Abundance, Distribution, and Characteristics of Gravel Mining Sites in Streams of the Salem Plateau, Missouri

Michael J. Roell
Missouri Department of Conservation
Resource Science Center
1110 South College Avenue
Columbia, Missouri 65201

Final Report Submitted to

United States Environmental Protection Agency
Region VII
901 North 5th Street
Kansas City, Kansas 66101

December 2003

ABSTRACT

Aerial observation was used to estimate the abundance, distribution, and physical characteristics of sand and gravel mine sites in streams of the Salem Plateau, Ozarks physiographic region, Missouri. In late summer, fall, and early winter 2001, active instream gravel mines occurred at 407 sites distributed in 44 counties. Excavators operated equipment in the water at about 70% of the sites and did not use a buffer between the site and adjacent water at 93% of sites, suggesting that prescribed buffers be considered for use by all excavators of instream materials. While only 2% of excavators used instream pit mining, 66% nevertheless excavated below water line. Two hundred twenty (220) instream mining sites had one or more bridges within one stream mile and, of course, all sites were adjacent to private and public land. A depth-of-excavation limit should be considered to limit risk of mining-induced channel instability and resulting damage to private and public property.

A viable sand and gravel mining industry, stewardship of stream resources, enhancement of stream-based recreation, and protection of stream side property should be four simultaneous goals of excavators, citizens, and resource agencies in Missouri. The challenge: balancing the economic benefits of mining with those from stream-based recreation as well as protecting against economic losses caused by damage to private and public property.

INTRODUCTION

Many Missouri stream channels and their floodplains are economical sources of sand and gravel for construction, road maintenance, and other purposes. In 1995, the value of sand and gravel extracted from stream systems was about $41 million in direct expenditures, which supported about 5,200 jobs (MICM 1999). Missouri streams also provide other economically important services to the state's citizens. For example, fishing on streams had a value of about $170 million in direct expenditures in 1996 (USDI and USDC 1998); unknown are the economic values associated with other popular forms of stream recreation such as swimming and boating.

Research in sand- and gravel-bed streams of the United States and elsewhere has shown that instream extraction of these minerals can increase sedimentation and destabilize the channel bed and banks (Lagasse et al. 1980; Heede and Rinne 1990; Waters 1995; Kondolf 1997). Channel instability and sedimentation simplifies aquatic habitats and reduces or eliminates populations of aquatic species including those that support important recreational fisheries (Alexander and Hansen 1986; Berkman and Rabeni 1987; Hartfield 1993; Brown et al. 1998; Roell 1999). Indiscriminate instream mining can result in damage to public and private property such as pipelines, utility lines, transportation infrastructure, and stream side land (Hartfield 1993; Kondolf 1997), and damage costs may exceed the value of the sand and gravel extracted from the stream (Kaminarides et al. 1996).

In Missouri, the majority of instream sand and gravel mining occurs in the Ozarks physiographic region. However, the total number of mine sites, the distribution of sites, and the mining practices used are poorly understood. In the latter half of 2001, this study was undertaken in the Salem Plateau of the Ozarks (1) to estimate abundance of instream mine sites,

(2) to map their distribution within each major watershed, and (3) to use site physical attributes to characterize mining practices at each site.

METHODS

This study focused on instream mining sites within the major watersheds of the Salem Plateau in the Ozarks Plateau physiographic region within Missouri (Figure 1); sites in small "fringe" watersheds draining directly to the Missouri and Mississippi rivers also were included. Mine sites were considered "instream" if they were located within the banks of the active channel. From early August 2001 through mid-February 2002, a fixed-wing aircraft was used to identify "active" mine sites on all fifth order and larger stream reaches and in a 30% sample of fourth order reaches that were randomly selected by a geographic information systems (GIS) analyst; previous experience locating sites in the Meramec River watershed revealed that few sites existed on third order and smaller reaches. The lower Meramec River from Eureka to the confluence with the Mississippi River (about 37 river miles near St. Louis) and a segment of Roubidoux Creek in the Gasconade River basin (about 9 miles in Fort Leonard Wood) could not be observed due to aviation restrictions arising from the events of 11 September 2001.

