Appendix A. Clarification of Issues

The purpose of this appendix is to clarify the issues stated in Chapter 2. Since each issue statement is one or two phrases, there is potential they could be misinterpreted. Therefore, we felt it was important that more information be available for those readers who wish to know more detail or are unclear about what an issue statement means. For ease of reading, the order of issues listed here is identical to that of chapter 2.

For reference, the Policy and Steering Committees' issues were included. This inclusion helps one see how their issues relate to those of the Stakeholder Committee.

A1. Clarification of Stakeholder Issues

Property Rights

1. Property rights: people want to have the choice to do what they want to with their property.

People that own property expect that over the life of ownership of the property, laws become no more restrictive over the use of the property than they currently are. They want to have the choice of how they use it, and they expect that the choice comes along with holding title to the property; these rights are commonly referred to as property rights.

2. Property rights: what one property owner chooses to do on their property should not adversely affect another person's use of their respective property.

A closely related topic to #1 above, people do not want the enjoyment, value or use of their property to be degraded by what other people do on their property. The most notable example of this in watershed work occurs when someone along a stream is affected by what somebody did upstream; for example, if upstream urbanization causes higher peak flows and more frequent flooding, a downstream person may have property damage and/or devaluation and increased costs to repair or protect infrastructure.

3. A portion of the watershed is public land, and therefore a larger group of people have an interest in that property.

There are several large tracts of public land in the watershed. As they are essentially owned and used by a large number of people (the public), any adverse impacts to those properties affects many more people than would similar impacts on privately held property.

4. Affected parties need notice of what is going on (i.e. notice of public meetings) in order to assure good public participation.

Since governmental decisions could affect landowners, the latter have the right to know what is going on and to participate in the process of making these decisions.

5. Landowners need to defend themselves from groups that try to restrict them.

Some landowners feel they have to protect their property rights (see above, #1), and feel these rights are being threatened or infringed upon by various groups and/or governmental agencies.

6. There is a need to integrate the future use of the watershed in such a manner as to allow for reasonable development while not infringing upon property owners' rights.

Streams/Conservation

7. Devil's Icebox Cave Branch getting muddier

Someone has observed that the water flowing from the Devil's Icebox Cave Branch is getting muddy (suspended sediment) after storms. They noticed that during the previous 30 years, this had never happened before. The suspended sediment can negatively affect aquatic life by destroying its habitat and clogging their oxygen exchange mechanisms.

8. There is higher and more frequent flooding than used to occur for a given amount of rain, bringing in garbage and moving sand bars; this also causes aquatic habitat destruction and subsequent lower low flows.

Some people have noticed that for a given amount of rain, the flood peaks (volume and height of water in a creek) have increased, as well as their frequency of occurrence has increased. This flooding has brought in garbage to the persons' property, and has changed the stream bed by moving sand bars.

Higher peaks and more frequent floods can drastically alter the stream-channel: cross-section area can increase by 2 to 10 times, pool-riffle structure can collapse, stream bed can lower or raise (depending on where it is in the stream), banks can collapse, and spaces between rocks can fill in with sediment. These stream channel alterations can decrease aquatic habitat and cause infrastructure damage. Since more of the water runs off, less infiltrates the ground, thereby decreasing the low flows between flood events; this lower flow leaves less habitat for aquatic organisms.

9. Urbanization can cause water quality degradation in streams.

There is a wide range of pollutants that enter streams both during and after construction. These pollutants include fecal bacteria, excess nutrients, pesticides, oil and grease, sediment, and heavy metals. They can enter the streams in a variety of ways, including: being transported as part of stormwater runoff; sewer malfunctioning (leaks, back flows, etc.); and being poured directly into the storm drainage system.

10. Endangered species could become eliminated from within the watershed.

There are several endangered species, some of which live in the water (Pink Planaria, Topeka Shiner), and some who eat many insects whose life-cycle is intertwined with the streams (Indiana and Gray Bats). If water quality decreases, and habitat is degraded, these species could be extirpated from the watershed.

11. The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection.

The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection. The parts of the subwatersheds that contribute to these waters (primarily, the area east of Rock Bridge M.S.P. and Three Creeks C.A.) are almost half of the entire 93 square mile project watershed.

12. Potential exists for a toxic spill that could negatively impact a stream.

The potential exists for a spill of toxic material which could severely devastate a stream. This could occur by a truck carrying toxic material having an accident. Also the Williams pipeline (which transports gasoline) could rupture, due to an earthquake, flooding (?), sabotage, or other mechanism. There should be a clear mechanism in place to protect the streams should an accident occur.

13. Small acreage landowners need to address the issue of erosion from overgrazed horse pastures (sometimes to the extreme of being bare).

Some horse pastures are severely overgrazed, especially when the horses are confined to small areas. These overgrazed areas can expose the soil to erosion, which can end up in streams causing problems for aquatic habitat. It is also a loss of the precious soil resource from the farm.

14. Erosion in road right of ways is a serious problem that needs to be addressed on both public and private land.

Many roads have ditches on one or both sides of them to convey stormwater runoff. Many times these ditches are not stable or do not have stable outlets. Many times this causes erosion from overland flow as water leaves these road ditches. Head cuts also migrate from some of the eroded ditches into fields, pastures or lawns as these ditches are eroding because of road culverts being lowered or ditches not being stable.

15. Many BMPs have been installed on crop and pasture land in the watershed, but there is always a need for additional BMPs as needs arise.

As new practices and techniques become available, many producers will be adding additional practices to there management. Some of the older BMPs are nearing the end of their useful life and producers will be updating these practices with newer and more improved methods.

16. It is important to protect the unique biological diversity (plant and animal) in the watershed.

The watershed has one of the highest levels of biological diversity of any watershed found in Northern Missouri. Part of what makes it unique is the high number of rare and endangered plants and animals that it has. This is due, in part, to the high diversity of habitats that the watershed still has (streams, springs, caves, sinkholes, bottomland forests, bluffs, glades, upland forests, old fields, and others). There are about 50 different species of plant and animals which live in the watershed which are officially listed by the State of Missouri as rare and endangered, five of which are listed by the Federal Government as threatened or endangered. Most of these rare and endangered species depend on the watershed's streams and caves for their survival. Therefore any negative impacts to the area's streams and caves will also have a negative impact on these unique species.

17. Much of this watershed is particularly environmentally sensitive because of the high number of karst structures (sinkholes, caves, springs, and losing streams) that it has; this makes the watershed very vulnerable to increased levels of contaminants and stormwater runoff.

In addition to the Devil's Icebox Cave, there are many other caves (over 20 in the Three Creeks Conservation Area), springs, sinkholes (Pierpont Sinkhole area), and losing streams (streams that lose more than 30% of their surface water to the groundwater and caves) in the watershed. The karst systems are very vulnerable to pollution due to their interconnection with surface water.

18. It is important to have plentiful drinking water that is of good quality, therefore it needs to be protected.

Drinking water (both private and public systems) in the watershed comes primarily from groundwater sources. The groundwater is replenished by precipitation filtering through the soil. Therefore, what happens on the surface affects both the quantity and quality of water that recharges the aquifer.

<u>Standards and Ordinances</u>

19. It is important to have standards not based on impervious cover, but on Best Management Practices (BMPs); there is science indicating impervious cover can be mitigated.

If impervious cover is limited, it would decrease the amount of construction in the area, thereby decreasing economic opportunities for those people involved with the construction process. In addition, housing opportunities and economic activity that would occur in the buildings is decreased.

20. Impervious surfaces can degrade streams and there is no clear science indicating they can be fully mitigated; therefore, in order to protect streams, impervious cover needs to be addressed in any standards.

With an increase in unmitigated impervious surfaces, there is an associated change in hydrology and water quality (see above, #27, 28).

21. Boone County, and the Cities of Columbia and Ashland, need to develop good stormwater management plans and ordinances in order to set good standards for the future development of this watershed; the standards should be meaningful (and not arbitrary), and designed so that going into a project everyone knows what the rules are.

In order to properly protect streams, good stormwater plans need to be implemented that have good, clear standards. In some instances, standards are implemented which are arbitrary and do not really protect streams. Standards that are enacted to protect the streams need to be effective at performing the purpose for which they were originally created. When someone wants to develop their property, they would like to know what the rules and standards are before they start. This is important so that they know how much it will cost to meet these standards.

22. Water quality should be protected without putting a strict ban on development.

It is important to protect streams. It is also important to allow development to occur since our population is growing. A good balance needs to be found to allow for both of these interests.

23. Some flexibility of recommendations and standards is needed.

Rigid standards may actually impede solving the very problems they were designed to address. For example, saying that a development must have curb, gutter, and storm drains in order to decrease flooding can increase flooding downstream; if a developer is allowed the flexibility to use alternative techniques (i.e. Low-Impact Development), they could take care of both localized and downstream flooding.

24. We need to develop a watershed-based plan that makes use of the best scientific data, as well as the best watershed plans from other communities, that will provide the best chance to protect the Greater Bonne Femme Watershed.

In order to preserve the quality of water resources, thinking ahead is required (a.k.a. planning). With a formalized plan that is backed by the community, implemented and adopted by the various governmental and private groups, there is greater likelihood streams will be adequately protected.

