Problems Causes & Sources

4.1: Sediment Loading & Soil Loss

Problem Statement #1 – Excessive Sediment Loading to waterways & Soil Loss from fields

Concern	Section(s) Validated
aquatic life	3.1.1, 3.1.2, 3.1.3
bridge design	3.7, 3.3.3 (bank inventory)
bridge scour	3.3.3
business/development	2.4.3
contaminants in the water	3.2, 3.1.3
erosion	2.4.2, 3.1.1, 3.1.2, 3.2, 3.3.2, 3.4
gully erosion	3.3.4 (gully inventory), 3.4
lack of filter/buffer strips	3.3.1, 3.4
more wascobs on the high ground to hold water in the hills	Not Validated, see section 3.4
natural debris accumulation	3.3.3
road side ditches	3.3.3
soil loss	2.4.2, 3.1.1, 3.1.2, 3.2, 3.3.2, 3.4
stream bank condition	3.3.3, 3.3.1
surface water quality	3.1.1, 3.1.2, 3.2, 3.1.3
washing where farms drain into the creek	3.4
waterway integrity/bank stability	3.3.3
waterway openings	3.3.3, 3.3.4, 3.4

Turbidity is high in surface waters, sediment is clogging drainage ways and burying aquatic habitat, causing low dissolved oxygen, and depositing in large amounts in the floodplain such as at the Oliver gas fields.

Stressors:

- Soil loss
- High sediment loading
- sedimentation

Sources:

1. *Tillage practices on fields >1.5% slope: corn & soybean rotations*

   Crop rotations involving corn and soybeans are the most common row crop types in the watershed. High disturbance tillage techniques are commonly used in these rotations to manage soil and reduce the amount of weeds. Tillage techniques have significant impacts on soil loss and sediment loading by affecting the amount of crop residue following a tillage operation. Crop residue is shown through the RUSLE2 equation to have significant impacts on soil loss associated with sheet and rill type erosion. Sheet and rill erosion is shown in the sediment inventory in section 3 to be the most significant source of sediment delivery to waterways.

   Tillage practices were determined by matching up operations in the RUSLE2 program with observations of residue cover collected during the windshield inventories. Residue cover ranged from 0-35% at planting on these fields considered to be sources of the soil loss and sediment loading problem. Tillage practices varied but mainly included one or more passes with a disk, field cultivator, chisel plow, and/or combination tool. On some fields tillage occurred both in the spring and in the fall.

   The focus of the source is on fields that have an average slope greater than or equal to 1.5%. Soil loss and sediment loading is strongly affected by the slope of the field; as the slope increases, the amount of soil loss from sheet and rill erosion increases and the amount of sediment that will settle in the field decreases. Fields with an average slope less than 1.5% are thought to be insignificant as a source when considering tillage practices, though they may be considered for other sources.

2. Tillage practices on fields > 1.5% slope: corn & double cropped wheat/soybean rotations

   The use of a crop rotation involving corn, winter wheat, and soybeans has become increasingly common in the Big Creek watershed. Adding winter wheat to the rotation following corn adds extra protection from erosion during winter and early spring in addition to providing farmers an extra crop to harvest for financial benefits. However, tillage is still common following soybeans before corn is planted and after corn before winter wheat is planted. This reduces the protection afforded by the winter wheat and often requires extra tillage in the early summer before the soybeans are planted to ensure an even planting bed required for germination. Similar to tillage practices on fields using corn & soybean rotations, a reduction in crop residue is incurred through the tillage resulting in increased soil loss and sediment loading.

Tillage practices for corn and double cropped wheat/soybeans were also determined by matching up operations in the RUSLE2 program with observation of residue cover collected during the windshield inventories. Residue cover was near 100% on most parts of the fields prior to soybean planting which is mostly done without tillage using a drill seeder. Residue cover following corn harvest at the time the winter wheat was planted was similar to the corn & soybean rotations ranging from 0-35%. Areas that were tilled to create an even seeding surface prior to planting soybeans in early summer were much lower in residue cover, ranging from 0-20%.

3. *Stream bank erosion*

Stream bank erosion occurs within the banks of streams, ditches, and the Big Creek main channel. There is a variety of causes including channels being undersized for the amount of peak flow that they receive, having steep banks, having unvegetated banks, and incurring regular herbicide application that kills plants to the roots. The source was determined from the windshield and GIS inventory and includes all the stream lengths determined to be medium to severe.

4. *Row Crop fields without stream-side buffers*

Stream-side buffers are strips of perennial vegetation planted or growing naturally in between crop fields and streams. When runoff carrying sediment travels over the buffer and sheet flow occurs, water velocities are reduced and sediment deposits in the field rather than the stream. In this way, stream-side buffers along crop fields significantly reduce the impact or eliminate the crop field as a source.

Sources were determined through the information obtained during the windshield and GIS inventory concerning stream-side vegetation. Crop fields adjacent to streams with less than 30 feet strip of perennial vegetation were identified as sources.

5. *Large row crop fields where concentrated flow results in gully erosion*

As crop field size increases the distance between changes in the landscape that disrupt flow also increase. This means the field experiences an increased length of flow where sheet flow becomes concentrated flow, and the force of water creates gully erosion regardless of the amount of crop residue cover.

In most crop fields where this occurs, the gully erosion is smoothed during tillage to create an even planting surface. In this case, the erosion is referred to as ephemeral or annual gully erosion and it generally happens each year in the same place. To create stability along the areas of concentrated flow, the fields are in need of erosion control structures that break up the flow (such as water and sediment control basins and other pipe structures), establish permanent cover (such as grassed waterways), or a combination of both. Fields identified as sources were found to have classic or ephemeral gully erosion during windshield and GIS inventories.

6. *Stream Access in Pastures*

Pastures along streams that do not have fencing or an appropriate stream crossing for livestock expose especially sensitive stream side areas to trampling and compaction from the increased livestock traffic. This results in the destruction of stabilizing vegetation and consequently creates stream bank and gully erosion. In addition, where a rocky stream bottom doesn't exist, livestock presence in the streams causes disturbance of sediments causing turbidity in the stream flow even during dry periods.

7. *Bare Areas in Pastures*

Bare areas in pastures occur primarily where livestock congregate (typically feeding areas, watering areas, and shaded areas), regularly travel (i.e. cow paths), or in pastures that are not large enough to support the number of animals that graze there. These areas are subject to high levels of sheet and rill erosion especially on steep slopes due to the lack of vegetative cover.

8. *Gully Erosion in Pastures*

Gully erosion occurs the same way in pastures as in crop fields; gullies may develop anywhere concentrated flow exists. In pastures the problem may continue for several years since pastures are not normally tilled like crop fields to flatten the rill once it begins to develop into a gully.

9. *Brine contaminated sites that are eroding*

Brine or high salinity water is a byproduct of mostly historical oil production that can surface and pollute soils so that they cannot sustain vegetation. Where there is a slope to the area, erosion is likely to occur since there is no vegetation. These sites must be remediated so that the salt content returns to normal and vegetation can become reestablished to stabilize the soils.

10. *Construction sites that are eroding*

Construction sites become sources of soil loss and sediment loading where there is not adequate protection against erosion. These areas are typically cleared of vegetation during construction which may last up to a year. Mostly sheet and rill erosion occurs at these sites, but on larger sites, gully erosion may occur as well.

4.1.1: Source Locations & Magnitude

Table 4.1.1-A: Soil Loss and Sediment Loading Sources: Locations and Magnitude shows the magnitude and location of the soil loss and sediment loading sources. This table provides both an assessment of the magnitude and location of the source and evidence that the source is significant according to the impairments associated with soil loss and sediment loading. The amount of each sources as determined from the results of the windshield and GIS inventory is compared to the level of impairment determined from the water monitoring that occurred through the project. The amount or magnitude of the source is shown as area or length of each source occurring in each sub-watershed. The impairments for total suspended solids and dissolved oxygen are shown in the right hand columns of the table. Partially impaired indicates

that a sub-watershed exceeded targets on between 1 and 10% of the samples collected. Impaired indicates that the sub-watershed exceeded targets on between 11 and 50% of the samples collected. Severely impaired indicates that the sub-watersheds exceeded targets on greater than 50% of the samples collected. Five mg/L is used as the dissolved oxygen target and turbidity is used as a substitute measurement for total suspended solids. The target for total suspended solids measured as turbidity is 20 NTU. This relationship is described below for each of the sources.

1. *Tillage of Fields >1.5% slope: Corn/Soybean rotation*

   As shown in the table, the amount fields greater that >1.5% where tillage occurs is considerable throughout the watershed ranging from about ¼ of the Little Creek-Headwaters (090) to greater than half of the Barr Creek Sub-watershed (050). Because the amount of this source is so large in each of the sub-watersheds and all the sub-watersheds are impaired for turbidity it is difficult to develop a relationship from the amount of this source alone. It is clear however, that the sub-watersheds with the least amount of this source (Little Creek-Headwaters (090) and Little Creek – Wolf Creek (100) seem to be the least affected by soil loss and sediment loading. While being "impaired" for turbidity, they are not impaired for dissolved oxygen. Other sub-watersheds that have lower levels of the source but still are impaired more than areas with less also have large amounts of other sources.

2. *Tillage of Fields >1.5% slope: Corn/Soybean/Wheat rotation*

   Since the amount of fields in this source is a measure of the amount of tillage, it is closely related to the amount in source #1. Where the amount of source #1 in a sub-watershed is high the amount of this source tends to be high as well. This is shown to be true in the Big Creek – Neuman Lateral (040), Caney Creek (060), and Big Creek – McAdoo Creek (130) Sub-watersheds. All three are among the highest in both tilled fields in a corn/soybean rotation and tilled fields in corn/soybean/wheat rotation. Although the addition of winter wheat to a previously corn/soybean rotation does reduce the amount sediment loading, the table shows that the current tillage methods in this rotation are not adequate to avoid impairments due to turbidity and dissolved oxygen. Two of the three sub-watersheds with the highest amount of this source (030 & 130) are severely impaired due to turbidity and impaired due to dissolved oxygen.

3. *Eroding stream banks*

   Eroding stream banks have an especially strong impact on sediment loading since the soil lost is always deposited directly into waterways leaving no chance for the sediment to settle out in a field or a stream-side buffer. Where stream bank erosion is occurring in the largest amounts (130, 140, & 150), there is always a severe impairment due to turbidity and either a partial or full impairment due to dissolved oxygen. This source is very strongly correlated with soil loss and sediment loading impairments even when considered alone.

4. *Row crop fields without buffers*

   Because most fields near streams are flatter and even sometimes have berms that prevent flow across the riparian area during normal storm events, this source is difficult to establish the sub-watersheds with the most fields without buffers as having the most

the soil loss and sediment loading related impairments. However, it is generally true that those sub-watersheds with the least amount of this source are affected the least by soil loss and sediment loading problems. This is especially true of the Little Creek – Headwaters and Little Creek – Wolf Creek Sub-watersheds which are only impaired for turbidity.

5. *Large row crop fields where concentrated flow results in gully erosion*

   The amount of fields needing erosion control structures to control erosion in areas of concentrated flow ranges from 7.1% in the Buente Creek – Maidlow Ditch Sub-watershed to 36.3% in the Big Creek – McAdoo Creek. In general it is true that the sub-watersheds with large amounts of this source also have the most impairments or most severe impairments. It should be noted however, that these sub-watersheds also have considerable amounts of other significant sources. This follows the estimates of erosion detailed in the sediment delivery inventory that show classic gully and ephemeral/annual gully erosion to be much less significant than sheet/rill and stream bank erosion. Regardless, in a few sub-watersheds this does represent a significant type of erosion and even where it is not, the gully erosion that is occurring must be controlled before a switch to a reduced or no-till method of farming can occur.

6. *Livestock stream access*

   Livestock stream access is fairly uncommon throughout the watershed, but is significant among the sources occurring on pastures because sediment is delivered directly to a stream. In addition, the disturbance of stream bottom sediments that occurs makes it among the most important sources in streams that are only exceeding turbidity standards during dry periods. Access is only occurring in 9 of the 16 sub-watersheds and the amount in need of fencing or an appropriate stream crossing ranges from about 500 to 2500 feet.

7. *Bare areas in Pastures*

   Since pastures are not a large land use in the watershed, this source is rarely large enough to be significant (at most this source represents only 0.2% of a single sub-watershed), though the load per acre may be relatively large.

8. *Gully erosion in Pastures*

   As with other pasture sources, this source is not nearly as large or significant as the other sources and cannot be correlated with any of the impairments, but still will likely be important in achieving all of the water quality standards.