Active sites were readily identified by the presence of excavation equipment, detailed tracks from equipment, newly furrowed sand and gravel, and/or stockpiled material. Inactive sites did not possess these characteristics (with the exception of older stockpiles) but did have obvious accumulations of leaves from fall 2000 as well as recently emerged vegetative growth from the spring and summer of 2001, thus indicating that excavation had not taken place in 2001. Very low precipitation throughout the Ozarks region in spring, summer, and fall of 2001 resulted in consistently low stream flows that allowed for the long-term persistence of the physical indicators used to identify active instream mine sites in late 2001.

Sites were identified from approximately 500-1000 feet above ground level using a Cessna 210 aircraft. Only sites that were approximately 15 feet by 15 feet (roughly two excavator blade widths) and larger were considered. Sites on the same stream segment were considered distinct if they were separated by at least one quarter stream mile; in very few instances were sites separated by less than one half stream mile. A global positioning system (GPS) and a GIS-based tracking system in a laptop computer were used to inventory all observed stream segments and to navigate efficiently among widespread segments. Each active mine site was point-mapped into the GIS and assigned a unique identification number. Each site was then videotaped with a Canon GL1 digital video camcorder (MiniDV media format). Sites were identified on tape by identification number and then coverage was collected in wide-angle and zoom perspectives as site conditions and flying conditions allowed. Nearly all sites were readily observable with the exception of some sites on narrower stream segments, where riparian trees occasionally hampered observation. Aerial observations were conducted on 14 dates (10, 13, 21, 31 August; 4, 10, 24, 26 September; 5, 6, 7 November; 4, 27 December; and 12 February) and required 79.4 hours of flight time.

Abundance of active instream mine sites was estimated by first extrapolating to 100% the number of sites from the 30% sample of fourth order stream reaches and then adding the resulting figure to the number of sites observed in the fifth order and larger stream segments. The map of mine site locations was used to measure the distance of the closest bridge within one stream mile upstream and one stream mile downstream of the site. Interpretation of the video coverage for each site entailed answering a series of questions about various physical characteristics of the site and environs. The following questions were asked:

- What date was the site observed?
- What is the identification number of the site?
- In which major watershed was the site observed?
- In which county was the site observed?
- On which stream is the site located?
- What is the stream order (Strahler 1957) at the site location?
- What is the distance (stream miles) of the first bridge upstream and downstream from the site?
- Was the site accessed through a forested or open riparian zone?
- Was the riparian forest recently cleared to access the site?
- Was there instream surface water adjacent to the site?
- Was there instream surface flow adjacent to the site?
- If surface water or flow was present, did excavation equipment cross the channel to access the site?
- Was material excavated by bar "skimming," pit excavation, or both? (Note: Material was considered to be "excavated" once it was moved from the location where it was last deposited naturally.)
- Was excavation conducted on a single bar or multiple bars?
- For multiple-bar excavations, was the channel used as a travel corridor between bars?
- Did the excavator leave an undisturbed buffer between the site and the water?

- Did the excavator leave an undisturbed buffer between the site and the adjacent stream bank?
- Was excavation equipment operated in the water?
- Was excavated material stockpiled in the active channel?
- Was excavated material pushed to the stream bank or into windrows, or was excavated material scooped for immediate removal?
- Was excavated material pushed to the stream bank only?
- Was stream flow fully, partially, or not blocked by excavated material?
- Was stream flow braided (in more than one flow path as compared to being largely in one flow path) in the adjacent riffle?
- Was the channel intentionally widened during excavation?
- Was the path of stream flow intentionally relocated?

If the answer to a question could not be clearly determined from the physical characteristics shown on the video coverage, the answer was considered "indeterminate." The presence or absence of head cutting could not be determined from aerial observation.

RESULTS

The number of active instream mine sites observed in fifth order and larger stream segments was 220, and the number of sites observed in the 30% sample of fourth order stream segments was 56 (270 inactive sites also were counted). Therefore, after extrapolating the 30% sample to 187 (56 multiplied by 3.333), the estimated abundance of all active sites in the study area is 407. Numbers of observed sites by watershed were Osage 62, Gasconade 54, Current 41, Meramec 33, White 20, Moreau 14, Castor 12, North Fork 12, Lamine 10, St. Francis 3, and small fringe watersheds 15 (Figure 1). Sites were observed in 44 counties. Eleven of the sites had corresponding floodplain mining operations, and 20 additional mine sites were floodplain sites only.

Two hundred twenty (220) instream mine sites had at least one bridge within one stream mile. Eighty four (84) sites had a bridge within one mile upstream only, and 57 sites had a bridge within one mile downstream only. Sixty (60) sites had a bridge within one mile both upstream and downstream, and 19 sites were located immediately adjacent to or under bridges.