25. Much of the stream can be protected with a buffering situation. Other portions of the stream would not likely be sufficiently protected with any amount of buffering

26. County zoning encourages development

27. Development should be given incentives to occur in areas with adequate infrastructure and discouraged in less suitable areas.

Infrastructure (roads, water, sewer, etc.) is very expensive to build and maintain, with the cost usually carried by taxpayers. Therefore, in order to serve the community most cost-effectively, development should be encouraged in areas with adequate infrastructure.

28. Development should be encouraged in less environmentally sensitive areas and discouraged in more environmentally sensitive areas.

As development occurs, it should be done in a way that protects environmentally sensitive areas. One way to do this is by having policies and measures that encourage it to happen in areas that are less environmentally sensitive. This helps relieve some of the pressure to develop in the more environmentally sensitive areas. These policies and measures should have counterparts that discourage development in more environmentally sensitive areas.

29. Erosion problems and stormwater need to be addressed in existing developed areas.

Most development that has occurred in the watershed has not adequately addressed the problems caused by stormwater. These need to be fixed in addition to preventing future developments' erosion and stormwater problems.

30. Guidelines for installing and maintaining BMPs need to be established. SWCD, NRCS, MDC, MDNR already have existing specifications for many practices.

Best management practices (BMPs) can be used to protect streams. As standards are written to use them, there needs to be clear guidelines to follow to meet the standards. Many agencies (i.e. SWCD, NRCS, MDC, MDNR, etc.) have some guidelines already in place that could be used.

Health

31. It is important never to see a sign posted warning people to stay out of a stream because of the quality of the water.

People enter streams for various recreational purposes (fishing, wading, etc.). Therefore, they do not want to be prohibited from entering the streams because of health threats.

32. Failing onsite sewage systems contaminate streams with fecal material (which is a human health hazard).

Onsite sewage systems contaminating streams with fecal material (a human health hazard), coming from poorly maintained or improperly built systems and illicit discharges. This becomes an area of concern since there are many people who like to recreate in the streams, especially in the caves, which are particularly susceptible to contamination because of their source water coming essentially unfiltered from the surface.

Science

33. Science is inexact.

The body of scientific knowledge concerning various issues related to streams is inexact and constantly being expanded upon. As such, planning needs to be flexible enough to allow for changes as the science behind decisions evolves.

34. There is a need to track sources of contaminants (i.e. microbial source tracking) in order to base long terms plans on good information and not guesses.

When making decisions about how to solve a pollution problem, it is important to know the source of the contaminant. Without this knowledge, decision makers would not have sufficient credibility if their proposals are not based on sound information. In addition, the problem might not be solved without the proper information.

35. Good mapping of sinkholes is needed.

Sinkholes are direct conduits for pollution to enter groundwater, especially that which feeds in to cave streams and springs. In order to prevent this pollution, it is necessary to have a good map indicating precisely where they are.

36. Facts and data should lead process, not biased opinion.

It is important that data and facts are driving the planning process. Otherwise, it could be biased opinion directing decision making, at which point proposed solutions might not adequately address the problems.

37. It is important not to base decisions on studies that have not had some type of review by a board of peers.

Closely related to #21, it is important that the data and/or methodology for collecting the data have had some type of peer review. The peer review process is our best mechanism to insure that information is valid and of high quality, so that the decisions are based on high quality information.

Education

38. There is a need to educate about why better practices are important to conserve resources, and about the differences between loess and karst.

People can help conserve resources by the types of choices they make. In order for them to make better-informed choices, there needs to be sufficient education as to what types of choices they can make. One example of this concerns homeowners with different landscape features, such as those dominated by karst and loess. In these instances, there are big differences in the outcomes of different types of choices they make (i.e. how they treat their wastewater)

39. Recreational use and enjoyment of public lands (Rock Bridge and Three Creeks) is at stake.

Stream degradation could cause a loss of aesthetics / psychological enjoyment, pose health hazards for those who wade in streams and wash out trails and bridges (funding for repairs is not guaranteed and is delayed by at least one year for bridges).

40. Educational opportunities concerning stream ecology could be lost affecting over 2,000 students each year who visit Rock Bridge Memorial State Park.

During these school-sponsored outings, students have the opportunity to interact with streams (wading, using nets, seeing and identifying stream animals).

41. It is important to educate people about the issues and rights of land owners within the watershed.

There are many educational opportunities concerning agriculture, industry and family. There is more than just streams and aquatic life in the watershed. Other issues are important to many residents that live there. In order to balance the stream-related educational opportunities, other education is needed to be available. These could cover topics such as private property rights, farming, business, history/genealogy and family tradition.

Agriculture

42. Maintaining agricultural productivity is important.

It is important to maintain agricultural productivity on agricultural land in order to provide food for people and maintain the source of income from the land.

43. Agriculture-related soil erosion causes problems.

Depending on the type of agricultural practice and how it is done, there can be significant amounts of soil erosion. This causes problems from degrading the soil resource upon which the farming activities are based. In addition, the sediment causes problems for aquatic life in the streams.

44. Excess agricultural chemicals and nutrients are emitted to streams, thereby polluting them.

Pesticides and nutrients are commonly used to enhance agricultural production. When used or stored improperly, they can enter into streams, causing water pollution.

45. Livestock have open access to streams, which accelerates streambank erosion and increases fecal bacterial concentrations in the streams.

Farmers often allow their livestock to get to streams. These animals can significantly increase erosion of the streambank by trampling vegetation and working the soil loose. They can also increase fecal bacterial levels in the stream, posing a human health hazard.

46. There is a need for a farmland preservation program since many people value open land and green space.

Many people value open space, green space, and farms. There should be some type of program in place to encourage or keep those properties in a similar land use.

47. Farms that use good agricultural practices are a benefit to the watershed.

Agricultural practices tend to have less impact on a watershed than urbanization. Farms that use good agricultural practices are a benefit to the watershed, and may lessen the impact of urbanization. We need to promote good agricultural practices, through education and demonstrations. We also need to encourage the survival of the small family farms in Boone County. With the continued population growth of the County, small family farms may be endangered.

A2. Clarification of Policy Committee Issues

The Policy Committee plays several key functions throughout the life of the project. They promote the Project and act as liaisons with their agencies about what is happening with the Project. Since the watershed lies in many different jurisdictions, their interagency coordination is important to ensure their efforts are synergistic and not counterproductive. They also provide input on the watershed plan and related policy and ordinances. Finally, they are key to implementing the governmental part of the plan since they are on the governing bodies that will be adopting the plan's recommendations.

The Policy Committee represents the following entities: Boone County Commission, Boone County Planning and Zoning Commission, Boone County Regional Sewer District, Boone County Water District #9, City of Ashland, City of Columbia Council, City of Columbia Planning and Zoning Commission, Consolidated Public Water Supply District #1, and University of Missouri-Columbia.

P1. What policies should the county and other governments follow for this specific watershed vs. the entire county, or should there be different rules for different watersheds?

Some people question how fair it is to treat one area differently or as more important than others, with the underlying question being "Doesn't every place have something beautiful and unique about it?" Others feel that is it okay to treat some places as being special and unique, similar to our national parks (see below, P9).

P2. It is necessary to expedite real collaborative planning and growth area management on urban fringes.

Currently, the decisions of where growth and development occur are largely in reaction to a proposal by a specific landowner or developer. They take a proposal to Columbia, Ashland, or Boone County, depending on the political and geographical situation. These local governments in turn go through their approval process. The approval or denial decisions are not always in the best interest of the community or local streams. Furthermore, these decisions are often not determined within a greater planning framework. The greater planning framework needs to be established jointly by the County and each of the Cities since they need to be working together to have a cohesive picture that works effectively.

P3. State regulations don't allow us to do what needs to be done in terms of joint planning.

As a corollary to issue #2, state statues hamper joint planning between different local governments (although they do not restrict informal collaborative work).

P4. There is a need to see what other areas have implemented planning tailored for karst areas.

Karst areas (those typified by caves, springs, sinkholes and losing streams) are unique natural features that require special measures to protect them. In order to avoid re-inventing the wheel, we should see what other areas have implemented good planning techniques designed specifically for karst.

P5. It is important to address the issues not on an entire watershed basis, but smaller area (i.e. subwatershed).

The entire Bonne Femme Watershed is a large area (~93 $mi.^2$). Since there is significant variation within the larger area, it is important to have smaller areas for comparison and prioritization of the resources (*editor's note: this was accomplished by studying the subwatersheds during the Subwatershed Sensitivity Analysis).*

P6. Sewage treatment will be challenged to meet the requirements of new state/federal regulations.

New state and federal regulations concerning sewage treatment come into effect at different times. Some of these regulations may add considerably to the cost of treating wastewater. New and existing sewage treatment facilities will likely have difficulty covering the added cost.

P7. It will be difficult to draw lines about which areas will require protection and which do not.

Some people believe it is unfair to have different policies and regulations for one area compared with other areas since that implies one place is more important than another.

P8. There's nothing wrong with people in Boone County saying we want to protect an area (similar to the nation's parks).