9. *Brine Contaminated Sites: Eroding*

   Despite over 10 years of remediation efforts, a small number of brine contaminated sites exist. These sites are fairly insignificant and at a maximum cover only 3.7 acres in any one particular sub-watershed. However, control and remediation of these remaining sites should be part of a comprehensive plan to reduce soil and sediment loading.

10. *Construction sites that are eroding*

No sites were identified during the two year span of the project as significantly contributing sediment to streams. However since construction sites, especially when they are large can cause impairments, they are listed here as a source and should be monitored especially if an increase in development in the watershed occurs.

	Sources					Impairments	
Sub-watershed	1. Acres Tilled Fields > 1.5% slope: C/S (%)	2. Acres Tilled Fields > 1.5% slope: DCWW (%)	3. Stream bank erosion (miles)	4. Acres (%) of row crop without Buffers	5. Fields needing Erosion Control Structures (%)	Turbidity (Total Suspended Solids)	Dissolved Oxygen
010	6368 (50.8%)	1535 (12.2%)	4.1	5430 (43%)	39 (12.2%)	**IMPAIRED**	**IMPAIRED**
020	3940 (48.1%)	807 (9.9%)	0.4	2992 (37%)	15 (7.1%)	**SEVERELY IMPAIRED**	**IMPAIRED**
030	4898 (48.4%)	1492 (14.7%)	1.3	4783 (47%)	50 (20.0%)	**SEVERELY IMPAIRED**	**IMPAIRED**
040	4917 (50.0%)	1941 (19.7%)	7.6	3111 (32%)	64 (34.4%)	**SEVERELY IMPAIRED**	*None*
050	4860 (54.0%)	1185 (13.2%)	6.1	2392 (27%)	64 (20.3%)	**IMPAIRED**	**IMPAIRED**
060	4383 (51.0%)	2187 (25.5%)	3.5	4616 (53%)	27 (14.5%)	**IMPAIRED**	**IMPAIRED**
070	3739 (45.0%)	1137 (13.7%)	8.4	2715 (33%)	49 (22.6%)	**SEVERELY IMPAIRED**	PARTIAL
080	7437 (47.8%)	2375 (15.3%)	12.9	5414 (34%)	143 (29.2%)	**SEVERELY IMPAIRED**	*None*
090	3479 (27.5%)	825 (6.5%)	3.4	973 (7%)	101 (10.8%)	**IMPAIRED**	*None*
100	2059 (30.2%)	185 (2.7%)	0.4	891 (13%)	35 (10.3%)	**IMPAIRED**	*None*
110	4384 (43.6%)	1424 (14.2%)	5.1	2898 (28%)	78 (20.3%)	**SEVERELY IMPAIRED**	*None*
120	4710 (44.7%)	1385 (13.1%)	5.9	3604 (34%)	72 (22.9%)	**SEVERELY IMPAIRED**	**IMPAIRED**
130	5868 (50.1%)	2439 (20.8%)	13.9	3652 (31%)	91 (36.3%)	**SEVERELY IMPAIRED**	**IMPAIRED**
140	3622 (39.2%)	1441 (15.6%)	17.5	3043 (32%)	56 (23.4%)	**SEVERELY IMPAIRED**	**IMPAIRED**
150	5655 (44.5%)	2285 (18.0%)	18.1	4311 (33%)	67 (27.5%)	**SEVERELY IMPAIRED**	PARTIAL
160	3284 (40.4%)	1138 (14.0%)	9.2	1398 (17%)	36 (17.5%)	**IMPAIRED**	**IMPAIRED**
Total	73603 (44.9%)	23782 (14.5%)	117.6	987 (21.3%)	987 (21.3%)		

Table 4.1.1-A: Sediment Loading and Soil Loss Sources- Location and Magnitude

	Sources				Impairments	
Sub-watershed	6. Livestock Stream Access (feet)	7. Acres of Bare Pasture Areas (%)	8. Pasture Gullies (Length in Feet)	9. Acres of Eroding Brine Sites	Turbidity (Total Suspended Solids)	Dissolved Oxygen
010	0	13 (0.1%)	0 (0)	0	**IMPAIRED**	**IMPAIRED**
020	0	4 (0.1%)	2 (337)	0	**SEVERELY IMPAIRED**	**IMPAIRED**
030	1416	5 (0.1%)	39 (6485)	0	**SEVERELY IMPAIRED**	**IMPAIRED**
040	0	0 (0.0%)	0 (0)	0	**SEVERELY IMPAIRED**	*None*
050	1229	5 (0.1%)	6 (797)	0	**IMPAIRED**	**IMPAIRED**
060	1417	3 (0.0%)	22 (2358)	0	**IMPAIRED**	**IMPAIRED**
070	555	14 (0.2%)	52 (9260)	0	**SEVERELY IMPAIRED**	PARTIAL
080	0	14 (0.1%)	45 (4842)	0.2	**SEVERELY IMPAIRED**	*None*
090	659	5 (0.0%)	31 (5267)	0	**IMPAIRED**	*None*
100	1278	1 (0.0%)	7 (1767)	0	**IMPAIRED**	*None*
110	0	1 (0.0%)	5 (288)	0.8	**SEVERELY IMPAIRED**	*None*
120	2536	7 (0.1%)	20 (2225)	0	**SEVERELY IMPAIRED**	**IMPAIRED**
130	0	2 (0.0%)	7 (265)	1.5	**SEVERELY IMPAIRED**	**IMPAIRED**
140	0	4 (0.0%)	40 (4582)	0.7	**SEVERELY IMPAIRED**	**IMPAIRED**
150	1930	5 (0.0%)	6 (484)	3.6	**SEVERELY IMPAIRED**	PARTIAL
160	1794	2 (0.0%)	0 (0)	0.5	**IMPAIRED**	**IMPAIRED**
Total	12814	85 (0.1%)	282 (38958)	9.3		

Figure 4.1.1-A: Sediment Loading and Soil Loss Sources- Location and Magnitude

To assist with prioritization and identifying critical areas, load duration curves were created for each sample point using the methodology developed by the Environmental Protection Agency. Load duration curves separate the data into five hydrologic conditions: high, moist, mid-range, dry, and low based on the percentage of historical flows that exceed a given flow rate. A load duration curve of these flows is multiplied by the target concentration to establish a maximum acceptable daily load for each flow value. The median of this acceptable load, or load allocation, for each hydrologic condition is compared to the 90th percentile observed load for that same condition. If the 90th percentile load is above the median load allocation then a reduction is necessary to achieve the desired concentration. The reduction for each hydrologic condition is then compared after disregarding the high and low hydrologic conditions (which represent extreme conditions). The highest reduction is adopted as the overall reduction needed to meet the target (USEPA 2007). An example of such an analysis is shown in *Figure 4.1.2-A: Load Duration Curve for Big Creek at Highway 66*.

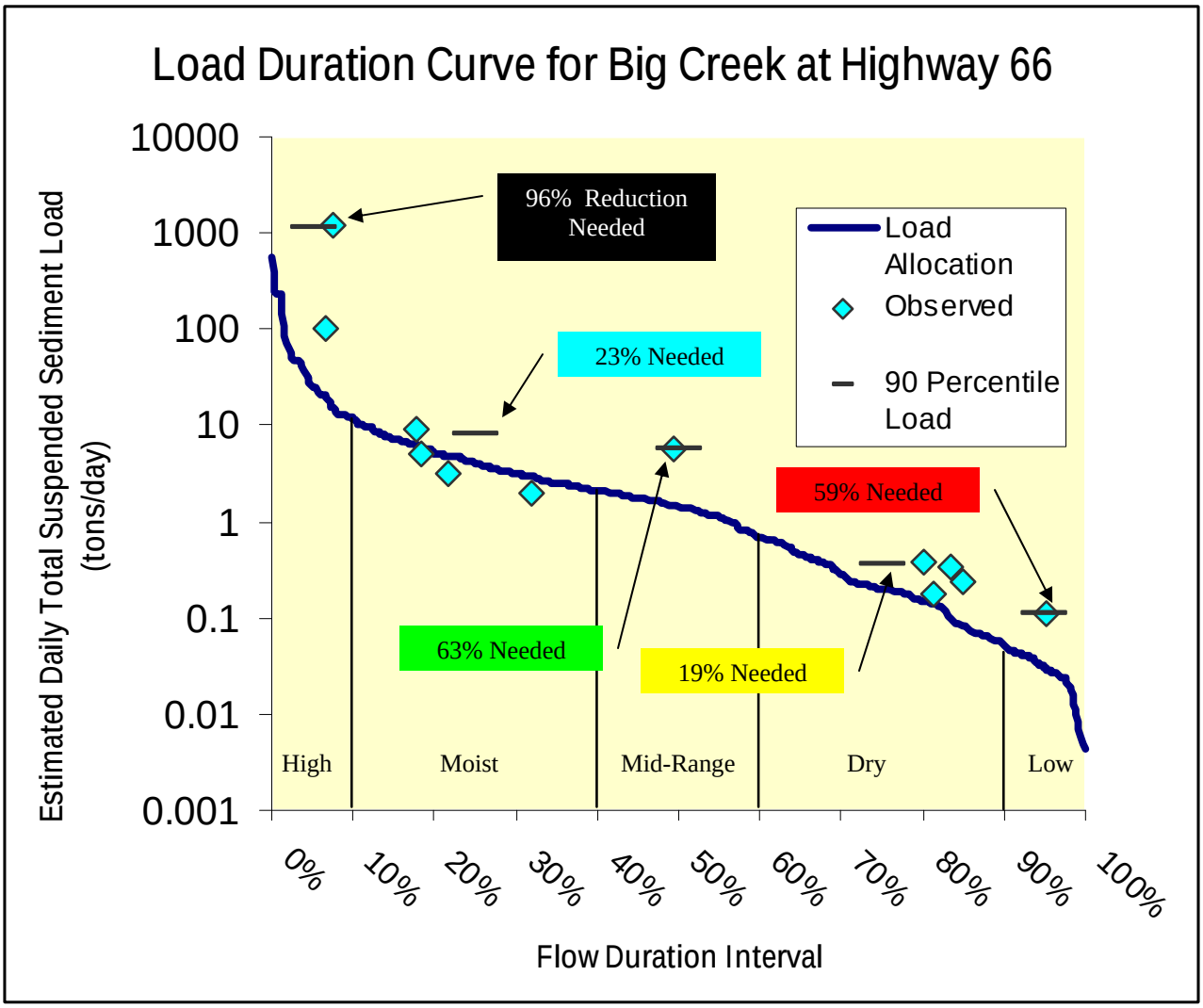

Figure 4.1.2-A: Load Duration Curve for Big Creek at Highway 66

As is shown in the figure, reductions are needed during each of the hydrologic conditions. The greatest reductions are needed during high flow conditions (96% as shown in the black box), but

since this represents extreme events, the next highest needed reduction is used, which is 63% for the mid-range flow conditions. Using this method, it's assumed that in order to achieve the desired concentration for total suspended solids, a 63% reduction in sediment loading within the area draining to sample point 23 must occur.

In addition to providing an estimate on the amount of reduction needed, a load duration curve analysis also provides insight into the types of efforts that will have the biggest impact. EPA guidance documents also provide information on the most effective measures as shown in *Figure 4.1.2-B:* below, taken from the documentation.

Contributing Source Area	Duration Curve Zone				
	High Flow	Moist	Mid-Range	Dry	Low Flow
Point Source				*M*	*H*
On-site wastewater systems			*H*	*M*	
Riparian Areas		*H*	*H*	*H*	
Storm water: Impervious Areas		*H*	*H*	*H*	
Combined sewer overflows	*H*	*H*	*H*		
Storm water: Upland	*H*	*H*	*M*		
Bank erosion	*H*	*M*			

Note: Potential relative importance of source area to contribute loads under given hydrologic condition *(H: High; M: Medium)*

According to the guidance, the most important source areas for the reductions at Big Creek near Highway 66 is riparian areas (combined sewer overflows do not exist in Big Creek and On-site wastewater systems are not expected to affect the total suspended solids load significantly).