Twenty physical attributes were evaluated to characterize mining practices at each instream site (Table 1). The following aspects are a summary of those characteristics:

- 76% of sites were accessed through forested riparian zones and 24% were accessed through non-forested zones,
- 0.4% of sites involved riparian forest clearing to provide access; nearly all sites were accessed by preexisting routes,
- 89% of sites had instream surface water present and, among those sites, 81% had surface water flow,
- 52% of sites with surface water present experienced excavation equipment crossing the channel to access the site,
- 46% of sites with surface water flow present experienced excavation equipment crossing the channel to access the site; 11% had some form of constructed crossing,
- 97% of sites had bar "skimming" as the method of excavation; 2% had pit excavation, and 1% had both methods,
- 59% of sites had excavation on a single bar, and 41% had excavation on multiple bars,

- 98% of sites with multiple-bar excavation experienced excavation equipment using the channel as a travel corridor among bars,
- 95% of sites with at least one fully mined bar did not have an undisturbed buffer between the site and the adjacent stream bank,
- 93% of sites with at least one fully mined bar did not have an undisturbed buffer between the site and instream surface water,
- 66% of sites experienced excavation below water level and 34% did not,
- 70% of sites experienced operation of excavation equipment in the water when instream surface water was present (this includes instances when equipment was in the water while using the channel as a travel corridor between bars),
- 71% of sites experienced operation of excavation equipment in the water when instream surface flow was present (this includes instances when equipment was in the water while using the channel as a travel corridor between bars),
- 7% of sites had excavated material stockpiled in the channel while 93% did not,
- 33% of sites had excavated material pushed to a stream bank or into windrows, and 67% had material scooped for immediate removal,
- 41% of sites had excavated material pushed to a stream bank,
- 31% of sites with surface water flow had flow that was partially blocked by excavated material, 69% did not, and no sites had fully blocked flow,
- 15% of sites with surface water flow had flow that was "braided" into more than one flow path, and 85% had flow largely confined to one flow path,
- 2% of sites experienced excavation that intentionally widened the channel (that is, mined directly into the floodplain), and 98% did not,

- 2% of sites experienced excavation that involved intentionally relocating the primary path of surface water flow, and 98% did not.

DISCUSSION

Instream sand and gravel mining was widespread in the Ozarks region of Missouri in 2001 (Figure 1), occurring in 44 counties at an estimated 407 sites. This abundance estimate was substantially conservative considering that (1) only actively mined sites were observed (approximately the same number of inactive sites as active sites was observed), (2) mine sites smaller than 15 feet by 15 feet were excluded from consideration, (3) mine sites in third order and smaller stream segments were excluded from consideration, and (4) about 46 miles of study stream segments could not be observed due to aviation restrictions. Furthermore, although not included in this study, instream sand and gravel mining also occurs in the Spring River basin in southwest Missouri as well as in stream segments of rivers traversing the river hills region along the Mississippi River in northeast Missouri.

Some instream mining practices have the potential to degrade aquatic communities, stream side land, recreational fisheries, and public infrastructure (Alexander and Hansen 1986; Berkman and Rabeni 1987; Hartfield 1993; Kondolf 1997; Brown et al. 1998; Roell 1999). Because mining occurs during relatively low stream flows, excavation equipment operated in the water suspend fine sediments which then deposit on important benthic habitats downstream. In this study, when mine sites had instream surface water or flow nearby, excavators at 70-71% of sites operated excavation equipment in the water (Table 1). At 98% of sites with more than one bar mined, excavators used the stream channel as a travel corridor among sites; 53% of these sites had surface flow, which the operators traversed. Furthermore, 95% of excavators did not leave an undisturbed buffer between the mine site and stream bank, and 93% did not use a buffer between the site and adjacent water. A buffer of prescribed width should be considered as a means of preventing equipment operation in flowing or standing water.

Some instream mining practices contribute to instability in stream channels and to subsequent increases in erosion that affect stream side land as well as aquatic habitats (WCC 1980a; Chang 1987; Heede and Rinne 1990). For example, head cutting initiated by excavation below water level increases bed and bank erosion well beyond the mine site (Scott 1973; Harvey and Schumm 1987; Hartfield 1993; Kondolf 1997), threatening the structural integrity of bridges and other infrastructure (Bull and Scott 1974; Dunne and Leopold 1978; Hartfield 1993; Kondolf and Swanson 1993; Kondolf 1997). In this study, two hundred twenty (220) instream mining sites had one or more bridges within one stream mile and, of course, all sites were adjacent to private and public land. While only 2% of excavators used instream pit mining that was identifiable from the air, 66% nevertheless excavated below water line. A depth of excavation limit should be considered to limit risk of mining-induced channel instability and resulting damage to private and public property.

