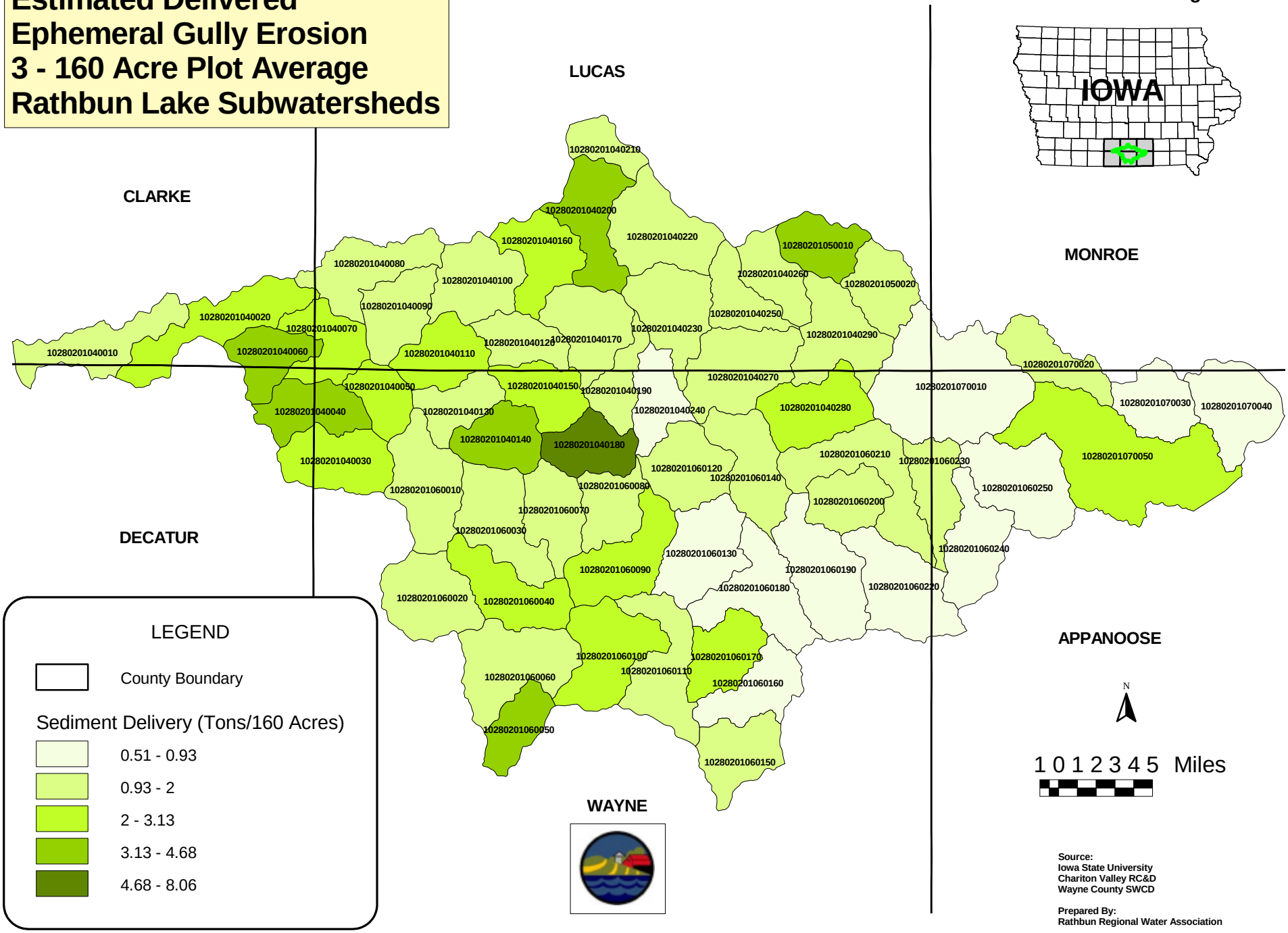
Estimated Delivered Ephemeral Gully Erosion 3 - 160 Acre Plot Average Rathbun Lake Subwatersheds

Figure 29

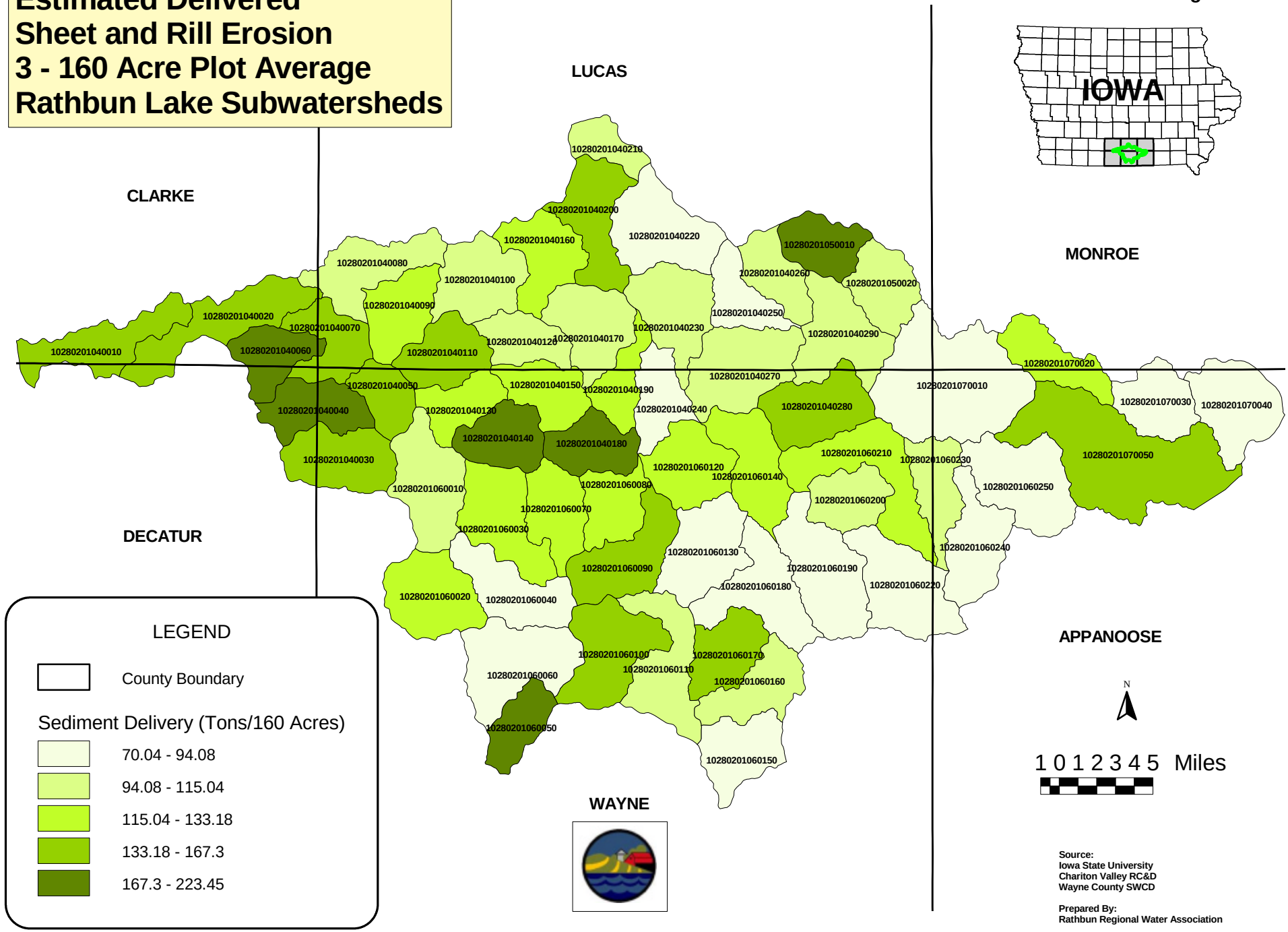


Source:
Iowa State University
Chariton Valley RC&D
Wayne County SWCD

Prepared By:
Rathbun Regional Water Association

Estimated Delivered Sheet and Rill Erosion 3 - 160 Acre Plot Average Rathbun Lake Subwatersheds

Figure 30

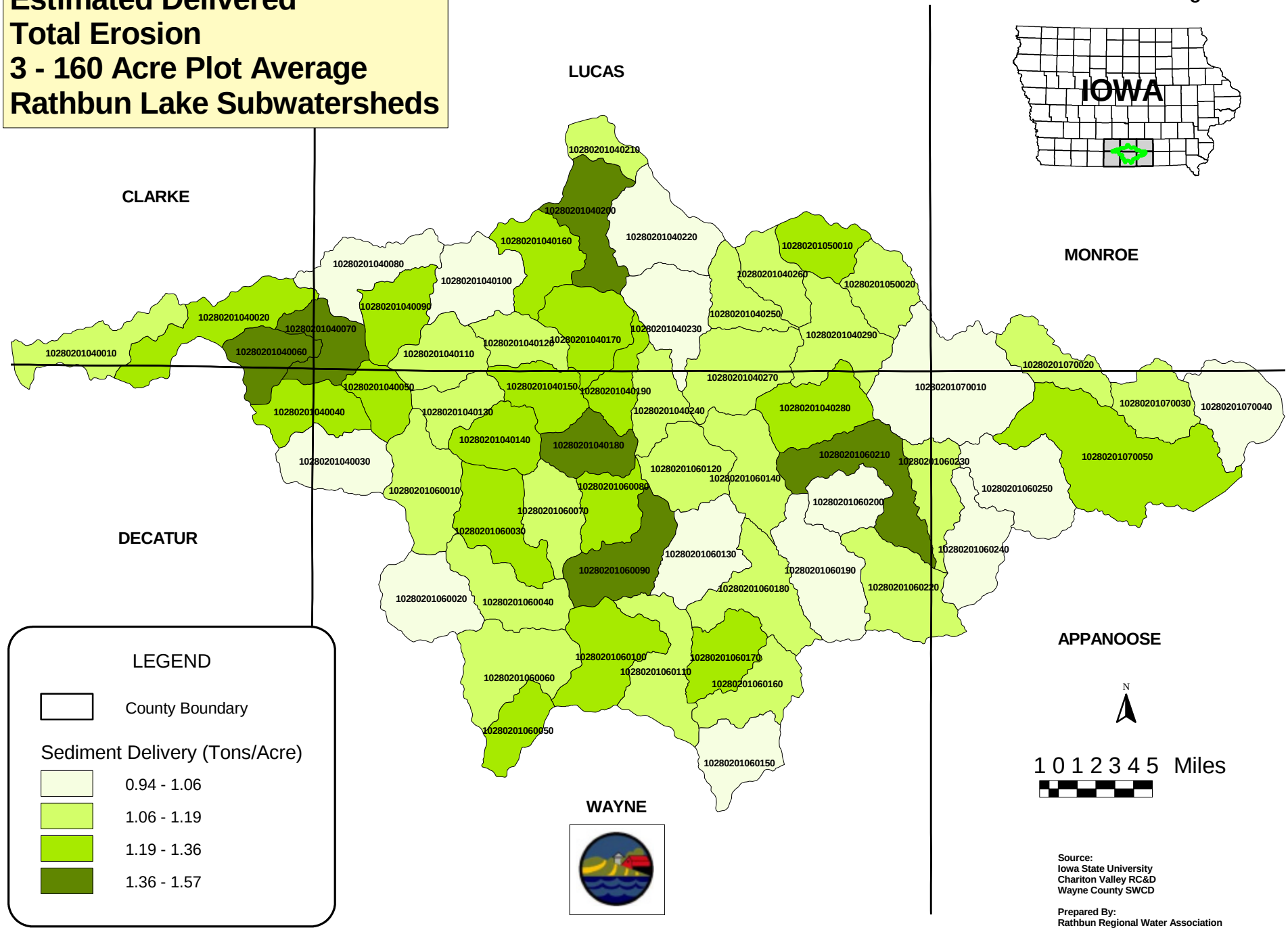


Source:
Iowa State University
Chariton Valley RC&D
Wayne County SWCD

Prepared By:
Rathbun Regional Water Association

Estimated Delivered Total Erosion 3 - 160 Acre Plot Average Rathbun Lake Subwatersheds

Figure 31



Source:
Iowa State University
Chariton Valley RC&D
Wayne County SWCD

Prepared By:
Rathbun Regional Water Association

Table 15

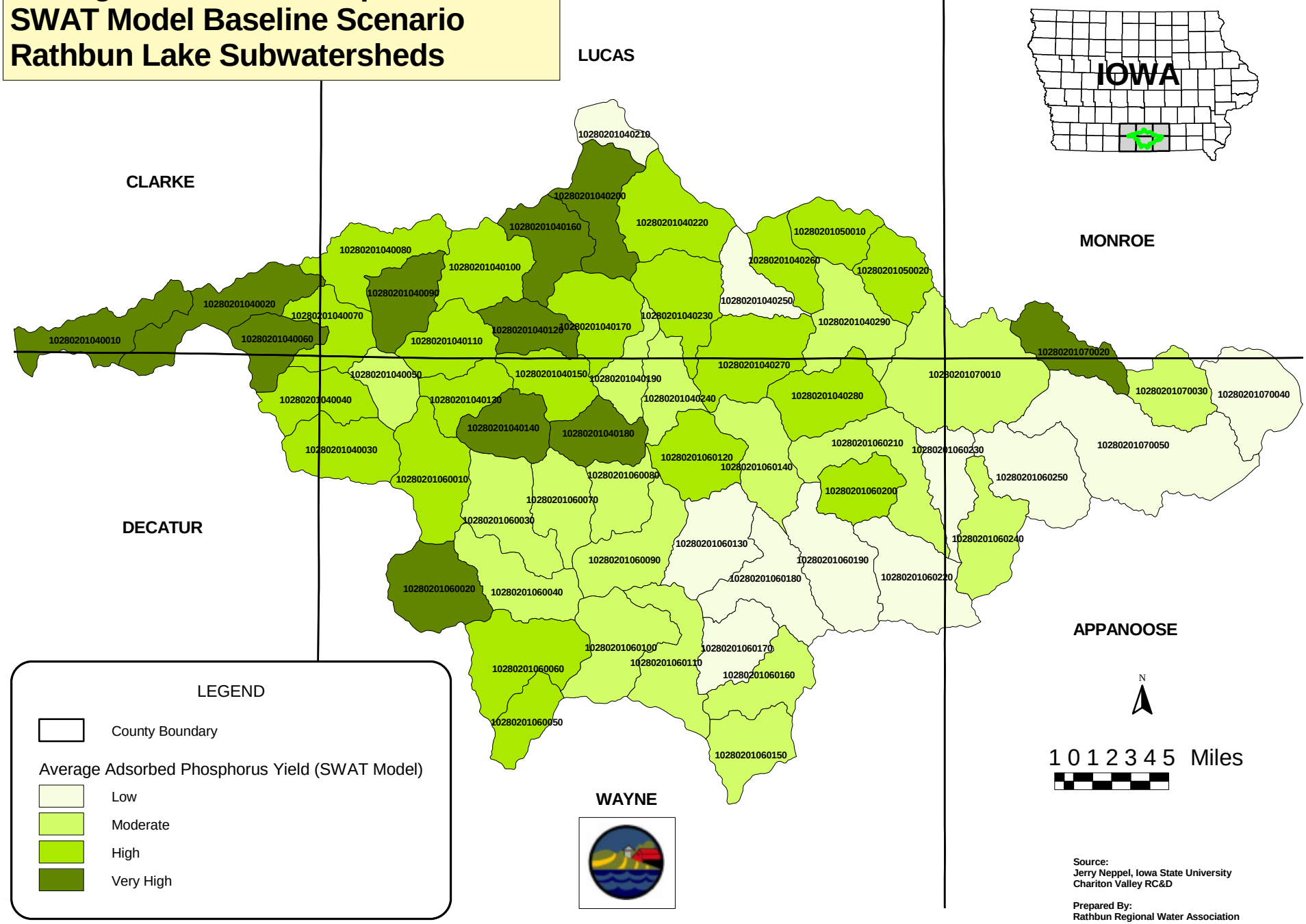
Estimated Sediment Delivery by Erosion Type							
14 Digit Sub-Watersheds							
Rathbun Lake Watershed							
14 Digit HU#	**Streambank (Tons/160 Acres)**	**Gully (Tons/160 Acres)**	**Ephemeral Gully (Tons/160 Acres)**	**Sheet and Rill (Tons/160 Acres)**	**Total (Tons/160 Acres)**	**Watershed Total (Tons)**	**Tons/Acre Total**
10280201040210	56.06	14.80	1.36	110.70	182.92	2952.18	1.14
10280201040200	42.93	14.42	3.49	162.47	223.32	8525.06	1.40
10280201040220	59.71	15.61	1.14	84.87	161.33	7443.41	1.01
10280201040160	51.33	15.77	2.47	133.18	202.75	6675.94	1.27
10280201050010	17.95	7.83	3.92	185.83	215.52	5577.17	1.35
10280201040260	55.42	15.38	1.15	101.66	173.61	4308.26	1.09
10280201040080	45.02	12.86	1.17	107.22	166.27	6301.20	1.04
10280201040100	36.20	11.57	1.29	107.81	156.87	5874.98	0.98
10280201050020	54.86	14.76	1.30	104.84	175.77	5031.89	1.10
10280201040250	70.93	17.49	1.29	87.67	177.39	4230.39	1.11
10280201040230	38.71	11.20	1.21	109.70	160.82	6295.59	1.01
10280201040090	52.84	15.29	1.63	129.03	198.79	6045.08	1.24
10280201040290	49.15	19.06	1.43	110.89	180.53	7550.91	1.13
10280201040020	22.44	8.25	2.41	167.30	200.40	8937.66	1.25
10280201040170	62.70	18.28	1.50	112.06	194.54	7158.90	1.22
10280201040010	26.57	8.06	1.80	141.17	177.60	6579.30	1.11
10280201040070	53.89	16.75	3.13	148.74	222.50	6217.51	1.39
10280201070010	58.85	14.86	0.85	81.53	156.09	14360.15	0.98
10280201040190	58.94	19.17	1.93	131.48	211.53	4282.50	1.32
10280201040120	49.85	14.08	1.30	111.68	176.91	4202.59	1.11
10280201040110	24.16	8.36	2.20	140.52	175.23	5282.58	1.10
10280201070020	45.94	11.69	1.54	122.33	181.49	5110.99	1.13
10280201040060	39.72	11.41	3.58	196.15	250.86	6384.30	1.57
10280201040270	44.08	13.13	1.77	115.04	174.02	8301.03	1.09
10280201040240	63.05	17.23	0.57	90.39	171.24	4294.97	1.07
10280201070030	67.13	17.78	0.93	90.72	176.56	5157.73	1.10
10280201040280	28.45	11.60	2.50	152.11	194.66	7515.38	1.22
10280201070040	53.86	14.91	0.66	83.47	152.89	6241.46	0.96
10280201040050	35.19	11.43	2.84	144.09	193.55	3970.66	1.21
10280201040150	67.86	19.76	2.25	125.84	215.72	5820.16	1.35
10280201040130	42.17	17.75	1.89	127.98	189.78	4325.35	1.19
10280201040040	14.26	8.20	3.60	187.88	213.93	6454.06	1.34
10280201070050	40.38	12.83	2.80	139.91	195.92	20045.03	1.22
10280201040140	11.11	6.36	3.76	194.43	215.66	6163.49	1.35
10280201060140	42.03	15.21	1.33	117.92	176.49	6528.93	1.10
10280201040180	0.00	5.41	8.06	223.45	232.94	6329.15	1.46
10280201060010	63.18	17.02	1.21	101.50	182.91	7846.70	1.14
10280201060210	96.92	19.89	1.99	122.80	241.60	11944.25	1.51
10280201060120	48.21	13.34	1.53	116.84	179.91	6246.02	1.12
10280201040030	0.00	3.71	2.36	161.01	167.03	6222.20	1.04
10280201060250	58.48	16.38	0.73	75.44	151.03	7260.50	0.94
10280201060230	58.75	16.48	1.38	106.32	182.92	4926.01	1.14
10280201060080	42.23	22.75	2.00	131.98	198.97	5167.54	1.24
10280201060070	49.12	14.57	1.53	125.88	191.10	5722.45	1.19
10280201060030	73.35	12.18	1.55	119.00	206.07	8535.77	1.29
10280201060200	40.33	15.21	1.39	113.24	170.17	4354.48	1.06
10280201060240	54.76	16.85	0.91	84.44	156.95	5607.89	0.98
10280201060090	63.06	21.89	2.92	155.38	243.26	9701.61	1.52