The results of the load duration curve method for determining reductions are summarized in Table 4.1.2-A: Reductions Needed to Achieve Total Suspended Solids Standard. The table reports the calculated reductions for each sample point during each hydrologic condition and a final overall reduction in the farthest column to the right. The largest reductions are shown in bold and the low and high conditions are shown in italics as they are disregarded in deciding the overall reduction. Sample points that have other sample points nested within their drainage area were subject to additional adjustments to reflect the load reduction that is expected from the upstream areas. For example, even though sample point 23 (Big Creek at Highway 66) was determined to require a 63% reduction (about 8 tons/day), the reductions required of the areas draining to sample points 25, 26, and 27 which are nested within the drainage area of sample point 23, exceed 8 tons/day. Adjustments were made to reflect the assumption that by achieving larger load reductions in upstream regions than what is needed at a common sample point below, target levels will be met at the common sample point as well. The equation below explains this concept. Where the load reduction of the area draining to X is 0 or less than zero then it is assumed that no load reduction is needed in the area draining exclusively to sample point to achieve the target as long as the necessary load reductions are achieved at the sample points located in areas also draining to X. In the table, reductions noted with an asterisk are those that were adjusted as described.

Load Reduction at Sample Point X – Sum of all Load Reductions at Sample Points that also drain to Sample Point X = Load Reduction of the Area Draining Exclusively to X

There are some caveats to using this method for determining reductions with the data that was available through this project. Turbidity was measured instead of performing a lab test for total suspended solids, and there is a lack of data during some hydrologic conditions. While turbidity can be correlated with total suspended solids, it also may be affected by other conditions such as algae growth, overcast skies, and differences in the coloration of soils and sediment. To estimate the total suspended solids level using the turbidity measure, a simplified formula was used where:

Total Suspended Solids (mg/L) = 1.5 X Turbidity (NTU)

While this is not an exact measurement, it is expected that this method will provide the estimate needed to gauge the reduction necessary to achieve the total suspended solids should further lab analysis be conducted.

	Reductions Needed to Achieve Total Suspended Solids Standard					
Sample Point	*Low*	**Dry**	**Mid-range**	**Moist**	*High*	**Reduction**
1	*0.0%*	0.0%	n/a	**82.3%**	*98.9%*	**NONE***
2	*n/a*	n/a	n/a	**69.8%**	*0.0%*	**69.8%**
3	*n/a*	n/a	n/a	**49.2%**	*0.0%*	**49.2%**
4	*0.0%*	17.9%	n/a	**90.7%**	*98.7%*	**11.4%***
5	*n/a*	65.3%	n/a	**82.5%**	*92.4%*	**82.5%**
6	*n/a*	0.0%	n/a	0.0%	*0.0%*	**NONE**
7	*n/a*	**60.2%**	n/a	51.2%	*41.2%*	**60.2%**
8	*4.9%*	59.5%	n/a	**90.2%**	*98.4%*	**25.1%***
9	*n/a*	0.0%	n/a	**68.5%**	*88.3%*	**68.5%**
10	*n/a*	0.0%	n/a	**19.8%**	*27.2%*	**19.8%**
11	*n/a*	0.0%	n/a	**76.0%**	*0.0%*	**62.9%***
12	*0.0%*	0.0%	n/a	**88.1%**	*98.3%*	**60.7%***
13a	*n/a*	0.0%	n/a	**29.6%**	*86.0%*	**29.6%**
13b	*n/a*	0.0%	n/a	**63.0%**	*90.0%*	**63.0%**
14	*n/a*	0.0%	n/a	**85.3%**	*92.3%*	**82.1%***
15	*n/a*	0.0%	n/a	**6.8%**	*89.9%*	**6.8%**
16	*n/a*	0.0%	**54.4%**	53.7%	*86.5%*	**13.7%***
17	*n/a*	n/a	**31.2%**	8.4%	*71.0%*	**31.2%**
18	*n/a*	n/a	**56.6%**	34.6%	*63.3%*	**56.6%**
19	*34.9%*	6.4%	**66.8%**	46.2%	*97.1%*	**0.0%***
20	*n/a*	n/a	0.0%	**17.3%**	*79.4%*	**17.3%**
21	*n/a*	n/a	83.7%	**87.5%**	*92.4%*	**87.5%**
22	*n/a*	n/a	0.0%	0.0%	*91.7%*	**NONE**
23	*58.8%*	18.8%	**62.7%**	22.9%	*96.5%*	**NONE***
24	*n/a*	n/a	0.0%	0.0%	*90.4%*	**NONE**
25	*n/a*	0.0%	63.2%	**87.5%**	*91.1%*	**87.5%**
26	*n/a*	0.0%	**65.4%**	0.0%	*86.0%*	**65.4%**
27	*0.0%*	0.0%	**74.1%**	0.0%	*96.7%*	**NONE***
28	*0.0%*	0.0%	**60.7%**	0.0%	*93.0%*	**60.7%**
29	*0.0%*	0.0%	**87.2%**	84.3%	*96.4%*	**NONE***
30	*n/a*	0.0%	63.2%	**50.0%**	*80.9%*	**50.0%**
31	*0.0%*	72.4%	66.5%	**80.7%**	*95.6%*	**71.2%***
32	*51.4%*	22.8%	32.4%	**40.9%**	*93.2%*	**NONE***
33	*0.0%*	11.6%	**73.1%**	72.5%	*92.8%*	**73.1%**
34	*0.0%*	0.0%	28.9%	**64.5%**	*88.8%*	**64.5%**

*Values adjusted to reflect reductions expected upstream

Table 4.1.2-A: Reductions Needed to Achieve Total Suspended Solids Standard

Figure 4.13.-A: Regions Created from Drainage Area Boundaries of Sample Points shows the areas draining exclusively to each sample point. They are named after the sample point to which they exclusively drain. These areas were used as boundaries for prioritizing the critical areas and calculating the amount of load reductions needed to achieve targets, all based on the water quality data. Water quality targets were used to set a desired load, and a reduction needed was calculated by subtracting the actual load from the desired load while assuming the concentration is within the standard, and the flow remains the same.

For each point whose drainage area includes one or more other sample points, the reduction needed in the nested drainage area is subtracted from the needed reduction from the next downstream sample point. This means that the reduction needed at each sample downstream of other points is calculated with the assumption that reductions will be achieved in the upstream areas. All sources which are located in sample point regions where load reductions are needed are considered critical. They are further prioritized based on the amount of the load reduction needed. Critical sources falling within the regions where the most reduction is needed have the highest priority. A map has been created showing the critical sources and the priority level of each sample point region based on the needed reduction. The resultant map is shown in *Figure 4.1.3-B: Critical Areas for Achieving Total Suspended Solids Standard*. Priority is shown as dark blue (1-20% - Lowest), light blue (21-40%), yellow (41-60%), orange (61-80%), or red outline with hash marks (81-88% - Highest) depending on the level of reduction needed. Critical sources are shown as a variety of symbols and colors. A closer look of this map can be found in Appendix E: Critical Areas – Sub-watershed Maps.

The most important areas for reducing sediment loading and loss according to the water monitoring are within the Big Creek-Lick Creek (080), Big Creek – Above Solitude (140), Little Creek – Lower (120), Big Creek – Blairsville gage (070), and Big Creek – Neuman Lateral (040) sub-watersheds. Here the most important sources are sheet/rill erosion sources except for the Big Creek – Above Solitude (140) sub-watershed where the most important sources are stream bank erosion sources. The most significant factors where sheet/rill is important are the amount of tilled fields and the amount of crop fields without buffers. Other significant sources within these sub-watersheds include ephemeral gully erosion sources and in the Big Creek – Lick Creek (080) and Big Creek – Blairsville (070) sub-watersheds, stream bank erosion source

A number of factors must be considered to understand the areas where implementation will have the most impact and the practices that will cause the most noticeable water quality changes. These include the steepness of the field, other landscape factors, and the likelihood of successful implementation based on popularity of a practice or ownership of a land area. These are considered in Chapter 6 where recommended measures are discussed.