Other physical characteristics were observed during the study. For example, although 76% of instream sites were accessed through stream side forest, less than 1% showed evidence of recent forest clearing, suggesting that excavators use previously established routes to access sites and likely have little direct effect on riparian wetlands. At some mine sites, excavated material was moved beyond what was necessary to remove the material for use. While only 7% of sites experienced stockpiling of material in the channel, 33% had excavators who pushed the material to another location, 41% did so to the stream bank, and 31% partially blocked stream flow with moved material (in no locations was flow fully blocked). At only a few sites (15%) was stream flow braided, the channel intentionally widened (2%), or the path of stream flow intentionally relocated (2%).

A viable sand and gravel mining industry, stewardship of stream resources, enhancement of stream-based recreation, and protection of stream side property should be four simultaneous goals of excavators, citizens, and resource agencies in Missouri. The challenge: balancing the economic benefits of mining with those from stream-based recreation as well as protecting against economic losses caused by damage to private and public property.

ACKNOWLEDGEMENTS

B. J. Gorlinsky and Mark Caldwell (Missouri Department of Conservation) provided valuable GIS support for this project. Ange Corson (MDC) did the tedious interpretation of the aerial video. Chet Hartley, John Reed, and Larry Strobel (MDC) supplied expert and safe aviation capability. The U.S. Environmental Protection Agency (USEPA) Region VII generously funded 75% of this work. Rich Wehnes (MDC) managed the USEPA grant and was instrumental in keeping the project on schedule. Suzanne Femmer and Robb Jacobson (U.S. Geological Survey); Scott Hamilton and Mike Larsen (Missouri Department of Natural Resources); Joe Hughes (U.S. Army Corps of Engineers); Raju Kakarlapudi (USEPA); and Paul Blanchard, John Fantz, Del Lobb, Bill Turner, and Rich Wehnes (MDC) provided important project planning guidance or critical review of this report.

REFERENCES

Alexander, G. R., and E. A. Hansen. 1986. Sand bed load in a brook trout stream. North American Journal of Fisheries Management 6:9-23.

Berkman, H. E., and C. F. Rabeni. 1987. Effect of siltation on stream fish communities. Environmental Biology of Fishes 18:285-294.

Brown, A. V., M. M. Lyttle, and K. B. Brown. 1998. Impacts of gravel mining on gravel bed streams. Transactions of the American Fisheries Society 127:979-994.

Bull, W. B., and K. M. Scott. 1974. Impact of mining gravel from urban stream beds in the southwestern United States. Geology 2:171-174.

Chang, H. H. 1987. Modeling fluvial processes in streams with gravel mining. Pages 977-988 *in* C. R. Thorne, J. C. Bathurst, and R. D. Hey, editors. Sediment transport in gravel-bed rivers. John Wiley, New York.

Dunne, T., and L. B. Leopold. 1978. Water in environmental planning. W. H. Freeman and Company, San Francisco.

Hartfield, P. 1993. Headcuts and their effect on freshwater mussels. Pages 131-141 in K. S. Cummings, A. C. Buchanan, and L. M. Loch, editors. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Harvey, M. D., and S. A. Schumm. 1987. Response of Dry Creek, California, to land use change, gravel mining and dam closure. Pages 451-460 *in* Erosion and sedimentation in the Pacific Rim. Proceedings of the Corvallis symposium, August 1987. International Association of Hydrological Sciences Publication 165.

Heede, B. H., and J. N. Rinne. 1990. Hydrodynamic and fluvial morphologic processes: implications for fisheries management and research. North American Journal of Fisheries Management 10:249-268.

Kaminarides, J. S., R. Kesselring, D. Marburger, R. Grippo, and G. Harp. 1996. An economic impact analysis of stream bed gravel mining. Report submitted to Arkansas Gravel Mining Task Force, State of Arkansas.

Kondolf, G. M. 1997. Hungry water: effects of dams and gravel mining on river channels. Environmental Management 21:533-551.

Kondolf, G. M., and M. L. Swanson. 1993. Channel adjustments to reservoir construction and instream gravel mining, Stony Creek, California. Environmental Geology and Water Science 21:256-269.

