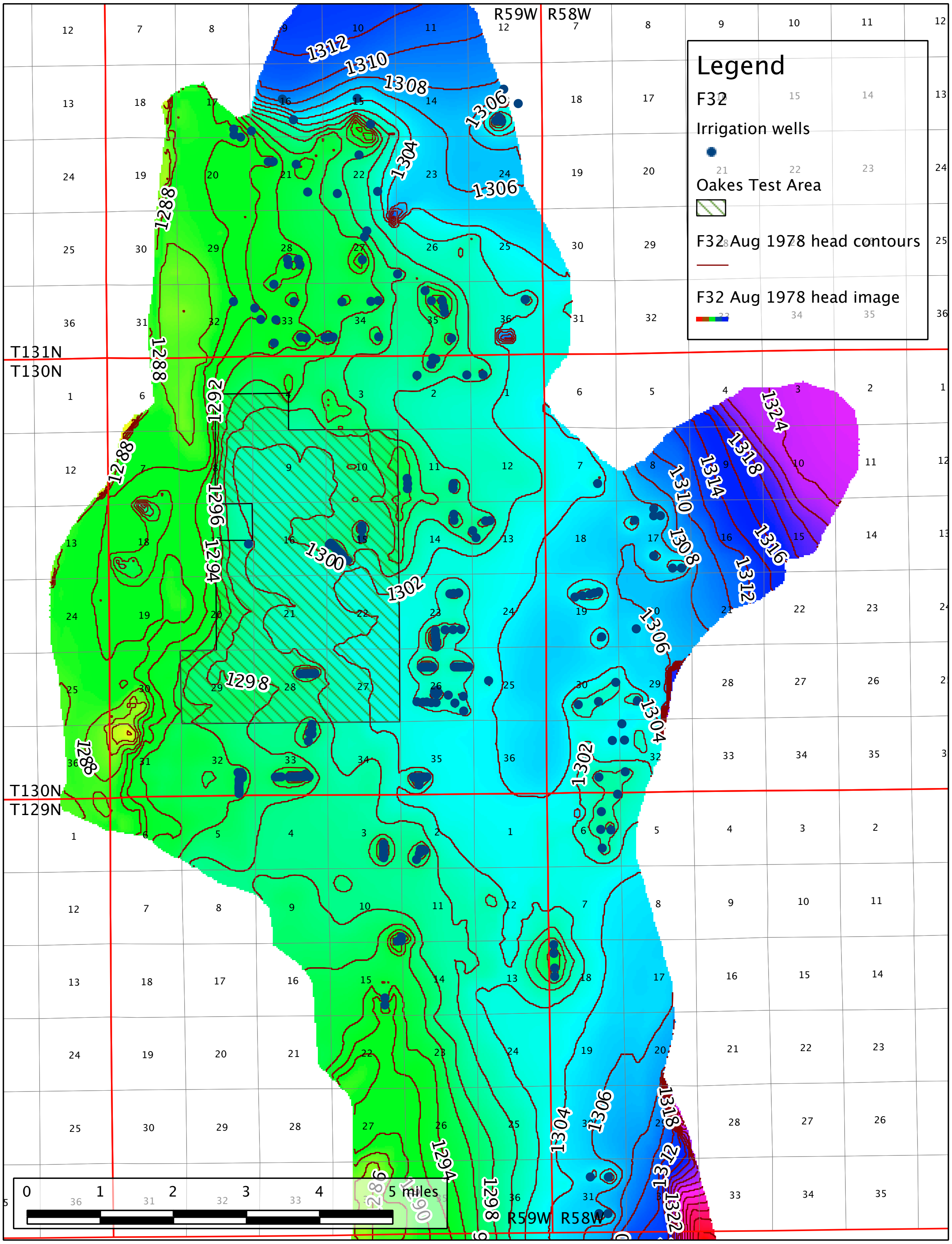

Figure F-24. Water level contours for **August 31, 1978. Run F32**, drains, permitted irrigation.

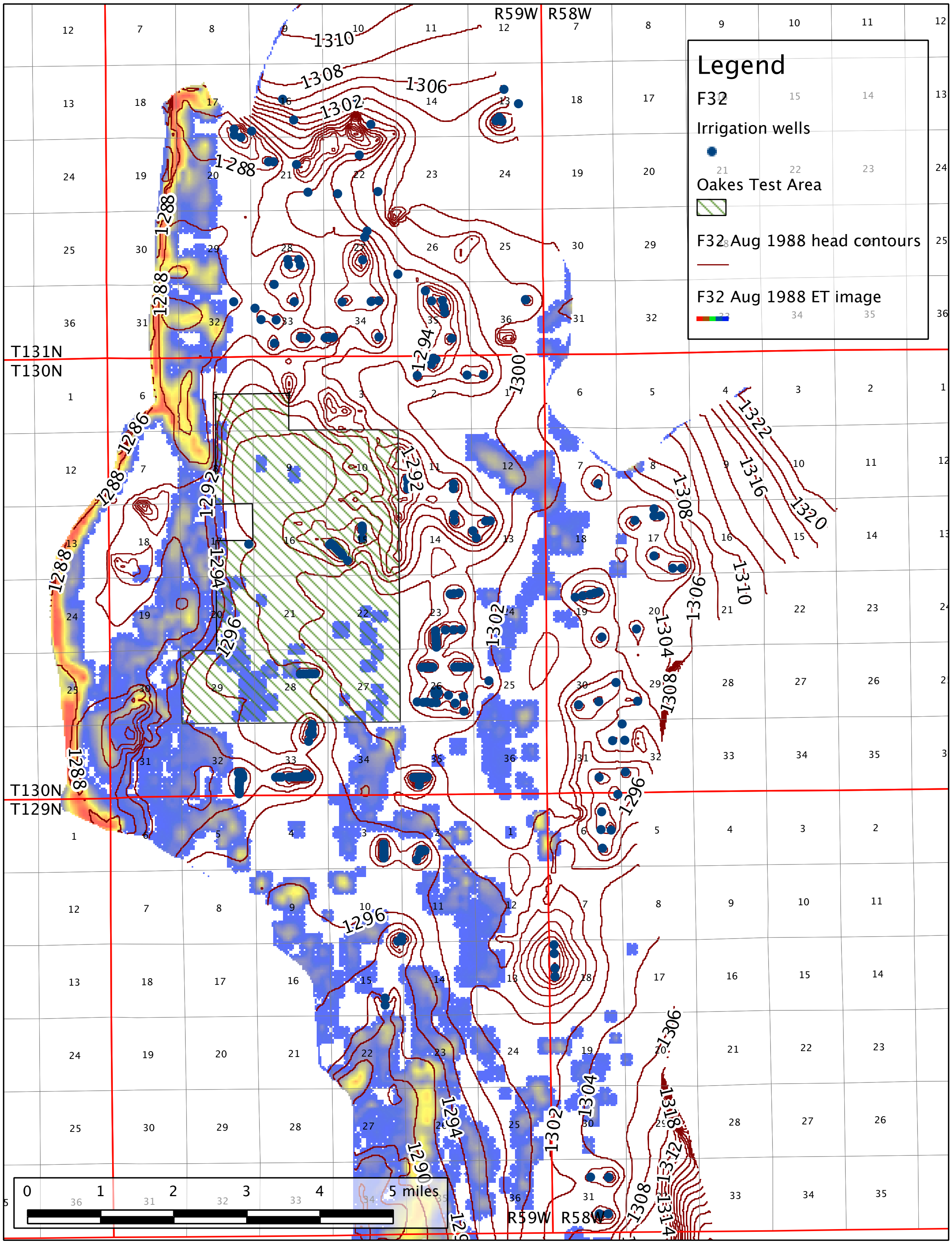

Figure F-25. Areas of evapotranspiration and water level contours for **August 31, 1988.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

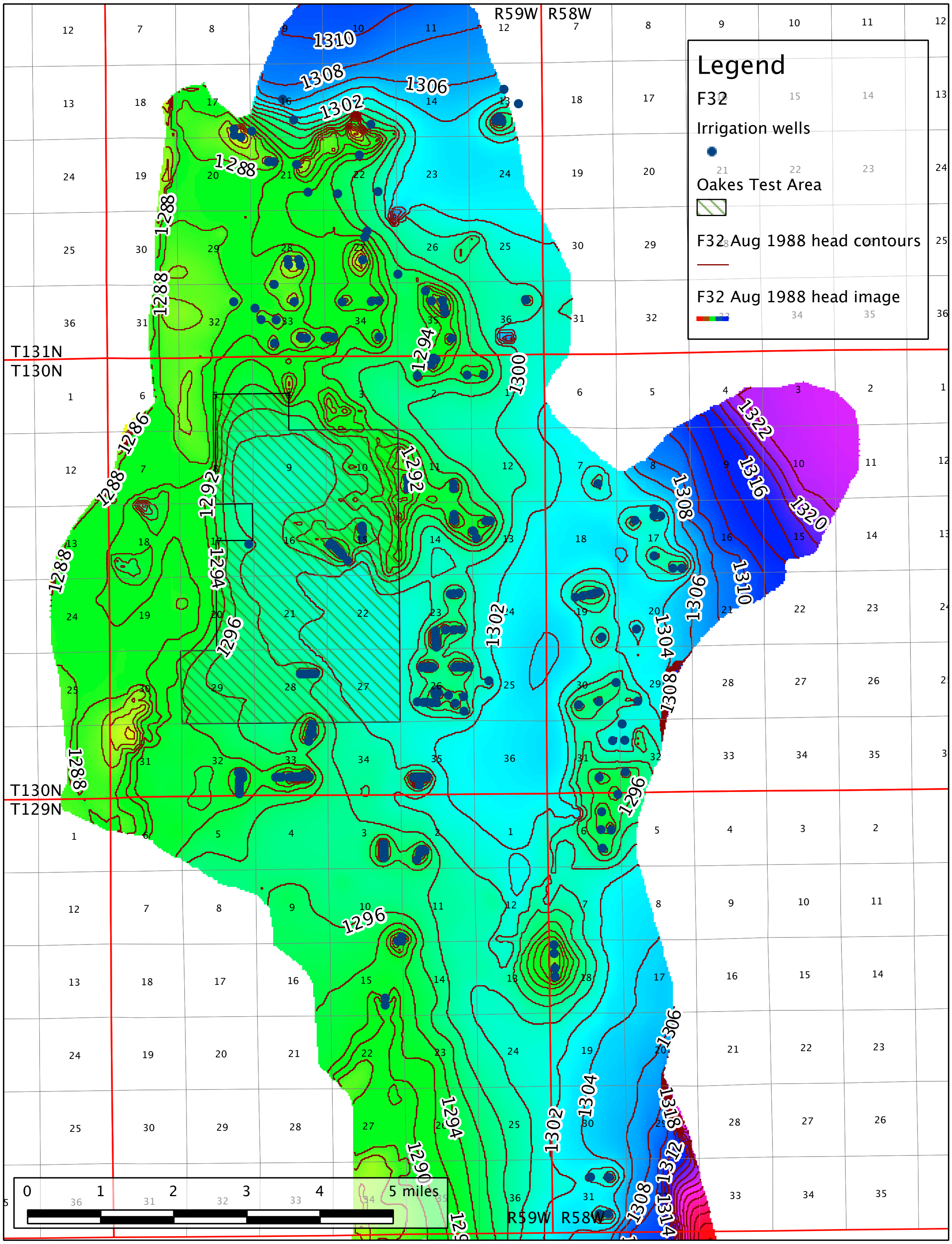

Figure F-26. Water level contours for **August 31, 1988. Run F32**, drains, permitted irrigation.

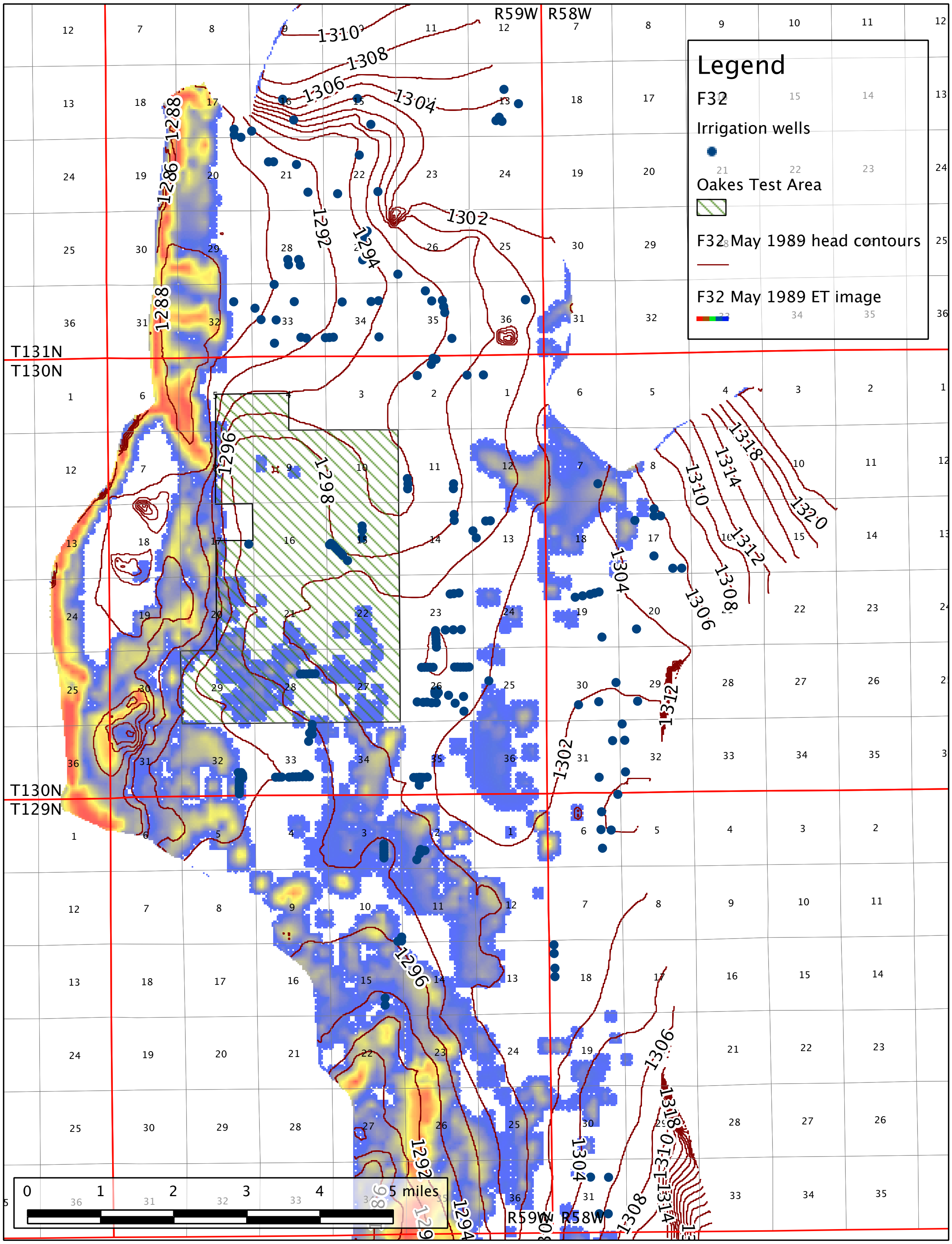

Figure F-27. Areas of evapotranspiration and water level contours for **May 31, 1989.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

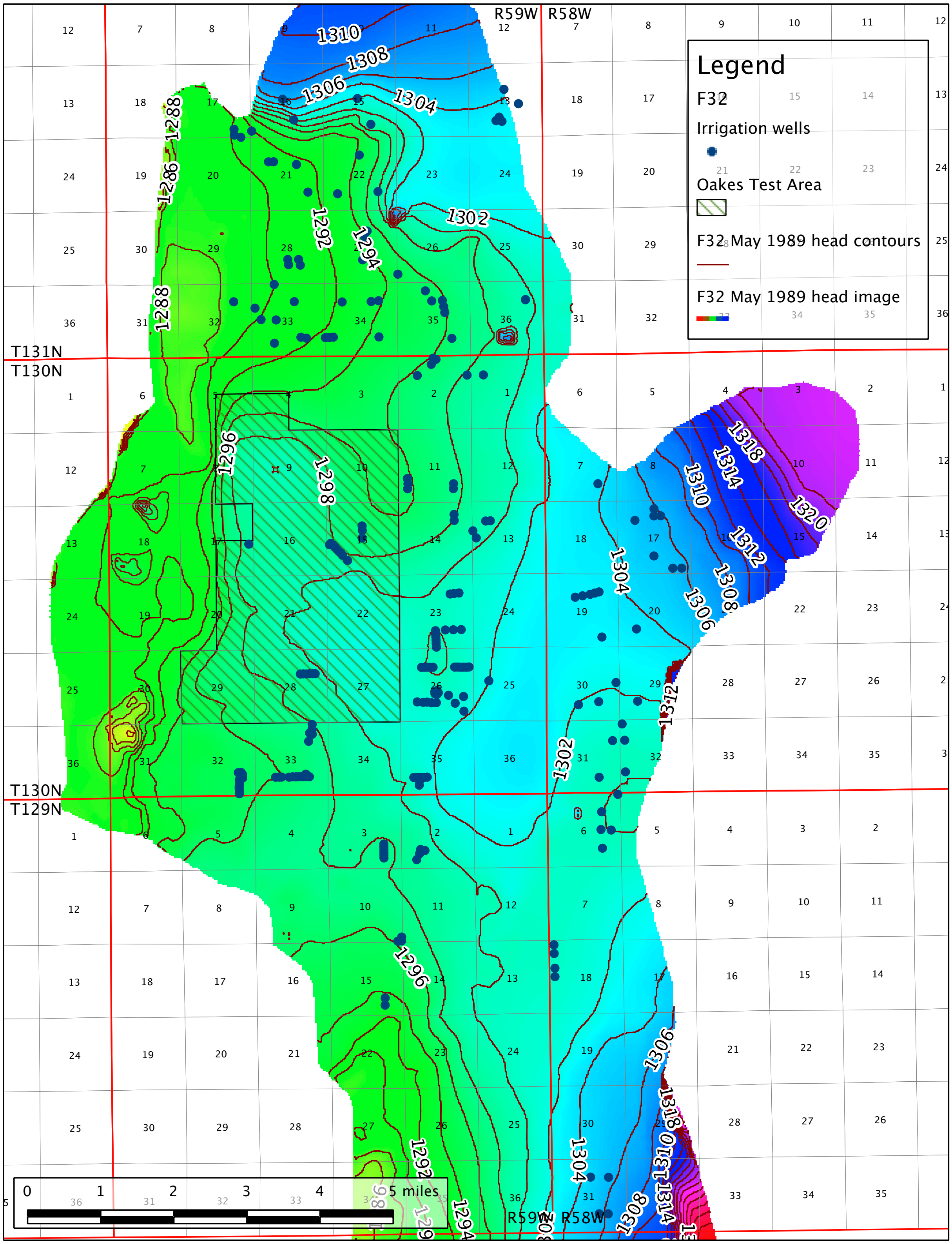

Figure F-28. Water level contours for **May 31, 1989. Run F32**, drains, permitted irrigation.

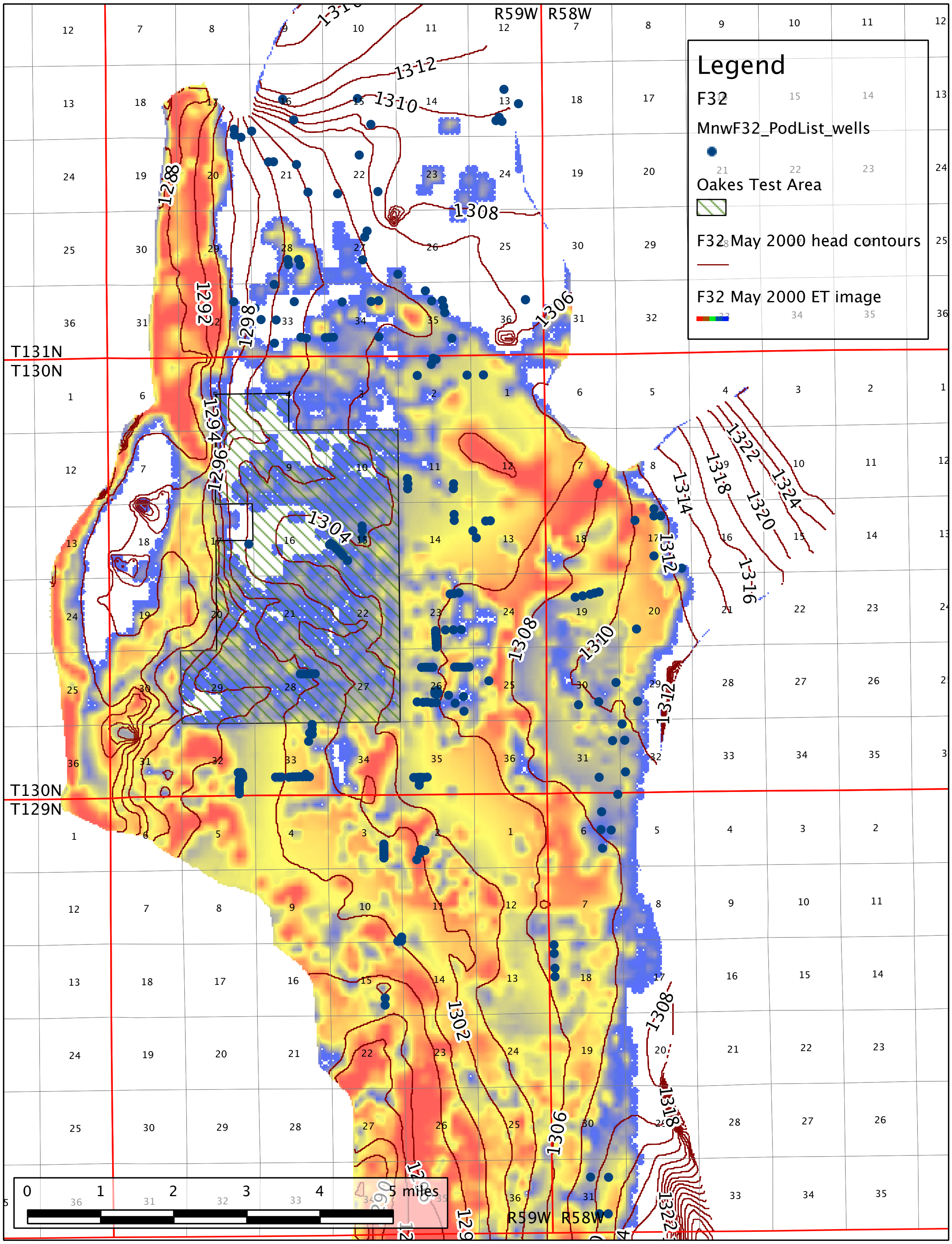

Figure F-29. Areas of evapotranspiration and water level contours for **May 31, 2000.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

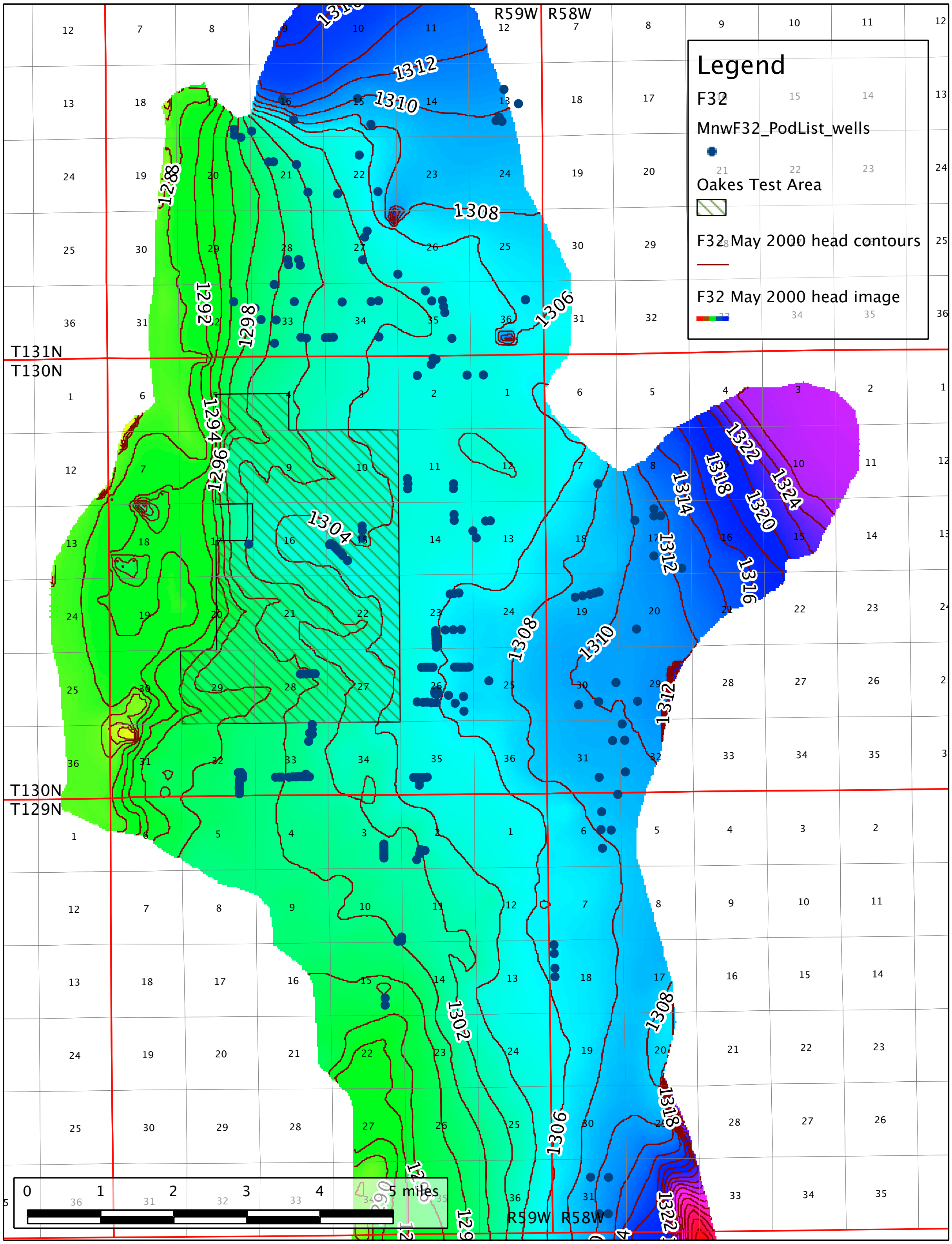

Figure F-30. Water level contours for **May 31, 2000. Run F32**, drains, permitted irrigation.

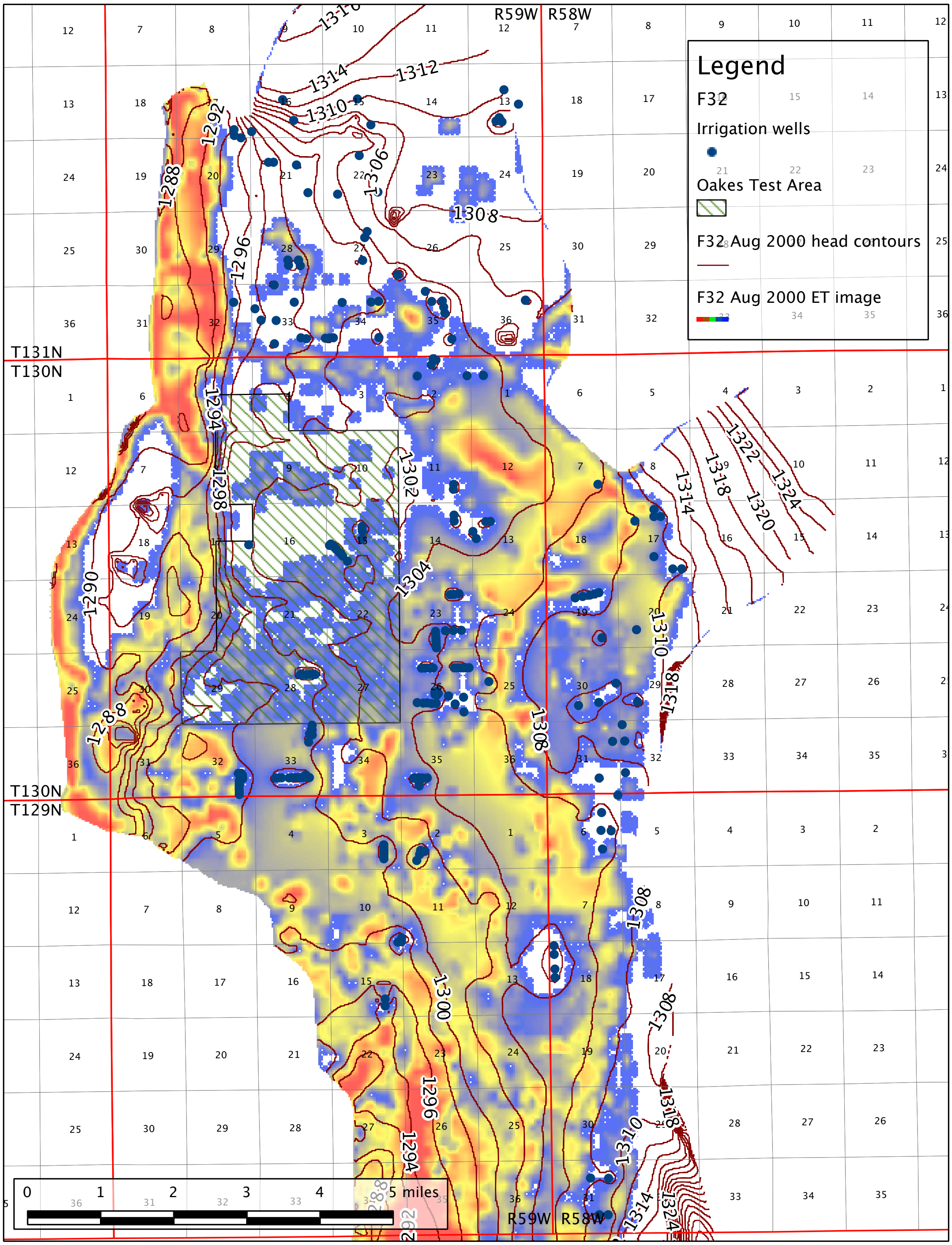

Figure F-31. Areas of evapotranspiration and water level contours for **August 31, 2000.** White is no ET. Red is maximum ET. **Run F32**, drains, permitted irrigation.

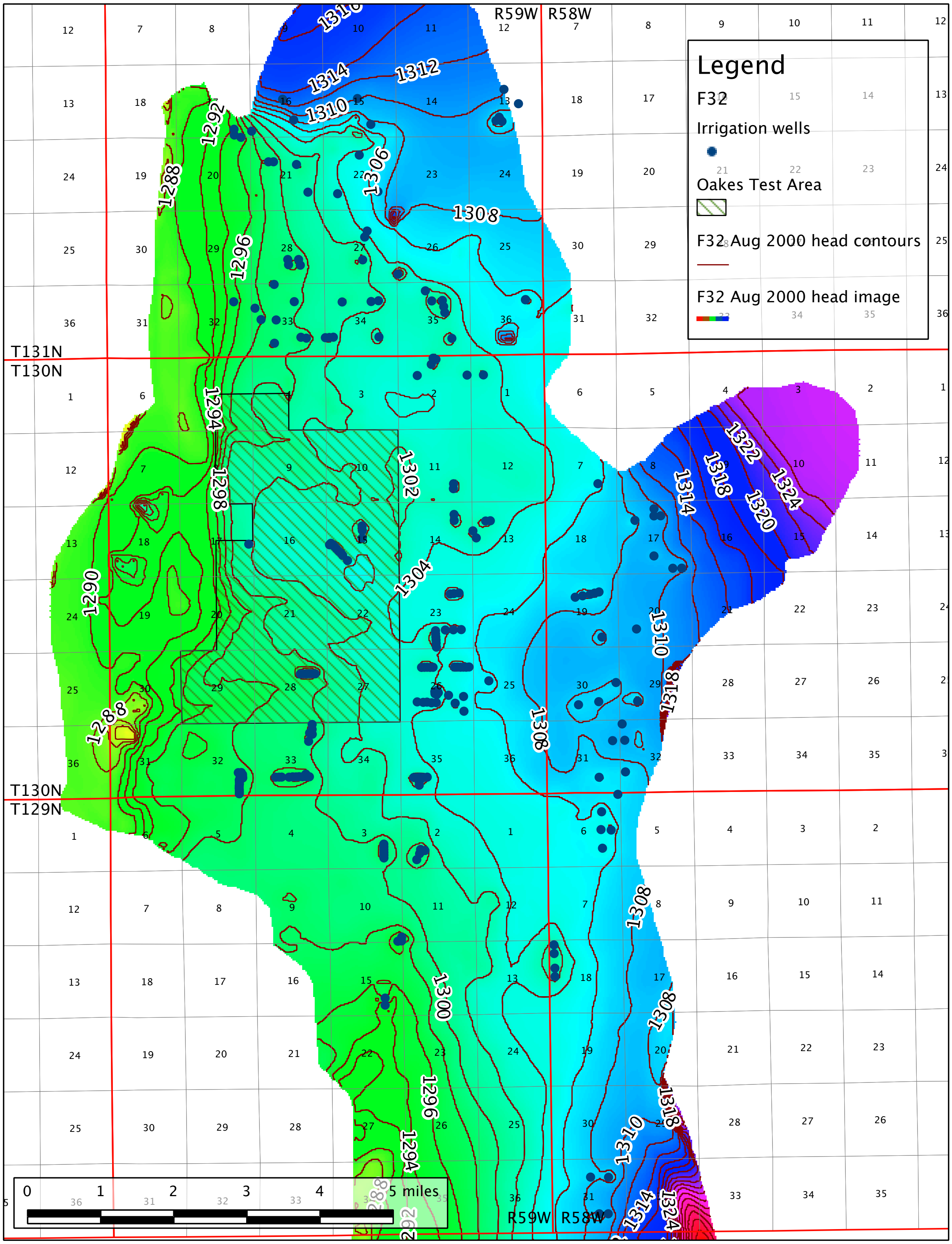

Figure F-32. Water level contours for **August 31, 2000. Run F32**, drains, permitted irrigation.

RUN F38b, DRAINS, PERMITTED+PENDING IRRIGATION

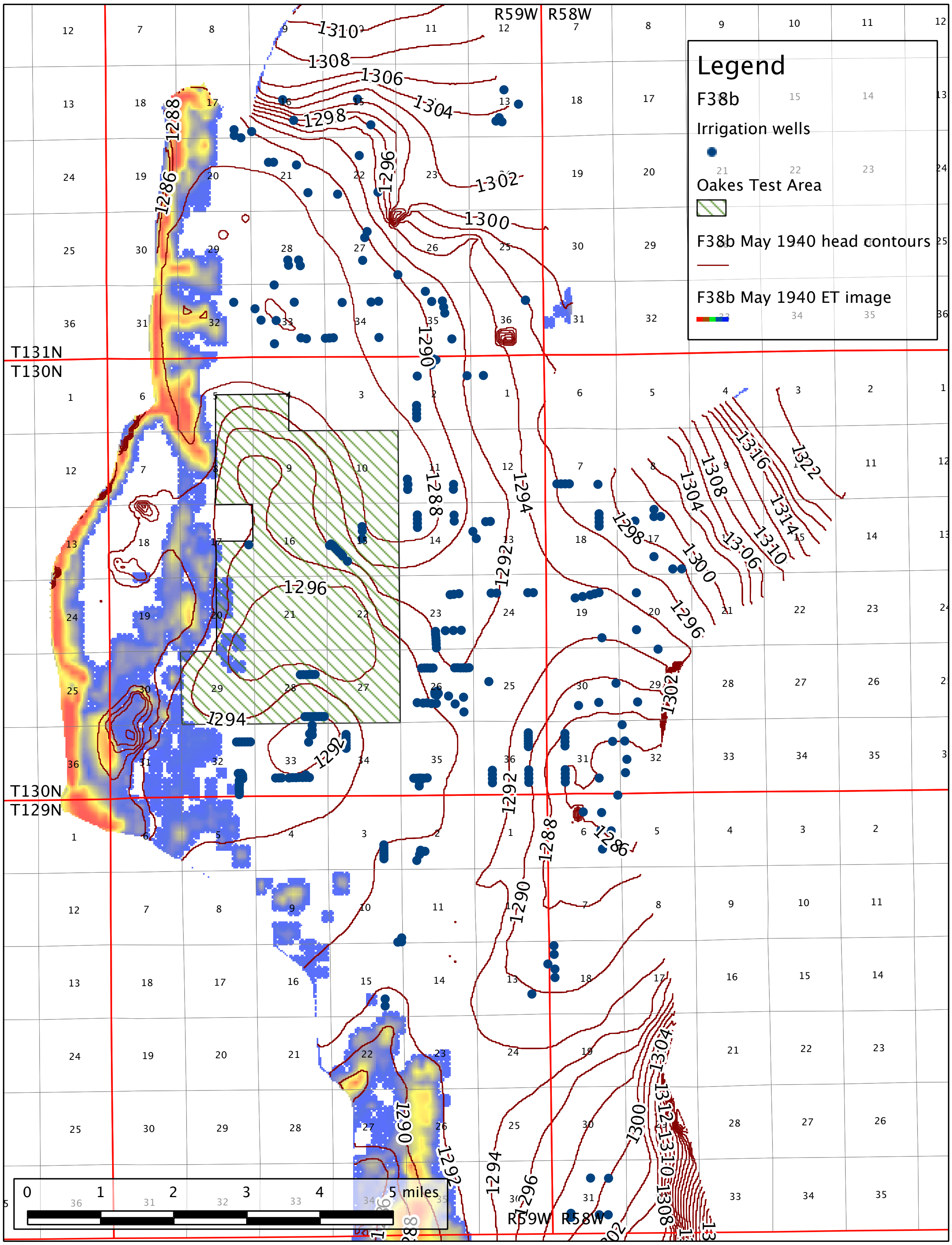

Figure F-33. Areas of evapotranspiration and water level contours for **May 31, 1940.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

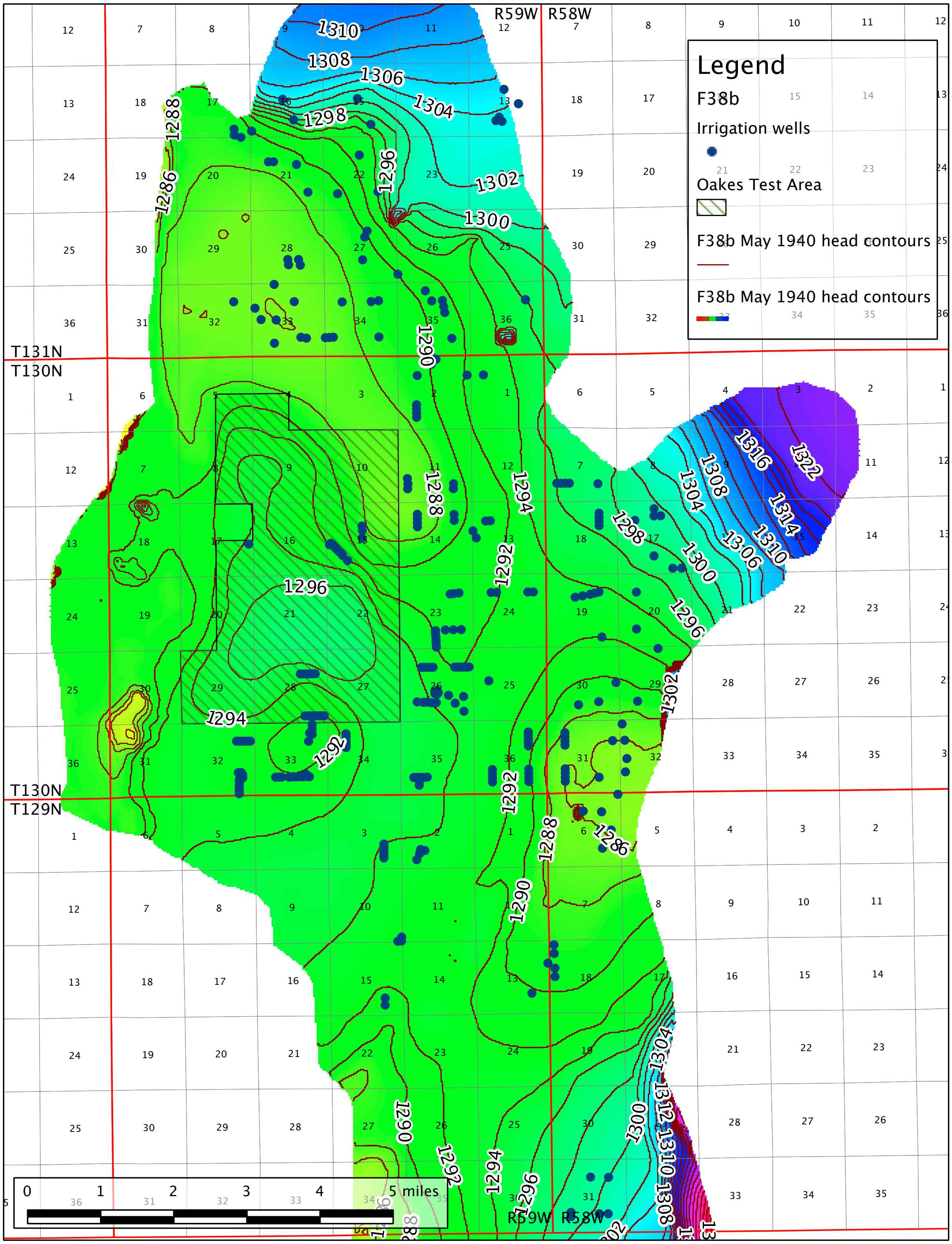

Figure F-34. Water level contours for **May 31, 1940. Run F38b**, drains, permitted + pending irrigation.

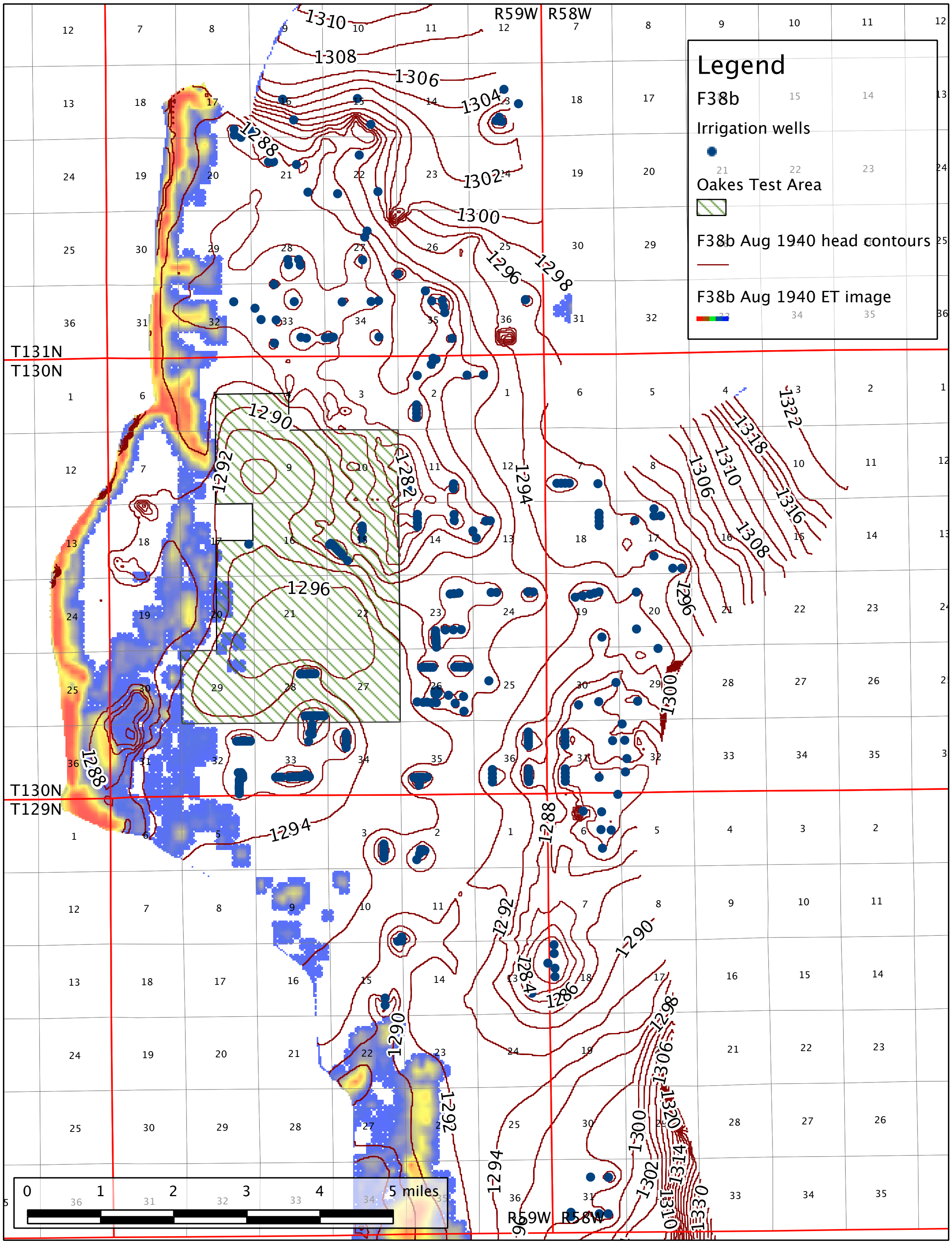

Figure F-35. Areas of evapotranspiration and water level contours for **August 31, 1940.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

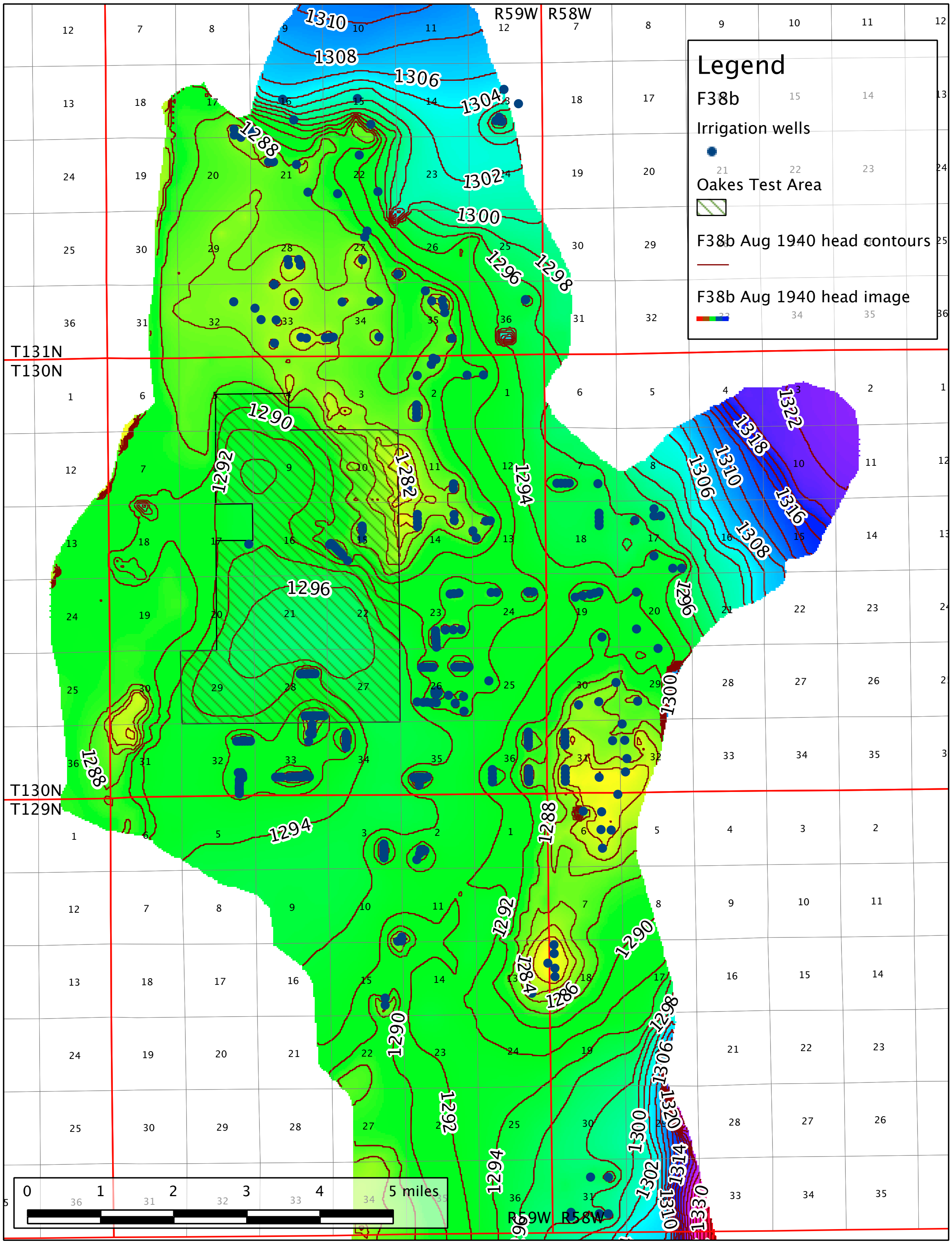

Figure F-36. Water level contours for **August 31, 1940. Run F38b**, drains, permitted + pending irrigation.

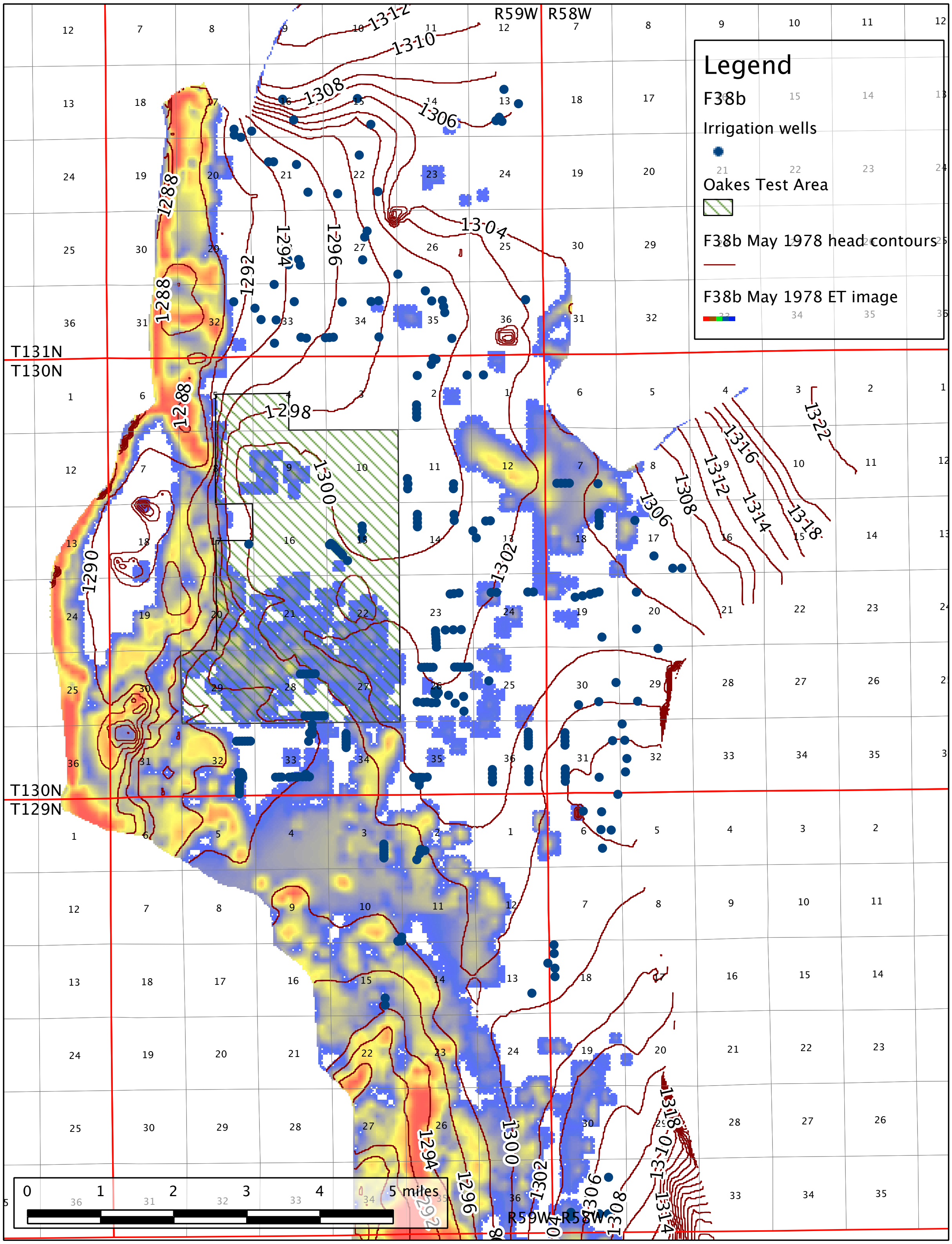

Figure F-37. Areas of evapotranspiration and water level contours for **May 31, 1978.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

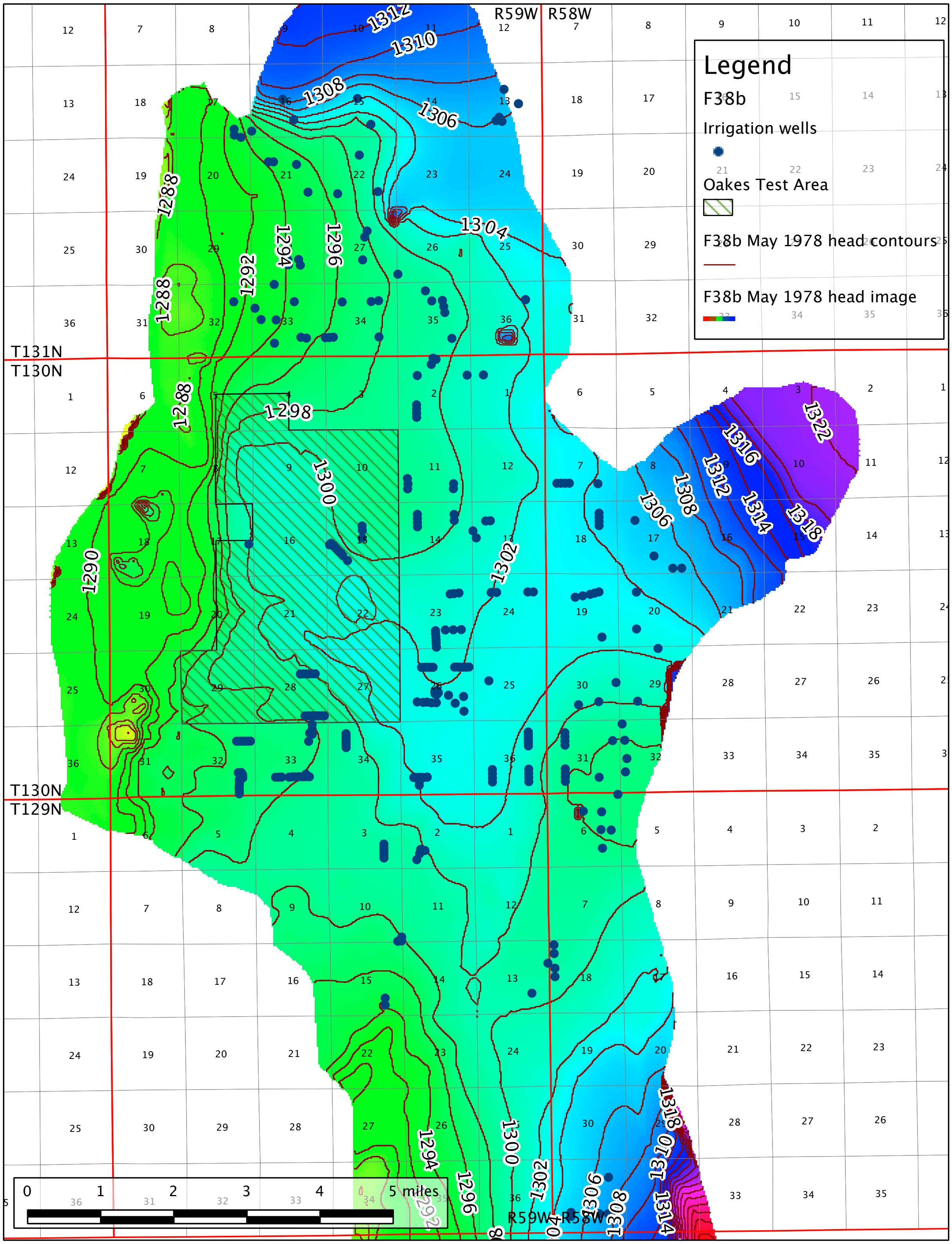

Figure F-38. Water level contours for **May 31, 1978. Run F38b**, drains, permitted + pending irrigation.

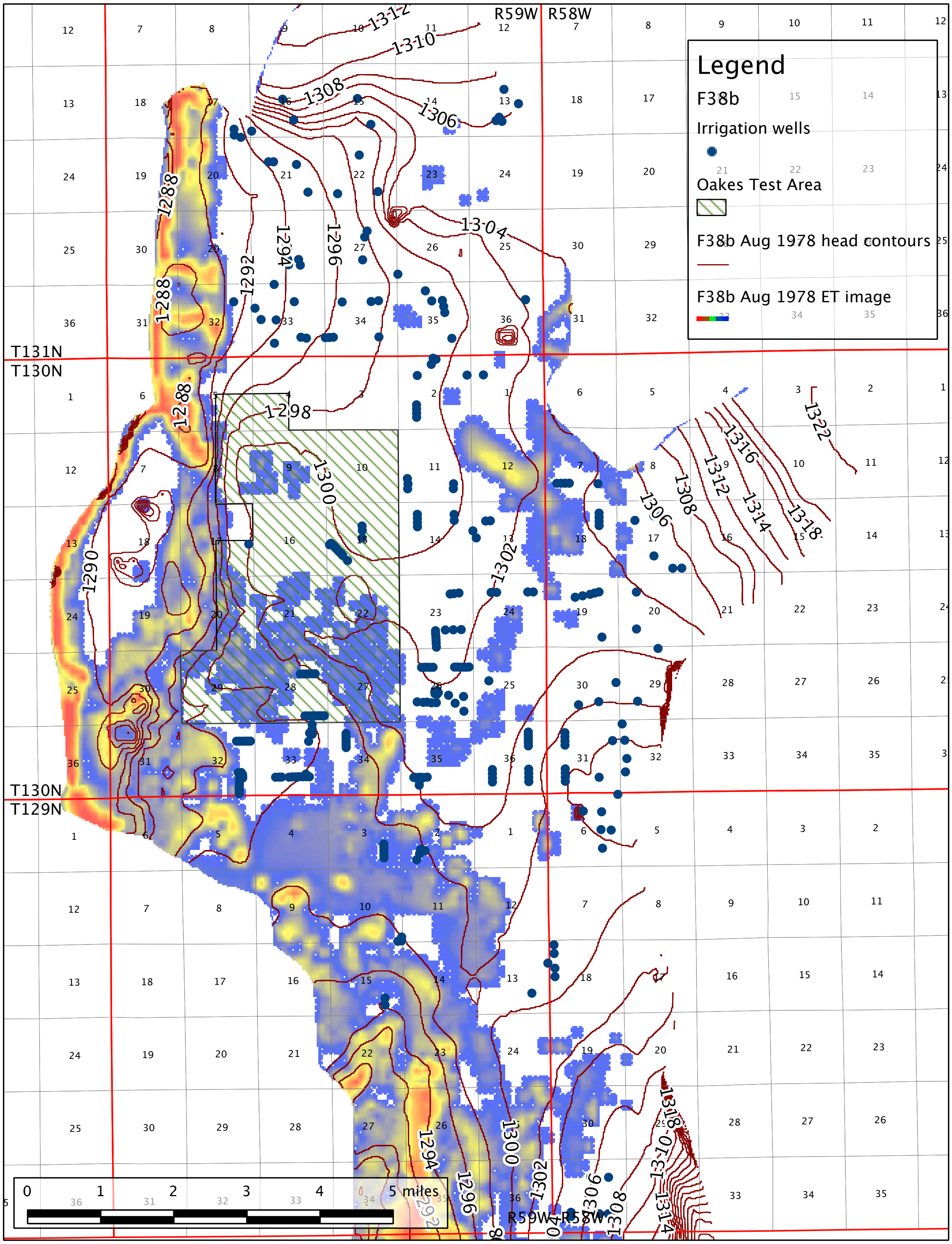

Figure F-39. Areas of evapotranspiration and water level contours for **August 31, 1978.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

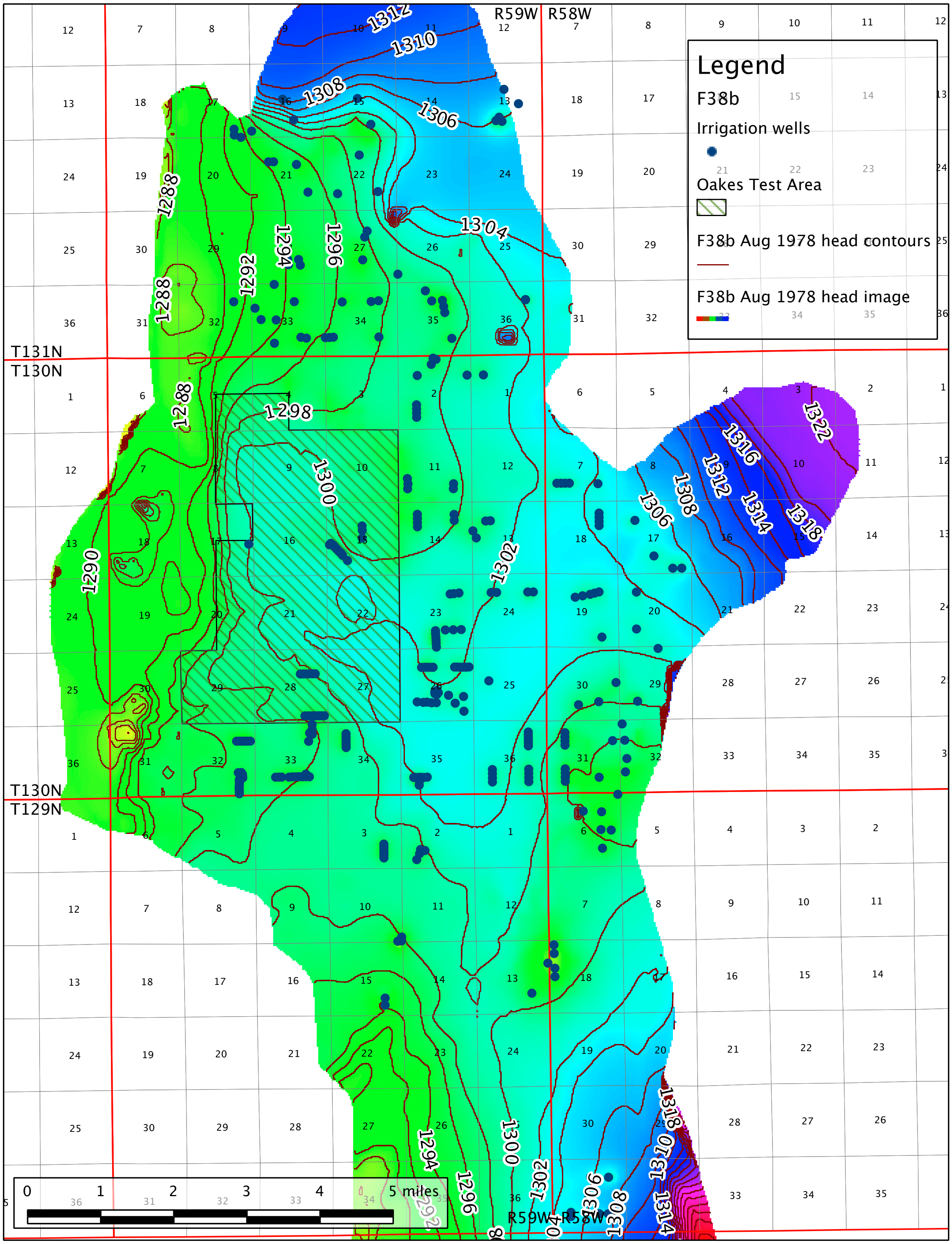

Figure F-40. Water level contours for **August 31, 1978. Run F38b**, drains, permitted + pending irrigation.