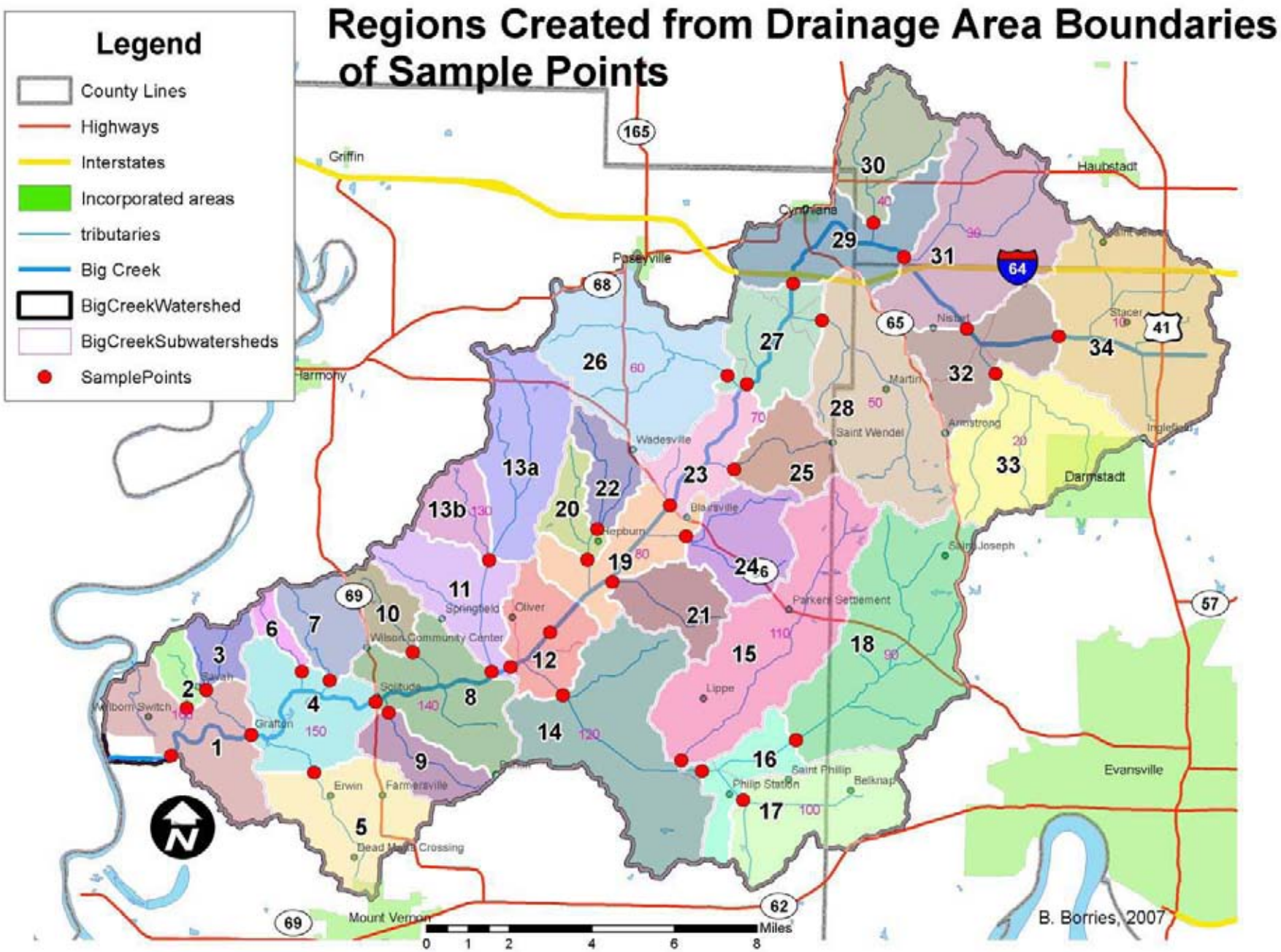

Figure 4.1.3-A: Regions Created from Drainage Area Boundaries of Sample Points

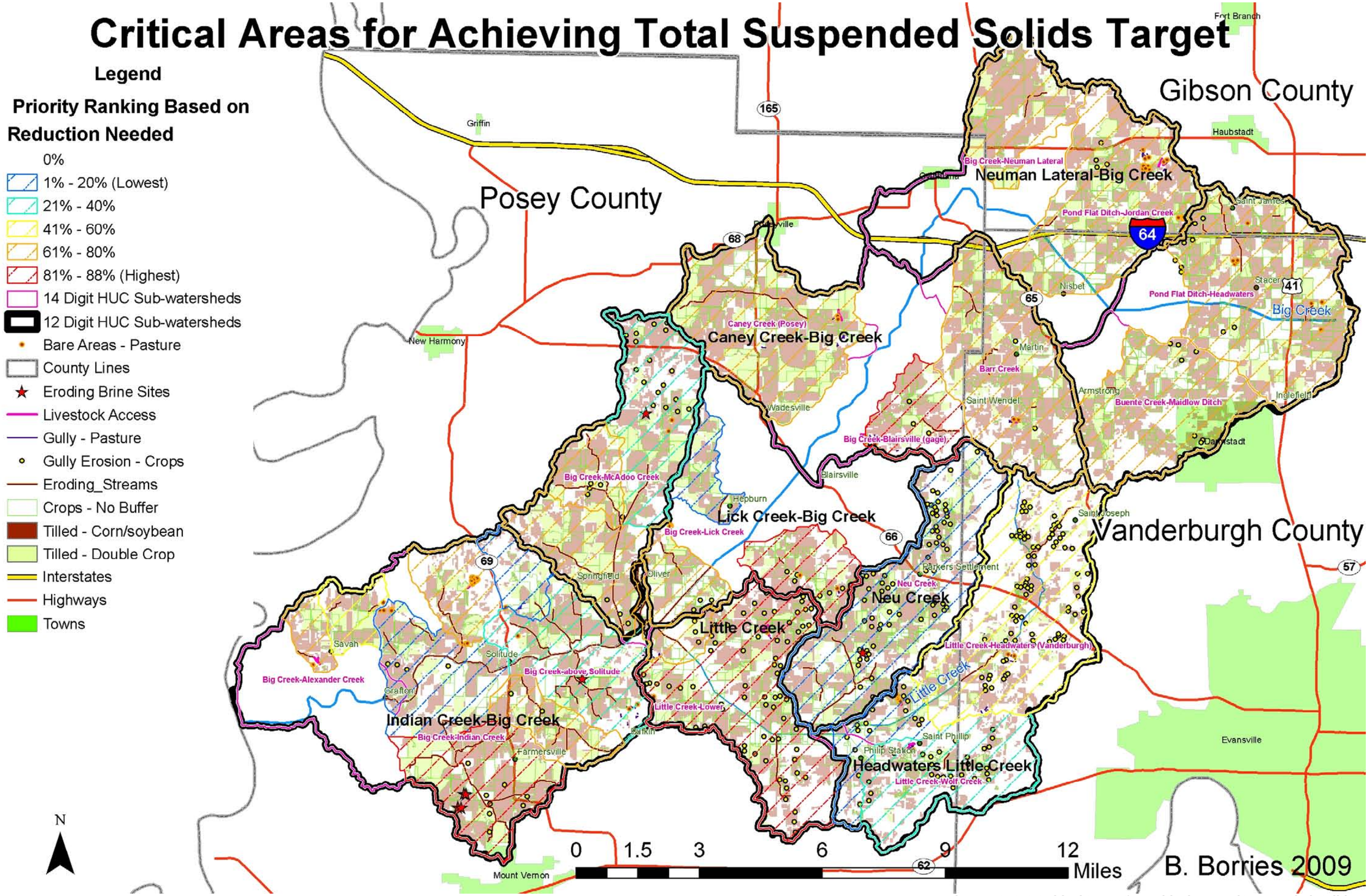

Figure 4.1.3-B: Critical Areas for Achieving Total Suspended Solids Target

Problem Statement #2 – Pathogens

Concern	Section(s) Validated
contaminants in the water	3.1.1, 3.1.2, 3.1.3
confined feeding	
groundwater quality	NOT VALIDATED, no data
packaged sewer treatment facilities	NOT VALIDATED, see section 3.5
contaminants in the water	3.1.3
lack of centralized wastewater treatment opportunities	3.6
lack of filter/buffer strips	3.3.1, 3.4
surface water quality	3.1.3
Pastures*	3.3.6

E. coli levels above the state standard for full body contact have been found in 100% of Big Creek waterways and levels above the recommended threshold for partial body contact have been found in about 10% of the waterways. *E coli* is an indicator that pathogens harmful to human and animal health are likely present. Pathogens make the streams and creeks unsafe, limiting recreation and fishing.

Stressors:
E. coli
Fecal Coliforms
other blood-borne pathogens

Sources:

1. *Households with Septic Systems and field bed areas or direct discharges*

   Septic systems are the only available wastewater treatment options in areas within the watershed not served by municipal sewer lines. Septic systems generally consist of a septic tank that allows for solids to settle and a field bed that spreads the liquid effluent out over the subsurface so that biological treatment can occur as it percolates through the sub-soil. Some households may still have a system that only has a septic tank and a direct discharge pipe rather than a field bed, but the number is not known. Septic systems are not a perfect system for treating contaminants associated with wastewater. When a confining layer restricts groundwater from traveling downward, or when excessive soil moisture occurs, groundwater will move up rather than down carrying untreated wastewater containing pathogens and other pollutants to the surface. High

water use or a system not sized for the amount of people using it can also increase this occurrence of this phenomenon.

The number of households with septic systems was estimated by identifying the areas with municipal services available and using 2000 census data to determine the households within these areas. Acreage for the field beds was estimated by multiplying the household value by a normal field bed area of 4000 square meters. This is useful in comparing the magnitude of the source to other area based magnitudes.

2. *Manure Use and Storage at Confined Feeding Operation*

Runoff containing recently applied manure or improperly stored manure often contains *E. coli* and other pathogens. Manure is applied to crop fields to increase fertility and to deal with the waste associated with confined animal production. Solid manure produced at poultry operations and on feedlots is surface applied with a spreader. Semi-solid and liquid manure produced at dairy operations and hog operations respectively is surface applied with a pump or injected into the soil. It is a common practice to maintain aerobic activity in lagoons by pumping the liquid onto crop land. Manure stored at these sites can contaminate runoff when it is stored without a roof or a densely vegetated filter area.

Sources were identified as farms with Confined Feeding Operation permits from IDEM. The amount of manure produced at a farm depends on the amount of animals and their weight. Any farm meeting or exceeding a threshold number of animals based on the weight of the animal must apply for a confined feeding operation permit under Indiana law. Assuming these farms do in fact have this threshold of animals at any given time, they are the most likely to produce the most manure. And since transportation costs are usually the most prohibitive in the reasons for not using manure as fertilizer, areas surrounding these CFOs can be considered likely areas where the manure is applied.

3. *Livestock with Stream Access*

Pastures along streams that do not have fencing or an appropriate stream crossing for livestock expose especially sensitive stream side areas to trampling and compaction from the increased livestock traffic. This results in the destruction of the stream-side buffer that would normally filter upslope runoff and for the animals in the stream, bypasses the filtering altogether. In addition when animals walk in the stream bottoms, they may dislodge particles containing *E. coli* and other pathogens engaging them in stream flow during sensitive dry periods.

4. *Bare Pasture Areas*

Bare areas in pastures occur primarily where livestock congregate (typically feeding areas, watering areas, and shaded areas), regularly travel (i.e. cow paths), or in pastures that are not large enough to support the number of animals that graze there. These areas are subject to high levels of sheet and rill erosion especially on steep slopes due to the lack of vegetative cover. The sediment transported through runoff may carry *E. coli* and other pathogens and un-vegetated areas cannot filter polluted runoff as effectively as a densely vegetated pasture area.

5. *Ponds and Lagoons in Need of Repair*

Ponds are often used in association with livestock as a watering source and a way to break up steep slopes that are common in pastures. Lagoons are commonly associated with storage of semi-solid manure and feedlots and are located immediately downstream of these areas to collect liquids and runoff. Ponds and lagoons are in need of repair and become a source when dams begin to break or when spillways are no longer covered in dense vegetation that can filter contaminated runoff when the ponds and lagoons overflow.

6. *Dead Wildlife in Streams*

   Although inconsequential during wet periods, dead wildlife left in streams by natural causes or by people can cause *E. coli* and other pathogen problems during low flow dry periods. Sources were identified during water monitoring rounds, but it is not clear if these areas experience sources each year.

4.2.1: Source Locations & Magnitudes

Table 4.2.1-A: Pathogen Sources: Locations and Magnitude shows the magnitude and location of the pathogen sources. This table provides both an assessment of the magnitude and location of the source and evidence that the source is significant according to the impairments associated with pathogens. The amount of each sources as determined from the results of the windshield and GIS inventory is compared to the level of impairment determined from the water monitoring that occurred through the project. The amount or magnitude of the source is shown as area or length of each source occurring in each sub-watershed. The impairment based on E. coli shown in the right hand columns of the table. “Partially impaired” indicates that a sub-watershed exceeded standards between 1 and 10% of the samples collected. “Impaired” indicates that the sub-watershed exceeded standards between 11 and 50% of the samples collected. “Severely impaired” indicates that the sub-watersheds exceeded standards greater than 50% of the samples collected. Two hundred thirty five colonies/100 mL is used as the E. coli standard. This relationship is described below for each of the sources.

In general, the impact of the sources is best understood when they are considered all together since each source can affect the level of *E. coli* during different hydrologic conditions. The combination of several sources results in a higher incidence of impairment than a greater magnitude of a single source, though a higher load of *E. coli* will commonly be associated with larger magnitudes.

1. *Households with Septic Systems and field bed areas or direct discharges*

   The relationship between the number of households on septic systems or in other terms the estimated acreage of field beds is difficult to confirm since the amount of households with septic systems is consistent throughout much of the watershed and every sub-watershed was found to be impaired for *E. coli.* The number of households with septic systems varies from 156 in the Big Creek – Alexander Creek Sub-watershed to 2129 households in the Little Creek – Headwaters Sub-watershed. Areas with the lesser number of households did not necessarily fall into the impaired rather than severely impaired category. This may be due in large part to the care and condition of individual septic systems which is independent of their geographic location. There is, however, a stronger relationship between the number of households and the percent reduction needed to achieve the standard. This phenomenon is explained above and relates to

the variations in impact for each source depending on hydrologic condition. A combination of several sources will result in a higher incidence of water standards being exceeded even though the magnitude of a single source in another sub-watershed is greater.

2. *Manure Use and Storage at Confined Feeding Operation*

   The number of confined feeding operations did have a correlation to the incidence of water samples exceeding the *E. coli* standard. This is most clear in the Pond Flat – Headwaters (010), Pond Flat – Jordan Creek (030), and Buente Creek – Maidlow Ditch (020) Sub-watersheds. These sub-watersheds had 1, 2, and 3 CFOs respectively and all three were found to be severely impaired based on the *E. coli* standard. As discussed seperately, however, each of these sub-watersheds also possessed additional sources including households with septic systems, bare pasture areas, and livestock with stream access. Other sub-watersheds that included CFOs and were found to be severely impaired based on *E. coli* included the Little Creek – Lower and Barr Creek Sub-watersheds with one in each. This accounts for 5 of the 6 sub-watersheds found to be severely impaired.

3. *Livestock with Stream Access*

   Livestock with stream access in 9 of the 16 sub-watersheds and in combination with other sources is associated with an increased number of water samples exceeding the standard. In the Big Creek – Alexander Creek it is the only source that is not the lowest in magnitude among the sub-watersheds. This indicates that livestock having stream access is at least partly responsible for impairments based on *E. coli.*

4. *Bare Pasture Areas*

   Bare pasture areas occupied, at most, 14 acres in any sub-watershed for a total of only 85 acres in the entire watershed. Due to its slight impact compared to other sources it is difficult to correlate with impairments since all sub-watersheds with bare pasture areas had a significant amount of some other source. It is best confirmed through the nature of the source which indicates that not only is the area devoid of vegetation and thus unable to filter pollutants, but is also likely where most livestock congregate and where the most manure will accumulate.

5. *Ponds and Lagoons in Need of Repair*

   Ponds and lagoons in need of repair were only identified in 2 sub-watersheds, but is still a significant source by itself in those areas where it occurs. This is due to the high amount of contamination that can occur from such a small area since it is where manure is stored

6. *Dead Wildlife in Streams*

   Similar to ponds and lagoons, the incidence of dead wildlife in streams is small, but it occurs in hot dry months when streams are most susceptible to contamination and can be caused to exceed standards with a very limited input of contaminant.