Lagasse, P. F., B. R. Winkley, and D. B. Simons. 1980. Impact of gravel mining on river system stability. Journal of the Waterway, Port, Coastal and Ocean Division 106:389-404.

MICM (Mining Industry Council of Missouri). 1999. The impacts on the economy of Missouri of mining industrial minerals for use in construction, 1995. MICM site on the World Wide Web (www.momic.com) in 1999.

Roell, M. J. 1999. Sand and gravel mining in Missouri stream systems: aquatic resource effects and management alternatives. Missouri Department of Conservation, Jefferson City.

Scott, K. M. 1973. Scour and fill in Tujunga Wash - a fanhead valley in urban southern California - 1969. U. S. Geological Survey Professional Paper 732-B.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38:913-920.

USDI and USDC (U.S. Department of Interior and U.S. Department of Commerce). 1998. 1996 national survey of fishing, hunting, and wildlife-associated recreation: Missouri. Washington, D.C.

Waters, T. F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7.

WCC (Woodward-Clyde Consultants). 1980a. Gravel removal studies in arctic and subarctic floodplains in Alaska. U.S. Fish and Wildlife Service, Report FWS/OBS-80/08, Washington, D.C.

Table 1. Attributes of instream mine sites observed in major watersheds of the Salem Plateau, Ozarks Plateau physiographic region, Missouri. Indeterminate are the number of sites for which each characteristic could not be clearly determined; they were not included in the calculations of percent of sites.

Site Attribute	Attribute Condition	Number of Sites	Percent of Sites
1. Was the site accessed through a forested or open riparian zone?	Forested	208	76
	Open	66	24
	Indeterminate	2	
2. Was the riparian forest recently cleared to access the site?	Yes	1	0.4
	No	274	99.6
	Indeterminate	1	
3. Was there instream surface water adjacent to the site?	Yes	242	89
	No	29	11
	Indeterminate	5	
4. Was there instream surface flow adjacent to the site?	Yes	145	81
	No	34	19
	Indeterminate	63	
5. If #3 was "Yes," did excavation equipment cross the channel to access the site?	Yes	106	52
	No	96	48
	Indeterminate	40	
6. If #4 was "Yes," did excavation equipment cross the channel to access the site?	Yes	59	46
	No	69	54
	Indeterminate	17	
7. What general excavation method was used?	Skimming	263	97
	Pit	6	2
	Both	3	1
	Indeterminate	4	
8. Was excavation on a single bar or multiple bars?	Single	142	59
	Multiple	97	41
	Indeterminate	37	

9. If #8 was "Multiple," was the channel used as a travel corridor?	Yes No Indeterminate	79 2 16	98 2
10. If at least one bar was fully mined, did the excavator leave an undisturbed buffer between the site and the adjacent stream bank?	Yes No Indeterminate	4 82 19	5 95
11. If #3 was "Yes" and at least one bar was fully mined, did the excavator leave an undisturbed buffer between the site and the water?	Yes No Indeterminate	6 85 12	7 93
12. If #3 was "Yes," did the excavator mine below water level?	Yes No Indeterminate	131 69 42	66 34
13. If #3 was "Yes," was excavation equipment operated in the water? (Note: Crossing the channel to access a bar from the opposite bank is not a "Yes." Using the channel as a travel corridor is a "Yes.")	Yes No Indeterminate	127 54 61	70 30
14. If #4 was "Yes," was excavation equipment operated in the water? (Note: Crossing the channel to access a bar from the opposite bank is not a "Yes." Using the channel as a travel corridor is a "Yes.")	Yes No Indeterminate	82 33 30	71 29
15. Was excavated material stockpiled in the channel?	Yes No Indeterminate	17 240 19	7 93
16. Was excavated material pushed to the stream bank or into windrows, or was excavated material scooped for immediate removal?	Pushed Scooped Indeterminate	83 169 24	33 67
17. Was excavated material pushed to the stream bank only?	Yes No Indeterminate	75 109 92	41 59
18. If #4 was "Yes," was stream flow fully, partially, or not blocked by excavated material?	Fully Partially Not	0 40 90	0 31 69