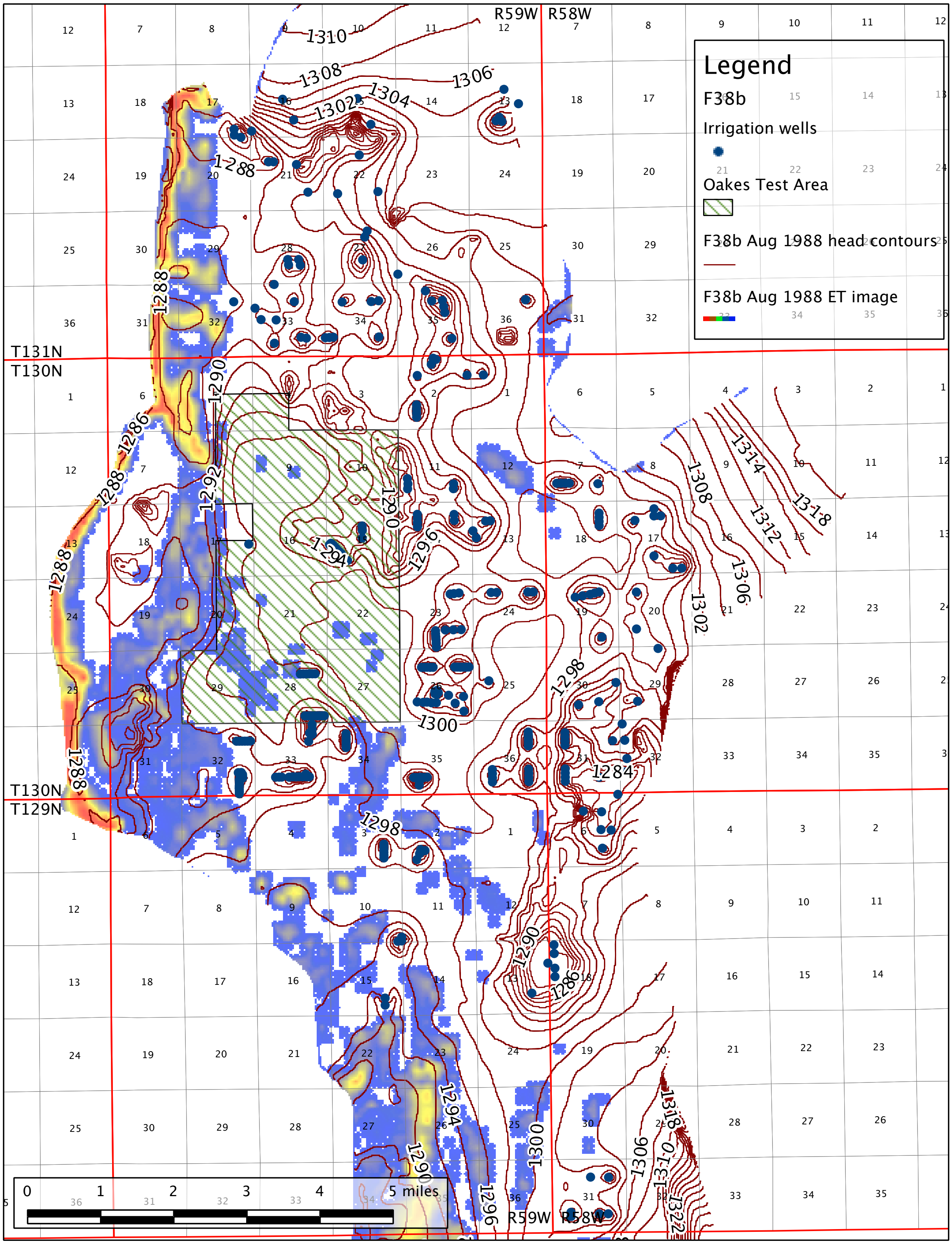

Figure F-41. Areas of evapotranspiration and water level contours for **August 31, 1988.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

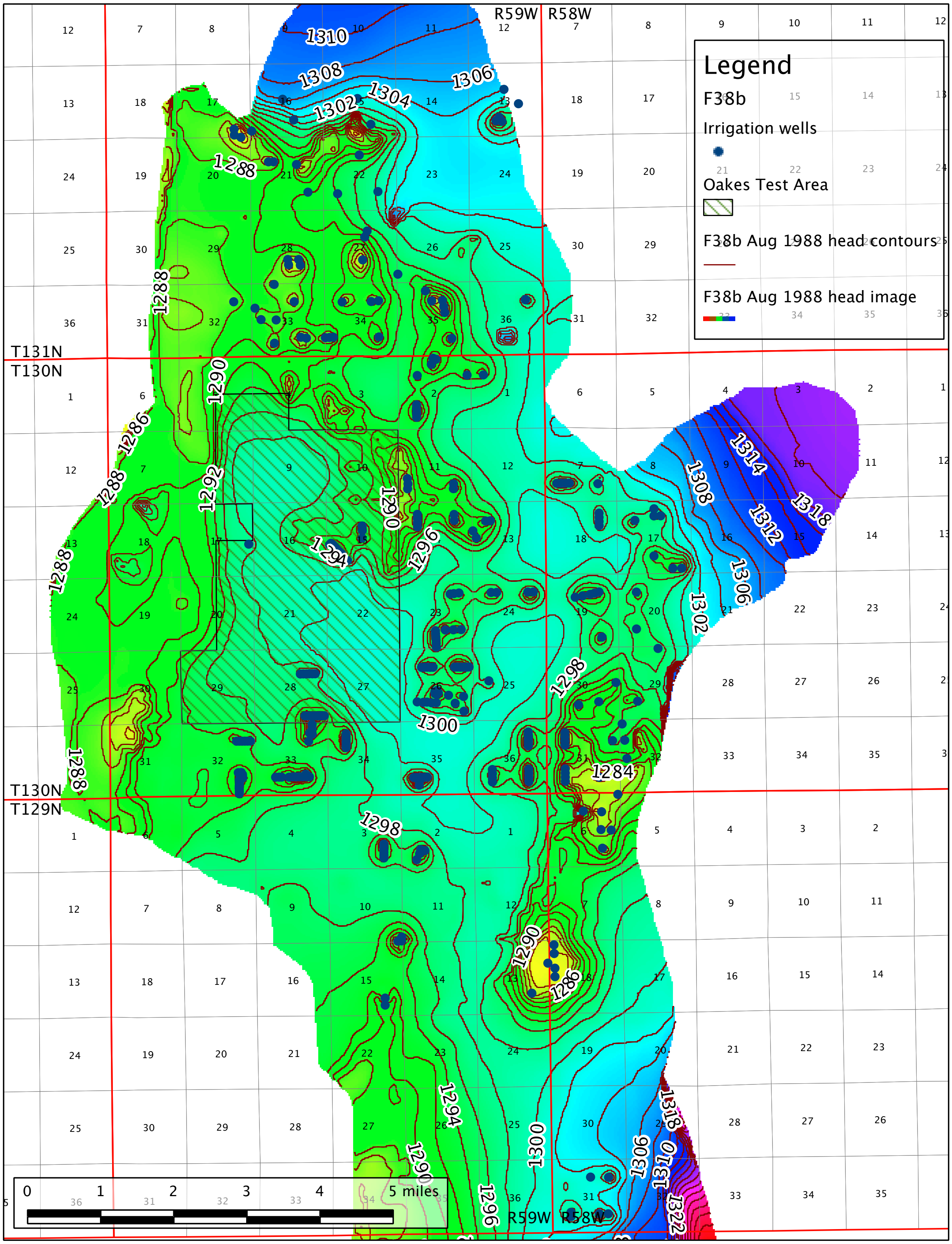

Figure F-42. Water level contours for **August 31, 1988. Run F38b**, drains, permitted + pending irrigation.

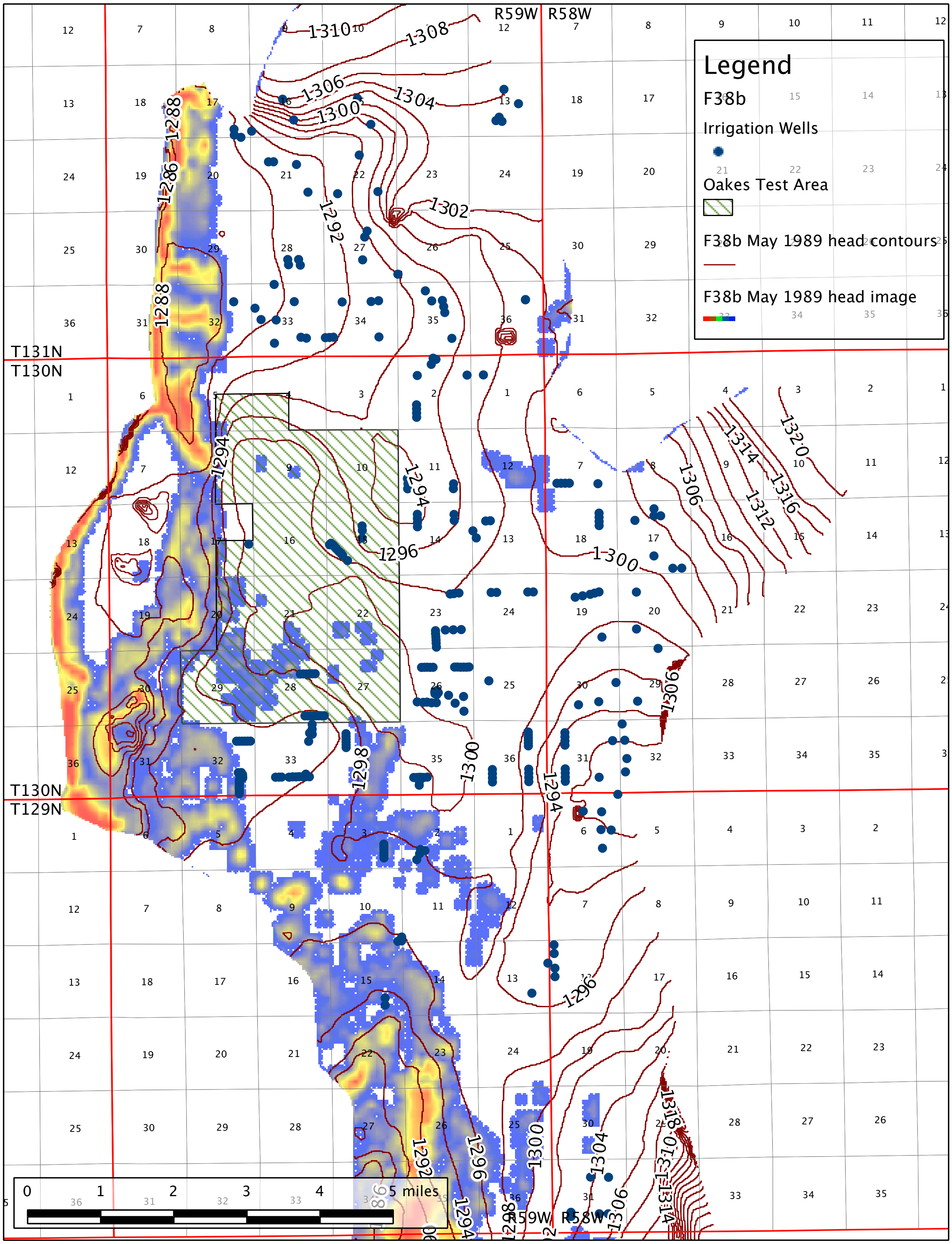

Figure F-43. Areas of evapotranspiration and water level contours for **May 31, 1989.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

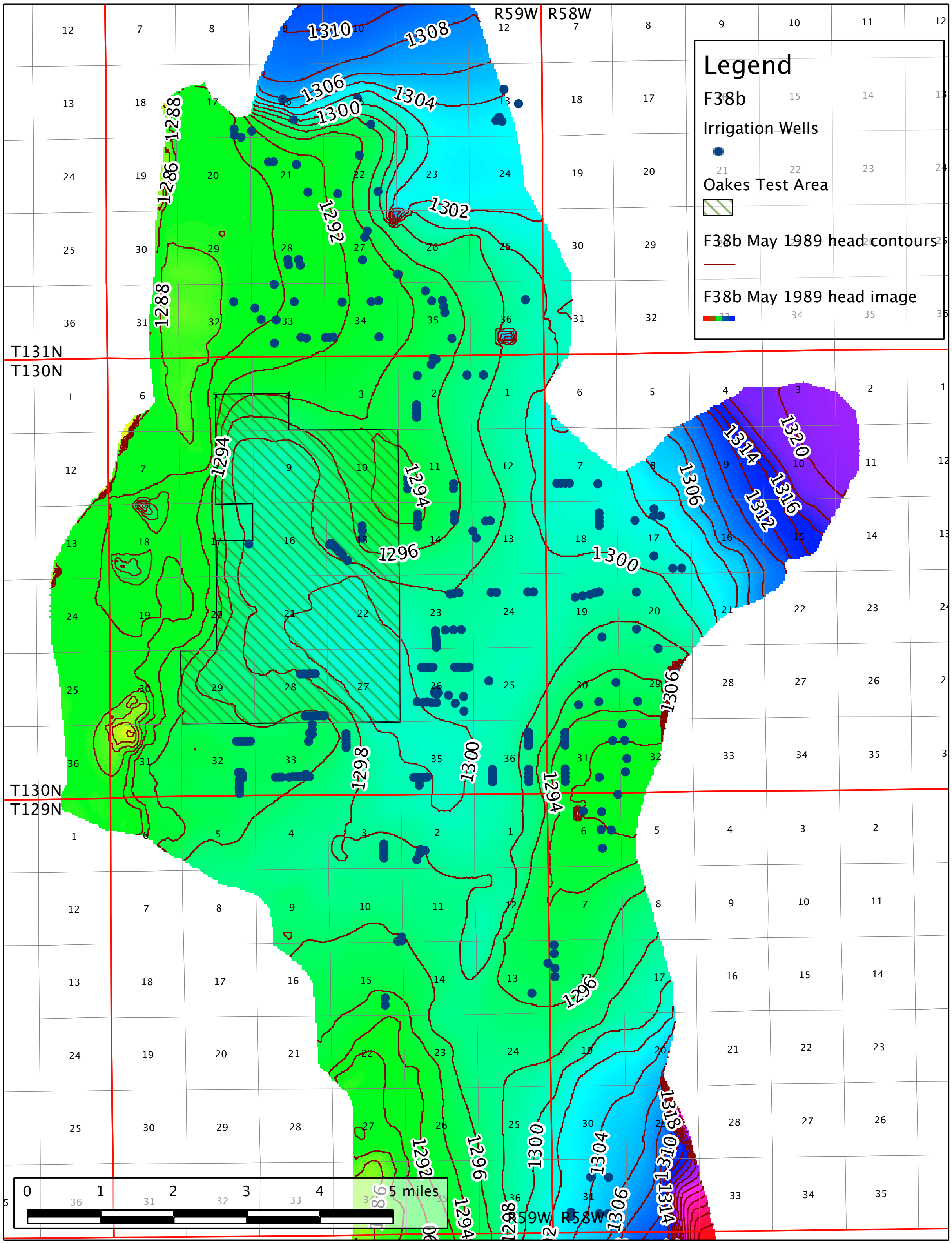

Figure F-44. Water level contours for **May 31, 1989. Run F38b**, drains, permitted + pending irrigation.

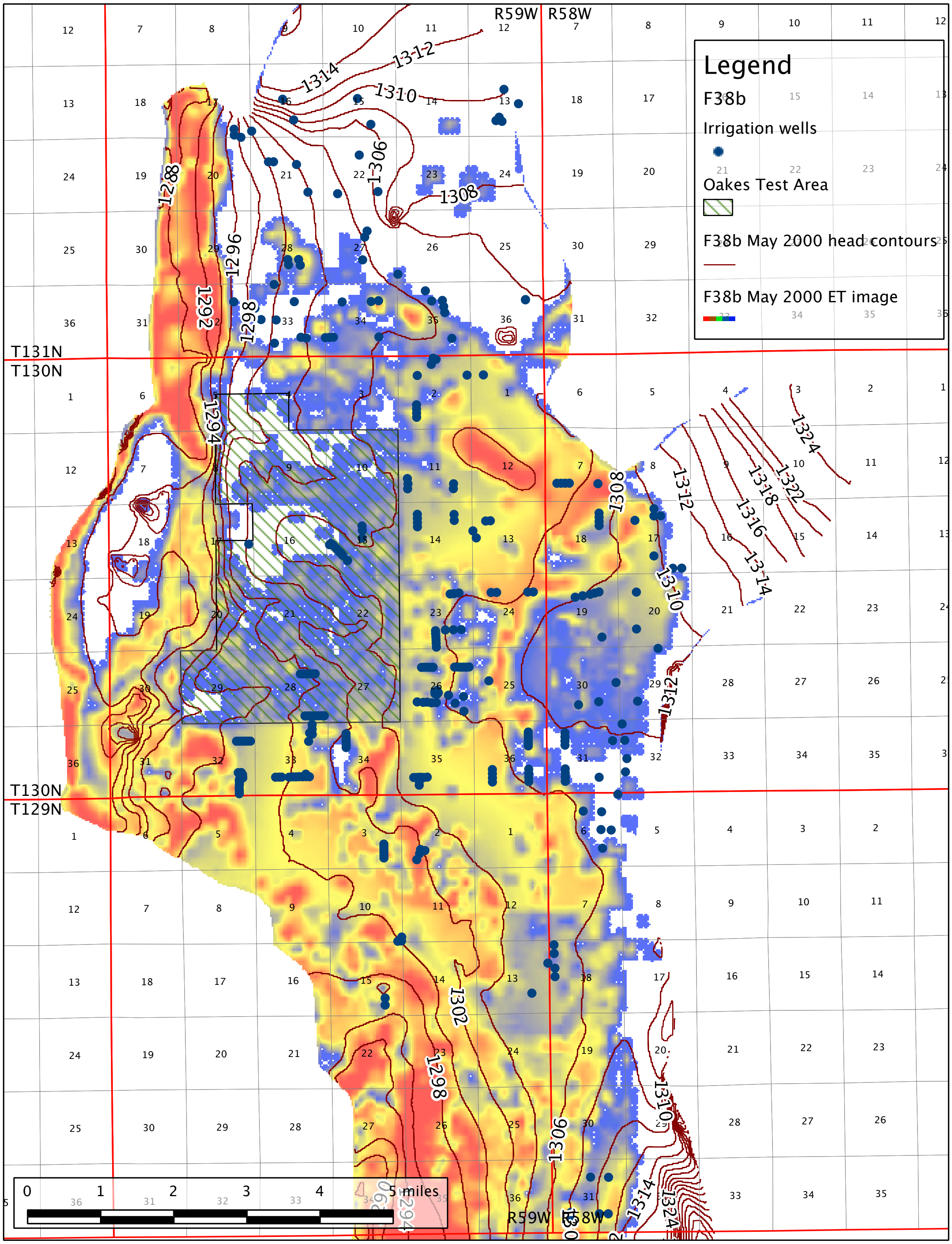

Figure F-45. Areas of evapotranspiration and water level contours for **May 31, 2000.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

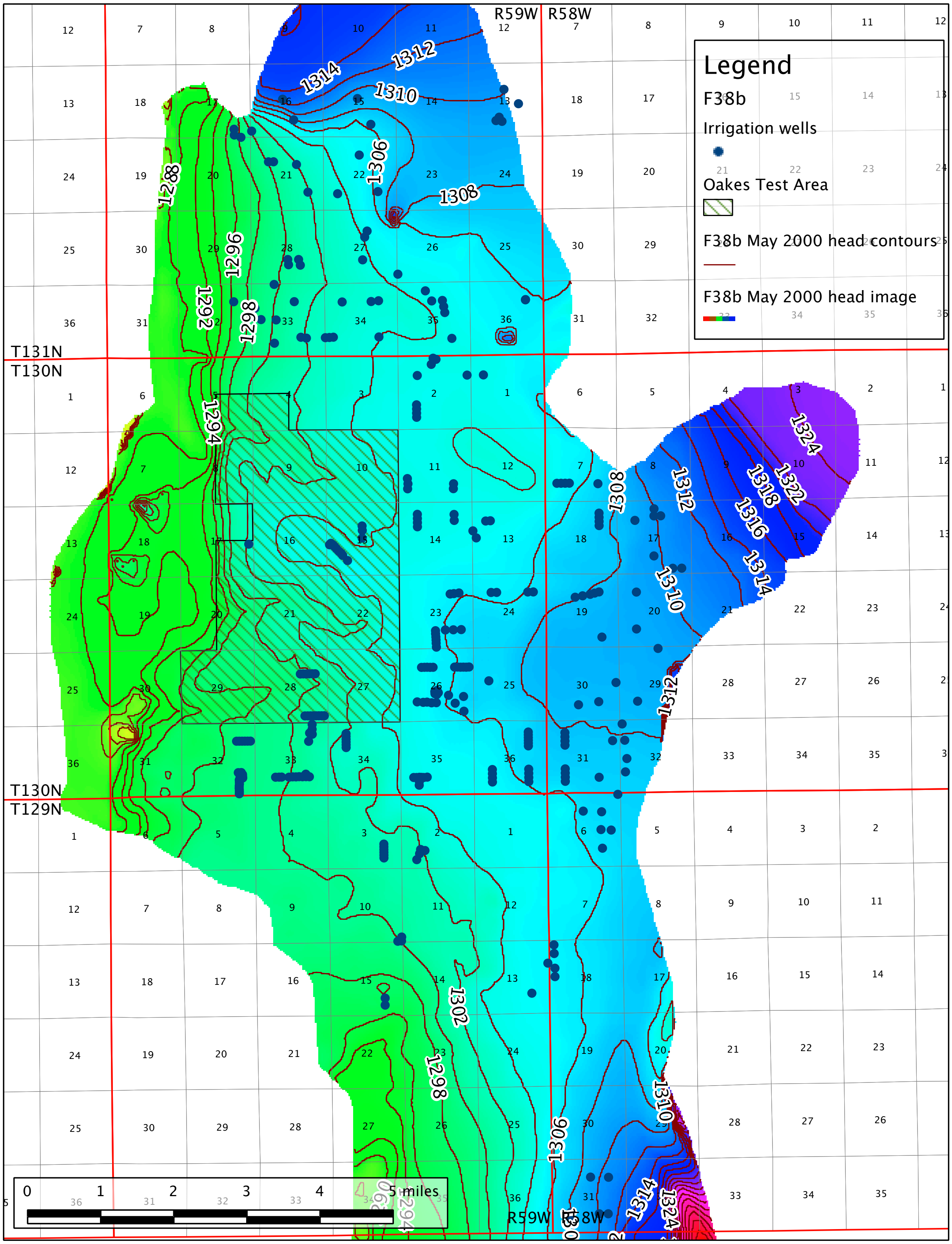

Figure F-46. Water level contours for **May 31, 2000. Run F38b**, drains, permitted + pending irrigation.

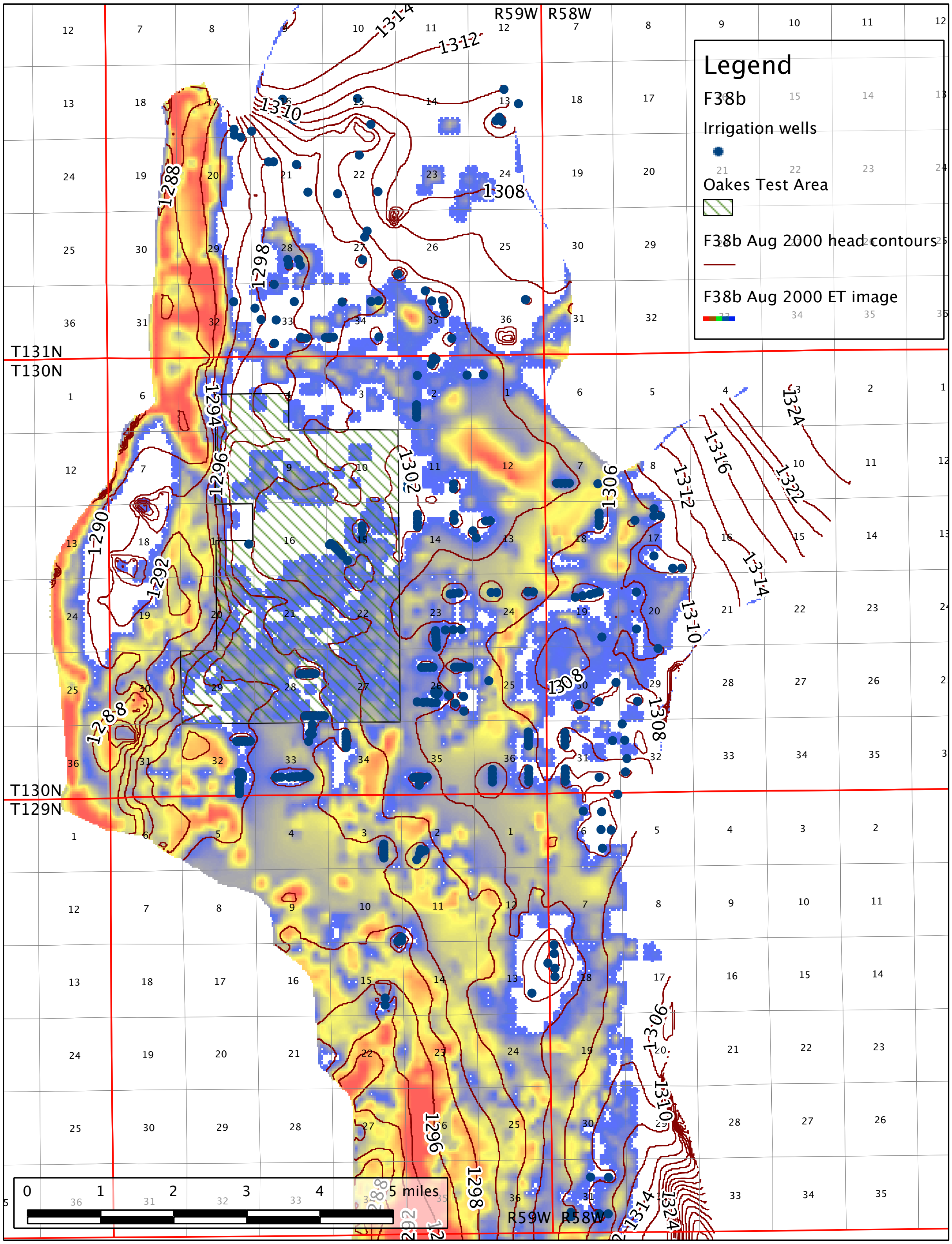

Figure F-47. Areas of evapotranspiration and water level contours for **August 31, 2000.** White is no ET. Red is maximum ET. **Run F38b**, drains, permitted + pending irrigation.

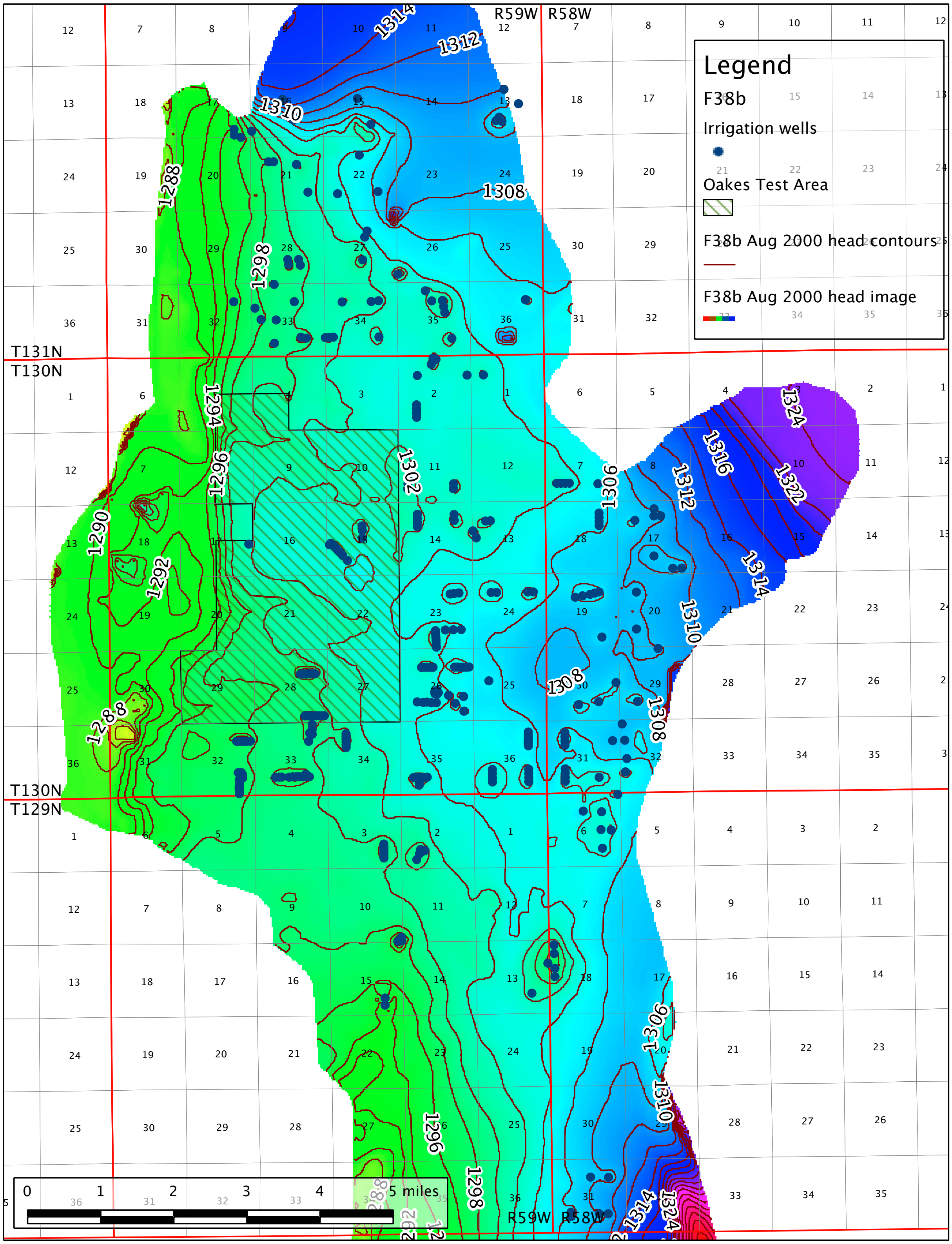

Figure F-48. Water level contours for **August 31, 2000. Run F38b**, drains, permitted + pending irrigation.

RUN H31, DRAINS, PERMITTED+PENDING+DSID-ESSER IRRIGATION - OAKES

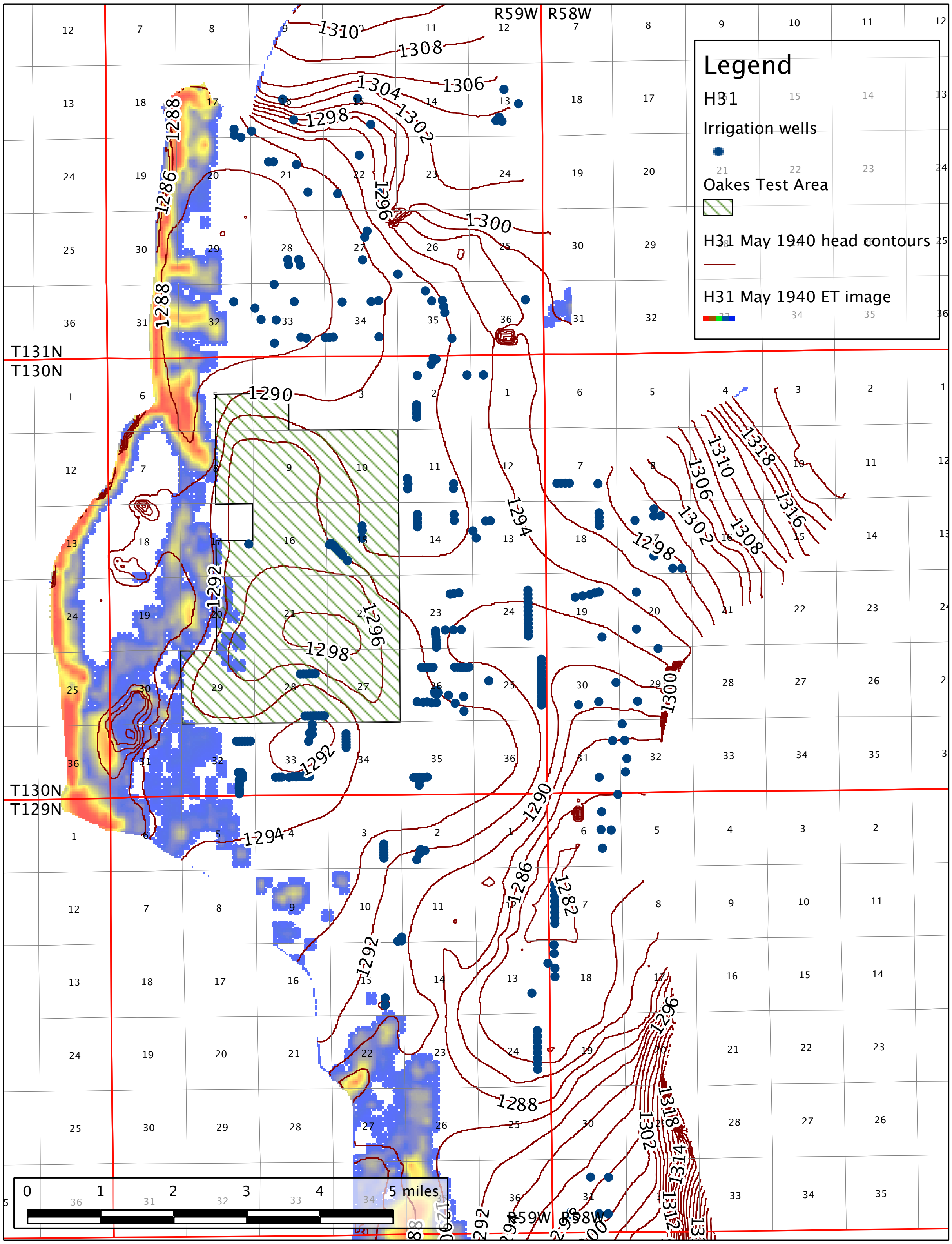

Figure F-49. Areas of evapotranspiration and water level contours for **May 31, 1940.** White is no ET. Red is maximum ET. **Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

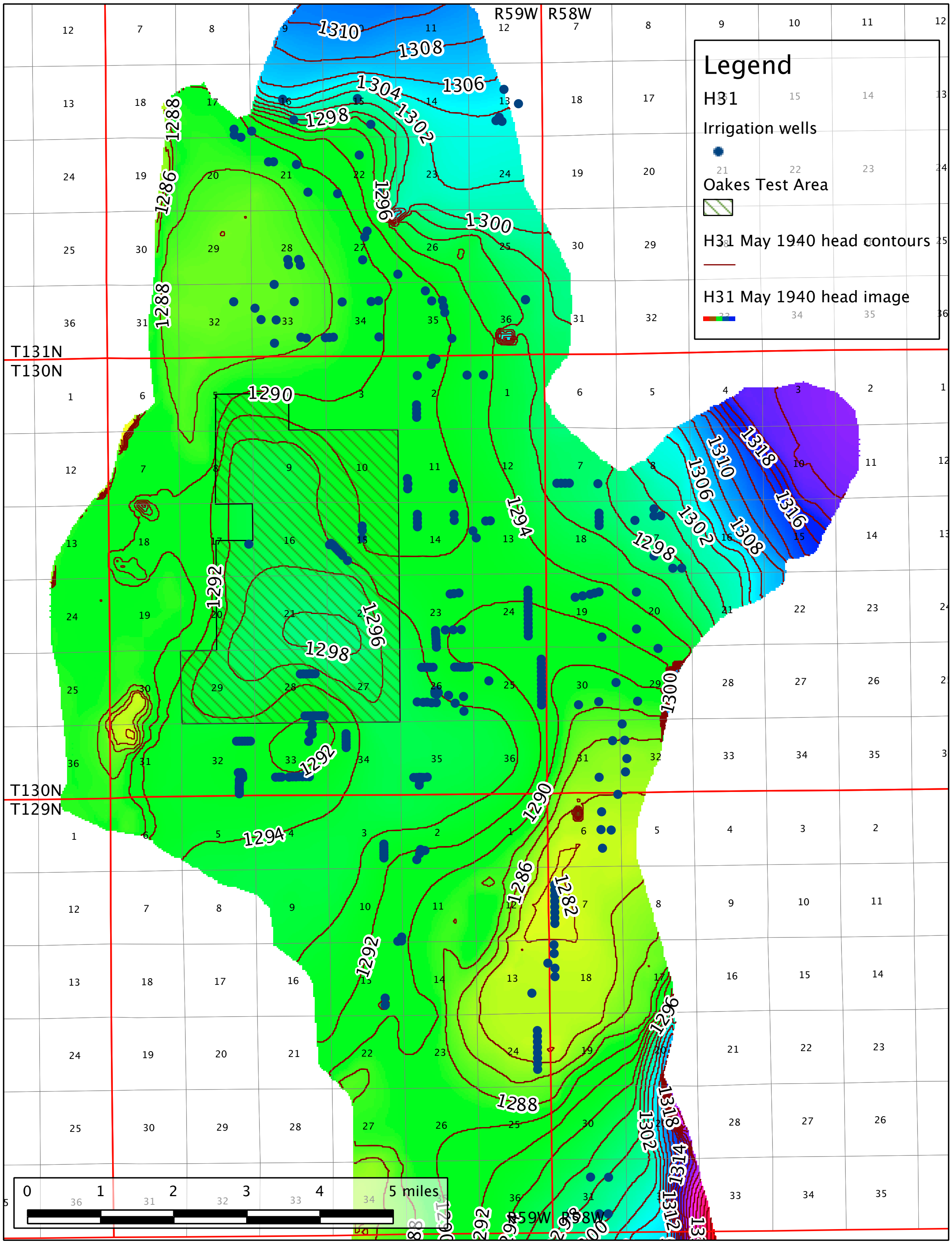

Figure F-50. Water level contours for **May 31, 1940. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

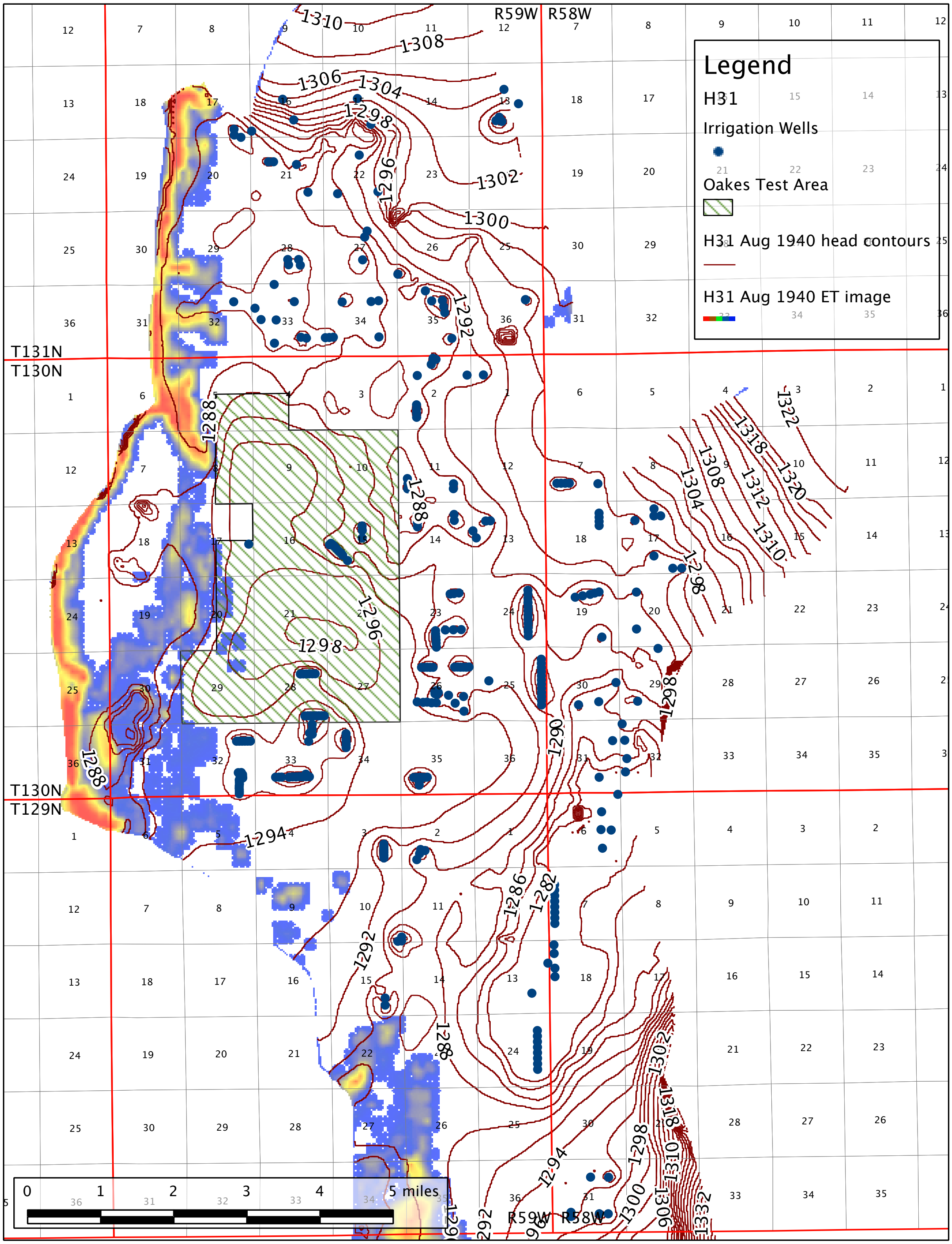

Figure F-51. Areas of evapotranspiration and water level contours for **August 31, 1940.** White is no ET. Red is maximum ET. **Run H31**, drains, DSID-ESSER irrigation. Oakes climate dataset.

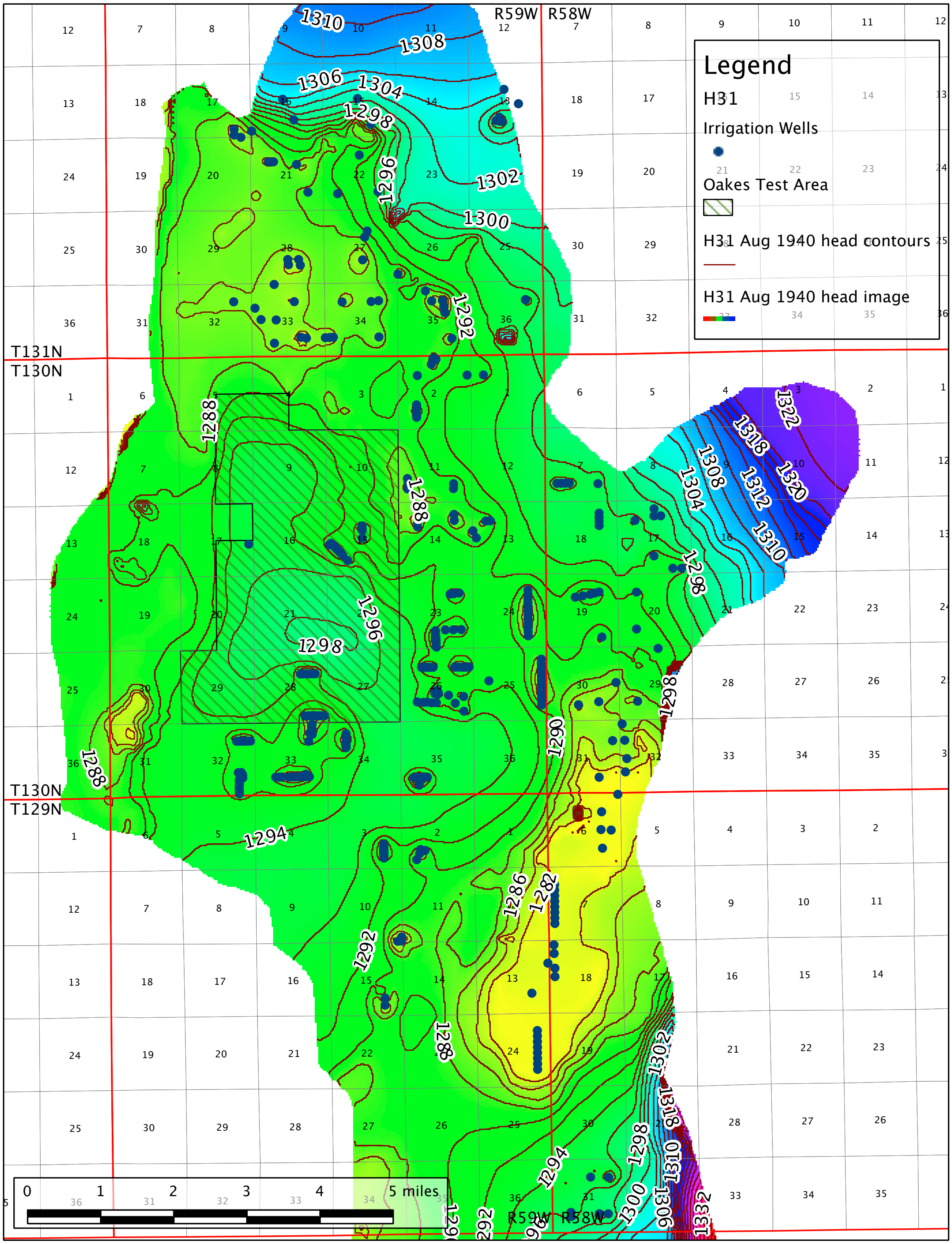

Figure F-52. Water level contours for **August 31, 1940. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

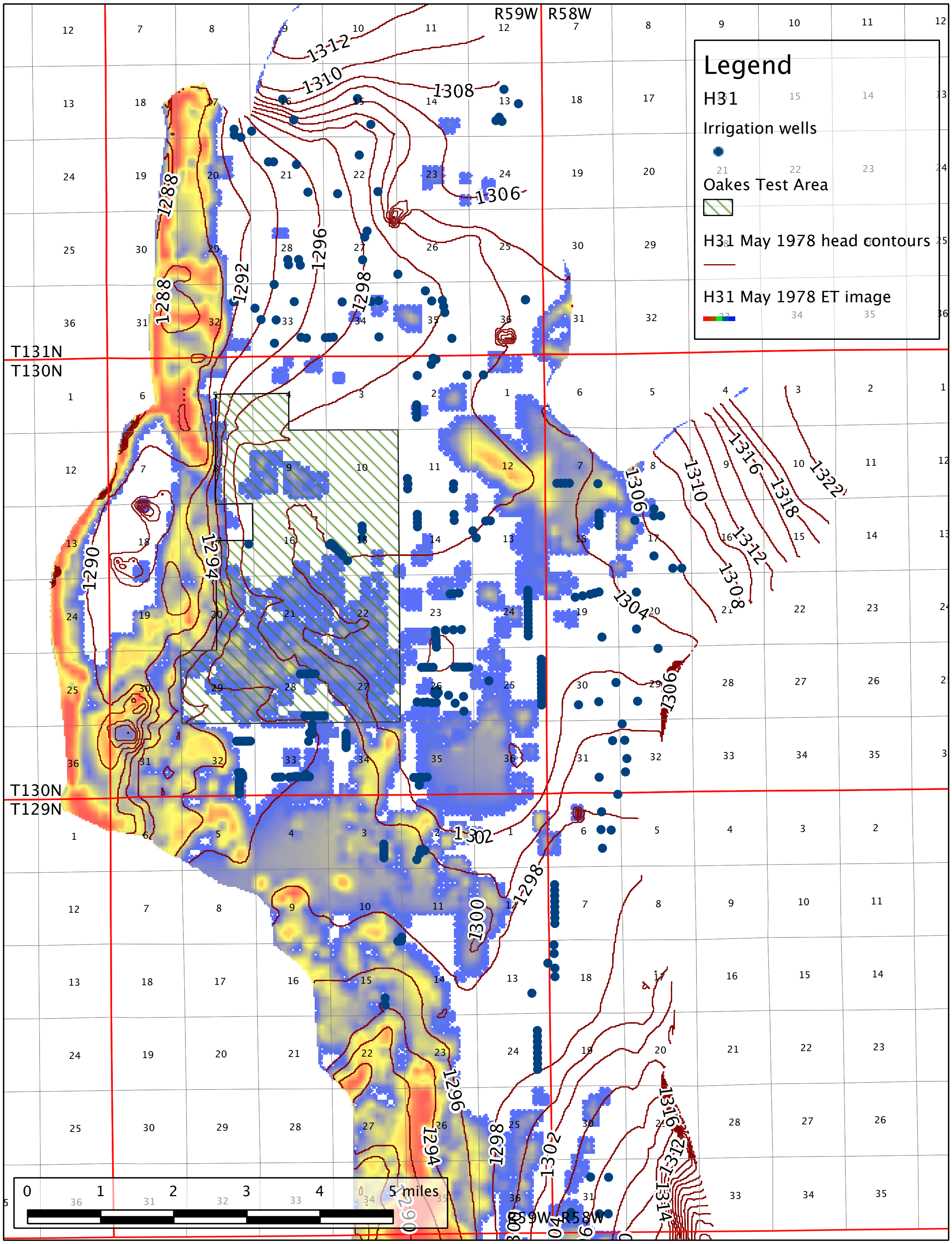

Figure F-53. Areas of evapotranspiration and water level contours for **May 31, 1978.** White is no ET. Red is maximum ET. **Run H31**, drains, DSID-ESSER irrigation. Oakes climate dataset.

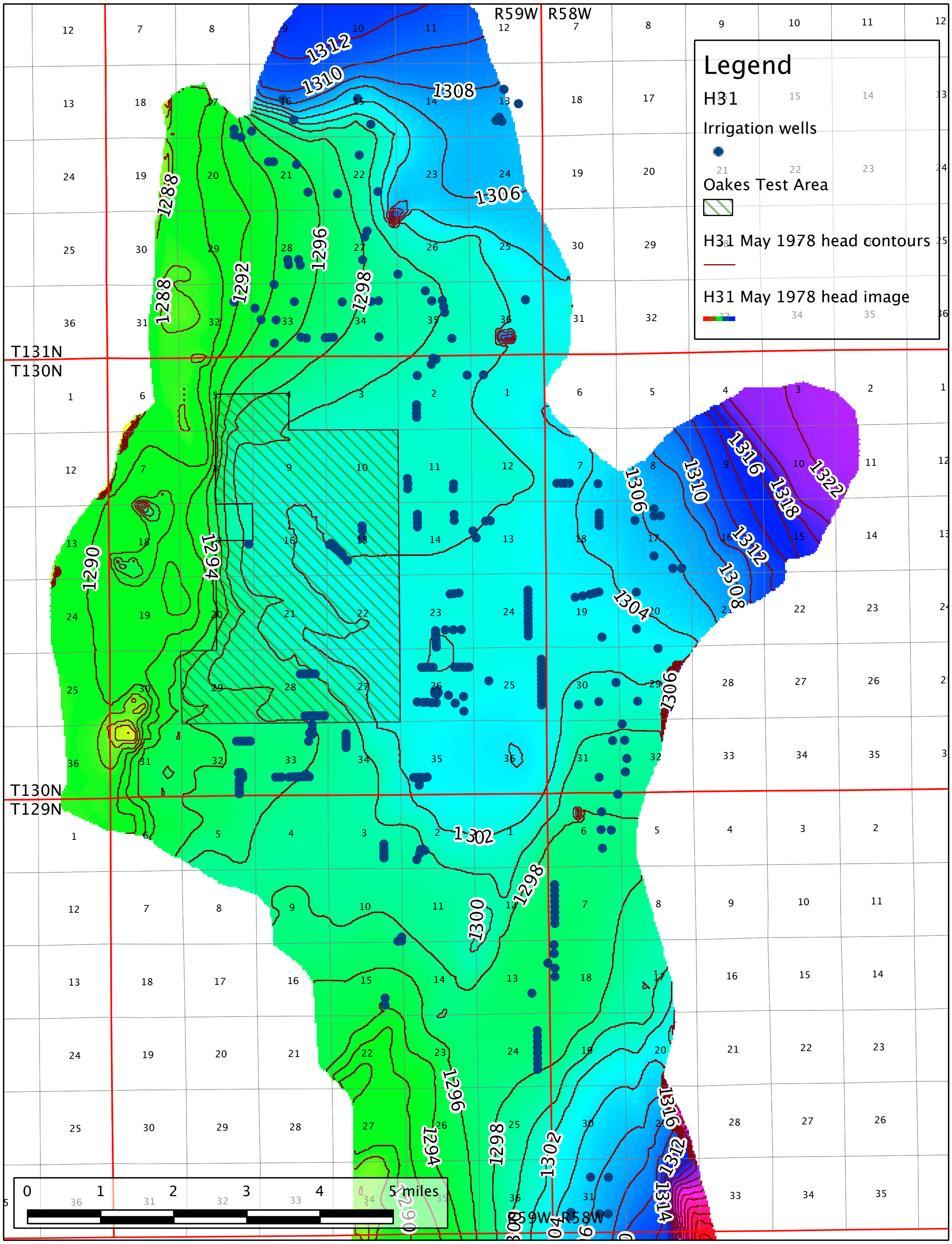

Figure F-54. Water level contours for **May 31, 1978. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

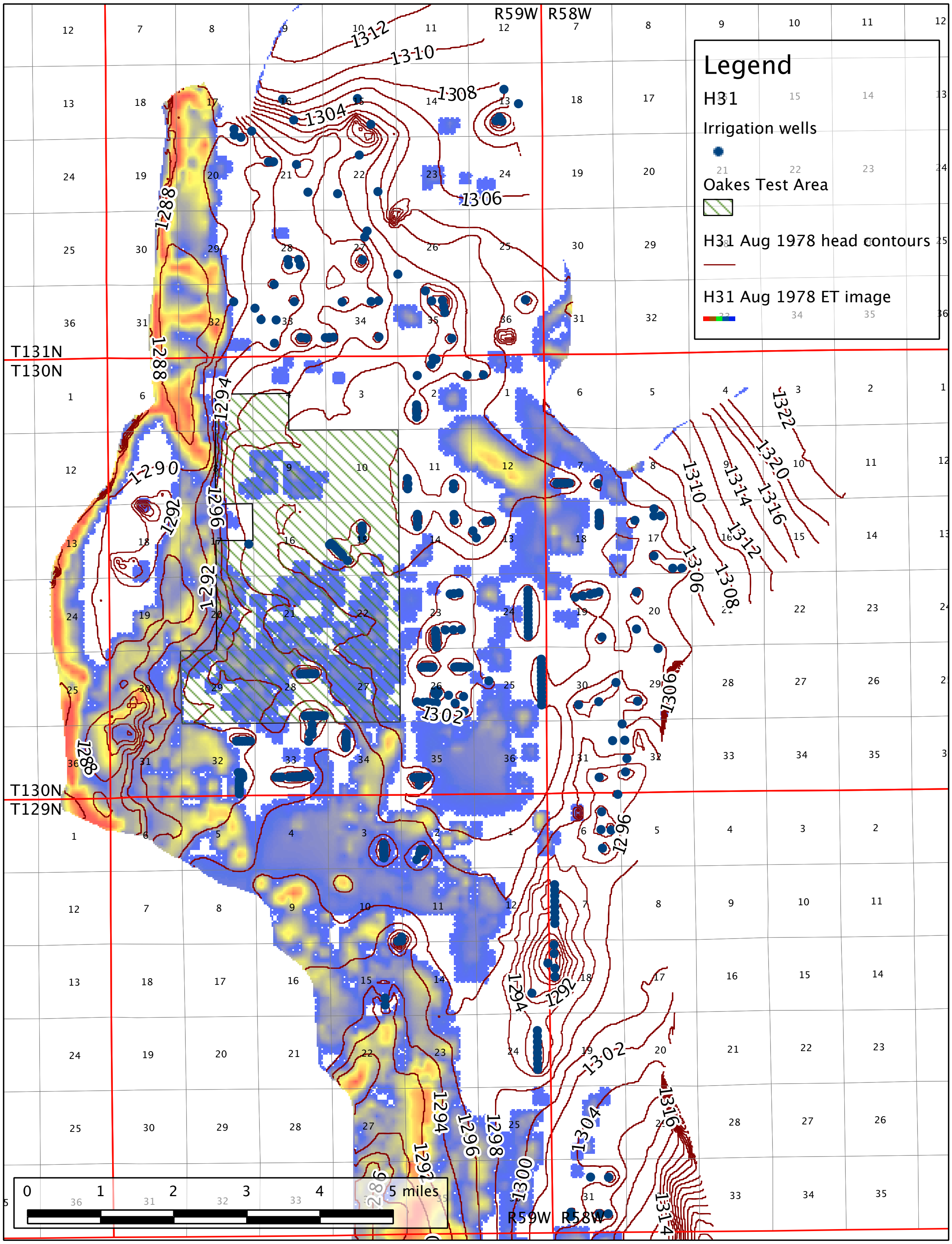

Figure F-55. Areas of evapotranspiration and water level contours for **August 31, 1978.** White is no ET. Red is maximum ET. **Run H31**, drains, DSID-ESSER irrigation. Oakes climate dataset.