	Sources							Impairments
Sub-watershed	1. Households with septics (est. #)	Estimated Field Bed Acreage	2. # CFO permits (active)	3. Feet of Cattle Access	4. Bare Pasture Acres (%)	5.Ponds, Lagoons in Need of Repair	6. Sightings of dead wildlife in creek bottoms	*E. coli*
010	542	50 (0.4%)	1		13 (0.1%)			**SEVERELY IMPAIRED**
020	472	43 (0.5%)	3		4 (0.1%)	1		**SEVERELY IMPAIRED**
030	489	45 (0.4%)	2	1416	5 (0.1%)			**SEVERELY IMPAIRED**
040	467	43 (0.4%)			0 (0.0%)			**IMPAIRED**
050	363	33 (0.4%)	1	1229	5 (0.1%)			**SEVERELY IMPAIRED**
060	331	30 (0.4%)	2	1417	3 (<0.1%)			**IMPAIRED**
070	344	32 (0.4%)		555	14 (0.2%)	1		**IMPAIRED**
080	633	58 (0.4%)			14 (0.1%)			**IMPAIRED**
090	2129	195 (1.5%)		659	5 (<0.1%)		1	**IMPAIRED**
100	935	86 (1.3%)		1278	1 (<0.1%)		1	**IMPAIRED**
110	620	57 (0.6%)			1 (<0.1%)			**IMPAIRED**
120	516	47 (0.4%)	1	2536	7 (0.1%)			**SEVERELY IMPAIRED**
130	359	33 (0.3%)			2 (<0.1%)		2	**IMPAIRED**
140	183	17 (0.2%)			4 (<0.1%)			**SEVERELY IMPAIRED**
150	396	36 (0.3%)	1	1930	5 (<0.1%)			**IMPAIRED**
160	156	14 (0.2%)		1794	2 (<0.1%)			**IMPAIRED**
Total	8963	823 (0.5%)	11	12814	85 (0.1%)		4	

Table 4.2.1-A: Pathogen Sources: Locations and Magnitude

In addition to the load duration curves developed for the sediment problem, *E. coli* load duration curves were developed for each sample point. The same methodology was used and the results are detailed below. *Figure 4.2.2-A: E. coli Load Duration Curve for Big Creek at Highway 66* shows an example of the curve using data from sample point 23 on Big Creek at Highway 66. Reductions for each hydrologic condition are also shown as an illustration of how the reductions are determined.

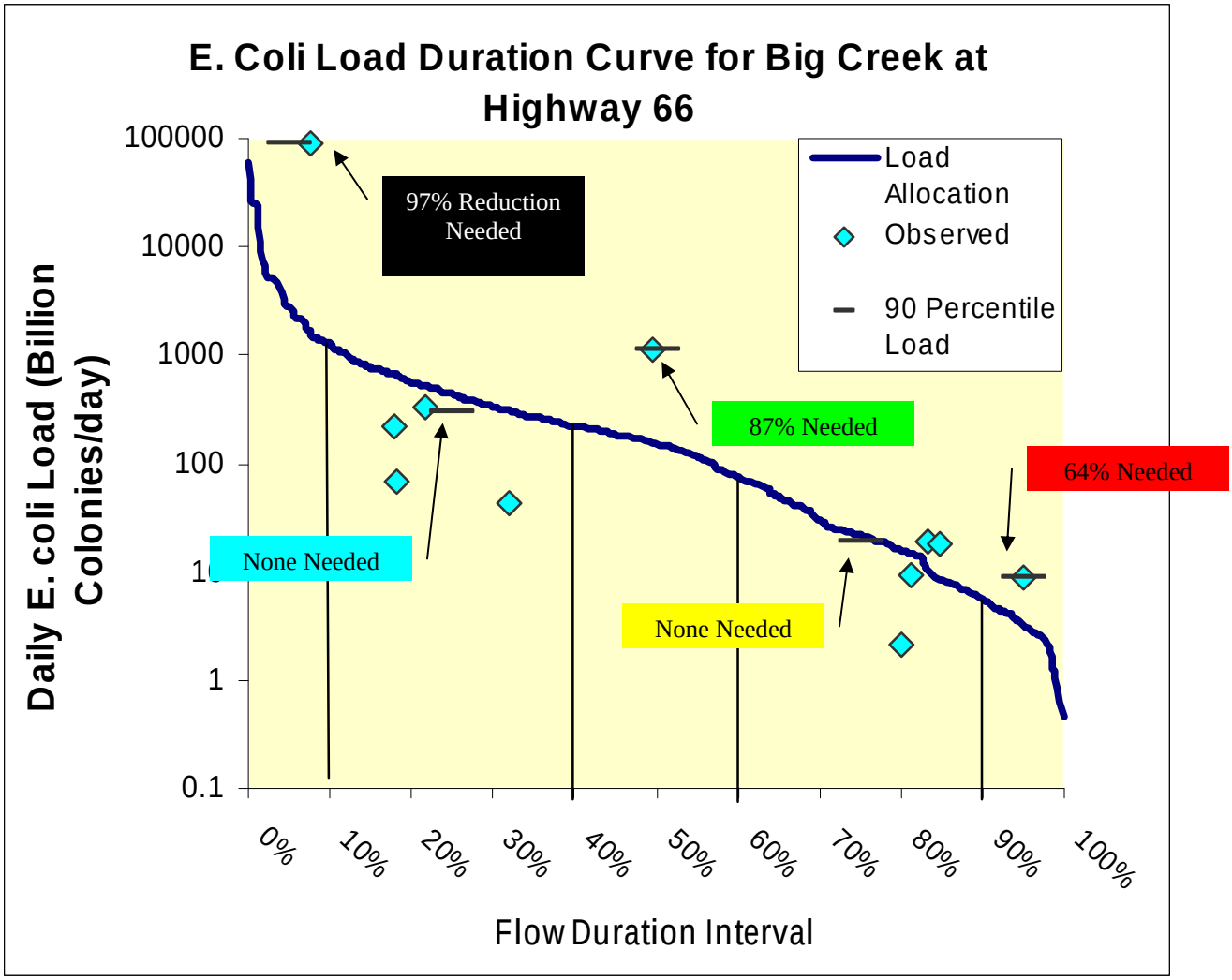

Figure 4.2.2-A: E. coli Load Duration Curve

As is shown in the figure, reductions are needed during three of the hydrologic conditions. The greatest reduction are needed during High flow conditions (97% as shown in the black box), but since this represents extreme events, the next highest needed reduction is used, which is 87% for the mid-range flow conditions. Using this method, it's assumed that in order to achieve the desired concentration for total suspended solids, an 87% reduction in *E. coli* loading within the area draining to sample point 23 must occur.

The results of the load duration curve method for determining reductions are summarized in *Table 4.1.2-A: Reductions Needed to Achieve E. coli Standard.* The table reports the calculated reductions for each sample point during each hydrologic condition and a final overall reduction in the farthest column to the right. The largest reductions are shown in bold and the low and high conditions are shown in italics as they are disregarded in deciding the overall reduction. Sample points that have other sample points nested within their drainage area were subject to additional adjustments to reflect the load reduction that is expected from the upstream areas. For example, even though sample point 23 (Big Creek at Highway 66) was determined to require a 87% reduction, the reductions required of the areas draining to sample points 25, 26, and 27 which are nested within the drainage area of sample point 23, exceed that of the necessary reduction for 23. For this reason the area draining to sample point 23, but not to sample points 25, 26, and 27 is deemed to need only 8% reduction in *E. coli* rather than 87%. In the table, reductions noted with an asterisk are those that were adjusted as described.

	Reduction Needed to Achieve *E. coli* Standard					
Sample Point	*Low*	**Dry**	**Mid-Range**	**Moist**	*High*	**Reduction**
1	*0.0%*	0.0%	n/a	0.0%	*n/a*	NONE*
2	*n/a*	n/a	n/a	0.0%	*n/a*	NONE
3	*n/a*	n/a	n/a	0.0%	*n/a*	NONE
4	*23.7%*	0.0%	n/a	0.0%	*n/a*	NONE*
5	*n/a*	**74.8%**	n/a	0.0%	*n/a*	74.8%
6	*n/a*	0.0%	n/a	0.0%	*n/a*	NONE
7	*n/a*	**88.5%**	n/a	0.0%	*n/a*	88.5%
8	*n/a*	**24.5%**	n/a	0.0%	*n/a*	20.3%*
9	*n/a*	**41.5%**	n/a	0.0%	*n/a*	41.5%
10	*n/a*	**87.6%**	n/a	0.0%	*n/a*	87.6%
11	*n/a*	0.0%	n/a	0.0%	*n/a*	NONE*
12	*0.0%*	0.0%	n/a	0.0%	*n/a*	NONE*
131	*n/a*	0.0%	n/a	0.0%	*n/a*	NONE
132	*n/a*	0.0%	n/a	**16.5%**	*n/a*	16.5%
14	*n/a*	0.0%	n/a	**16.6%**	*n/a*	1.2%*
15	*n/a*	0.0%	n/a	**17.7%**	*99.2%*	17.7%
16	*n/a*	0.0%	43.4%	0.0%	*87.8%*	NONE*
17	*n/a*	n/a	**62.3%**	37.6%	*92.5%*	62.3%
18	*n/a*	n/a	**54.7%**	0.0%	*93.9%*	54.7%
19	*0.0%*	0.0%	90.6%	0.0%	*97.3%*	35.6%*
20	*n/a*	n/a	**81.1%**	0.0%	*89.1%*	81.1%*
21	*n/a*	n/a	**77.4%**	0.0%	*89.1%*	77.4%
22	*n/a*	n/a	**24.6%**	3.7%	*80.5%*	24.6%
23	*63.5%*	0.0%	**86.7%**	0.0%	*96.9%*	7.5%*
24	*n/a*	n/a	**71.7%**	42.6%	*91.1%*	71.7%
25	*n/a*	70.0%	**74.9%**	0.0%	*93.0%*	74.9%
26	*n/a*	0.0%	**94.3%**	0.0%	*87.8%*	94.3%
27	*0.0%*	0.0%	**82.6%**	0.0%	*96.7%*	NONE*
28	*n/a*	66.5%	**92.7%**	0.0%	*96.5%*	92.7%
29	*0.0%*	0.0%	**83.8%**	0.0%	*97.6%*	NONE*
30	*n/a*	0.0%	**82.6%**	17.4%	*86.0%*	82.6%
31	*32.2%*	74.4%	**92.5%**	13.9%	*99.2%*	NONE*
32	*70.4%*	63.9%	**97.2%**	31.8%	*99.2%*	52.5%*
33	*n/a*	59.1%	**91.6%**	18.5%	*99.2%*	91.6%
34	*5.1%*	42.1%	**96.2%**	37.0%	*99.2%*	96.2%

*Values adjusted to reflect reductions expected upstream

Table 4.2.2-A: Reductions Needed to Achieve E. coli Standard

4.2.3: Critical Areas

Critical areas were identified from the problem sources and water monitoring data was used to prioritize the critical areas. The water quality standard for *E. coli* was used to set a desired load. Reduction needed was calculated by subtracting the actual load from the desired load, assuming the concentration is within the standard and the flow remains the same. For each point whose drainage area includes one or more other sample points, the reduction needed in the nested drainage area is subtracted from the needed reduction from the next downstream sample point. This means that the reduction needed at each sample downstream of other points is calculated assuming necessary reductions were achieved in the upstream areas as calculated. The highest priority areas are those with the most reduction needed. The resultant map is shown in *Figure 4.2.3-A: Critical Areas for Achieving E. coli Standard*. Priority is shown as dark blue (1-20% - Lowest), light blue (21-40%), yellow (41-60%), orange (61-80%), or red outline (81-97.2% - Highest) depending on the level of reduction needed. Critical sources are shown as a variety of symbols and colors. A closer look at the critical area map can be found in Appendix E: Critical Areas – Sub-watershed Maps.

Within these critical areas as determined by water monitoring, the highest priority sources for restoration are those with the greatest estimated magnitude and the most important factors in each sub-watershed are those with the greatest acreage. They will have the most likelihood of being mitigated by having a greater pool of participants from which to choose especially when there is great variation in the magnitude per acre of the sources within the sub-watershed.

The most substantial *E. coli* loading reductions are needed in the Pond Flat - Headwaters (010), Pond Flat – Jordan Creek (020), Neu Creek (110), and Big Creek – McAdoo Creek sub-watersheds. In the Pond Flat – Headwaters and Pond Flat – Jordan Creek sub-watersheds, the most common sources by area are livestock. In the Neu Creek sub-watershed, the only source identified was Septic Systems and in the Big Creek – McAdoo Creek sub-watershed, livestock sources were the most common.