Table 15

14 Digit HU#	Streambank (Tons/160 Acres)	Gully (Tons/160 Acres)	Ephemeral Gully (Tons/160 Acres)	Sheet and Rill (Tons/160 Acres)	Total (Tons/160 Acres)	Watershed Total (Tons)	Tons/Acre Total
10280201060190	70.37	18.48	0.51	70.04	159.40	7909.58	1.00
10280201060130	60.51	15.03	0.75	83.42	159.72	6588.02	1.00
10280201060180	69.19	18.30	0.81	84.65	172.95	7586.18	1.08
10280201060220	77.29	18.94	0.91	84.67	181.81	8679.23	1.14
10280201060040	67.82	21.44	2.50	90.47	182.24	6788.84	1.14
10280201060020	31.09	10.75	1.43	120.37	163.65	6629.68	1.02
10280201060110	64.23	16.39	1.49	105.81	187.91	7754.23	1.17
10280201060100	47.09	14.00	3.00	145.31	209.40	9404.73	1.31
10280201060170	61.12	16.05	2.81	138.36	218.35	6435.53	1.36
10280201060060	59.09	17.00	1.60	94.08	171.77	8450.48	1.07
10280201060160	64.93	18.92	0.88	101.90	186.63	5664.00	1.17
10280201060050	12.77	6.56	4.68	189.30	213.31	4696.72	1.33
10280201060150	65.25	17.56	1.52	82.81	167.14	5258.76	1.04

Average Adsorbed Phosphorus Yield
SWAT Model Baseline Scenario
Rathbun Lake Subwatersheds

Figure 32

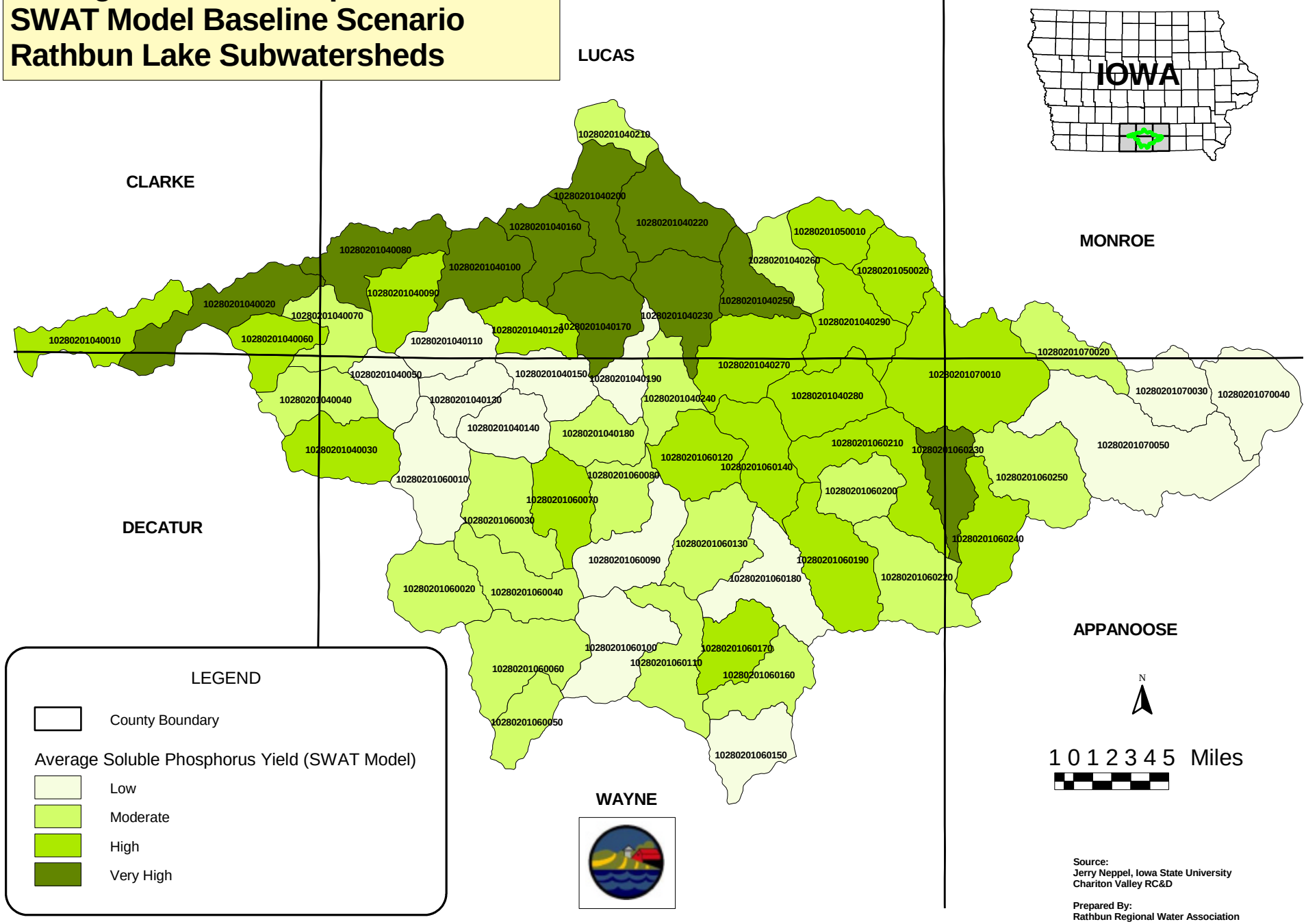


Source:
Jerry Neppel, Iowa State University
Chariton Valley RC&D

Prepared By:
Rathbun Regional Water Association

Average Soluble Phosphorus Yield
SWAT Model Baseline Scenario
Rathbun Lake Subwatersheds

Figure 33

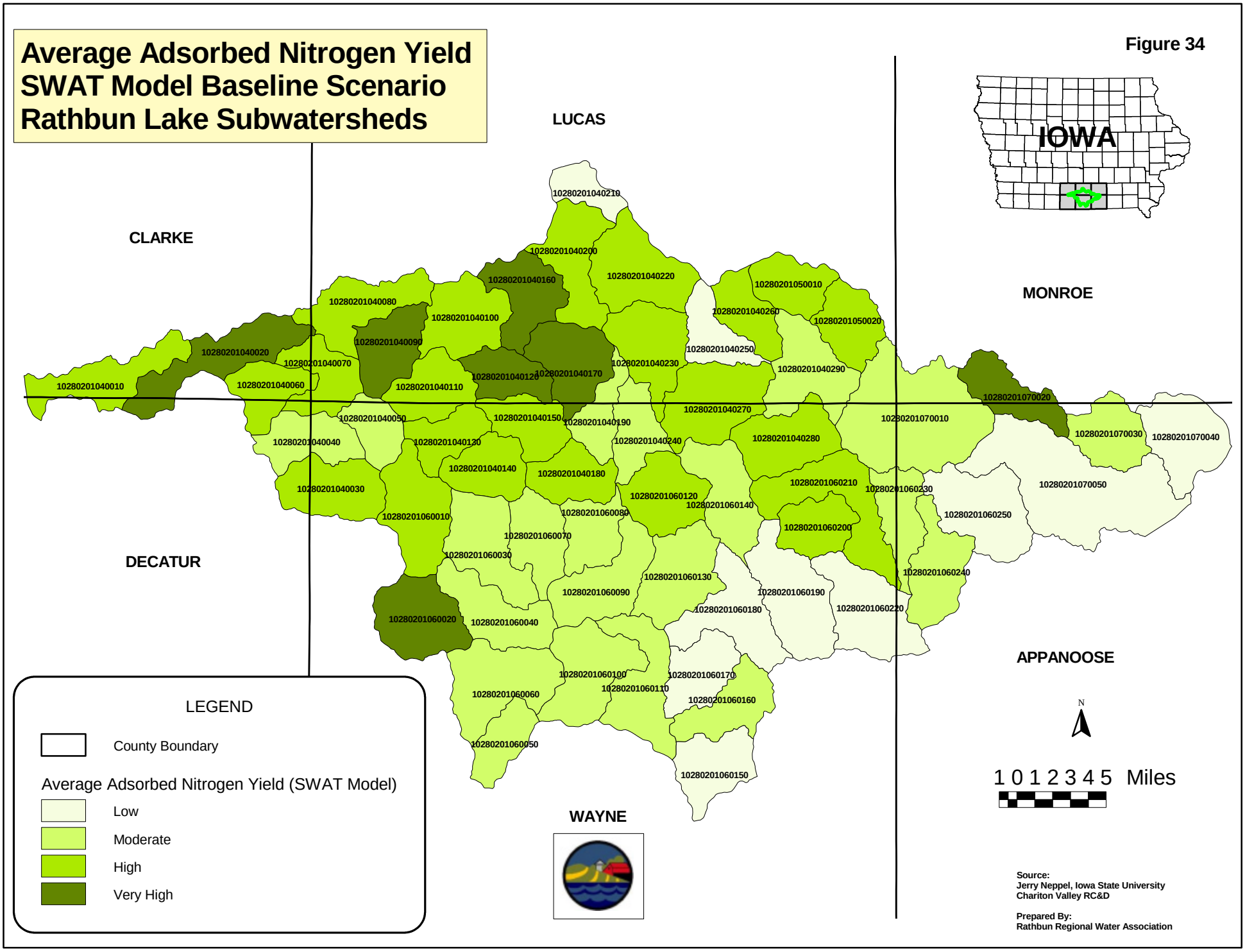


Source:
Jerry Neppel, Iowa State University
Chariton Valley RC&D

Prepared By:
Rathbun Regional Water Association

Average Adsorbed Nitrogen Yield
SWAT Model Baseline Scenario
Rathbun Lake Subwatersheds

Figure 34

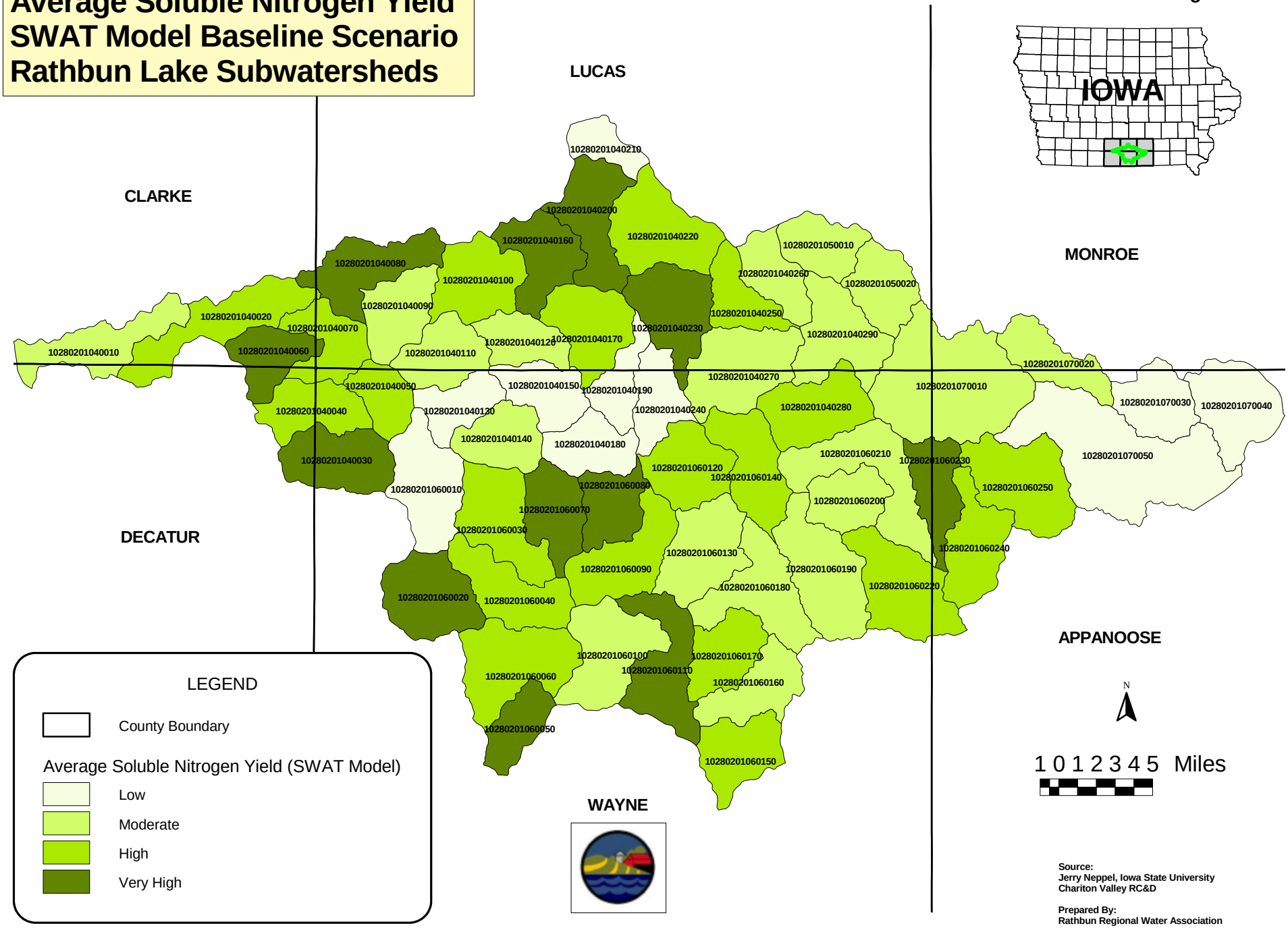


Source:
Jerry Neppel, Iowa State University
Chariton Valley RC&D

Prepared By:
Rathbun Regional Water Association

Average Soluble Nitrogen Yield
SWAT Model Baseline Scenario
Rathbun Lake Subwatersheds