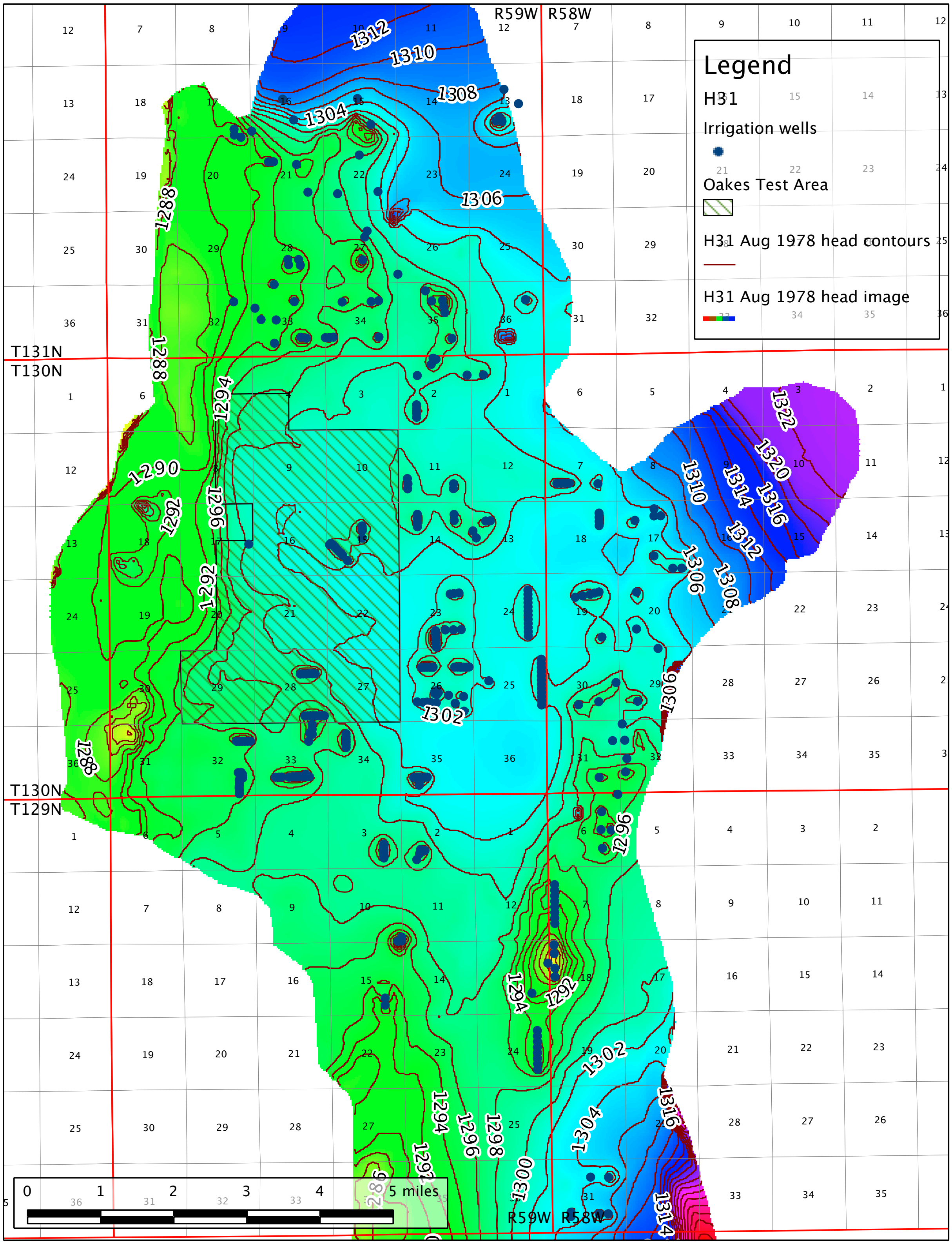

Figure F-56. Water level contours for **August 31, 1978. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

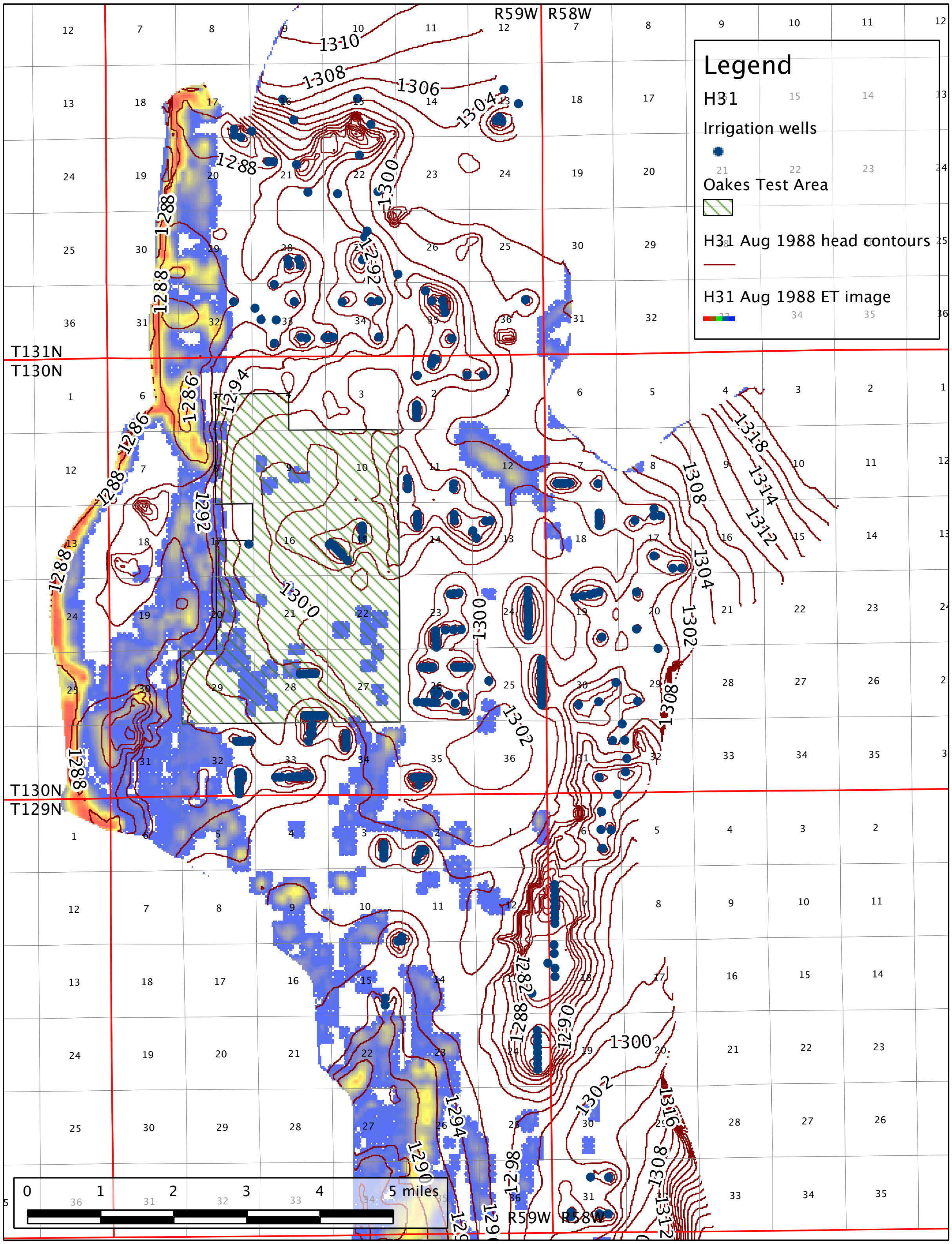

Figure F-57. Areas of evapotranspiration and water level contours for **August 31, 1988.** White is no ET. Red is maximum ET. **Run H31**, drains, DSID-ESSER irrigation. Oakes climate dataset.

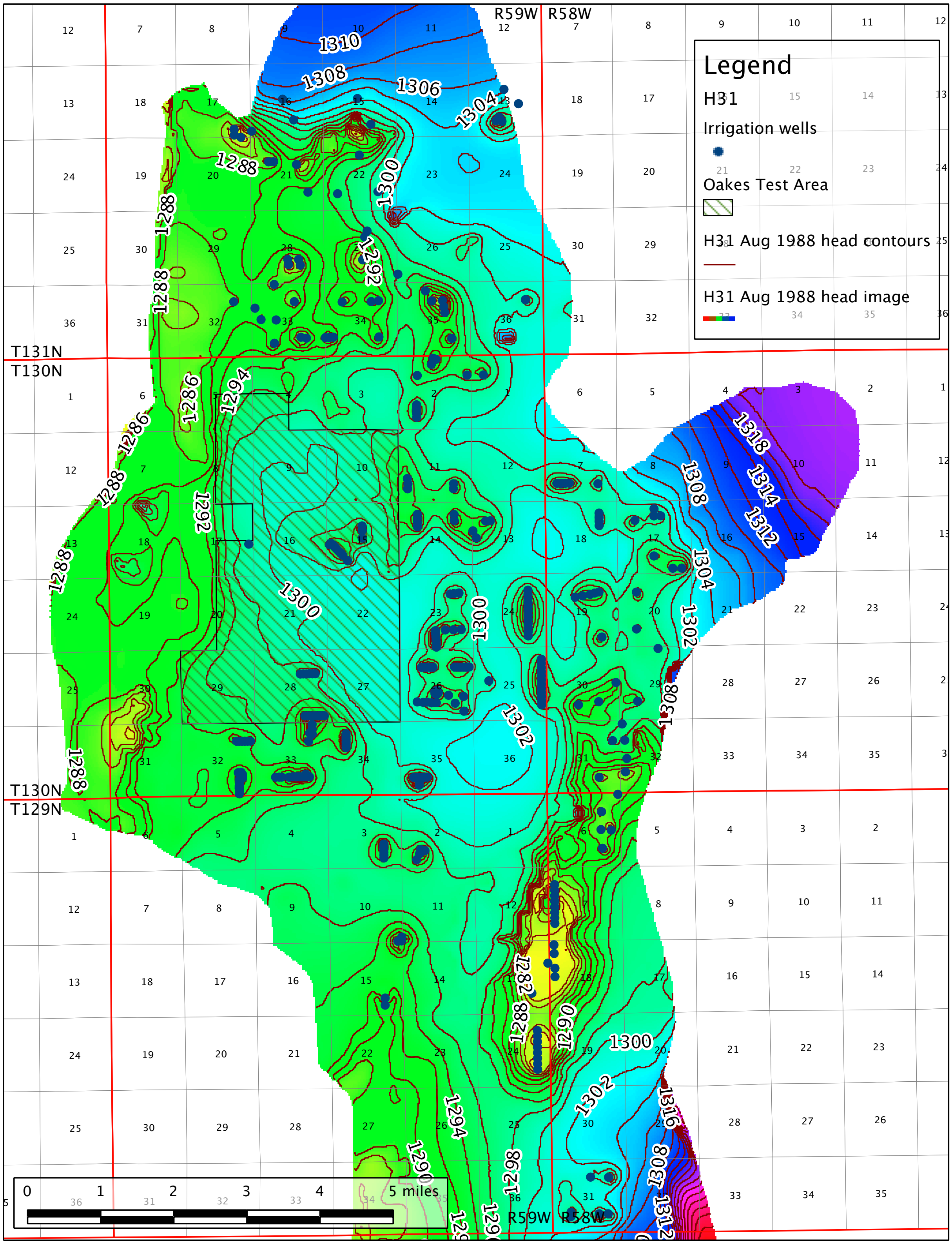

Figure F-58. Water level contours for **August 31, 1988. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

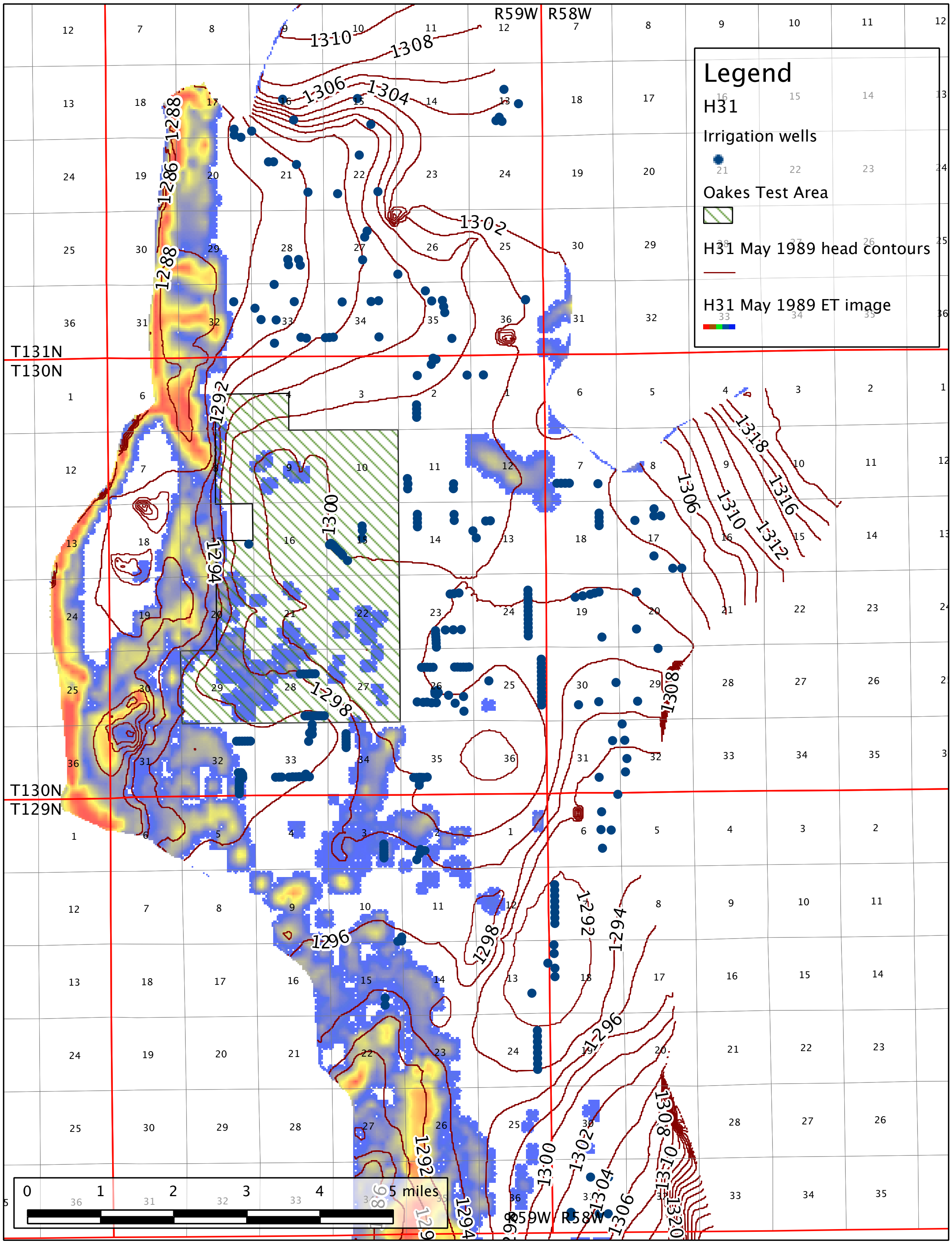

Figure F-59. Areas of evapotranspiration and water level contours for **May 31, 1989.** White is no ET. Red is maximum ET. **Run H31**, drains, DSID-ESSER irrigation. Oakes climate dataset.

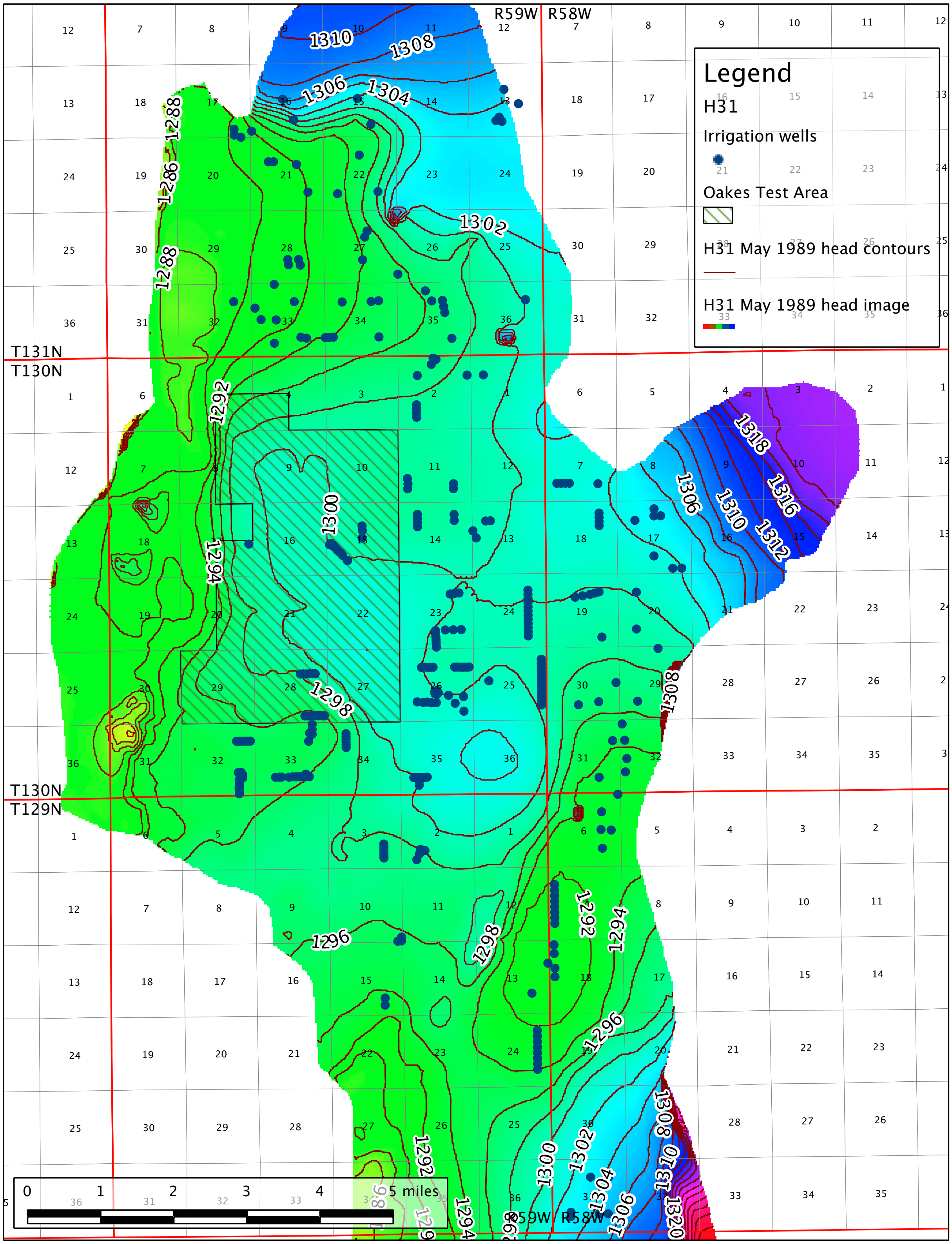

Figure F-60. Water level contours for **May 31, 1989. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

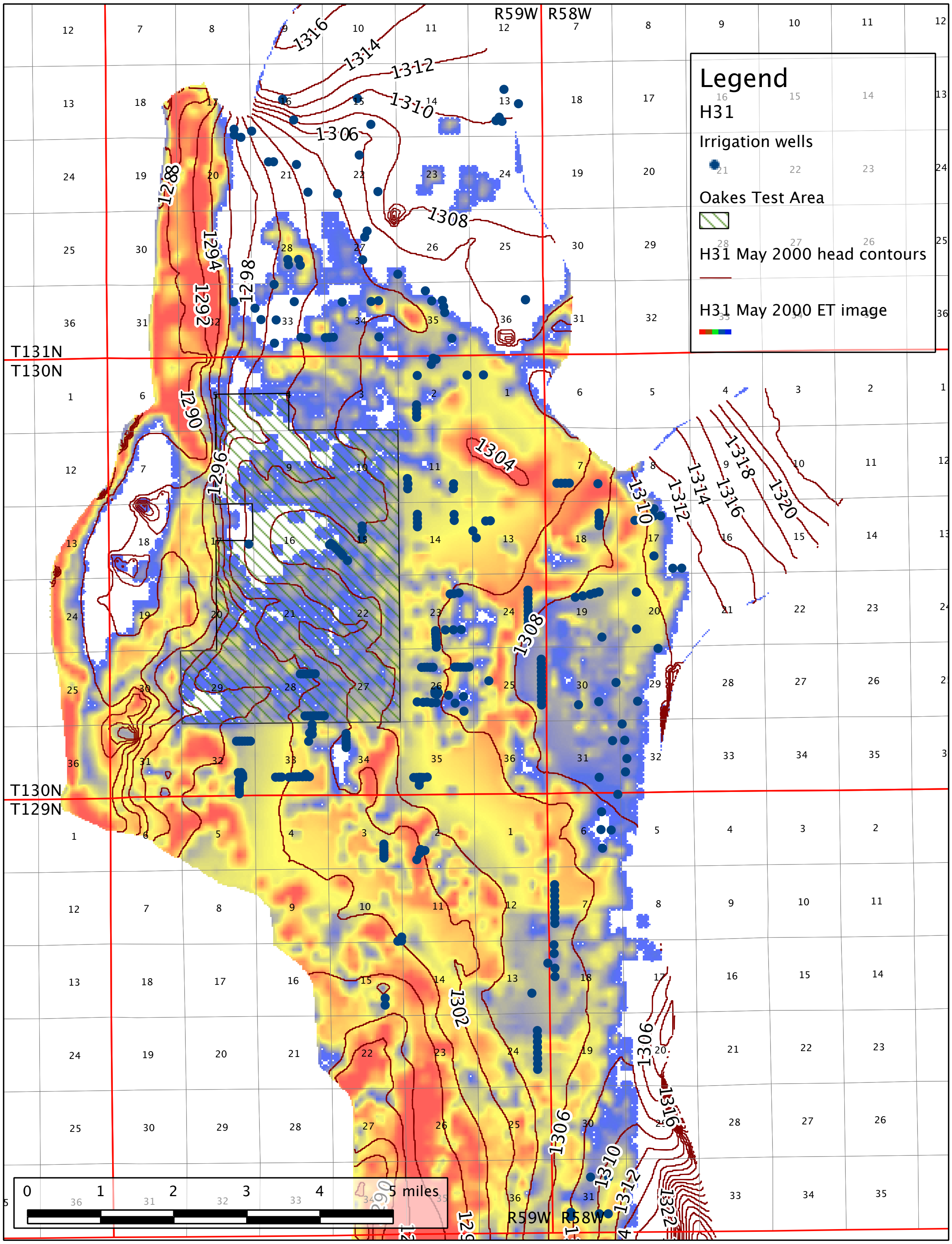

Figure F-61. Areas of evapotranspiration and water level contours for **May 31, 2000.** White is no ET. Red is maximum ET. **Run H31**, drains, DSID-ESSER irrigation. Oakes climate dataset.

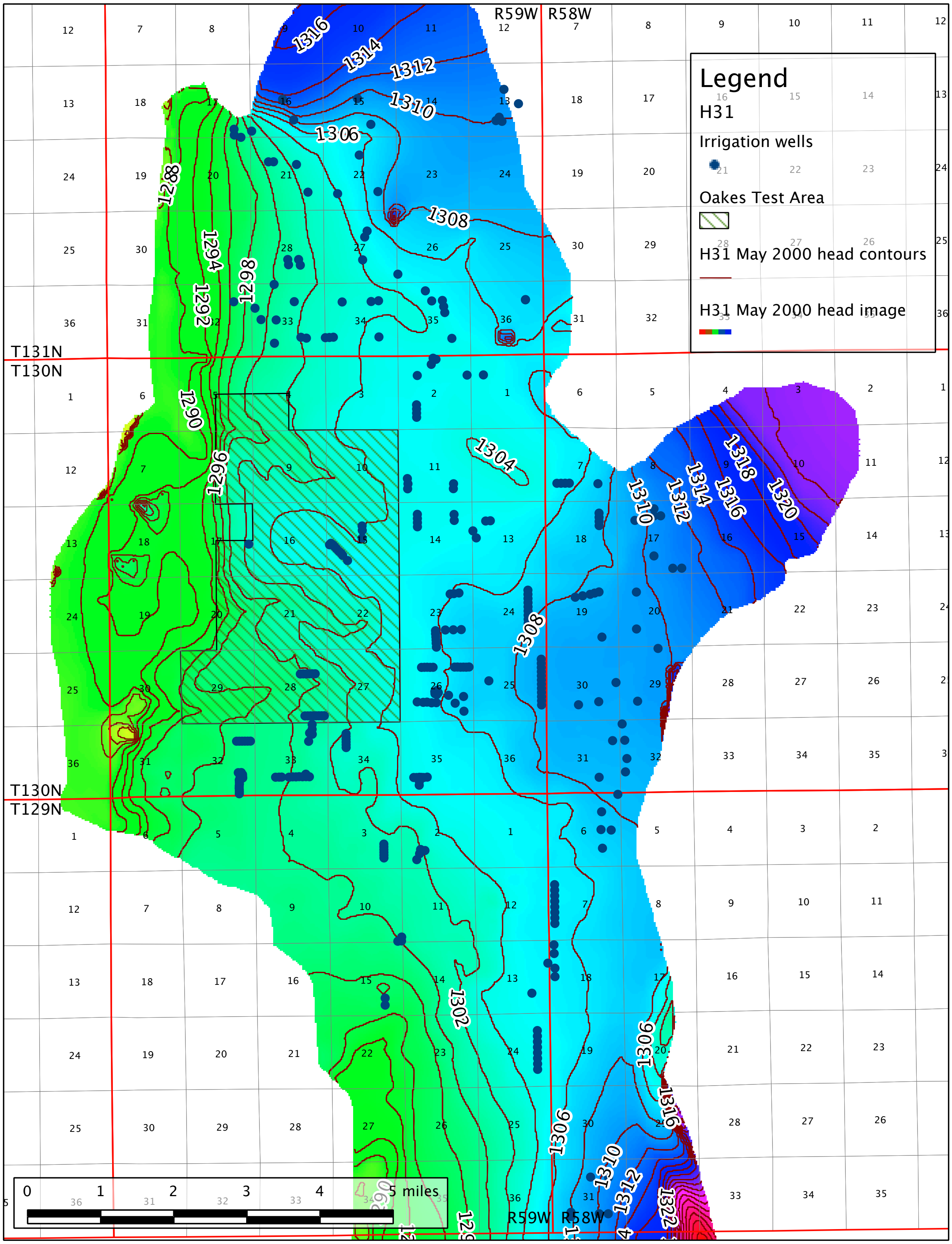

Figure F-62. Water level contours for **May 31, 2000. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

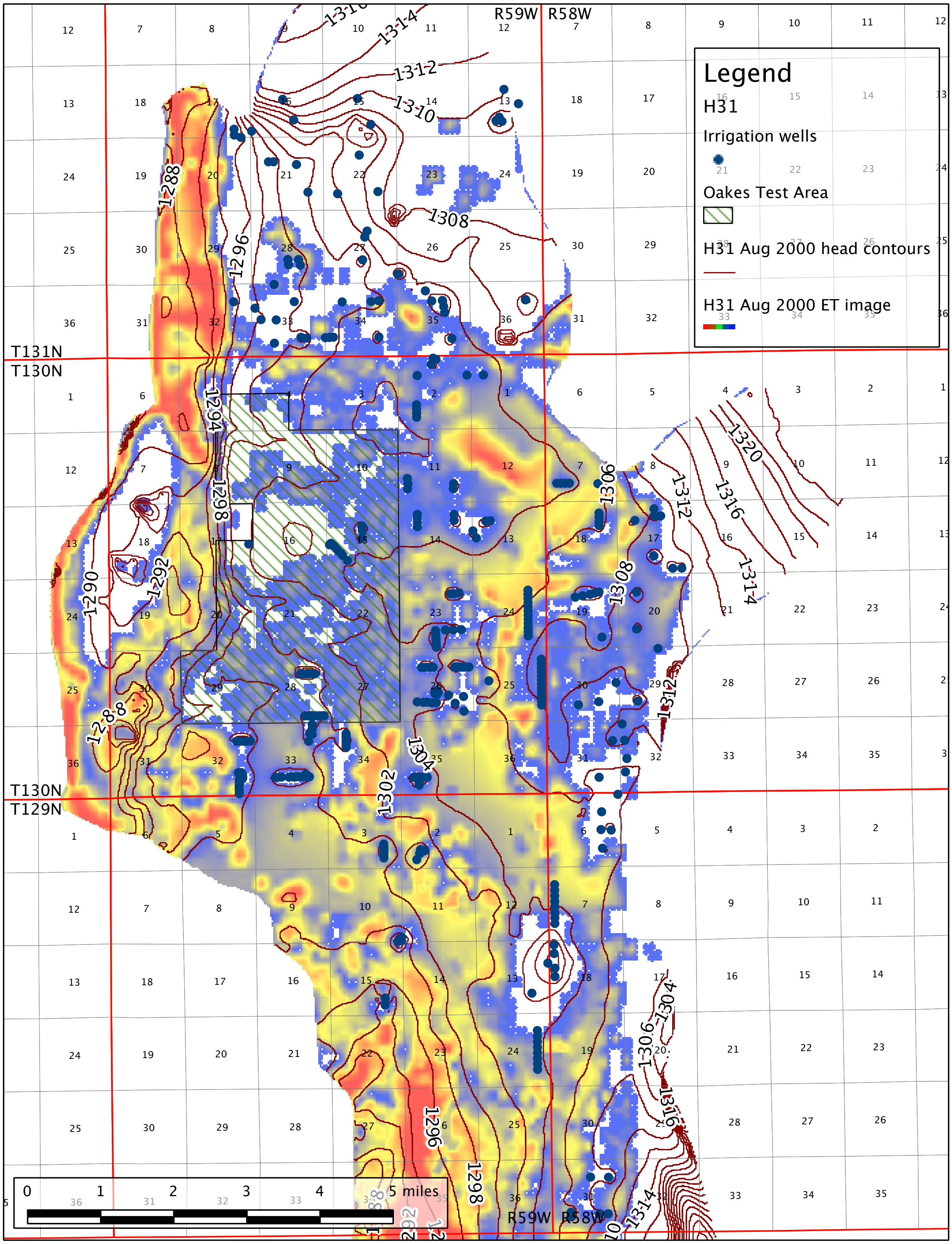

Figure F-63. Areas of evapotranspiration and water level contours for **August 31, 2000.** White is no ET. Red is maximum ET. **Run H31**, DSID-ESSER irrigation. Oakes climate dataset.

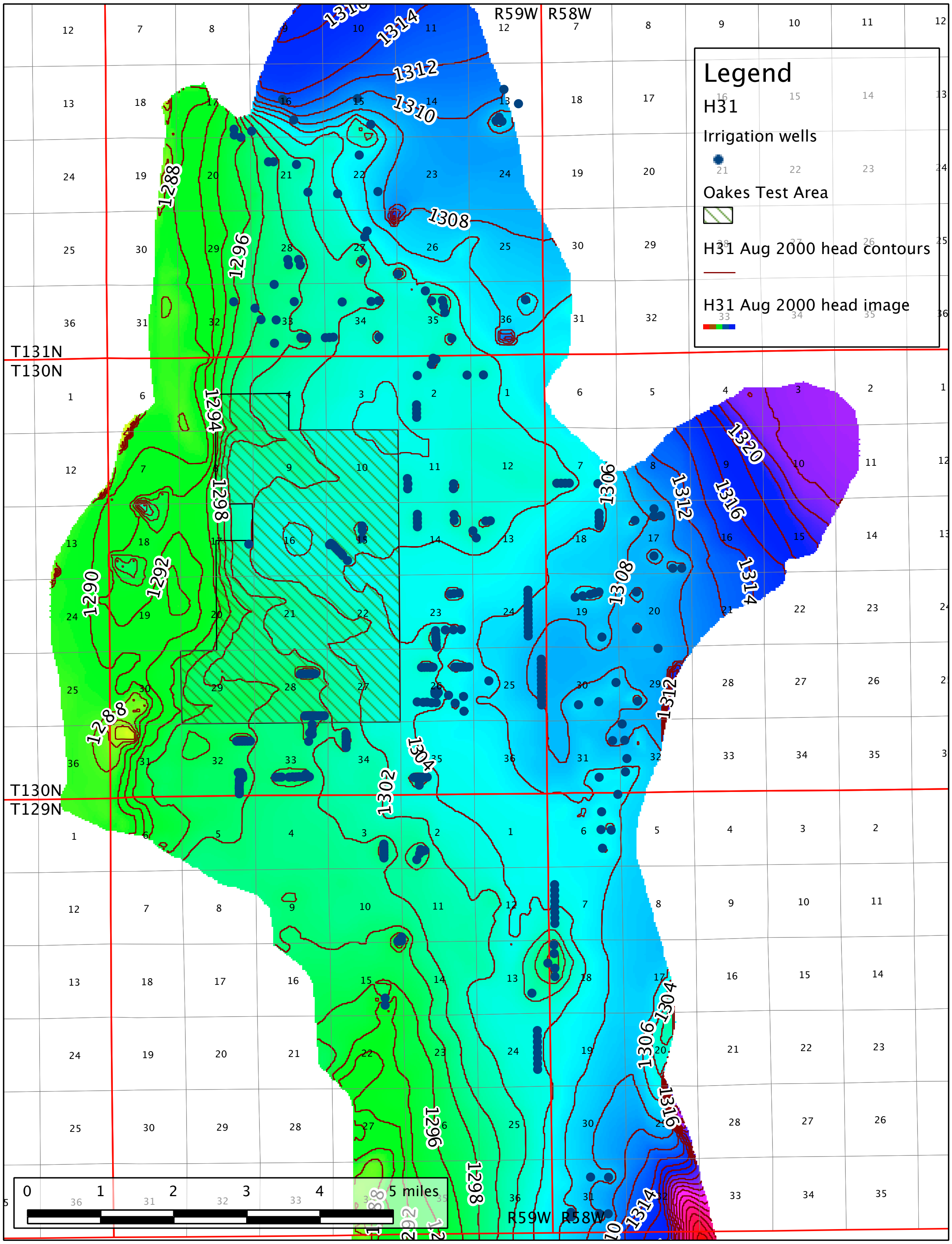

Figure F-64. Water level contours for **August 31, 2000. Run H31**, drains, permitted + DSID-ESSER irrigation. Oakes climate dataset.

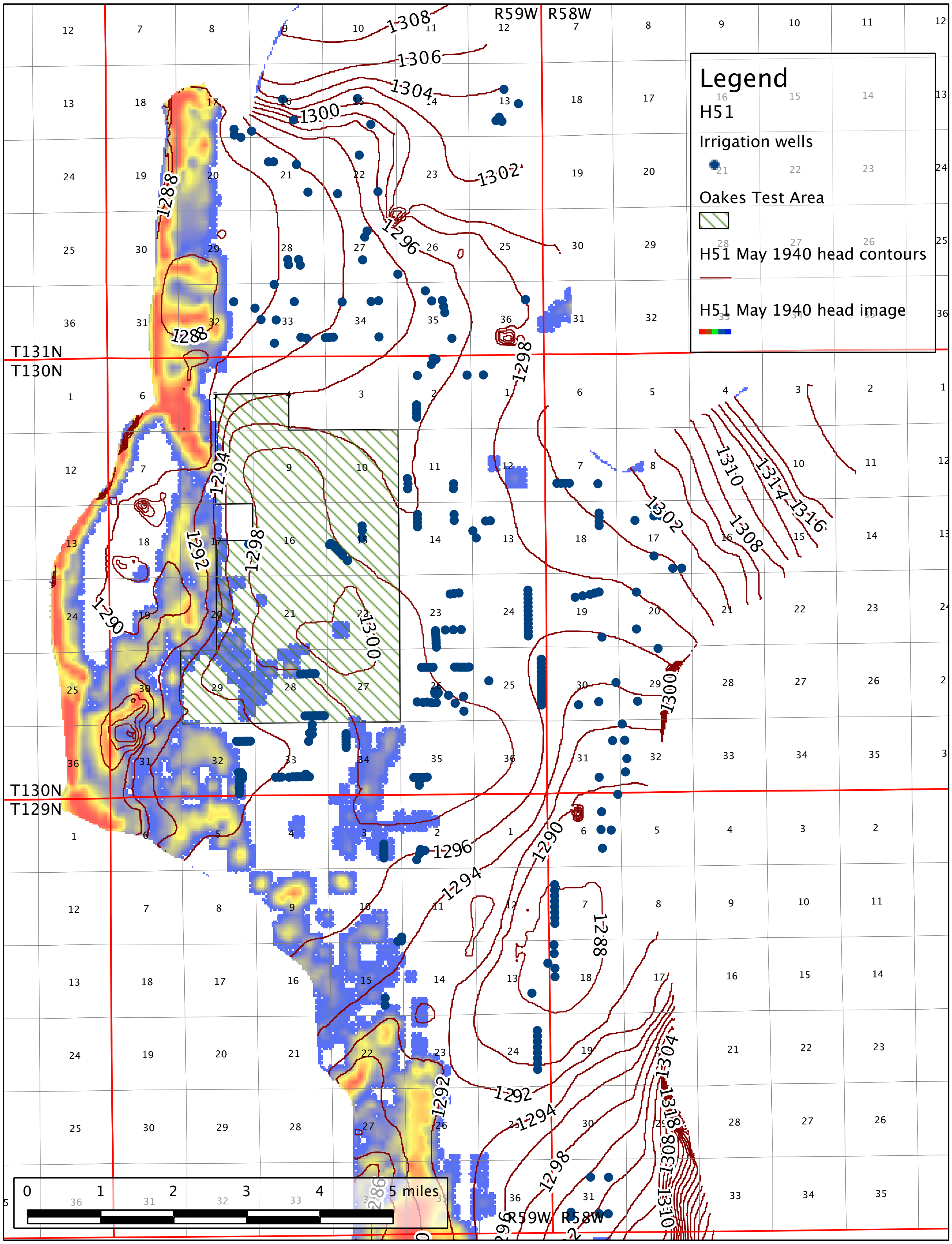

Figure F-65. Areas of evapotranspiration and water level contours for **May 31, 1940.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

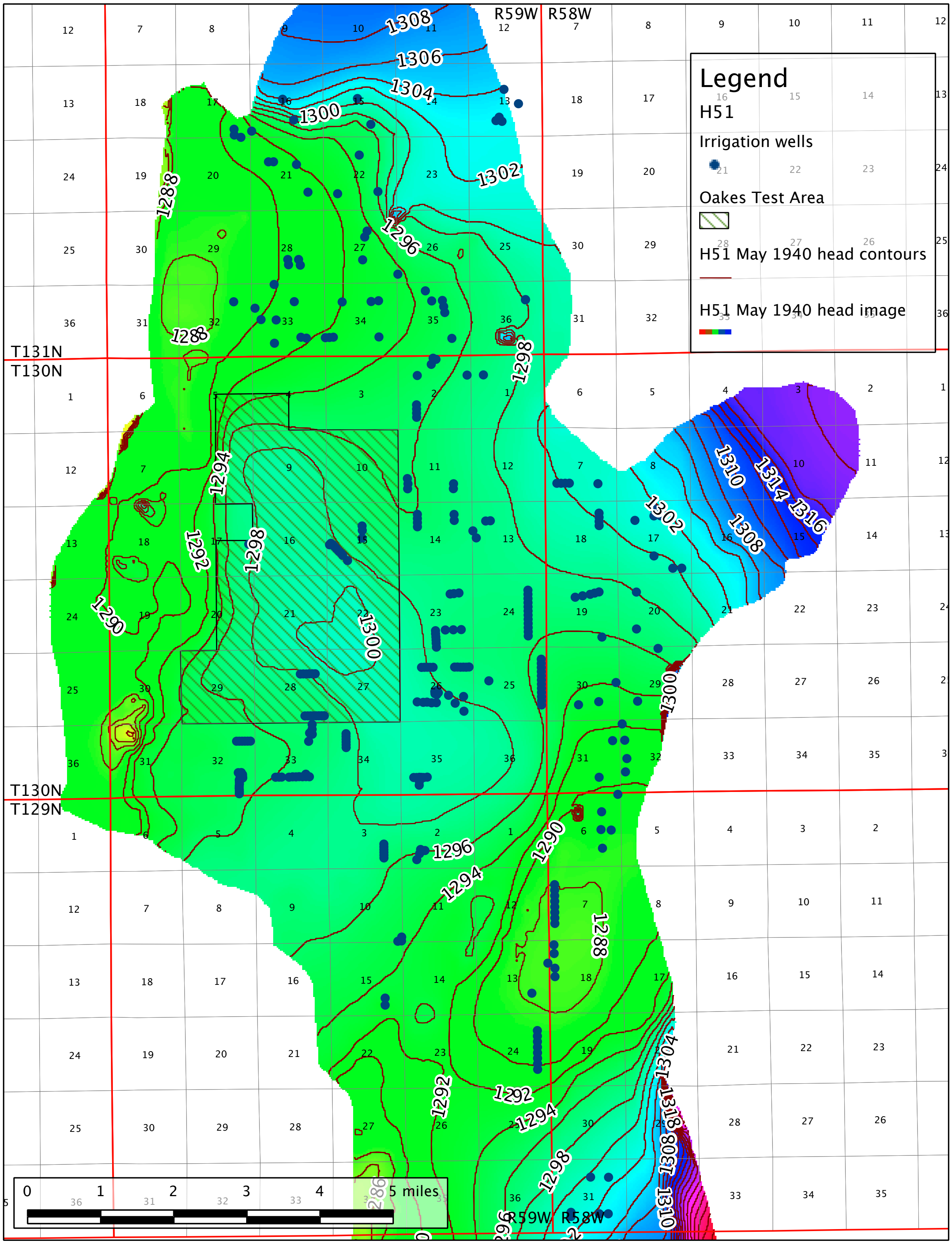

Figure F-66. Water level contours for **May 31, 1940. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

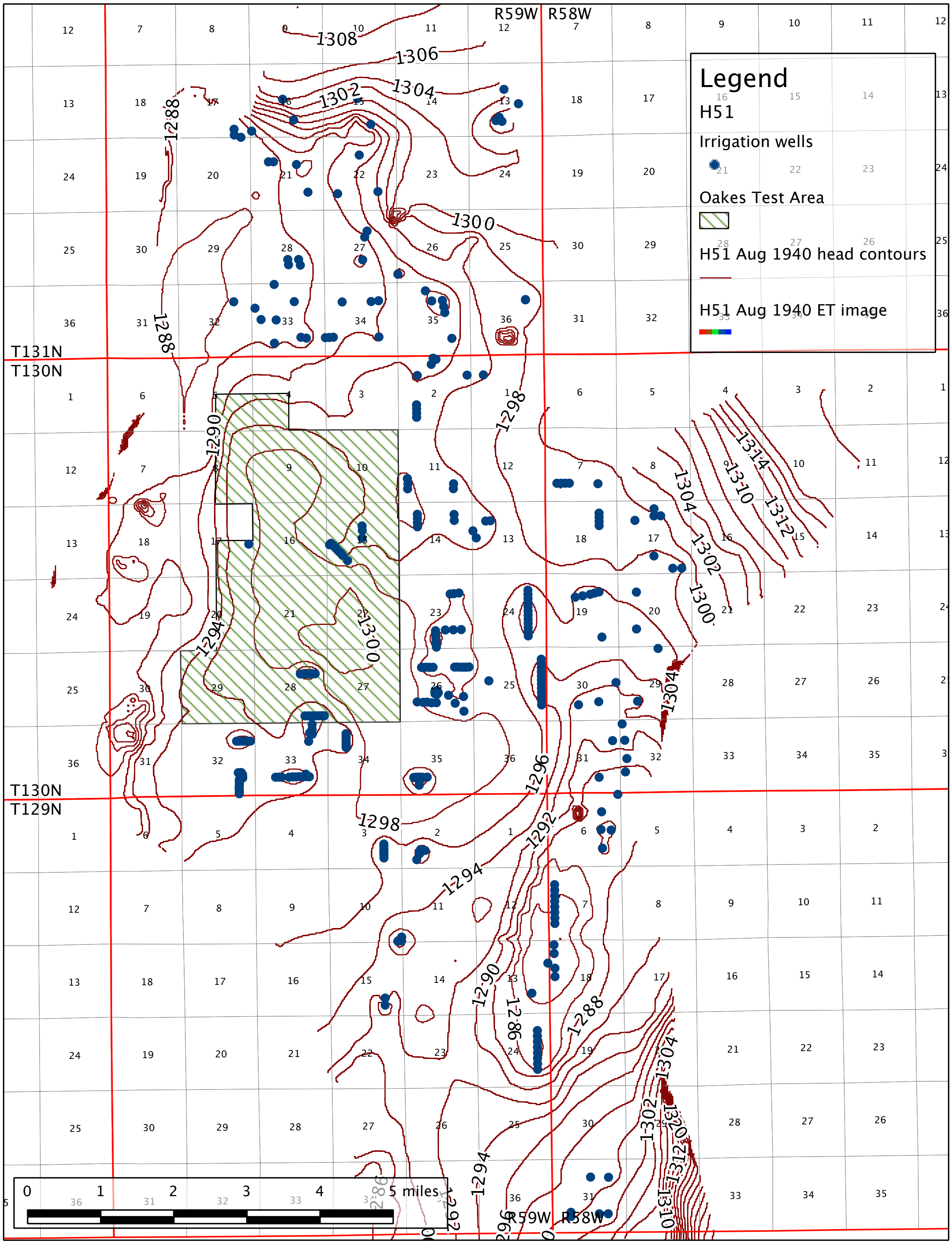

Figure F-67. Areas of evapotranspiration and water level contours for **August 31, 1940.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

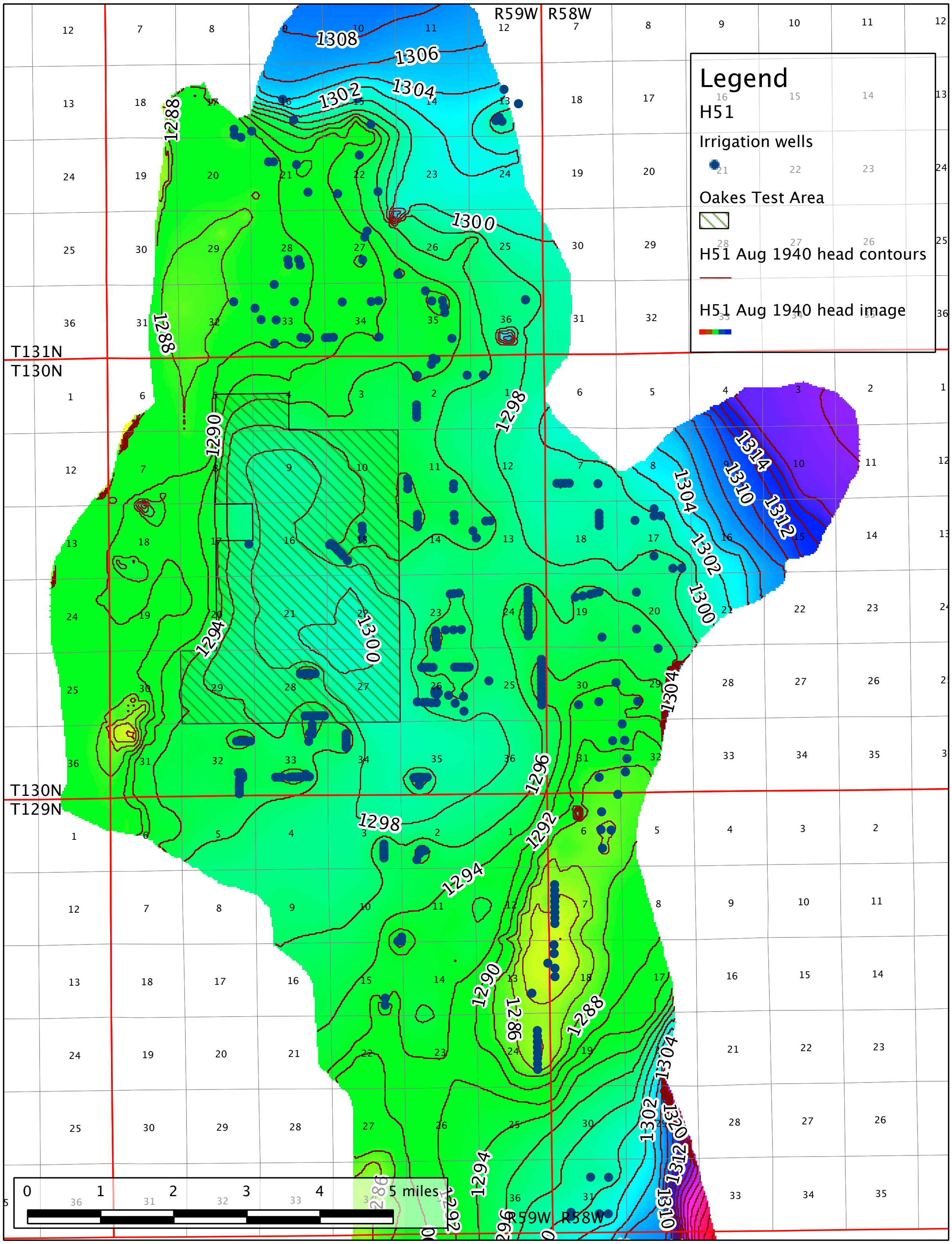

Figure F-68. Water level contours for **August 31, 1940. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

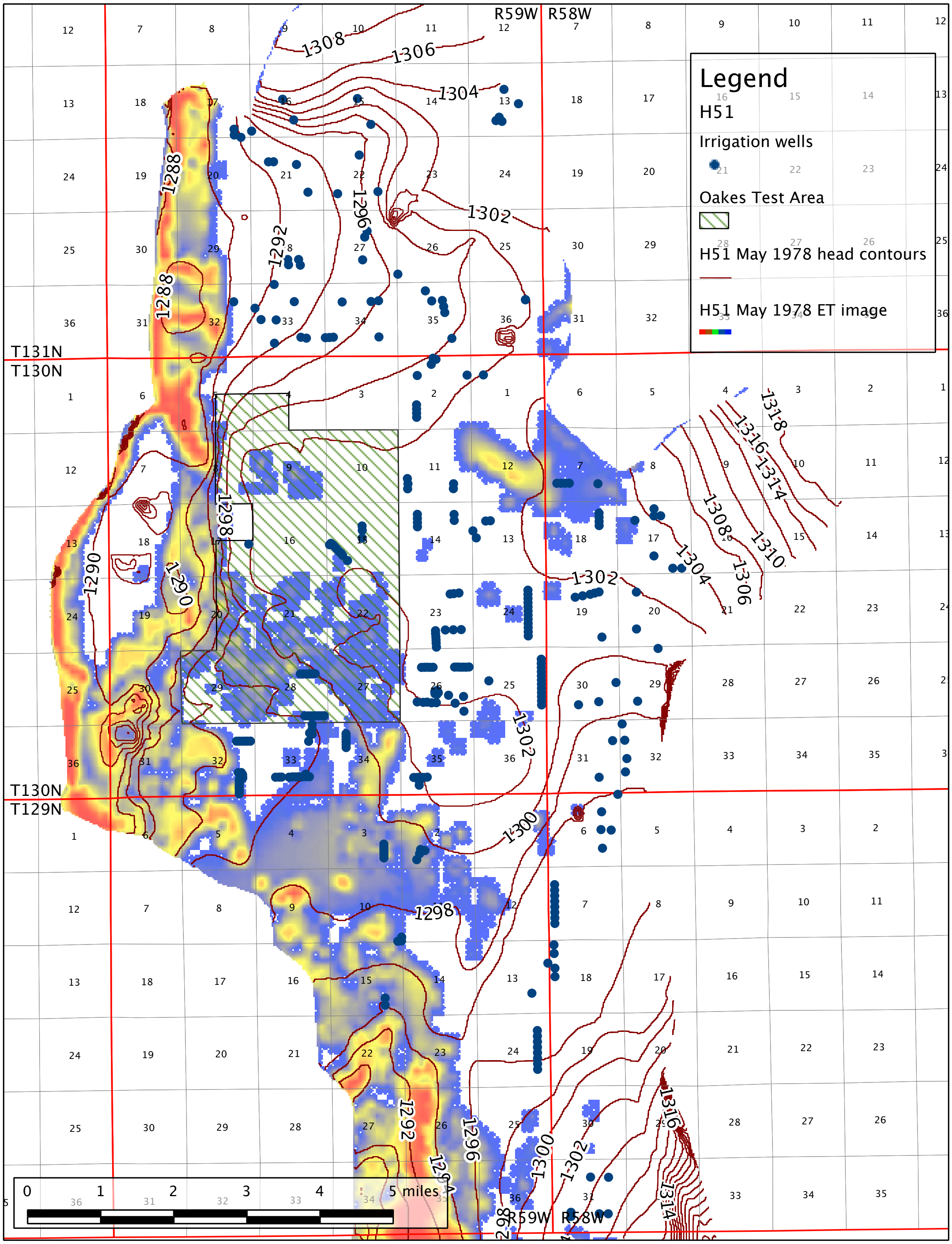

Figure F-69. Areas of evapotranspiration and water level contours for **May 31, 1978.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

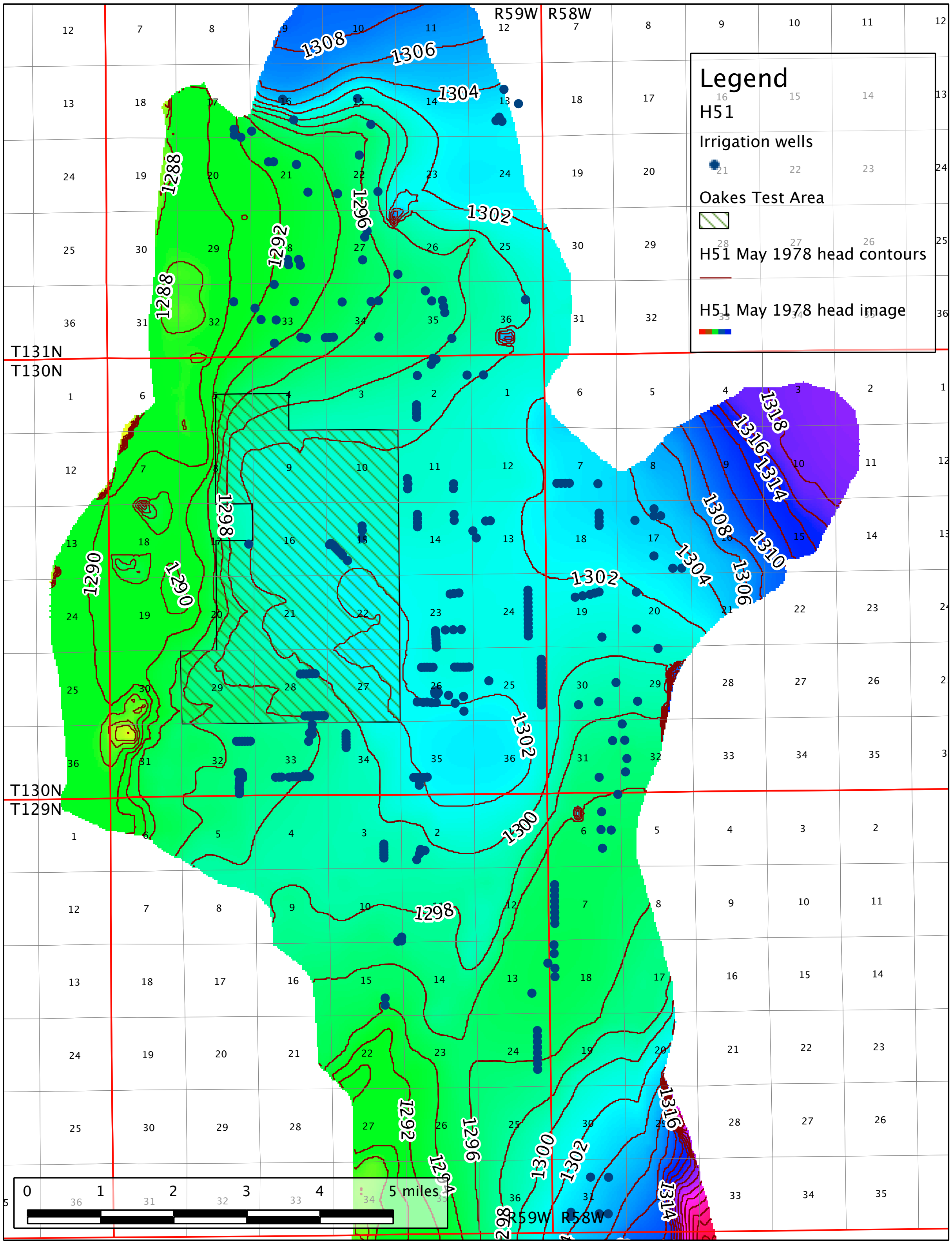

Figure F-70. Water level contours for **May 31, 1978. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

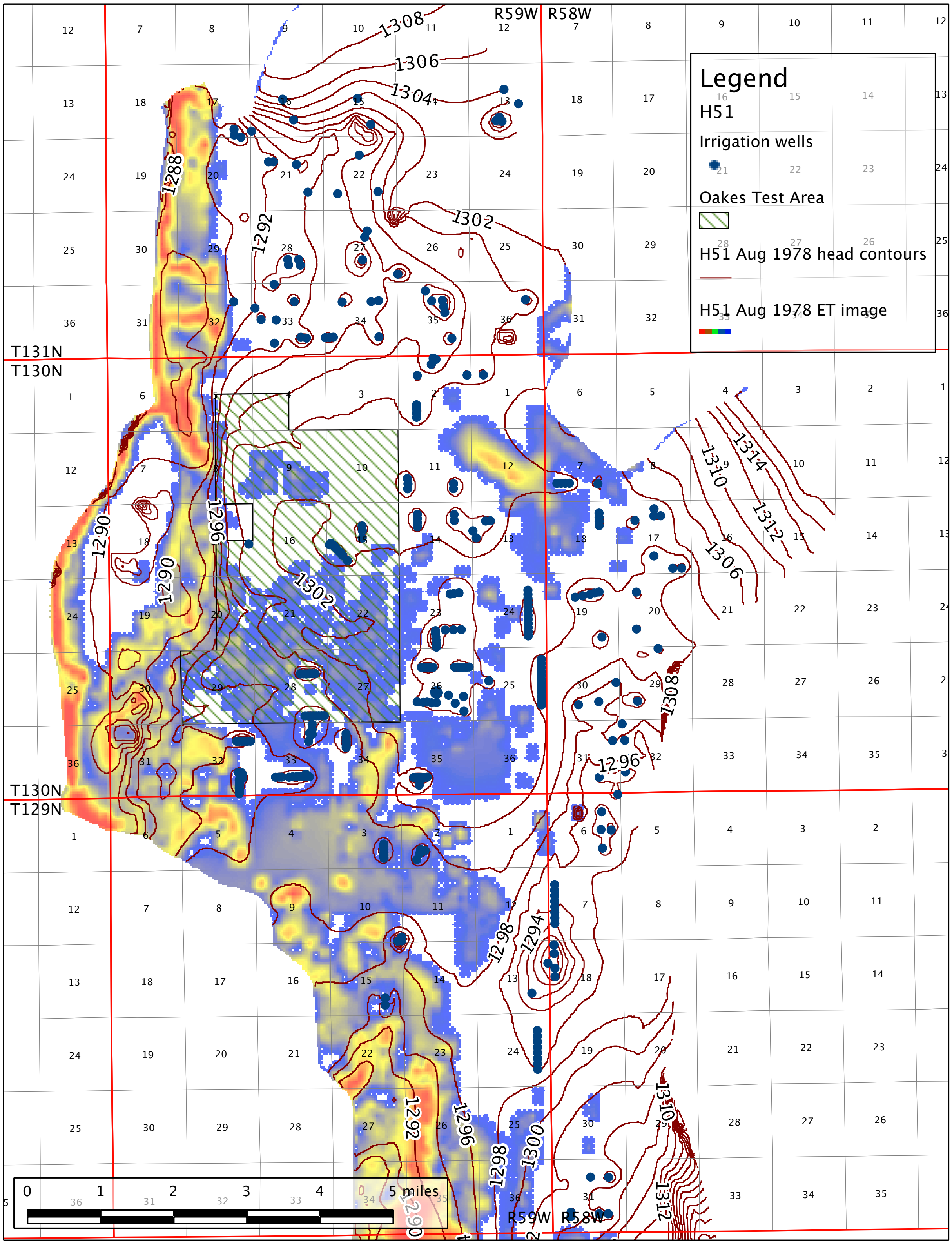

Figure F-71. Areas of evapotranspiration and water level contours for **August 31, 1978.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