Contrasting with the previous issue, some people believe it is acceptable and even laudable to protect environmentally sensitive areas. As a nation and a state, we have decided to do this selective protection through our National Park Service, Missouri's State Parks and Conservation Areas, and other similar measures.

P9. It is necessary to figure out policies that create fairness for people that are in sensitive/less developable areas.

Policies or ordinances may be passed in sensitive areas to protect streams. These could limit the economic development potential for some parcels of land if measures are not enacted to create a fair situation for those property owners.

P10. We do not want to make it so hard to develop that people leave the county to develop.

Some people are concerned that if there are too many regulations in place, people will take their money and economic development potential out of the county.

P11. Utilities would like to know what areas are going to develop so that they can put their infrastructure in order to get a good return on the investment.

Installing infrastructure is a costly endeavor for a utility. They want to place it to maximize the return on the investment, which is accomplished when development occurs in the area serviced by the new infrastructure.

P12. Landowners should be protected from legal actions arising from the policies and practices encouraged in the plan.

Practices and policies in the plan will encourage or require landowners to follow certain guidelines. A landowner's adherence to the guidelines should not open them up to being sued when they would not have been liable had they not followed the guidelines.

P13. It is important not to infringe upon landowners' rights.

Landowners expect to have certain rights that come with owning property, namely that they get to choose to treat the property as they see fit (within the applicable federal, state, and local laws). As regulation increases, they feel that their right to do what they want to on the property has been infringed upon. Similarly, people don't want the use or value of their property diminished by what other people do on their respective property.

P14. Agriculture-related business should not be hampered to the point that they can no longer run their business profitably.

Ordinances and policies that are enacted to protect streams have the potential to increase costs for landowners. This could be difficult for some farmers since they do not have large incomes, especially if some of the costs were proportional to the size of their property.

P15. The plan should not conflict with practices and policies of other agencies (i.e. FSA, USDA, MDNR, BCSWCD, etc.).

Various governmental agencies have their respective interests and points of view. As such, they sometimes propose practices and policies that conflict with those of another agency. It would be a good idea if the policies and practices recommended in the plan did not conflict with those of another agency.

A3. Clarification of Steering Committee Issues

The Steering Committee is the group of people overseeing the entire workings of the project and its staff, including administering the grant. They help coordinate the other two committees' work and provide technical assistance to them. They have representatives from Boone County Planning and Building Inspection, Missouri Department of Natural Resources (319 program and Rock Bridge Memorial State Park), Missouri Department of Conservation, and USDA-Agricultural Research Service.

Appendix A

Note: Since the Steering Committee's issues were the same as some of the Stakeholders' issues, the numbering of this list is the same as that of the Stakeholders' list in order to make it easier to cross-reference between the two lists.

8. There is higher and more frequent flooding than used to occur for a given amount of rain, bringing in garbage and moving sand bars; this also causes aquatic habitat destruction and subsequent lower low flows.

Some people have noticed that for a given amount of rain, the flood peaks (volume and height of water in a creek) have increased, as well as their frequency of occurrence has increased. This flooding has brought in garbage to the persons' property, and has changed the stream bed by moving sand bars.

Higher peaks and more frequent floods can drastically alter the stream-channel: cross-section area can increase by 2 to 10 times, pool-riffle structure can collapse, stream bed can lower or raise (depending on where it is in the stream), banks can collapse, and spaces between rocks can fill in with sediment. These stream channel alterations can decrease aquatic habitat and cause infrastructure damage. Since more of the water runs off, less infiltrates the ground, thereby decreasing the low flows between flood events; this lower flow leaves less habitat for aquatic organisms.

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There is a wide range of pollutants that enter streams both during and after construction. These pollutants include fecal bacteria, excess nutrients, pesticides, oil and grease, sediment, and heavy metals. They can enter the streams in a variety of ways, including: being transported as part of stormwater runoff; sewer malfunctioning (leaks, back flows, etc.); and being poured directly into the storm drainage system.

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There are several endangered species, some of which live in the water (Pink Planaria, Topeka Shiner), and some who eat many insects whose life-cycle is intertwined with the streams (Indiana and Gray Bats). If water quality decreases, and habitat is degraded, these species could be extirpated from the watershed.

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The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection. The parts of the subwatersheds that contribute to these waters (primarily, the area east of Rock Bridge M.S.P. and Three Creeks C.A.) are almost half of the entire 93 square mile project watershed.

Appendix B. Glossary

Adsorb To accumulate gases, liquids, or solutes on the surface of a solid or liquid.

Amphipod Any of several *crustaceans* with one set of feet for jumping or walking and another set for swimming.

Aquifer Groundwater-bearing geologic formations that yield water in usable quantities.

Benthic Relating to or characteristic of the bottom of a sea, lake, or deep river, or the animals and plants that live there.

Best management practice (BMP) A practice used to reduce impacts from a particular land use.

Biodiversity The range of organisms living in an ecological community or system.

Biomonitoring (aquatic) The gathering of biological data in both the laboratory and the field for the purposes of making an assessment, or determining whether regulatory standards and criteria are being met in aquatic ecosystems.

Bioretention The use of a vegetated depression located on a site that is designed to collect, store and infiltrate *stormwater* runoff.

BMP *see* Best Management Practice.

Coliform Rod-shaped bacteria that are normally found in the colons of humans and animals.

Crustacean Arthropods, including shrimp, crabs, crayfish and lobsters, that usually live in the water and breathe through gills; they have a hard outer shell and jointed appendages and bodies.

Depauperate Lacking or depleted in the variety of plant or animal species.

DI Devil's Icebox Cave Branch.

Dye trace A method of determining where water flows (typically, underground) by injecting dye into flowing water and recording where it appears.

Appendix B

Echolocation A means of locating an object based on an emitted sound and the reflection back from it, used naturally by some animals (e.g. bats).

Endangered species A species that is in danger of extinction and whose survival is unlikely if the causal factors of its decline continue (U.S. Fish and Wildlife Service official designation).

Ecosystem A localized group of interdependent organisms together with the environment that they inhabit and upon which they depend.

Endemic species Species found in only one location.

Ephemeroptera One of the insect *orders*, made up of the mayflies, characterized by membranous wings, nonfunctional mouthparts, two or three abdominal appendages, and incomplete metamorphosis.

EPT Refers to three orders of insects, *Ephemeroptera, Plecoptera, Trichoptera*; often, these orders are used as a *metric* for stream health.

Eutrophication The process by which a body of water becomes rich in dissolved nutrients from fertilizers or sewage, thereby encouraging the growth and decomposition of oxygen-depleting plant life and resulting in harm to other organisms.

Flow regime The quantity, frequency and seasonal nature of water flows.

Fluvial Produced by, or found in, a river or stream.

GIS (Geographic Information Systems) A computer system designed to allow users to collect, manage and analyze large volumes of spatially referenced information and associated data.

Glacial till Unsorted geological material deposited directly by glaciers.

Globally imperiled/vulnerable Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range.

GPS (Global Positioning System) A system of satellites and receiving devices used to compute positions on the Earth.

Grab sample A sample of water taken by placing a jar in a stream, used for analyzing its chemical and physical properties.

HC Hunters Cave.

Hydrology The study of water occurrence, distribution, movement and balances in ecosystems; the seasonal patterns of a river's flow.

Joint program reciprocity This occurs when two programs from different political jurisdictions have a reciprocal agreement such that they have similar ordinances across the political boundaries.

Impervious Surfaces Surfaces which do not allow water to *infiltrate* into the ground.

Infiltrate To penetrate the interstices of a tissue or substance.

Invertebrate An animal that does not have a backbone.

Isopod A small invertebrate animal with a flattened body and seven pairs of legs.

Karst An area possessing surface topography resulting from the underground solution of subsurface limestone or dolomite. Karst includes features such as *sinkholes, losing streams*, caves, and springs.

Land use plan A written, comprehensive document that includes goals and strategies for future development or preservation of land.

LID *see* Low impact development.

Limestone A sedimentary rock consisting mainly of calcium carbonate, often composed of the organic remains of sea animals such as crinoids, corals, etc. It dissolves relatively easily, allowing the formation of *karst* features such as caves, *sinkholes, losing streams*, and springs.

Loess A type of soil composed of silt and clay sized materials that were transported and deposited by wind.

Losing stream A stream whose water seeps into the groundwater; its flow decreases as one moves downstream.

Appendix B

Low impact development (LID) A development strategy designed to mimic a site's predevelopment hydrology by using techniques that infiltrate, filter, store, evaporate, and detain *stormwate*r runoff close to its source.

Macroinvertebrate An invertebrate animal large enough to be seen with the naked eye.

Matter of right A part of an ordinance automatically allowing a certain action to occur if certain, specified conditions are met.

Mesic Refers to sites characterized by intermediate moisture conditions neither decidedly wet nor decidedly dry.

Metabolite A by-product of metabolism.

Metric A system of measurement.

MDC Missouri Department of Conservation.

MDNR Missouri Department of Natural Resources.

Neotropical migrant bird Songbirds that spend the summers in the US and Canada, and winters in tropical regions to the south.

No discharge area Area requiring wastewater disposal systems that do not discharge water to surface or subsurface waters of the State.