Figure 35

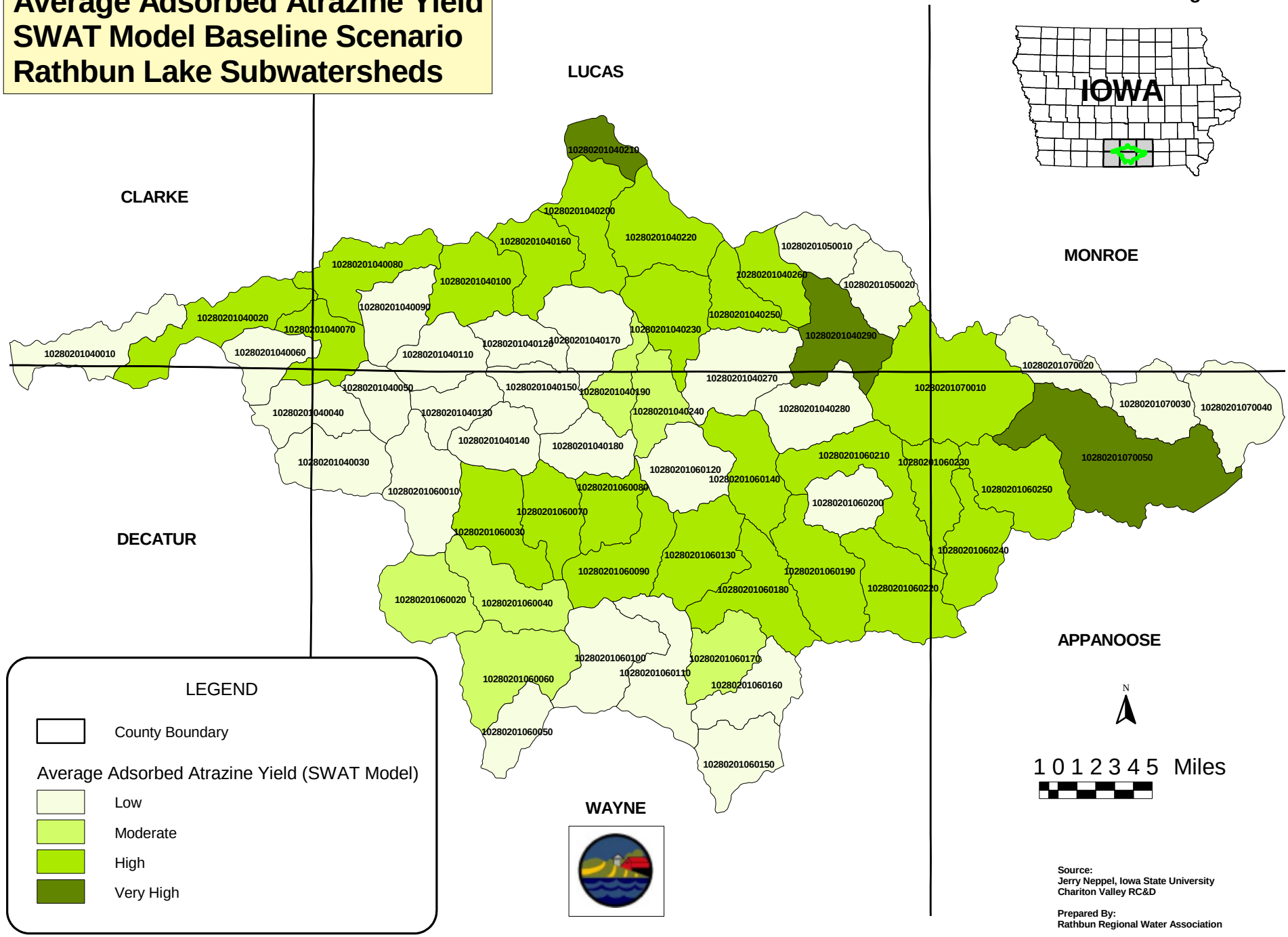


Source:
Jerry Neppel, Iowa State University
Chariton Valley RC&D

Prepared By:
Rathbun Regional Water Association

Average Adsorbed Atrazine Yield
SWAT Model Baseline Scenario
Rathbun Lake Subwatersheds

Figure 36

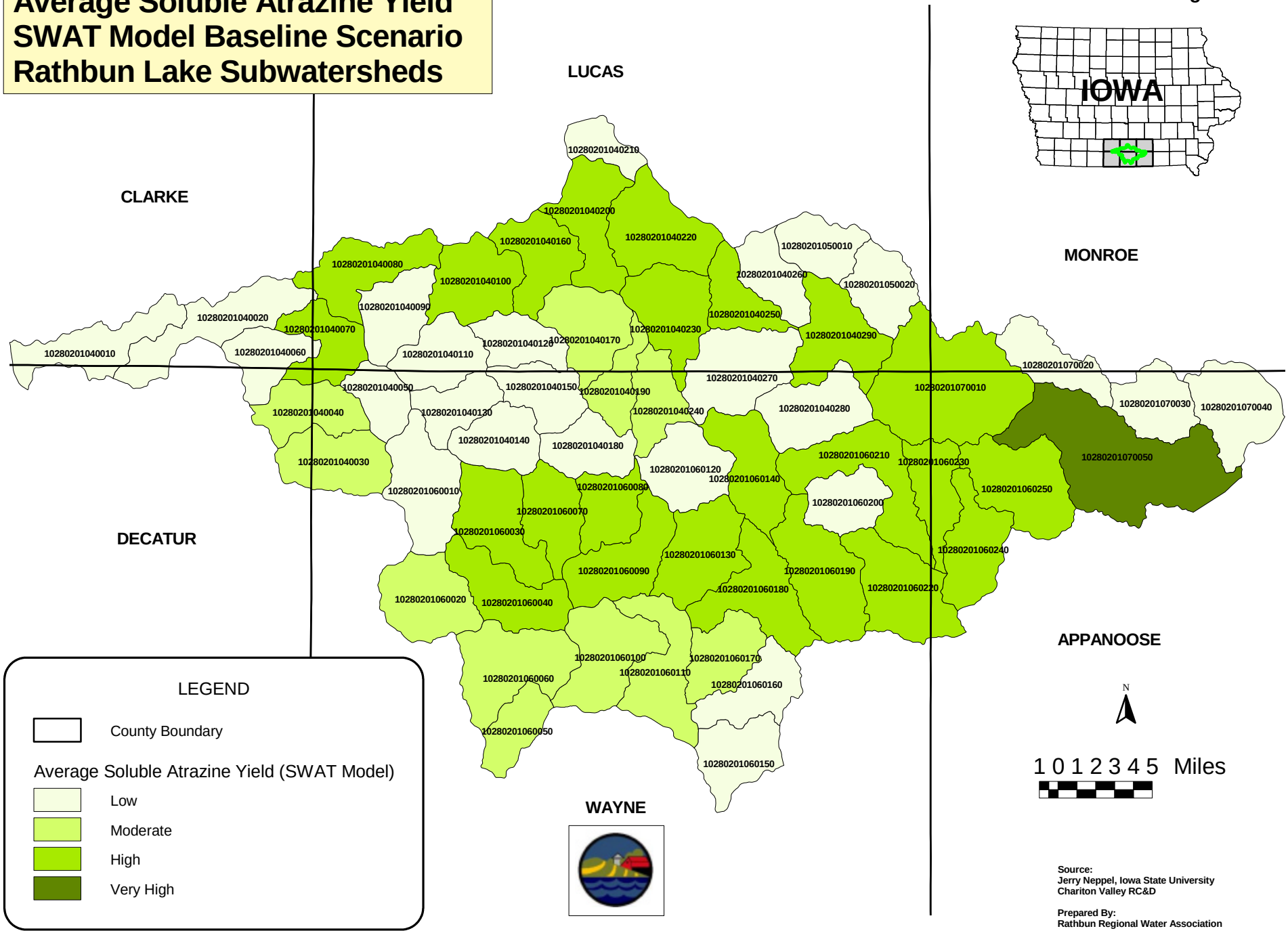


Source:
Jerry Neppel, Iowa State University
Chariton Valley RC&D

Prepared By:
Rathbun Regional Water Association

Average Soluble Atrazine Yield
SWAT Model Baseline Scenario
Rathbun Lake Subwatersheds

Figure 37

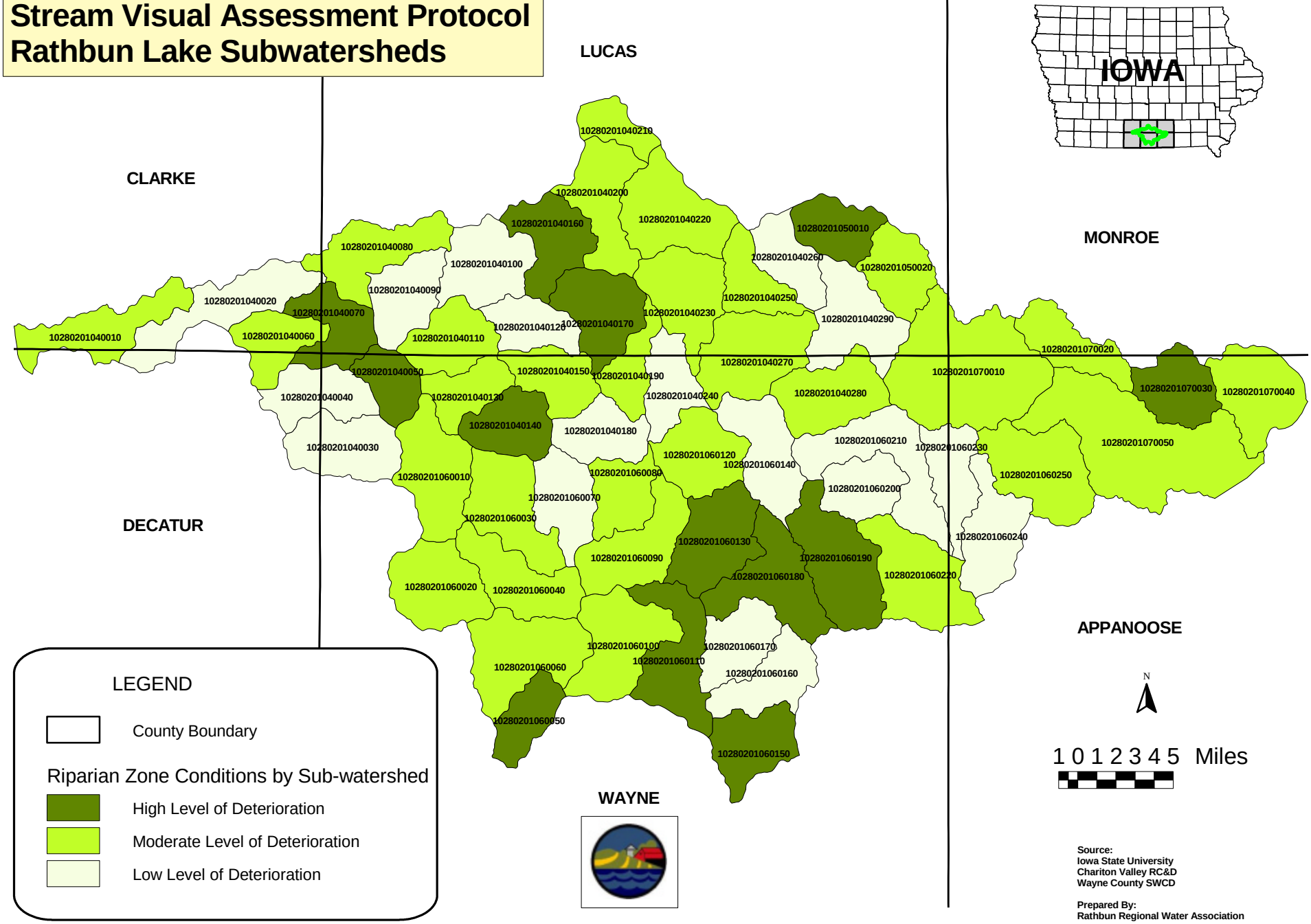


Source:
Jerry Neppel, Iowa State University
Chariton Valley RC&D

Prepared By:
Rathbun Regional Water Association

Riparian Zone Conditions
Stream Visual Assessment Protocol
Rathbun Lake Subwatersheds

Figure 38



Source:
Iowa State University
Chariton Valley RC&D
Wayne County SWCD

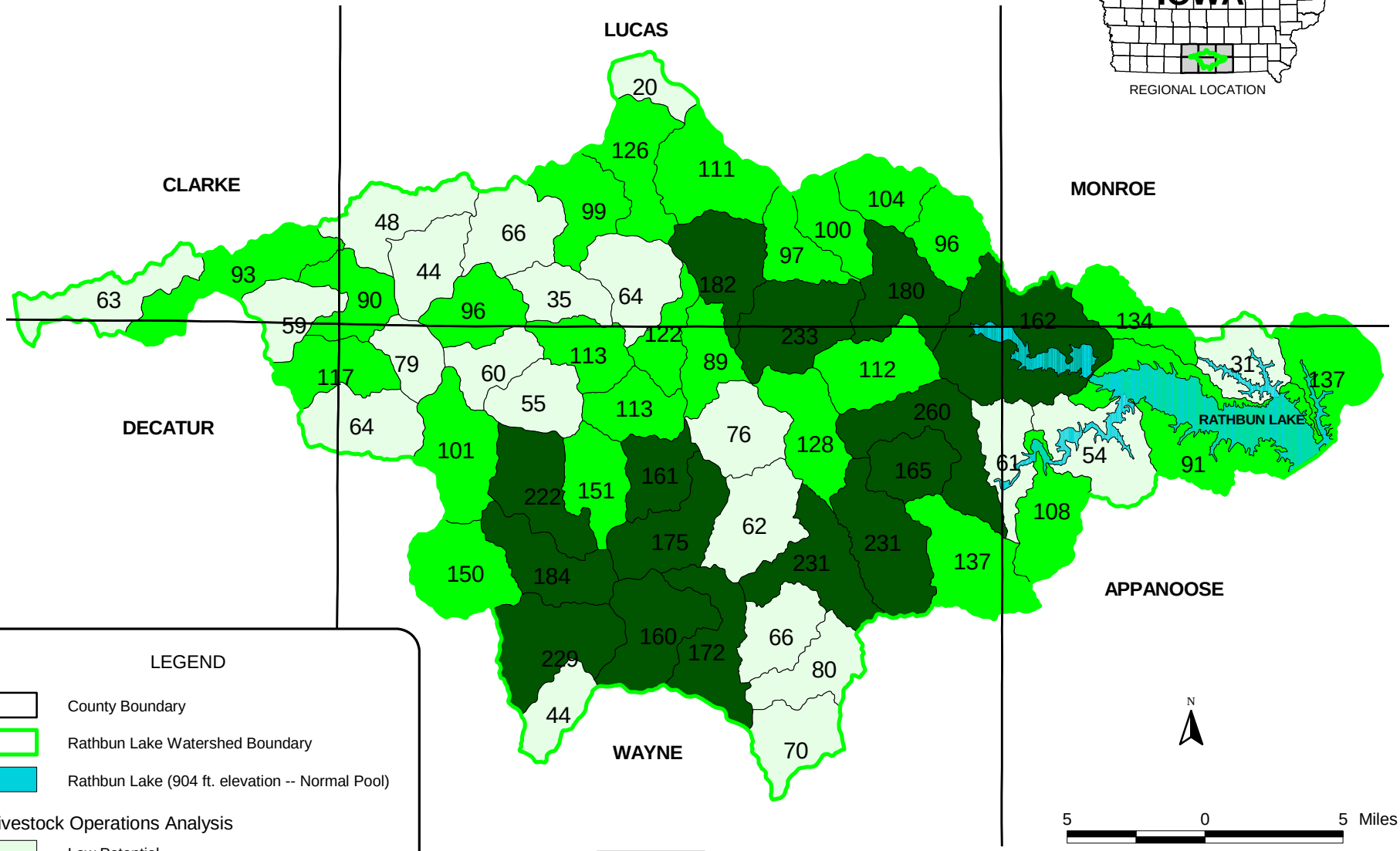
Prepared By:
Rathbun Regional Water Association

Table 16

Riparian Zone Conditions	
14 Digit Sub-Watersheds	
Rathbun Lake Watershed	
14 Digit HU#	**Average Stream Visual Assessment Protocol Score**
10280201040010	7.95
10280201040020	8.80
10280201040030	8.80
10280201040040	8.40
10280201040050	6.90
10280201040060	7.90
10280201040070	7.20
10280201040080	7.80
10280201040090	8.20
10280201040100	8.30
10280201040110	7.70
10280201040120	8.80
10280201040130	8.10
10280201040140	7.10
10280201040150	7.65
10280201040160	6.60
10280201040170	7.25
10280201040180	8.80
10280201040190	8.00
10280201040200	7.90
10280201040210	8.13
10280201040220	8.00
10280201040230	7.65
10280201040240	8.43
10280201040250	8.17
10280201040260	8.25
10280201040270	7.80
10280201040280	7.50
10280201040290	8.25
10280201050010	6.90
10280201050020	7.80
10280201060010	8.15
10280201060020	8.10
10280201060030	8.05
10280201060040	7.63
10280201060050	7.10
10280201060060	7.67
10280201060070	8.80
10280201060080	7.70
10280201060090	7.70
10280201060100	8.15
10280201060110	6.70
10280201060120	7.90
10280201060130	6.15
10280201060140	8.60
10280201060150	7.00
10280201060160	8.37
10280201060170	8.60
10280201060180	7.30
10280201060190	7.40
10280201060200	8.40
10280201060210	8.40
10280201060220	8.07
10280201060230	8.35
10280201060240	8.40
10280201060250	7.60
10280201070010	7.80
10280201070020	7.80
10280201070030	7.23
10280201070040	8.00
10280201070050	7.60

RATHBUN LAKE WATERSHED
Livestock Operations Analysis by Sub-watershed
South Central Iowa

Figure 39



LEGEND

- County Boundary
- Rathbun Lake Watershed Boundary
- Rathbun Lake (904 ft. elevation -- Normal Pool)

Livestock Operations Analysis

- Low Potential
- Moderate Potential
- High Potential

Source: Chariton Valley RC&D
Wayne County Soil and Water Conservation District
Iowa DNR NRGIS
USDA Natural Resources Conservation Service