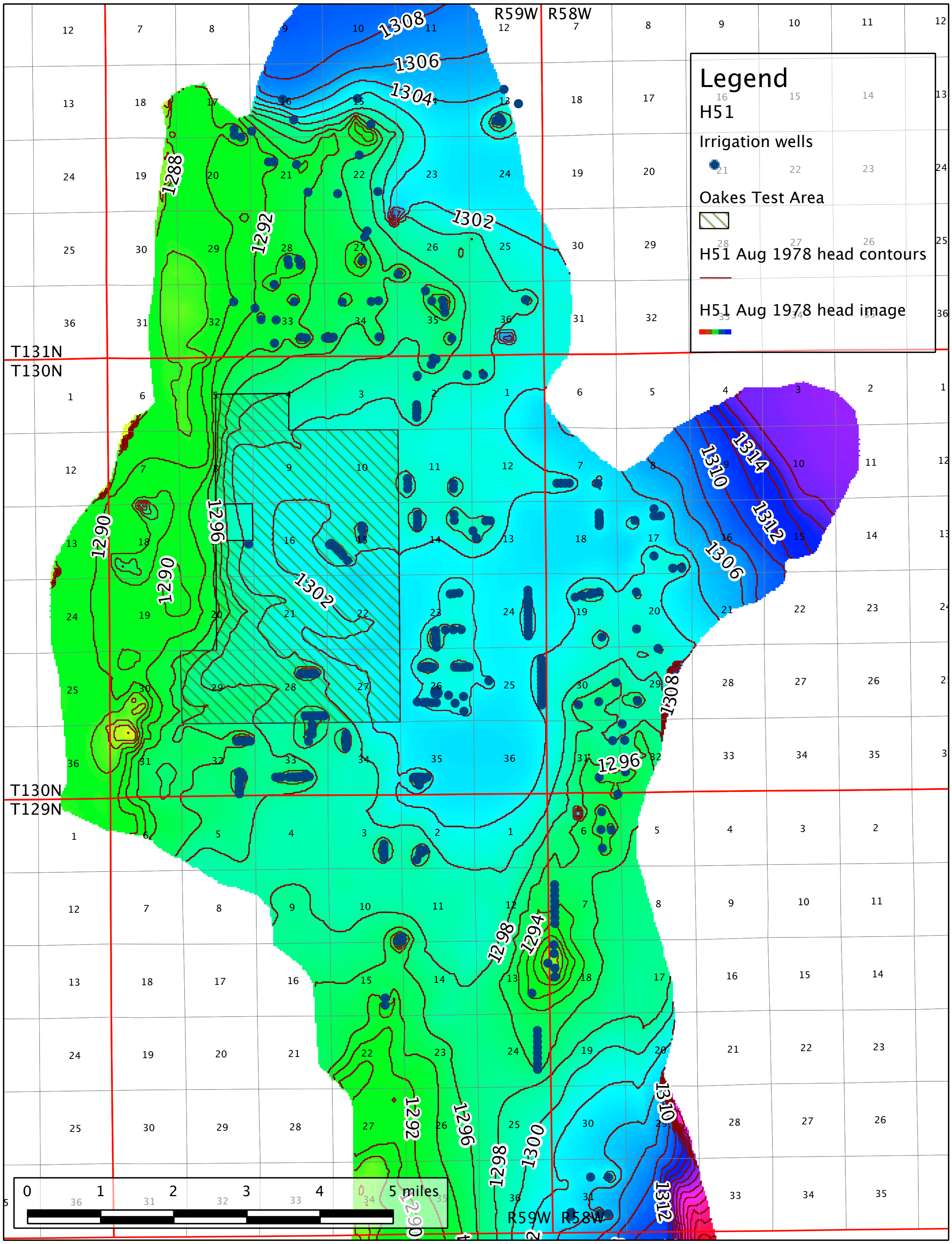

Figure F-72. Water level contours for **August 31, 1978. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

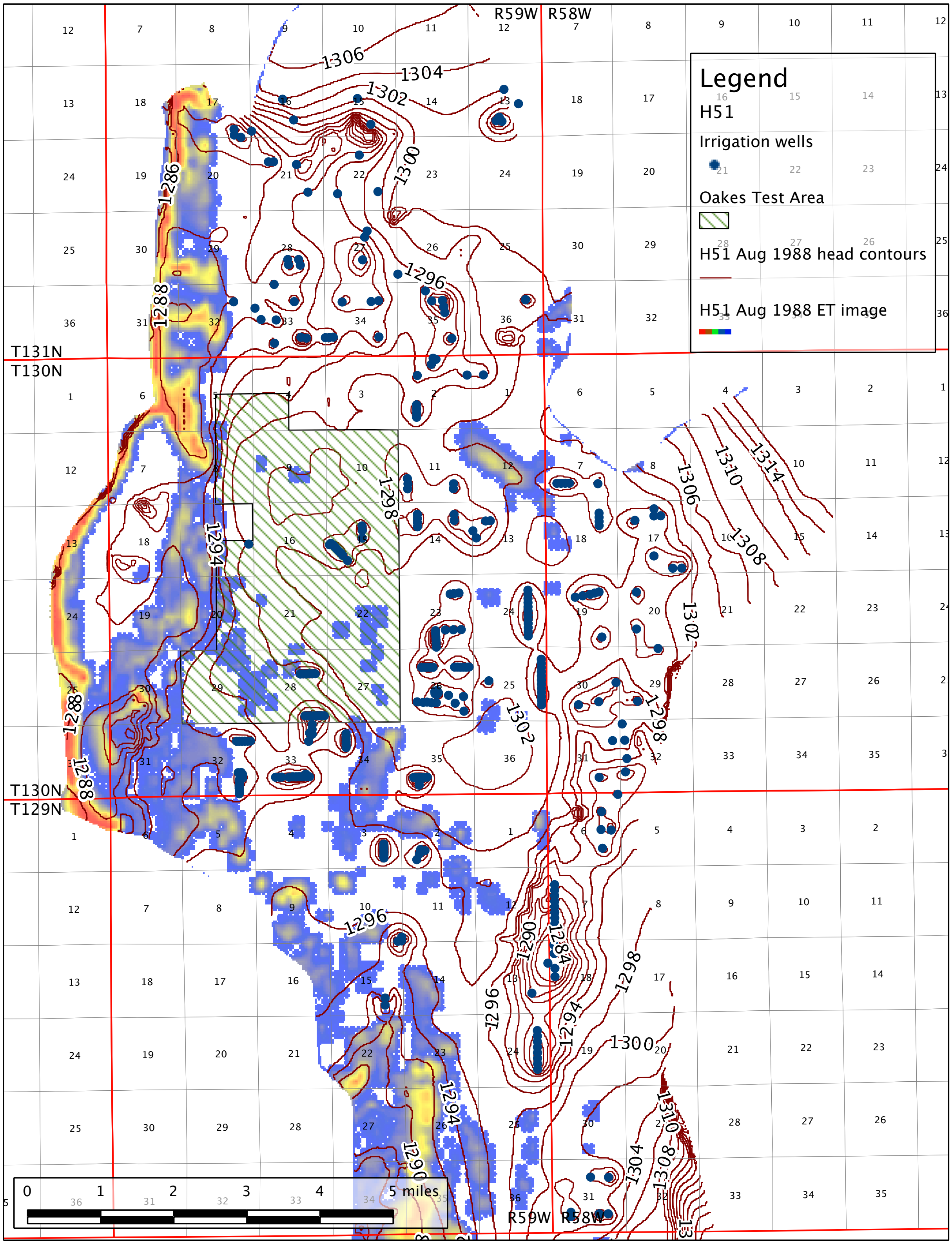

Figure F-73. Areas of evapotranspiration and water level contours for **August 31, 1988.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

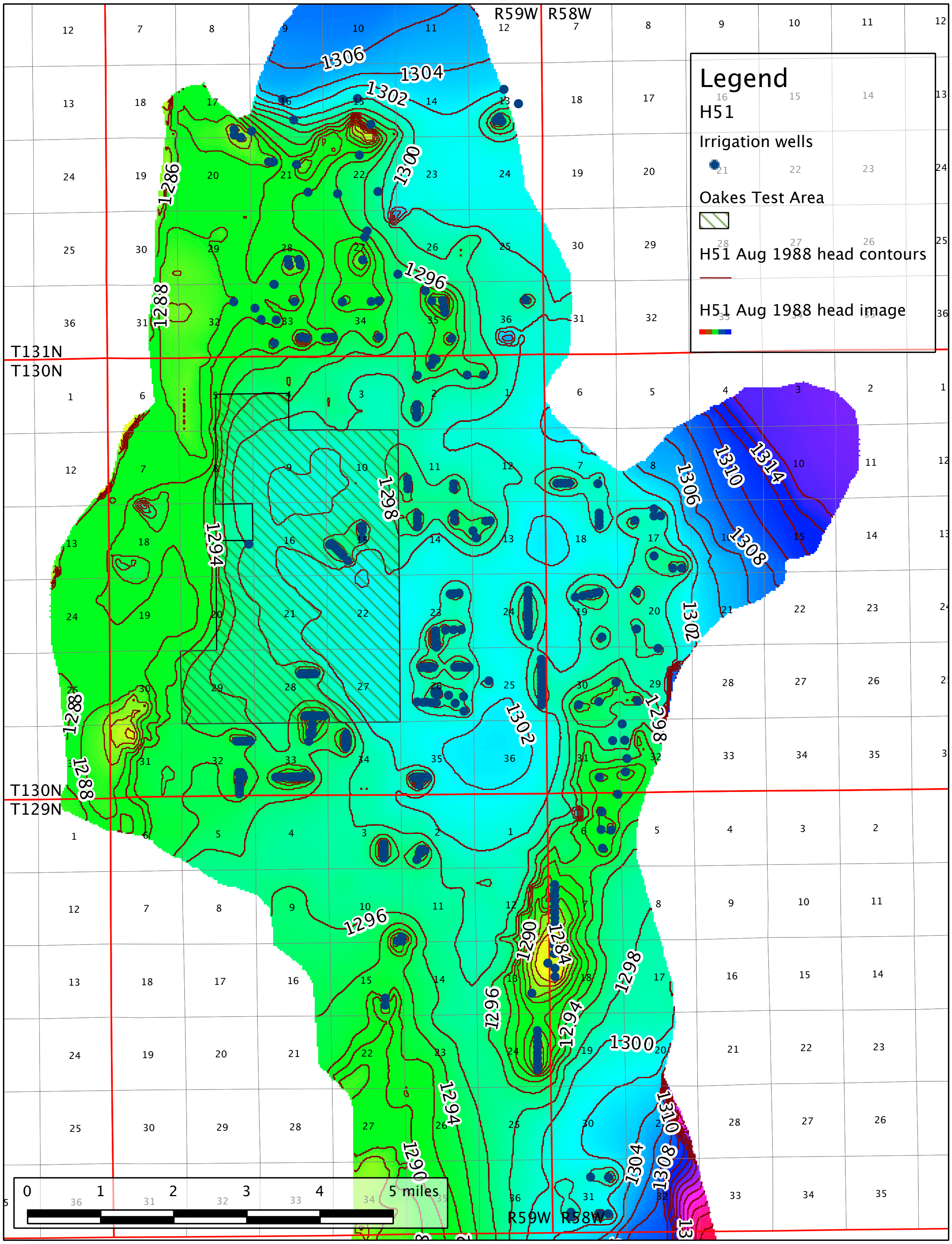

Figure F-74. Water level contours for **August 31, 1988. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

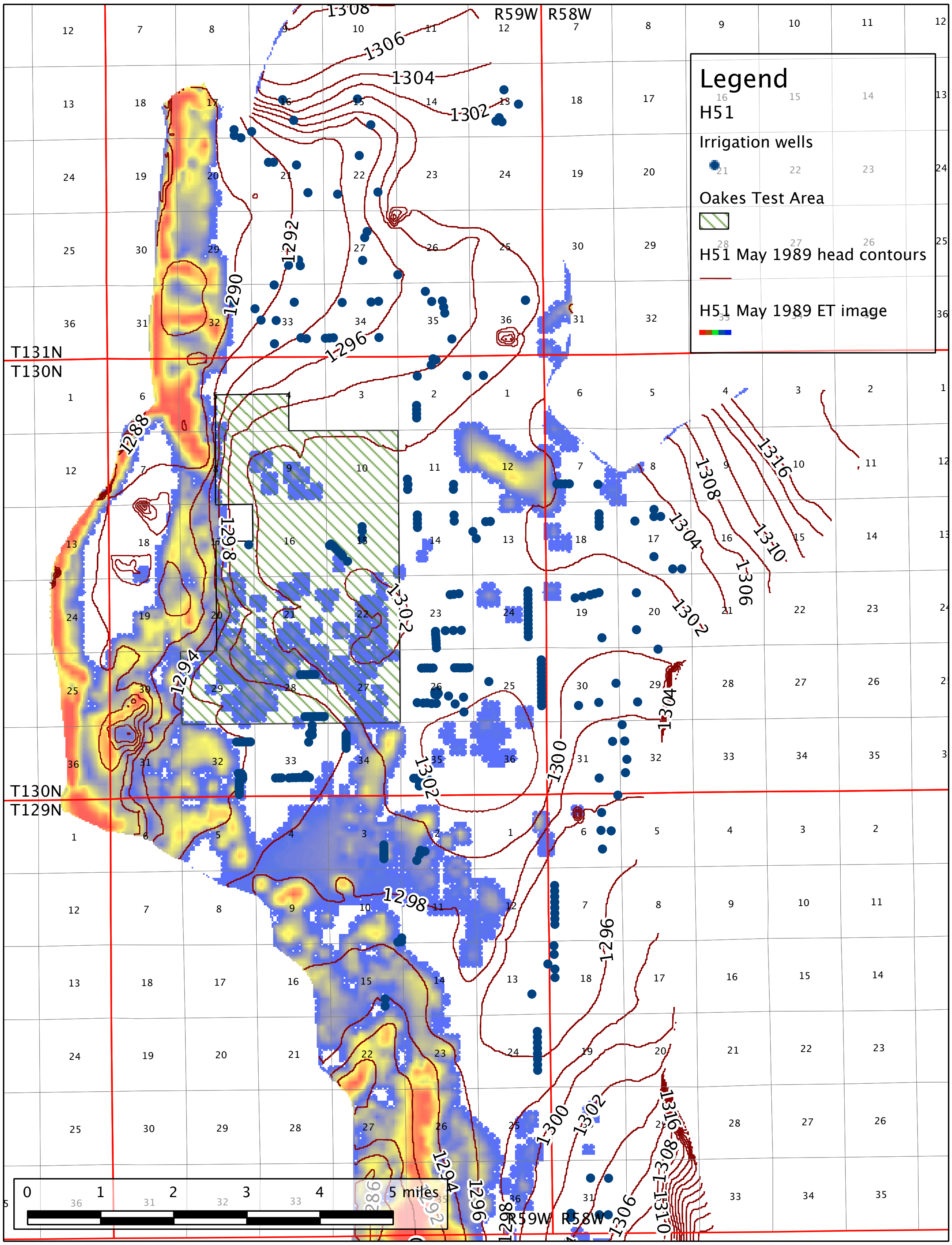

Figure F-75. Areas of evapotranspiration and water level contours for **May 31, 1989.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

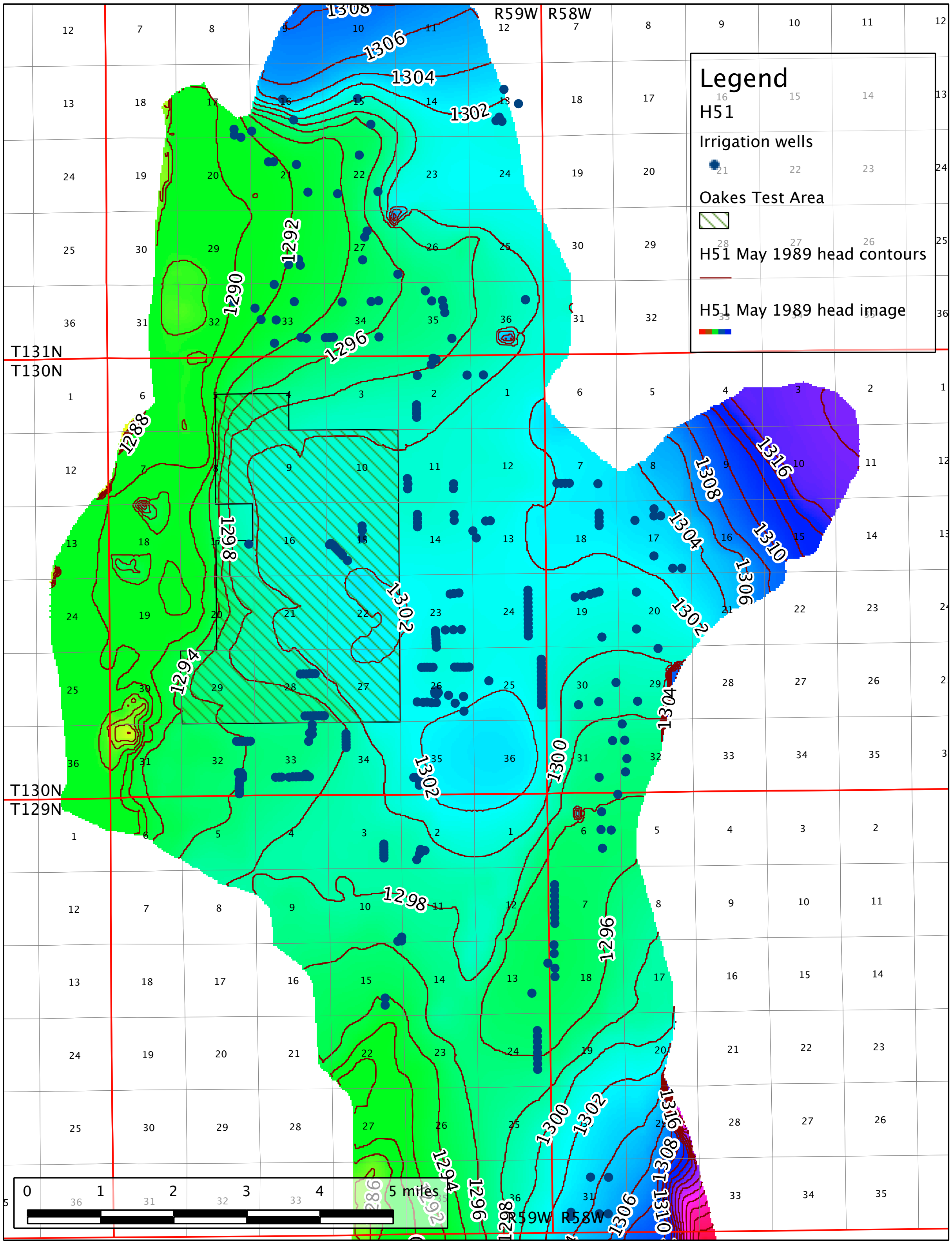

Figure F-76. Water level contours for **May 31, 1989. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

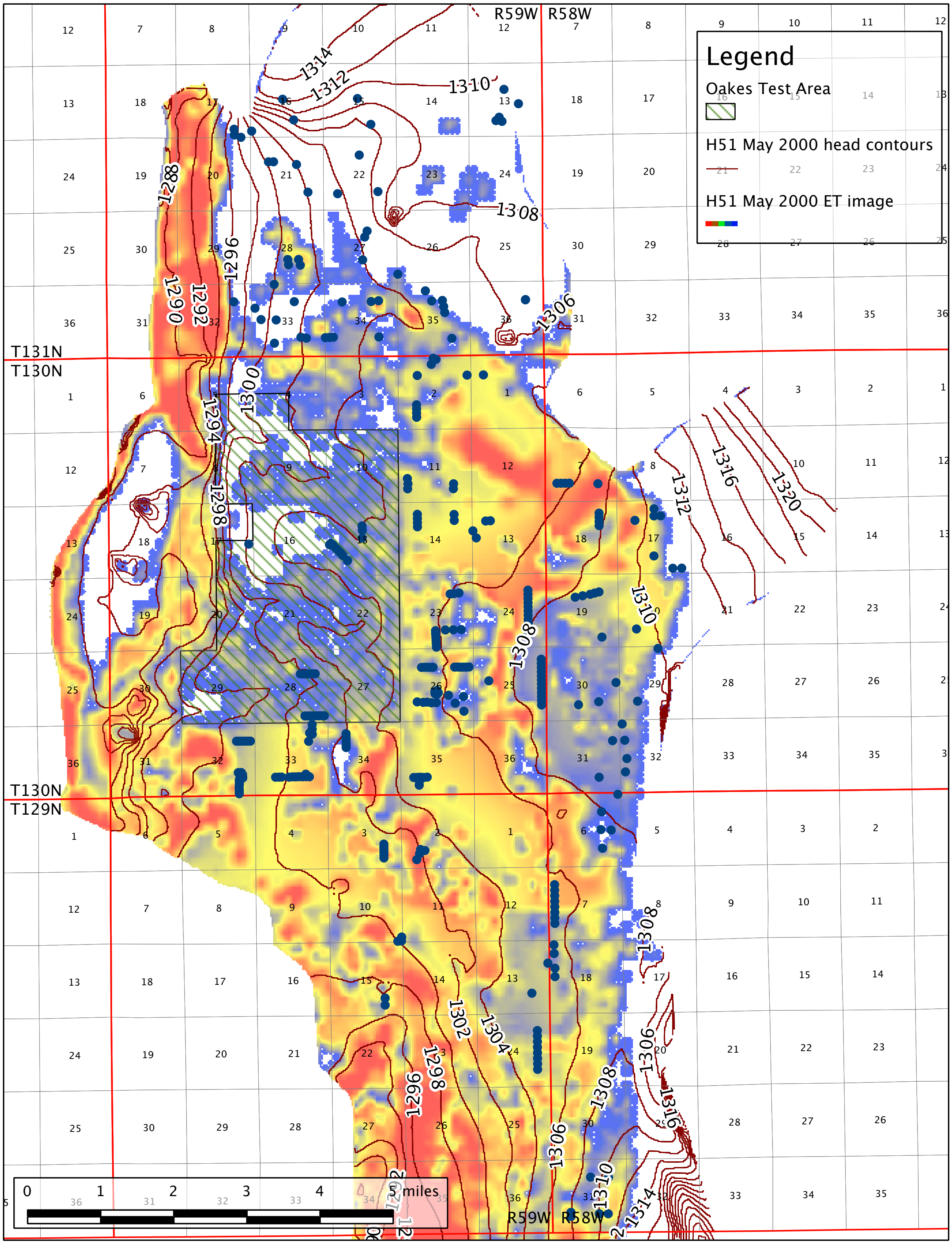

Figure F-77. Areas of evapotranspiration and water level contours for **May 31, 2000.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

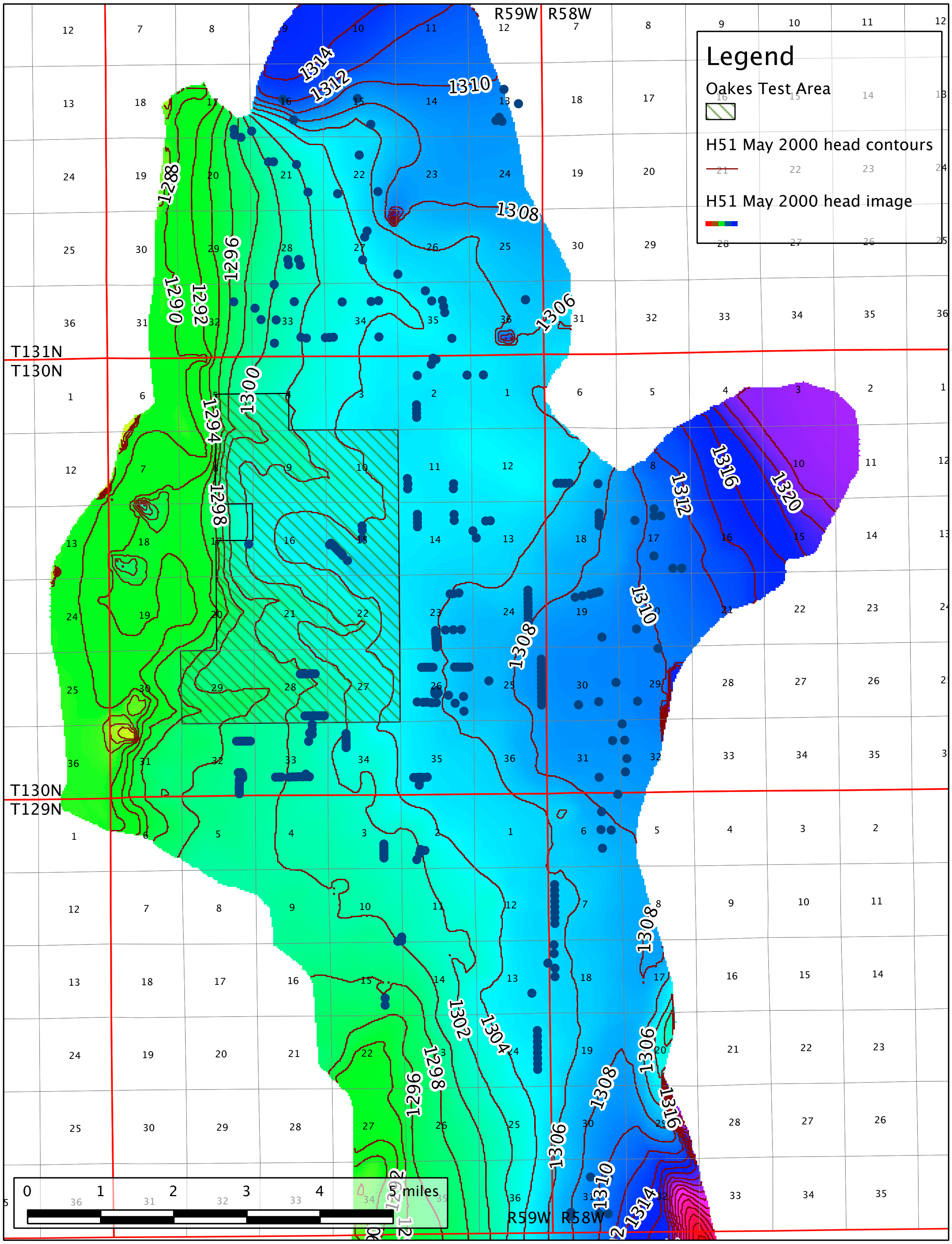

Figure F-78. Water level contours for **May 31, 2000. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

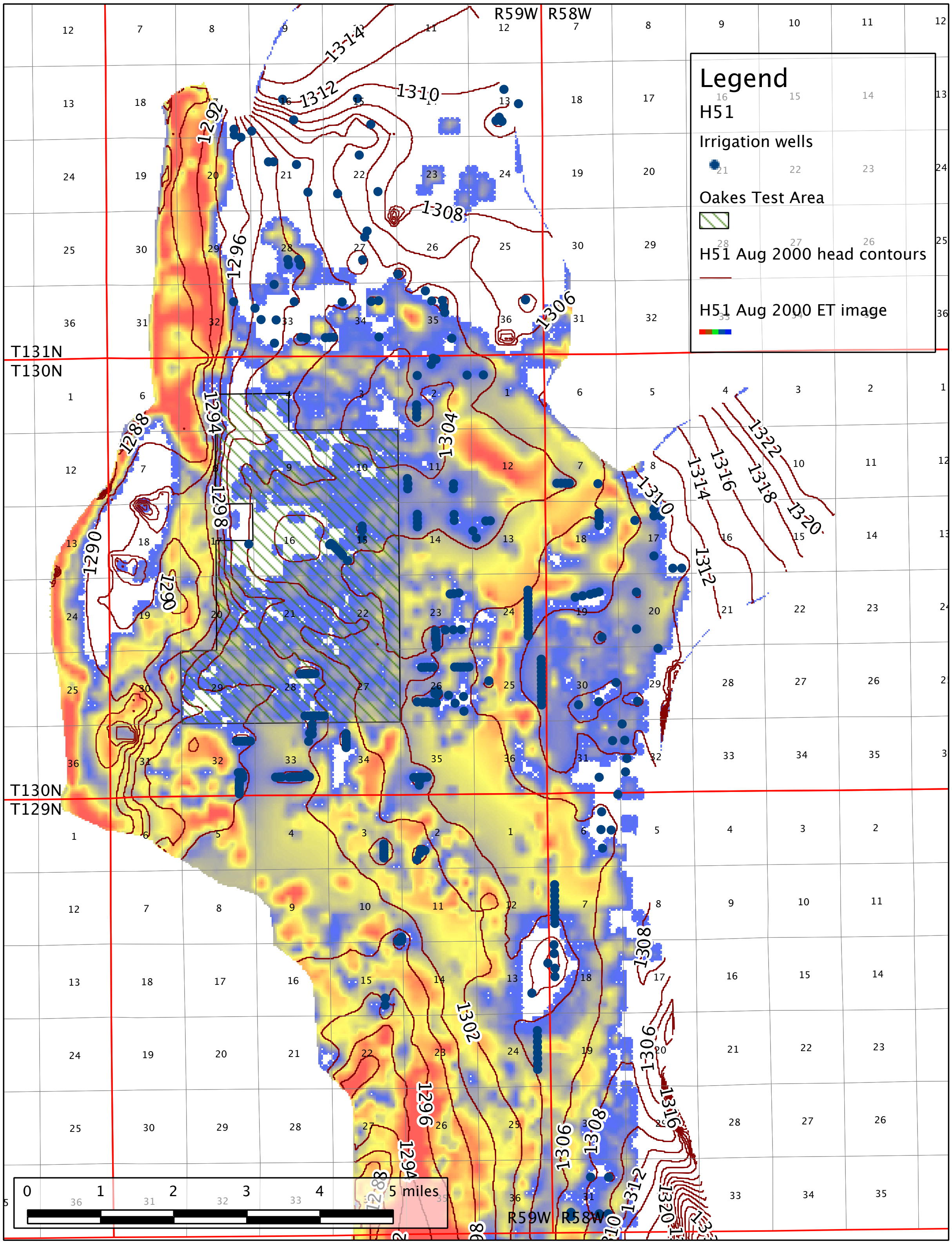

Figure F-79. Areas of evapotranspiration and water level contours for **August 31, 2000.** White is no ET. Red is maximum ET. **Run H51**, DSID-ESSER irrigation. Forman climate dataset.

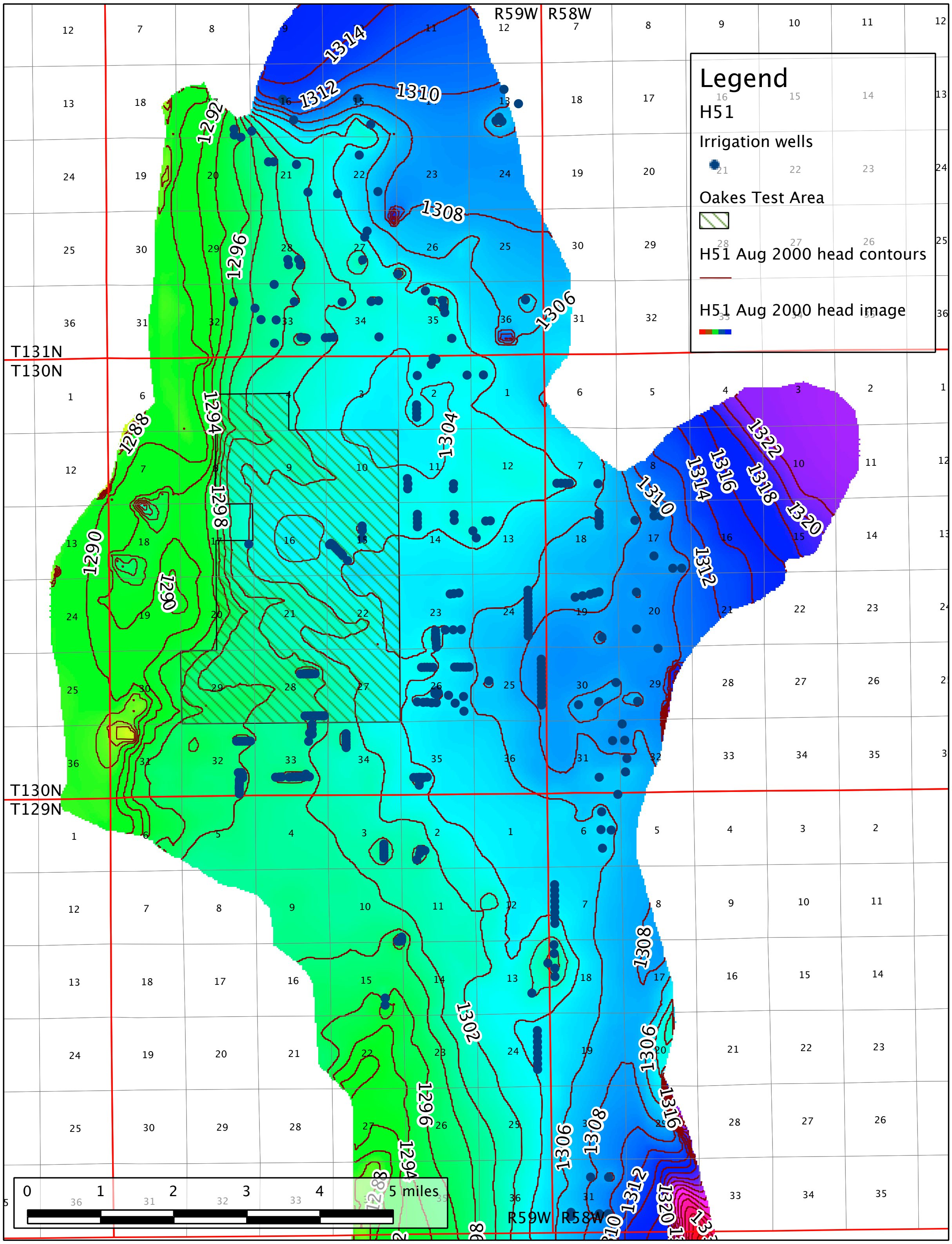

Figure F-80. Water level contours for **August 31, 2000. Run H51**, drains, permitted + DSID-ESSER irrigation. Forman climate dataset.

RUN H81. DRAINS. PERMITTED+PENDING+DSID-ESSER IRRIGATION - FULLERTON

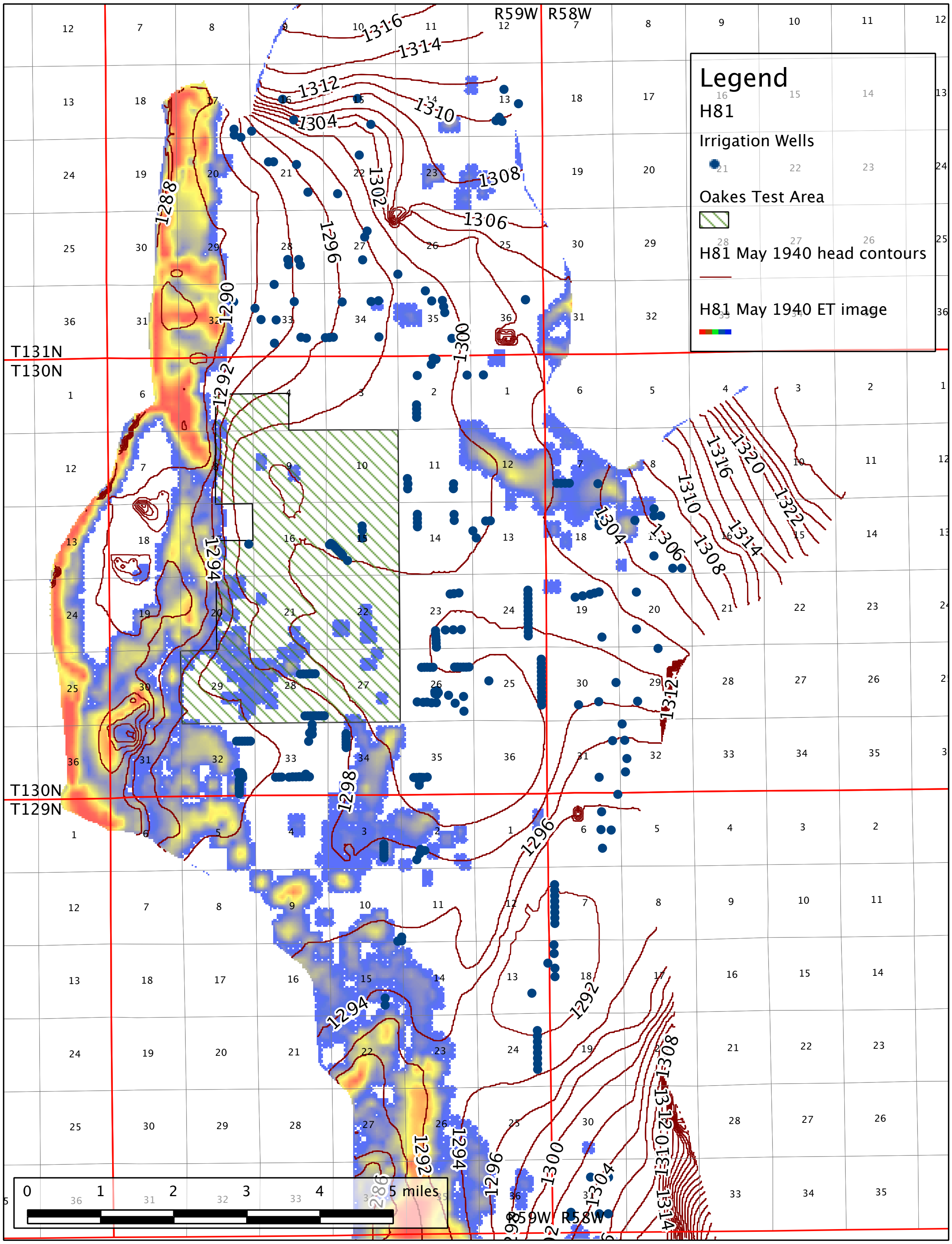

Figure F-81. Areas of evapotranspiration and water level contours for **MAY 31, 1940.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

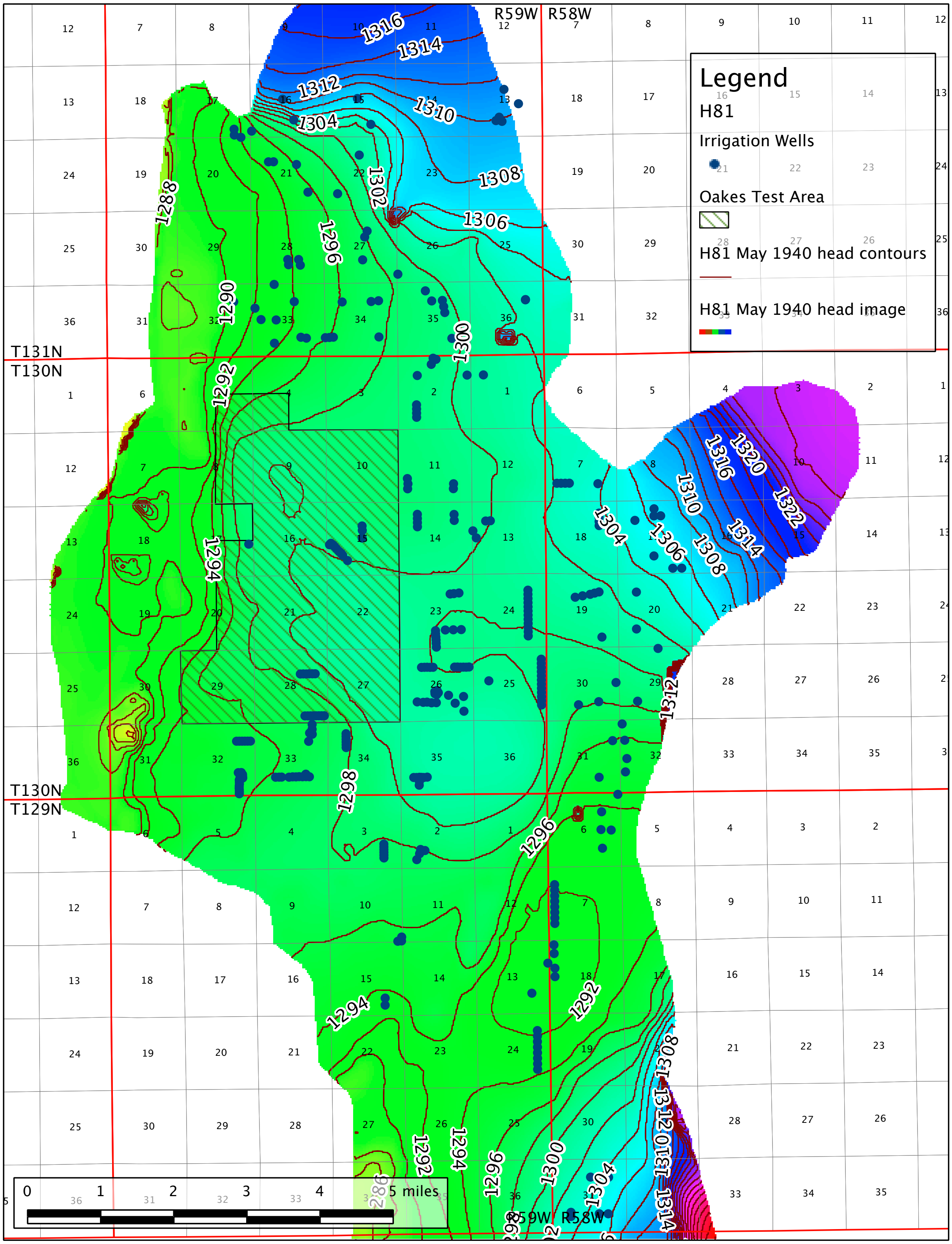

Figure F-82. Water level contours for **May 31, 1940. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

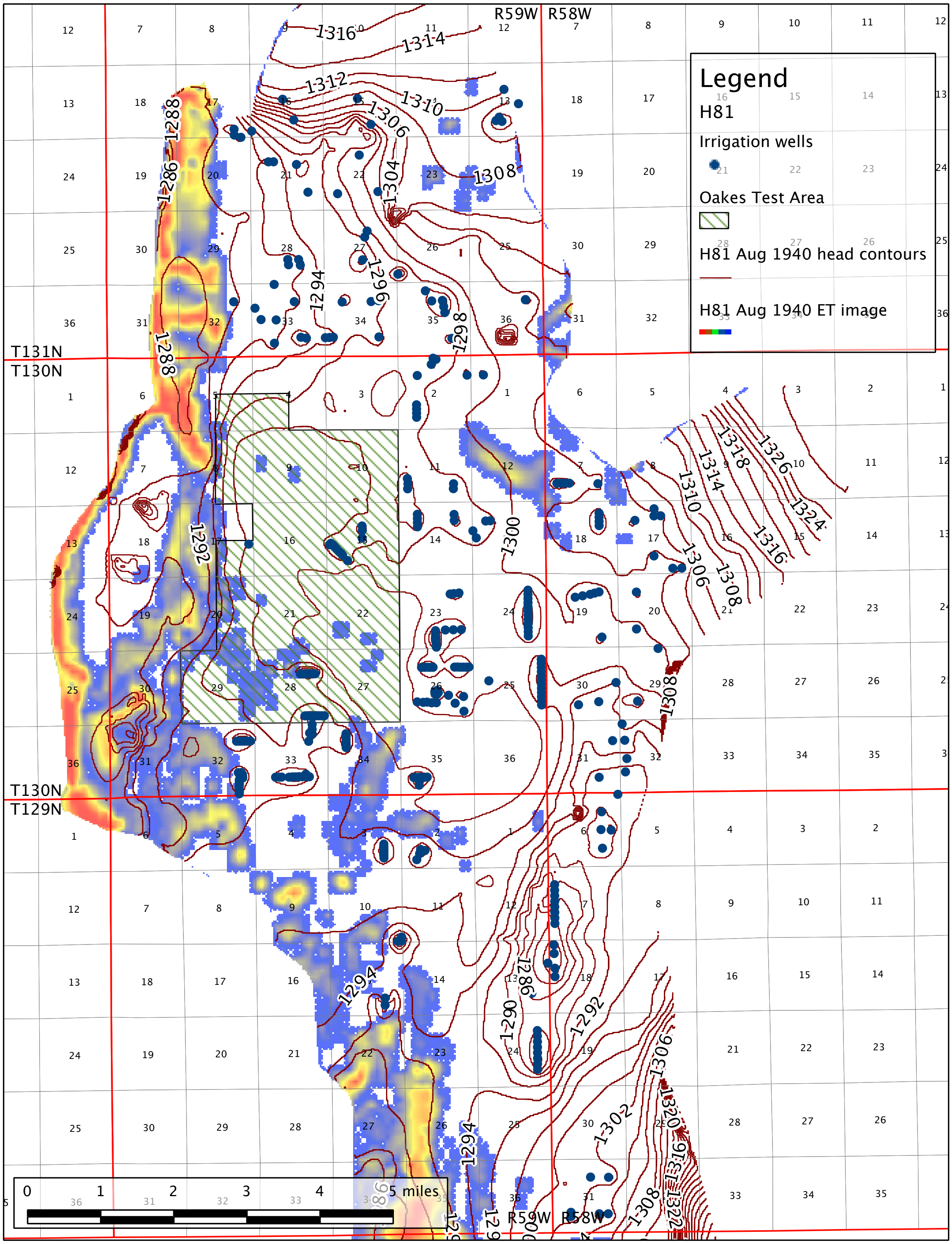

Figure F-83. Areas of evapotranspiration and water level contours for **August 31, 1940.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

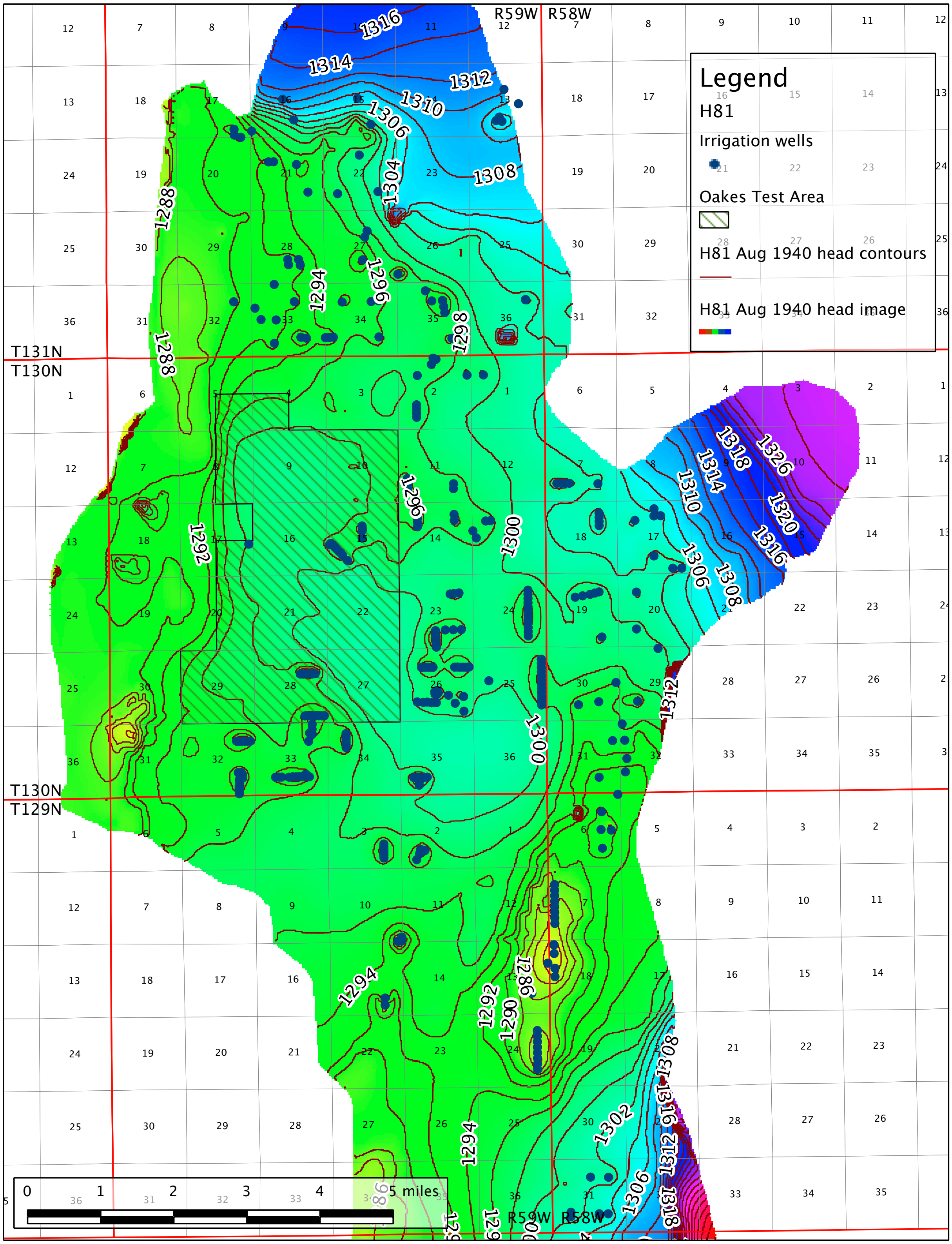

Figure F-84. Water level contours for **August 31, 1940. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

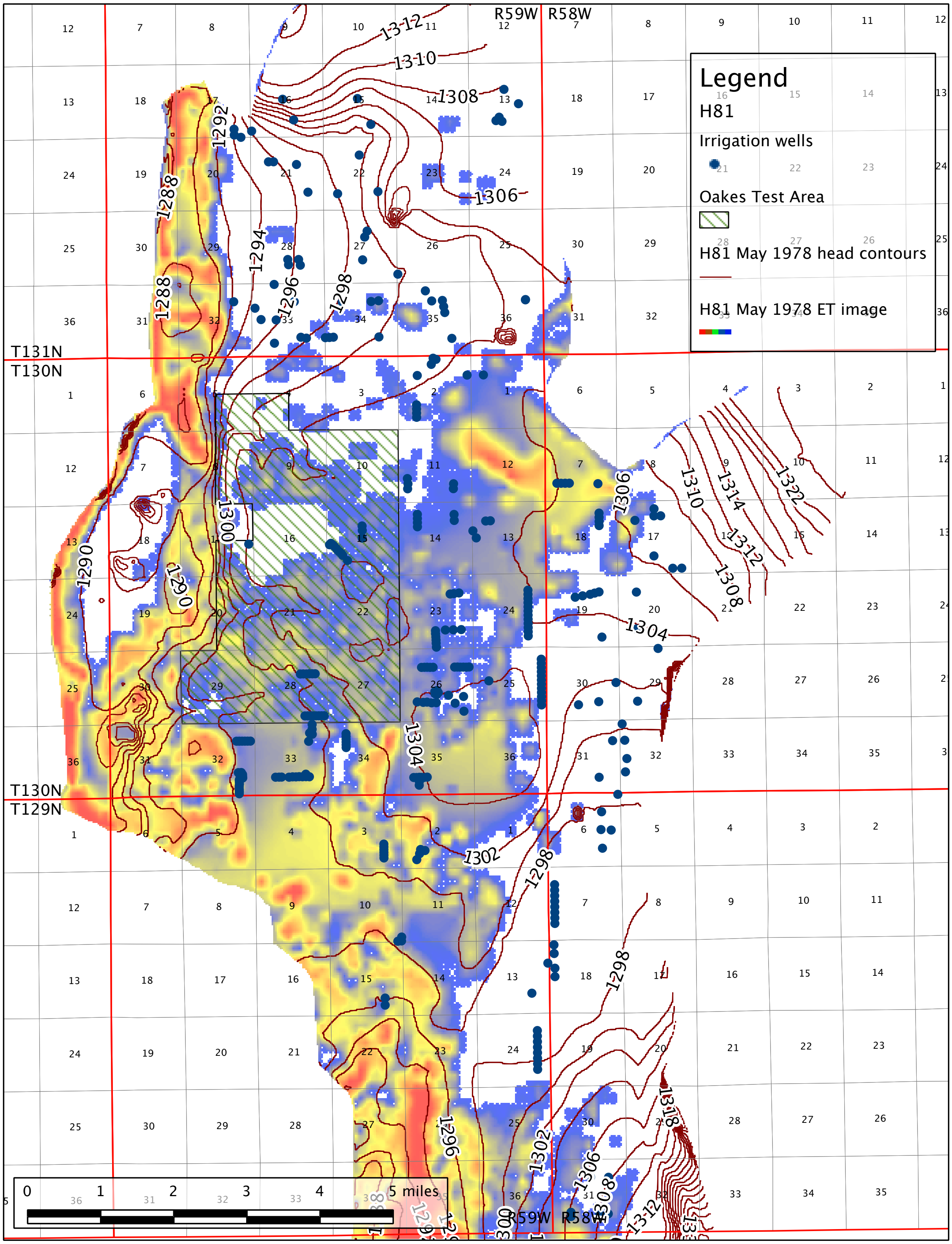

Figure F-85. Areas of evapotranspiration and water level contours for **MAY 31, 1978.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

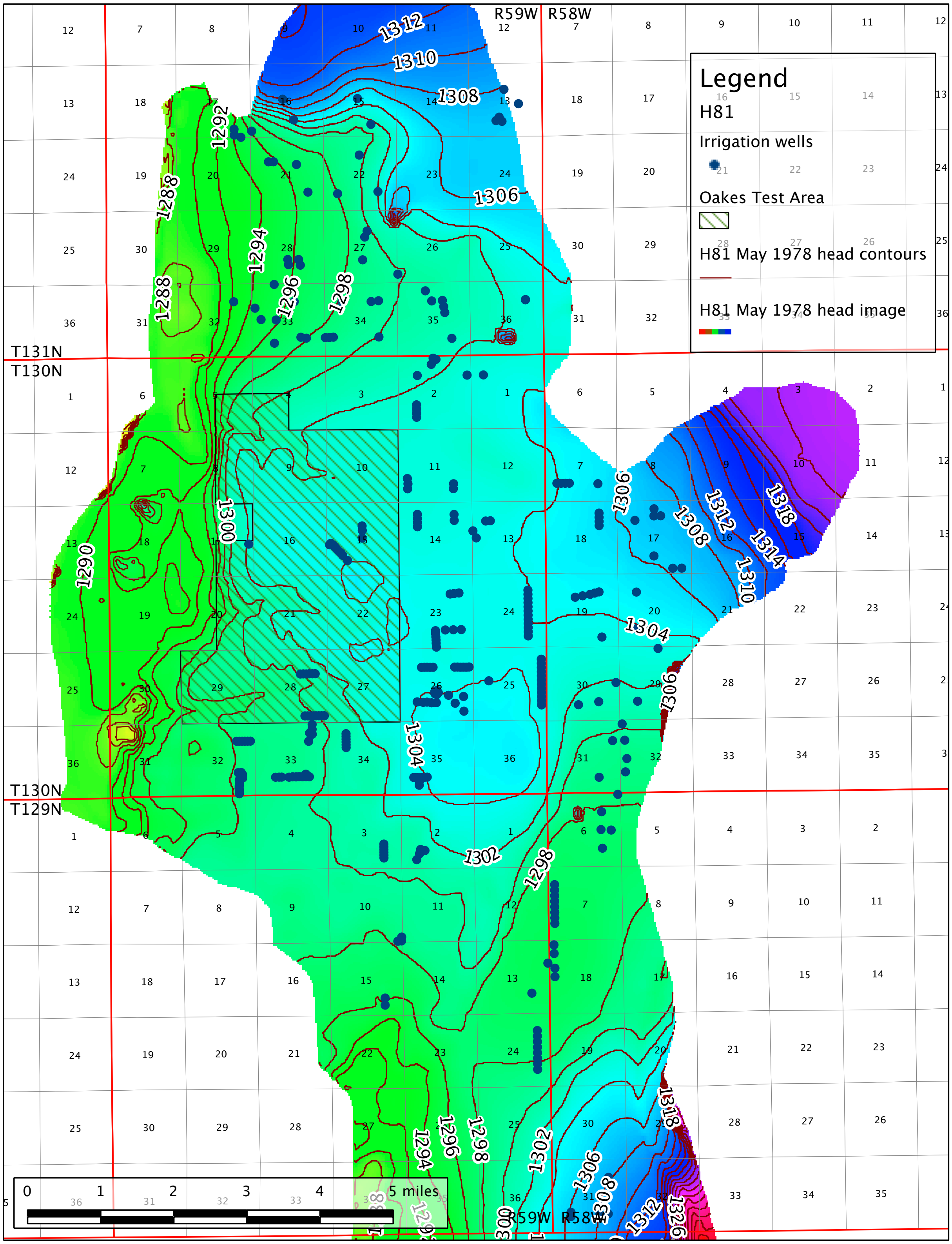

Figure F-86. Water level contours for **May 31, 1978. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

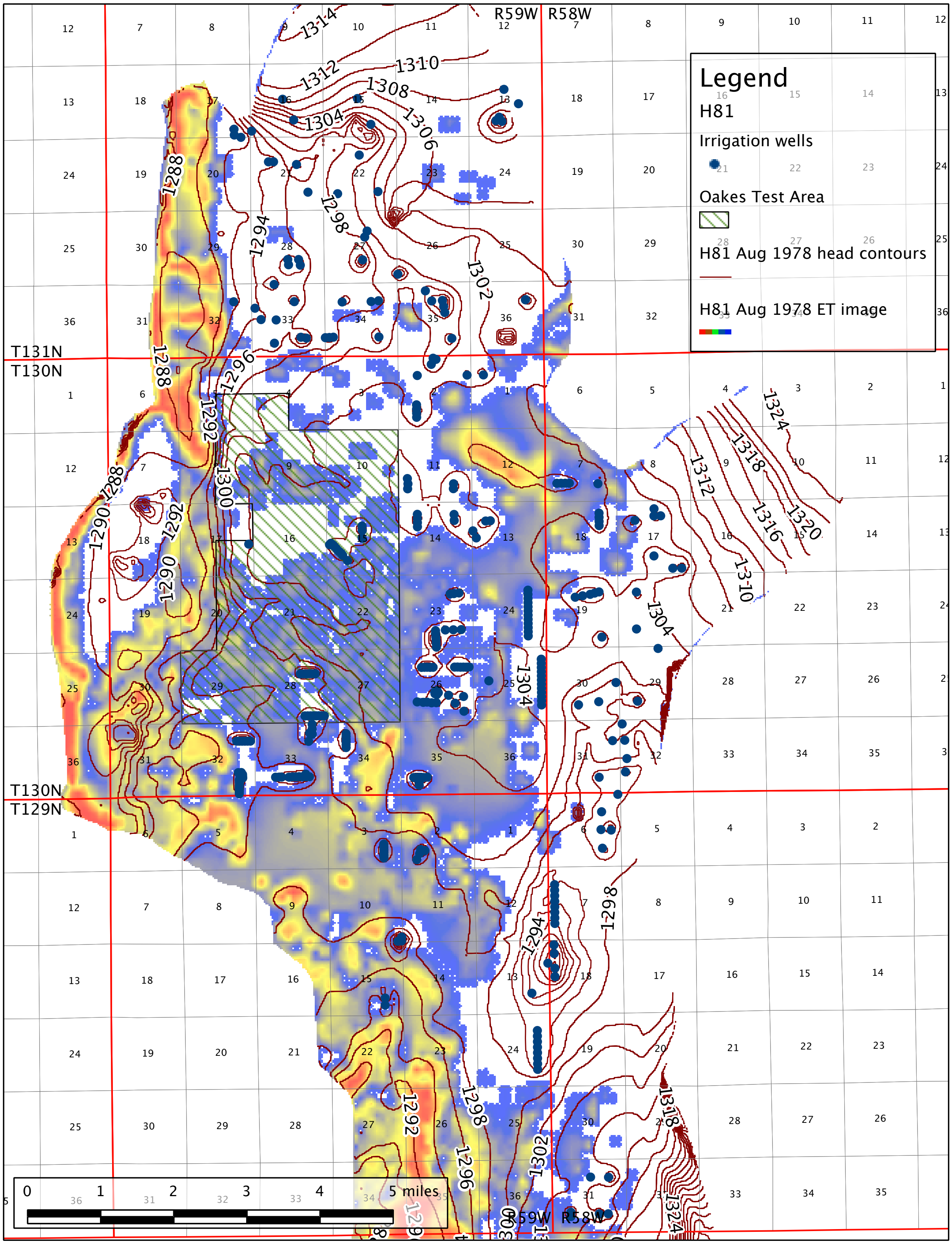

Figure F-87. Areas of evapotranspiration and water level contours for **August 31, 1978.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

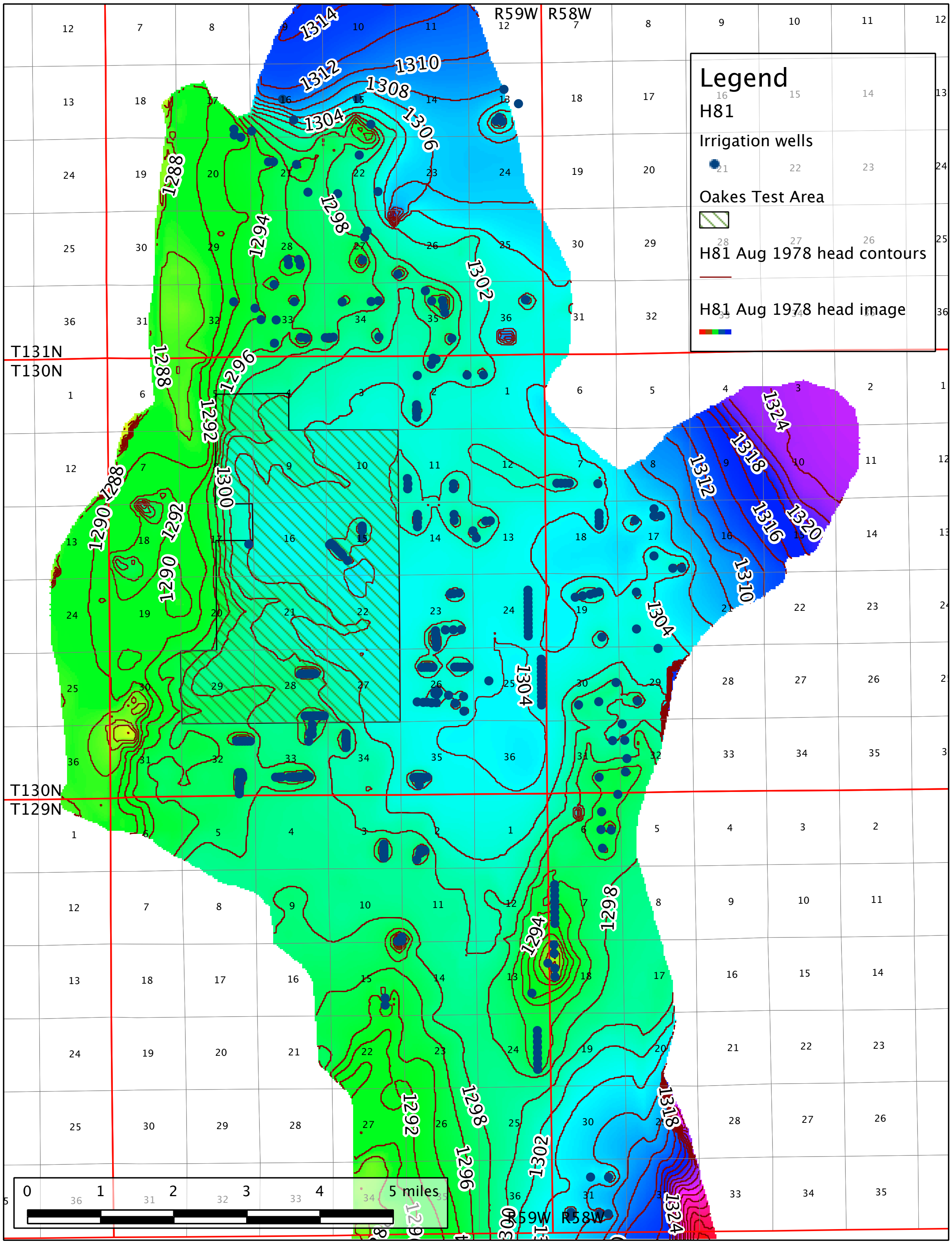

Figure F-88. Water level contours for **August 31, 1978. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