Critical Areas for Achieving *E. coli* Standard

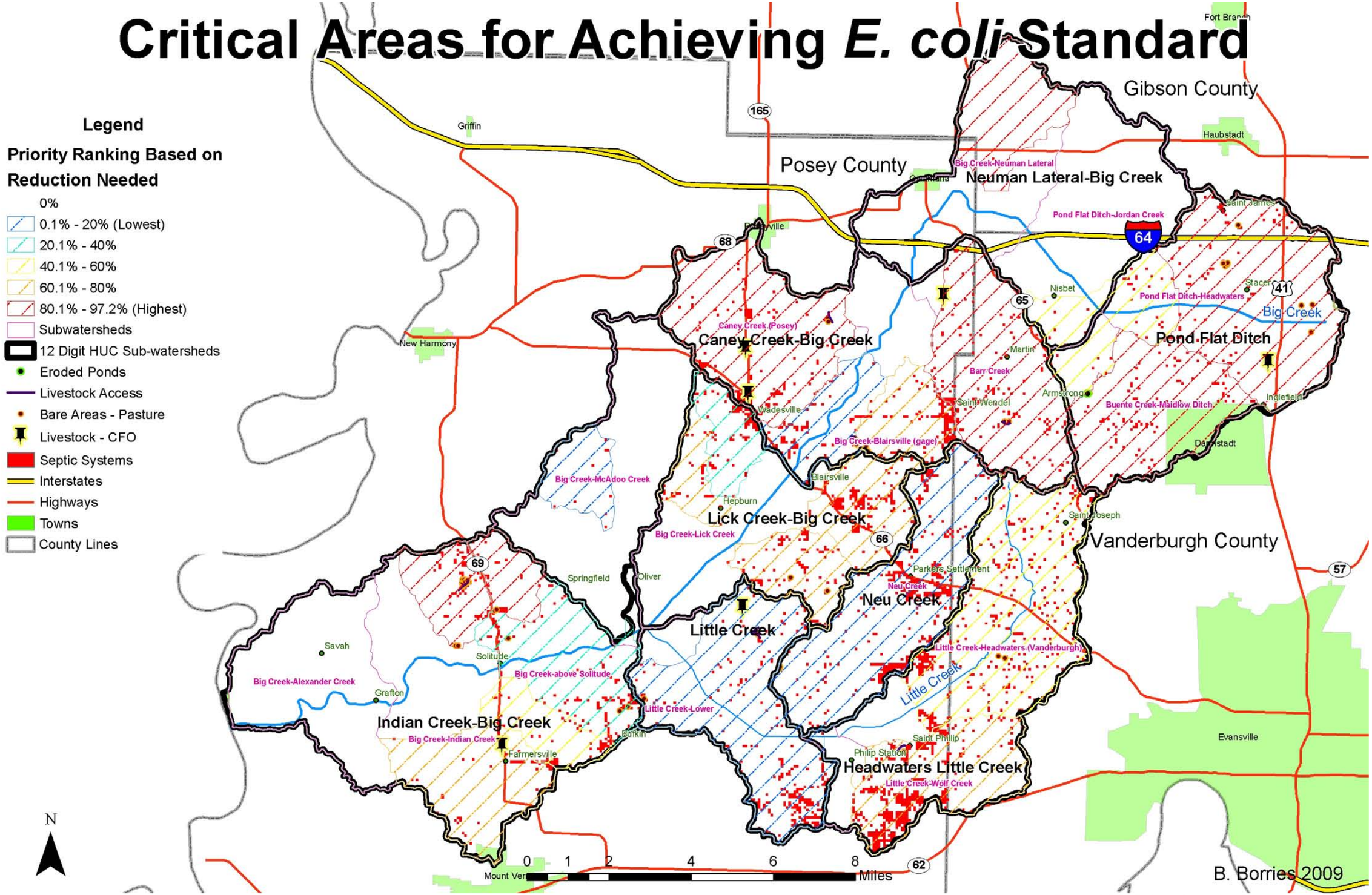

Figure 4.2.3: Critical Areas for Achieving E. coli Standard

Problem Statement #3 – Channel Quality

Concern	Section(s) Validated
aquatic life	3.1.1, 3.1.2, 3.1.3
bridge design	3.7, 3.3.3
bridge scour	3.3.3
business/development	2.4.3
contaminants in the water	3.2, 3.1.3
erosion	3.1.2, 3.2, 3.3.3, 3.4
gully erosion	3.3.4, 3.4
lack of filter/buffer strips	3.3.1, 3.4
more wascobs on the high ground to hold water in the hills	NOT VALIDATED, see section 3.4
natural debris accumulation	3.3.3
road side ditches	3.3.3
soil loss	2.4.2, 3.1.1, 3.1.2, 3.2, 3.3.2, 3.4
stream bank condition	3.3.3, 3.3.1
surface water quality	3.1.1, 3.1.2, 3.2, 3.1.3
washing where farms drain into the creek	3.4
waterway integrity/bank stability	3.3.3
waterway openings	3.3.3, 3.3.4, 3.4
backflow gates creating flooding on downstream people	NOT VALIDATED, no data available
drainage	3.7
flooding	3.7
legislative involvement	1.5
Resources going towards legal drains	2.3.4
Waterway integrity/bank stability	3.3.3
Wetlands mitigation/uses/planning	NOT VALIDATED, no data available

A high degree of channel instability has led to an unpredictable response to storm events, changes in baseflow, changes in locations of saturation, direct damage to aquatic communities, and direct damage to near channel assets and investments.

Stressors:

Non-chemical stressors leading to channel instability and poor channel quality are defined below based on the Watershed Assessment of River Stability and Sediment Supply (WARSSS):

- Direct channel impacts
- Flow increases
- Aggradation
- Degradation (channel down-cutting)
- (Unstable) Channel evolution
- Channel enlargement
- Bank erosion potential
- Hillslope sediment delivery
- Habitat Degradation

Sources:

The most important sources affecting the stressors in the Big Creek Watershed include:

1. **Domination of riparian vegetation by row crops and annual forbs**
2. **Berms or spoil piles places near a channel after "silt-dipping"**
3. **Channelization**
4. **Chemical and mechanical control of riparian vegetation**
5. **Tilled crop fields**

4.3.1: Source Locations and Problem Magnitude

Table 4.3.1-A: Channel Quality Sources: Locations and Magnitude shows the amount of sources of channel quality problems in each watershed. This is compared to the amount of impairments related to channel quality defined by the fish IBI, the QHEI, and the WARSSS. Sub-watersheds are considered impaired for the each metric or index if more than half of the sites evaluated had a score less than the desired criteria. They are considered to have a partial impairment if less than half the sites did not meet the target and considered to have no impairment if none of the sites did not meet the target. Sub-watersheds listed as n/a did not have a metric or index assessed for any site in the sub-watershed. The target used for the fish IBI is the state standard of greater than 35, the target used for the QHEI is the state standard of greater than 51, and the target for the WARSSS is a risk score of less than 3. The amount of each source and the relationship to the level of impairment is described below.

1. *Domination of riparian vegetation by row crops and annual forbs*

   A combination of factors has resulted in dominance of the riparian vegetation by annual forbs (row crops is a result of a lack of adequate stream buffer). Giant ragweed, the dominant species out-competes even willows by emerging early and shading out the understory plants. But then, in the winter and early spring, it dies back and its shallow root system does not stay attached to the bank leaving banks bare and vulnerable to

erosion. Amounts of streams affected by this source varied for 15% to 70%. In the sub-watershed with the least stream segments affected by this source, reed canary grass dominates and while it is perennial and reduces stream bank erosion, it does not contribute to stability and aquatic habitat as much as trees or sedges. This source is very closely linked to all three assessments of the level of the channel quality problem. All of the sub-watersheds with greater than 60% of stream segments dominated by annual forbs did not meet the fish IBI target except for the Big Creek – McAdoo Creek Sub-watershed (130) which was found to be impaired for both of the other measures, the WARSSS and QHEI

2. *Berms or spoil piles placed near a channel after "silt-dipping"*

   Because of historic dredging and some recent dredging nearly all of Big Creek main channel and most of the other regulated drains have berms at the top of the channel banks. Many other streams also have this condition if they were modified. The berms cause a decreased width-depth ration and a higher entrenchment ratio causing instability at the location of the berm and downstream of the berm. The highest amounts of stream segments affected by this source are found in the Pond Flat – Headwaters (010) sub-watershed. However, since the reed canary grass has become so dominate in this area, it has a stabilizing effect on the banks and the instability caused by the berms is encountered more downstream of this area in segments of the Big Creek main channel in Posey and Gibson Counties. Otherwise, most of the remaining sub-watersheds have around 40% of stream segments affected by this source except for sub-watersheds 040, 050, 090, 100, and 160 which have less modified stream segments. This source affects most directly the WARSSS. The two sub-watersheds, Little Creek – Headwaters (090) and Little Creek – Wolf Creek (100) which have no impairment based on the WARSSS also have the least amounts of stream segments affected by the source.

3. *Channelization*

   Much of the channels found in the Big Creek watershed, about 60%, are modified drainages or drainage ditches dug into floodplains. Channelization causes instability at the site and downstream of site. It also degrades habitat by removing pools and riffles and in the process of channelization may actually cause the removal of substrates important to aquatic life. The highest amounts of channelized stream segments are found in the Pond Flat – Headwaters (010) sub-watershed and the Caney Creek (060) sub-watershed. The source is very closely linked the channel quality impairments and the two sub-watersheds with the least amounts of channelized stream segments, Little Creek – Headwaters (090) and Little Creek – Wolf Creek (100), also have no impairments based on the fish IBI an WARSSS.

4. *Chemical and mechanical control of stream-side vegetation*

   All of the regulated drains in Big Creek have experienced chemical and mechanical control of stream-side vegetation. This amounts to as much as 10.74 miles of stream segments in the Pond Flat – Headwaters (010) sub-watershed to the minimum of 1.7 miles in the Little Creek – Headwaters (090) sub-watershed. As a direct cause of destabilization of stream banks and degraded aquatic habitat, this source is closely linked to the impairments for channel quality and is high in most sub-watershed with the greatest amount of channel quality impairments.

5. *Tilled crop fields*

Though not a direct channel impact, the amount of tilled crop fields impacts the channel quality by causing siltation and increased storm flows. Like the other sources described, sub-watersheds with a high percentage of tilled crop fields such as Caney Creek (060) and Barr Creek (050) are consistent with impairments in channel quality based on either two or all three of the channel quality assessment indices and metrics.

	Sources					Impairments		
Sub-watershed	1. Percent Dominance by Annual Forbs	Channels with Berms	Channel-ization (%)	Contol of Vegetation (miles)	Acres of tilled crop fields > 1.5% slope	Fish IBI	QHEI	WARSSS
010	15%	75%	90%	10.74	7,903 (63.0%)	*None*	IMPAIRED	IMPAIRED
020	65%	40%	55%	10.95	4,747 (58.0%)	***None***	**n/a**	**IMPAIRED**
030	45%	40%	90%	5.00	6,390 (63.1%)	PARTIAL	IMPAIRED	IMPAIRED
040	45%	25%	50%	5.25	6,858 (69.7%)	PARTIAL	IMPAIRED	IMPAIRED
050	60%	20%	70%	5.88	6,045 (67.2%)	IMPAIRED	IMPAIRED	IMPAIRED
060	70%	35%	90%	0.43	6,570 (76.5%)	IMPAIRED	IMPAIRED	IMPAIRED
070	45%	40%	45%	7.62	4,876 (58.7%)	PARTIAL	*None*	PARTIAL
080	55%	40%	60%	10.15	9,812 (63.1%)	PARTIAL	IMPAIRED	PARTIAL
090	45%	10%	35%	3.07	4,304 (34.0%)	*None*	IMPAIRED	*None*
100	30%	10%	40%	1.70	2,244 (32.9%)	*None*	PARTIAL	*None*
110	60%	45%	35%	1.75	5,808 (57.8%)	IMPAIRED	IMPAIRED	IMPAIRED
120	65%	45%	65%	8.05	6,095 (57.8%)	IMPAIRED	n/a	IMPAIRED
130	60%	45%	70%	1.64	8,307 (70.9%)	*None*	IMPAIRED	IMPAIRED
140	60%	40%	65%	5.05	5,063 (54.8%)	PARTIAL	IMPAIRED	PARTIAL
150	50%	35%	65%	3.75	7,940 (62.5%)	*None*	PARTIAL	PARTIAL
160	35%	20%	35%	4.94	4,422 (54.0%)	IMPAIRED	PARTIAL	IMPAIRED
Total	50%	35%	60%	85.98	97,385 (59.4%)			