	Indeterminate	15	
19. If #4 was "Yes," was stream flow braided (i.e., in more than one flow path as compared to being largely in one flow path) in the adjacent riffle?	Yes	20	15
	No	112	85
	Indeterminate	13	
20. Was the channel intentionally widened during excavation?	Yes	5	2
	No	204	98
	Indeterminate	67	
21. If #4 was "Yes," was the path of stream flow intentionally relocated?	Yes	3	2
	No	130	98
	Indeterminate	12	

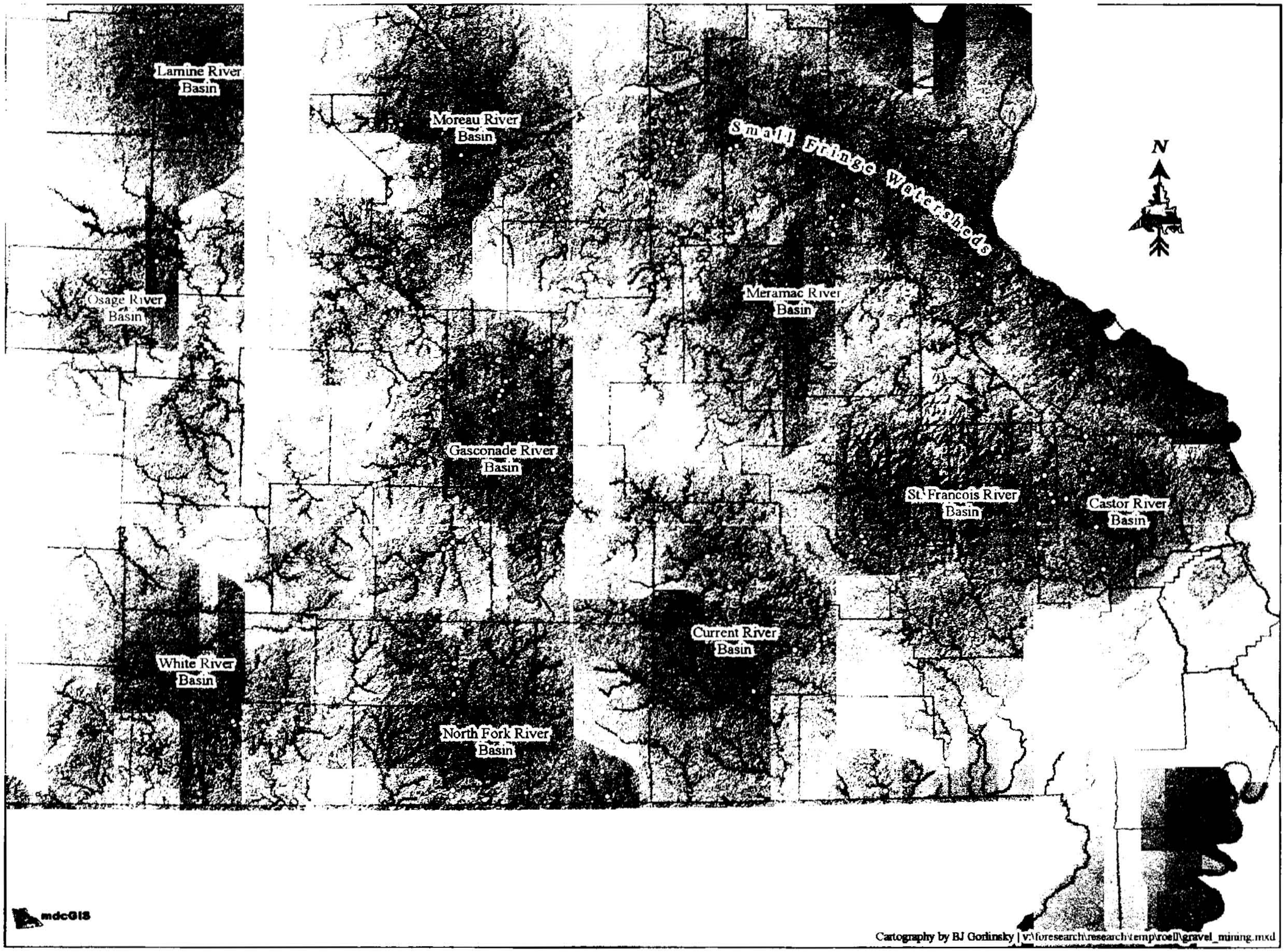

Figure 1. Instream mining sites observed on all 5th order and larger stream segments (blue) and on a 30% sample of 4th order segments (green); the 70% of 4th order segments not sampled are in red. Small fringe watersheds north of the Missouri River were not sampled.