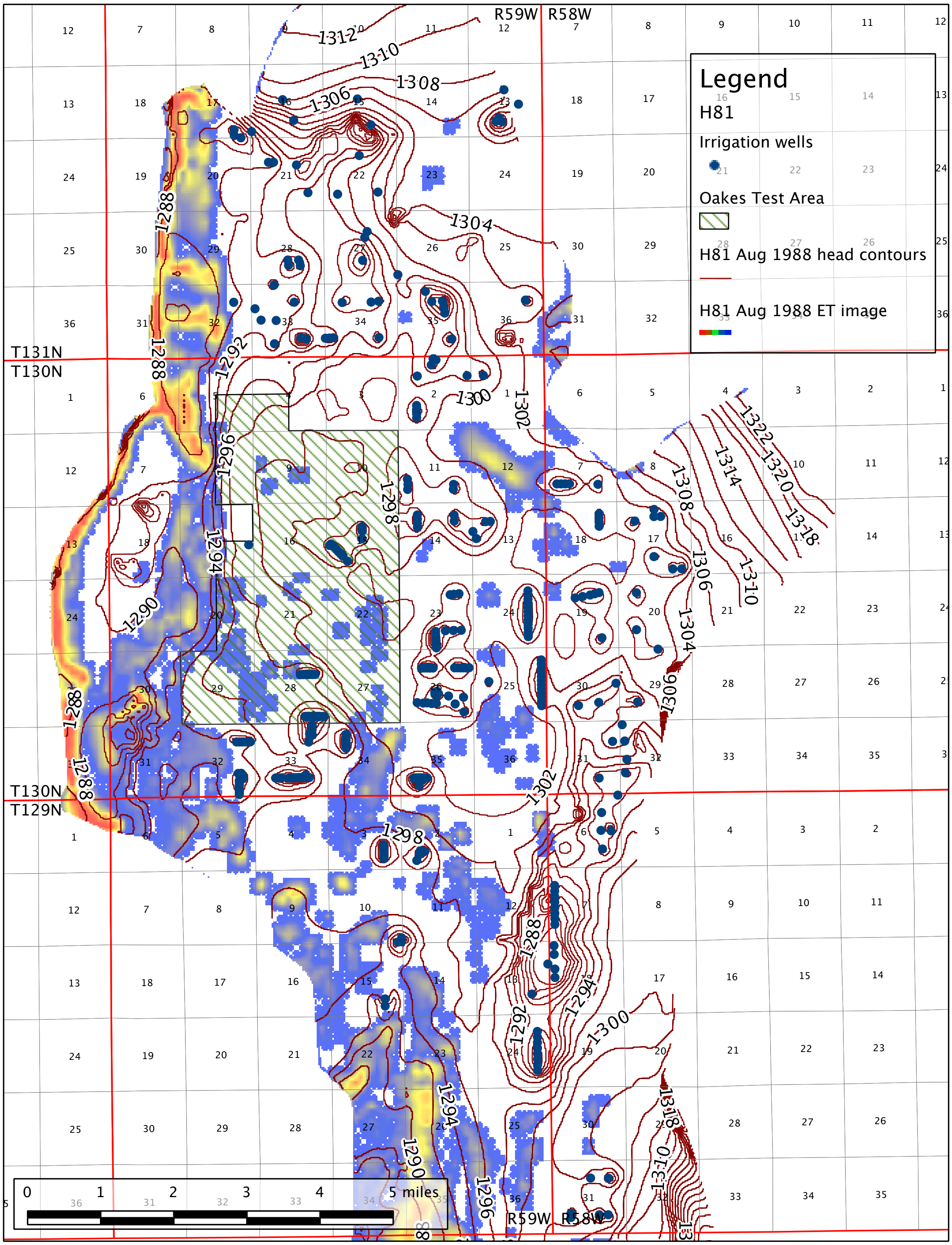

Figure F-89. Areas of evapotranspiration and water level contours for **August 31, 1988.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

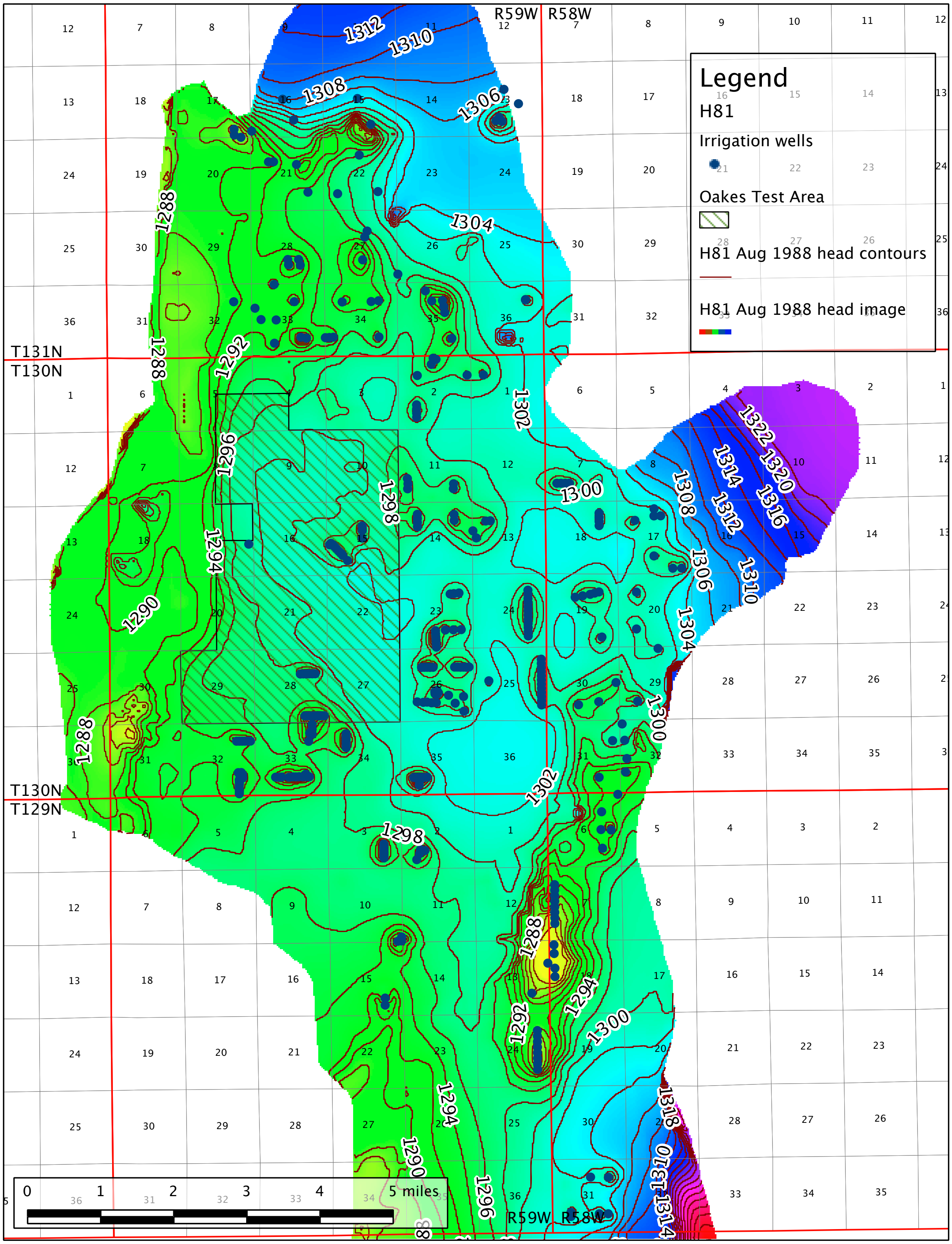

Figure F-90. Water level contours for **August 31, 1988. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

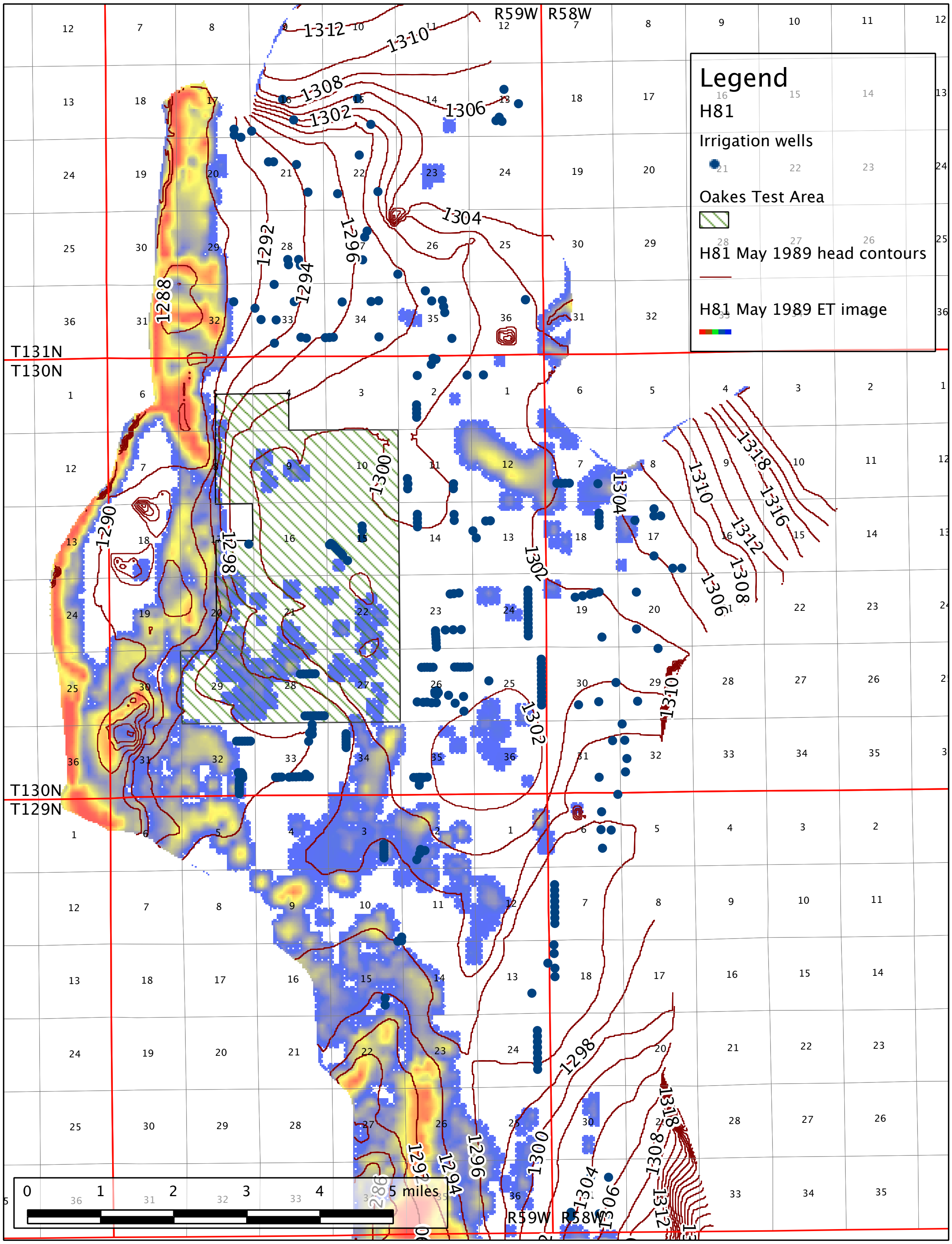

Figure F-91. Areas of evapotranspiration and water level contours for **MAY 31, 1989.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

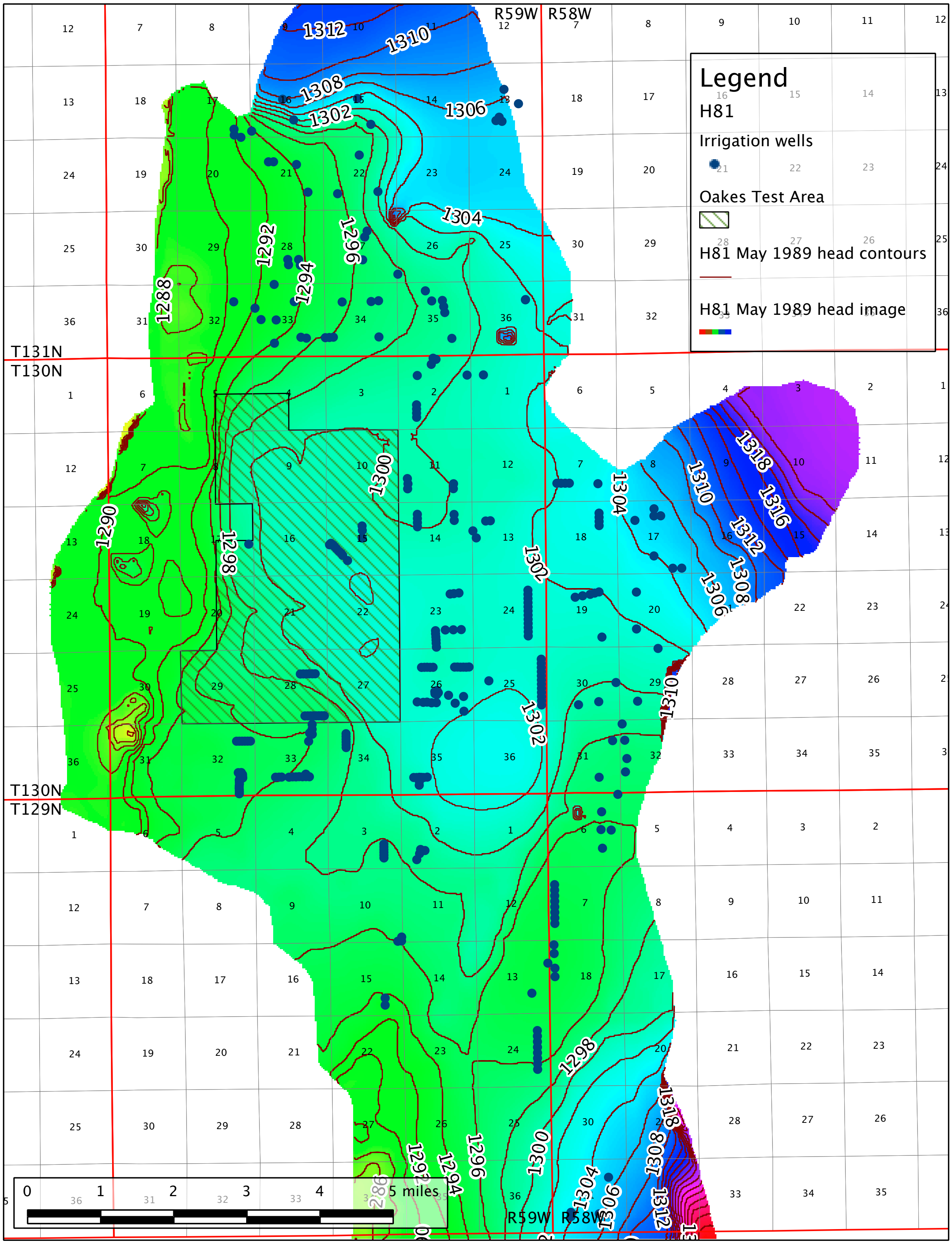

Figure F-92. Water level contours for **May 31, 1989. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

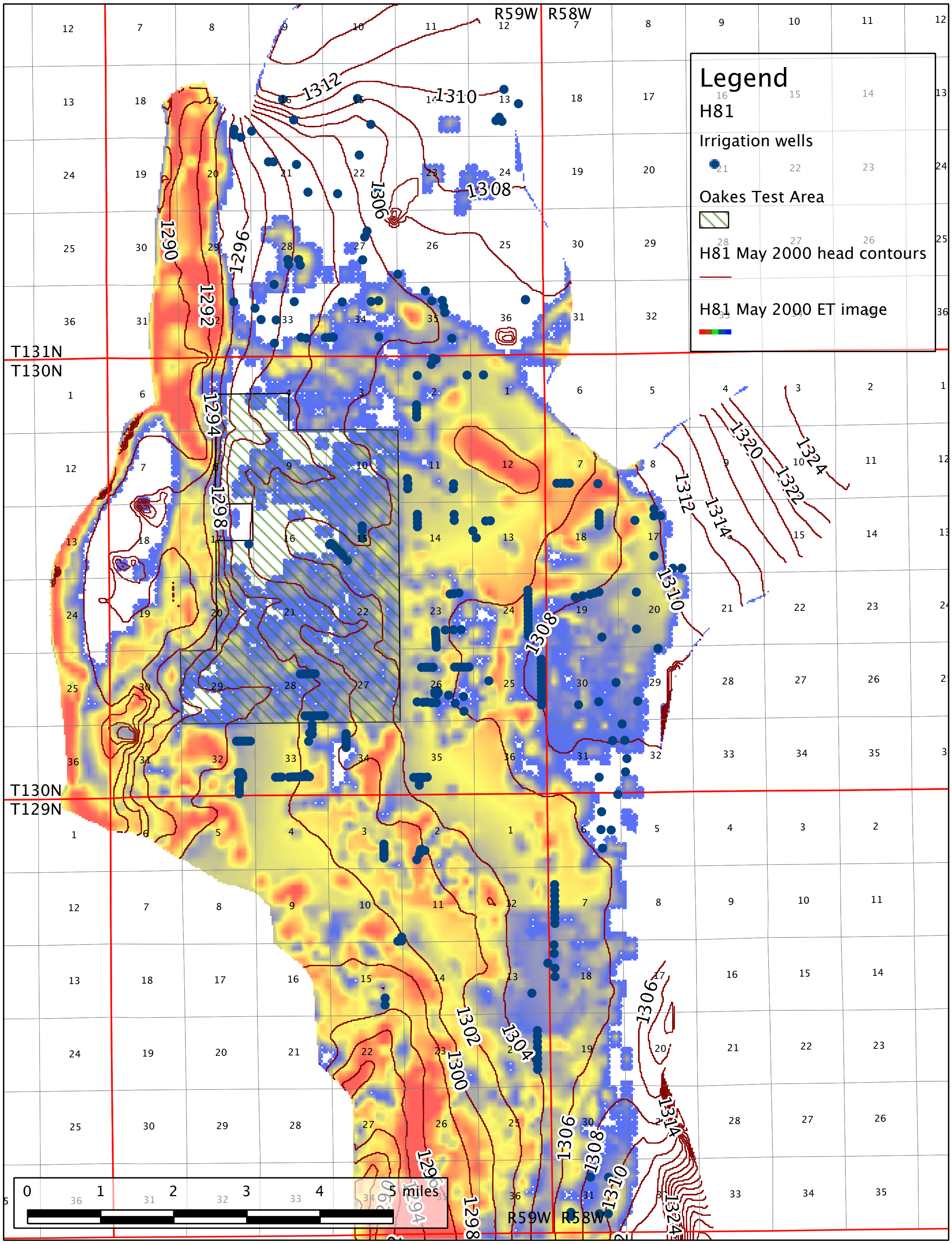

Figure F-93. Areas of evapotranspiration and water level contours for **MAY 31, 2000.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

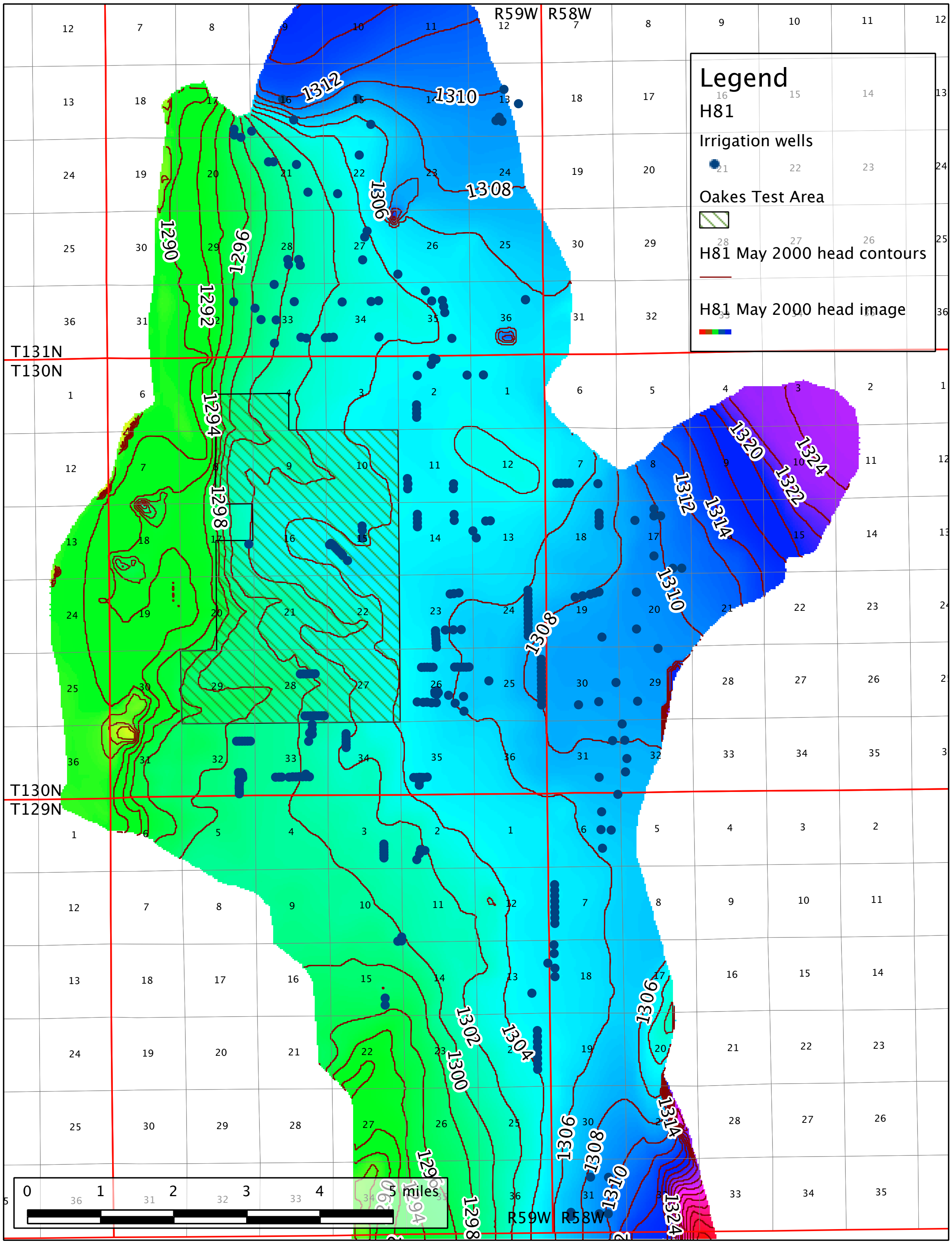

Figure F-94. Water level contours for **May 31, 2000. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

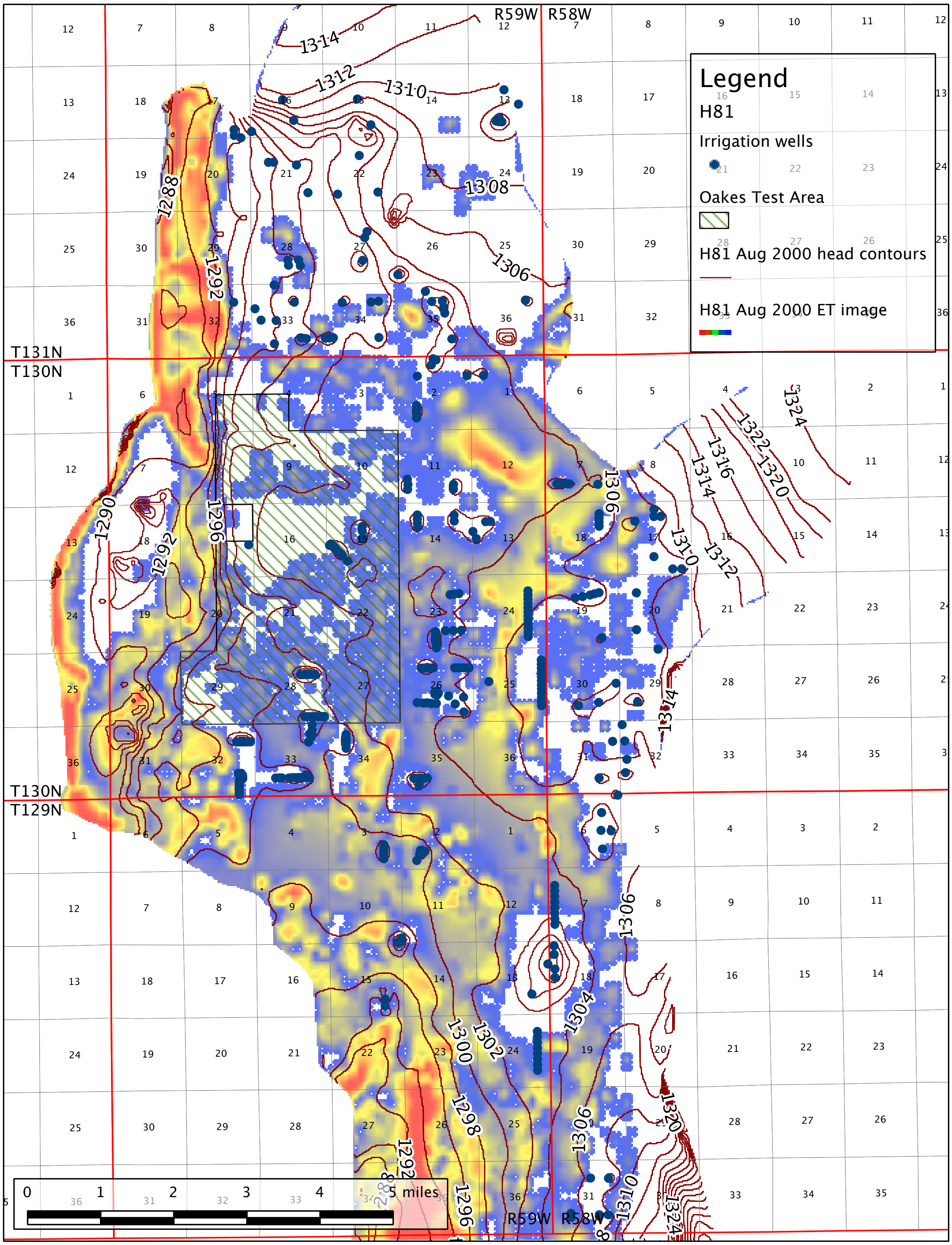

Figure F-95. Areas of evapotranspiration and water level contours for **August 31, 2000.** White is no ET. Red is maximum ET. **Run H81**, DSID-ESSER irrigation. Fullerton climate dataset.

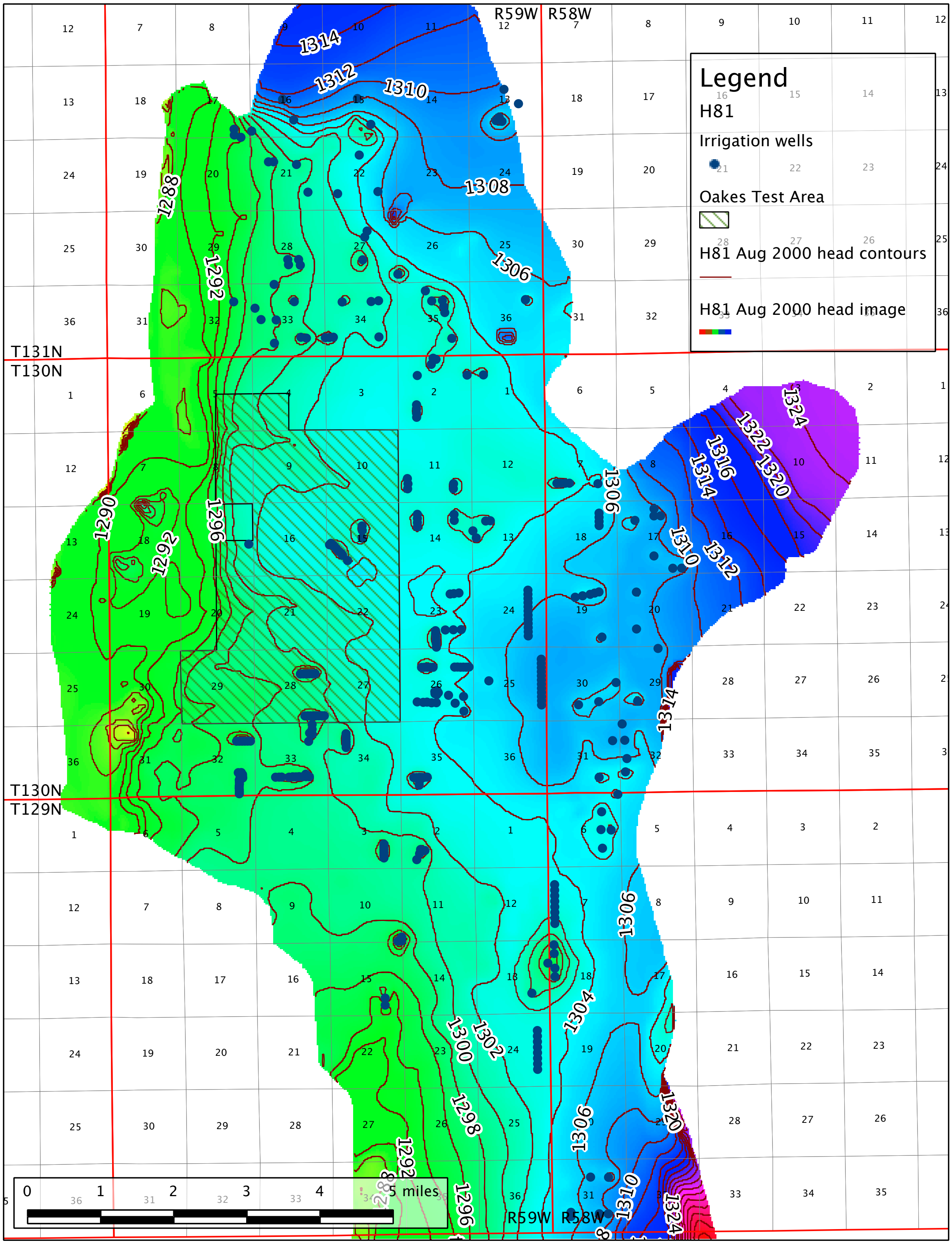

Figure F-96. Water level contours for **August 31, 2000. Run H81**, drains, permitted + DSID-ESSER irrigation. Fullerton climate dataset.

RUN F32, DRAINS, PERMITTED IRRIGATION - OAKES

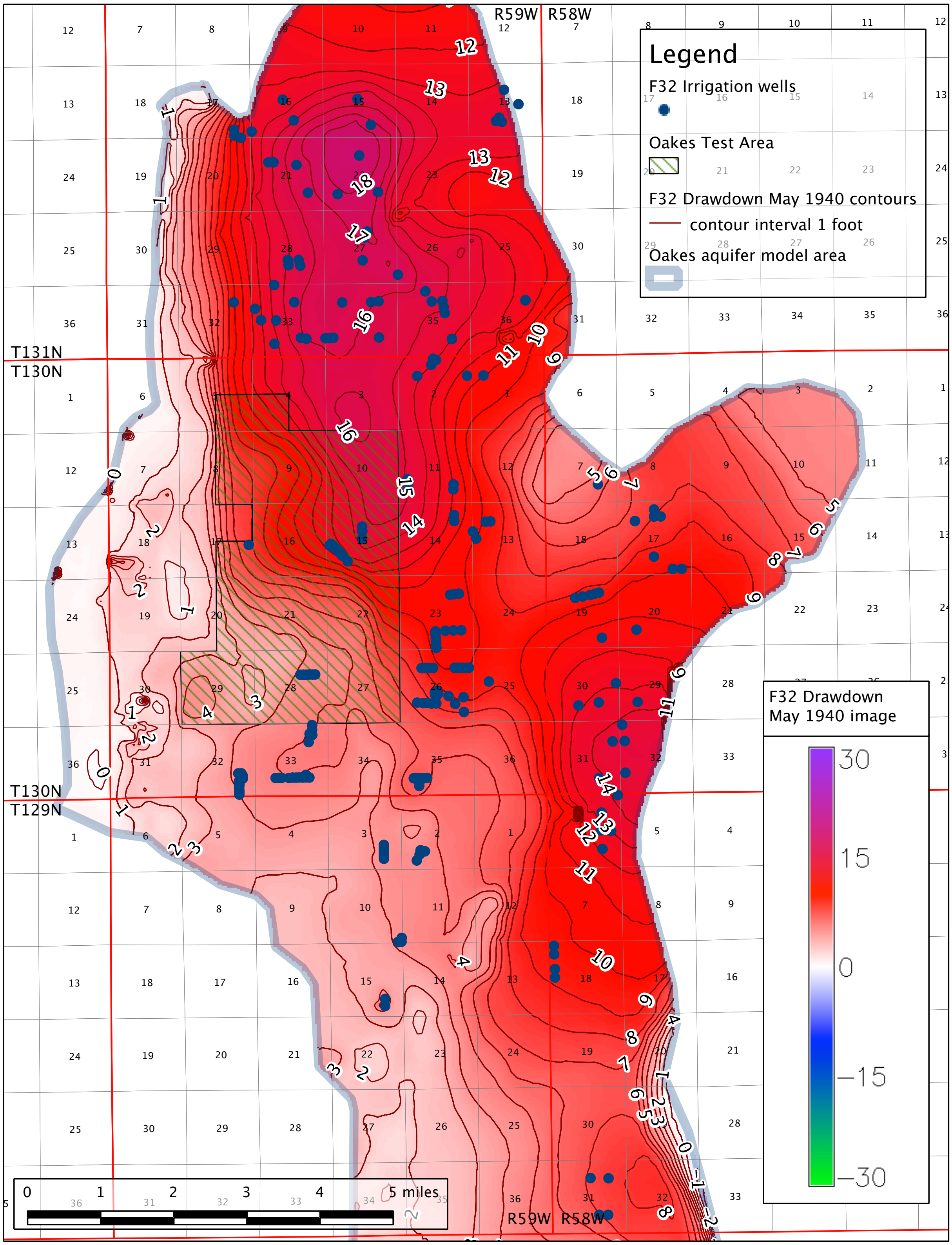

Figure F-97. Drawdown on **May 31, 1940 for** drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

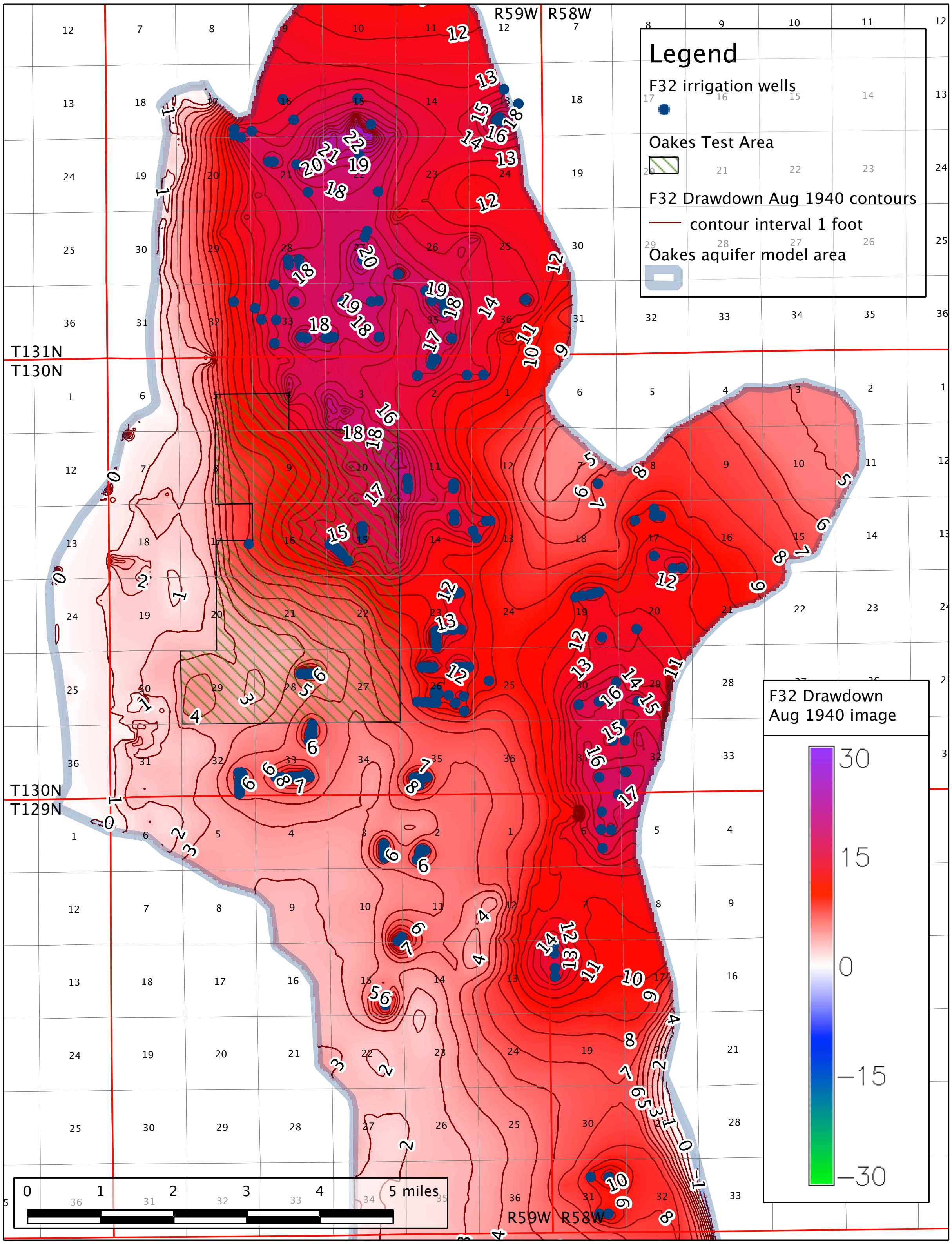

Figure F-98. Drawdown on **August 31, 1940** for drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

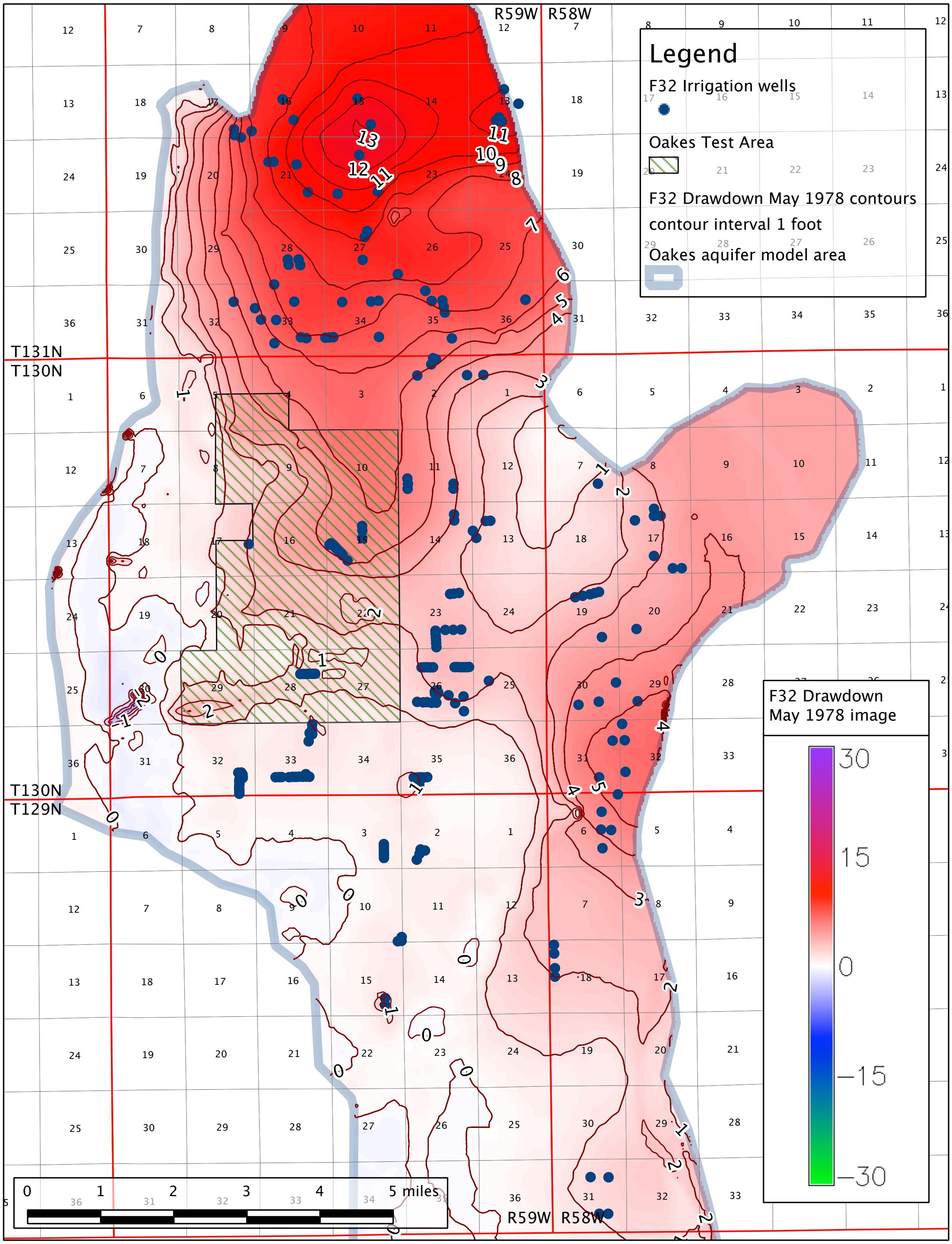

Figure F-99. Drawdown on **May 31, 1978** for drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

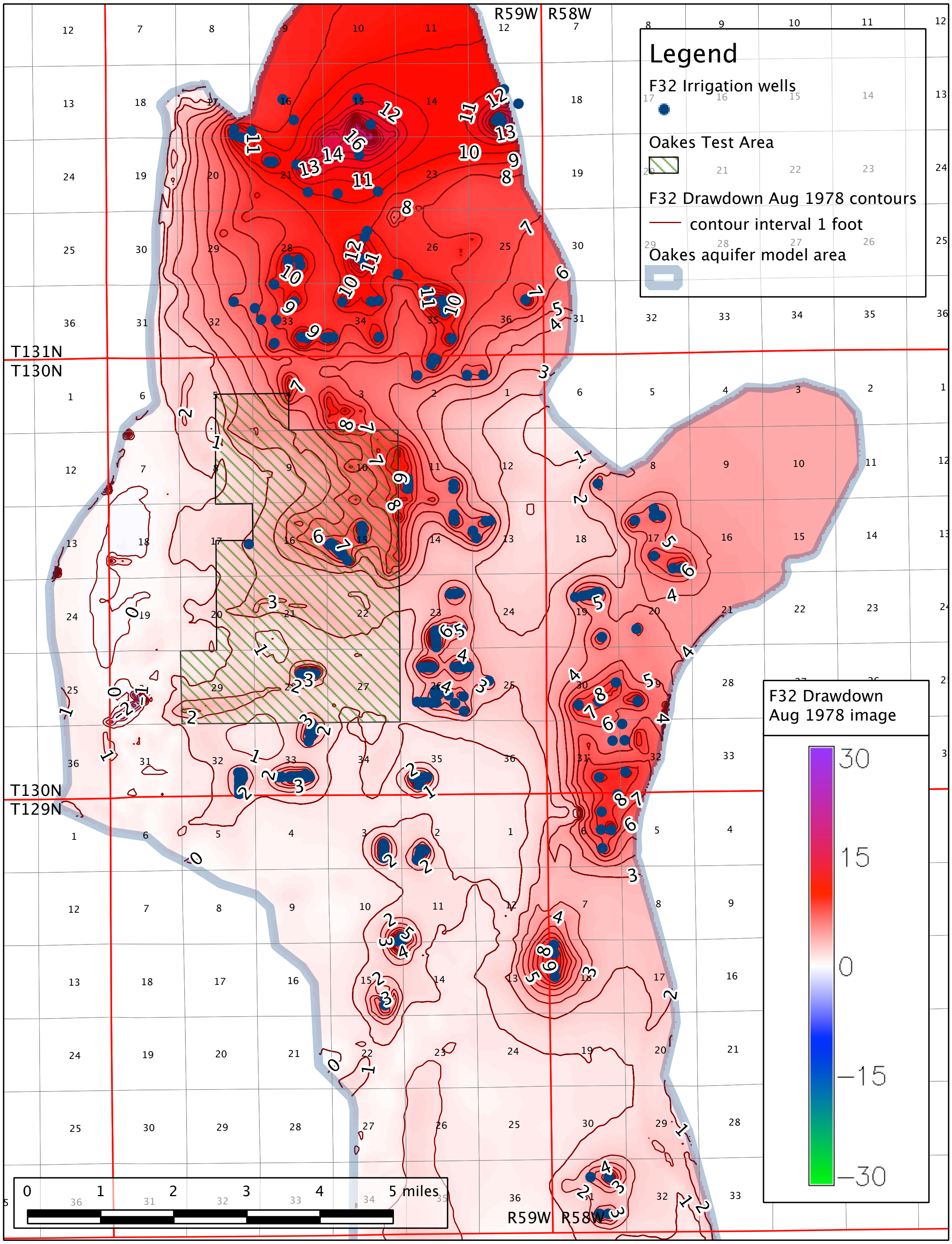

Figure F-100. Drawdown on **August 31, 1978** for drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

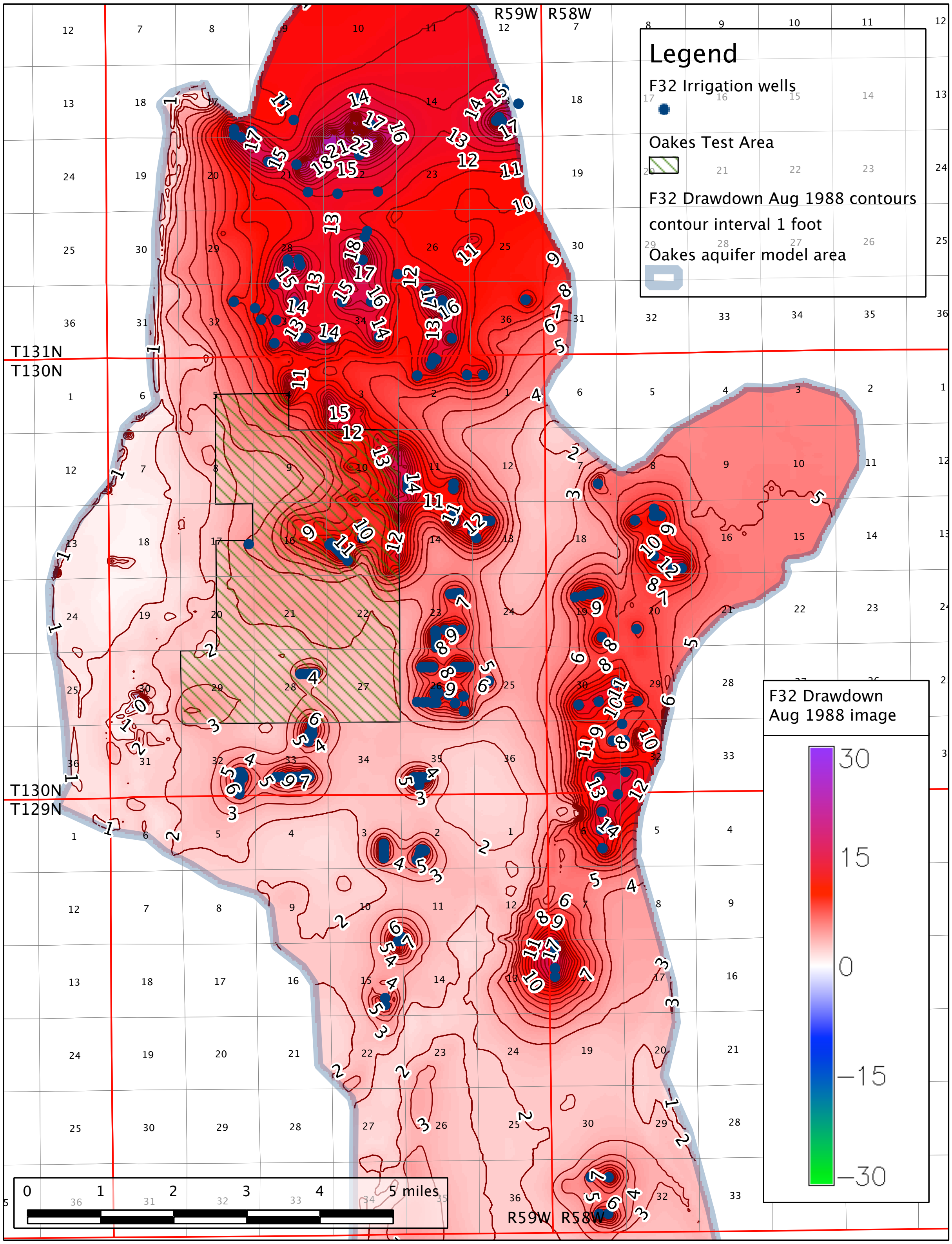

Figure F-101. Drawdown on **August 31, 1988** for drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

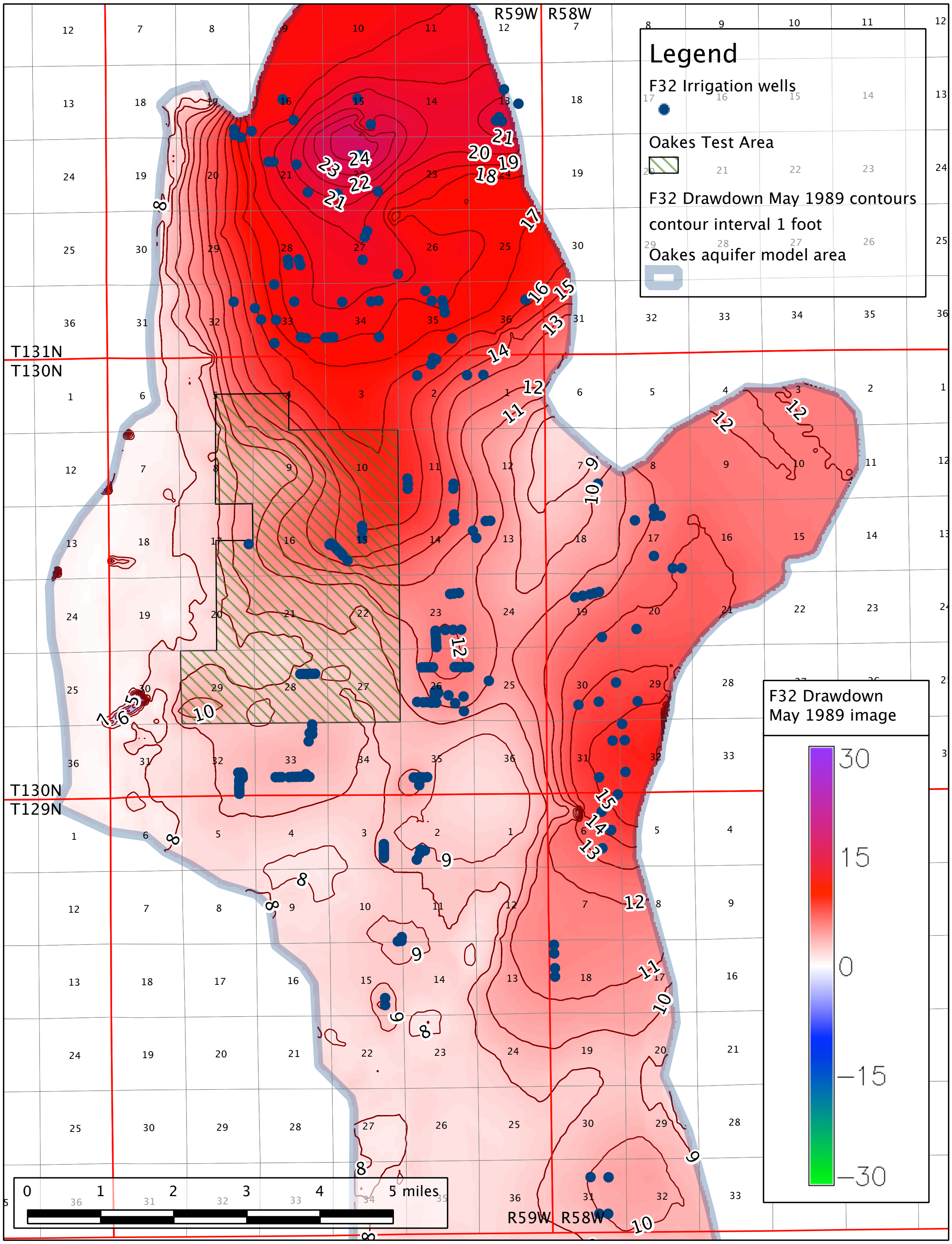

Figure F-102. Drawdown on **May 31, 1989** for drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

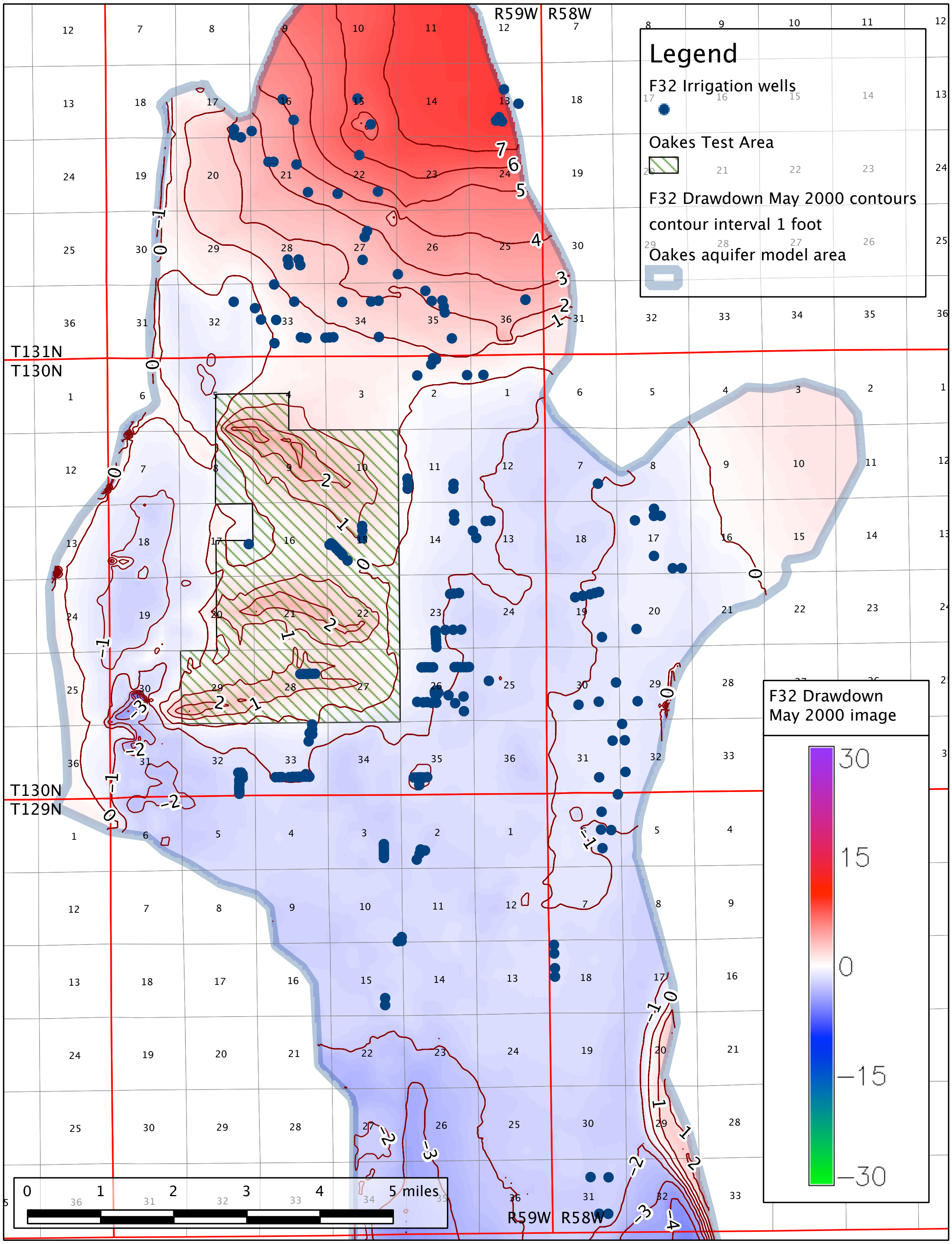

Figure F-103. Drawdown on **May 31, 2000 for** drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

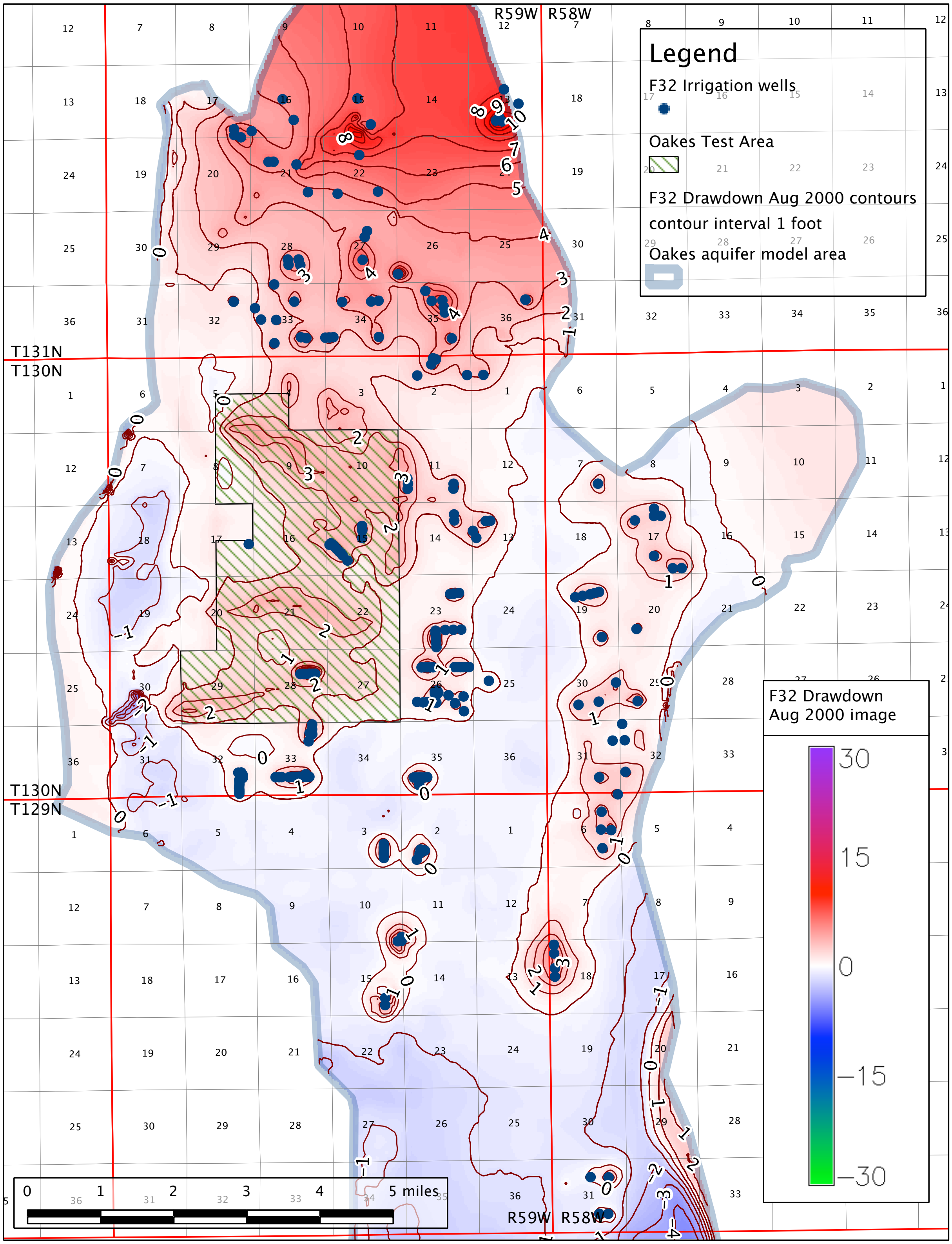

Figure F-104. Drawdown on **August 31, 2000** for drains and permitted irrigation simulation using Oakes climate dataset (**run F32**). Simulation period 1905 to 2005.