Table4.3.1-A: Channel Quality Sources: Locations and Magnitude

4.3.2: Critical Areas

Critical areas for channel quality were determined by looking at the sources of channel quality, the effects of channel quality, and ease of access to do channel work. Channels were deemed critical if they were eroding, had no or a very narrow stream-side buffer or filter strip, and were in the sub-watersheds with the most amount of impairments related to channel quality. The sub-watersheds with the most impairment include all sub-watersheds except Buente Creek – Maidlow Ditch (020), Little Creek – Headwaters (090), and Little Creek – Wolf Creek (100). In addition, because of the management measures that often cause the effects to be felt downstream and not at the site they occur, all regulated drains are considered critical. The most critical management measures that are associated with regulated drains include the placement of spoils next to the stream to create berms and the mechanical and chemical removal of stream-side vegetation. *Figure 4.3.2-A: Critical Areas for Channel Quality* shows the location of the stream-segments critical for improving channel quality. In addition, all row crops with greater than a 1.5% slope where tillage occurs that are in the watershed of a critical stream segment should be considered critical. Locations of these fields can be found in *Figure 4.1.3-B.*

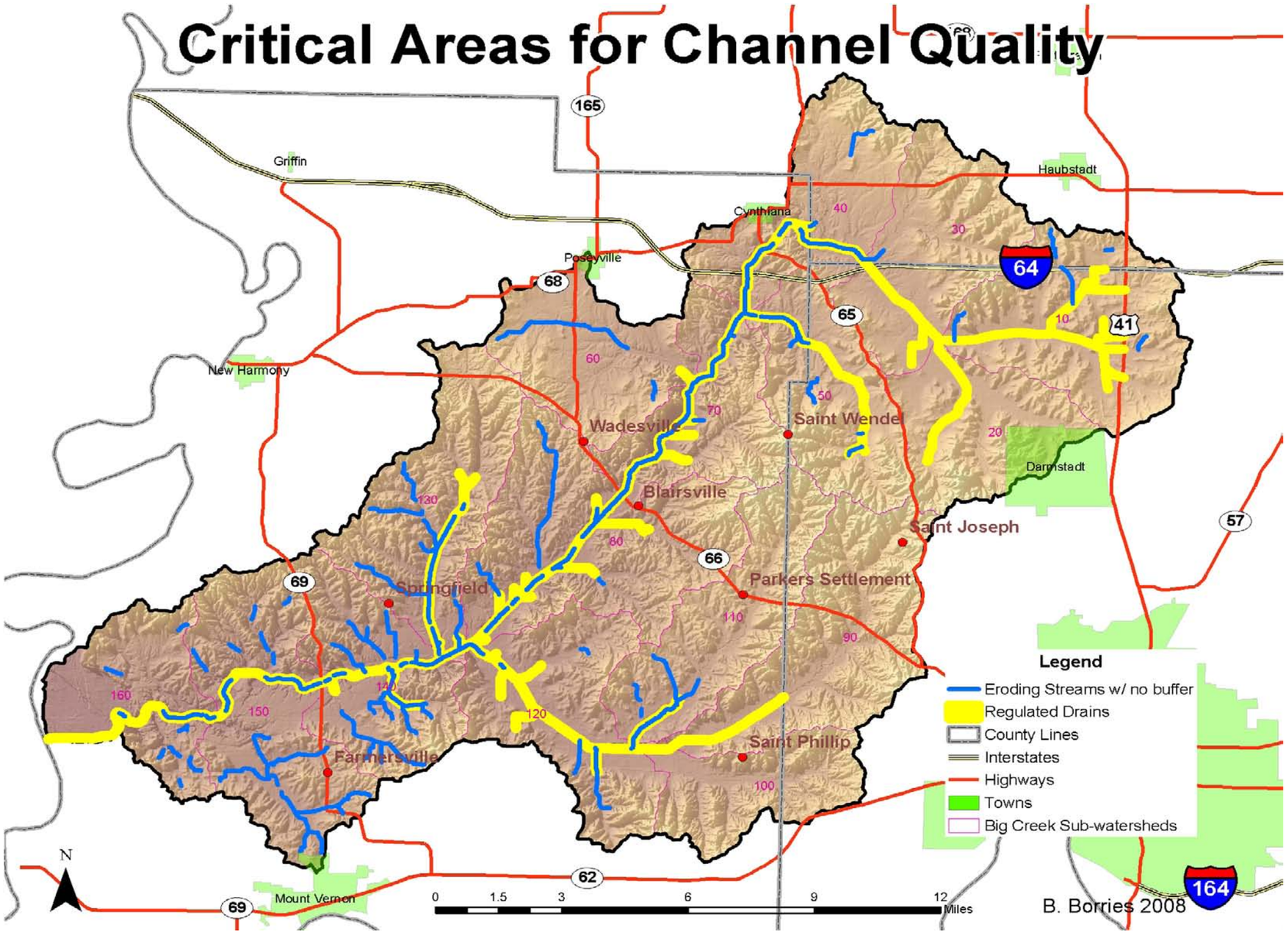

Figure 4.3.2-A: Critical Areas for Channel Quality

Problem Statement #4 –Nutrient Loading to Waterways

Concern	Section(s) Validated
Aquatic life	3.1.2, 3.1.3, 3.2.2
contaminants in the water	2.4.2, 3.1.3, 3.2.2, 3.3.2, 3.4
confined feeding	
erosion	3.1.2, 2.4.2, 3.1.3, 3.2.2, 3.3.2, 3.4
groundwater quality	NOT VALIDATED, no data
packaged sewer treatment facilities	3.5
lack of centralized wastewater treatment opportunities	3.6
lack of filter/buffer strips	3.3.1, 3.4
surface water quality	2.4.2, 3.1.3, 3.2.2, 3.4
Soil loss	3.1.2, 2.4.2, 3.1.3, 3.2.2, 3.3.2, 3.4
Pastures*	3.3.6

Excessive nutrient levels found during recent monitoring are negatively affecting the quality of Big Creek waterways as well as contributing to hypoxia in the Gulf of Mexico and other water quality issues downstream. Algae blooms are very common depleting dissolved oxygen and reducing available aquatic habitat. Levels were found above the drinking water standard and well water is vulnerable to nitrate pollution where conduits to the groundwater exist.

Stressors:
Forms of nitrogen (nitrate, nitrite, ammonia nitrogen, and soil bound nitrogen) and phosphorous (phosphates and soil bound phosphorous).

Sources:

1. Row Crop Fields where Fertilizer is Applied

   According to estimates by National Agricultural Statistics Surface, chemical fertilizer is applied to nearly 100% of crop fields in the Big Creek watershed. The only exception may be fields that are in soybeans because they possess root nodules that fix nitrogen from the atmosphere and soil. However, soybeans are not grown in successive years, and the years before and after corn or wheat (generally grown in the same year) will be grown requiring the application of chemical fertilizers. This is especially a problematic source since decisions made about fertilizer rates are based on the best possible yields rather than the expected yields. Any time the actual yield is less than the yield that the fertilizer application was based upon, the surplus fertilizer remains in the soil and will be lost to either water or the air (through denitrification) before the next crop is planted.

The source was identified through aerial photos and on the ground confirmation along with Farm Service Agency common land use files and land cover datasets.

2. *Row Crop Fields without Buffers*

   Stream-side buffers work both to remove nutrients and filter sediment, slowing runoff and causing particles to fall out of suspension onto the field. Additionally, robust buffers with deep root systems cause treatment to occur beneath the ground as shallow groundwater moves towards the stream. Here water soluble nutrients such as nitrates are taken up by the vegetation or treated through de-nitrification. Row crop fields without buffers do not experience this benefit and have an increased concentration of nutrients in the runoff as well as an increased amount of runoff.

   Row crop fields without buffers were identified through the windshield and GIS inventory.

3. *"Package" Wastewater Treatment Systems*

   "Packaged" wastewater treatment systems are centralized water treatment facilities that service a small number of houses or a larger facility or school. Packaged systems are regulated through the NPDES program, but records indicate historically exceeding water quality standards for ammonia nitrogen as described in Section 3. These sources were identified using records on the facilities provided by the NPDES database and GIS shapfile.

4. *Households with Septic Systems*

   Nutrient loading occurs from septic systems when the wastewater is not completely treated and the effluent either surfaces or travels to a waterway through groundwater. Households with septic systems were identified in the same way as the source described for the pathogen problem.

4.4.1: Source Locations & Magnitude

Table 4.2.1-A: Nutrient Loading to Waterways Sources: Locations and Magnitude shows the magnitude and location of the nutrient sources. This table provides both an assessment of the magnitude and location of the source and evidence that the source is significant according to the impairments associated with soil loss and sediment loading. The amount of each source as determined from the results of the windshield and GIS inventory is compared to the level of impairment determined from the water monitoring that occurred through the project. The amount or magnitude of the source is shown as area or number of each source occurring in each sub-watershed. The impairment based on nutrients (general), nitrate, and ammonia nitrogen is shown in the right hand columns of the table. "Partially impaired" indicates that a sub-watershed exceeded standards on between 1 and 10% of the samples collected. "Impaired" indicates that the sub-watershed exceeded standards on between 11 and 50% of the samples collected. The standards for the general nutrients criteria are described in sections 3.1.3 and 3.2.1, 10 mg/L is the standard (drinking water) for nitrate, and the water quality standard for ammonia nitrogen is dependent on the pH and temperature at the time the sample was collected. This relationship is described below for each of the sources.

1. *Row Crop Fields where Fertilizer is Applied*

Row crops where fertilizer is applied occupy 75% of the entire watershed and as much as 93% to as little as 40% of any given sub-watershed. Correlations between the amount of row crops and water quality samples exceeding nitrate are the strongest between any of the sources and a corresponding water quality indicator. 3 of the four sub-watersheds listed as being severely impaired based on nitrate contain the highest amount of row crops of any of the sub-watersheds. Orthophosphate, however, is not as strongly correlated and seems to be more dependent upon landscape factors such as slope. No correlation is obvious between the amount of row crops and water quality samples exceeding ammonia nitrogen standards.

2. *Row Crop Fields without Buffers*

   Row crop fields without stream-side buffers occupy 21% of the entire watershed and range from 7% to 53% in any given watershed. Little correlation is seen between the amount of this source and the number of water samples exceeding indicators. This may be because the other sources such as the amount of row crops are much more important factors or because some stream-side buffers are not as effective as others. In addition, tile drains in slowly draining land and riser inlets in WaSCoBs and other structures provide runoff an alternate route to waterways that bypass the filtering effect of the buffers all together. Regardless, row crops without stream-side buffers are still considered a significant source, but a more comprehensive approach to identifying the priority fields for establishing buffers must exist that considers the alternate routes provided by riser inlets and tile drains.

3. "*Packaged" Wastewater Treatment Systems*

   There are very few packaged treatment systems in the watershed, but 2 of the 3 sub-watersheds impaired for ammonia nitrogen contain all but one of these facilities. In addition, these impairments are only seen when flows are low. This is the time when a pipe discharge such as the one that exists at a packaged treatment system has the most impact.

4. *Households with Septic Systems*

   Since households with septic systems are likely to contribute a much smaller load of nutrients that the other 3 sources, it is difficult to correlate with the water quality monitoring data. However, there is a correlation between the number of households with septic system and impairments for ammonia nitrogen.