Nonpoint source pollution (NPS) Pollution originating from runoff from diffuse areas (land surface or atmosphere) having no well-defined source.

NPS *see* Nonpoint source pollution.

NRCS Natural Resources Conservation Service (part of U.S. Department of Agriculture)

Order A *taxonomic* classification made up of related families of organisms.

Outstanding state resource waters High-quality waters that may require exceptionally stringent water quality management (official State of Missouri designation).

Partners in flight A group of public and private organizations working together to conserve bird populations in the western hemisphere.

Pathogen A living organism that can cause disease, such as a bacterium or a virus.

Periphyton biomass The mass of living organisms (plants and animals) that live in water attached to rocks and other submerged objects.

Photolysis The irreversible decomposition of a chemical compound as a result of the absorption of electromagnetic radiation, especially visible light.

Planarian A small, soft-bodied, free-living flatworm (Phylum Platyhelminthes) with bilateral symmetry and a primitive brain.

Plecoptera One of the insect *orders*, made up of the stoneflies, characterized by membranous wings, chewing mouthparts, two short abdominal appendages, and incomplete metamorphosis.

Recharge area The area that feeds water into an aquifer.

Recording stream gage Instrument that measures and records the elevation of a stream's water surface. These data are used to calculate the flow of water.

Residual Soils Soil that develops directly from weathering of the rock below.

Resdiuum *see* residual soils.

Riffle An area of rough water caused by submerged rocks or a sandbar.

Riparian Situated or taking place along or near the bank of a river or stream.

Siltation The deposition of finely divided soil and rock particles upon the bottom of stream and river beds and reservoirs.

Sinkhole A bowl-shaped depressions in the ground formed when cracked *limestone* below it collapses. Surface water flows into a sinkhole to join an underground drainage system.

Species of conservation concern Species that the Missouri Department of Conservation is concerned about due to population declines or apparent vulnerability.

Appendix B

Specific conductivity A measure of the ability of a substance (e.g. water) to conduct an electrical current. It is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids content of the water.

Stalactite An icicle-shaped formation in a cave that has gradually built up as a deposit of calcium carbonate precipitated out of groundwater that has seeped through the cave's roof.

Stalagmite A conical formation in a cave that has gradually built up as a deposit of calcium carbonate precipitated out of groundwater that has seeped through the cave's roof and dripped onto the top of the formation.

Stormwater Water that accumulates on land as a result of storms. Often, it refers to runoff from urban sources.

Substrate The mineral and/or organic material that forms the bed of the stream.

Subwatershed sensitivity analysis (SWSA) For the purpose of this plan, SWSA refers to an assessment of the subwatersheds within the Bonne Femme watershed (for more information, see Chapter 3 and Appendix G).

SWCD Soil and Water Conservation District

Taxon A group to which organisms are assigned according to the principles of *taxonomy*, including species, genus, family, order, class, and phylum.

Taxonomy The science of classifying plants, animals, and microorganisms into increasingly broader categories based on shared features.

Trichoptera One of the insect *orders*, made up of the caddisflies, characterized by hairy, moth-like wings, long hairlike antennae, nonfunctional mouthparts, and complete metamorphosis.

Troglobite An animal that lives its entire life within a cave and is specifically adapted to life in total darkness.

Troglophile An animal that can live inside or outside a cave.

USGS United States Geological Survey, part of the Interior Department.

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Appendix D. Bonne Femme Watershed Committee Membership

Policy Committee:

Consolidated PWSD #1	Gary Woody
Boone County Water District #9	Roger Ballew
Boone County Regional Sewer District	Debbie Schnedler
Ashland	Mike Asmus, Ashland Alderman
Columbia	Barbara Hoppe, Ward 6, City Council (replaced Bob Hutton, Ward 3)
City of Columbia P&Z Commission	Jerry Wade
UMC	Peter Ashbrook, Director, Environmental Health and Safety
Boone County	Karen Miller
Boone County P&Z Commission	Larry Oetting

Stakeholder Committee:	**Interest**

Note: There may be interests for each person that are not listed.

Dave Bedan	member Audubon Society, Mo. Parks Assn., recreator
Dave Bennett	engineer
Steve Cheavens	landowner, farmer lower Bonne Femme Subwatershed
Randal Clark	resident Gans Creek Subwatershed, watershed partnership, recreator
Amelia Cottle	PTSA, Voluntary Action Center, Friends of Rock Bridge, recreator
Robin Crane	landowner, farmer Gans Creek Subwatershed
Bill Crockett	engineer (resigned from committee)
Donne Dodge	farmer, educator (deceased before the end of the Stakeholder Plan)
Glen Ehrhardt	lawyer, Columbia Chamber Commerce
David Grant	landowner, farmer (resigned from committee)
Larry Henneke	educator (resigned from committee)
Ben Londeree	recreator
MaryLou Mayse	landowner, farmer (resigned from committee)
Chuck Miller	educator, farmer (resigned from committee)

Joe Miller	banker (resigned from committee)
George Montgomery	resident, recreator, engineer, farmer Little Bonne Femme Subwatershed
Annie Pope	Homebuilders Association of Columbia
Steve Sapp	landowner, farmer Devil's Icebox recharge area
Stephanie Smith	landowner, farmer Turkey Creek Subwatershed, Boone Co. Soil and Water Conservation District
Steve Sowers	banker
Don Stamper	Central Missouri Development Council (resigned from committee)
Carolyn Terry	landowner, Gans Creek Subwatershed
Jane Ann Travlos	recreator, Girl Scout Day Camp Director at Rock Bridge Memorial State Park
Carol Van Gorp	Columbia Board of REALTORS®
Rob Wolverton	Central Missouri Development Council

Steering Committee:

USDA-ARS	Bob Lerch, Soil Scientist
Boone County	Bill Florea, Senior Planner
Boone County	Terry Frueh, Urban Watershed Conservationist
MDNR	Georganne Bowman, Environmental Specialist (replaced John Johnson and John Knudsen, Environmental Specialists)
Rock Bridge Memorial State Park	Roxie Campbell, Naturalist
Rock Bridge Memorial State Park	Scott Schulte, Superintendent (retired)
MDC	Scott Voney, Fisheries Biologist

Appendix E. Valuation of Ecological Services

Following are the calculations for determining the values reported in chapter 1.d Economics for the value of ecological services for the watershed.

Table E.1 Ecological valuation of watershed following the methodology of Costanza *et al*. (1997).

Note that the land use/land cover data are the most current (1991).

Land Use/Land Cover	acres	value ($/acre)	total value ($)
urban impervious	520.8	0	0
urban vegetated	80.9	0	0
crops	10783.1	37.25	401637
pasture	27247.0	93.93	2559237
pasture (warm season)	7.8	93.93	732
cedar/deciduous forest/ woodland	6239.6	122.27	762894
deciduous woodland	1565.1	122.27	191357
deciduous forest	12872.7	122.27	1573913
bottomland hardwood	90.4	122.27	11050
marsh/wet herbaceous	13.1	7927.13	104073
open water	318.0	3440.49	1094073
Totals	59,738.5		6,698,965

Table E.2 Ecological valuation of the watershed following the methodology of IDC, 1993.

(from Valuing Ecosystem Services: Toward Better Environmental Decision-Making, p. 170)

	total acres	value ($)/acre	total value ($)
floodplain	3,423.9	8,177	27,996,983

Appendix F. Stakeholder Decision-Making

This appendix clarifies how the Stakeholder Committee operated during their planning process. The Stakeholders approved of these rules at their December 13, 2004 meeting.

1. **Officers:** Ben Londeree and Glen Ehrhardt were selected to co-chair the meetings. The committee decided to have co-chairs in order to maintain balance of leadership, and to ensure there would be continuity in running the meetings should one of the co-chairs be unable to attend.

2. **How meetings will be run:** A co-chair ran the meetings. Terry Frueh (Bonne Femme Watershed Project Staff) acted as secretary for the meetings. Meeting agendas were jointly drafted by Mr. Frueh and the co-chairs. Agenda items for a meeting could be suggested by anyone on the committee, either at the end of the previous meeting or two weeks prior to the meeting. The co-chairs considered these suggestions for inclusion on the agenda. Terry sent out the agenda to Stakeholders one week prior to the meeting.

3. **Decision-Making:** For policy decisions, a super-majority of three-fourths of members present at a meeting was required for passage of the vote, with a quorum required for voting defined as 10 people. These decisions had two readings at consecutive meetings, with a vote at the second meeting. Minority reports discussing the viewpoints of those who differ with a decision were allowed.

Ground Rules: The committee decided that common courtesy was sufficient.

Appendix G

Appendix G. Science

G.1 EPT report

Benthic Macroinvertebrate Collections and Identifications within 8 Streams of the Bonne Femme Watershed.
A Final Report to the Boone County Watershed Coordinator
April 26, 2006
Prepared by Kathy E. Doisy

Introduction

The Bonne Femme Watershed Project is a 4-year, EPA-funded initiative sponsored by Boone County, Missouri. Partners in the project include the Boone County Commission, City of Columbia, City of Ashland, Missouri Department of Conservation, Missouri Department of Natural Resources, Boone County Soil and Water Conservation District, University of Missouri, USDA-Agricultural Research Service, Chouteau Grotto, and the Friends of Rock Bridge.