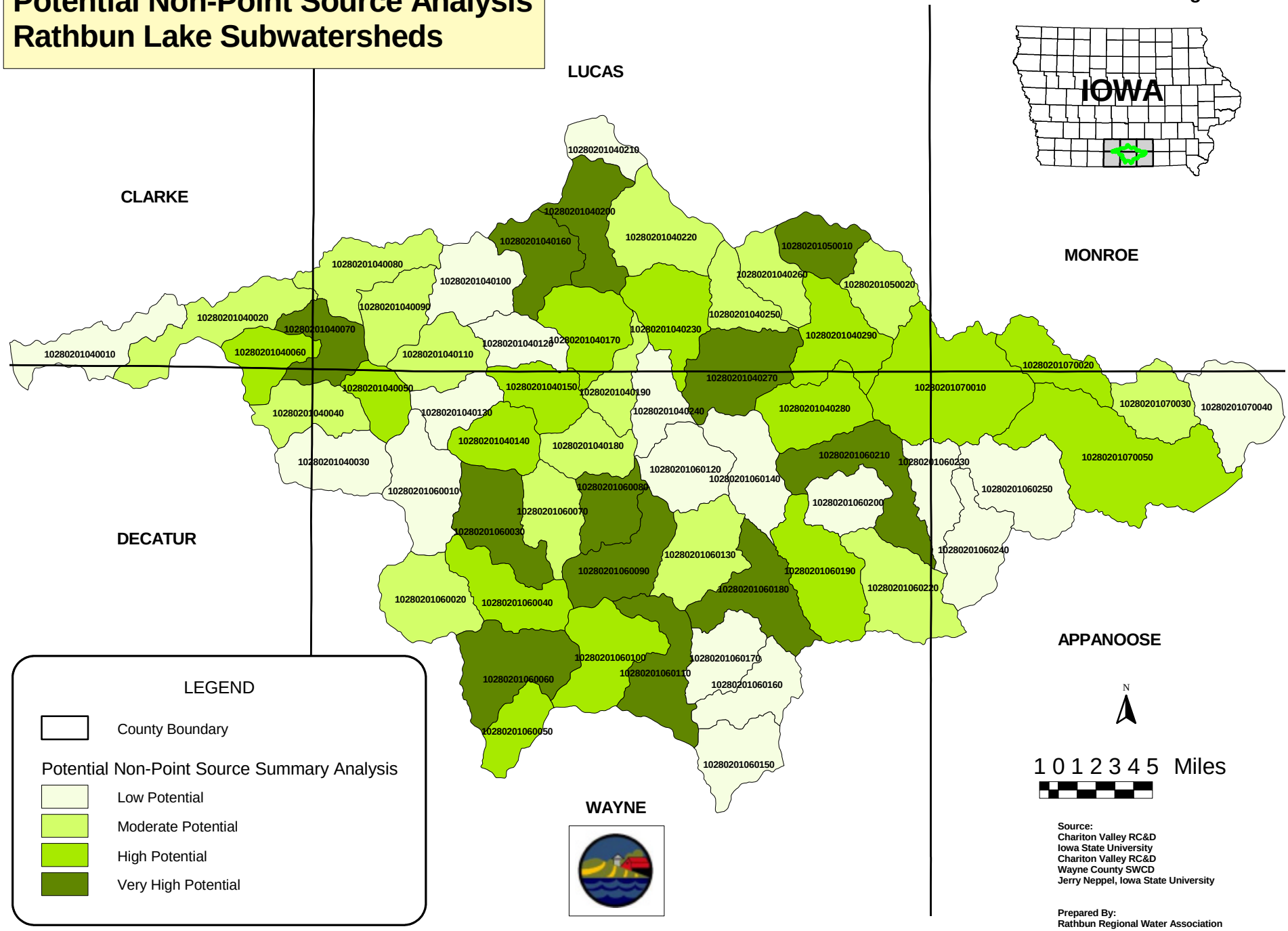
Prepared By: Rathbun Regional Water Association

Table 17

Livestock Operations Inventory and Analysis			
Rathbun Lake Watershed			
Livestock Operations		**Number of HUCS (Subwatersheds)**	
High Risk Potential		15	
Moderate Risk Potential		25	
Low Risk Potential		21	
61 Sub-watershed Analysis -- Livestock			
HUC ID	**14 Digit HU #**	**Livestock Operations**	**Total HU Risk Score**
1	10280201040210	1	20
2	10280201040200	8	126
3	10280201040220	7	111
4	10280201040160	7	99
5	10280201050010	7	104
6	10280201040260	7	100
7	10280201040080	4	48
8	10280201040100	5	66
9	10280201050020	6	96
10	10280201040250	6	97
11	10280201040230	12	182
12	10280201040090	5	44
13	10280201040290	11	180
14	10280201040020	9	93
15	10280201040170	4	64
16	10280201040010	7	63
17	10280201040070	8	90
18	10280201070010	10	162
19	10280201040190	8	122
20	10280201040120	2	35
21	10280201040110	7	96
22	10280201070020	8	134
23	10280201040060	5	59
24	10280201040270	15	233
25	10280201040240	6	89
26	10280201070030	2	31
27	10280201040280	7	112
28	10280201070040	8	137
29	10280201040050	7	79
30	10280201040150	8	113
31	10280201040130	6	60
32	10280201040040	8	117
33	10280201070050	6	91
34	10280201040140	6	55
35	10280201060140	8	128
36	10280201040180	7	113
37	10280201060010	7	101
38	10280201060210	17	260
39	10280201060120	5	76
40	10280201040030	5	64
41	10280201060250	4	54
42	10280201060230	4	61
43	10280201060080	11	161
44	10280201060070	10	151
45	10280201060030	15	222
46	10280201060200	10	165
47	10280201060240	7	108
48	10280201060090	11	175
49	10280201060190	14	231
50	10280201060130	4	62
51	10280201060180	14	231
52	10280201060220	9	137
53	10280201060040	11	184
54	10280201060020	10	150
55	10280201060110	10	172
56	10280201060100	11	160
57	10280201060170	4	66
58	10280201060060	14	229
59	10280201060160	5	80
60	10280201060050	3	44
61	10280201060150	5	70

Potential Non-Point Source Analysis
Rathbun Lake Subwatersheds

Figure 40



Source:
Chariton Valley RC&D
Iowa State University
Chariton Valley RC&D
Wayne County SWCD
Jerry Neppel, Iowa State University

Prepared By:
Rathbun Regional Water Association

Table 18

Potential Non-Point Source Summary Analysis											
Ranking Score Criteria											
Low = 1											
Moderate = 2											
High = 3											
Very High = 4											
14 Digit HU #	**Sediment Score**	**Adsorbed P Score**	**Sol P Score**	**Adsorbed N Score**	**Sol N Score**	**Adsorbed Atrazine Score**	**Sol Atrazine Score**	**Avg. Chem Score**	**SVAP Score**	**Livestock Score**	**Total**
10280201040030	1	3	3	3	4	1	2	2.7	1	1	5.7
10280201060160	2	2	2	2	2	1	1	1.7	1	1	5.7
10280201040120	2	4	3	4	2	1	1	2.5	1	1	6.5
10280201040210	2	1	2	1	1	4	1	1.7	2	1	6.7
10280201040130	2	3	1	3	1	1	1	1.7	2	1	6.7
10280201060240	1	2	3	2	3	3	3	2.7	1	2	6.7
10280201040240	2	2	2	2	1	2	2	1.8	1	2	6.8
10280201060230	2	1	4	2	4	3	3	2.8	1	1	6.8
10280201070040	1	1	1	1	1	1	1	1	2	3	7
10280201060200	1	3	2	3	2	1	1	2	1	3	7
10280201060170	3	1	3	1	3	2	2	2	1	1	7
10280201040100	1	3	4	3	3	3	3	3.2	2	1	7.2
10280201060250	1	1	2	1	3	3	3	2.2	3	1	7.2
10280201040010	2	4	3	3	2	1	1	2.3	2	1	7.3
10280201060120	2	3	3	3	3	1	1	2.3	2	1	7.3
10280201060150	1	2	1	1	3	1	1	1.5	4	1	7.5
10280201060140	2	2	3	2	3	3	3	2.7	1	2	7.7
10280201060010	2	3	1	3	1	1	1	1.7	2	2	7.7
10280201040220	1	3	4	3	3	3	3	3.2	2	2	8.2
10280201040040	3	3	2	2	3	1	2	2.2	1	2	8.2
10280201060130	1	1	2	2	2	3	3	2.2	4	1	8.2
10280201040260	2	3	2	3	2	3	1	2.3	2	2	8.3
10280201040080	1	3	4	3	4	3	3	3.3	3	1	8.3
10280201070030	2	2	1	2	1	1	1	1.3	4	1	8.3
10280201040250	2	1	4	1	3	3	3	2.5	2	2	8.5
10280201040090	3	4	3	4	2	1	1	2.5	2	1	8.5
10280201040190	3	2	1	2	1	2	2	1.7	2	2	8.7
10280201040110	2	3	1	3	2	1	1	1.8	3	2	8.8
10280201060070	2	2	3	2	4	3	3	2.8	1	3	8.8
10280201040180	4	4	2	3	1	1	1	2	1	2	9
10280201060020	1	4	2	4	4	2	2	3	2	3	9
10280201050020	2	3	3	3	2	1	1	2.2	3	2	9.2
10280201040020	3	4	4	4	3	3	1	3.2	1	2	9.2
10280201060220	2	1	2	1	3	3	3	2.2	2	3	9.2
10280201070010	1	2	3	2	2	3	3	2.5	3	3	9.5
10280201040290	2	2	3	2	2	4	3	2.7	2	3	9.7
10280201040060	4	4	3	3	4	1	1	2.7	2	1	9.7
10280201040050	3	2	1	2	3	1	1	1.7	4	1	9.7
10280201040150	3	3	1	3	1	1	1	1.7	3	2	9.7
10280201060100	3	2	1	2	2	1	2	1.7	2	3	9.7
10280201070050	3	1	1	1	1	4	4	2	3	2	10
10280201040140	3	4	1	3	2	1	1	2	4	1	10
10280201060190	1	1	3	1	2	3	3	2.2	3	4	10.2

Table 18

14 Digit HU #	Sediment Score	Adsorbed P Score	Sol P Score	Adsorbed N Score	Sol N Score	Adsorbed Atrazine Score	Sol Atrazine Score	Avg. Chem Score	SVAP Score	Livestock Score	Total
10280201040230	1	3	4	3	4	3	3	3.3	3	3	10.3
10280201070020	2	4	2	4	2	1	1	2.3	3	3	10.3
10280201040280	3	3	3	3	3	1	1	2.3	3	2	10.3
10280201060040	2	2	2	2	3	2	3	2.3	3	3	10.3
10280201060050	3	3	2	2	4	1	2	2.3	4	1	10.3
10280201040170	3	3	4	4	3	1	2	2.8	4	1	10.8
10280201050010	3	3	3	3	2	1	1	2.2	4	2	11.2
10280201040270	2	3	3	3	2	1	1	2.2	3	4	11.2
10280201060110	2	2	2	2	4	1	2	2.2	4	3	11.2
10280201060060	2	3	2	2	3	2	2	2.3	3	4	11.3
10280201040200	4	4	4	3	4	3	3	3.5	2	2	11.5
10280201060030	3	2	2	2	3	3	3	2.5	2	4	11.5
10280201060210	4	2	3	3	2	3	3	2.7	1	4	11.7
10280201060080	3	2	2	2	4	3	3	2.7	3	3	11.7
10280201060180	2	1	1	1	2	3	3	1.8	4	4	11.8
10280201060090	4	2	1	2	3	3	3	2.3	3	3	12.3
10280201040160	3	4	4	4	4	3	3	3.7	4	2	12.7
10280201040070	4	3	2	3	3	3	3	2.8	4	2	12.8

SECTION VII

SECTION VII MANAGEMENT STRATEGIES FOR THE RATHBUN LAKE WATERSHED

The assessment identifies and prioritizes potential point and non-point sources of contaminants that may impair water quality in Rathbun Lake. Assessment results provide members and partners of the Rathbun Land and Water Alliance the information needed to develop and pursue management strategies that will reduce and prevent water pollution in Rathbun Lake from these potential sources.

Management Strategies for the Rathbun Lake Watershed

Management strategies for the Rathbun Lake watershed include using assessment results to:

- Plan and apply practices to control water pollution from priority point sources.
- Plan and apply practices to control water pollution from priority non-point sources.
- Match program objectives with water quality protection needs.

Use of assessment results to plan and apply practices to control priority point sources: The assessment identified possible point sources that have the highest potential to impair water quality in Rathbun Lake. Efforts will initially be directed toward determining the need for and implementing practices to reduce and prevent any water pollution from these high potential point sources. Best management practices for these potential point sources will include:

- *Livestock waste management:* Install waste management practices with livestock feeding operations in the 15 sub-watersheds that have a high potential for livestock operations to impair water quality.
- *Wastewater treatment systems:* Construct and improve community and household wastewater treatment systems in the 26 areas with concentrations of septic systems that have a high potential to cause water pollution.
- *Runoff management:* Apply practices such as retention structures and buffers to manage runoff and prevent pollution from intersections, facilities, residential and commercial areas, and quarry sites that have a high potential to impair water quality.
- *Shoreline erosion control:* Install measures to control shoreline erosion at the 37 priority sites identified at Rathbun Lake.

Shoreline erosion control measures can reduce the sediment that enters Rathbun Lake. *(Photo courtesy ACOE)*

Use of assessment results to plan and apply practices to control priority non-point sources: The assessment identified the sub-watersheds that have the highest potential for eroded soil and chemicals carried in runoff, deteriorated riparian conditions, and livestock operations to impair water quality in Rathbun Lake. Efforts will first be directed toward evaluating the need for and applying practices on cropland, grassland, and riparian zones in the 12 sub-watersheds with a very high potential and 15 sub-watersheds with a high potential for non-point sources to impair water quality in Rathbun Lake. Best management practices for these potential non-point sources will include:

- *Practices most likely to be effective on cropland in these sub-watersheds:*
  - Install and rehabilitate terrace systems.
  - No-till, contour stripcropping, and grassed waterways.
  - Construct water and sediment control basins and grade stabilization structures.
  - Nutrient and pest management.
  - Convert marginal cropland to grassland.

SECTION VII CONTD.

Grade stabilization structures can reduce the amounts of sediment and chemicals that enter Rathbun Lake.

- *Practices most likely to be effective on grassland in the sub-watersheds:*
  - Pasture planting, fencing, rotational grazing, and nutrient and brush management.
  - Construct ponds and install tanks, troughs, and pipeline for livestock watering systems.

Improved grazing practices that include fencing and rotational use of paddocks can reduce water pollution in Rathbun Lake.

- Practices most likely to be effective in riparian zones in the sub-watersheds:
  - Plant and manage riparian forest buffers and filter strips.
  - Install measures to protect sites from heavy livestock use such as stream crossings and to exclude livestock from critical areas.

Use of assessment results to match program objectives with water quality protection needs: Assessment results can also be used to match the objectives of financial and technical assistance programs with the need for best management practices to control potential point and non-point sources of water pollution in the Rathbun Lake watershed. This use of assessment results might include:

- Programs that provide assistance to protect aquatic habitat from sediment can be directed toward the 23 sub-watersheds with a high to very high potential for eroded soil to be carried in runoff and the 37 priority shoreline erosion control sites at Rathbun Lake.
- Programs that offer assistance to reduce and prevent water pollution from farm chemicals can be used to target the 15 sub-watersheds with a high to very high potential for chemicals to be carried in runoff.
- Programs that are primarily concerned with preventing water pollution from livestock operations can be used in the 15 sub-watersheds with a high potential for livestock to impair water quality in Rathbun Lake.
- Programs that help residents improve and replace poorly operating septic systems can be directed toward the 26 areas with concentrations of septic systems that have a high potential to cause water pollution.
- Programs that are regulatory in nature such as the development of Total Maximum Daily Load (TMDL) requirements for water bodies in Iowa can use assessment results to improve the effectiveness of their water quality protection efforts.

SECTION VII CONTD.

Water Quality Protection Efforts that Support Management Strategies

Members and partners of the Rathbun Land and Water Alliance have initiated water quality protection efforts that will support the successful implementation of management strategies to reduce and prevent water pollution in Rathbun Lake. These efforts include:

Rathbun Land and Water Alliance: The Alliance will continue to serve as the locally-led organization responsible for encouraging and coordinating voluntary water quality protection efforts in the Rathbun Lake watershed. Alliance members and partners will work together to accomplish the actions in the organization's strategic plan in the areas of education, landowner and water user involvement, resource management, partnership development, and Alliance operations.

The Alliance will continue to encourage and coordinate voluntary water quality protection efforts in the Rathbun Lake watershed.

Water quality education: Water quality education efforts have included field days to demonstrate best management practices, displays at recreational facilities, newsletter articles, and volunteer water quality monitoring events. Activities will continue to educate landowners, residents, public officials, business owners and employees, and facility managers and users about potential threats to water quality in Rathbun Lake, measures to reduce and avoid water quality impairment in the lake, and actions that they can take to help prevent water pollution. Educational activities will emphasize the use of personal contacts, articles in farm magazines, Rathbun Regional Water Association's (RRWA) newsletter, informational meetings, and field days. Educational activities will also be conducted through the Internet as its use as an information source becomes more common.

Landowners in the watershed find meetings and field days helpful sources of information.