RUN F38b, DRAINS, PERMITTED+PENDING IRRIGATION - OAKES

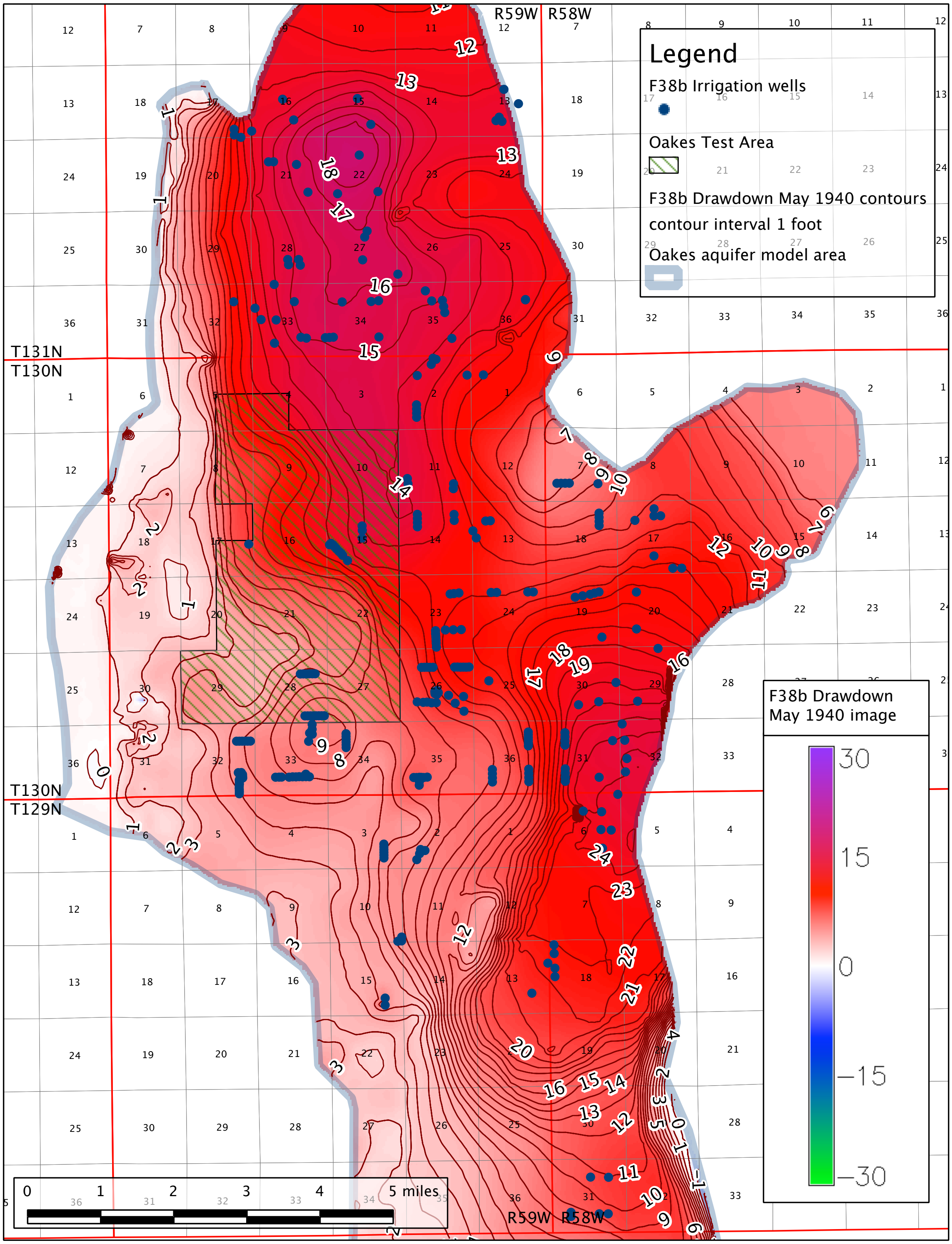

Figure F-105. Drawdown on **May 31, 1940** for drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

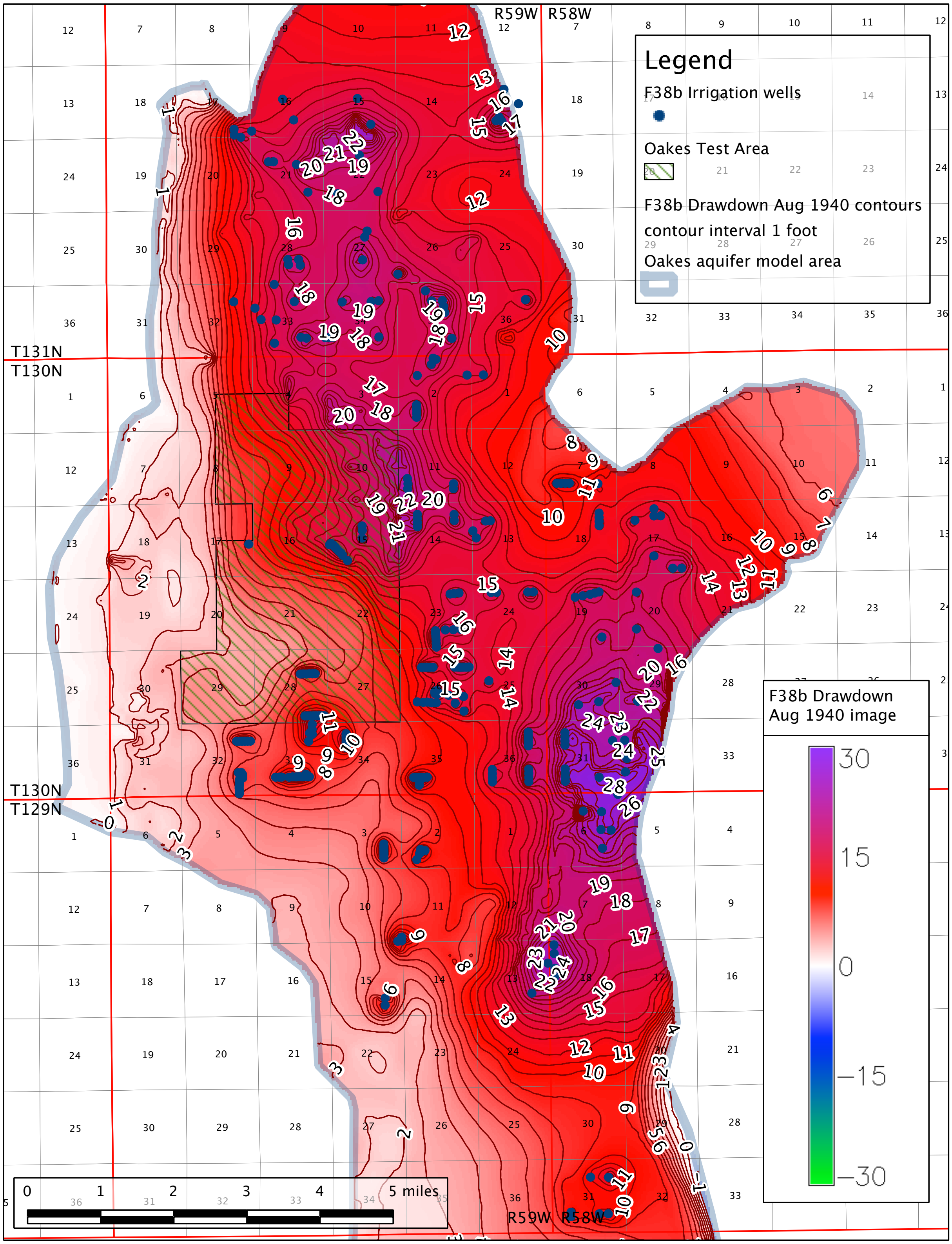

Figure F-106. Drawdown on **August 31, 1940** for drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

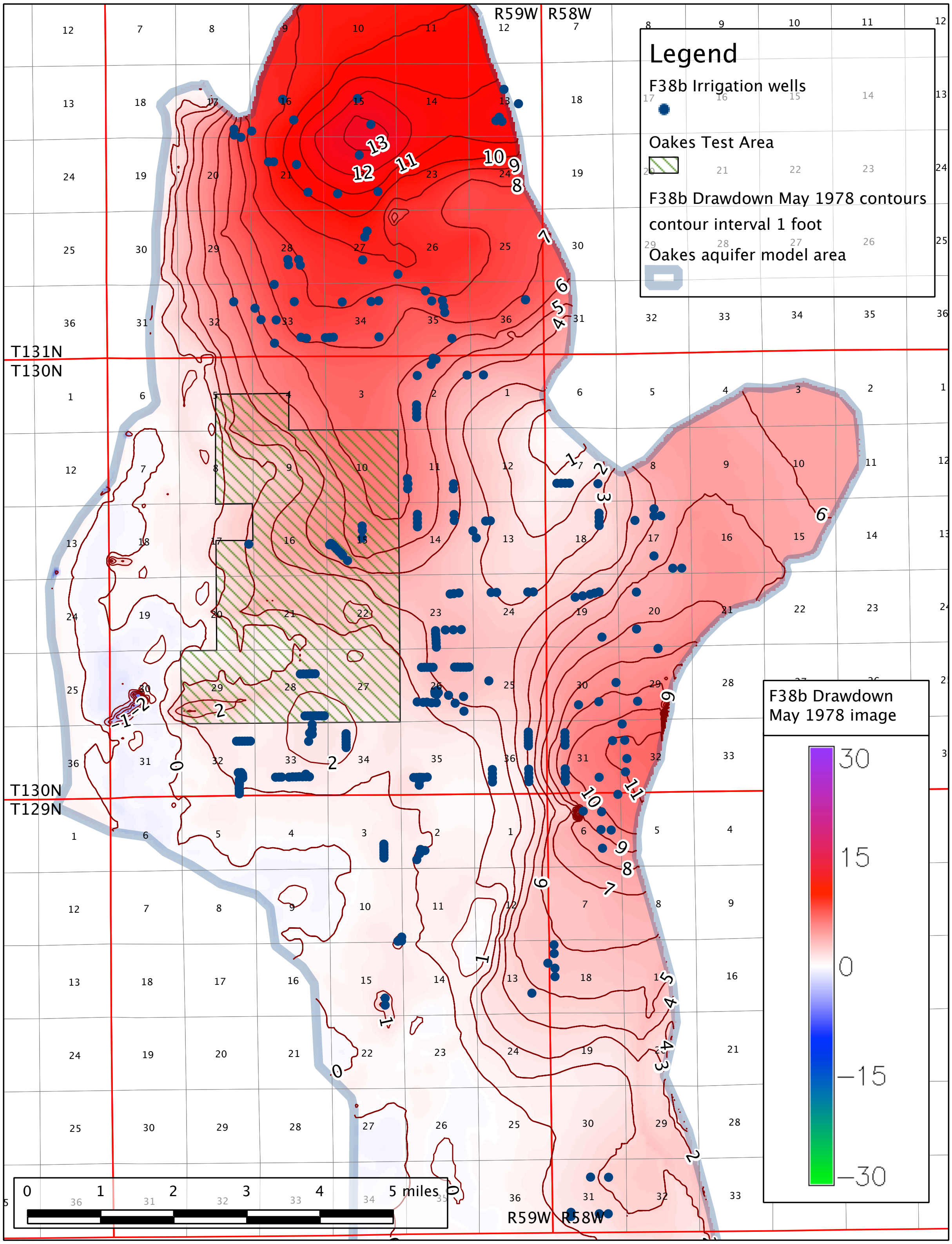

Figure F-107. Drawdown on **May 31, 1978** for drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

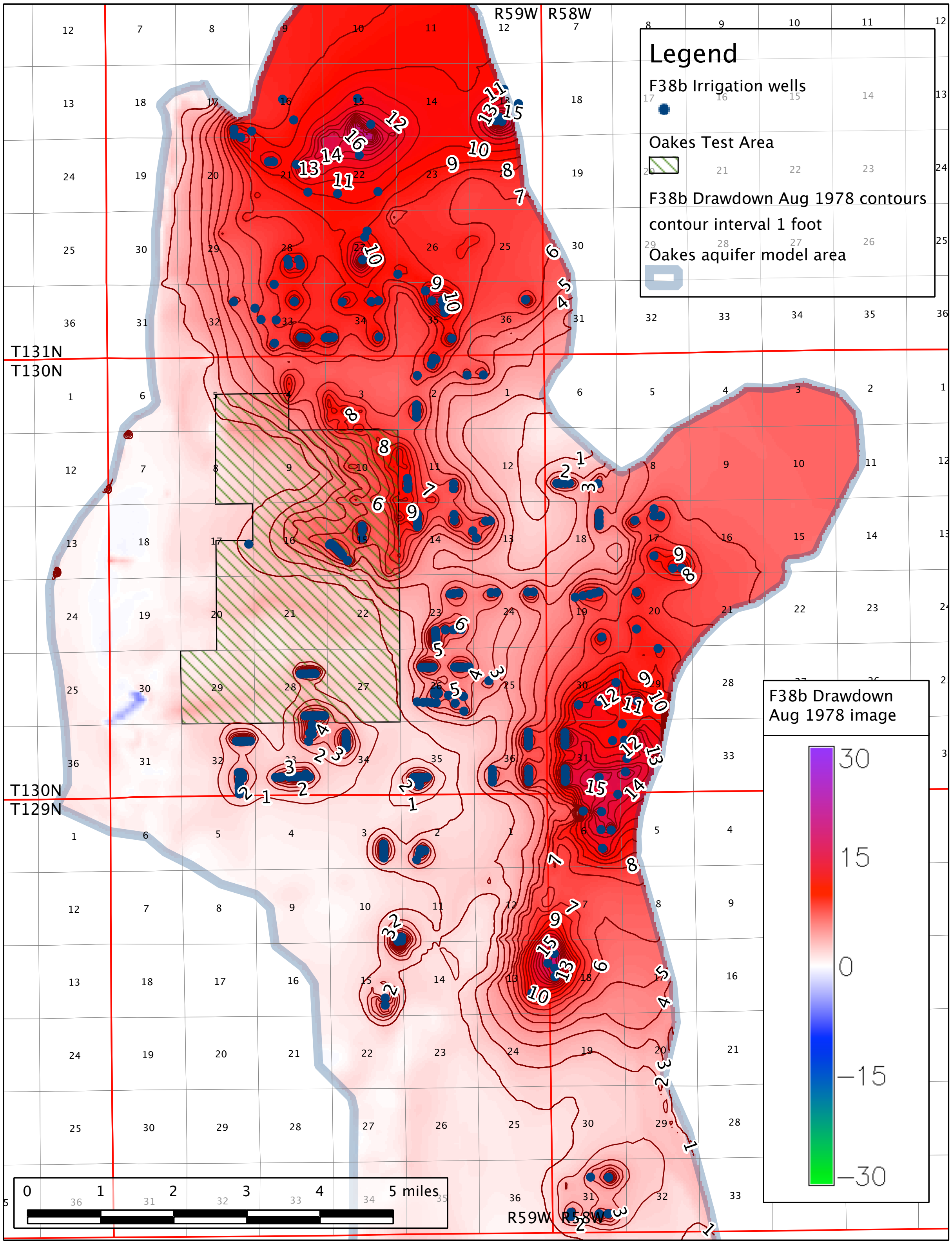

Figure F-108. Drawdown on **August 31, 1978** for drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

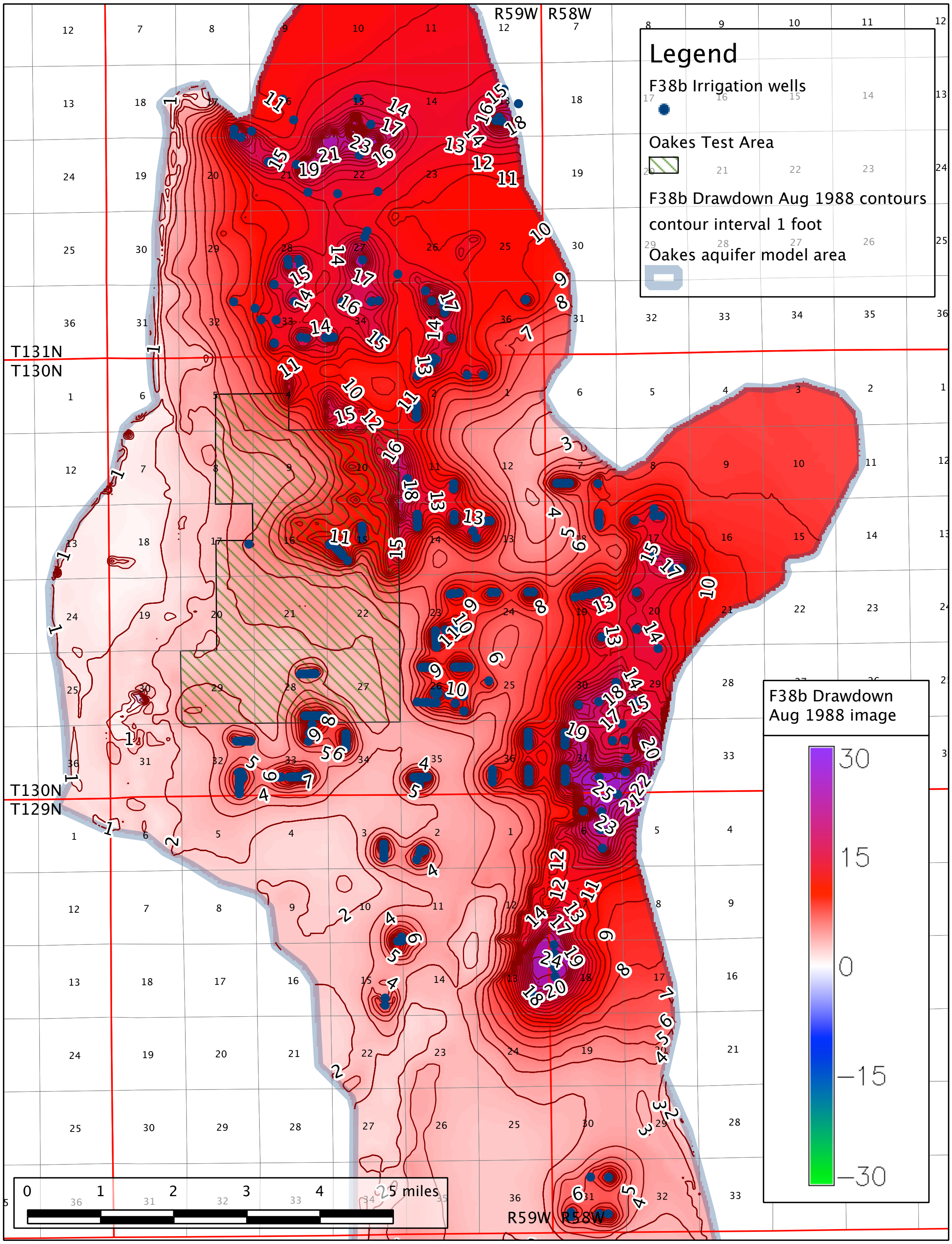

Figure F-109. Drawdown on **August 31, 1988** for drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

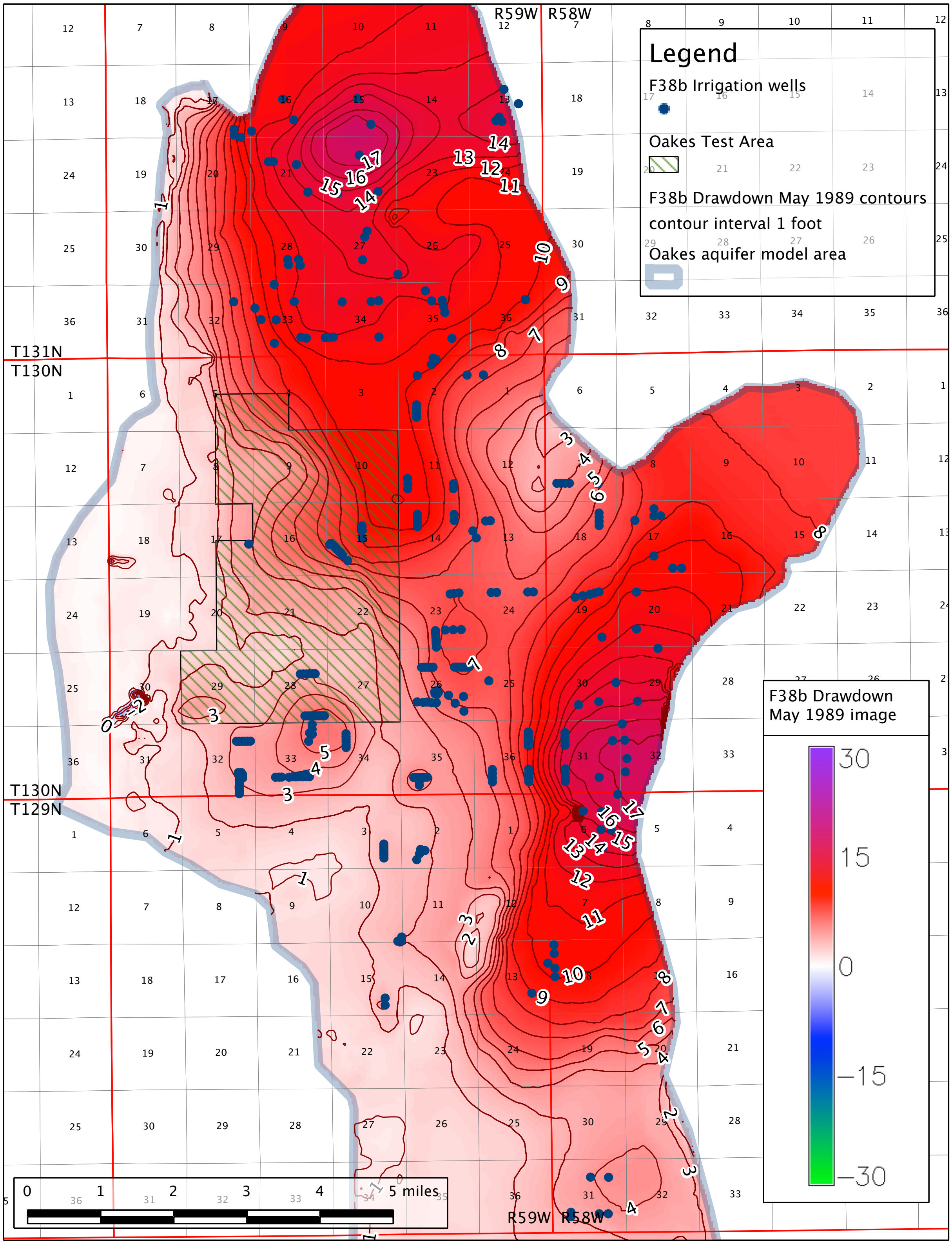

Figure F-110. Drawdown on **May 31, 1989** for drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

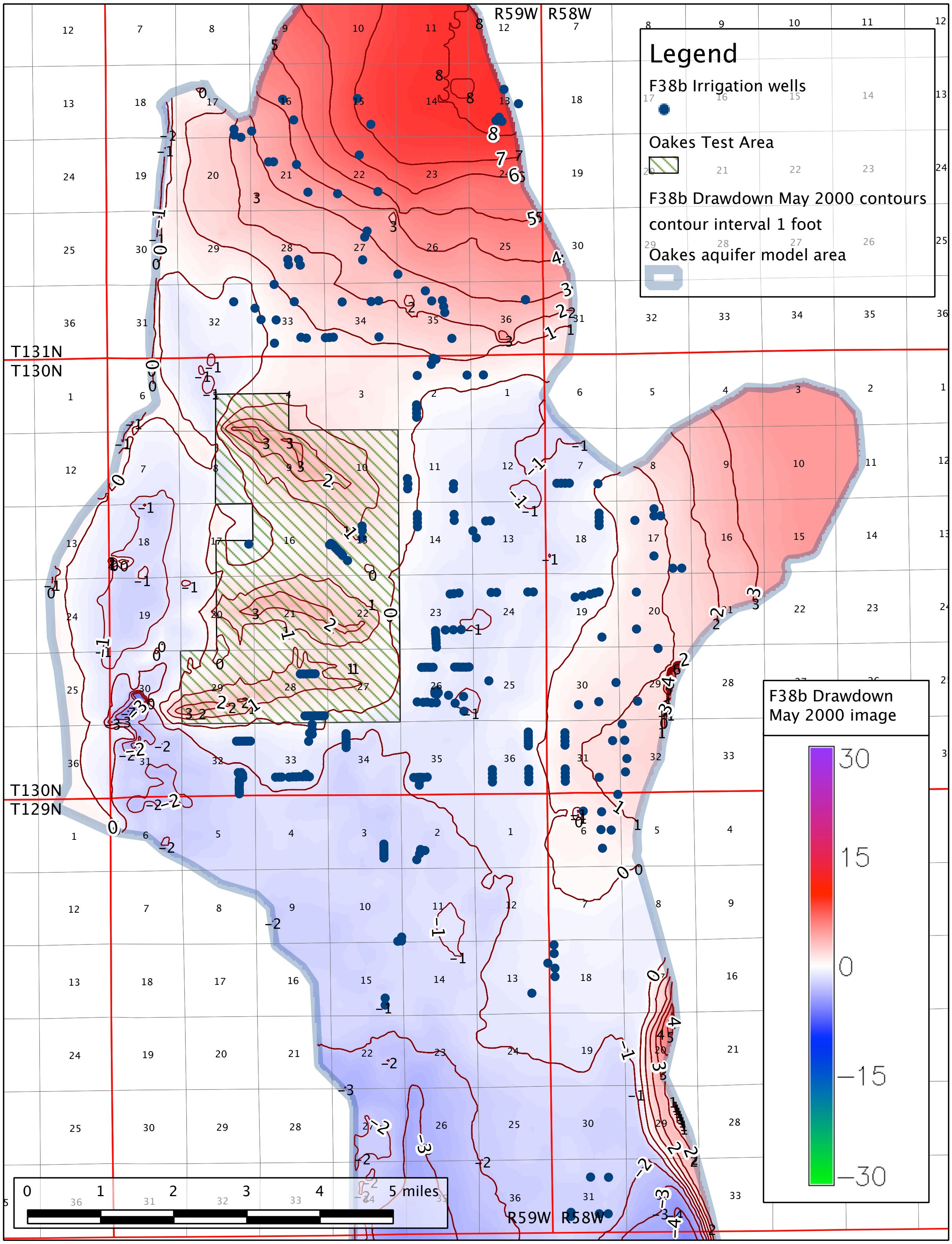

Figure F-111. Drawdown on **May 31, 2000 for** drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

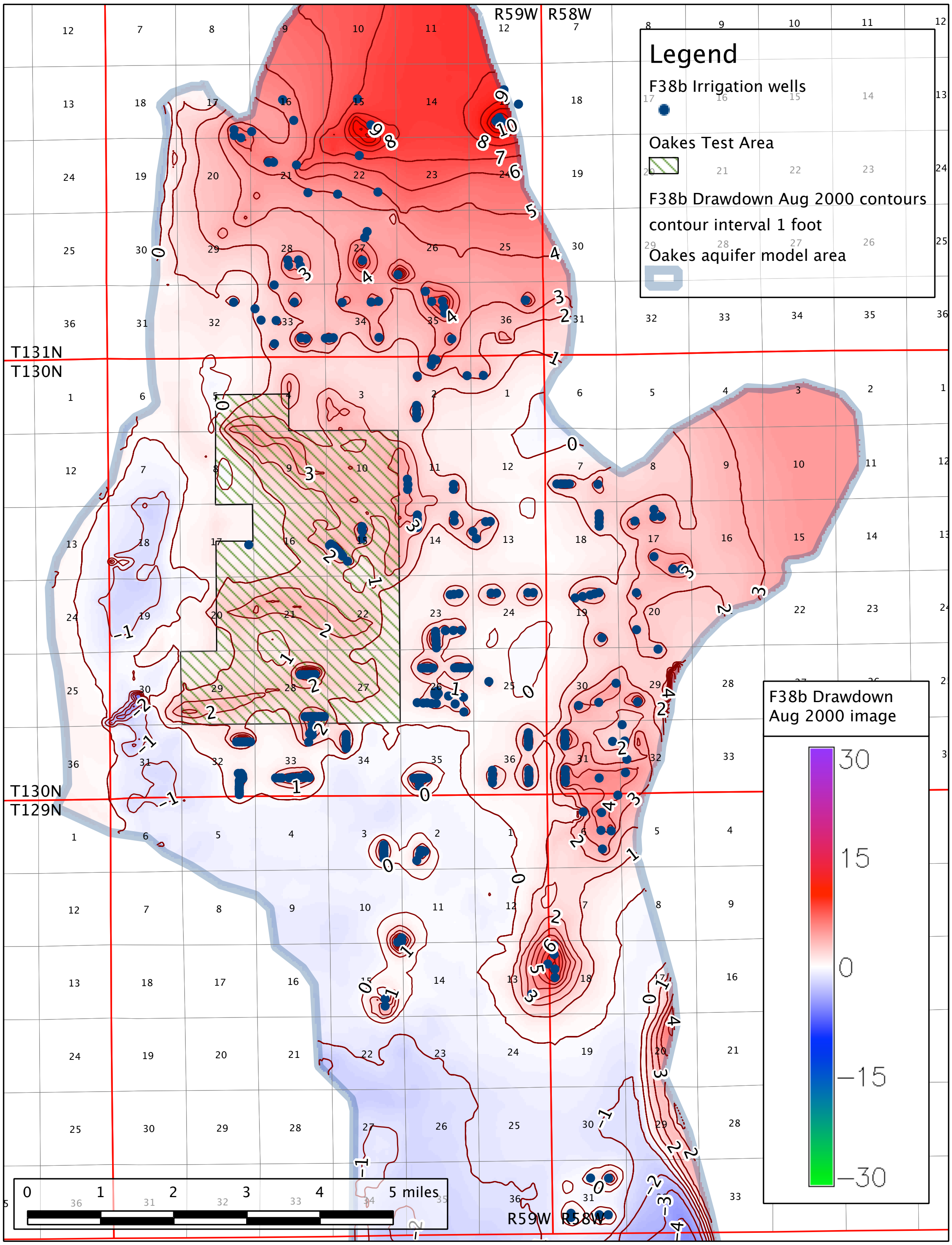

Figure F-112. Drawdown on **August 31, 2000** for drains and permitted + pending irrigation simulation using Oakes climate dataset (**run F38b**). Simulation period 1905 to 2005.

RUN H31, DRAINS, PERMITTED+PENDING+DSID-ESSER IRRIGATION - OAKES

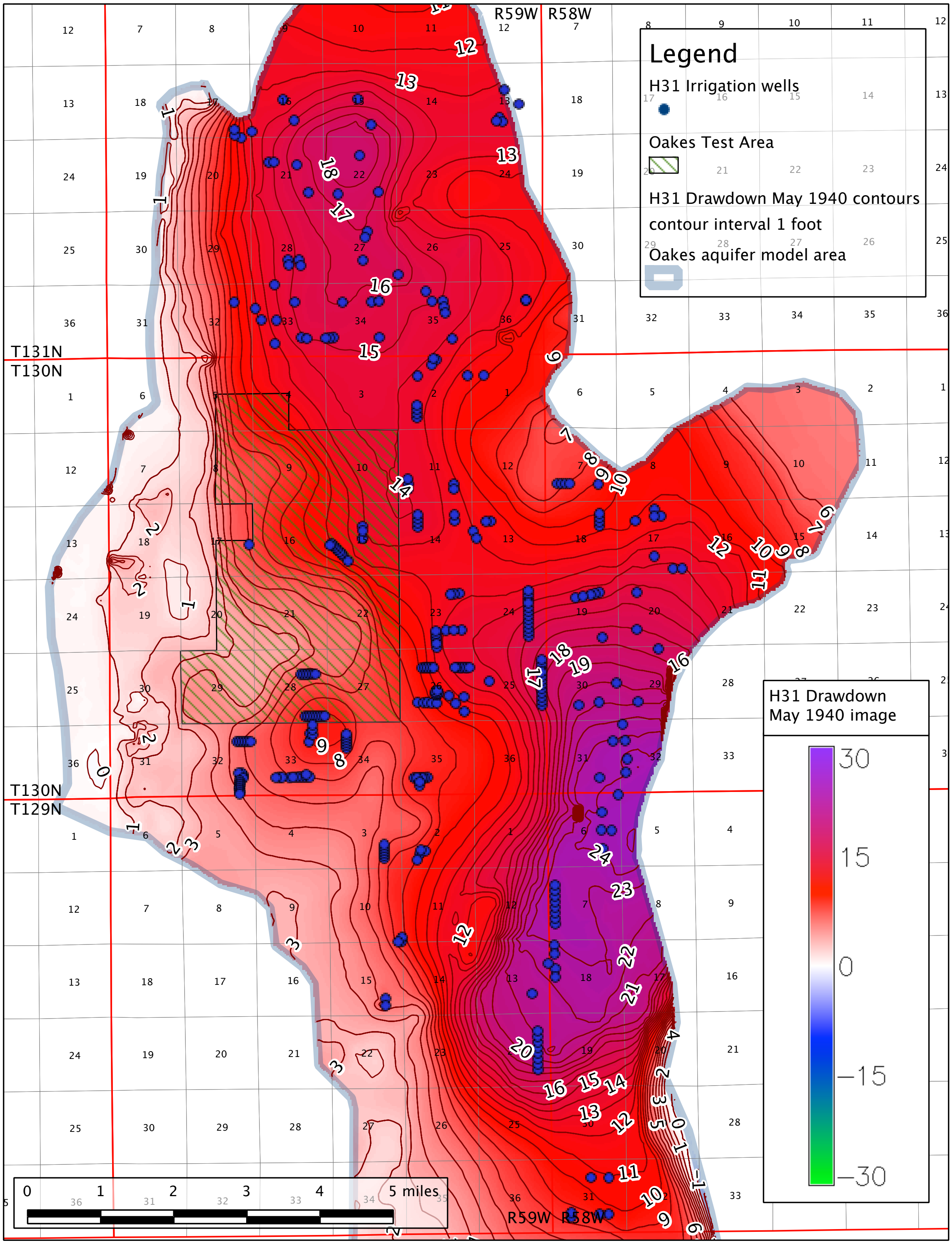

Figure F-113. Drawdown on **May 31, 1940** for drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

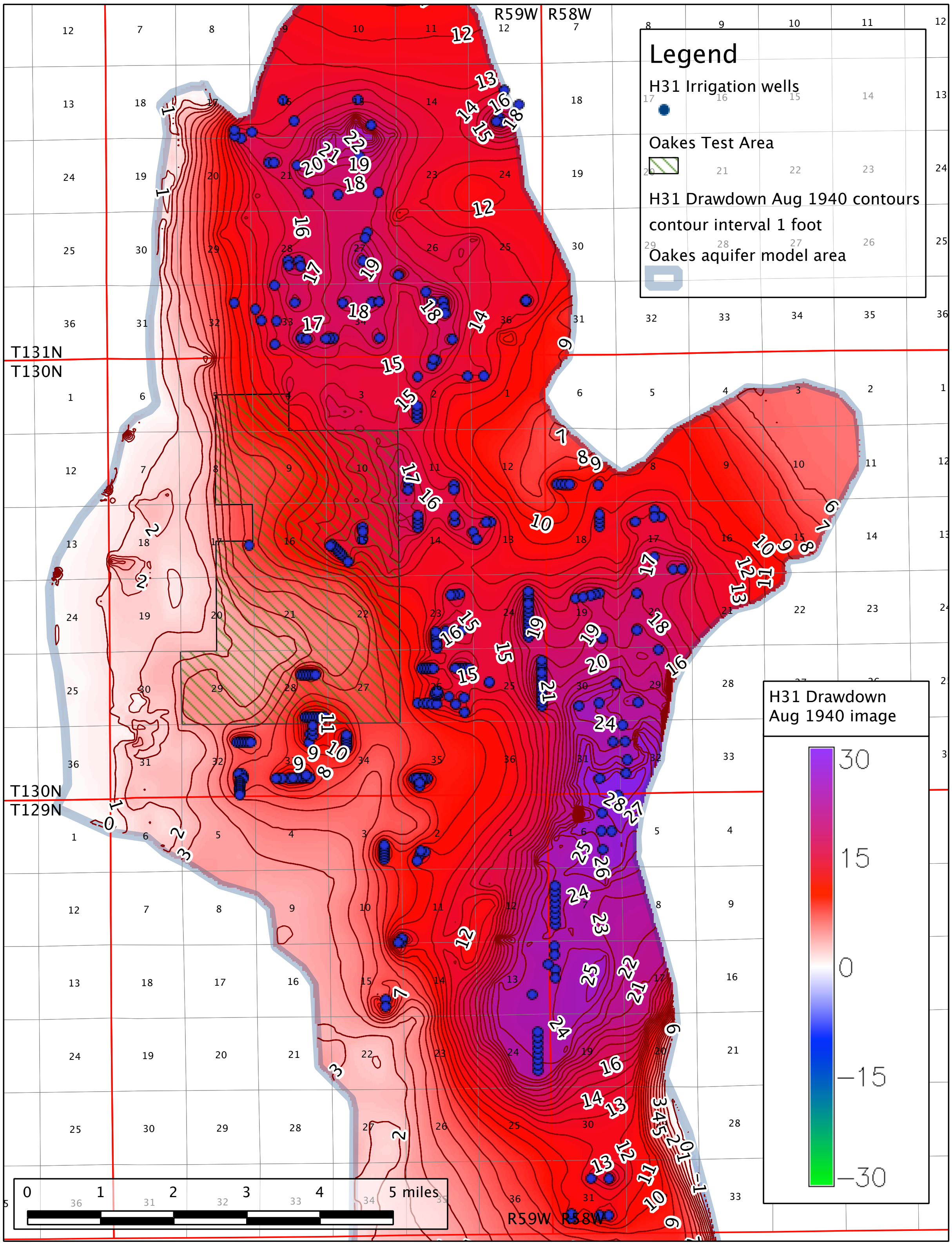

Figure F-114. Drawdown on **August 31, 1940** for drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

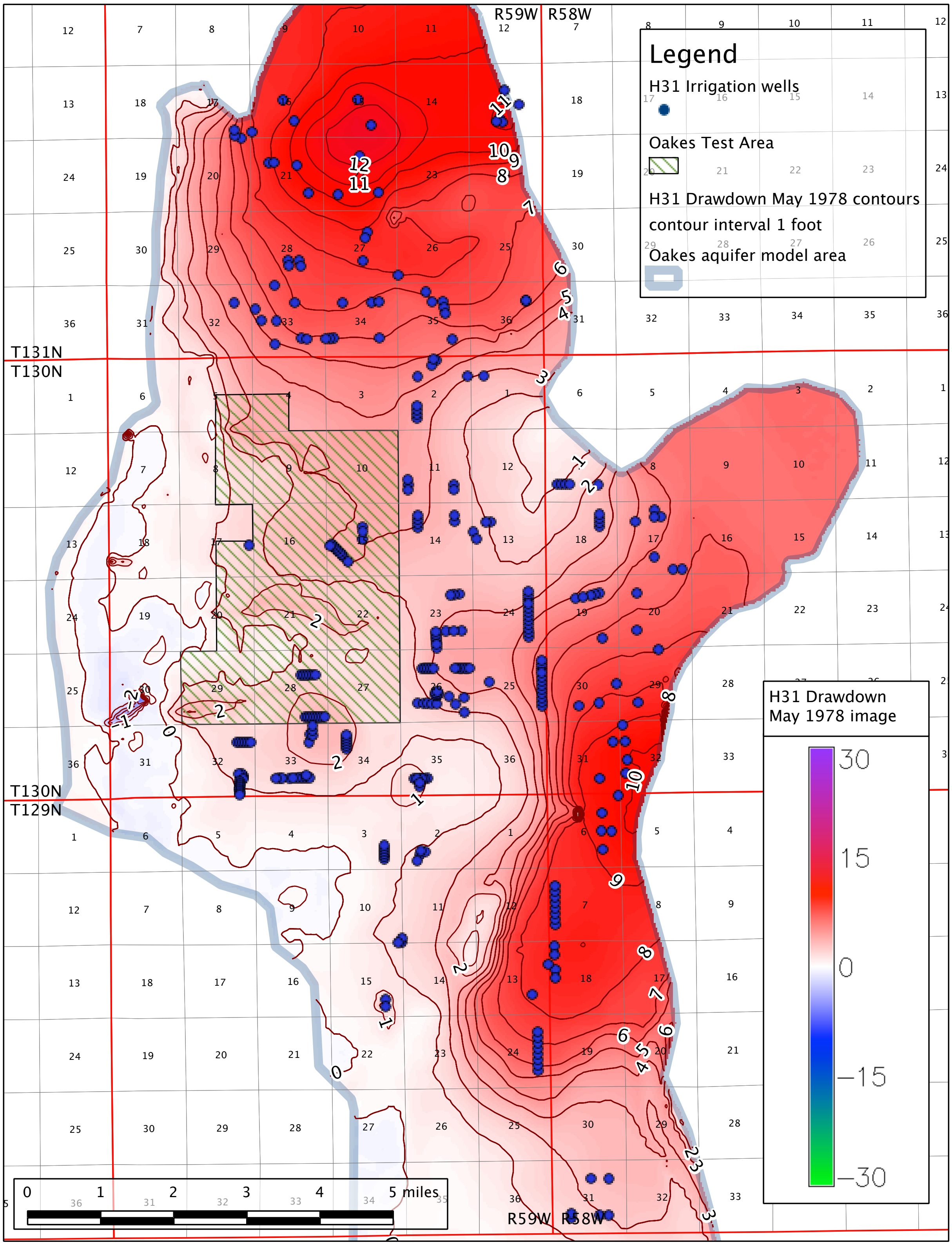

Figure F-115. Drawdown on **May 31, 1978 for** drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

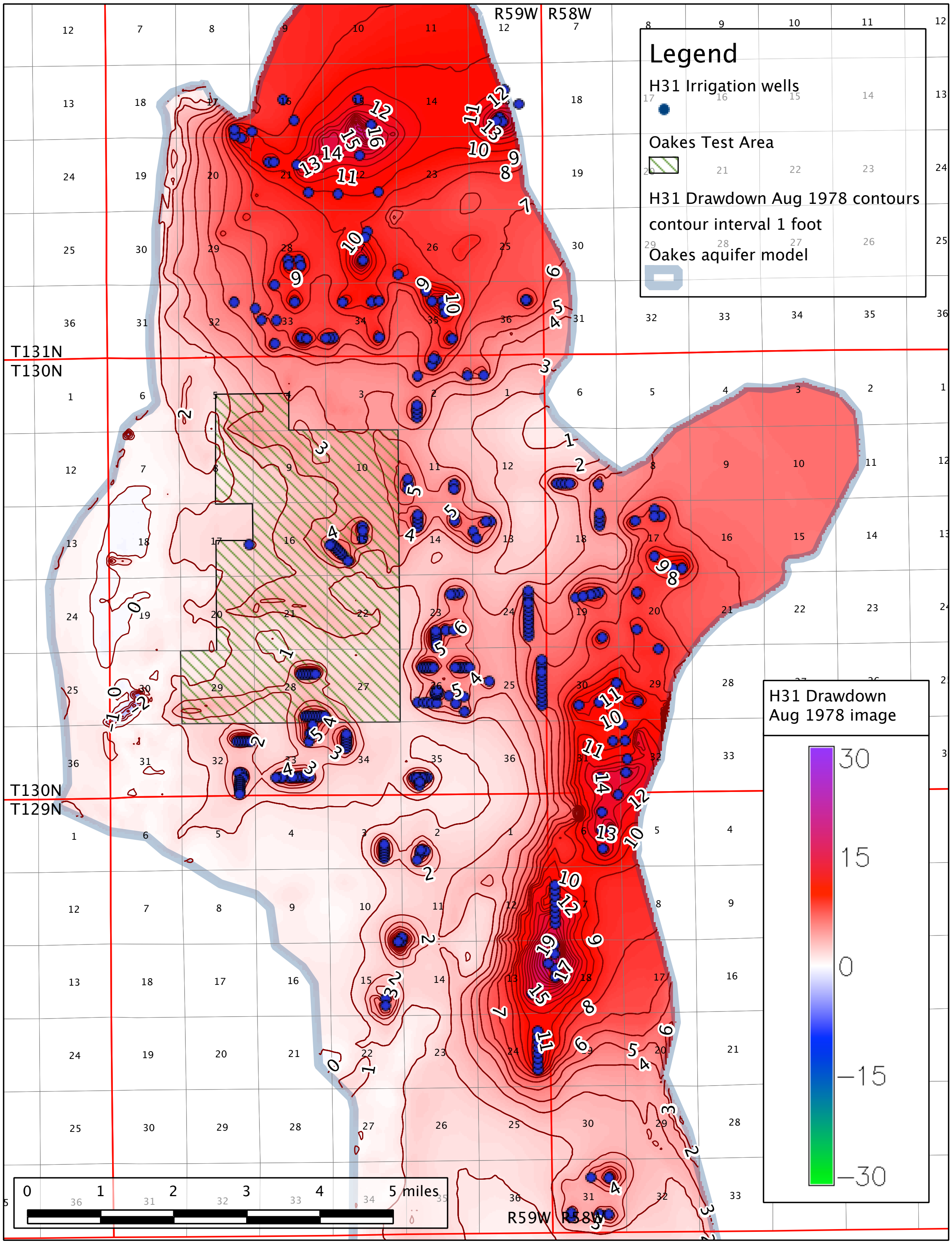

Figure F-116. Drawdown on **August 31, 1978** for drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

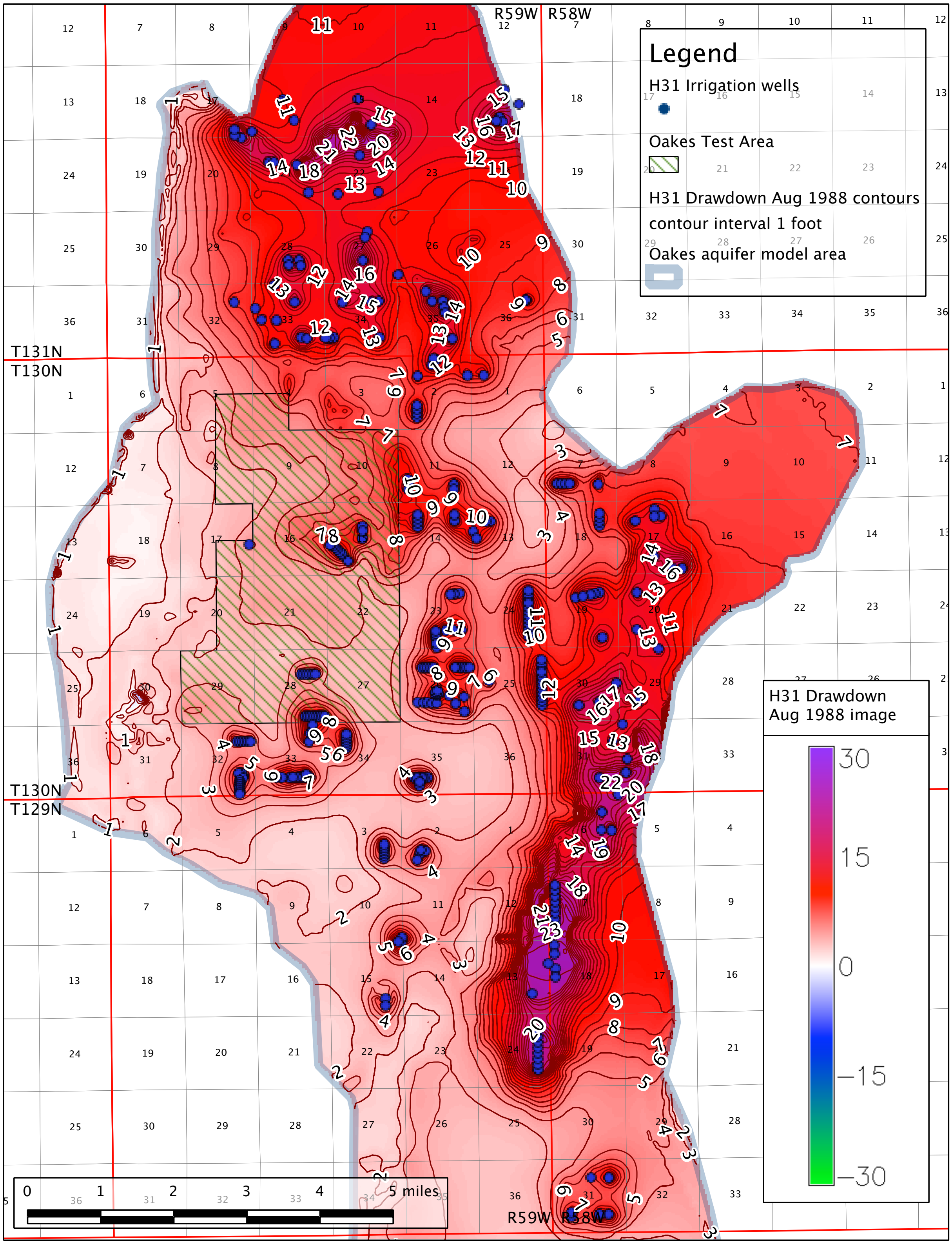

Figure F-117. Drawdown on **August 31, 1988** for drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

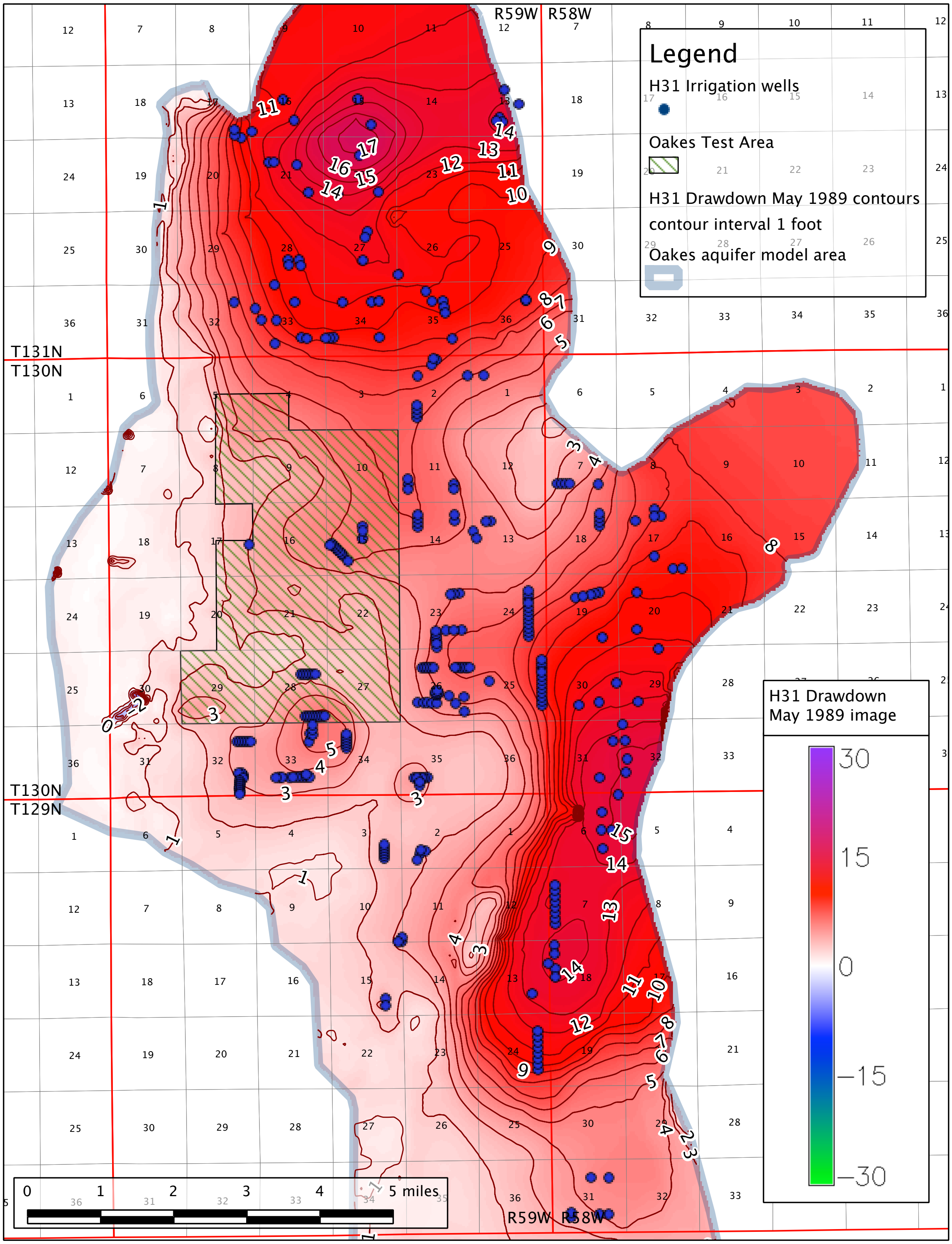

Figure F-118. Drawdown on **May 31, 1989 for** drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

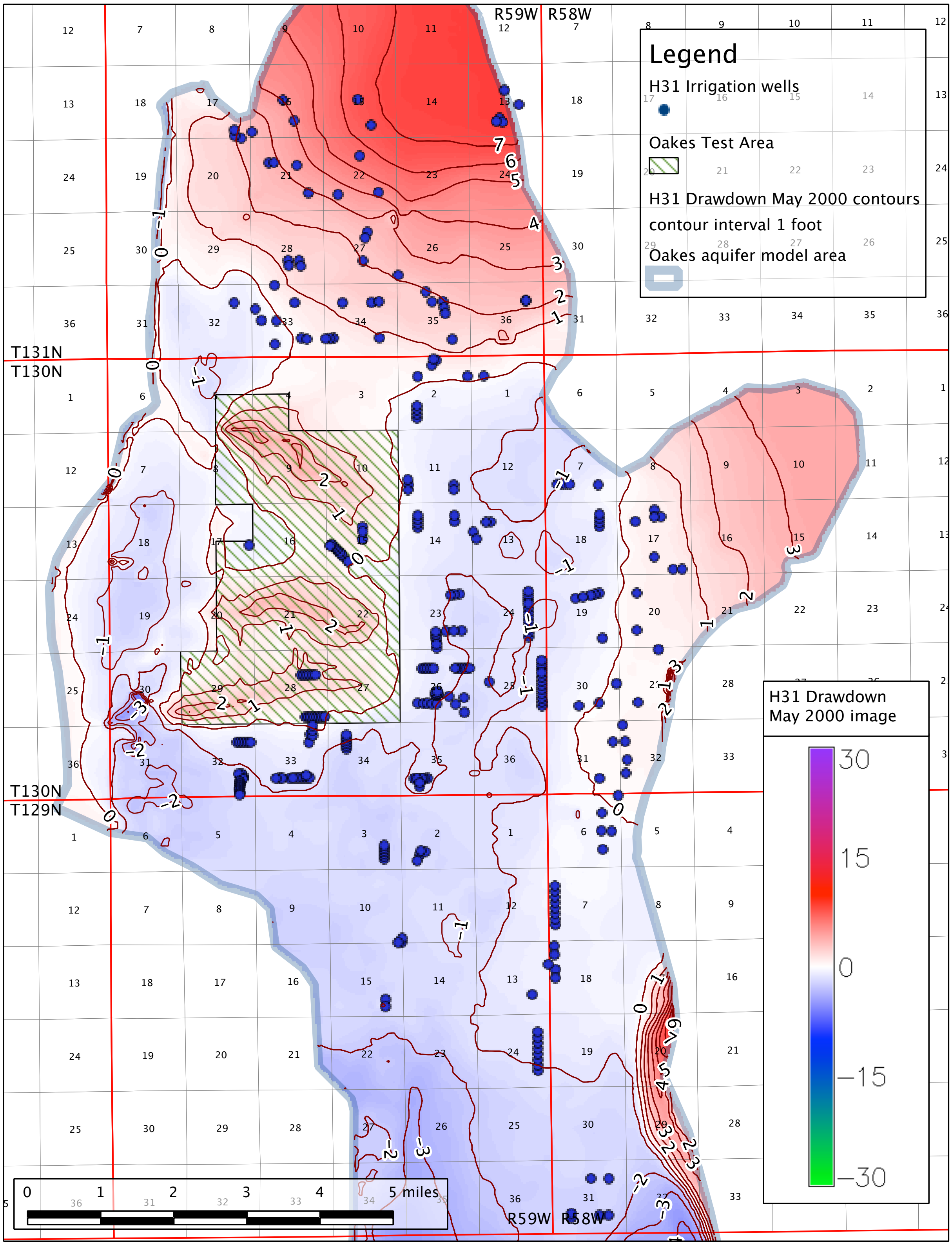

Figure F-119. Drawdown on **May 31, 2000 for** drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

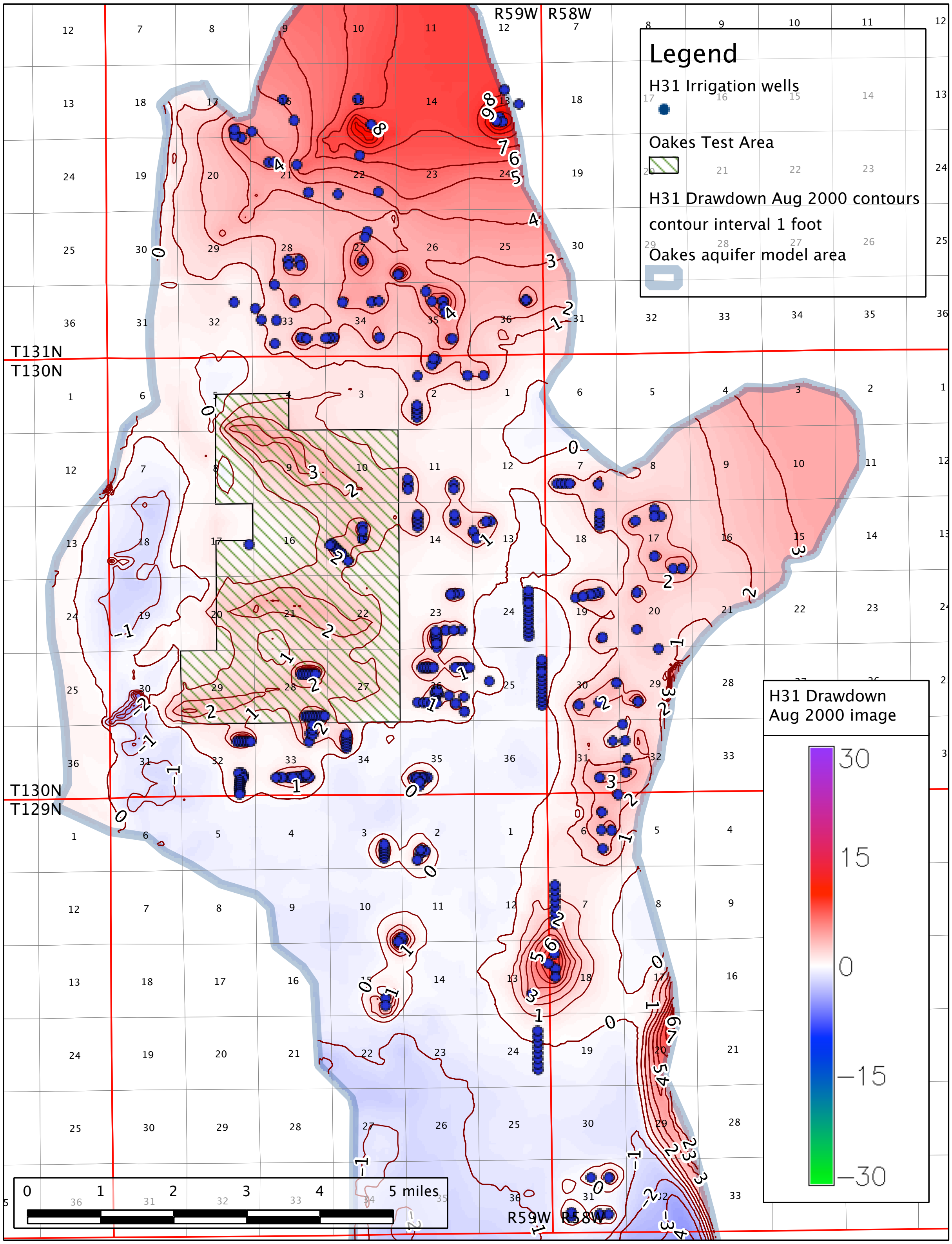

Figure F-120. Drawdown on **August 31, 2000** for drains and permitted + DSID-ESSER irrigation simulation using Oakes climate dataset (**run H31**). Simulation period 1905 to 2005.