The main objective of this project is to maintain long-term water quality within the Bonne Femme watershed using watershed planning as a tool to manage growth and prevent further watershed degradation. This report addresses a small portion of the project goals in relation to the monitoring of streams within the watershed with the use of biological criteria.

The 1972 Amendments to the Federal Water Pollution Control Act and the Clean Water Act of 1987 changed the concept of water quality management in the United States. Management efforts shifted from simply determining what goes into a particular water body, to a more integrated approach that addresses the needs of the aquatic community. This new goal of "ecological integrity" refers to a system that has the capability of supporting and maintaining a balanced, integrated and adaptive community that has good diversity and resiliency. In other words, it is a system that can withstand an assault and recover. This requires more than just good water quality. Research by Judy et al. (1984) and others (Karr et al., 1985) has shown that halting the chemical degradation of water doesn't assure the restoration of its ecological or biological integrity. Changes in the energy source, habitat structure or flow regime can also profoundly affect the aquatic communities (Karr et al., 1986).

This change in focus has also resulted in a change in monitoring technology. Classical water quality monitoring was done using physical and/or chemical parameters. This was problematic because these data only provide information about the conditions that exist at the time of sampling. Most current monitoring programs have added a third component known as "biological monitoring" or "*biomonitoring*." This is the systematic use of biological responses (called "*metrics*") to evaluate changes in the environment. Biological impairment of the benthic community may be indicated by the absence of generally pollution-sensitive macroinvertebrate *taxa*, dominance by any particular taxon combined with low overall taxon richness, or appreciable shifts in community composition relative to the reference condition (Plafkin et al., 1989). These data can provide an indication of the cumulative effects of conditions changing over time.

For this study, the biological data presented herein will serve as a baseline data set to help researchers assess how stream health of the Bonne Femme watershed has changed over time, and help evaluate the effectiveness of the watershed planning and cost-share program.

Site locations

The *GPS* locations of the 8 sites that are the focus of this study are reported in Table G.1. Macroinvertebrate samples were taken according to MDNR protocol starting at the lower end of the reach and moving upstream to prevent disturbance of the habitats to be sampled. Site 1 indicates the first or lower end of the reach (Table G.1). It should be noted that Rock Bridge Creek [*a.k.a. Devil's Icebox Spring Branch –editor*], was included in these collections despite the expectation that its macroinvertebrate community would not be comparable to the other sites. The flow of this site comes up to the surface just a few feet upstream of the collection site from an underground cave. Localities with this type of "karst" topography are areas where the surface and groundwater are integrally connected. Unlike groundwater that is filtered through dense soil layers, groundwater in karst systems often moves rapidly through underground channels that fail to provide the effective natural filtration and absorption that characterizes other systems. As a result, these waters often contain contaminants and pollutants not found in groundwater. For these reasons this site was included in the collections due to its value as a sentinel site of possible perturbations in that area.

Table G.1 X, Y coordinates for the upper and lower ends of the sample reaches.
The X, Y numbers are in the following projection: feet with X= east, Y = north in reference to the fixed point NAD 1983 State Plane Missouri Central FIPS 2402 Feet.

Location	Site 1 X	Site 1 Y	Site 6 X	Site 6 Y
Bass Creek	1701103.43375	1092750.87158	1701853.96909	1092273.08773
Bonne Femme at 63 highway	1709216.18352	1107780.41314	1709668.54104	1108180.25056
Bonne Femme at Nashville Church	1689737.01449	1088629.47664	1690268.43553	1089049.75344
Clear Creek	1689772.42773	1108887.20800	1690132.94993	1109087.20387
Fox Hollow	1681833.83088	1077074.31629	1681832.91073	1076844.38539
Gans Creek	1690451.56558	1107722.12855	1691230.81796	1107527.09812
Rock Bridge Creek	1689788.13216	1106103.73720	--	--
Turkey Creek	1700157.08049	1092885.08328	1700149.22058	1093341.86078

Appendix G

Methods

The coarse flow habitats of 8 reaches of streams of interest within the Bonne Femme watershed were sampled according to MDNR protocol (Semi-Quantitative Macroinvertebrate Stream Bioassessment, June 20, 2003) from 28 March to 13 April, 2006. Modifications to the MDNR laboratory sorting protocol (MDNR-WQMS-209) were submitted to the MDNR project manager and approved prior to collections (see below, section G.1.a). All identifications were made to the lowest possible level. Species identifications are reported for two genera, *Perlesta* and *Rhyacophila*, which are only reported to the genus level according to MDNR protocol. This information was included since it may prove of value in future investigations. However for this report, those sites with more than one species of these genera are restricted to a count of one to compare with the detection coefficients developed by the Missouri Department of Resources Environmental Services Program.

As indicated in section G.1.a, biomonitoring for this project has been limited to surveillance of the *EPT* [*Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), *Trichoptera* (caddisflies)] *taxa*, three orders of (generally) pollution-intolerant *benthic* insects. Although a multi-metric approach is used by the MDNR (Biological Criteria for Wadeable/Perennial Streams of Missouri, February 2002), the EPT richness metric has been reported in multiple studies to be a highly sensitive indicator of a variety of stream perturbations (Barbour *et al.*, 1992; Wallace *et al.*, 1996; Rabeni *et al.*, 1997). The EPT richness metric measures the species richness (number of taxa) of the aforementioned orders, providing a consistent, quantifiable biometric of stream health.

Results and Discussion

MDNR has published baseline or "reference" biocriteria for each of the ecological drainage units (EDU) within the state for either spring or fall collections (Missouri Biocriteria Wadeable/Perennial stream 25th Percentile and Bisection Values, 10 January 2006). The intended uses of these biological criteria as stated by MDNR include: the establishment of regional attainment goals within Missouri that are relevant to aquatic communities and protect the resource, establishing a scientific benchmark or baseline for monitoring the effectiveness of best management practices and restoration efforts, and to allow a baseline for evaluating the status of waterways and any changes over time. These baseline data, to which other streams may be compared, were developed by MDNR from multiple samplings of streams within each EDU. Reference conditions are represented by values that fall above the 25th percentile for the EPT richness metric. For details on the methodology see the Biological Criteria for Wadeable/Perennial Streams of Missouri, February 2002.

The current EPT richness metric reference data for warm water streams within the Ozark/Moreau/Loutre drainages sampled between 15 March and 15 April are 13 for the 25th percentile and 6 for the bisection value. Since this study is based on a single metric out of the four metrics suggested by the MDNR, these results can not be considered the final statement regarding stream conditions. In addition, it should be noted that the values presented by MDNR are based on riffle and pool habitat, in contrast to the use here of riffle habitat alone[1]. Despite this, examination of the single metric may allow for tentative conclusions about stream conditions. Streams with metric values higher than the 25th percentile may be considered fully biologically supporting, values equal to or less than the 25th percentile and greater than or equal to the bisection are partially biologically supporting, while values below the bisection indicate streams that should be considered non-biologically supporting.

Results of the sampling are reported in Table G.2. For the 7 streams (excluding Rock Bridge Creek) the EPT richness metric ranged from 6 – 11 taxa. None of the sampled sites appear to be in reference (fully biologically supporting) condition, although all of them are equal to or above the bisection value for this area. The site with the highest EPT richness was Bass Creek, while the site with the lowest was the Bonne Femme at Highway 63. All the sites, excluding Rock Bridge, had at least one species of each order. Although the exact sampling locations are unknown, a previous study (early May 2001) of coarse flow habitat of some of these streams by the Community Storm Water Project found higher EPT richness values for Turkey (13) and Gans (11) creeks. There was no difference in EPT richness for Bass Creek, while the 2001 collections in Clear Creek found one less species.

Although abundance data were not part of this study, it should be noted that both Clear Creek and Gans Creek had exceptionally low numbers of specimens as compared to the other sites despite comparable collecting methods. Reductions in abundance may indicate chronic impact(s).

Another aspect of these data is the sensitivity of the collected taxa. Certain species from these collections are considered more sensitive to pollutants than others. These taxa include all the stoneflies, and the caddisflies *Chimarra*, *Polycentropus*, and *Rhyacophila*. In this regard, Turkey Creek scores the highest or best with 7 of these more sensitive taxa, followed by Bass Creek and Bonne Femme (at Nashville Church) with 6, and Fox Hollow with 5.

The collections from Rock Bridge Creek had only one relatively tolerant caddisfly, *Cheumatopsyche*. Since there are no previously reported collections from this location no assessment of conditions can be made at this time.

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G.1.a

Modifications to the Missouri Department of Natural Resources Semi-Quantitative Macroinvertebrate Stream Bioassessment (SOP#8) of the QUALITY ASSURANCE PROJECT PLAN FOR WATER QUALITY MONITORING IN BONNE FEMME WATERSHED

Prepared by Kathy E. Doisy for the Boone County Watershed Conservationist, Terry Frueh.