Water quality monitoring: Water quality monitoring will continue in Rathbun Lake and tributaries in the watershed. Monitoring conducted from 1997 to 2001 has consisted of monthly and event sampling and analysis for sediment, chemicals, and bacteria. Monitoring results are used to assess water quality conditions that impact Rathbun Lake's use as a drinking water supply and for recreation and fish and wildlife habitat. Results will also be used to help plan, apply, and evaluate the effectiveness of best management practices to protect water quality in the lake. For example, Figure 41 in this section presents relative rates of sediment loss per acre by sub-watersheds based on monitoring data from 1999.

Landowner and water user surveys: Surveys of landowners in the watershed and RRWA water customers have identified opportunities to work with these two important groups to protect water quality in Rathbun Lake. The surveys found that half of the landowners and water users consider water pollution an important problem in Rathbun Lake and three-quarters worry about the purity of their drinking water. Three-quarters of the water users agree that it is more cost effective to protect water from being polluted than to treat polluted water and are willing to invest money to ensure safe drinking water in their home. Half of the landowners expressed interest in assistance to adopt better erosion control methods and reduce sources of water pollution on their property. The survey findings will continue to be used to encourage landowner and water user participation in efforts to protect water quality in Rathbun Lake.

Resource-based rural development: Efforts will continue to develop economic opportunities for land uses that protect water quality in Rathbun Lake. Current efforts include the Chariton Valley Biomass Project that produces and tests forages for alternative uses such as renewable fuels. Another local effort is Chariton Valley Beef, a producer-led initiative to develop value-added markets for high quality beef cattle. In addition, the Chariton River Corridor and Honey Creek Destination Park projects are examples of local efforts to restore natural wetland and prairie areas and develop associated facilities to encourage tourism and recreation.

Switchgrass harvested from land in the watershed to be used as a renewable fuel in the Chariton Valley Biomass Project.

Local support for water quality protection: Members and partners of the Rathbun Land and Water Alliance have demonstrated strong support for water quality protection in Rathbun Lake through their commitment of funds and personnel. These resources have been used to carry out water quality education activities, conduct water quality monitoring, and install best management practices. Landowners in the watershed have also demonstrated their support through a willingness to invest time and money to apply practices that protect water quality in Rathbun Lake. As an example, landowner requests for assistance from the USDA's Environmental Quality Incentives Program to apply best management practices in the watershed has greatly exceeded available funds. In addition, landowners have actively participated in developing and implementing two TMDL projects in the watershed, Bob White Lake and Corydon Reservoir.

Implementing Management Strategies for the Rathbun Lake Watershed

A primary focus of Rathbun Land and Water Alliance efforts will now be to assemble the financial and technical resources needed to work with landowners, residents, public officials, business owners, and facility managers to implement management strategies for the Rathbun Lake watershed. In order to accomplish this, the Alliance will use assessment results and build on the water quality protection efforts currently underway to:

Prioritize potential point and non-point sources: Select priority point and non-point sources in the watershed and determine the need for best management practices to reduce and prevent water quality impairment in Rathbun Lake from these sources.

Develop water quality protection plans: Develop detailed water quality protection plans that will describe the specific best management practices required to reduce and prevent water pollution from priority point and non-point sources and identify the financial and technical resources needed to apply these practices.

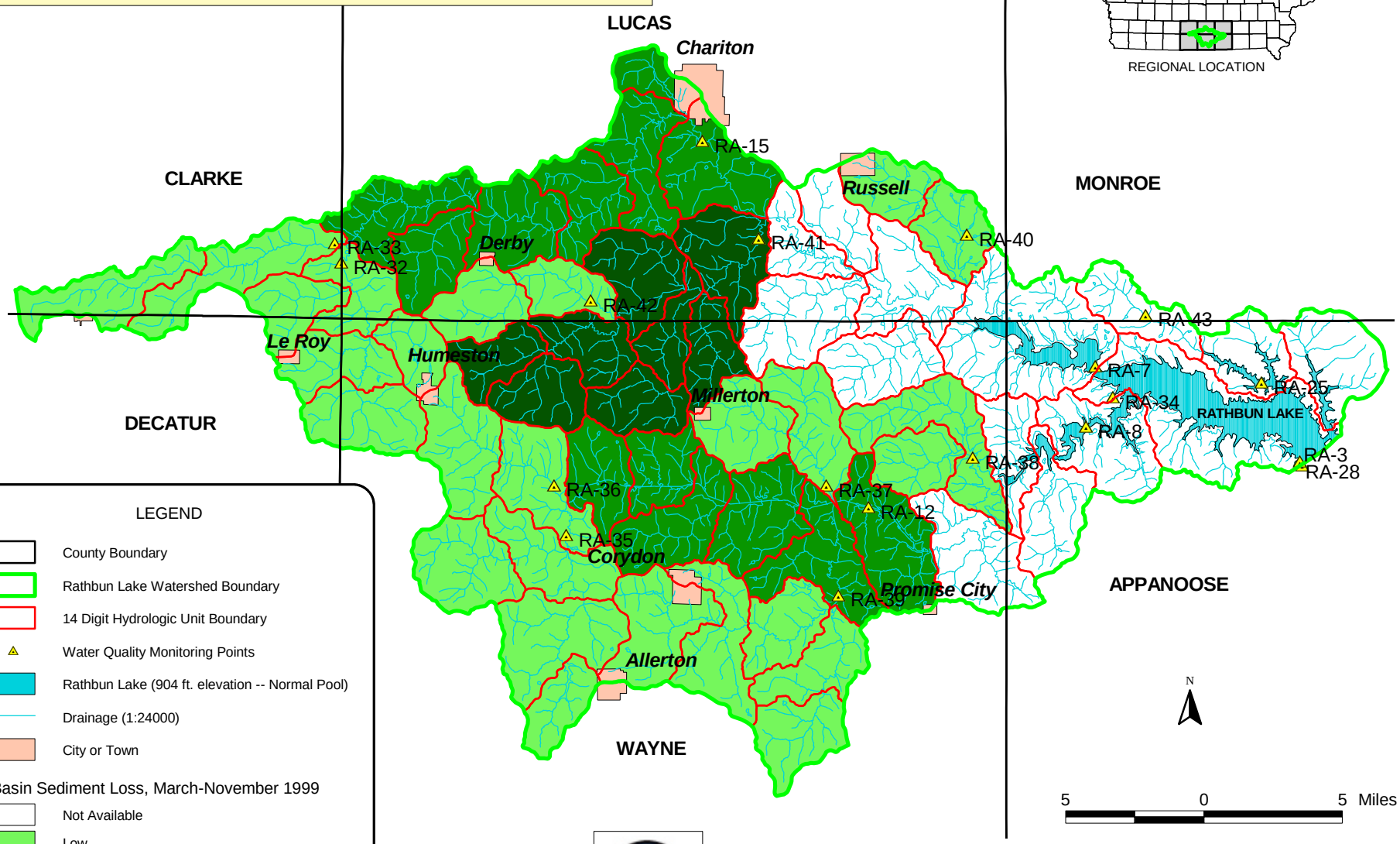
Secure and commit technical and financial resources: Approach representatives of sources of financial and technical assistance to request support that, together with the commitment of local resources, will be used to implement the water quality protection plans.

Install best management practices: Coordinate the effective use of financial and technical resources to install best management practices described in water quality protection plans that will reduce and prevent water pollution in Rathbun Lake.

A primary focus of Alliance efforts will now be to assemble the financial and technical resources needed to implement management strategies for the Rathbun Lake watershed.

RATHBUN LAKE WATERSHED
Water Quality Monitoring Data and Points
Basin Sediment Loss, March-November 1999
South Central Iowa

Figure 41



LEGEND

- County Boundary
- Rathbun Lake Watershed Boundary
- 14 Digit Hydrologic Unit Boundary
- Water Quality Monitoring Points
- Rathbun Lake (904 ft. elevation -- Normal Pool)
- Drainage (1:24000)
- City or Town

Basin Sediment Loss, March-November 1999

- Not Available
- Low
- Moderate
- High

Source: Chariton Valley RC&D
Iowa DNR NRGIS
US Army Corps of Engineers
Wayne County SWCD
Iowa State University

Prepared By: Rathbun Regional Water Association

APPENDIX A

WATER QUALITY PROTECTION FOR RATHBUN LAKE

Rathbun Land and Water Alliance: Rathbun Regional Water Association with the six counties and soil and water conservation districts in the watershed are working together on projects to protect and improve water quality in Rathbun Lake. Technical and financial assistance are provided by the Iowa DNR, IDALS DSC, ISU, USDA NRCS and FSA, Corps of Engineers, EPA, Farm Bureau and many other partners.

Southern Iowa Development and Conservation Authority: Ten member counties cooperating on projects to protect and improve rural infrastructure and water resources in southern Iowa.

Rathbun Lake Watershed Assessment: Inventory and evaluation of potential threats in the watershed to water quality in the lake.

Water Quality Monitoring Program: Collection and analysis of samples from 19 locations in the watershed and lake for sediment, chemicals, and bacteria.

Environmental Quality Incentive Projects: Priority areas in Appanoose, Lucas, and Monroe counties. Landowners eligible for financial assistance to install conservation practices. Proposed priority area in remainder of watershed.

Honey Creek Watershed Project: Resource inventory completed in preparation for a water quality protection project.

Corps Section 206 Project: Preliminary plan approved by the Corps and feasibility study initiated that may result in up to $5 million to install structural practices in the watershed and along the shoreline.

Water Quality in Rathbun Lake Project: Provides funds for project coordinator and to assist landowners with installation of demonstration conservation practices to protect water quality.

Road Structure Training and Demonstration: Develop and conduct a training course for engineers on design and construction of road structures. Includes installation of up to six demonstration structures.

Wayne and Lucas County Road Structure Projects: Funds to assist counties with the installation of up to six road structures to improve rural transportation system and protect water quality.

Livestock Waste Management Demonstrations: Assist landowners with the installation of low cost methods of managing livestock wastes in grazing and feeding operations to protect water quality.

Bob White Lake and Corydon Reservoir Projects: Funds for second project coordinator and to assist landowners with the installation of practices to protect water quality.

RATHBUN LAKE
WATER QUALITY MONITORING

Description of Monitoring Activities

The Rathbun Lake water quality monitoring program consists of monthly and event samples collected at 14 sites in tributaries to the lake, 4 sites in the lake, and 1 site at the lake outlet in the Chariton River. Monitoring results will help assess water quality parameters that impact Rathbun Lake's ability to support its multiple uses including drinking water supply, flood protection, recreation, and fish and wildlife habitat. Results will be used to develop and implement watershed management strategies to reduce water quality impairment in the lake.

Summary of Monitoring Results 1997 – 2000

- High levels of atrazine, alachlor, metolochlor, and cyanazine have been reported every year, from every site, both tributaries and the lake.

- During the normal precipitation year of 1999, selected basins in the watershed experienced nitrogen losses in excess of 20 lbs./acre.

- The average concentration of total phosphorus in tributaries to Rathbun Lake was 310 ppb based on 532 measurements taken from 1997-2000. This tributary flow is the primary source of water to Rathbun Lake.

- The average concentration of total phosphorus in Rathbun Lake water was 120 ppb based on 337 measurements taken from 1997-2000. EPA will soon be implementing water quality criteria for lakes. These criteria will likely not be less than 100 ppb.

- Lake water phosphorus levels greater than 70 ppb facilitate blooms of toxic algae in the lake, and the persistence of potentially harmful bacteria in the water.

- Extensive sedimentation has occurred in the lake, and large volumes of sediment continue to move downstream to the lake.

- The reduction in nutrient, sediment, and contaminant levels in the outflow below the lake results from containment of these materials in the lake. As the lake's capacity to contain these materials decreases, their transport downstream will increase.

- Rathbun Lake stratifies in the summer, and the hypolimnion becomes anoxic. These anoxic conditions promote the release of toxic substances from the accumulated sediments on the lake bottom. This is particularly important because the lake's water outlet pulls water from the bottom of the lake, and this is the water supply for Rathbun Regional Water Association.

- There are large differences, both spatially and temporally, in the movement of materials from the watershed to the lake.

RATHBUN LAKE WATERSHED
WATER QUALITY SURVEY

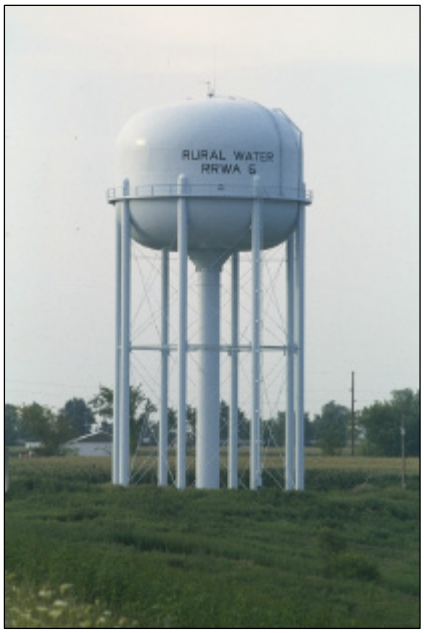
Summary of Findings

The Rathbun Land and Water Alliance, in cooperation with Iowa State University, conducted a survey of water users with the Rathbun Regional Water Association (RRWA). Rathbun Lake is the primary source of water for the RRWA. RRWA is the largest rural water system in Iowa serving over 60,000 people in 18 counties and more than 40 communities. The results of the survey will assist decision-makers and policy-makers in planning future efforts to protect water quality in Rathbun Lake. Survey findings are based on the responses of 716 RRWA water users from a sample of 1,150 for a response rate of 62%.

- When asked to rate the quality of water supplied by RRWA, more than four of every five water users indicated "very good" or “good“. At the same time, close to 70% of the respondents indicated that they worry about the purity of their drinking water and more than half of the water users considered water contamination to be an important environmental problem in the Rathbun Lake area.

- Primary threats to water quality in the Rathbun Lake watershed, according to most respondents, include farm pesticides and fertilizers and the improper disposal of livestock manure. Over one third identified sediment from the erosion of farmland and septic tanks and untreated sewage as potential threats to water quality in Rathbun Lake.

- More than three-fourths of the respondents indicated that they viewed Rathbun Lake as an economic asset in southern Iowa, for example, the lake attracts tourists and businesses, and that poor water quality in Rathbun Lake would affect economic development in that part of the state.



- By a ratio of 4-to-1, water users agreed that it would be more cost effective to emphasize protecting water from becoming polluted rather than extracting pollutants from water after it has been polluted. Respondents felt that the most effective approaches to resolving potential threats to water quality in Rathbun Lake would be to work with farmers and residents to reduce sources of pollution and stronger enforcement of current regulations.

- Nearly three of every four water users indicated that they would be willing to invest $5 per month to ensure safe drinking water in their home. Fewer than half indicated a willingness to spend $10 or more per month to ensure safe drinking water in their home.

- On average, respondents indicated that the federal and state governments should bear the largest portions of financial burden to ensure water from Rathbun Lake is a good source to serve the needs of residents in southern Iowa. Close to one half of the respondents indicated that they knew what steps to take to conserve soil and water and one third expressed interest in assistance to reduce sources of water pollution on their property.

RATHBUN LAKE WATERSHED
LAND USE AND FARMING PRACTICE SURVEY

Summary of Findings

The Rathbun Land and Water Alliance, in cooperation with the Iowa Department of Natural Resources and Iowa State University, conducted a land use and farming practice survey of landowners in the Rathbun Lake watershed. Survey findings will be used to develop and implement effective approaches to working with landowners to protect and improve water quality in Rathbun Lake. A total of 430 of the 927 landowners in the watershed returned completed surveys for a usable response rate of 50%.

- Three-fourths of the landowners agreed that water contamination is an important problem in the Rathbun Lake area, 73% are concerned about the purity of their drinking water, and 69% agreed that poor water quality in Rathbun Lake would effect economic development in southern Iowa.

- Even though landowners reported that 40% of farmland acres were planted to row crops in 2000, 80% indicated they would consider converting cropland to hay or pasture if the per acre profit was the same.

- The most common reason offered by landowners for not converting cropland to grassland was that government programs are more advantageous with row crop production than with livestock production.

- Landowners reported no-till as the dominant tillage practice for corn following soybeans (51%) and soybeans following sod or meadow (64%).

- Over one-third of landowners identified small gullies as the most prevalent erosion problem on their farm, 27% identified sheet and rill erosion, and less than 20% identified large gullies and stream bank erosion.

- Seven of every 10 landowners reported using commercial fertilizers, 60% used herbicides, and half used insecticides. More than 60% reported that custom applicators applied most of these chemicals.

- Just over 27% of the landowners reported scouting their fields seven or more times during the growing season. Only 18% reported keeping records at both the field and farm levels.

- Forty-eight percent of landowners indicated that they are very interested in adopting better soil erosion control methods.

- The majority of landowners agreed that better erosion control, marketing of alternative crops, and better pesticide management would be very effective means of improving water quality in Rathbun Lake.

- USDA FSA and NRCS were identified as the leading sources of conservation information. More than half of the landowners consider personal contact as the best means of obtaining helpful information.

APPENDIX B

Time Of Travel For South Fork Chariton And Chariton Rivers Within Rathbun Watershed

John A. Kost
Iowa State University
Ames, IA.

A susceptibility analysis is to be conducted as required by the 1996 Clean Water Drinking Act under the auspices of the Iowa Department of Natural Resources, in order to determine the potential threat of a released pollutant into the two major rivers of the Lake Rathbun Watershed. The South Fork Chariton and Chariton Rivers provide rural drinking water to the Rathbun Regional Rural Water Association (RRWA) from the Rathbun Lake Reservoir.