WATER LEVEL DIFFERENCE RUN H31 (DSID_ESSER) - F32 (permitted)

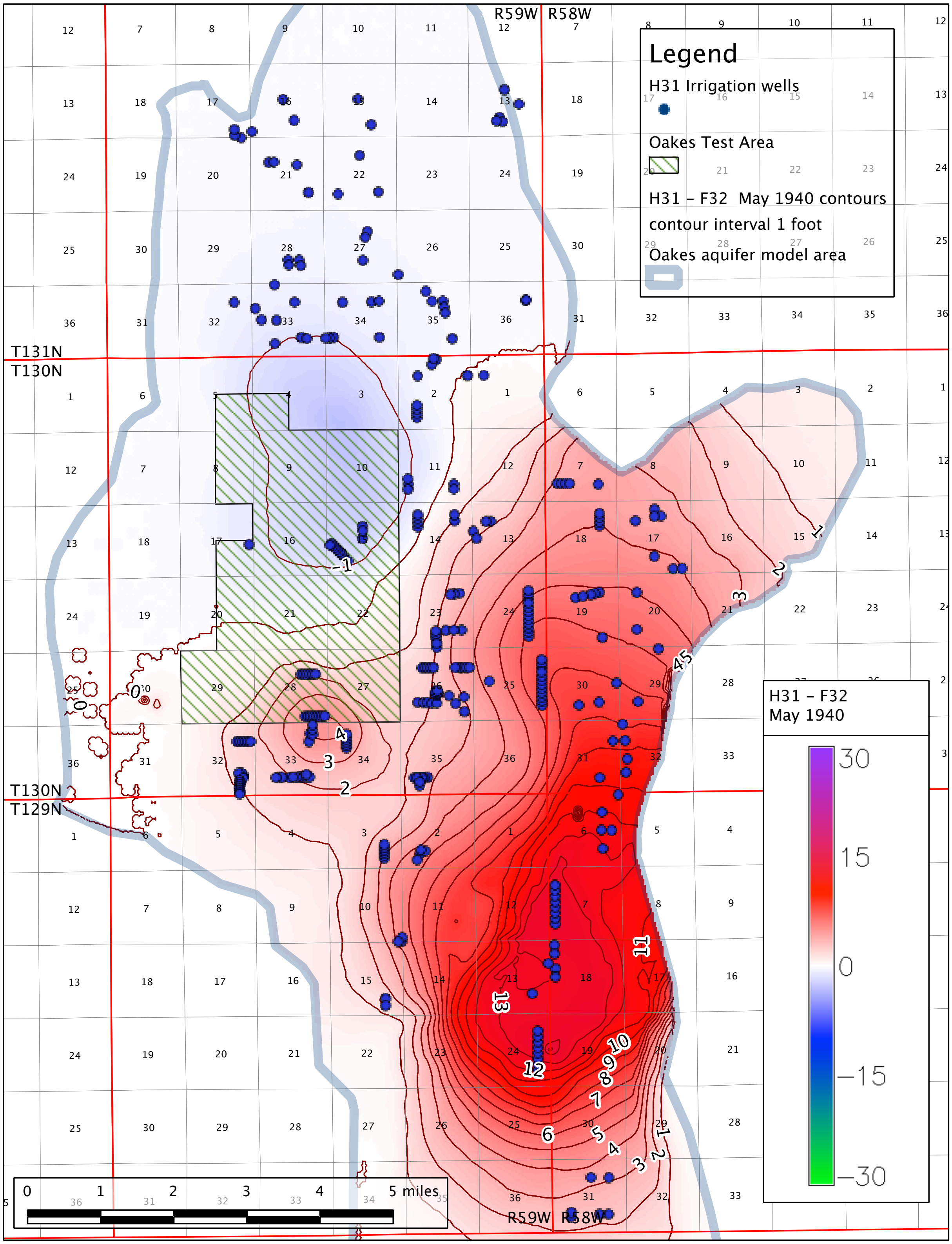

Figure F-121. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **May 31, 1940** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

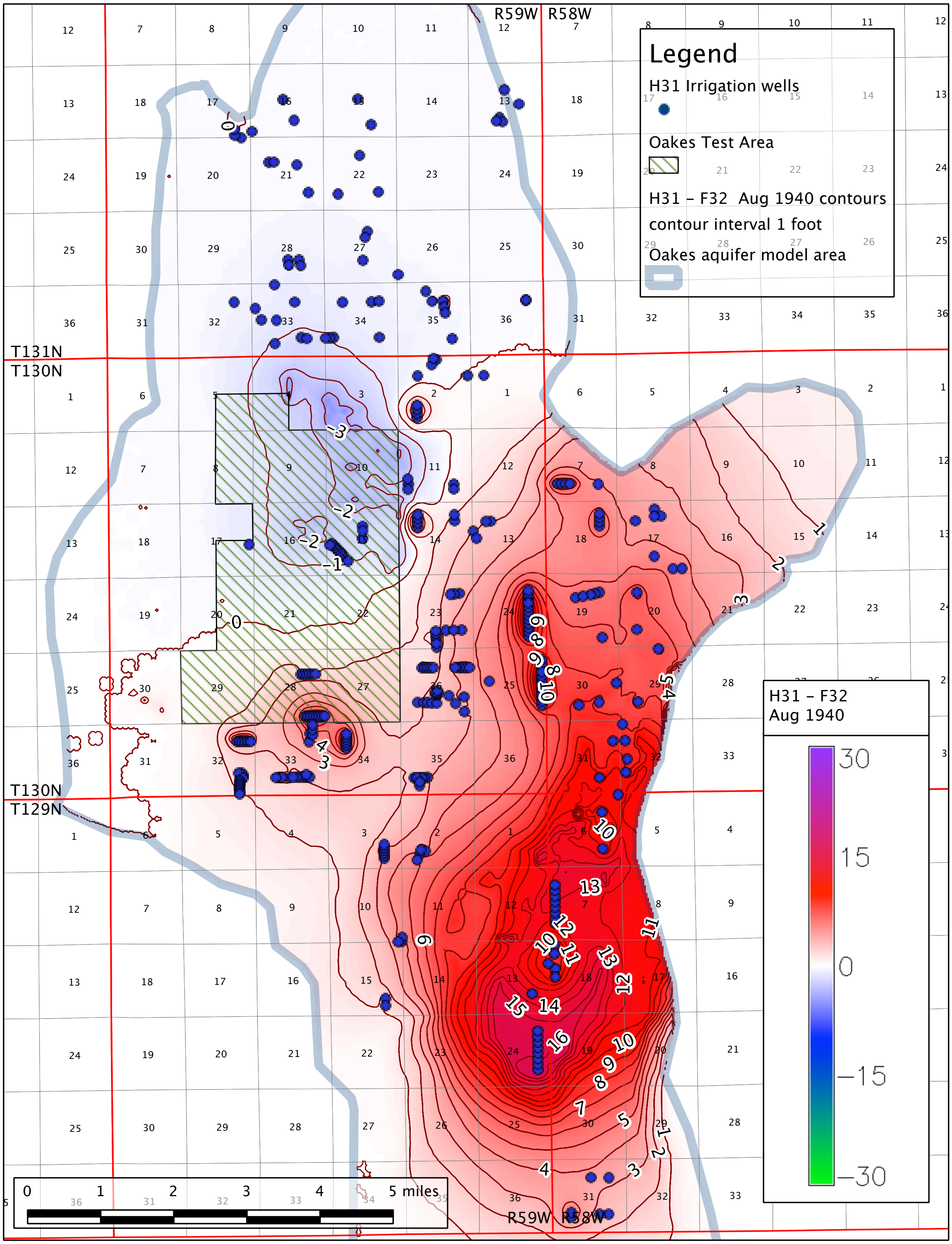

Figure F-122. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **August 31, 1940** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

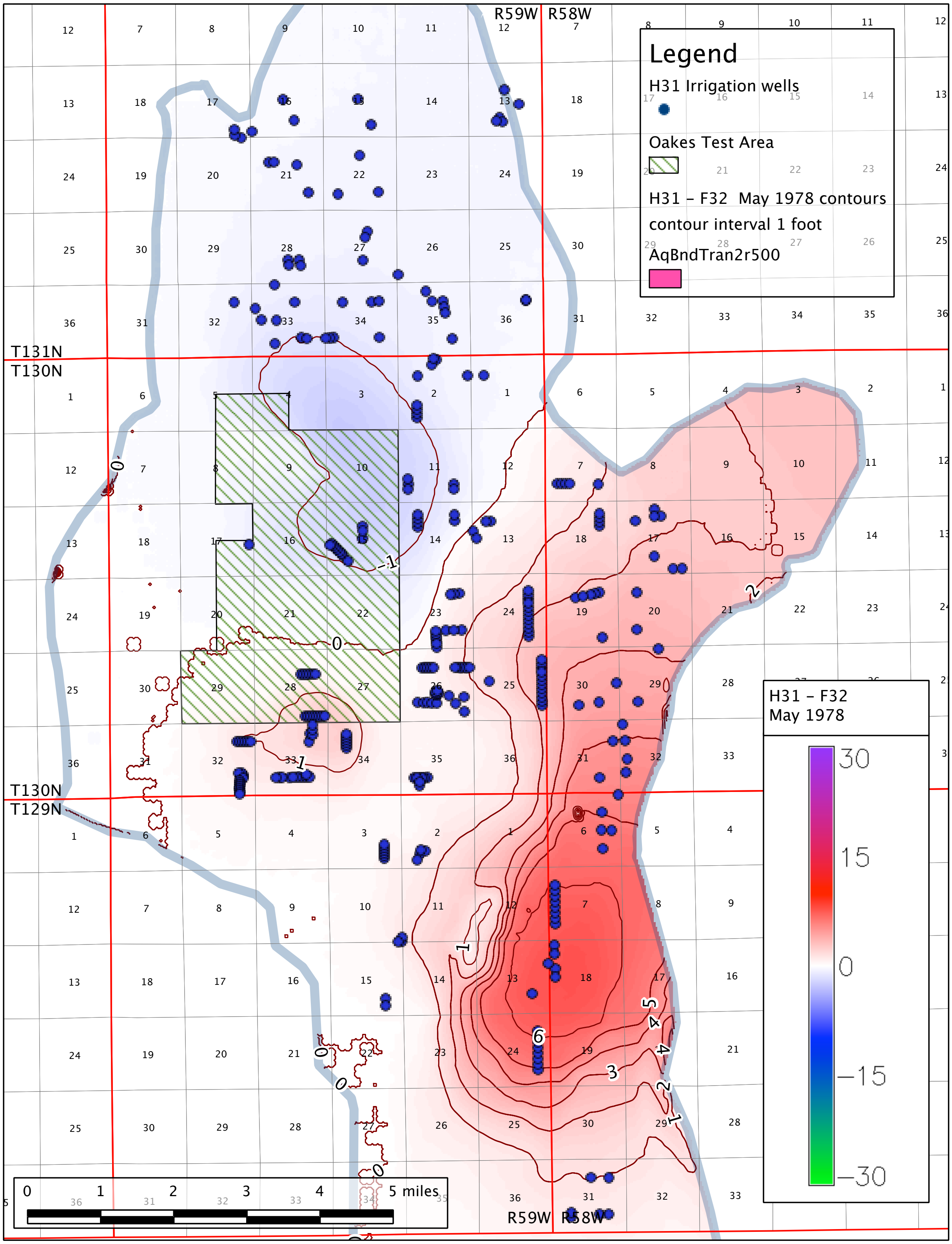

Figure F-123. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **May 31, 1978** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

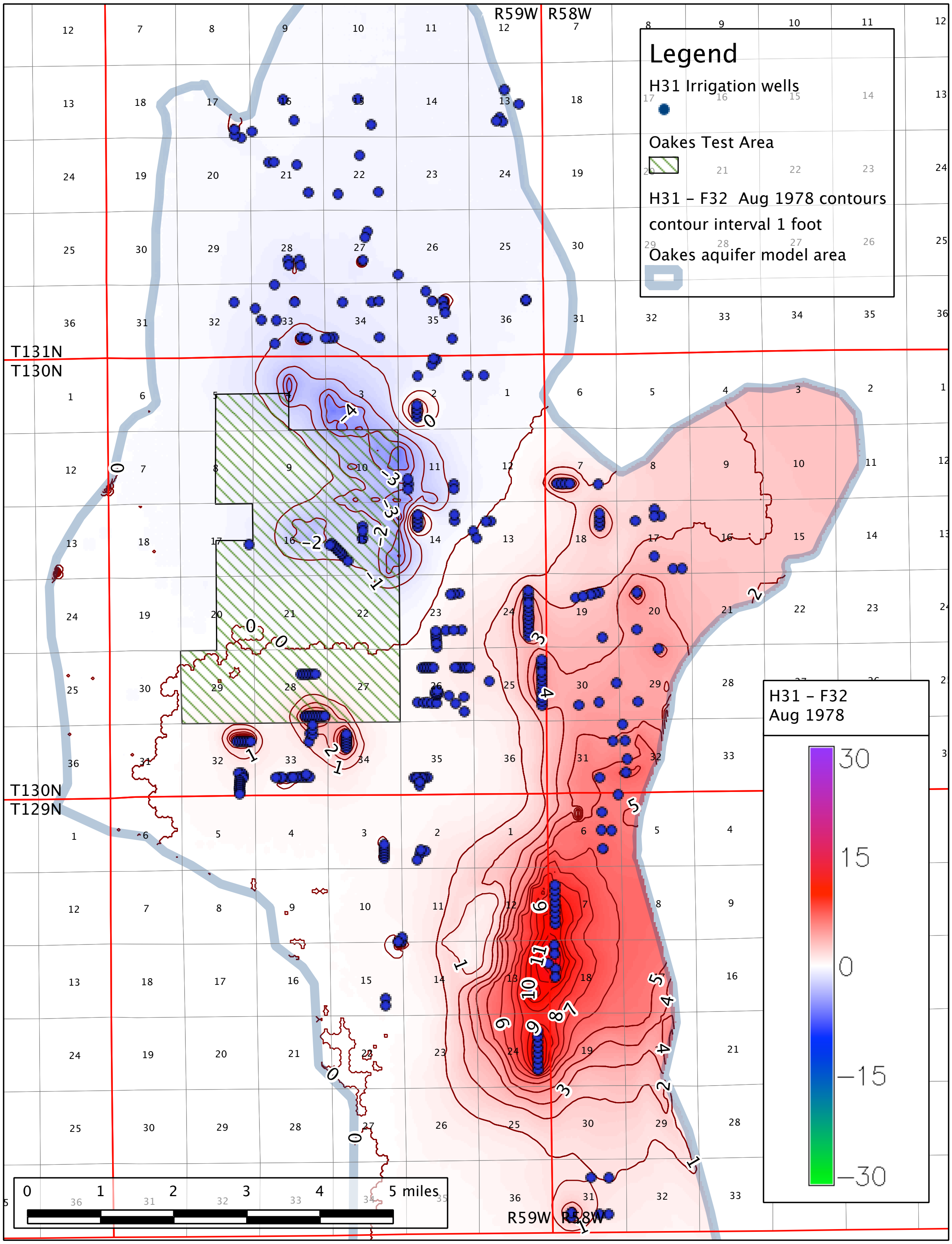

Figure F-124. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **August 31, 1978** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

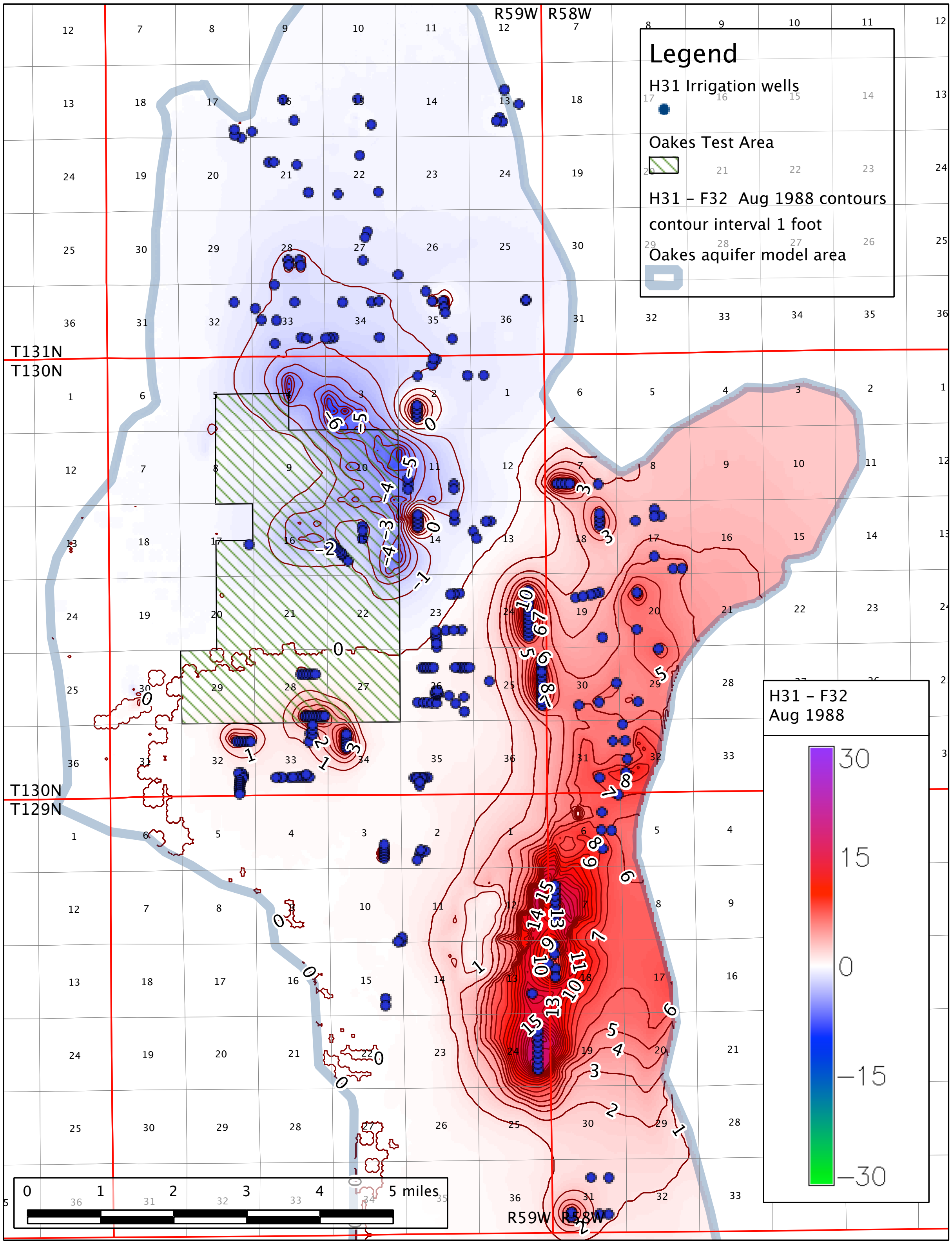

Figure F-125. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **August 31, 1988** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

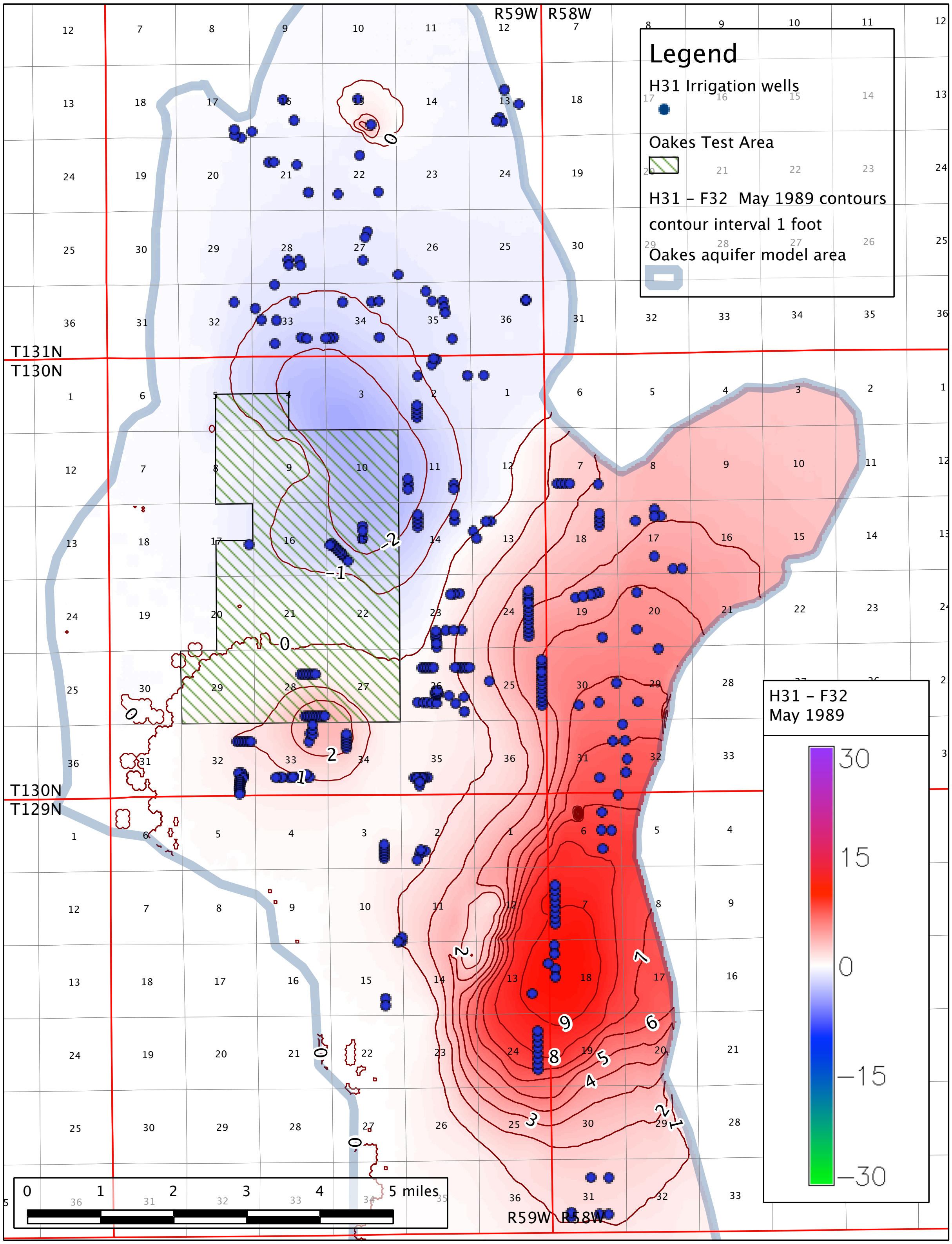

Figure F-126. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **May 31, 1989** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

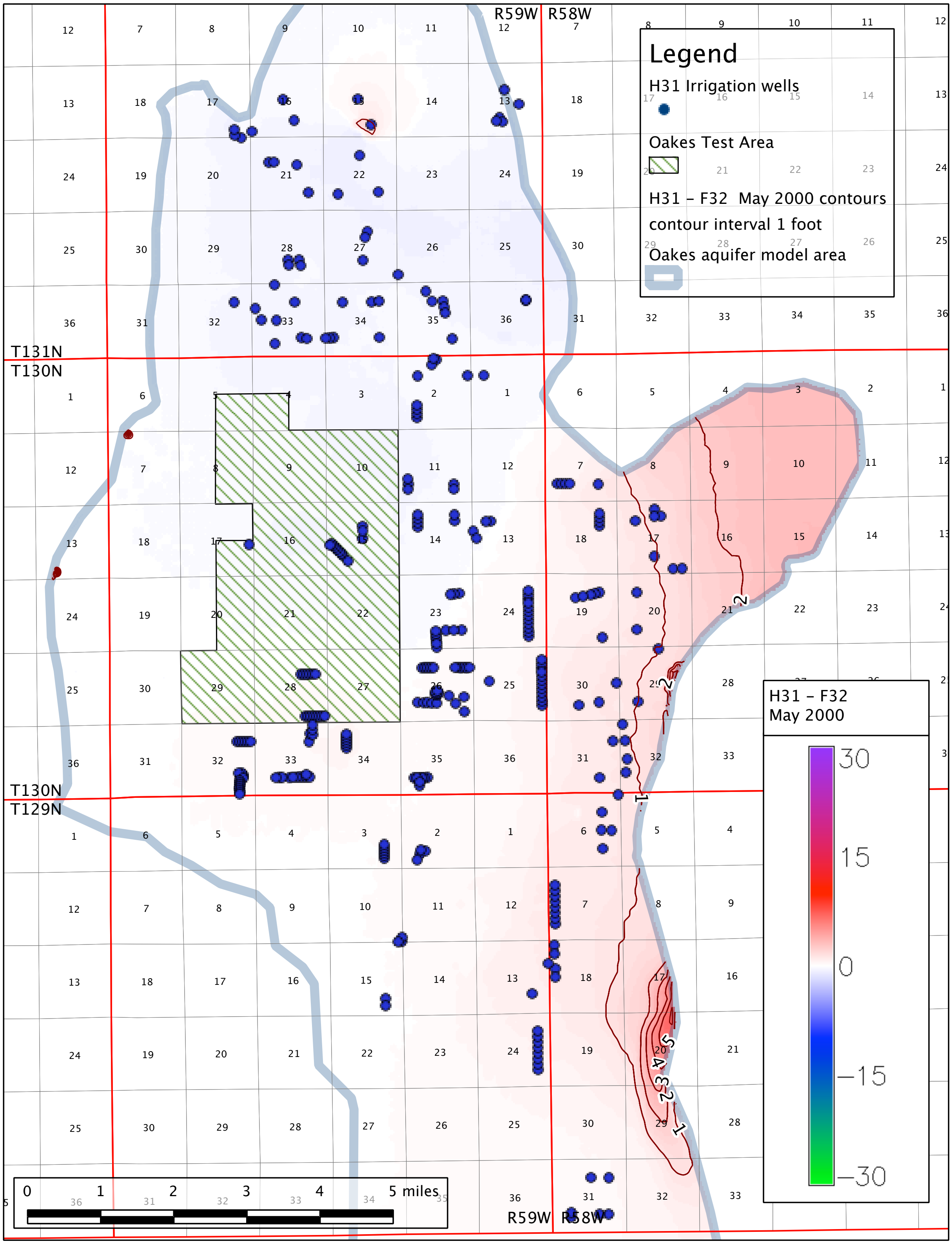

Figure F-127. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **May 31, 2000** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

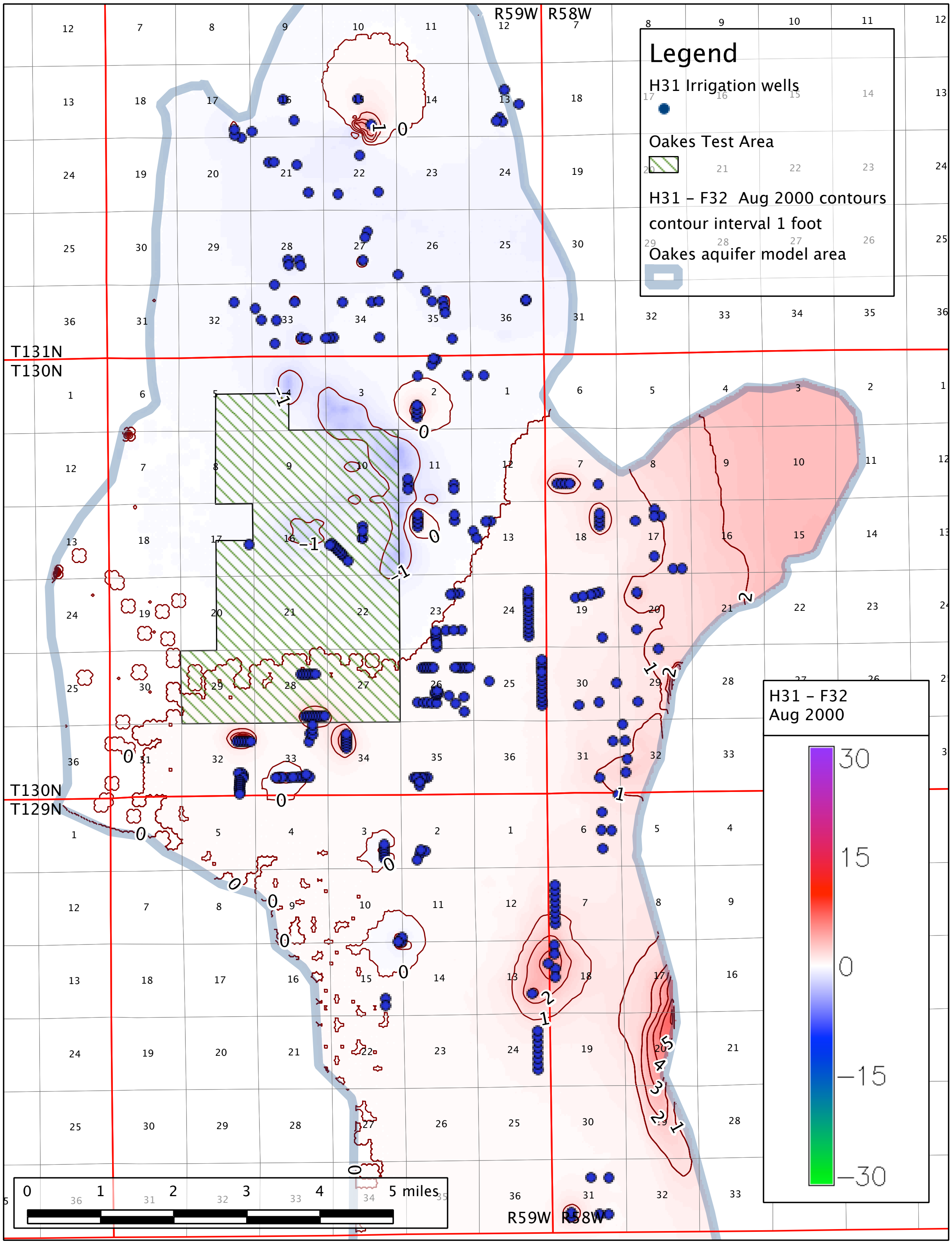

Figure F-128. Difference in water levels between DSID-Esser (**run H31**) and permitted (**run F32**) for **August 31, 2000** of 1905 to 2005 simulation. Run H31 minus run F32. Blue is less drawdown and red is more drawdown for DSID-Esser.

WATER LEVEL DIFFERENCE RUN H31 (DSID_ESSER) - F38b (permitted+pending)

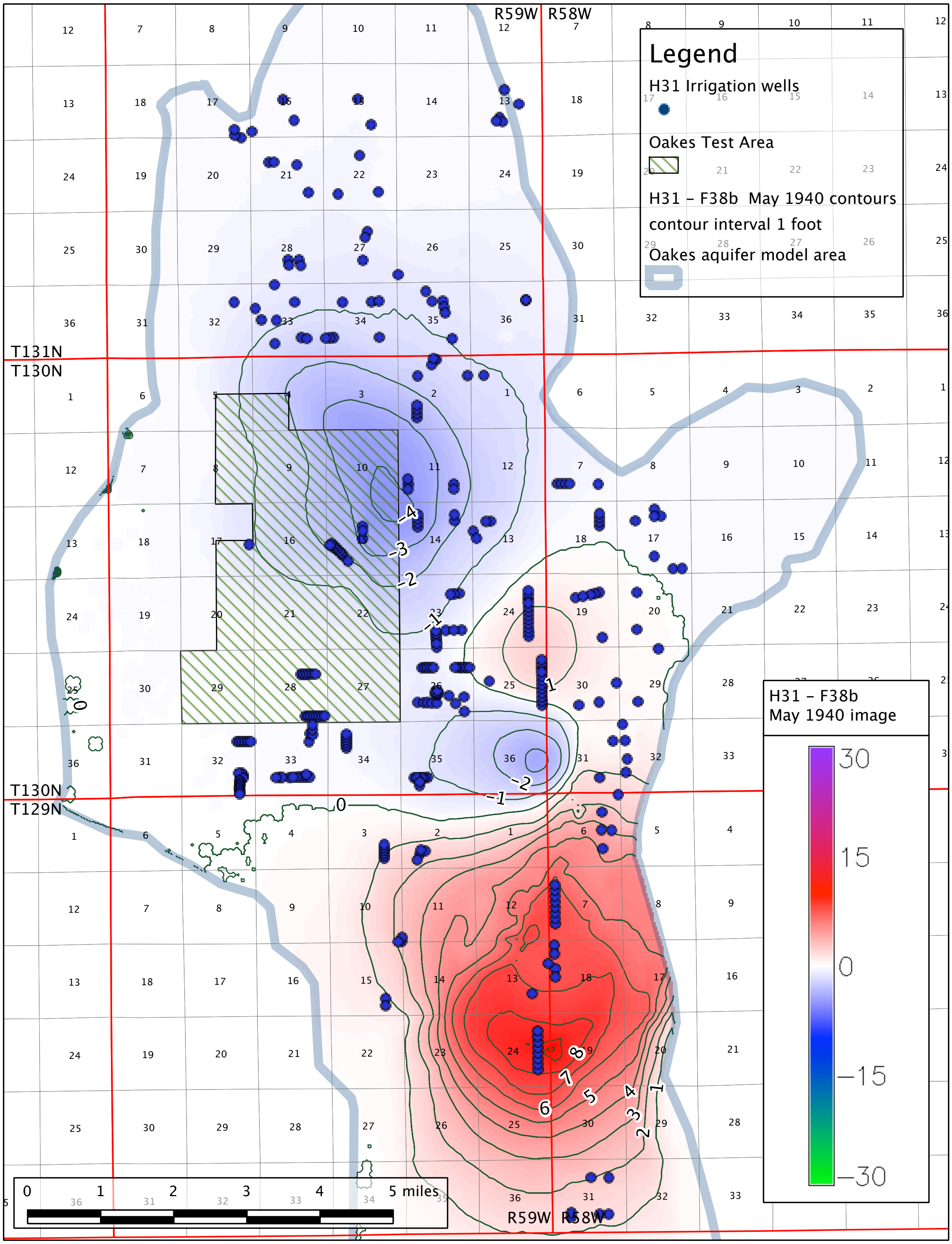

Figure F-129. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **May 31, 1940** of 1905 to 2005 simulation. H31 minus F38b. Blue is less drawdown and red is more drawdown.

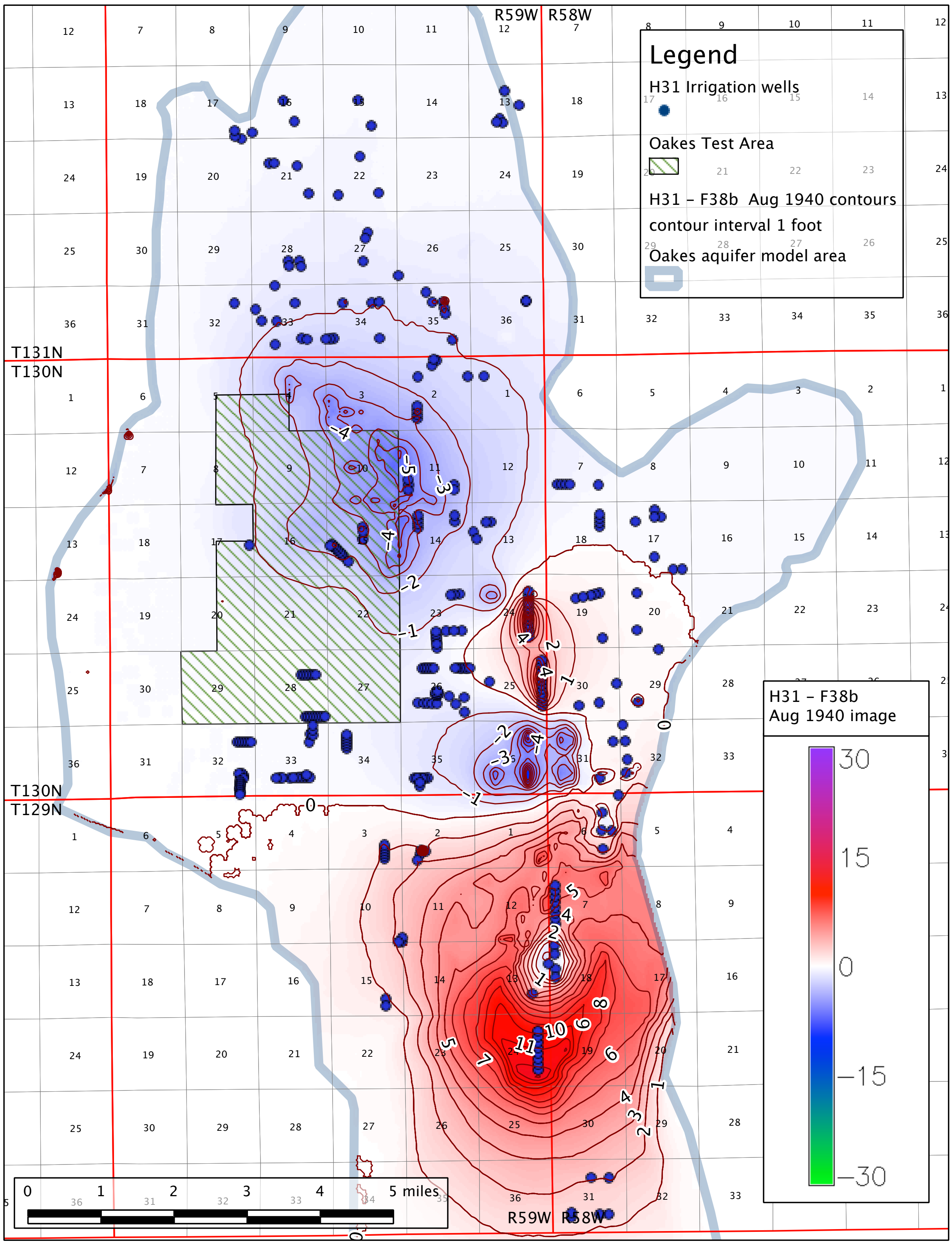

Figure F-130. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **August 31, 1940** of 1905 to 2005 simulation. Run H31 minus run F38b. Blue is less drawdown and red is more drawdown for DSID-Esser.

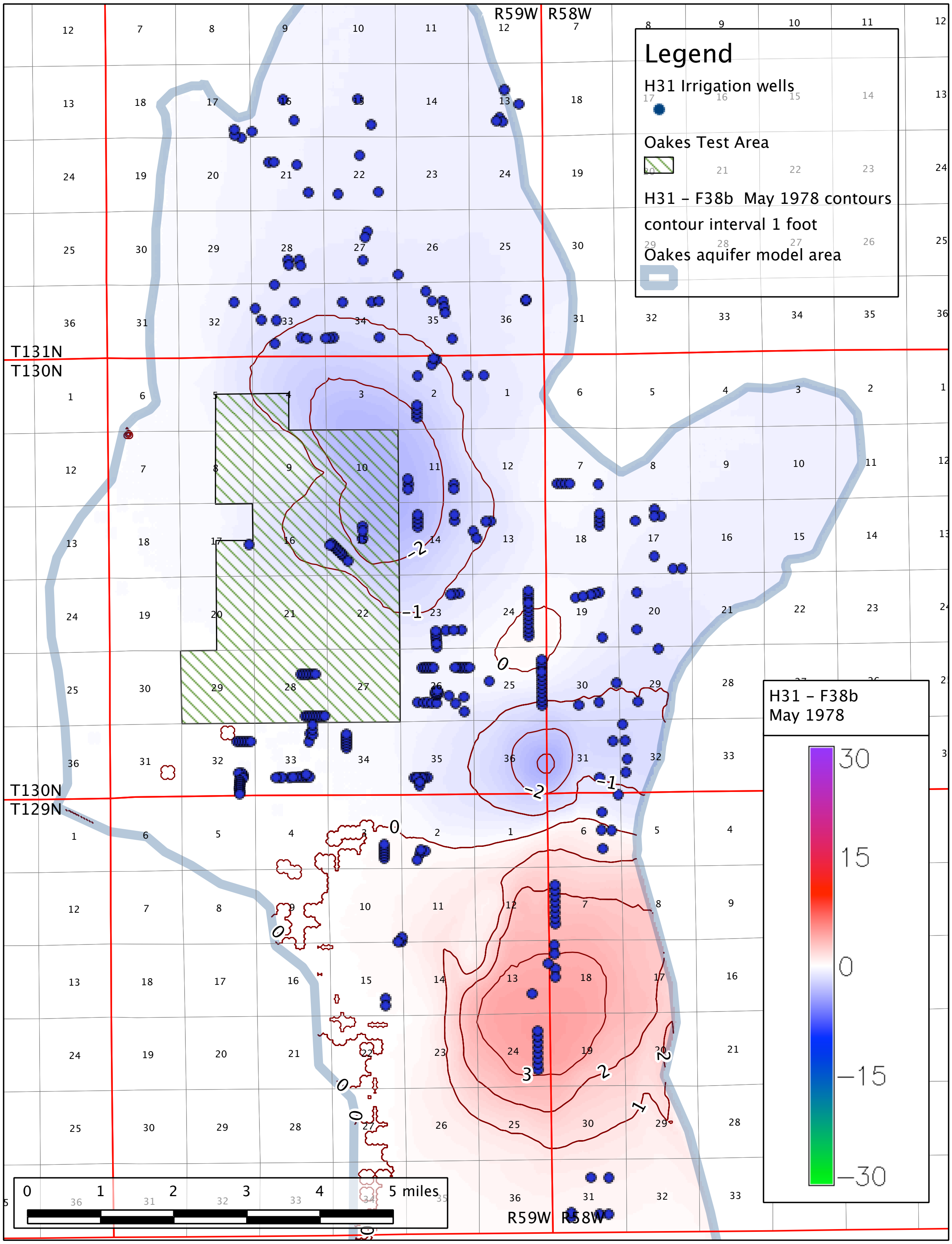

Figure F-131. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **May 31, 1978** of 1905 to 2005 simulation. Run H31 minus run F38b. Blue is less drawdown and red is more drawdown for DSID-Esser.

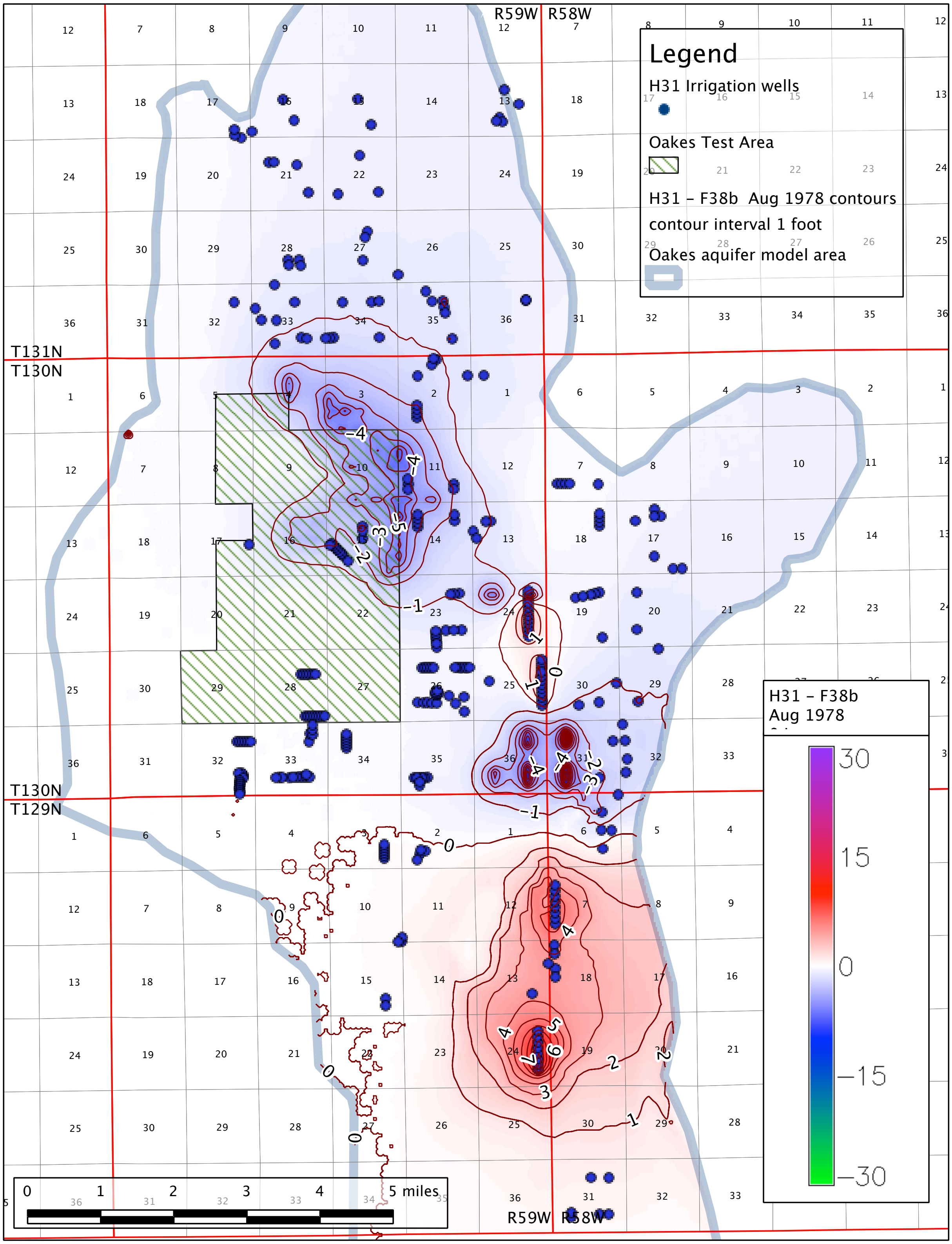

Figure F-132. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **August 31, 1978** of 1905 to 2005 simulation. Run H31 minus run F38b. Blue is less drawdown and red is more drawdown for DSID-Esser.

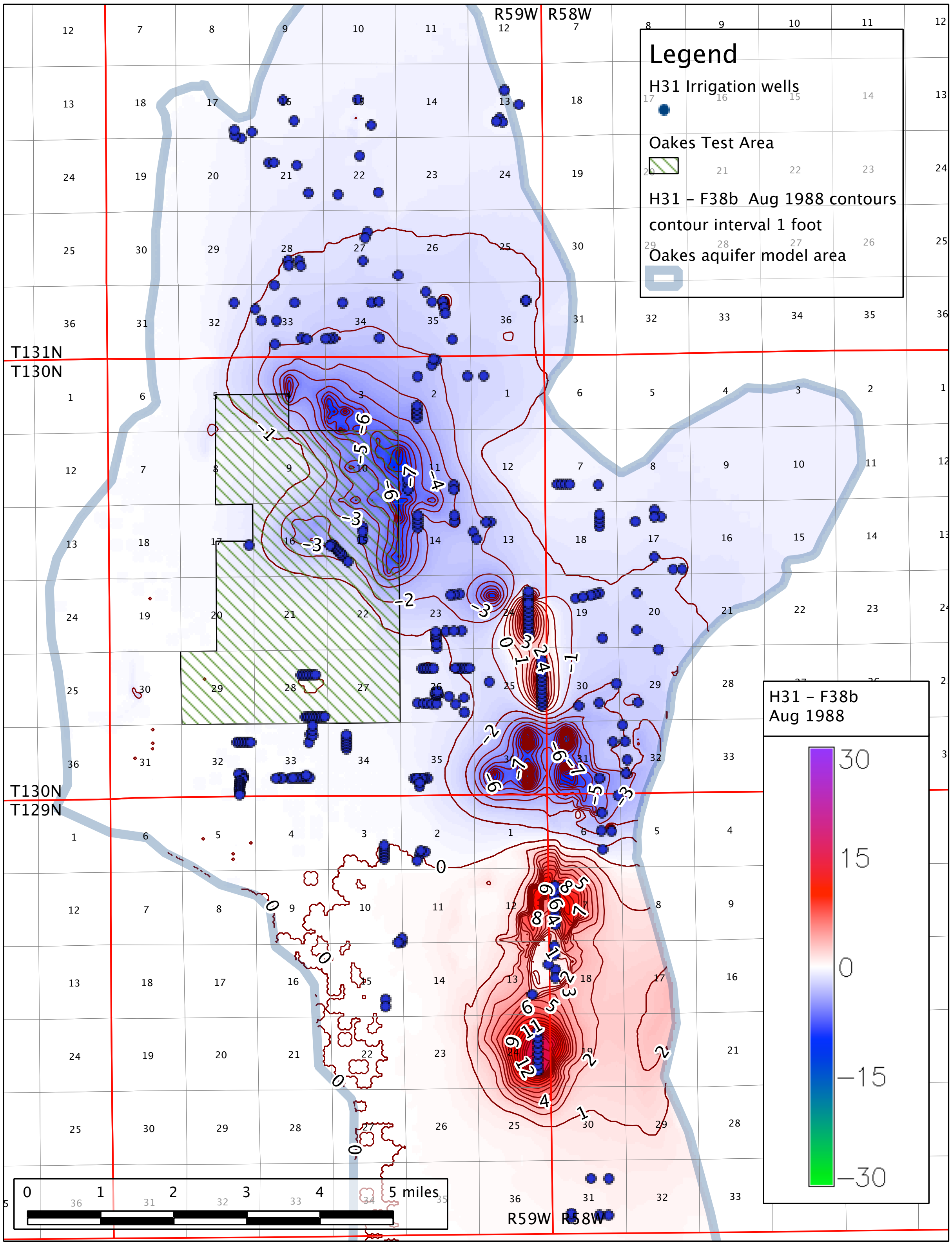

Figure F-133. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **August 31, 1988** of 1905 to 2005 simulation. Run H31 minus run F38b. Blue is less drawdown and red is more drawdown for DSID-Esser.

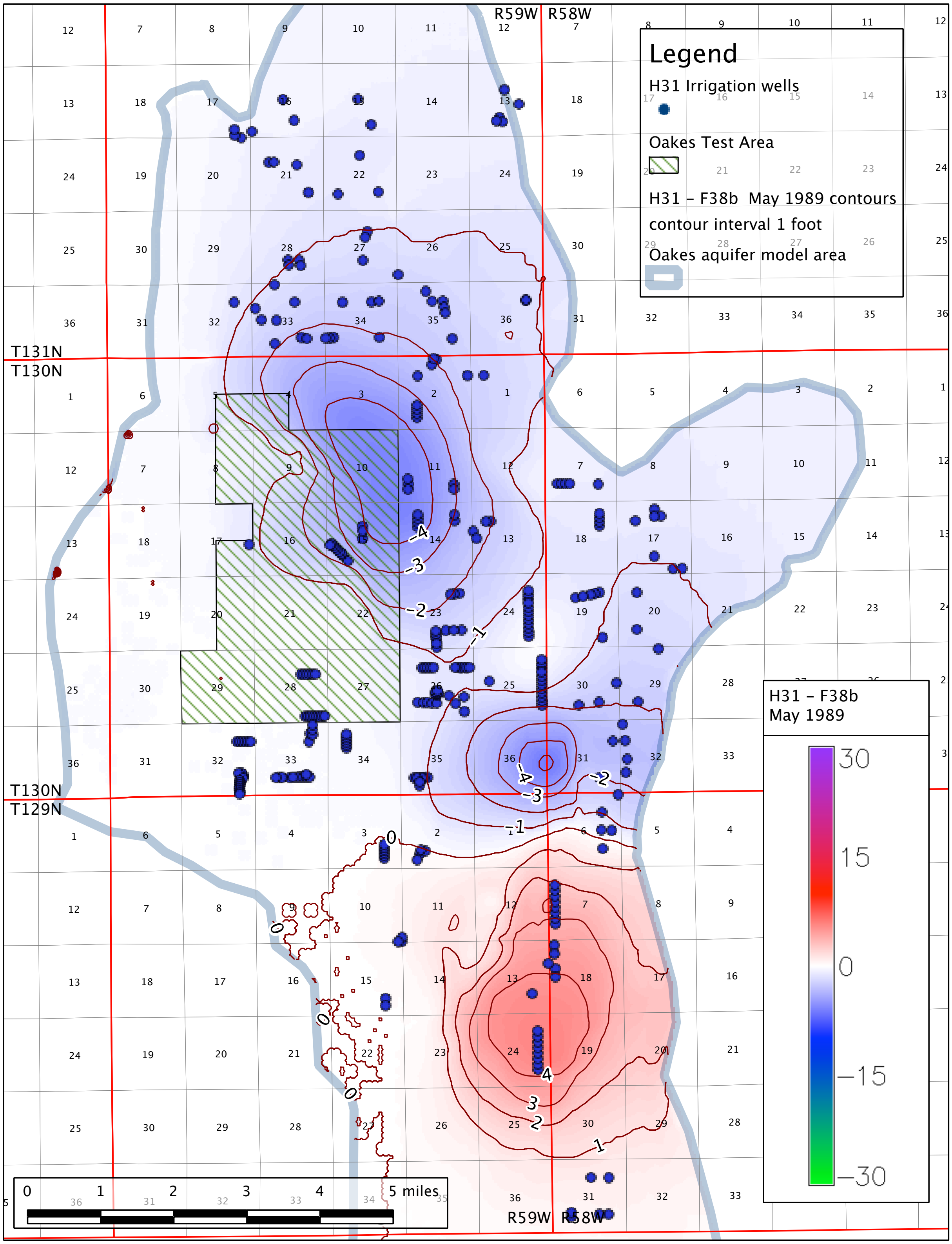

Figure F-134. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **May 31, 1989** of 1905 to 2005 simulation. Run H31 minus run F38b. Blue is less drawdown and red is more drawdown for DSID-Esser.

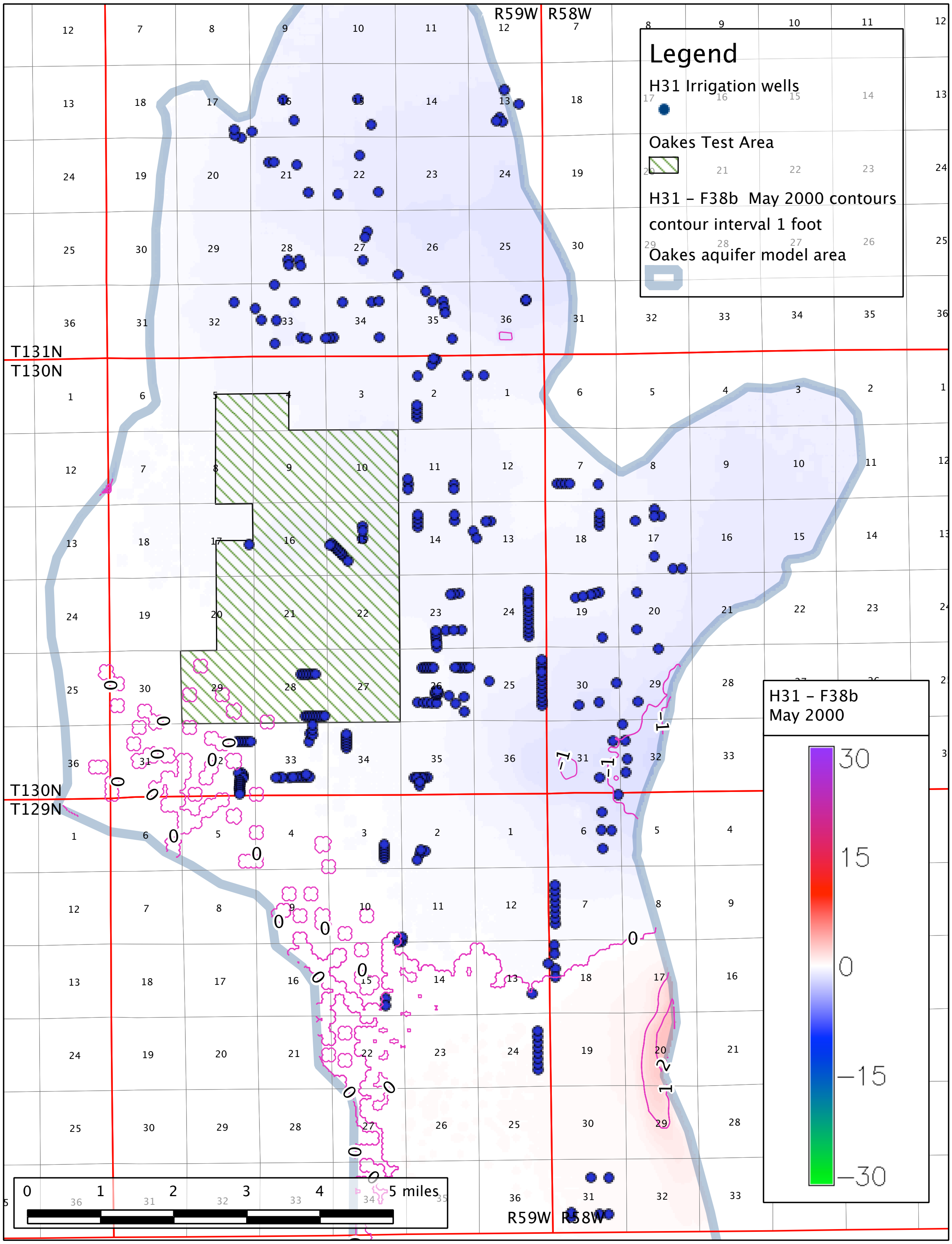

Figure F-135. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **May 31, 2000** of 1905 to 2005 simulation. Run H31 minus run F38b. Blue is less drawdown and red is more drawdown for DSID-Esser.

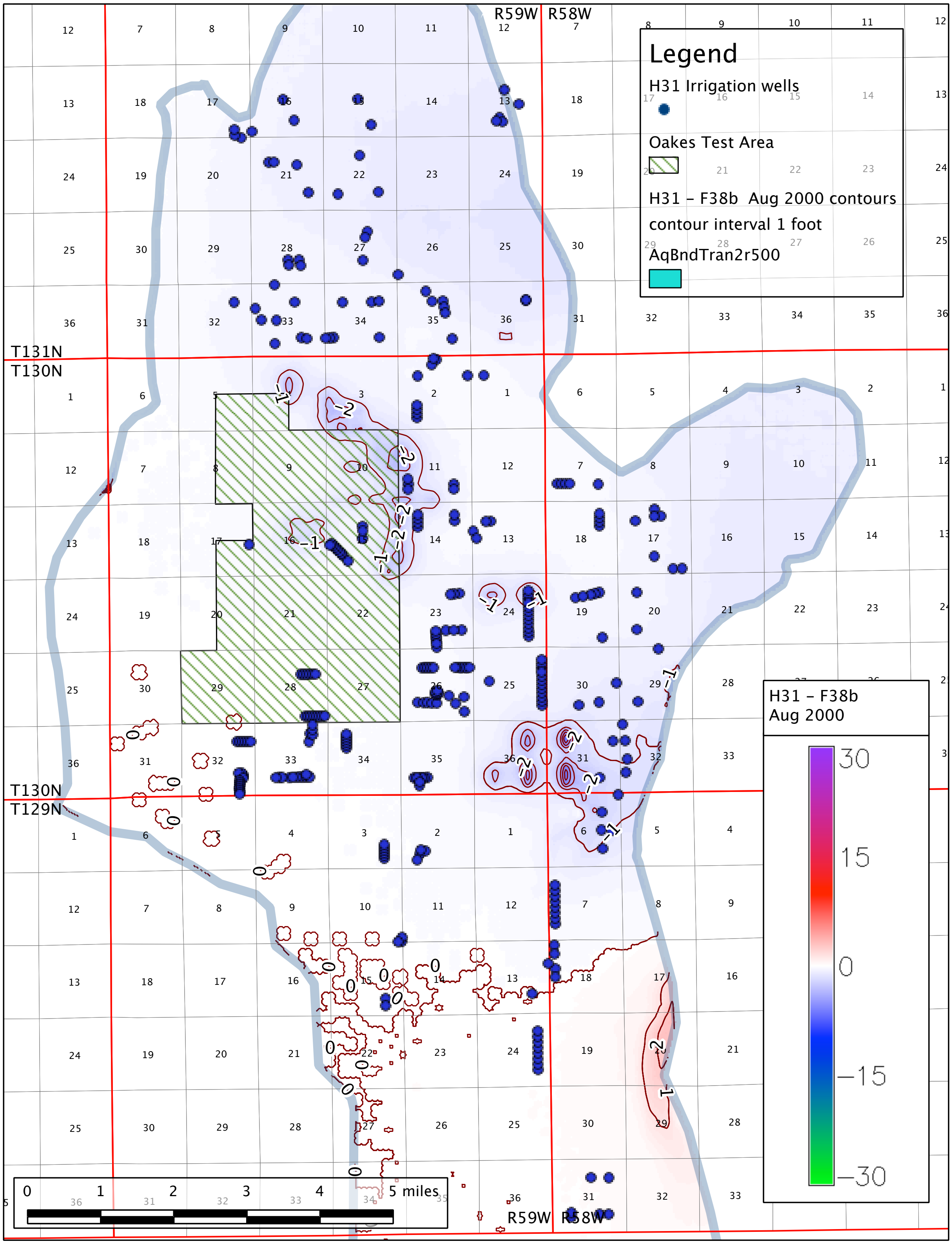

Figure F-136. Difference in water levels between DSID-Esser (**run H31**) and permitted + pending (**run F38b**) for **August 31, 2000** of 1905 to 2005 simulation. Run H31 minus run F38b. Blue is less drawdown and red is more drawdown for DSID-Esser.

Appendix G. Analysis of Surface Water Supplies for DSID.