The following change will be made to the MDNR Semi-Quantitative Macroinvertebrate Stream Bioassessment (June 20, 2003) under section 3.0 Laboratory Processing of Samples:

The protocol for this project has been limited to riffle samples of 8 streams within the Bonne Femme watershed. In addition, metric calculations will be limited to EPT richness. Due to monetary constraints and the lack of interest in metrics related to abundance, field collected samples will not be sub-sampled as indicated in the MDNR protocol. Instead the complete sample will be returned to the laboratory, drained of the preservative (75% ethyl alcohol), rinsed in distilled water, and placed in a white enamel pan where the macroinvertebrates will be separated from debris and sediment using a sugar floatation procedure described by

Table G.2. Presence/absence of EPT taxa at the eight sites, spring 2006 collections. Presence is indicated by a "1". An asterisk also indicates presence but these were not included in the taxa count since MDNR does not identify to the species level for the indicated genera.									
		Bass	Bonne Femme	Bonne Femme	Clear	Fox	Gans	Rock Bridge	Turkey
		Creek	at 63 Highway	at Nashville Church	Creek	Hollow	Creek	Creek	Creek
	TAXA IDENTIFIED	3/29/06	4/4/05	4/5/06	4/3/06	4/5/06	3/28/06	4/13/05	3/29/06
	Number of mayfly taxa	3	2	3	4	3	4	0	3
	Number of plecoptera taxa	3	2	4	1	3	1	0	4
	Number of trichoptera taxa	5	2	3	4	3	3	1	3
	EPT richness	11	6	10	9	9	8	1	10
codes									
from	Ephemeroptera								
MDNR	Baetidae								
1040	Acerpenna				1		1		
	Heptageniidae								
1240	Stenacron interpunctatum	1		1	1	1	1		1
1263	Stenonema femoratum	1	1	1	1	1	1		1
	Caenidae								
1444	Caenis latipennis	1	1	1	1	1	1		1
	Plecoptera								
	Nemouridae								
3200	Amphinemura			1		1			1
	Perlidae								
3590	Perlesta cintipes			*					
3590	Perlesta fusca	1	1	1	1	1	1		1
3621	Perlinella drymo								1
	Perlodidae								
3690	Isoperla mohri	1		1		1			1
3438	Chloroperlidae		1						
3460	Haploperla brevis	1		1					
	Trichoptera								
	Hydropsychidae								
5130	Cheumatopsyche	1	1	1	1	1	1	1	
5160	Hydropsyche	1							
	Polycentropidae								
5090	Polycentropus	1			1	1	1		1
	Philopotamidae								
5030	Chimarra	1		1	1				1
	Rhyacophilidae								
5240	Rhyacophila fenestra	1	1	1	1	1	1		1
5240	Rhyacophila lobifera	*	*				*		*

Anderson (1959). Each sample will be repeatedly hydrated with distilled water and re-floated until no new specimens of Ephemeroptera, Plecoptera, or Trichoptera are recovered during a 5-min inspection under an illuminated magnifying ring. This method ought to closely replicate the large and rare search method used by MDNR allowing the comparison of these EPT richness results with those all ready in place by MDNR.

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G.2 Devil's Icebox Cave Branch Biomonitoring

Biomonitoring is the process of measuring the presence and numbers of living organisms in an environment. This approach, applied to stream life, speaks volumes about the health of the stream. These living organisms function as indicator species, like the proverbial canary in the coal mine. For surface streams, measuring bottom dwelling or "benthic" organisms like the EPT invertebrates described above serves well, since these macroinvertebrates are known to be sensitive to water pollution. It is still very important to test the water itself to monitor its quality. However, biomonitoring does something that water quality monitoring cannot do. The effect of factors not tested for and the combined effect of multiple factors can be demonstrated by the indicator species that must live under these conditions. Biomonitoring also reflects conditions over time, whereas water samples are taken at one point in time. This section explores why EPT monitoring is problematic for springs and cave streams and describes the biomonitoring program being used for Devil's Icebox Cave Branch.

In a report titled "Benthic Macroinvertebrate Collections and Identifications within Eight Streams of the Bonne Femme Watershed", Doisy (2006) points out that Rock Bridge Creek (the water of Devil's Icebox Cave Branch 100 ft. downstream from where it exits the cave) was sampled not for the purpose of comparing its EPT richness score to that of surface streams, but for the purpose of comparing its current data with future data. Doisy and Rabeni (2005) report that "Spring communities typically are represented by fewer species and have less diversity than downstream areas as a result of an environment with relatively constant temperature regimes, mineralization (high dissolved solids), low dissolved oxygen, absence of plankton as a food source, and *depauperate* (impoverished) habitats." Therefore it was expected that the EPT sampling of Rock Bridge Creek would have a low EPT richness score. One of the listed factors (low dissolved oxygen) was not however present in this case. Unlike many springs, Devil's Icebox Cave Stream Branch flows in contact with air in about 3.5 miles of passageways, making its dissolved oxygen levels of 9 to 12 milligrams per liter (Lerch, 2005), comparable to those of surface streams.

One would suppose that we could compare one Missouri spring to another. Rock Bridge Creek's EPT richness score was lower than that of the eight springs monitored for the Ozark National Scenic Riverways. However, Doisy and Rabeni (2005) found that EPT richness scores for those eight springs had an unexpectedly wide range, from 4 to 15. When investigating the possible causes of the variability, they evaluated water depth and velocity, electrical conductivity (affected by dissolved mineral content), acidity or pH, minimum and maximum volume of water discharge, size of the rock substrate and percentage of plant cover within the spring brook. The discharge volume or size of the spring appeared to be the prevailing influence on the invertebrate community. The report concludes, "These data indicate that the spring communities are too different to use one set of biomonitoring standards for all." The authors recommend that a customized biomonitoring protocol be developed for each spring (Doisy and Rabeni, 2005).

A customized *EPT* protocol may have been a viable option for Rock Bridge Creek had its EPT richness been greater. But given that only one relatively pollution-tolerant EPT species was found, that species' future presence or absence would not tell us much about the health of the cave stream.

Many springs flow from water-filled passages, making monitoring outside of the spring the only feasible option. Devil's Icebox Spring differs from the usual model however, since we have the option to enter and conduct biomonitoring inside the cave. This provides us with the opportunity to monitor cave invertebrates directly. We know little about the sensitivity of cave invertebrates other than the EPT insects to water quality, so that monitoring those other organisms may not be so indicative of stream health as monitoring EPT insects. However, since one cave invertebrate, the pink planarian, is a "species of conservation concern", a reduction in its numbers would be cause for alarm. The pink planarian is aquatic, making it likely that a reduction in its population is due to changes in water quality or quantity. Therefore, one important biological indicator species for Devil's Icebox Cave Branch is the pink planarian. It is listed as a *species of conservation concern* by the State of Missouri, considered not only locally but globally imperiled because it is endemic to Devil's Icebox Cave Branch, not known to live anywhere else.

A customized biomonitoring plan for Devil's Icebox Cave Branch should therefore include monitoring the numbers of pink planarians as well as the organisms that associate with them. Documented cases (EPA, 1981, Lewis 1987, 1989, Poulson, 1996, Quinlan, 1977) indicate that an increase in invertebrates that can live either on the land or in caves (*troglophiles*) is associated with a decline or elimination of cave-restricted species (*troglobites*) due to competition within the habitat. Therefore, an increase in the numbers of invertebrates that are troglophile species is a danger signal for troglobites. Both types of organisms are monitored in the Devil's Icebox Cave. This ongoing project at Rock Bridge Memorial Park is known as the Pink Planarian Project, or P3. Michael Sutton of the Cave Research Foundation developed the protocol for the P3 Project during a study he conducted in 2002-2004.

While observation records have been kept for many years, the P3 scientific protocol has been followed for only two years. Because it is not possible to search the entire cave stream to determine a total population number for the pink planarian, three survey "plots" of preferred habitat were selected to follow population trends.

Numbers of pink planarians observed have varied with the season of the year. Fall numbers have averaged 27, while spring numbers have averaged 12. To date, no pink planarians have been found in tributary streams. Sutton stated, "The apparent absence of planarians from the tributary streams is of serious conservation concern, since if the main stream population suffers a catastrophe, there may not be sub-populations available to repopulate the habitat (2004)."

Below is a snapshot of the P3, showing the organisms found during the September 13, 2002 survey of a survey plot named The Shark (for a flowstone):

Table G.3 P3 results of Pink Planarian monitoring.

Date	# in 3 survey plots
9-10-04	21
4-30-05	13
9-11-05	35
5-7-06	11
9-28-06	24

Table G.4 Devil's Icebox Cave biological sampling.

Cave animals found at "The Shark" survey plot on September 13, 2002 inside Devil's Icebox Cave.

Scientific Name	Common Name	Type	Number
Macrocotyla glandulosa	Pink planarian	Troglobite	10
Caecidotea brevicauda	Isopod	Troglophile	409
Crangonyx forbesi	Amphipod	Troglophile	43
Bactrurus brachycaudus	Amphipod	Troglobite	2
Physa sp.	Snail	Troglophile	38
Effort			96 min.