In order to fulfill the requirement for phase I of the susceptibility analysis for surface water sources providing drinking water to a public water source the following information must be obtained: It is necessary to "determine the distance equivalent to a 72-hour time of travel upstream of the Public Water Source (PWS) intake…" where the 72 hour time of travel distance is estimated… "under average flow conditions" (Source Water Assessment and Protection Program and Implementation Strategy for the State of Iowa, April 1999). "Average" flow on a water body is commonly determined from stream gage data records. This is represented as 'mean average' flow in published data by the United States Geological Survey. Flow velocity was calculated to determine 72 hour time of travel. Mean average flow data were used, as well as stage data under static channel conditions from stream gage stations #069037000 and #069034000 of the South Fork Chariton and Chariton Rivers respectively, within the Rathbun watershed. GIS data and hydrological flow equations were also used. Although it was not measured directly, flow velocity for 72 hour TOT was calculated by determining the hydraulic radius of both rivers, then using that result in Manning's equation to calculate flow velocity. The actual width of channel (factor t in the hydraulic radius equation) could not be determined, so it was estimated mathematically for the recorded mean average flows of both rivers: The

widths of both rivers were predicted, then used to calculate the velocity using Manning's equation, and the area using the formula for the cross-sectional area of a round-bottom channel $\left(a = \frac{2}{3} td\right)$. These values were then plugged into the discharge equation $(q = va)$, where q is a known value, to verify the predictions. The hydraulic radius, discharge, and Manning's equations were used, with *Chow's Open Channel Hydraulics* value of .045 for the n roughness coefficient.

<u>Hydraulic Radius:</u>

$$R = \frac{t^2 \; d}{1.5t^2 + 4d^2} \qquad \begin{array}{l} t = channel \;\; width \\ d = \;\; flow \; depth \end{array}$$

<u>Manning's Equation:</u>

$$v = \frac{1.50 \; R^{2/3} \; S^{1/2}}{n} \qquad \begin{array}{l} R = hydraulic \; radius \\ S = bed \;\; slope \\ n = roughness \; coefficient \end{array}$$

$$Where \; bed \;\; slope \; (S) = \frac{\Delta \; elevation}{length \; of \;\; reach}$$

<u>Discharge:</u>

$$q = va \qquad \begin{array}{l} v = velocity \\ a = channel \;\; cross - \sec tional \;\; area \end{array}$$

$$Where \; cross \sec tional \;\; area \; (a) = \frac{2}{3} \; td \;\; for \; round \; bottomed \; channels.$$

<u>South Fork Chariton River Calculations:</u>

Known data:

- *Annual mean average flow (water years 1968 – 1999):* **130 cfs**
- *Flow depth at gage (d):* **4.68 ft**
- *Roughness coefficient (n):* **.045** *(normal streams on plain- clean, winding, some pools, shoals, weeds, & stones)*
- *River elevation at start of watershed:* **1082 ft above sea level**
- *River elevation at end of watershed:* **904 ft above sea level** *(Lake Rathbun Reservoir Normal Pool Level)*
- *Total river miles within watershed:* **32.8 miles** (173,184 ft)

Bed slope:

$$S = \frac{\Delta\ Elevation}{Length\ \ of\ \ \mathrm{Re}ach} = \frac{1082\,ft - 904\,ft}{173{,}184\,ft} = .0010\,ft$$

Hydraulic Radius: (20 ft. 3/16 in. estimated channel width @ 130 *ft3/s*)

$$R = \frac{t^2\ d}{1.5t^2 + 4d^2} = \frac{(20.1875\,ft)^2\ \ (4.68\,ft)}{1.5\,(20.1875\ \ ft)^2 + 4\,(4.68\ \ ft\ \ )^2} = 2.7289\ \ ft$$

Manning's Equation:

$$v = \frac{1.50\ R^{2/3}\ S^{1/2}}{n} = \frac{1.50\,(2.7289\ \ ft)^{2/3}\ (.0010\ \ ft)^{1/2}}{.045} = 2.0584\ \ ft/s$$

Discharge Verification (based on calculated velocity from estimated channel width):

$$cross\ sectional\ area\ (a) = \frac{2}{3}td = \frac{2}{3}(20.1875\ ft)(4.68\ ft) = 62.9850\ ft^2$$

$$discharge\ (q) = va = 2.0584\ {}^{ft}\!/_{s}\ (62.9850\ ft^2) = 129.6483\ {}^{ft^3}\!/_{s}$$

TOT based on calculated velocity:

$$2.0584\ {}^{ft}\!/_{s}\left(\frac{259{,}200\ seconds}{72\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right) = 101.05\ {}^{miles}\!/_{72\ hours}$$

$$2.0584\ {}^{ft}\!/_{s}\left(\frac{172{,}800\ seconds}{48\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right) = 67.37\ {}^{miles}\!/_{48\ hours}$$

$$2.0584\ {}^{ft}\!/_{s}\left(\frac{86{,}400\ seconds}{24\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right) = 33.68\ {}^{miles}\!/_{24\ hours}$$

$$2.0584\ {}^{ft}\!/_{s}\left(\frac{3600\ seconds}{hour}\right)\left(\frac{1\ mile}{5280\ ft}\right) = 1.40\ {}^{miles}\!/_{hour}$$

<u>Chariton River Calculations:</u>

Known data:

- *Annual mean average flow (water years 1966 – 1999):* **128 cfs**
- *Flow depth at gage (d):* **7.84 ft**
- *Roughness coefficient (n):* **.045** *(normal streams on plain- clean, winding, some pools, shoals, weeds, & stones)*
- *River elevation at start of watershed:* **1100 ft above sea level**
- *River elevation at end of watershed:* **904 ft above sea level** *(Lake Rathbun Reservoir Normal Pool Level)*

- *Total river miles within watershed:* **53.4 miles** (281,952 ft)

Bed slope:

$$S = \frac{\Delta\ Elevation}{Length\ \ of\ \ \mathrm{Re}ach} = \frac{1100\,ft - 904\,ft}{281{,}952\,ft} = 6.95\ x\,10^{-4}\ ft$$

Hydraulic Radius: (13 ft. 7/8 in. estimated channel width @ 128 cfs)

$$R = \frac{t^2\ d}{1.5t^2 + 4d^2} = \frac{(13.8750\,ft)^2\ \ (7.84\,ft)}{1.5\,(13.8750\ \ ft)^2 + 4\,(7.84\ \ ft\ \ )^2} = 2.8231\,ft$$

Manning's Equation:

$$v = \frac{1.50\ R^{2/3}\ S^{1/2}}{n} = \frac{1.50\,(2.8231\ \ ft)^{2/3}\ (6.95\ x\,10^{-4}\ \ ft)^{1/2}}{.045} = 1.7578\ \ ft/s$$

Discharge Verification (based on calculated velocity from estimated channel width):

$$cross\ \mathrm{sec}tional\ \ area\ (a) = \frac{2}{3}\,td = \frac{2}{3}\,(13.8750\ \ ft)\,(7.84\ \ ft) = 72.5200\ \ ft^2$$

$$disch\,\mathrm{arg}e\ (q) = va = 1.7578\ \ ft/s\ (72.5200\ \ ft^2) = 127.4757\ \ ft^3/s$$

TOT based on calculated velocity:

$$1.7578\ ft/s\left(\frac{259{,}200\ \mathrm{sec}onds}{72\ hours}\right)\left(\frac{1\,mile}{5280\ \ ft}\right) = 86.29\ miles/72\ hours$$

$$1.7578\ {}^{ft}\!/_{s}\left(\frac{172{,}800\ \text{seconds}}{48\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right)=57.53\ {}^{miles}\!/_{48\ hours}$$

$$1.7578\ {}^{ft}\!/_{s}\left(\frac{86{,}400\ \text{seconds}}{24\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right)=28.76\ {}^{miles}\!/_{24\ hours}$$

$$1.7578\ {}^{ft}\!/_{s}\left(\frac{3600\ \text{seconds}}{hour}\right)\left(\frac{1\ mile}{5280\ ft}\right)=1.20\ {}^{miles}\!/_{hour}$$

As demonstrated in the calculations above, the use of mean average flows to estimate 72 hour time of travel resulted in unusually high travel distances that exceeded the total river miles of both rivers within the watershed. Recent high flow events from unusually wet years have contributed in elevating this average to a flow level that is unrealized most times of a year. In approximately 30 years of recorded USGS mean average flow conditions at gauging stations, the South Fork and Chariton Rivers have produced a mathematical average discharge of 130 cfs and 128 cfs respectively. These values are relatively high compared to flows that are commonly carried by these rivers at most times of the year and would not be considered accurate for the calculation of time of travel. Flows most representative, and occurring most commonly during the year for these two rivers, are those recorded as “50 percent exceedance”(the median value), by the USGS in annual water year reports. Fifty percent exceedance values for the South Fork Chariton and Chariton Rivers are 15 cfs and 14 cfs, respectively. These values were used to determine 72-hour time of travel. The South Fork Chariton River 72 and 48 TOT miles still exceeded the total river miles within the watershed (seen in the calculations below). The median flow is still preferable because it is more representative than the mean average value. It is not advisable, however, that median flows be used exclusively for

these rivers, because higher flows may occur in periods of higher than normal snow melt or rainfall, and lower flows may occur in times of drought.

<u>South Fork Chariton River Calculations:</u>

Known data:

- *Median flow (water years 1968 – 1999):* **15 cfs**
- *Flow depth at gage (d):* **3.45 ft**
- *Roughness coefficient (n):* **.045** *(normal streams on plain- clean, winding, some pools, shoals, weeds, & stones)*
- *River elevation at start of watershed:* **1082 ft above sea level**
- *River elevation at end of watershed:* **904 ft above sea level** *(Lake Rathbun Reservoir Normal Pool Level)*
- *Total river miles within watershed:* **32.8 miles** (173,184 ft)

Bed slope:

$$S = \frac{\Delta\ Elevation}{Length\ \ of\ \ \mathrm{Re}ach} = \frac{1082\,ft - 904\,ft}{173{,}184\,ft} = .0010\,ft$$

Hydraulic Radius: (5 ft. 5/8 in. estimated channel width @ 15 cfs)

$$R = \frac{t^2\ d}{1.5t^2 + 4d^2} = \frac{(5.6250\,ft)^2\ \ (3.45\,ft)}{1.5\,(5.6250\ \ ft)^2 + 4\,(3.45\ \ ft\ \ )^2} = 1.1482\,ft$$

Manning's Equation:

$$v = \frac{1.50\ R^{2/3}\ S^{1/2}}{n} = \frac{1.50\ (1.1482\ ft)^{2/3}\ (.0010\ ft)^{1/2}}{.045} = 1.1550\ ft/s$$

Discharge Verification (based on calculated velocity from estimated channel width):

$$cross\ sectional\ area\ (a) = \frac{2}{3}\ td = \frac{2}{3}\ (5.6250\ ft)(3.45\ ft) = 12.9375\ ft^2$$

$$discharge\ (q) = va = 1.1550\ ft/s\ (12.9375\ ft^2) = 14.9428\ ft^3/s$$

TOT based on calculated velocity:

$$1.1550\ ft/s\left(\frac{259{,}200\ seconds}{72\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right) = 56.70\ miles/72\ hours$$

$$1.1550\ ft/s\left(\frac{172{,}800\ seconds}{48\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right) = 37.80\ miles/48\ hours$$

$$1.1550\ ft/s\left(\frac{86{,}400\ seconds}{24\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right) = 18.90\ miles/24\ hours$$

$$1.1550\ ft/s\left(\frac{3600\ seconds}{hour}\right)\left(\frac{1\ mile}{5280\ ft}\right) = .7875\ miles/hour$$

<u>Chariton River Calculations:</u>

Known data:

- *Median flow (water years 1965 – 1999):* **14 cfs**
- *Flow depth at gage (d):* **5.63 ft**

- *Roughness coefficient (n):* **.045** *(normal streams on plain- clean, winding, some pools, shoals, weeds, & stones)*
- *River elevation at start of watershed:* **1100 ft above sea level**
- *River elevation at end of watershed:* **904 ft above sea level** *(Lake Rathbun Reservoir Normal Pool Level)*
- *Total river miles within watershed:* **53.4 miles** (281,952 ft)

Bed slope:

$$S = \frac{\Delta\ Elevation}{Length\ \ of\ \ \mathrm{Re}ach} = \frac{1100\,ft - 904\,ft}{281{,}952\,ft} = 6.95\ x\,10^{-4}\ ft$$

Hydraulic Radius: (4 ft. 13/16 in. estimated channel width @ 14 cfs)

$$R = \frac{t^2\ d}{1.5t^2 + 4d^2} = \frac{(4.8125\,ft)^2\ \ (5.63\,ft)}{1.5\,(4.8125\ \ ft)^2 + 4\,(5.63\ \ ft\ \ )^2} = .8072\,ft$$

Manning's Equation:

$$v = \frac{1.50\ R^{2/3}\ S^{1/2}}{n} = \frac{1.50\,(.8072\ \ ft)^{2/3}\ (6.95\ x\,10^{-4}\ \ ft)^{1/2}}{.045} = .7629\ \ ft/s$$

Discharge Verification (based on calculated velocity from estimated channel width):

$$cross\ \mathrm{sec}tional\ \ area\ (a) = \frac{2}{3}\,td = \frac{2}{3}\,(4.8125\ \ ft)\,(5.63\ \ ft) = 18.0629\ \ ft^2$$

$$disch\,\mathrm{arg}e\ (q) = va = .7629\ \ ft/s\ (18.0629\ \ ft^2) = 13.7802\ \ ft^3/s$$

TOT based on calculated velocity:

$$.7629\ {}^{ft}\!/_{s}\left(\frac{259{,}200\ \text{seconds}}{72\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right)=\ 37.45\ {}^{miles}\!/_{72\ hours}$$

$$.7629\ {}^{ft}\!/_{s}\left(\frac{172{,}800\ \text{seconds}}{48\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right)=\ 24.97\ {}^{miles}\!/_{48\ hours}$$

$$.7629\ {}^{ft}\!/_{s}\left(\frac{86{,}400\ \text{seconds}}{24\ hours}\right)\left(\frac{1\ mile}{5280\ ft}\right)=\ 12.48\ {}^{miles}\!/_{24\ hours}$$

$$.7629\ {}^{ft}\!/_{s}\left(\frac{3600\ \text{seconds}}{hour}\right)\left(\frac{1\ mile}{5280\ ft}\right)=\ .5202\ {}^{miles}\!/_{hour}$$

APPENDIX C

Environmental Assessment for the Rathbun Lake Watershed: Sampling Design, Methods and Results

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4.1. Introduction

The Rathbun Lake Watershed, located on the Chariton River in southern Iowa, provides water to more than 60,000 residents in Iowa and Missouri. The watershed includes over 354,000 acres, including part of Clarke, Lucas, Monroe, Decatur, Wayne and Appanoose counties. Numerous small livestock feeding operations are located in the watershed, and about 133,000 acres in the watershed are highly erodible cropland, making Rathbun Lake vulnerable to both point and non-point sources of water pollution. The most important non-point source pollution is thought to be soil loss from agricultural land, causing faster sedimentation rate, high level of turbidity and elevated herbicide level in the water. Due to the importance of Rathbun Lake as a water supply, wildlife resource and its recreational value, the water quality in the lake is of great concern (Rathbun Lake Project, 1999).

In 1999, a team of scientists from Iowa State University, the Chariton Valley Resource Conservation and Development office and the U.S. Department of Agriculture Natural resources Conservation Service initiated a project to assess the environmental health of the watershed and to develop a management plan for improving its future environmental health. The Rathbun Lake watershed is divided into 61 sub-watersheds defined by the 14-digit Hydrologic Unit Codes (HUC), with an average size of 5,800 acres each. Estimation of the pollution by subwatersheds is one of the major objectives of the project and will make it possible to develop locally targeted management plans. The ultimate objective of the study is to achieve targeted levels of water quality protection and improvement in Rathbun Lake.

Since erosion represents one of the major components to water pollution in the watershed, a survey was designed to estimate the total amount of erosion that is delivered to the streams in the watershed. Erosion sources need to be identified and the amounts of erosion delivered into local waterways from each sources need to be quantified. Common sources of erosion are sheet and rill, ephemeral gullies, gullies, streambanks, roads, construction sites, and feedlots. After source and quantity are identified, a sediment delivery procedure can used to determine delivery to a specific location. This survey, together with a complete enumeration of the major point sources of erosion and other water pollutants (e.g. livestock feedlots), made it possible to describe the most important impairments to water quality in the Rathbun Lake watershed.

In addition to quantifying the water pollution impacts, it was also of interest to assess the current ecological health status of waterways in the watershed. Biological or ecological integrity of stream systems is commonly defined as "the ability to support and maintain a balanced, integrated, and adaptive community with a biological diversity, composition, and functional organization comparable to those of natural aquatic ecosystems in the region" (Frey 1977). Karr and Dudley (1981) list four main classes of variables as determinants of the ecological integrity of running water systems: flow regime, habitat structure, water quality, and energy relationships and community dynamics. Therefore, a second concurrent survey was used to perform an assessment of the quality of riparian and stream habitat

This document describes the methodology and results of both surveys conducted as part of the watershed health assessment. The first survey measures erosion from all major sources on agricultural land on 183 randomly selected 160-acre plots. The second survey is an assessment of the quality of riparian and stream habitat, measured at 110 stream sites in the watershed. The document is structured as follows. Section 4.2 describes the sampling design of the surveys. In Section 4.3, the measurement instruments and data collection methodologies are discussed. Section 4.4 provides some background on the calculation of the estimates. Finally, Section 4.5 describes the results from the surveys.