An analysis was performed by Dale Esser, Garrison Diversion Conservancy District (GDCD), to determine the annual quantities of groundwater that would be needed to supplement water available from the James River flows and Jamestown Reservoir conservation pool. Estimated annual irrigation water requirements were provided for 1905 to 2005 for the Forman, Fullerton, and Oakes climate datasets. The estimates were determined using the Versatile Soil Moisture Budget Model (VB2K) (see Recharge, ETgw, and Irrigation Water Use in the Model results section of the report and Appendix E).

The results of the analysis were provided to the NDSWC as an Excel spreadsheet file, Surface water estimates for permit modeling.xls. The contents of the spreadsheet are present in the following Notes section and tables G-1 to G-10.

Notes Describing Contents of Spreadsheet

Estimates of Jamestown Reservoir conservation pool availability for release to Oakes and availability of surplus James River flows:

Pre-1955 Worksheet

- The 1928 to 1954 flow data at Jamestown is from Milt Lindvig's report on potential water sources for Oakes.
- Jamestown flow was separated in Pipestem Creek/James River flow by comparing 1974 to 2009 reservoir inflows (Pipestem worksheet).
    - Two relationships were apparent, less than 60,000 acre-feet total flow per year and more than 60,000 acre-feet.
    - On average, 35% of flow could be attributed to Jamestown Reservoir in years of less than 60,000 acre-feet of flow.
    - On average, 60% of flow could be attributed to Jamestown Reservoir in years of more than 60,000 acre-feet of flow.
    - The calculations dividing river flows is in the Pre-1955 river flows worksheet.
- There is no data for 1934 to 1937 and 1940 to 1942.

Pre-1955 River Flows Worksheet

- The flow data is from Milt Lindvig's report on potential water sources for Oakes.
- On the right side of the worksheet, an if/then statement is used to estimate the acre-feet of flow assigned to Jamestown Reservoir.

1955 to Current Worksheet

- Actual inflow and discharge data was used.

Conveyance Worksheet

- The ability of summer river flows to convey conservation pool releases to Oakes was estimated.
- To simulate flows in pre-reservoir years the March to August flows were totaled and an average May to August discharge rate was determined.
- Evaporation losses were assumed to be 12 inches per year (taken from James River Comprehensive Report, Appendix B, September 1989)
    - Jamestown Reservoir = 2,113 acres at elevation 1430.

Pipestem Worksheet

- The left side lists actual Pipestem Reservoir inflow/discharge data.
- Pipestem and Jamestown Reservoir data is compared, calculating the percentage of actual flow into each reservoir.
- Data was then divided into two categories, less than 60,000 acre-feet total flow and more than 60,000 acre-feet.
- In years of low flow (<60,000 ac-ft), less of the flow tends to be from the James River, averaging 35%.
- In years of high flow (>60,000 ac-ft), more of the flow tends to be from the James River, averaging 60%.

State Hospital Worksheet

- Rainfall data from State Hospital was used to estimate whether there may have been flow to refill the Jamestown Reservoir conservation pool during years of no river flow data.

Surplus Flows Worksheet

- Three datasets were used to estimate availability of surplus:
  - 1929 to 1949 = Jamestown gage
  - 1950 to 1981 = LaMoure gage
  - 1982 to present = State Line (Ludden) gage
- Based on comparison of average monthly discharge rates, the following average rates were selected as satisfying Sand Lake National Wildlife Refuge Operating Principles targets:
  - Jamestown gage - 600 cubic feet per second
  - LaMoure gage - 750 cfs
  - Ludden gage - 850 cfs

Demand Worksheet

- Modeled irrigation demand was provided by the ND State Water Commission. Three weather datasets were used - Oakes, Forman and Fullerton.
- Recaptured drain flows were conservatively set to average 500 acre-feet per year.
- In years surplus flows would be available, they are assumed to be total irrigation demand minus recaptured drain flows.
- The supply from the Jamestown Reservoir conservation pool releases is referenced from the Pre-1955 and 1955 to current worksheets.

Red River Worksheet

- Red River and James River flow data for 1929 to 1955 was compared to determine if there is any correlation.
- There is no relationship in flows between the two rivers, so Red River flows cannot be used to interpolate James River flows.

Table G-1. Summary: Estimate of Availability of Surplus Flows and Jamestown Reservoir Conservation Pool Water, 1929 to 2005 and Estimate of Groundwater Volumes Required.

Estimate of Availability of Surplus Flows and Jamestown
Reservoir Conservation Pool Water, 1929 to 2005
and Estimates of Groundwater Volumes Required

Year	Recaptured Drain Flows (ac-ft)	---Surplus Flows ---- Oakes Weather	Fullerton Weather	Forman Weather	Jamestown Reservoir Conservation Pool Releases Pumped at Oakes (ac-ft)	---Groundwater ---- Oakes Weather	Fullerton Weather	Forman Weather
		--- acre-feet used ---				--- acre-feet needed ---		
1929	500	0	0	0	1,846	3,333	2,350	2,771
1930	500	0	0	0	1,846	2,612	2,183	2,508
1931	500	0	0	0	1,380	2,195	2,349	2,628
1932	500	0	0	0	1,380	2,424	2,716	2,020
1933	500	0	0	0	0	4,871	3,733	4,663
1934	500	0	0	0	0	6,500	6,054	6,467
1935	500	0	0	0	1,380	1,420	903	1,216
1936	500	0	0	0	0	7,542	6,696	7,638
1937	500	0	0	0	1,380	3,224	3,374	491
1938	500	0	0	0	0	4,613	4,408	2,975
1939	500	0	0	0	0	3,392	3,375	3,158
1940	500	0	0	0	0	3,258	2,800	2,258
1941	500	0	0	0	1,380	2,337	2,270	1,870
1942	500	0	0	0	1,380	670	245	403
1943	500	1,888	1,488	1,713	0	0	0	0
1944	500	0	0	0	1,380	0	291	416
1945	500	0	0	0	1,846	1,654	1,729	1,687
1946	500	0	0	0	0	3,463	2,388	2,863
1947	500	0	0	0	1,846	2,050	1,583	2,121
1948	500	3,008	3,550	2,475	0	0	0	0
1949	500	4,092	3,679	1,958	0	0	0	0
1950	500	4,504	4,521	4,092	0	0	0	0
1951	500	1,917	2,017	2,633	0	0	0	0
1952	500	3,167	4,129	3,517	0	0	0	0
1953	500	0	0	0	1,846	579	1,191	1,558
1954	500	0	0	0	1,846	1,541	1,954	2,254
1955	500	0	0	0	0	2,042	2,029	2,092
1956	500	0	0	0	1,846	0	729	591
1957	500	0	0	0	0	1,567	2,146	2,029
1958	500	0	0	0	0	2,792	3,629	3,604
1959	500	0	0	0	0	3,163	4,758	2,758
1960	500	0	0	0	1,846	412	1,637	1,371
1961	500	0	0	0	1,380	1,583	2,716	2,195
1962	500	0	0	0	1,846	0	0	0
1963	500	0	0	0	6	2,619	2,865	2,919
1964	500	0	0	0	0	2,188	2,617	2,075
1965	500	0	0	0	1,846	421	0	0
1966	500	2,358	2,275	1,600	0	0	0	0
1967	500	0	0	0	1,846	1,346	2,371	983
1968	500	0	0	0	1,846	696	937	1,091
1969	500	0	0	0	1,846	1,071	1,708	1,429
1970	500	0	0	0	1,846	2,341	3,033	2,666
1971	500	0	0	0	1,846	746	987	1,041
1972	500	0	0	0	1,846	616	1,166	908
1973	500	0	0	0	1,380	3,062	5,078	2,183
1974	500	0	0	0	1,846	1,896	3,054	2,746
1975	500	0	0	0	1,846	1,154	1,154	521
1976	500	0	0	0	1,846	4,841	4,675	3,716
1977	500	0	0	0	1,380	2,512	2,224	1,570
1978	500	0	0	0	1,846	1,733	1,179	571
1979	500	3,317	3,158	2,375	0	0	0	0
1980	500	0	0	0	1,846	3,171	3,100	1,696
1981	500	0	0	0	1,846	2,283	325	462
1982	500	0	0	0	1,846	3,721	3,271	2,337
1983	500	0	0	0	1,846	1,116	2,316	1,229
1984	500	4,004	4,167	3,246	0	0	0	0
1985	500	0	0	0	1,846	2,425	3,129	1,421
1986	500	0	0	0	1,846	346	512	0
1987	500	4,067	3,375	3,392	0	0	0	0
1988	500	0	0	0	1,846	6,358	4,666	3,871
1989	500	0	0	0	1,846	1,425	1,971	1,421
1990	500	0	0	0	1,380	2,424	1,837	1,678
1991	500	0	0	0	0	3,083	3,179	2,154
1992	500	0	0	0	0	2,088	1,771	1,663
1993	500	0	0	0	0	1,179	908	825
1994	500	3,158	2,342	2,275	0	0	0	0
1995	500	2,750	1,613	2,054	0	0	0	0
1996	500	3,167	3,625	3,483	0	0	0	0
1997	500	3,029	2,396	2,150	0	0	0	0
1998	500	2,175	1,513	2,171	0	0	0	0
1999	500	1,392	1,388	1,367	0	0	0	0
2000	500	0	0	0	1,846	0	91	0
2001	500	2,767	2,492	2,529	0	0	0	0
2002	500	0	0	0	1,846	0	1,087	0
2003	500	0	0	0	1,846	950	1,646	625
2004	500	2,504	2,500	1,971	0	0	0	0
2005	500	0	0	0	1,846	0	0	0
Total	38,500	53,263	50,225	45,000	74,262	127,040	133,093	110,403

Table G-2. Jamestown Reservoir: Estimates of conservation pool availability, pre-1955.

Jamestown Reservoir
Estimates of conservation pool availability
Pre-1955

7,000 ac-ft = total storage in conservation pool for irrigation
33% = maximum percentage of conservation pool used in any year
2,331 ac-ft = maximum release from conservation pool in any year

Assumptions:
- no refilling of conservation space in fall with joint use pool water
- as per the Operating Principles, the joint use pool is filled first (6,153 ac-ft)
- the calculations assume refuge needs have been meet and passing inflows would not be required
- delivery losses assumed to be 12% of the amount released
- operational losses assumed to average 10% of the water reaching Oakes
- the conservation pool was full at the start
- reservoir evaporation came from the joint use pool
- no conservation pool releases if volume available is less than 500 acre-feet
- low flow years (<50 cfs average) assessed an additional 20% delivery losses

	Acre-feet					Acre-feet March to June				Acre-Feet		
Year	Start of Year Volume	Volume Refilled in Spring	Volume Available to Release	Volume Released for Oakes	End of Year Volume	Estimated Reservoir Inflow	Refill Volume Available	Delivery Losses (10%)	Avg Flow >40 cfs	Low Flow Delivery Loss (20%)	Operational Losses (12%)	Net Acre-Feet Available at Oakes
1929	7,000	0	7,000	2,331	4,669	5,625	0	233	Y	0	252	1,846
1930	4,669	2,331	7,000	2,331	4,669	10,779	4,626	233	Y	0	252	1,846
1931	4,669	0	4,669	2,331	2,338	1,002	0	233	N	466	252	1,380
1932	2,338	0	2,338	2,331	7	3,058	0	233	N	466	252	1,380
1933	7	0	7	0	7	4,045	0	0	N	0	0	0
1934	7	0	7	0	7	NA	0	0	NA	0	0	0
1935	7	2,500	2,507	2,331	176	NA	2,500	233	NA	466	252	1,380
1936	176	0	176	0	176	NA	0	0	NA	0	0	0
1937	176	2,500	2,676	2,331	345	NA	2,500	233	NA	466	252	1,380
1938	345	0	345	0	345	428	0	0	N	0	0	0
1939	345	0	345	0	345	564	0	0	N	0	0	0
1940	345	0	345	0	345	NA	0	0	NA	0	0	0
1941	345	2,500	2,845	2,331	514	NA	2,500	233	NA	466	252	1,380
1942	514	2,500	3,014	2,331	683	NA	2,500	233	NA	466	252	1,380
1943	683	6,317	7,000	0	7,000	36,969	30,816	0	Y	0	0	0
1944	7,000	0	7,000	2,331	4,669	2,626	0	233	N	466	252	1,380
1945	4,669	0	4,669	2,331	2,338	5,568	0	233	Y	0	252	1,846
1946	2,338	0	2,338	0	2,338	3,824	0	0	N	0	0	0
1947	2,338	3,773	6,111	2,331	3,780	9,926	3,773	233	Y	0	252	1,846
1948	3,780	3,220	7,000	0	7,000	78,645	72,492	0	Y	0	0	0
1949	7,000	0	7,000	0	7,000	20,874	14,721	0	Y	0	0	0
1950	7,000	0	7,000	0	7,000	177,517	171,364	0	Y	0	0	0
1951	7,000	0	7,000	0	7,000	16,881	10,728	0	Y	0	0	0
1952	7,000	0	7,000	0	7,000	16,865	10,712	0	Y	0	0	0
1953	7,000	0	7,000	2,331	4,669	5,796	0	233	Y	0	252	1,846
1954	4,669	0	4,669	2,331	2,338	3,716	0	233	Y	0	252	1,846

Table G-3. Jamestown Reservoir: Estimates of conservation pool availability, 1955 to 2009.

Jamestown Reservoir
Estimates of conservation pool availability
1955 to 2009

7,000 ac-ft = total storage in conservation pool for irrigation
33% = maximum percentage of conservation pool used in any year
2,331 ac-ft = maximum release from conservation pool in any year

Assumptions:
- no refilling of conservation space in fall with joint use pool water
- as per the Operating Principles, the joint use pool is filled first (6,153 ac-ft)
- the calculations assume refuge needs have been meet and passing inflows would not be required
- delivery losses assumed to be 10% of the amount released
- operational losses assumed to average 12% of the water reaching Oakes
- reservoir evaporation came from the joint use pool
- no conservation pool releases if volume available is less than 500 acre-feet

	Acre-feet					Acre-feet, March to June						Acre-Feet		
Year	Start of Year Volume	Volume Refilled in Spring	Volume Available to Release	Volume Released for Oakes	End of Year Volume	Computed Reservoir Inflow	Total Reservoir Discharge	Total Inflow	Refill Volume Available	Delivery Losses (10%)	Avg Flow >40 cfs	Low Flow Delivery Loss (20%)	Operational Losses (12%)	Net Acre-Feet Available at Oakes
1955	2,338	0	2,338	0	2,338	6,772	0	6,772	619	0	Y	0	0	0
1956	2,338	2,431	4,769	2,331	2,438	8,584	0	8,584	2,431	233	Y	0	252	1,846
1957	2,438	0	2,438	0	2,438	0	0	0	0	0	N	0	0	0
1958	2,438	0	2,438	0	2,438	5,521	0	5,521	0	0	Y	0	0	0
1959	2,438	0	2,438	0	2,438	-1,869	0	-1,869	0	0	N	0	0	0
1960	2,438	4,562	7,000	2,331	4,669	11,284	0	11,284	5,131	233	Y	0	252	1,846
1961	4,669	0	4,669	2,331	2,338	378	0	378	0	233	N	466	252	1,380
1962	2,338	0	2,338	2,331	7	2,816	0	2,816	0	233	Y	0	252	1,846
1963	7	0	7	7	0	-189	0	-189	0	1	Y	0	1	6
1964	0	0	0	0	0	1,514	0	1,514	0	0	Y	0	0	0
1965	0	7,000	7,000	2,331	4,669	21,788	6,958	28,746	22,593	233	Y	0	252	1,846
1966	4,669	2,331	7,000	0	7,000	69,222	60,277	129,499	123,346	0	Y	0	0	0
1967	7,000	0	7,000	2,331	4,669	29,612	19,503	49,115	42,962	233	Y	0	252	1,846
1968	4,669	0	4,669	2,331	2,338	2,387	0	2,387	0	233	Y	0	252	1,846
1969	2,338	4,662	7,000	2,331	4,669	86,887	48,599	135,486	129,333	233	Y	0	252	1,846
1970	4,669	0	4,669	2,331	2,338	368	0	368	0	233	Y	0	252	1,846
1971	2,338	4,662	7,000	2,331	4,669	20,700	16,504	37,204	31,051	233	Y	0	252	1,846
1972	4,669	2,331	7,000	2,331	4,669	12,854	5,550	18,404	12,251	233	Y	0	252	1,846
1973	4,669	0	4,669	2,331	2,338	592	0	592	0	233	N	466	252	1,380
1974	2,338	4,662	7,000	2,331	4,669	37,809	23,494	61,303	55,150	233	Y	0	252	1,846
1975	4,669	2,331	7,000	2,331	4,669	63,274	39,012	102,286	96,133	233	Y	0	252	1,846
1976	4,669	2,331	7,000	2,331	4,669	16,335	9,710	26,045	19,892	233	Y	0	252	1,846
1977	4,669	0	4,669	2,331	2,338	-611	0	-611	0	233	N	466	252	1,380
1978	2,338	4,662	7,000	2,331	4,669	14,873	4,889	19,762	13,609	233	Y	0	252	1,846
1979	4,669	2,331	7,000	0	7,000	64,581	39,106	103,687	97,534	0	Y	0	0	0
1980	7,000	0	7,000	2,331	4,669	879	0	879	0	233	Y	0	252	1,846
1981	4,669	1,220	5,889	2,331	3,558	7,373	0	7,373	1,220	233	Y	0	252	1,846
1982	3,558	3,442	7,000	2,331	4,669	44,259	24,994	69,253	63,100	233	Y	0	252	1,846
1983	4,669	2,331	7,000	2,331	4,669	75,788	59,022	134,810	128,657	233	Y	0	252	1,846
1984	4,669	2,331	7,000	0	7,000	38,486	30,954	69,440	63,287	0	Y	0	0	0
1985	7,000	0	7,000	2,331	4,669	4,297	0	4,297	0	233	Y	0	252	1,846
1986	4,669	2,331	7,000	2,331	4,669	19,991	13,460	33,451	27,298	233	Y	0	252	1,846
1987	4,669	2,331	7,000	0	7,000	68,925	53,306	122,231	116,078	0	Y	0	0	0
1988	7,000	0	7,000	2,331	4,669	2,550	0	2,550	0	233	Y	0	252	1,846
1989	4,669	0	4,669	2,331	2,338	272	0	272	0	233	Y	0	252	1,846
1990	2,338	0	2,338	2,331	7	-238	0	-238	0	233	N	466	252	1,380
1991	7	0	7	0	7	-46	0	-46	0	0	N	0	0	0

Table G-3. Jamestown Reservoir: Estimates of conservation pool availability, 1955 to 2009 (cont.).

1992	7	0	7	0	7	-790	0	-790	0	0	N	0	0	0
1993	7	6,993	7,000	0	7,000	19,311	0	19,311	13,158	0	Y	0	0	0
1994	7,000	0	7,000	0	7,000	77,336	74,535	151,871	145,718	0	Y	0	0	0
1995	7,000	0	7,000	0	7,000	147,702	136,967	284,669	278,516	0	Y	0	0	0
1996	7,000	0	7,000	0	7,000	137,102	120,723	257,825	251,672	0	Y	0	0	0
1997	7,000	0	7,000	0	7,000	202,170	168,915	371,085	364,932	0	Y	0	0	0
1998	7,000	0	7,000	0	7,000	58,764	48,662	107,426	101,273	0	Y	0	0	0
1999	7,000	0	7,000	0	7,000	164,127	104,703	268,830	262,677	0	Y	0	0	0
2000	7,000	0	7,000	2,331	4,669	17,997	6,115	24,112	17,959	233	Y	0	252	1,846
2001	4,669	2,331	7,000	0	7,000	132,000	121,076	253,076	246,923	0	Y	0	0	0
2002	7,000	0	7,000	2,331	4,669	10,236	9,842	20,078	13,925	233	Y	0	252	1,846
2003	4,669	2,331	7,000	2,331	4,669	18,316	13,441	31,757	25,604	233	Y	0	252	1,846
2004	4,669	2,331	7,000	0	7,000	73,131	69,557	142,688	136,535	0	Y	0	0	0
2005	7,000	0	7,000	2,331	4,669	15,580	13,384	28,964	22,811	233	Y	0	252	1,846
2006	4,669	2,331	7,000	2,331	4,669	8,796	3,665	12,461	6,308	233	Y	0	252	1,846
2007	4,669	2,331	7,000	2,331	4,669	21,090	14,284	35,374	29,221	233	Y	0	252	1,846
2008	4,669	1,377	6,046	2,331	3,715	5,624	1,906	7,530	1,377	233	Y	0	252	1,846
2009	3,715	3,285	7,000	2,331	4,669	289,248	252,193	541,441	535,288	233	Y	0	252	1,846
										7,926			8,560	60,910

This method ignores the effect of reservoir losses during a multi-year dry period. It is possible that four of the years (1955, 1960 and 1981) a portion of the inflows in excess of that needed to refill the joint use pool would have been required to replace evaporation from the conservation space, or be required to be released for refuge needs.

Table G-4. Jamestown Reservoir: Estimates of conservation pool availability1929 to 1955

James River Flows at Jamestown in Acre-Feet
(taken from Milt Lindvig's report on Inventory of Potential Water Sources for the OTA)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	March to June
1928										12,913	2,835	1,535	0
1929	646	329	155	123	111	11,203	2,470	1,685	714	257	47	60	16,072
1930	122	97	52	52	6,181	16,221	9,134	4,390	1,053	358	43	57	30,798
1931		58	44	61	266	793	1,857	138	76	61	69	103	2,863
1932	81	38	70	76	3,750	4,870	2,303	756	809	183	65	235	8,738
1933	601	54	46	63	1,572	6,604	3,273	1,562	120	41	14	12	11,558
1934													
1935													
1936													
1937												43	0
1938	61	60	53	59	62	947	109	85	83	99	59	45	1,223
1939	33	21	41	37	33	1,279	60	65	208	52	43	51	1,612
1940													
1941													
1942													
1943							40,285	7,286	14,043	6,751	972	308	61,615
1944	68	64	62	62	58	107	1,095	2,915	3,386	1,500	609	542	7,502
1945	208	667	738	162	143	8,897	4,499	1,673	839	169	252	150	15,908
1946	119	85	90	86	69	3,739	5,653	1,224	310	286	163	135	10,925
1947	276	84	114	151	110	6,352	16,316	3,081	2,612	3,480	707	85	28,361
1948	122	132	151	152	120	6,850	86,758	33,444	4,023	2,281	1,777	157	131,074
1949	175	124	111	132	113	5,639	40,963	7,016	6,022	1,457	221	133	59,639
1950	135	123	120	111	94	1,691	114,835	157,349	21,987	5,325	818	270	295,862
1951	345	314	286	210	173	5,350	32,127	8,590	2,166	515	208	152	48,232
1952	138	155	166	115	125	818	42,415	4,378	574	2,736	254	881	48,185
1953	163	127	127	131	130	1,359	1,333	4,323	9,545	3,376	430	526	16,559
1954	150	163	177	171	833	458	857	520	8,783	1,285	329	246	10,618
1955	177	93	147	121	113	978	6,799	793	2,041	1,402	243	204	10,610

Allocating March to June Flows to Pipestem and Jamestown Reservoirs

Year	Total March to June Flows	Acre-Feet of Inflow Assigned to Jamestown Res.
1928		
1929	16,072	5,625
1930	30,798	10,779
1931	2,863	1,002
1932	8,738	3,058
1933	11,558	4,045
1934		
1935		
1936		
1937		
1938	1,223	428
1939	1,612	564
1940		
1941		
1942		
1943	61,615	36,969
1944	7,502	2,626
1945	15,908	5,568
1946	10,925	3,824
1947	28,361	9,926
1948	131,074	78,645
1949	59,639	20,874
1950	295,862	177,517
1951	48,232	16,881
1952	48,185	16,865
1953	16,559	5,796
1954	10,618	3,716
1955	10,610	3,714

Notes:

Used 35% for low flow years (less than 60,000 acre-feet)
Used 60% for high flow years (more than 60,000 acre-feet)
The analysis for 35/65% is on Pipestem page.

Table G-5. Estimates of James River Flow Rates with Reservoir in Place.

Estimates of Average James River Flow Rates with Reservoirs in Place
(Estimate of ability to convey conservation pool releases to Oakes)

	Projected Conservation Pool	Spring/Irrigation Season Flows at Jamestown ---- Average Discharge (cfs) ------						Spring/Irrigation Season Flows at LaMoure ---- Average Discharge (cfs) ------						March to August Total Flows Averaged over May to August		May to August Avg Flow > 40 cfs?	
Year	Releases	March	April	May	June	July	August	March	April	May	June	July	August	Jamestown	LaMoure	Jamestown	LaMoure
1929	1,846	182	42	27	12	4	1							58		Y	
1930	1,846	264	154	71	18	6	1							120		Y	
1931	1,846	13	31	2	1	1	1							4		N	
1932	1,846	79	39	12	14	3	1							28		N	
1933	0	107	55	25	2	1	0							39		N	
1934	0																
1935	1,846																
1936	0																
1937	1,846																
1938	0	15	2	1	1	2	1							-3		N	
1939	0	21	1	1	4	1	1							-2		N	
1940	0																
1941	1,846																
1942	1,846																
1943	1,846		677	119	236	110	16							281		Y	
1944	1,846	2	18	47	57	24	10							31		N	
1945	1,846	145	76	27	14	3	4							58		Y	
1946	0	61	95	20	5	5	3							38		N	
1947	1,846	103	274	50	44	57	12							126		Y	
1948	1,846	111	1,458	544	68	37	29							553		Y	
1949	1,846	92	688	114	101	24	4							247		Y	
1950	1,846	28	2,434	2,559	370	87	13			3,114	578	135	47	1,364	960	Y	Y
1951	1,846	87	540	140	36	8	3	55	800	219	85	33	18	195	294	Y	Y
1952	1,846	13	713	71	10	45	4	17	1,513	139	32	49	16	205	433	Y	Y
1953	1,846	22	22	70	160	55	7	84	42	63	418	130	27	76	183	Y	Y
1954	1,846	7	14	8	148	21	5	28	32	22	278	142	19	42	122	Y	Y
1955	0	16	114	13	34	23	4	42	147	26	72	86	21	42	90	Y	Y
1956	1,846	19	44	50	126	17	5	41	99	55	279	42	18	57	125	Y	Y
1957	0	19	20	18	5	6	3	21	50	36	21	14	12	9	30	N	N
1958	0	113	97	26	20	19	6	223	140	45	48	29	10	61	115	Y	Y
1959	0	10	5	7	7	11	7	18	24	20	26	27	6	3	22	N	N
1960	1,846	120	242	23	18	7	5	97	461	45	36	13	7	95	156	Y	Y
1961	1,846	14	11	7	2	2	2	44	29	22	9	5	3	1	19	N	N
1962	456	66	59	27	39	254	46	123	158	57	86	825	182	114	349	Y	Y
1963	0	9	22	18	12	7	3	33	66	52	35	21	17	9	47	N	Y
1964	0	4	31	17	143	37	11	12	70	39	186	70	19	52	90	Y	Y
1965	1,846	3	417	138	34	65	172	10	565	177	67	86	170	199	260	Y	Y
1966	1,846	731	512	439	378	148	33	1,202	661	519	408	215	68	552	759	Y	Y
1967	1,846	248	143	177	233	116	29	226	281	247	266	156	33	228	293	Y	Y
1968	1,846	31	31	27	28	12	4	53	51	51	168	31	13	24	83	N	Y
1969	1,846	16	949	425	430	367	272	5	17	461	455	405	292	606	400	Y	Y
1970	1,846	10	49	85	30	12	3	35	161	112	44	15	5	39	84	N	Y
1971	1,846	33	153	161	167	43	12	85	167	164	179	67	10	133	159	Y	Y
1972	1,846	190	150	65	65	19	50	391	194	104	81	33	48	126	204	Y	Y
1973	1,846	39	8	6	6	7	9	93	30	15	8	2	9	10	31	N	N
1974	1,846	9	10	108	333	76	37	115	132	134	396	90	33	135	216	Y	Y
1975	1,846	6	174	523	360	124	2,937	20	615	610	552	387	290	1,022	610	Y	Y
1976	1,846	69	262	81	18	18	17	168	314	150	41	25	14	107	169	Y	Y
1977	1,846	5	5	3	2	7	3	32	23	12	23	35	10	-2	25	N	N
1978	1,846	68	85	156	153	106	48	430	246	214	225	145	64	145	322	Y	Y
1979	1,846	23	141	482	405	267	240	59	1,165	591	488	309	257	381	709	Y	Y
1980	1,846	47	33	7	23	10	11	114	84	24	32	17	16	24	63	N	Y
1981	1,846	51	24	11	13	11	15	63	48	25	26	24	12	23	41	N	Y

Table G-5. Estimates of James River Flow Rates with Reservoir in Place (cont.).

1982	1,846	172	227	257	232	242	155	85	697	325	283	217	144	313	429	Y	Y
1983	1,846	274	468	285	302	275	231	531	538	348	347	389	216	450	584	Y	Y
1984	1,846	108	285	267	273	206	136	274	439	350	261	187	128	310	401	Y	Y
1985	1,846	138	42	5	6	14	26	100	82	23	15	17	32	49	59	Y	Y
1986	1,846	121	133	204	116	39	20	251	242	309	181	71	58	149	269	Y	Y
1987	1,846	111	439	475	326	247	204	762	610	543	368	262	213	442	681	Y	Y
1988	1,846	87	105	6	18	23	17	95	132	27	27	27	24	55	74	Y	Y
1989	1,846	29	8	3	2	6	4	189	142	25	20	20	6	4	92	N	Y
1990	0	4	4	2	9	3	1	15	20	15	26	13	4	-3	15	N	N
1991	0	3	7	10	6	2	1	18	18	29	31	17	5	-1	21	N	N
1992	0	49	16	31	2	1	1	83	29	32	16	10	5	16	35	N	N
1993	1,846	28	91	50	84	233	713	57	111	62	93	1,020	886	291	549	Y	Y
1994	1,846	128	602	592	434	376	225	419	859	736	496	518	278	580	818	Y	Y
1995	1,846	253	843	1,065	1,086	1,024	761	678	1,177	1,364	1,187	1,165	894	1,249	1,608	Y	Y
1996	1,846	140	829	1,262	696	384	384	552	1,548	1,299	814	444	424	915	1,262	Y	Y
1997	1,846	183	1,348	1,714	1,266	482	382	587	3,209	1,905	1,369	742	459	1,335	2,059	Y	Y
1998	1,846	171	445	480	418	211	115	559	682	589	533	316	163	451	702	Y	Y
1999	1,846	95	657	850	789	780	722	442	941	1,619	914	895	825	965	1,400	Y	Y
2000	1,846	64	40	52	143	332	480	293	112	122	173	457	511	269	408	Y	Y
2001	1,846	74	745	1,104	1,197	726	497	140	1,403	1,243	1,399	899	667	1,077	1,429	Y	Y
2002	1,846	16	84	129	62	35	17	25	118	2,013	78	116	62	77	594	Y	Y
2003	1,846	20	20	131	227	165	117	67	55	259	298	220	148	161	253	Y	Y
2004	1,846	21	366	461	434	447	208	162	471	549	817	652	289	476	726	Y	Y
2005	1,846	25	27	133	196	202	170	89	91	194	649	289	347	180	406	Y	Y
2006	1,846	49	58	88	18	19	18	127	155	158	65	41	36	54	137	Y	Y
2007	1,846	35	102	161	339	326	295	309	382	328	1,074	477	364	306	725	Y	Y
2008	1,846	23	26	20	60	68	62	85	99	63	170	99	94	56	144	Y	Y
2009	1,846	56	1,928	3,020	1,963	1,051	310	688	4,598	3,648	2,286	1,227	471	2,074	3,221	Y	Y

Table G-6. Estimates of James River Flow Rates with Reservoir in Place.

Pipestem Reservoir flows vs Jamestown Reservoir 1975 to 2009

----March to June ----

	Computed Daily Reservoir Inflow	Total Daily Reservoir Discharge	Total Inflow
1975	48,687	14,462	63,149
1976	13,687	13,965	27,652
1977	data unavailable		
1978	19,424	15,890	35,314
1979	48,324	15,536	63,860
1980	5,456	6,256	11,712
1981	4,830	5,657	10,487
1982	30,285	15,109	45,394
1983	36,287	14,688	50,975
1984	33,316	17,952	51,268
1985	3,981	6,741	10,722
1986		3,791	3,791
1987	44,145	18,111	62,256
1988	9,751	9,471	19,222
1989	15,032	13,695	28,727
1990	0	0	0
1991	data unavailable		
1992	data unavailable		
1993	data unavailable		
1994	data unavailable		
1995	data unavailable		
1996	data unavailable		
1997	data unavailable		
1998	data unavailable		
1999		27,057	
2000	82,953	70,498	153,451
2001	44,239	22,388	66,627
2002	8,918	8,062	16,980
2003	13,850	8,282	22,132
2004	22,440	6,075	28,515
2005	15,597	4,880	20,477
2006	295	0	295
2007	37,353	16,258	53,611
2008	7,302	3,058	10,360
2009	158,707	141,627	300,334

Comparison of March to June Reservoir Inflows

Year	Pipestem Reservoir	Jamestown Reservoir	Total Inflow	-- Percent -- Pipestem	Jamestown
1975	63,149	102,286	165,435	38.2%	61.8%
1976	27,652	26,045	53,697	51.5%	48.5%
1977					
1978	35,314	19,762	55,076	64.1%	35.9%
1979	63,860	103,687	167,547	38.1%	61.9%
1980	11,712	879	12,591	93.0%	7.0%
1981	10,487	7,373	17,860	58.7%	41.3%
1982	45,394	69,253	114,647	39.6%	60.4%
1983	50,975	134,810	185,785	27.4%	72.6%
1984	51,268	69,440	120,708	42.5%	57.5%
1985	10,722	4,297	15,019	71.4%	28.6%
1986					
1987	62,256	122,231	184,487	33.7%	66.3%
1988	19,222	2,550	21,772	88.3%	11.7%
1989	28,727	272	28,999	99.1%	0.9%
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000	153,451	24,112	177,563	86.4%	13.6%
2001	66,627	253,076	319,703	20.8%	79.2%
2002	16,980	20,078	37,058	45.8%	54.2%
2003	22,132	31,757	53,889	41.1%	58.9%
2004	28,515	142,688	171,203	16.7%	83.3%
2005	20,477	28,964	49,441	41.4%	58.6%
2006					
2007	53,611	35,374	88,985	60.2%	39.8%
2008	10,360	7,530	17,890	57.9%	42.1%
2009	300,334	541,441	841,775	35.7%	64.3%
Total	951,538	1,495,246	2,446,784	38.9%	61.1%
Average	55,973	87,956	143,928	38.9%	61.1%
Median	32,021	30,361	72,031	44.1%	55.9%
Maximum	300,334	541,441	841,775		

March to June Inflows Less than 60,000 Acre-Feet

Year	Pipestem Reservoir	Jamestown Reservoir	Total Inflow	-- Percent -- Pipestem	Jamestown
1976	27,652	26,045	53,697	51.5%	48.5%
1978	35,314	19,762	55,076	64.1%	35.9%
1980	11,712	879	12,591	93.0%	7.0%
1981	10,487	7,373	17,860	58.7%	41.3%
1985	10,722	4,297	15,019	71.4%	28.6%
1988	19,222	2,550	21,772	88.3%	11.7%
1989	28,727	272	28,999	99.1%	0.9%
2002	16,980	20,078	37,058	45.8%	54.2%
2003	22,132	31,757	53,889	41.1%	58.9%
2005	20,477	28,964	49,441	41.4%	58.6%
2008	10,360	7,530	17,890	57.9%	42.1%
Average	19,435	13,592	33,027	64.8%	35.2%
Median	19,222	7,530	28,999	58.7%	41.3%

March to June Inflows Greater than 60,000 Acre-Feet

Year	Pipestem Reservoir	Jamestown Reservoir	Total Inflow	-- Percent -- Pipestem	Jamestown
1975	63,149	102,286	165,435	38.2%	61.8%
1979	63,860	103,687	167,547	38.1%	61.9%
1982	45,394	69,253	114,647	39.6%	60.4%
1983	50,975	134,810	185,785	27.4%	72.6%
1984	51,268	69,440	120,708	42.5%	57.5%
1987	62,256	122,231	184,487	33.7%	66.3%
2000	153,451	24,112	177,563	86.4%	13.6%
2001	66,627	253,076	319,703	20.8%	79.2%
2004	28,515	142,688	171,203	16.7%	83.3%
2007	53,611	35,374	88,985	60.2%	39.8%
2009	300,334	541,441	841,775	35.7%	64.3%
Average	85,404	145,309	230,713	39.9%	60.1%
Median	62,256	103,687	171,203	38.1%	61.9%

Table G-7. State Hospital Precipitation. Data from NCDC weather site.

State Hospital Precipitation

Data from NCDC weather site

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
1931	9	78	99	238	254	230	291	223	133	244	142	29	1970
1932	55	51	77	305	450	370	158	151	72	198	69	13	1969
1933	102	19	45	196	334	175	326	68	33	66	151	75	1590
1934	14	19	72	42	62	338	134	199	121	290	87	23	1401
1935	70	35	150	407	248	218	408	386	58	15	47	121	2163
1936	43	57	95	31	34	33	81	180	34	32	25	46	691
1937	129	98	68	374	192	284	245	145	55	66	68	120	1844
1938	45	130	101	129	238	250	417	60	15	29	95	43	1552
1939	57	134	45	160	133	743	75	145	101	118	0	43	1754
1940	31	63	155	149	145	349	299	241	70	385	100	108	2095
1941	40	20	62	285	174	456	210	320	364	231	77	5	2244
1942	8	25	179	346	405	278	203	337	222	82	24	47	2156
1943	37	158	170	114	191	533	232	303	27	40	36	20	1861
1944	21	30	127	55	231	161	193	550	77	2	265	0	1712
1945	39	37	54	134	81	170	191	306	252	25	11	76	1376
1946	18	54	72	90	137	328	257	164	556	204	5	86	1971
1947	16	89	44	145	130	438	252	176	152	220	138	24	1824
1948	27	66	69	124	72	262	284	215	69	156	71	8	1423
1949	94	27	86	35	259		696	43	61	263	36	69	1669
1950	91	0	138	96	518	323	222	155	200	28	12	51	1834
1951	54	65	31	127	189	313	241	377	74	103	8	87	1669
1952	58	77	72	10	46	199	313	66	99	11	85	44	1080

Converted to inches

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		Actual River Flows @ Jamestown	Previous Winter Precip	March to June Precip	Total		
1931	0.09	0.78	0.99	2.38	2.54	2.30	2.91	2.23	1.33	2.44	1.42	0.29	19.7	2,863					
1932	0.55	0.51	0.77	3.05	4.50	3.70	1.58	1.51	0.72	1.98	0.69	0.13	19.69	8,738	2.77	12.02	14.79	5.79	20.58
1933	1.02	0.19	0.45	1.96	3.34	1.75	3.26	0.68	0.33	0.66	1.51	0.75	15.9	11,558	2.03	7.50	9.53	4.93	14.46
1934	0.14	0.19	0.72	0.42	0.62	3.38	1.34	1.99	1.21	2.90	0.87	0.23	14.01		2.59	5.14	7.73	7.44	15.17
1935	0.70	0.35	1.50	4.07	2.48	2.18	4.08	3.86	0.58	0.15	0.47	1.21	21.63		2.15	10.23	12.38	8.67	21.05
1936	0.43	0.57	0.95	0.31	0.34	0.33	0.81	1.80	0.34	0.32	0.25	0.46	6.91		2.68	1.93	4.61	3.27	7.88
1937	1.29	0.98	0.68	3.74	1.92	2.84	2.45	1.45	0.55	0.66	0.68	1.20	18.44	0	2.98	9.18	12.16	5.11	17.27
1938	0.45	1.30	1.01	1.29	2.38	2.50	4.17	0.60	0.15	0.29	0.95	0.43	15.52	1,223	3.63	7.18	10.81	5.21	16.02
1939	0.57	1.34	0.45	1.60	1.33	7.43	0.75	1.45	1.01	1.18	0.00	0.43	17.54	1,612	3.29	10.81	14.10	4.39	18.49
1940	0.31	0.63	1.55	1.49	1.45	3.49	2.99	2.41	0.70	3.85	1.00	1.08	20.95		1.37	7.98	9.35	9.95	19.30
1941	0.40	0.20	0.62	2.85	1.74	4.56	2.10	3.20	3.64	2.31	0.77	0.05	22.44		2.68	9.77	12.45	11.25	23.70
1942	0.08	0.25	1.79	3.46	4.05	2.78	2.03	3.37	2.22	0.82	0.24	0.47	21.56		1.15	12.08	13.23	8.44	21.67
1943	0.37	1.58	1.70	1.14	1.91	5.33	2.32	3.03	0.27	0.40	0.36	0.20	18.61	61,615	2.66	10.08	12.74	6.02	18.76
1944	0.21	0.30	1.27	0.55	2.31	1.61	1.93	5.50	0.77	0.02	2.65	0.00	17.12	7,502	1.07	5.74	6.81	8.22	15.03
1945	0.39	0.37	0.54	1.34	0.81	1.70	1.91	3.06	2.52	0.25	0.11	0.76	13.76	15,908	3.41	4.39	7.80	7.74	15.54
1946	0.18	0.54	0.72	0.90	1.37	3.28	2.57	1.64	5.56	2.04	0.05	0.86	19.71	10,925	1.59	6.27	7.86	11.81	19.67
1947	0.16	0.89	0.44	1.45	1.30	4.38	2.52	1.76	1.52	2.20	1.38	0.24	18.24	28,361	1.96	7.57	9.53	8.00	17.53
1948	0.27	0.66	0.69	1.24	0.72	2.62	2.84	2.15	0.69	1.56	0.71	0.08	14.23	131,074	2.55	5.27	7.82	7.24	15.06
1949	0.94	0.27	0.86	0.35	2.59	0.00	6.96	0.43	0.61	2.63	0.36	0.69	16.69	59,639	2.00	3.80	5.80	10.63	16.43
1950	0.91	0.00	1.38	0.96	5.18	3.23	2.22	1.55	2.00	0.28	0.12	0.51	18.34	295,862	1.96	10.75	12.71	6.05	18.76
1951	0.54	0.65	0.31	1.27	1.89	3.13	2.41	3.77	0.74	1.03	0.08	0.87	16.69	48,232	1.82	6.60	8.42	7.95	16.37
1952	0.58	0.77	0.72	0.10	0.46	1.99	3.13	0.66	0.99	0.11	0.85	0.44	10.8	48,185	2.30	3.27	5.57	4.89	10.46
														16,559					
														10,618					
														10,610					

Year	Winter	Spring	Summer	Fall	Estimated Spring Inflows	Estimated refill volume
1933				Avg		
1934	Avg	Dry	Avg	Wet	Low	0
1935	Dry	Wet	Wet	Dry	Above average	3000
1936	Dry	Dry	Dry	Dry	Low	0
1937	Avg	Wet	Ave	Dry	Above average	3000
1939				Avg		
1940	Dry	Avg	Above	Avg	Below average	0
1941	Dry	Above	Above	Avg	Above average	3000
1942	Dry	Wet	Above	Dry	Above average	3000

Table G-8. Surplus Flows: Comparison of Peak Monthly Average Flow vs Operating Principles Targets.

Comparison of Peak Monthly Average Flow vs Operating Principles Targets

Year	Refuge Targets Actually Reached?	Peak March to June Monthly CFS: State Line	LaMoure	Bear Creek
1992	N	144	83	4
1993	N	199	111	28
1994	Y	1,180	859	108
1995	Y	1,416	1,364	122
1996	Y	1,845	1,548	183
1997	Y	4,617	3,209	679
1998	Y	1,058	682	142
1999	Y	1,175	941	176
2000	N	208	173	35
2001	Y	1,723	1,403	148
2002	N	286	202	8
2003	N	474	298	42
2004	Y	850	817	19
2005	Y	934	649	83
2006	N	332	158	104
2007	Y	1,315	1,074	75
2008	N	169	170	16
2009	Y	5,862	4,598	640

Year	Monthly Mean Discharge (cfs): Mar	Apr	May	June	July	August	Enough Flow to Achieve Refuge Targets?
1928	---- @ Jamestown Gage ------						
1929	182	42	27	12	4	1	N
1930	264	154	71	18	6	1	N
1931	13	31	2	1	1	1	N
1932	79	39	12	14	3	1	N
1933	107	55	25	2	1	0	N
1934							N
1935							N
1936							N
1937							N
1938	15	2	1	1	2	1	N
1939	21	1	1	4	1	1	N
1940							N
1941							N
1942							N
1943		677	119	236	110	16	Y
1944	2	18	47	57	24	10	N
1945	145	76	27	14	3	4	N
1946	61	95	20	5	5	3	N
1947	103	274	50	44	57	12	N
1948	111	1,458	544	68	37	29	Y
1949	92	688	114	101	24	4	Y
	----@ LaMoure Gage -------						
1950			3,114	578	135	47	Y
1951	55	800	219	85	33	18	Y
1952	17	1,513	139	32	49	16	Y
1953	84	42	63	418	130	27	N
1954	28	32	22	278	142	19	N
1955	42	147	26	72	86	21	N
1956	41	99	55	279	42	18	N
1957	21	50	36	21	14	12	N
1958	223	140	45	48	29	10	N
1959	18	24	20	26	27	6	N
1960	97	461	45	36	13	7	N
1961	44	29	22	9	5	3	N
1962	123	158	57	86	825	182	N
1963	33	66	52	35	21	17	N
1964	12	70	39	186	70	19	N
1965	10	565	177	67	86	170	N
1966	1,202	661	519	408	215	68	Y
1967	226	281	247	266	156	33	N
1968	53	51	51	168	31	13	N
1969	5	17	461	455	405	292	N
1970	35	161	112	44	15	5	N
1971	85	167	164	179	67	10	N
1972	391	194	104	81	33	48	N
1973	93	30	15	8	2	9	N
1974	115	132	134	396	90	33	N
1975	20	615	610	552	387	290	N
1976	168	314	150	41	25	14	N
1977	32	23	12	23	35	10	N
1978	430	246	214	225	145	64	N
1979	59	1,165	591	488	309	257	Y
1980	114	84	24	32	17	16	N
1981	63	48	25	26	24	12	N
	----@ State Line -------						
1982	55	816	289	242	211	142	N
1983	672	517	316	204	226	207	N
1984	244	943	307	301	195	117	Y
1985	133	91	22	12	1	1	N
1986	359	306	523	180	81	63	N
1987	800	977	579	373	227	187	Y
1988	102	135	25	2	0	0	N
1989	161	496	31	8	1	0	N
1990	26	33	10	20	6	0	N
1991	29	46	52	111	59	2	N
1992	144	42	11	28	12	2	N
1993	99	199	42	118	713	1,143	N
1994	423	1,180	848	493	544	313	Y
1995	853	1,209	1,416	1,200	1,181	1,006	Y
1996	677	1,845	1,552	1,099	454	405	Y
1997	317	4,617	2,316	1,447	1,000	585	Y
1998	693	1,058	794	714	678	264	Y
1999	587	1,175	1,968	1,416	1,050	929	Y
2000	525	208	208	211	490	478	N
2001	174	1,723	1,315	1,403	946	659	Y
2002	94	188	286	153	168	70	N
2003	92	88	414	474	244	131	N
2004	153	526	541	850	625	254	Y
2005	119	126	225	934	447	369	Y
2006	180	332	191	47	5	5	N
2007	377	572	723	1,315	702	383	Y
2008	86	128	53	169	64	58	N
2009	731	5,862	4,011	2,581	1,485	629	Y

Table G-9. Demand: Modeled Irrigation Demand with Oakes, Fullerton, and Forman Weather Data.

	Modeled Irrigation Demand With Oakes, Fullerton & Forman Weather Data						Recaptured Drain Flows		Surplus Flows			Jamestown Reservoir Conservation	Ac-ft of Groundwater Needed		
	Oakes		Fullerton		Forman			Avail-	Oakes Weather	Fullerton Weather	Forman Weather				
Year	In/Ac	Ac-ft	In/Ac	Ac-ft	In/Ac	Ac-ft	(ac-ft)	ble?	--- acre-feet used ---			Pool (ac-ft)	Oakes	Fullerton	Forman
1929	13.63	5,679	11.27	4,696	12.28	5,117	500	N	0	0	0	1,846	3,333	2,350	2,771
1930	11.9	4,958	10.87	4,529	11.65	4,854	500	N	0	0	0	1,846	2,612	2,183	2,508
1931	9.78	4,075	10.15	4,229	10.82	4,508	500	N	0	0	0	1,380	2,195	2,349	2,628
1932	10.33	4,304	11.03	4,596	9.36	3,900	500	N	0	0	0	1,380	2,424	2,716	2,020
1933	12.89	5,371	10.16	4,233	12.39	5,163	500	N	0	0	0	0	4,871	3,733	4,663
1934	16.8	7,000	15.73	6,554	16.72	6,967	500	N	0	0	0	0	6,500	6,054	6,467
1935	7.92	3,300	6.68	2,783	7.43	3,096	500	N	0	0	0	1,380	1,420	903	1,216
1936	19.3	8,042	17.27	7,196	19.53	8,138	500	N	0	0	0	0	7,542	6,696	7,638
1937	12.25	5,104	12.61	5,254	5.69	2,371	500	N	0	0	0	1,380	3,224	3,374	491
1938	12.27	5,113	11.78	4,908	8.34	3,475	500	N	0	0	0	0	4,613	4,408	2,975
1939	9.34	3,892	9.3	3,875	8.78	3,658	500	N	0	0	0	0	3,392	3,375	3,158
1940	9.02	3,758	7.92	3,300	6.62	2,758	500	N	0	0	0	0	3,258	2,800	2,258
1941	10.12	4,217	9.96	4,150	9	3,750	500	N	0	0	0	1,380	2,337	2,270	1,870
1942	6.12	2,550	5.1	2,125	5.48	2,283	500	N	0	0	0	1,380	670	245	403
1943	5.73	2,388	4.77	1,988	5.31	2,213	500	Y	1,888	1,488	1,713	0	0	0	0
1944	4.28	1,783	5.21	2,171	5.51	2,296	500	N	0	0	0	1,380	0	291	416
1945	9.6	4,000	9.78	4,075	9.68	4,033	500	N	0	0	0	1,846	1,654	1,729	1,687
1946	9.51	3,963	6.93	2,888	8.07	3,363	500	N	0	0	0	0	3,463	2,388	2,863
1947	10.55	4,396	9.43	3,929	10.72	4,467	500	N	0	0	0	1,846	2,050	1,583	2,121
1948	8.42	3,508	9.72	4,050	7.14	2,975	500	Y	3,008	3,550	2,475	0	0	0	0
1949	11.02	4,592	10.03	4,179	5.9	2,458	500	Y	4,092	3,679	1,958	0	0	0	0
1950	12.01	5,004	12.05	5,021	11.02	4,592	500	Y	4,504	4,521	4,092	0	0	0	0
1951	5.8	2,417	6.04	2,517	7.52	3,133	500	Y	1,917	2,017	2,633	0	0	0	0
1952	8.8	3,667	11.11	4,629	9.64	4,017	500	Y	3,167	4,129	3,517	0	0	0	0
1953	7.02	2,925	8.49	3,538	9.37	3,904	500	N	0	0	0	1,846	579	1,191	1,558
1954	9.33	3,888	10.32	4,300	11.04	4,600	500	N	0	0	0	1,846	1,541	1,954	2,254
1955	6.1	2,542	6.07	2,529	6.22	2,592	500	N	0	0	0	0	2,042	2,029	2,092
1956	5.56	2,317	7.38	3,075	7.05	2,938	500	N	0	0	0	1,846	0	729	591
1957	4.96	2,067	6.35	2,646	6.07	2,529	500	N	0	0	0	0	1,567	2,146	2,029
1958	7.9	3,292	9.91	4,129	9.85	4,104	500	N	0	0	0	0	2,792	3,629	3,604
1959	8.79	3,663	12.62	5,258	7.82	3,258	500	N	0	0	0	0	3,163	4,758	2,758
1960	6.62	2,758	9.56	3,983	8.92	3,717	500	N	0	0	0	1,846	412	1,637	1,371
1961	8.31	3,463	11.03	4,596	9.78	4,075	500	N	0	0	0	1,380	1,583	2,716	2,195
1962	3.75	1,563	5.27	2,196	3.48	1,450	500	N	0	0	0	1,846	0	0	0
1963	7.5	3,125	8.09	3,371	8.22	3,425	500	N	0	0	0	6	2,619	2,865	2,919
1964	6.45	2,688	7.48	3,117	6.18	2,575	500	N	0	0	0	0	2,188	2,617	2,075
1965	6.64	2,767	5.32	2,217	4.75	1,979	500	N	0	0	0	1,846	421	0	0
1966	6.86	2,858	6.66	2,775	5.04	2,100	500	Y	2,358	2,275	1,600	0	0	0	0
1967	8.86	3,692	11.32	4,717	7.99	3,329	500	N	0	0	0	1,846	1,346	2,371	983
1968	7.3	3,042	7.88	3,283	8.25	3,438	500	N	0	0	0	1,846	696	937	1,091
1969	8.2	3,417	9.73	4,054	9.06	3,775	500	N	0	0	0	1,846	1,071	1,708	1,429
1970	11.25	4,688	12.91	5,379	12.03	5,013	500	N	0	0	0	1,846	2,341	3,033	2,666
1971	7.42	3,092	8	3,333	8.13	3,388	500	N	0	0	0	1,846	746	987	1,041
1972	7.11	2,963	8.43	3,513	7.81	3,254	500	N	0	0	0	1,846	616	1,166	908
1973	11.86	4,942	16.7	6,958	9.75	4,063	500	N	0	0	0	1,380	3,062	5,078	2,183
1974	10.18	4,242	12.96	5,400	12.22	5,092	500	N	0	0	0	1,846	1,896	3,054	2,746
1975	8.4	3,500	8.4	3,500	6.88	2,867	500	N	0	0	0	1,846	1,154	1,154	521
1976	17.25	7,188	16.85	7,021	14.55	6,063	500	N	0	0	0	1,846	4,841	4,675	3,716
1977	10.54	4,392	9.85	4,104	8.28	3,450	500	N	0	0	0	1,380	2,512	2,224	1,570
1978	9.79	4,079	8.46	3,525	7	2,917	500	N	0	0	0	1,846	1,733	1,179	571
1979	9.16	3,817	8.78	3,658	6.9	2,875	500	Y	3,317	3,158	2,375	0	0	0	0
1980	13.24	5,517	13.07	5,446	9.7	4,042	500	N	0	0	0	1,846	3,171	3,100	1,696
1981	11.11	4,629	6.41	2,671	6.74	2,808	500	N	0	0	0	1,846	2,283	325	462
1982	14.56	6,067	13.48	5,617	11.24	4,683	500	N	0	0	0	1,846	3,721	3,271	2,337
1983	8.31	3,463	11.19	4,663	8.58	3,575	500	N	0	0	0	1,846	1,116	2,316	1,229
1984	10.81	4,504	11.2	4,667	8.99	3,746	500	Y	4,004	4,167	3,246	0	0	0	0

Table G-9. Demand: Modeled Irrigation Demand with Oakes, Fullerton, and Forman Weather Data (cont.).

1985	11.45	4,771	13.14	5,475	9.04	3,767	500	N	0	0	0	1,846	2,425	3,129	1,421
1986	6.46	2,692	6.86	2,858	4.98	2,075	500	N	0	0	0	1,846	346	512	0
1987	10.96	4,567	9.3	3,875	9.34	3,892	500	Y	4,067	3,375	3,392	0	0	0	0
1988	20.89	8,704	16.83	7,013	14.92	6,217	500	N	0	0	0	1,846	6,358	4,666	3,871
1989	9.05	3,771	10.36	4,317	9.04	3,767	500	N	0	0	0	1,846	1,425	1,971	1,421
1990	10.33	4,304	8.92	3,717	8.54	3,558	500	N	0	0	0	1,380	2,424	1,837	1,678
1991	8.6	3,583	8.83	3,679	6.37	2,654	500	N	0	0	0	0	3,083	3,179	2,154
1992	6.21	2,588	5.45	2,271	5.19	2,163	500	N	0	0	0	0	2,088	1,771	1,663
1993	4.03	1,679	3.38	1,408	3.18	1,325	500	N	0	0	0	0	1,179	908	825
1994	8.78	3,658	6.82	2,842	6.66	2,775	500	Y	3,158	2,342	2,275	0	0	0	0
1995	7.8	3,250	5.07	2,113	6.13	2,554	500	Y	2,750	1,613	2,054	0	0	0	0
1996	8.8	3,667	9.9	4,125	9.56	3,983	500	Y	3,167	3,625	3,483	0	0	0	0
1997	8.47	3,529	6.95	2,896	6.36	2,650	500	Y	3,029	2,396	2,150	0	0	0	0
1998	6.42	2,675	4.83	2,013	6.41	2,671	500	Y	2,175	1,513	2,171	0	0	0	0
1999	4.54	1,892	4.53	1,888	4.48	1,867	500	Y	1,392	1,388	1,367	0	0	0	0
2000	5.44	2,267	5.85	2,438	4.82	2,008	500	N	0	0	0	1,846	0	91	0
2001	7.84	3,267	7.18	2,992	7.27	3,029	500	Y	2,767	2,492	2,529	0	0	0	0
2002	5.62	2,342	8.24	3,433	3.78	1,575	500	N	0	0	0	1,846	0	1,087	0
2003	7.91	3,296	9.58	3,992	7.13	2,971	500	N	0	0	0	1,846	950	1,646	625
2004	7.21	3,004	7.2	3,000	5.93	2,471	500	Y	2,504	2,500	1,971	0	0	0	0
2005	3.59	1,496	5.53	2,304	3.08	1,283	500	N	0	0	0	1,846	0	0	0
2006								N							
2007								Y							
2008								N							
2009								Y							
		291,221		295,758		264,458	38,500		53,263	50,225	45,000	74,262	127,040	133,093	110,403

Notes:
- Modeled irrigation demand provided by state water commission
- Ac-ft of modeled demand based on 5,000 acres
- 500 ac-ft of recaptured drain flows per year is conservative
- Surplus flows assumes there is sufficient flow to meet all demands in years available
- No Jamestown Reservoir conservation pool releases when surplus flows are avaialble
- Surplus flow use = total modeled demand minus recaptured drain flows

Table G-10. Red River Valley Flows 1925 to 1959

Red River Valley

Year	Monthly Mean Discharge in CFS: March	April	May	June	Monthly Mean Discharge in Acre-Feet: March	April	May	June	Total	March to June Flows at Jamestown
1925	158	297	236	564	9,742	17,654	14,521	33,563	75,480	
1926	474	352	204	172	29,165	20,951	12,535	10,255	72,906	
1927	846	918	520	629	52,020	54,657	31,970	37,444	176,091	
1928	949	499	371	295	58,367	29,724	22,806	17,582	128,479	
1929	1,421	514	357	174	87,397	30,564	21,957	10,327	150,244	16,072
1930	711	398	590	290	43,723	23,707	36,294	17,273	120,996	30,798
1931	128	190	168	132	7,873	11,333	10,308	7,857	37,370	2,863
1932	135	232	56	33	8,297	13,797	3,420	1,976	27,489	8,738
1933	129	207	74	51	7,952	12,309	4,527	3,041	27,829	11,558
1934	43	102	8	3	2,645	6,077	499	197	9,418	
1935	386	152	113	87	23,759	9,017	6,925	5,160	44,862	
1936	161	428	87	3	9,921	25,475	5,332	171	40,898	
1937	27	445	253	183	1,648	26,463	15,542	10,916	54,569	
1938	236	164	426	330	14,540	9,737	26,182	19,648	70,107	1,223
1939	739	706	213	130	45,470	41,997	13,100	7,761	108,329	1,612
1940	40	447	384	186	2,466	26,582	23,642	11,041	63,731	
1941	252	644	324	485	15,524	38,349	19,952	28,885	102,709	
1942	190	326	1,299	1,665	11,686	19,380	79,894	99,101	210,060	
1943	464	6,164	1,860	2,803	28,513	366,881	114,397	166,835	676,627	61,615
1944	255	868	1,196	2,128	15,702	51,675	73,559	126,659	267,595	7,502
1945	2,814	1,671	999	1,107	173,072	99,458	61,461	65,889	399,880	15,908
1946	1,550	1,348	640	420	95,331	80,233	39,350	25,022	239,937	10,925
1947	513	3,537	1,881	1,612	31,564	210,522	115,689	95,946	453,721	28,361
1948	216	1,806	1,619	625	13,266	107,493	99,575	37,224	257,558	131,074
1949	181	718	251	225	11,126	42,723	15,450	13,362	82,662	59,639
1950	527	3,669	3,320	1,768	32,425	218,379	204,193	105,231	560,228	295,862
1951	256	3,233	1,712	1,114	15,714	192,428	105,295	66,305	379,743	48,232
1952	533	7,257	2,149	1,609	32,806	431,937	132,172	95,768	692,683	48,185
1953	686	692	1,253	3,281	42,186	41,158	77,065	195,285	355,693	16,559
1954	631	863	944	1,190	38,834	51,366	58,054	70,829	219,082	10,618
1955	277	863	375	322	17,012	51,342	23,089	19,171	110,614	10,610
1956	251	1,410	834	831	15,425	83,923	51,313	49,455	200,116	
1957	459	902	962	1,112	28,218	53,687	59,148	66,186	207,240	
1958	574	850	379	164	35,309	50,562	23,316	9,767	118,955	
1959	364	408	428	687	22,400	24,254	26,311	40,914	113,880	
					0	0	0	0	0	