In summary, the Pink Planarian Project (P3) begun in 2002 provides a sound, customized biomonitoring protocol for Devil's Icebox Cave Branch. Twice a year, survey plots inside the cave are monitored for the pink planarian and other invertebrates that share this dark aquatic *ecosystem*. P3 provides data on a species of conservation concern, and at the same time provides some indication of water quality.

G.3 Water Quality Monitoring, 2001-2006

Water quality monitoring in the Bonne Femme watershed has been ongoing since 1999, when studies were initiated at Hunters and Devil's Icebox Spring Branches (Lerch *et al.*, 2001; Lerch *et al.*, 2005). In 2001, the monitoring was expanded to include six surface sub-watersheds in addition to the two caves, and with the initiation of the Bonne Femme 319 project in 2003, an additional two surface sites were added bringing the total number of monitoring sites to ten (Figure G.1). The current monitoring program includes eight surface sub-watersheds (Clear Creek., Gans Creek., Upper Bonne Femme (at US 63), Turkey Creek., Bass Creek., Lower Bonne Femme (at Nashville Church Rd.), Little Bonne Femme Creek., and Fox Hollow) and the two karst recharge areas (Devil's Icebox and Hunters spring branches). This monitoring scheme covers about 80% of the entire watershed. Samples were collected once per quarter, since 4th quarter 2003, for nutrients, turbidity, pH, dissolved oxygen, *specific conductivity*, and temperature at all sites. Sampling for fecal bacteria was conducted for 4 weeks each quarter, with samples collected at weekly intervals. Bacterial analyses included fecal coliforms (FC), generic E. Coli (EC), and qualitative analyses for specific *pathogenic* bacteria – E. Coli O157:H7, Salmonella, and Shigella. FC analyses have been conducted at eight of ten sites since 2001; EC analyses have been conducted since 4th quarter 2004; and pathogen specific analyses have been conducted since 4th quarter 2005. If there was no stream flow, samples were not collected from stagnant pools. All laboratory methods and the sampling scheme were detailed in the Quality Assurance Project Plan (Lerch, 2004).

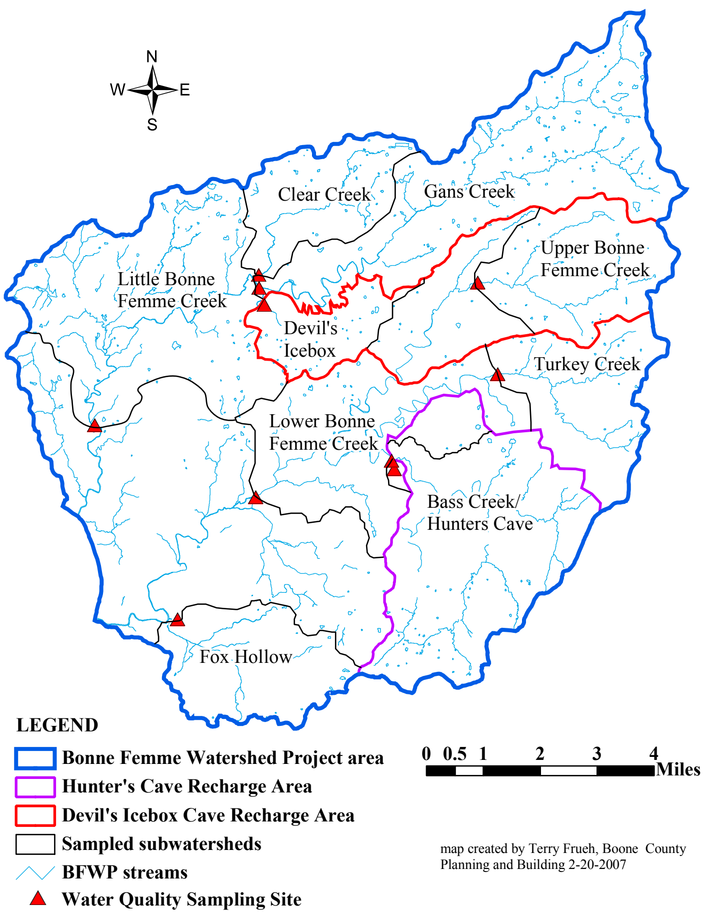

Figure G.1 Bonne Femme watershed monitoring sites.

Appendix G

General Stream Water Properties

The general water quality properties included temperature, *specific conductivity* (how many ions are in solution), dissolved oxygen, pH, and turbidity. These parameters were measured once each quarter and coincided with the collection of samples for nutrients, herbicides (2nd quarter only), and one of the weekly *pathogen* samples within a quarter. The dissolved oxygen data are expressed as absolute concentration (mg/L) and relative concentration (% saturation). Percent saturation is the measured dissolved oxygen as a percentage of the oxygen solubility in water for a given water temperature.

The general parameters were typically not statistically different over sites when the data were averaged over all ten quarters (Table G.5). Only pH was statistically different, with the Upper Bonne Femme Creek site having significantly lower pH than all but two sites. The Upper Bonne Femme Creek sub-watershed has the highest intensity of row crops (67% of the sub-watershed), and the lower pH may reflect the impact of NH_4-based fertilizer usage. Overall, the slightly alkaline pH and moderately high *specific conductivity* reflected the influence of the limestone bedrock on the water chemistry. Limestone bedrock will create slightly alkaline conditions as the limestone is dissolved by the groundwater which recharges the streams. The soluble nature of limestone, compared to most other bedrock, results in fairly high dissolved

Table G.5 General stream water properties by site.

Site	Temperature	pH	Specific Conductance	Dissolved Oxygen	Dissolved Oxygen	Turbidity
	°C*		µS/cm	mg/L	% Saturation	NTU***
Clear Creek.	13.1	7.88	525	11.84	111.2	3.6
Gans Creek.	11.7	7.76	397	11.57	105.2	17.5
Devils Icebox	11.6	7.53	424	11.05	101.7	22.9
Upper Bonne Femme	13.6	7.22	478	9.79	95.7	28.3
Turkey Creek.	13.8	7.49	586	12.04	117.1	22.7
Hunters Cave	11.5	7.73	409	11.37	103.7	11.9
Bass Creek.	13.7	7.80	455	14.39	140.3	12.6
Lower Bonne Femme	12.8	7.47	408	11.39	108.6	12.1
Little Bonne Femme	12.6	7.63	446	11.06	99.4	19.4
Fox Hollow	14.6	7.60	520	10.92	107.0	3.3
Average across sites	12.9	7.61	465	11.54	109.0	15.4
LSD**	NS	0.28	NS	NS	NS	NS

* °C= Celsius. Fahrenheit = (9/5 °C) + 32

**LSD = least significant difference. This value is the minimum difference between sites to be considered statistically different. NS = not significantly different across sites. Data are averaged over 10 quarters (3rd quarter 2004 – 4th quarter 2006).

***NTU = Nephelometric Turbidity Units.

ion levels in the water, and this is reflected in the specific conductivity data. In addition, Upper Bonne Femme Creek and Turkey Creek occasionally had very high specific conductance (>700 μS/cm) due to the use of salt on US 63 in the winter months. Eight of ten sites had average dissolved oxygen levels that were at or near 100% saturation. The lowest observed dissolved oxygen levels occurred in the third quarter of each year when the stream water temperature was highest. The lowest dissolved oxygen level observed was 5.11 mg/L (62.6% saturation); therefore, no site was under the state standard level of 5.0 mg/L. The much >100% saturation levels observed at Turkey and Bass Creeks reflected the persistent nuisance algal growth conditions at these sites. Turbidity measures the clarity of the water, and thus, both suspended sediment and algae can contribute to lower clarity and higher turbidity. Highest turbidity was observed under runoff conditions when the suspended sediment content of the water is high. Turbidity levels were occasionally elevated under low flow conditions, suggesting that algal growth was negatively impacting water clarity, especially in the 2nd and 3rd quarters of the year.

Dissolved oxygen and turbidity levels showed that eutrophication was not a problem in these streams, but nuisance algal growth was a common condition (see additional discussion in the Nutrient section). Eutrophication is a condition marked by excessive algal growth which occurs because of high nitrogen and phosphorus concentrations in the streams. The algal bloom phase begins as water temperature rises in the spring, and dissolved oxygen levels may greatly exceed 100% saturation because algae are photosynthetic organisms and photosynthesis generates oxygen. The algal bloom phase is then followed by death and decay of the algae during the late summer to early fall, resulting in very low dissolved oxygen levels that are harmful to fish and other aquatic life. Although the 3rd quarter dissolved oxygen data were the lowest of any quarter, this was mainly an effect of water temperature rather than algal decay.

Nutrients

Five separate nutrient analyses were conducted: total Nitrogen (TN); total Phosphorous (TP); dissolved nitrate-N (NO_3-N); dissolved ammonium-N (NH_4-N); and dissolved orthophosphate-P (PO_4-P). Average nutrient concentrations by site are summarized in Table G.6. Statistical analyses (analysis of variance) were conducted to determine if significant differences in average concentration existed between sites.