4.2. Sampling Design

We will first describe the sampling design for the erosion survey. The sampling unit is a plot of approximately 160 acres, corresponding to a quarter of a section as defined by the Public Land Survey System (PLSS).

As in many geographical surveys, the main factor for deciding the size and number of sampling units depends on the trade-off between cost and precision for the variables of interest. If in each sub-watershed, the total area one would like to measure in the field is fixed, one wants to choose, ideally, many small sampling units. If plots are spatially close, they are likely to be more similar to each other, and the variables of interest may be correlated with each other. Therefore, the sampling units should be large enough to conduct meaningful measurements, but small enough to have many sampled units. This will minimize the overall variances of resulting estimators. However, a main constraint for doing so is available resources, i.e., how many people/days are available to do the work and finish it within in a reasonable amount of time? Combining these two factors, the choice between 160-acre and 40-acre was considered for this survey. From the precision of estimation point of view, a 40-acre plot seems to be a better choice. One 160-acre plot, which can be split into four 40-acre plots, results in data that are more similar than that derived from four 40-acre plots selected at random over a larger area, and therefore may be a less efficient design. However, numerous smaller plots will increase the effort of data collection significantly, including more time of travelling, locating sample areas and finding features of interest. Another advantage of the 160-acre quarter-section is that ownership in Iowa frequently follows these same areal units, thereby simplifying identification in the field as well as landowner contact. After extensive discussion with the local data collection staff, a sample unit of 160 acres seemed to represent a practical choice.

The universe of sampling units in the Rathbun Lake watershed was defined using ArcInfo on digital maps. A "quarter-section coverage" for the area of interest was created by identifying the center points of each PLSS section, and then connecting them with the neighboring 4 other center points. Since the actual area of each section is slightly different from one another, the areas of the quarter-sections are not exactly the same.

However, they are approximately 160 acres (mean: 159.9 acre, standard deviation: 4.0 acre), so we will continue to refer to them as 160-acre plots.

Because the subwatersheds are the units of primary interest, the sampling design was stratified by these units, and three 160-acre plots were to be selected in each. However, since the watershed and subwatershed boundaries did not correspond to those of the quartersections, it was necessary to develop a method for assigning the 160-acre plots to the strata. Figure 4.1 shows an overlay of the quarter-section coverage with the 14-digit HUC map (green squares are sample locations: see below). Figure 4.2 shows the same area as Figure 4.1 and more clearly displays the quarter-section coverage. Clearly, some plots straddle the boundaries of two or more subwatersheds, and some contain areas that are outside of the Rathbun Lake watershed altogether. In addition, some plots fall partially or completely in Lake Rathbun and therefore contain little or no agricultural land. In order to create a frame of sampling units, three decision rules were implemented. First, a 160-acre plot is included in the sampling frame if the majority of its surface area falls in the watershed. Second, it is assigned to the subwatershed (stratum) that contains most of its surface area. Third, plots containing more than 80 acres of water are excluded from the sampling frame. Using these rules, the Rathbun Lake watershed contains 2146 eligible quarter-section plots, and each plot belongs to exactly one subwatershed.

For the purpose of sampling design and analysis, the subwatersheds were redefined in terms of the 160-acre plots that were assigned to it. This corresponds to creating a "gridded" version of the Lake Rathbun watershed, with the subwatershed boundaries now following the boundaries of the quarter-sections. Figure 4.3 displays the new subwatershed boundaries.

An alternative approach to design a sample for the watershed would have been to maintain the original subwatershed boundaries, and either exclude the part of the plot that falls in the "wrong" subwatershed, or divide the plot measurement between both subwatersheds. Because the original subwatershed boundaries cannot be observed in the field, and are generally considered to be difficult to observe precisely even on a map, it was decided that redefining the boundaries to match the sampling units was an acceptable way to divide the watershed for survey purposes. In addition, erosion measurements are

unlikely to vary abruptly across subwatershed boundaries, so that this should have little effect on the estimates as well.

Using the new boundary definitions, the largest subwatershed contains 82 eligible quarter-sections, and the smallest subwatershed contains 15. Table 4.1 gives the information on number of valid quarter-sections, mean area per quarter-section, and total surface area for the redefined and original subwatersheds. A few of the subwatersheds (e.g. HUC 10280201070050) display a large difference between redefined and original acreage. This is due to the fact that all the quarter-sections containing more than 80 acres of water are excluded from the sampling frame, while the water area is still included in the original size column.

Within each redefined subwatershed (stratum), three 160-acre plots were selected using systematic sampling. Systematic sampling was used to achieve a good geographic spread within each subwatershed. A brief summary of the sampling procedure follows. The plots were labeled sequentially from east to west within a row and from north to south between rows, and the *fractional interval method* (Särndal *et al.* (1992), p.77) was initially used to select four plots. Then, three of the four plots are selected by simple random sampling. The main purpose for initially drawing four plots was to have a replacement available in case a plot could not be surveyed because of access or permission issues. In addition, we replaced a few of the selected plots because they were too close to each other. Even though systematic sampling was used, this situation could occur because the two-dimensional way of labeling does not guarantee a uniform spread of the sample plots over a 2-dimensional area. Therefore, when selected plots were directly adjacent to each other, one of them was chosen randomly to be replaced by the unselected plot. Figure 4.4 shows the final selected 160-acre plots included in the sample. For the purpose of estimation, this sample will be treated as a stratified simple random sample, as is common practice in survey statistics (Särndal *et al.* (1992), p.83). Within each plot, the erosion measurements are made on all eligible agricultural lands.

For the riparian and stream habitat survey, a stream point was randomly selected within each selected 160-acre plot. Eligible streams were defined as the “blue line” streams identified on the USGS 1:100,000 scale coverages for the counties in the watershed. A total of 173 quarter-sections out of 183 selected quarter-sections contain

streams, or about 95%. For each plot containing streams, all stream segments were ordered and their lengths added up from east to west and from north to south to get the total length L A random point *l* was selected uniformly from (0, L) as the location for assessment. That point was then mapped back onto the original stream based on the ordered stream units within the quarter-section. Figure 4.5 shows the selected stream point locations.

During the field survey, a large number of plots were found not to contain a stream with sufficient flow to perform the assessment. In those cases, the stream location inside the plot closest to the selected point was selected instead. Even after this adjustment, many plots were found not to contain any suitable streams. In those cases, the fourth plot initially selected in the same watershed was used if it still was available and contained a stream. No additional plots were selected beyond the four initial ones, even if no eligible streams were sampled in a subwatershed.

Table 4.2 shows the number of erosion plots and the number of stream assessment points visited in each subwatershed.

4.3 Data Collection

4.3.1 Sediment Erosion and Delivery

The erosion and sediment delivery procedure developed by the USDA-Natural Resources Conservation Service was utilized as a component of the overall Rathbun Lake Watershed Assessment. The primary objectives of this component were to help identify sources of erosion, quantify erosion amounts, and provide information on sediment delivery procedures. The procedure incorporated sheet and rill, ephemeral gully, gully, and streambank erosion along with procedures for estimating the delivery ratio to receiving water bodies.

Two tools were used to determine various types of erosion estimates from the Rathbun Lake watershed. The Erosion and Sediment Delivery Procedure (ESDP) (NRCS, 1999) was used to estimate streambank, gully, and ephemeral gully erosion within the selected sample plots within the watershed. Sheet and rill calculations were computed for the sample plots using the Universal Soil Loss Equation (USLE) developed by the Natural Resource Conservation Service (NRCS, 1999). These methods were

chosen for this project because: 1) They are accepted procedures used by the USDA NRCS, 2) access to skilled personnel for training 3) and their effectiveness and relative ease to use.

After the 160-acre plots were selected (see Section 4.2), permission to collect the data was obtained by telephone conversations with landowners and data was collected during a field visit by the watershed assessment team. Team members walked the sample plots and collected data on ephemeral gullies, gullies, and streambank erosion using field data sheets associated with the ESDP. Eroding length, bank height, widening rate, and soil density estimates were used to calculate soil loss. Sediment delivery ratios were calculated based on landform regions in Iowa using modifiers for watershed shape, predominant topography, channel density, type of channel, and type of drainage.

For the sheet and rill erosion component, Farm Bill compliance plans associated with the USDA NRCS offices for their respective counties were used to identify land use and crop rotations for the sample plots. Sheet and rill erosion calculations were computed for each individual field using the USDA's USLE procedure. Erosion and sediment delivery assessments were completed in the Fall 1999-Spring 2000.

4.3.2 Stream Visual Assessment Protocol

Data were collected for stream characterization using the Stream Visual Assessment Protocol (SVAP). Description of this procedure and approach used at the sampling sites identified in this chapter are given in Appendix E.

4.4 Estimators

4.4.1 Sediment Erosion and Delivery

We first describe the erosion estimators. Estimators are desired for five types of erosion: stream, gully, ephemeral gully, sheet and rill, and total erosion. As mentioned in Section 4.2, the sample design will be treated as stratified simple random sampling for the purpose of estimation. Subwatershed-level estimates for each of the erosion components can then be found by calculating the average of the observed measurements and multiplying by the number of plots in the subwatershed. The erosion component

estimates for the whole watershed are the sum of the subwatershed estimates. We will refer to these estimates as the *direct estimates*.

The problem with this design-based approach, however, is that the subwatershed estimates are based on only three observations, and are therefore highly variable. It was therefore decided to use small area estimation techniques (Gosh and Rao, 1994) to improve the precision of the subwatershed estimates. We will briefly review the approach here. More details can be found in Opsomer *et al.* (2001).

Land use and topography are considered major determinants of erosion. Digital elevation and land use classification coverages were available for the Rathbun Lake watershed and provided a source for auxiliary information for the region. During discussion with local scientists and field staff, the following eight categories of different combinations of soil slope class and vegetation types were formed:

1. 0 to 9% Slope -- Grass
2. 0 to 9% Slope -- Row Crop
3. 0 to 9% Slope -- Forest
4. 9 to 18% Slope -- Grass
5. 9 to 18% Slope -- Row Crop
6. 9 to 18% Slope -- Forest
7. 18 to 40% Slope -- Grass, Row, Forest
8. All Other (excluding water)

Permanent water was excluded as a category and not counted in the classification. Based on the digital coverages, the composition of each quarter-section in the watershed in terms of these eight categories was computed. Table 4.3 shows the composition of the watershed in terms of these categories. Since these compositions were available for both the sampled and unsampled 160-acre plots, they can be used as auxiliary variables to improve the erosion estimators.

Stepwise regression was used to identify a subset of these categories with the best predictive power for the five types of erosion. While none of the erosion regressions had a high predictive power, the two row crop categories with low and high slope were found to be the best variables across erosion types. Because these variables are available for all plots, it is possible to compute a regression predictions for each plot in each

subwatershed, and calculate subwatershed-level regression estimates by summing the plot regression predictions for the subwatersheds. These estimates are often referred to as *synthetic estimates* (Gosh and Rao, 1994). Because they are based on a regression fitted on all the data, these estimates are much less variable than the direct estimates discussed earlier. However, since these are based on a watershed-wide regression, they are also less responsive to subwatershed-specific features or other local effects. Small area estimation is a statistical methodology to combine the direct and synthetic estimates and produce *composite estimates*. In this case, the linear mixed model regression method proposed by Battese *et al.* (1988) was implemented, with the percentage in low slope and high slope row crop as the auxiliary variables.

An issue in implementing the Battese *et al.* (1988) method is that its synthetic and composite estimators require a separate regression for each erosion type, and different weights for the combination of the direct and synthetic estimators. We decided to instead use the regression and the weights calculated for the total erosion and apply these to each of the individual erosion components. This results in a small loss of precision in the estimation of the erosion components, but it preserves the additivity of the components, in that the subwatershed-level estimates of erosion components sum exactly to the subwatershed estimated total erosion. After the erosion was estimated for each source and each subwatershed, these numbers were multiplied by source- and subwatershed-specific sediment delivery ratios to obtain estimates of delivered erosion.

4.4.2 Stream Visual Assessment Protocol

The SVAP data is difficult to aggregate into subwatershed and watershed estimates. The scale is composed of 15 separate indices as well as an aggregate index, and not all indices are calculated at all sites. Direct subwatershed estimates can be calculated by averaging the available observations within each subwatershed, and an overall watershed estimate can be computed as a weighted average of the subwatershed estimates. It is not immediately clear how to interpret the watershed averages, however, since they are based on ordinal indices, not actual numerical measurements. It seems therefore preferable to work with the individual observations or possibly the subwatershed means.

4.5 Results

Table 4.4 shows the composite estimators for the average erosion rate for each subwatershed, for each erosion component as well as for total erosion and sediment delivery to the nearest water body. If estimates of total erosion loadings for a subwatershed are desired, these numbers should be multiplied by the subwatershed size (available in Table 4.1). This will provide estimates of totals from each source for a subwatershed. According to the discussion in Section 4.2, this should be performed using the redefined boundaries to be totally consistent with the sampling approach. Figures 4.6-4.10 display the final erosion component and sediment delivery estimates by subwatershed for the Rathbun Lake watershed.

The following standard deviations were estimated for the subwatershed rate estimates in Table 4.4:

Stream erosion: 29.05

Gully erosion: 10.34

Ephemeral gully erosion: 4.09

Sheet and rill erosion: 65.80

Total erosion: 74.00

Normal approximation 95% confidence intervals for the estimates for each subwatershed can be obtained by taking ±1.96 times these standard deviations. If the estimates are scaled to compute total subwatershed loadings, the same scaling should be applied to the standard deviations.

This project used different methods to estimate total erosion and sediment delivery to the nearest water body (most frequently streams) for each of the sediment sources. Methods used contained both quantitative and qualitative elements. Even though the methods varied and the standard deviation for each estimate is relatively high, it seems warranted to compare the values, at least in relative terms. It also seems quite reasonable to compare spatial distribution of total erosion estimates across the Rathbun Lake watershed.

Sediment delivery to the nearest water body is highest in the western half of the watershed (Fig. 4.10). This is best correlated with sheet/rill (Fig. 4.9) and ephemeral gully (Fig 4.8) delivered sediment. In that sheet and rill erosion is much higher than any

other of the components (Table 4.4), this correlation in observed spatial patterns between composite (total) and sheet and rill is not surprising. It is also noteworthy that the highest soil erosion losses occur to water bodies relatively remote from Lake Rathbun. Because direct sediment delivery to Lake Rathbun is highly distance dependent, those subwatersheds closest to the lake that display higher erosion rates are a significant immediate concern. The heavier composite losses observed in the western part of the watershed are a long-term concern. Much of this sediment may be deposited in the stream. However, once sediment is in the waterways, it is readily available for movement to the lake.

Table 4.4 provides the erosion loss estimates of the different erosion components, as well as the estimated total delivered erosion (after applying delivery ratios to each of the erosion components). As previously mentioned, note that erosion from sheet and rill erosion greatly overshadows other estimates. Also recall these estimates are based on existing management practices on this watershed. Farm management practices have the greatest potential to affect this component of erosion loss. The potential for switchgrass production for biomass and energy therefore seems well suited for evaluation as a cropping system to have a favorable impact on soil erosion losses and ultimately sediment delivery to Rathbun Lake. Those watersheds closest to Rathbun Lake that have the highest loss rates should likely be highest priority for evaluation.

Table 3.1 in Appendix E shows the measurements at the 110 stream locations where SVAP data were collected. Only the first 14 indices are included, because the 15th measurement related to the macro-invertebrate populations was not collected at any of the stream locations. The number "88" in the table means that the information for that index was not collected and that it was marked as such on the SVAP form. The number "99" means that this index was left blank on the form. Both numbers indicate missing data and should be excluded if subwatershed index averages are computed. Results from this segment of the study are discussed in Appendix E.

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Figure 4.2: Lake Rathbun watershed with quarter-section grid highlighted.

Figure 4.3: Rathbun Lake watershed with the subwatershed boundaries redefined in terms of the quarter-section boundaries.

Figure 4.4: Sampled 160-acre plots.

Figure 4.5: Sampled stream point locations.

Figure 4.6: Estimated delivered stream erosion by subwatershed.

Figure 4.7: Estimated delivered gully erosion by subwatershed.

Figure 4.8: Estimated delivered ephemeral gully erosion by subwatershed.

Figure 4.9: Estimated delivered sheet and rill erosion by subwatershed.

Figure 4.10: Estimated delivered total erosion by subwatershed.

Table 4.1. Information on Original and Redefined 14-digit HUC Subwatersheds.

HUC	Number of Valid Quarter-sections	Mean Area /Quarter-section (in acres)	Total Area (Redefined) (in acres)	Total Area (Original) (in acres)
10280201040010	37	160.6	5941	5927
10280201040020	45	160.8	7234	7150
10280201040030	39	161.0	6279	5983
10280201040040	30	158.3	4748	4816
10280201040050	23	154.4	3550	3281
10280201040060	26	159.1	4136	4066
10280201040070	27	156.3	4220	4473
10280201040080	39	160.0	6239	6059
10280201040090	30	159.9	4797	4875
10280201040100	35	160.5	5618	5995
10280201040110	31	158.1	4900	4802
10280201040120	25	159.3	3982	3786
10280201040130	23	157.7	3628	3635
10280201040140	27	161.6	4363	4565
10280201040150	28	153.3	4292	4311
10280201040160	33	161.1	5317	5256
10280201040170	36	160.4	5776	5868
10280201040180	25	161.2	4030	4335
10280201040190	21	157.8	3314	3244
10280201040200	39	161.2	6288	6089
10280201040210	15	159.8	2396	2590
10280201040220	43	164.1	7057	7369
10280201040230	40	160.1	6404	6233
10280201040240	26	158.5	4121	4014
10280201040250	24	159.1	3818	3811
10280201040260	24	160.3	3847	3952
10280201040270	46	157.4	7239	7615
10280201040280	39	156.7	6113	6160
10280201040290	41	158.4	6494	6682
10280201050010	25	164.1	4102	4131
10280201050020	29	158.5	4596	4574
10280201060010	44	160.9	7078	6883
10280201060020	42	159.3	6689	6499
10280201060030	37	162.8	6022	6617
10280201060040	37	162.0	5994	5955
10280201060050	25	159.3	3982	3531
10280201060060	50	161.3	8064	7897
10280201060070	32	161.6	5172	4809
10280201060080	25	161.3	4033	4167
10280201060090	40	162.3	6490	6382
10280201060100	45	159.9	7197	7179
10280201060110	41	160.4	6576	6627
10280201060120	35	161.1	5639	5577

Table 4.1 (continued). Information on Original and Redefined 14-digit HUC Subwatersheds.