	Sources					Impairments		
Sub-watershed	1. Row Crop Acres (%): Fertilized	2. Acres (%) of row crop without Buffers	3. Packaged Treatment Systems	4. Households with Septic Systems	Field Bed acreage (%)	Nutrients (general)	Nitrate	Ammonia Nitrogen
010	9900 (82.5%)	5430 (43%)	0	542	50 (0.4%)	PARTIAL	*None*	*None*
020	5571 (71.9%)	2992 (37%)	0	472	43 (0.5%)	*None*	*None*	*None*
030	8355 (87.1%)	4783 (47%)	0	489	45 (0.4%)	**IMPAIRED**	*None*	*None*
040	8392 (90.3%)	3111 (32%)	0	467	43 (0.4%)	PARTIAL	**IMPAIRED**	*None*
050	6558 (76.4%)	2392 (27%)	0	363	33 (0.4%)	**IMPAIRED**	**IMPAIRED**	*None*
060	7654(92.9%)	4616 (53%)	0	331	30 (0.4%)	**IMPAIRED**	**IMPAIRED**	*None*
070	5419 (69.5%)	2715 (33%)	0	344	32 (0.4%)	PARTIAL	PARTIAL	*None*
080	11932 (81.9%)	5414 (34%)	0	633	58 (0.4%)	**IMPAIRED**	**IMPAIRED**	*None*
090	4899 (40.4%)	973 (7%)	2	2129	195 (1.5%)	*None*	*None*	**IMPAIRED**
100	2760 (42.7%)	891 (13%)	1	935	86 (1.3%)	PARTIAL	*None*	**IMPAIRED**
110	6263 (65.6%)	2898 (28%)	1	620	57 (0.6%)	**IMPAIRED**	**IMPAIRED**	*None*
120	7679 (77.0%)	3604 (34%)	0	516	47 (0.4%)	**IMPAIRED**	*None*	*None*
130	9199 (82.9%)	3652 (31%)	0	359	33 (0.3%)	**IMPAIRED**	**IMPAIRED**	PARTIAL
140	6162 (71.4%)	3043 (32%)	0	183	17 (0.2%)	PARTIAL	PARTIAL	*None*
150	9447 (79.2%)	4311 (33%)	0	396	36 (0.3%)	PARTIAL	**IMPAIRED**	*None*
160	5965 (79.9%)	1398 (17%)	0	156	14 (0.2%)	**IMPAIRED**	PARTIAL	*None*
Total	116154 (75%)	987 (21.3%)	4	8963	823 (0.5%)			

Table 4.4.1-A: Nutrient Loading to Waterways Sources: Locations & Magnitude

4.4.2: Problem Magnitude & Pollutant Loads

Reducing nitrate and ammonia nitrogen loading will serve as the most important action for addressing the excessive nutrient loading and loss problem. The nutrient criteria impairment will be the ultimate indicator, however, of the five parameters (total phosphate, nitrate, dissolved oxygen, pH, and algal cover), only total phosphate and nitrate are appropriate for calculating loads and necessary load reductions. Since total phosphate can be significantly reduced through reducing sediment loading, it will be estimated through practices that affect sediment loading and addressed through the sediment loading & loss problem. Reducing nitrate, instead, will be the main focus of the excessive nutrient loading & loss problem. It's expected that by addressing total phosphate loading through sediment load reductions and nitrate through reductions targeted at reducing nitrate specifically, the nutrient criteria will be achieved. Since not all sub-watershed that were impaired for the general nutrient criteria exceeded the state standard of 10 mg/L in nitrate, a more stringent desired level of four mg/L will be set for nitrate when calculating load reductions. The standard of 1.6 mg/L adopted to protect aquatic communities by other states such as Ohio was determined to be too stringent to be attainable and so instead, the maximum level of nitrate observed at sample points that did not have nutrient related water quality effects such as algal blooms was used. Sample points 18 on Little Creek did not exceed a nitrate level of 4 mg/L during any samples and also did not exhibit severe algal blooms. This level of 4 mg/L was chosen as the target for nitrate.

Ammonia nitrogen impairments were also identified through the monitoring and will be treated separately.

Similar to *E. coli* and total suspended solids, load duration curves were created for each of the sample points to estimate the reduction needed to achieve a desired level of 4 mg/L in all of the waterways. The results are shown in *Table 4.4.2-A: Reductions Needed to Achieve Nitrate Goal*.

4.4.3: Critical Areas

Critical areas were identified from the problem sources and water monitoring data was used to prioritize the critical areas. Water quality targets were used to set a desired load and a reduction needed was calculated by subtracting the actual load from the desired load assuming the concentration is within the standard and the flow remains the same. For each point whose drainage area includes one or more other sample points, the reduction needed in the nested drainage area is subtracted from the needed reduction from the next downstream sample point. This means that the reduction needed at each sample downstream of other points is calculated assuming the necessary reductions were achieved in the upstream areas. The highest priority areas are those with the most reduction needed. The resultant maps are shown in figure 4.4.3-A: Critical Areas for Achieving Nitrogen Targets. Priority is shown as dark blue (0-15% - Lowest), light blue (15.1-30%), yellow (30.1-45%), orange, or red outline (45.1-62.3% - Highest) depending on the level of reduction needed. Critical sources are shown as a variety of symbols and colors. A closer look at the critical area maps can be found in Appendix E: Critical Areas – Sub-watershed maps.

	Reductions Needed to Achieve Nitrate Goal					
Sample Point	*Low*	**Dry**	**Mid-Range**	**Moist**	*High*	**Reduction**
1	*0.0%*	9.5%	n/a	**77.5%**	*77.5%*	18.6%
2	*n/a*	n/a	n/a	**27.9%**	*0.0%*	27.9%
3	*n/a*	n/a	n/a	**48.6%**	*27.9%*	48.6%
4	*0.0%*	0.0%	n/a	**73.2%**	*48.6%*	NONE
5	*n/a*	0.0%	n/a	**52.0%**	*73.2%*	52.0%
6	*n/a*	0.0%	n/a	**0.0%**	*0.0%*	NONE
7	*n/a*	0.0%	n/a	**0.0%**	*52.0%*	NONE
8	*n/a*	0.0%	n/a	**74.4%**	*0.0%*	11.3%
9	*n/a*	0.0%	n/a	**35.6%**	*0.0%*	35.6%
10	*n/a*	0.0%	n/a	**20.8%**	*0.0%*	20.8%
11	*n/a*	0.0%	n/a	**61.2%**	*0.0%*	23.0%
12	*0.0%*	0.0%	n/a	**73.2%**	*74.4%*	57.7%
131	*n/a*	0.0%	n/a	**59.0%**	*47.3%*	59.0%
132	*n/a*	0.0%	n/a	**62.3%**	*51.5%*	62.3%
14	*n/a*	0.0%	n/a	**19.5%**	*0.0%*	19.1%
15	*n/a*	0.0%	n/a	**2.1%**	*35.6%*	2.1%
16	*n/a*	0.0%	0.0%	**0.0%**	*0.0%*	NONE
17	*n/a*	n/a	0.0%	**0.0%**	*0.0%*	NONE
18	*n/a*	n/a	0.0%	**0.0%**	*0.0%*	NONE
19	*0.0%*	0.0%	0.0%	**43.2%**	*20.8%*	NONE
20	*n/a*	n/a	0.0%	**41.0%**	*61.2%*	28.5%
21	*n/a*	n/a	3.0%	**30.7%**	*73.2%*	30.7%
22	*n/a*	n/a	0.0%	**27.6%**	*19.5%*	27.6%
23	*0.0%*	0.0%	0.0%	**46.7%**	*2.1%*	NONE
24	*n/a*	n/a	0.0%	**19.1%**	*0.0%*	19.1%
25	*n/a*	0.0%	0.0%	**42.7%**	*0.0%*	42.7%
26	*n/a*	0.0%	0.0%	**47.3%**	*0.0%*	47.3%
27	*0.0%*	0.0%	0.0%	**51.5%**	*43.2%*	7.0%
28	*n/a*	0.0%	0.0%	**36.9%**	*41.0%*	36.9%
29	*0.0%*	0.0%	0.0%	**51.6%**	*30.7%*	11.8%
30	*n/a*	0.0%	0.0%	**52.5%**	*27.6%*	52.5%
31	*0.0%*	0.0%	0.0%	**48.1%**	*46.7%*	18.3%
32	*0.0%*	0.0%	0.0%	**44.6%**	*0.0%*	3.0%
33	*n/a*	0.0%	0.0%	**27.7%**	*19.1%*	27.7%
34	*0.0%*	0.0%	0.0%	**56.6%**	*42.7%*	56.6%

Table 4.4.3-A: Reductions Needed to Achieve Nitrate Goal

Critical Areas for Achieving Nitrogen Targets

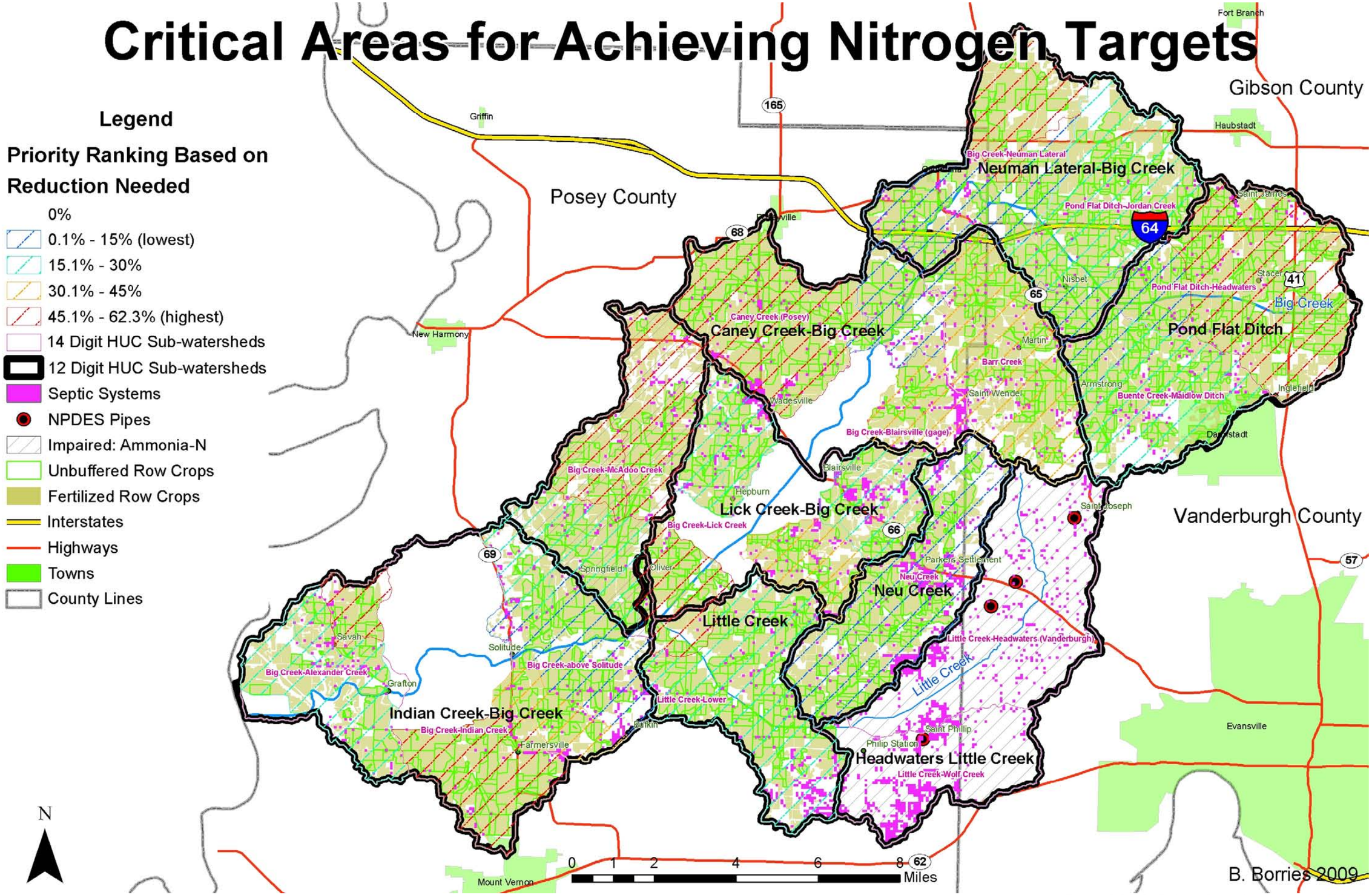

Figure 4.4.3-A: Critical Areas for Achieving Nitrate Goal

Concern	Section(s) Validated
business/development	3.1.2, 3.1.3, 3.2.2
groundwater quality	2.4.2, 3.1.3, 3.2.2, 3.3.2, 3.4
invasive species-particularly scouring rush	
lack of filter/buffer strips	3.1.2, 2.4.2, 3.1.3, 3.2.2, 3.3.2, 3.4
lack of information	NOT VALIDATED, no data
litter	3.5
noxious species-particularly Johnson grass	3.6
lack of information	3.3.1, 3.4
oil contamination/brine sites	2.4.2, 3.1.3, 3.2.2, 3.4

Problem Statement #5 – Education

Land-users often do not realize the impact they collectively have on surface waters and there are no targeted programs to educate people on issues specific to the Big Creek watershed. Historic oil & brine damage has occurred in several areas in the watershed and many people do not realize that their site may be affecting water quality and that it can even be remediated. Even small problems that may not be evident in water monitoring, but are visible to the community can create a “business as usual attitude” that stifles overall achievements. Increasingly, ownership of land is by “absentee landowners” who must make the final decision about the land, but who are often overlooked as they rent their land to tenants that farm the land. Overall, there is not a great enough awareness of the Big Creek watershed, appreciation for its resources, and knowledge of the potential to maintain broad involvement and improve water quality.

Stressors:
Landowners who are unaware of local environmental issues

Sources:
- Inadequate amount of information reaching land-users
- Apathy
- Lack of appreciation for natural resources
- Lack of awareness
- Not enough technical support for residential areas

Critical Areas:
- Absentee landowners
- Residential areas
- Eroding brine sites
- Bridges where trash is regularly seen in the creek bottom
- Community groups and clubs