HUC	Number of Valid Quarter-sections	Mean Area /Quarter-section (in acres)	Total Area (Redefined) (in acres)	Total Area (Original) (in acres)
10280201060130	41	160.9	6595	6588
10280201060140	37	160.1	5922	5935
10280201060150	30	160.7	4820	5056
10280201060160	29	160.6	4659	4841
10280201060170	31	159.6	4948	4732
10280201060180	44	161.1	7090	7024
10280201060190	48	161.0	7727	7909
10280201060200	26	161.6	4201	4108
10280201060210	50	160.9	8046	7910
10280201060220	47	160.8	7558	7613
10280201060230	24	158.9	3814	4321
10280201060240	34	161.3	5485	5722
10280201060250	45	160.0	7200	7724
10280201070010	82	158.0	12960	14653
10280201070020	28	157.5	4409	4523
10280201070030	25	157.0	3926	4689
10280201070040	43	156.0	6709	6501
10280201070050	58	159.8	9268	16430

Table 4.2. Results of Sample Selected and Field Visits, by Subwatershed.

HUC	Sampled and visited 160-acre plots	Sampled and visited stream locations
10280201040010	3	2
10280201040020	3	1
10280201040030	3	0
10280201040040	3	1
10280201040050	3	2
10280201040060	3	2
10280201040070	3	1
10280201040080	3	2
10280201040090	3	3
10280201040100	3	1
10280201040110	3	1
10280201040120	3	0
10280201040130	3	1
10280201040140	3	2
10280201040150	3	2
10280201040160	3	1
10280201040170	3	2
10280201040180	3	0
10280201040190	3	2

Table 4.2 (continued). Results of Sample Selected and Field Visits, by Subwatershed.

HUC	Sampled and visited 160-acre plots	Sampled and visited stream locations
10280201040200	3	1
10280201040210	3	3
10280201040220	3	3
10280201040230	3	2
10280201040240	3	3
10280201040250	3	3
10280201040260	3	2
10280201040270	3	1
10280201040280	3	1
10280201040290	3	2
10280201050010	3	1
10280201050020	3	1
10280201060010	3	2
10280201060020	3	1
10280201060030	3	2
10280201060040	3	3
10280201060050	3	1
10280201060060	3	3
10280201060070	3	2
10280201060080	3	2
10280201060090	3	3
10280201060100	3	2
10280201060110	3	3
10280201060120	3	3
10280201060130	3	2
10280201060140	3	1
10280201060150	3	1
10280201060160	3	3
10280201060170	3	2
10280201060180	3	1
10280201060190	3	2
10280201060200	3	1
10280201060210	3	1
10280201060220	3	3
10280201060230	3	2
10280201060240	3	2
10280201060250	3	2
10280201070010	3	2
10280201070020	3	2
10280201070030	3	3
10280201070040	3	2
10280201070050	3	2
Total	183	110

Table 4.3. Category Distribution for Whole Watershed

category	acres	proportion
0-9% grassland	148602	0.43
0-9% row crop	83056	0.24
0-9% forest land	15948	0.05
9-18% grassland	63281	0.18
9-18% row crop	10635	0.03
9-18% forest land	9677	0.03
18-40% grass, crop, forest	6671	0.02
other	5820	0.02
total (water excluded)	343692	1.00
water	10387	

Table 4.4. Composite Estimates for Average Erosion, in Tons per 160-acre Plot.

HUC	Streambank	Gully	Ephemeral gully	Sheet & Rill	Total	Total Delivered
10280201040010	33.21	10.08	3.61	455.39	502.28	157.25
10280201040020	28.05	10.32	4.82	539.67	582.86	218.11
10280201040030	-0.07	4.64	4.71	555.22	564.50	158.01
10280201040040	17.82	10.25	7.19	626.25	661.52	259.56
10280201040050	43.99	14.29	5.69	423.79	487.75	210.87
10280201040060	49.66	14.26	7.16	594.39	665.47	277.81
10280201040070	67.36	20.94	6.26	495.79	590.35	205.78
10280201040080	56.28	16.08	2.33	345.87	420.56	111.35
10280201040090	66.05	19.12	3.26	403.23	491.65	222.27
10280201040100	45.26	14.46	2.58	371.75	434.05	107.41
10280201040110	30.20	10.45	4.39	468.39	513.42	116.85
10280201040120	62.32	17.59	2.60	338.42	420.93	96.43
10280201040130	52.71	22.18	3.78	387.82	466.48	254.11
10280201040140	13.89	7.94	7.52	648.10	677.46	195.72
10280201040150	84.83	24.70	4.51	405.94	519.97	272.08
10280201040160	64.17	19.71	4.94	416.19	505.01	101.96
10280201040170	78.38	22.85	3.00	386.41	490.64	243.01
10280201040180	-4.98	6.77	16.12	720.82	738.73	271.29
10280201040190	73.68	23.97	3.86	386.72	488.23	225.28
10280201040200	53.67	18.03	6.98	524.10	602.77	130.27
10280201040210	70.08	18.50	2.72	316.29	407.59	131.88
10280201040220	74.64	19.51	2.27	292.64	389.07	82.01
10280201040230	48.38	14.00	2.42	353.87	418.67	89.46
10280201040240	78.81	21.54	1.14	273.90	375.39	168.42
10280201040250	88.67	21.86	2.59	302.32	415.44	138.06
10280201040260	69.28	19.23	2.30	308.05	398.85	83.79
10280201040270	55.10	16.42	3.54	371.09	446.15	59.52
10280201040280	35.57	14.50	5.00	490.66	545.73	185.73
10280201040290	61.44	23.82	2.87	357.71	445.83	153.19
10280201050010	22.44	9.78	7.84	563.12	603.17	148.06
10280201050020	68.58	18.45	2.61	349.48	439.11	162.59
10280201060010	78.98	21.28	2.43	349.99	452.68	235.51
10280201060020	38.87	13.44	2.86	415.07	470.24	158.40

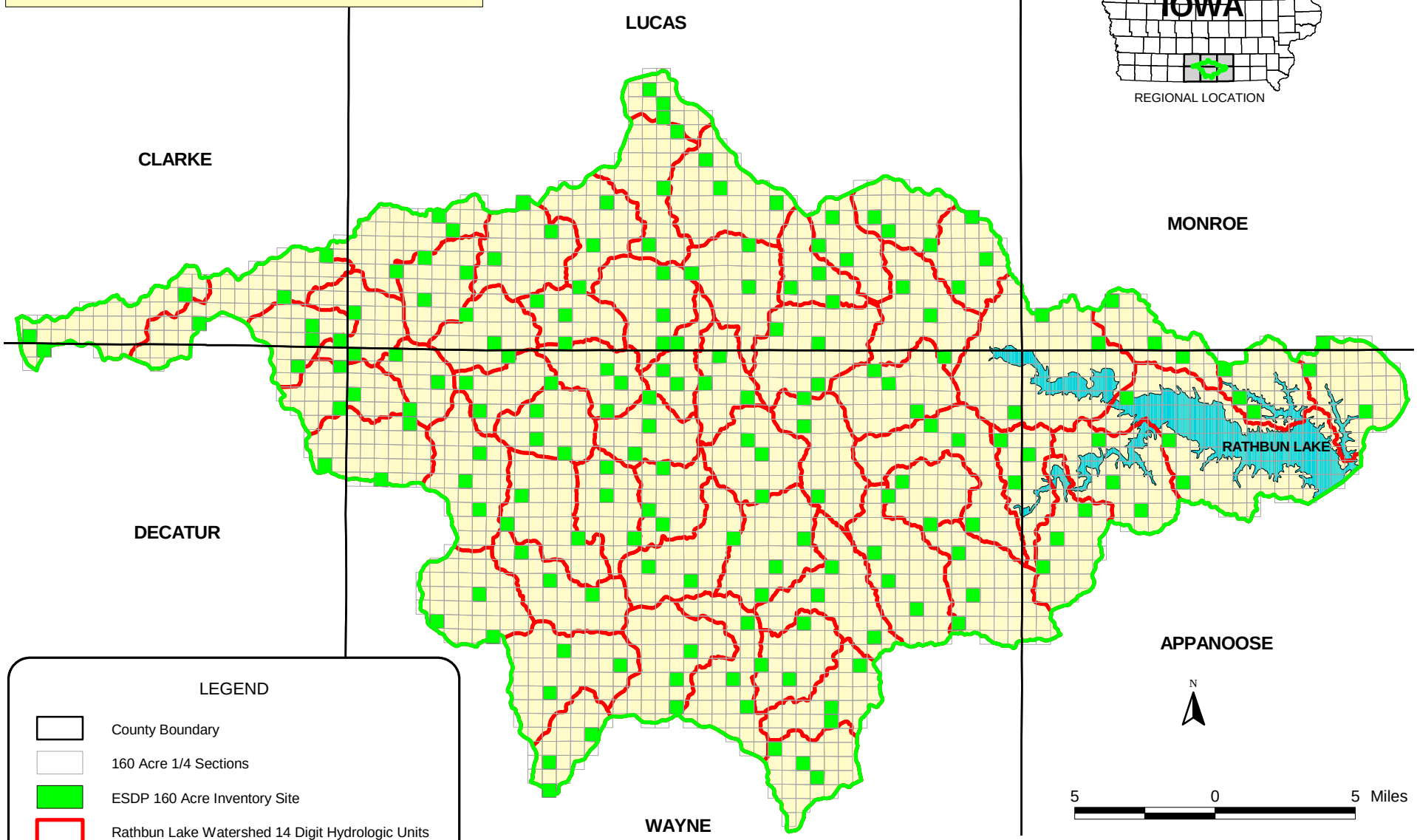
Table 4.4 (continued). Composite Estimates for Average Erosion per 160-acre Plot.

HUC	Streambank	Gully	Ephemeral gully	Sheet & Rill	Total	Total Delivered
10280201060030	91.68	15.22	3.09	383.86	493.86	363.28
10280201060040	84.78	26.81	5.00	311.96	428.55	201.80
10280201060050	15.96	8.21	9.35	556.76	590.28	259.38
10280201060060	73.86	21.25	3.20	336.01	434.32	200.84
10280201060070	61.40	18.21	3.05	419.60	502.27	282.36
10280201060080	52.79	28.44	4.01	425.75	510.99	249.46
10280201060090	78.83	27.37	5.85	501.23	613.27	357.96
10280201060100	58.87	17.50	6.00	468.73	551.10	163.87
10280201060110	80.29	20.48	2.98	341.31	445.06	164.37
10280201060120	60.26	16.68	3.05	402.90	482.88	206.70
10280201060130	75.64	18.79	1.50	287.67	383.60	127.77
10280201060140	52.54	19.02	2.65	380.40	454.61	183.84
10280201060150	81.56	21.95	3.05	276.02	382.58	158.69
10280201060160	81.17	23.65	1.75	318.42	424.99	247.33
10280201060170	76.40	20.07	5.63	432.38	534.48	352.95
10280201060180	86.48	22.88	1.63	273.07	384.06	148.47
10280201060190	87.96	23.10	1.03	233.48	345.56	115.00
10280201060200	50.41	19.02	2.79	365.29	437.50	137.05
10280201060210	121.15	24.87	3.97	409.33	559.32	517.15
10280201060220	96.62	23.68	1.82	291.96	414.07	259.78
10280201060230	73.44	20.60	2.75	322.17	418.96	105.40
10280201060240	68.45	21.06	1.82	291.17	382.50	111.55
10280201060250	73.10	20.48	1.47	279.39	374.44	113.73
10280201070010	73.56	18.58	1.69	301.95	395.79	147.07
10280201070020	57.43	14.61	3.07	407.77	482.88	227.62
10280201070030	83.91	22.22	1.87	292.65	400.65	179.16
10280201070040	67.32	18.64	1.32	309.13	396.42	140.56
10280201070050	50.48	16.04	5.60	466.37	538.49	127.42

RATHBUN LAKE WATERSHED
ESDP 160 Acre Inventory Sites
South Central Iowa

Figure 4.1

REGIONAL LOCATION



LEGEND

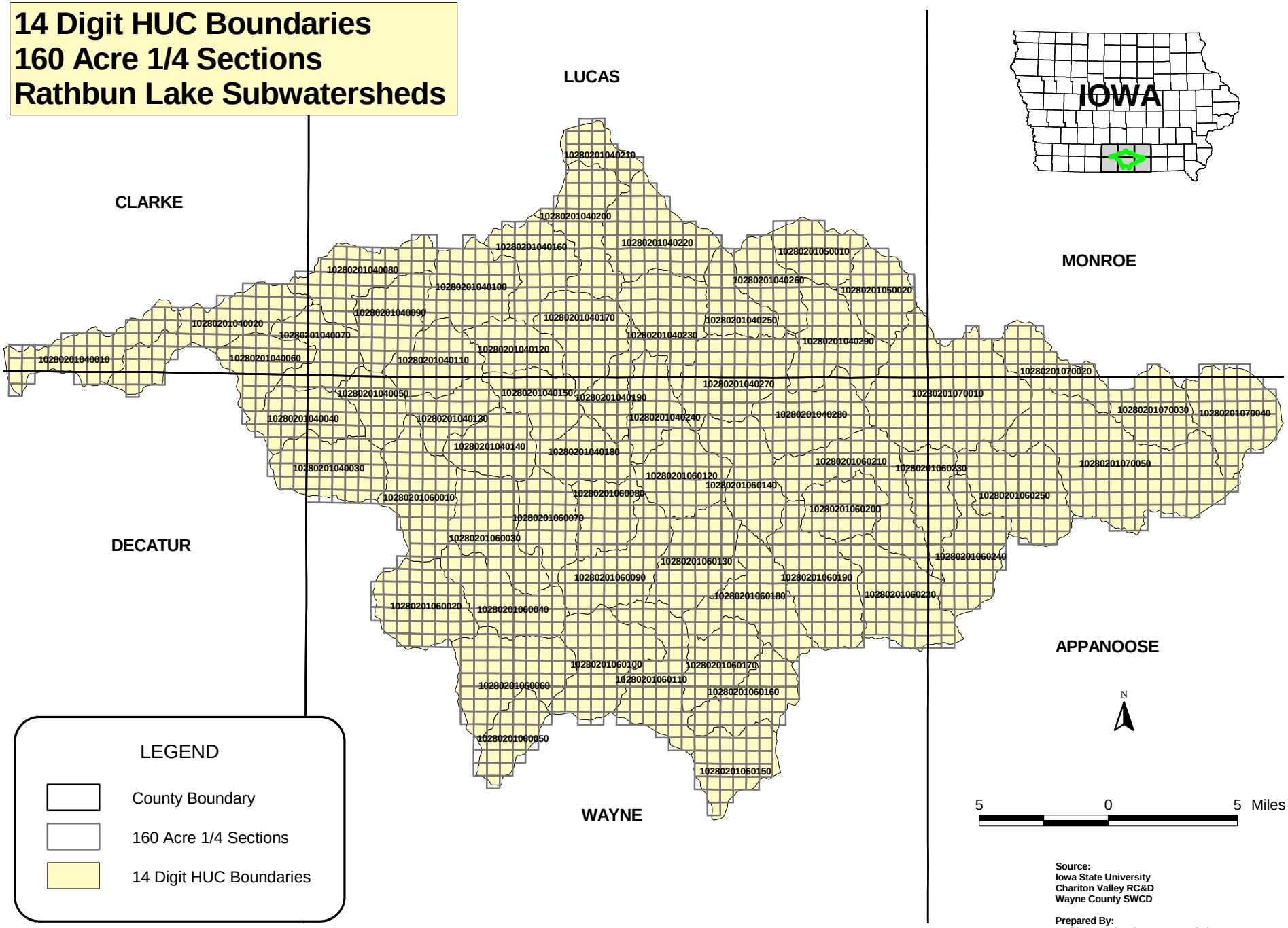
- County Boundary
- 160 Acre 1/4 Sections
- ESDP 160 Acre Inventory Site
- Rathbun Lake Watershed 14 Digit Hydrologic Units
- Rathbun Lake (904 ft. elevation -- Normal Pool)
- Rathbun Lake Watershed (354,000 Acres)

Source: Iowa Department of Ag and Land Stewardship
Chariton Valley RC&D
Iowa State University
Iowa DNR NRGIS
USDA Natural Resources Conservation Service

Prepared By: Rathbun Regional Water Association

Figure 4.2

14 Digit HUC Boundaries
160 Acre 1/4 Sections
Rathbun Lake Subwatersheds



Source:
Iowa State University
Chariton Valley RC&D
Wayne County SWCD

Prepared By:
Rathbun Regional Water Association