In general, nutrient concentrations in the Bonne Femme sub-watersheds were similar to or lower than other agricultural watersheds in northern Missouri (Blanchard and Lerch, 2000; Goolsby *et al.*, 1999). This is partially due to the lower row crop intensity of the Bonne Femme watershed compared to most northern Missouri watersheds. In addition, soils in the most intensively cropped sub-watersheds (Upper Bonne Femme Creek, Turkey Creek, Bass Creek, and Gans Creek) are predominantly claypan soils of the Mexico-Leonard Association, and these soils, although runoff prone, tend to have lower nutrient concentrations than the more well-drained soils of north-central and especially northwestern Missouri. Perhaps a better way to put these data into perspective, however, is to compare nutrient concentrations of the Bonne

Femme sub-watersheds to the recommended nutrient criteria established by the U.S. Environmental Protection Agency (EPA) (USEPA, 2000). EPA established these nutrient criteria to maintain aquatic invertebrate diversity and to prevent nuisance algal growth and *eutrophication* (excessive algal growth leading to low dissolved oxygen conditions). Based on the nitrogen criteria, all sub-watersheds suffer some degree of impairment, and this is consistent with field observations and the *EPT* (stream bug) data. The criteria for TP and PO_4-P would suggest that some streams are eutrophic, but this has not been observed as indicated above by the dissolved oxygen data. Instead, nuisance algal growth conditions and some loss of invertebrate diversity appear to be the predominant conditions throughout the watershed.

Significant differences were observed only for TN and NO_3-N across sites. For both TN and NO_3-N, the Devil's Icebox Spring Branch had the highest concentrations while Clear Creek had the lowest concentrations. TN concentrations in the Devil's Icebox Spring Branch were significantly higher than all sites except Bass Creek, and they were, on average, more than twice the concentration of six of the sites. For NO_3-N, the Devil's Icebox Spring Branch had significantly greater concentrations than six of the other nine sites. Averaged across sites,

Table G.6 Average nutrient concentrations by site*.

Site	Total N	NO_3-N	NH_4-N	Total P	PO_4-P
	mg/L				
Clear Creek.	0.33	0.14	0.028	0.068	0.053
Gans Creek.	0.68	0.23	0.046	0.163	0.059
Devils Icebox	2.11	1.71	0.032	0.159	0.102
Upper Bonne Femme Creek.	1.26	1.03	0.079	0.205	0.094
Turkey Creek.	1.24	0.97	0.048	0.155	0.076
Hunters Cave	0.65	0.24	0.019	0.102	0.039
Bass Creek.	1.48	1.09	0.033	0.092	0.055
Lower Bonne Femme Creek.	0.61	0.45	0.039	0.104	0.049
Little Bonne Femme Creek.	0.87	0.46	0.049	0.091	0.034
Fox Hollow	0.58	0.27	0.044	0.087	0.049
Average across sites	0.98	0.66	0.042	0.123	0.061
LSD**	0.72	0.75	NS	NS	NS
EPA Nutrient Criteria***	0.28-1.50	0.03-1.0^		0.01-0.09	0.003-0.06

*Average of all samples from 4th quarter 2003 to 3rd quarter 2006 (no. of samples = 11-13).
**LSD = least significant difference. This value is the minimum difference between sites to be considered statistically different. NS = not significantly different across sites.
***Lower end of the concentration range may cause decreased invertebrate diversity and nuisance algal growth while higher concentrations cause eutrophication.
^Combination of NO_3-N and NH_4-N.

NO_3-N accounted for about 67% of the TN, but those sites with the highest NO_3-N concentrations had >70% of their TN as NO_3-N, suggesting that nitrogen sources such as fertilizers, on-site sewers, and animal manures were impacting these sites. Comparisons of water quality between the two cave streams and their primary losing streams showed opposite trends for TN and NO_3-N. For the Devil's Icebox Spring Branch, the concentrations of TN and NO_3-N were much higher than its primary source of water, which is the Upper Bonne Femme Creek. The Pierpont sinkhole plain is the only land area that lies between the Upper Bonne Femme Creek and the resurgence of the Devil's Icebox spring, leading to the conclusion that the increased TN and NO_3-N were derived from the sinkhole plain. Land uses within the sinkhole plain are mainly pasture land and some residential development. Since pastures generally receive little or no fertilizer inputs, the likely sources of nitrogen were cattle and on-site sewers. The primary source of water for Hunters Cave is Bass Creek. Here the comparison between the cave stream and its water source showed the TN and NO_3-N concentrations were significantly lower in the cave stream compared to its surface water source. Apparently, the other sources of water to Hunters Cave (two tributaries of Turkey Creek) had lower TN and NO_3-N concentrations which diluted the more contaminated Bass Creek water.

Although TP and PO_4-P concentrations were not significantly different across sites, there was a considerable range in the data. TP concentrations varied from a low of 0.068 mg/L at Clear Creek to a high of 0.205 mg/L at Upper Bonne Femme Creek. PO_4-P concentrations varied from a low of 0.034 mg/L at Little Bonne Femme Creek to a high of 0.102 mg/L at the Devil's Icebox Spring Branch. Three of the fours sites with the highest TN concentrations also had the some of the highest TP concentrations, but there was generally not a good correlation between TN and TP concentrations or between NO_3-N and PO_4-P concentrations. For instance, Gans Creek had low TN concentrations, but it had the second highest TP concentration. Bass Creek had the second highest NO_3-N concentration, but it was in the lower half of the sites for its PO_4-P concentration.

Herbicides

One or more herbicides were detected at every site for the four sets of samples collected in the 2nd quarter of the year (Table G.7). There were no statistical differences in average herbicide levels across sites for any of the herbicides measured, indicating widespread transport of these chemicals from agricultural production, but it also reflected the generally low levels of the herbicides detected. Herbicide levels in row crop watersheds typically peak during the 2nd quarter of the year since this is when most of the herbicides are applied in the Midwest (Blanchard and Lerch, 2000; Lerch and Blanchard, 2003). However, average concentrations by site were lower than concentrations measured in streams of northern Missouri and southern Iowa (Lerch and Blanchard, 2003). Overall, atrazine and its *metabolites* were detected at higher levels compared to the acetanilide herbicides (i.e., metolachlor, alachlor, and acetochlor), reflecting the common usage of atrazine and its high propensity to be transported by surface runoff. Concentrations of atrazine, DEA, DIA, metolachlor, and acetochlor generally were related to the amount of row crops in each sub-watershed. For example Upper Bonne Femme and Turkey Creeks have the highest proportion of land area in row crops among the ten sites, and they also had the overall highest herbicide levels. Metribuzin and alachlor usage were apparently very low as these two herbicides were generally not detected. Low usage of these compounds also reflects state wide trends. It should be noted that the sampling scheme used in this study was too infrequent to adequately characterize herbicide concentrations. Peak herbicide concentrations were most likely much higher than those reflected in this report. However, previous research at Hunters Cave and Devil's Icebox Spring Branch showed that herbicide transport was not the primary water quality problem in the Bonne Femme watershed (Lerch *et al.,* 2001).

Table G.7 Average herbicide concentrations by site*.

Site	Atrazine	DEA**	DIA**	Metribuzin	Metolachlor	Acetochlor	Alachlor
	-------------------	-------------------	----------µg/L***----------	-------------------	-------------------	-------------------	-------------------
Clear Creek.	0.050	0.032	<0.010	0.011	0.004	<0.006	<0.005
Gans Creek.	0.770	0.314	0.129	<0.010	0.033	0.107	<0.005
Devils Icebox Spring	1.81	1.23	0.551	<0.010	0.177	0.225	<0.005
Upper Bonne Femme	4.23	1.94	0.824	<0.010	0.476	0.360	<0.005
Turkey Creek.	2.07	1.38	0.663	<0.010	0.221	0.468	<0.005
Hunters Cave	0.536	0.242	0.054	0.010	0.003	<0.006	<0.005
Bass Creek.	1.92	0.591	0.203	<0.010	0.004	0.094	0.183
Lower Bonne Femme	1.53	0.732	0.313	<0.010	0.082	0.250	0.121
Little Bonne Femme	1.60	0.641	0.304	<0.010	0.133	0.135	0.005
Fox Hollow	0.359	0.127	0.043	<0.010	0.051	0.076	<0.005
Average across sites	1.49	0.723	0.308	<0.010	0.118	0.172	0.031

*Average of samples collected in the 2nd quarter of 2004, 2005, and 2006 (no. of samples = 3 or 4).
**Atrazine metabolites. DEA = deethylatrazine; DIA = deisopropylatrazine.
***µg/L = parts per billion.

<u>Fecal Bacteria</u>

Two indicator groups of water-borne *pathogen*s were monitored in the streams, fecal *coliform* and *E. Coli*. Both groups are considered indicator organisms associated with improper waste management. Fecal coliforms represent a broad array of bacterial species present in mammal feces while *E. Coli* is a single bacterial species that is also present in mammal feces. *E. Coli* is also a subset of the fecal coliforms, thus *E. Coli* levels for a given sample will be less than the fecal coliform concentrations. These indicator bacteria generally do not survive long in soils or water; thus, there consistent detection in water over time indicates one or more sources of continual input. Neither of these groups represents direct measurement of disease-causing (i.e., pathogenic) organisms, but pathogens are likely to be present when the levels of these indicator bacteria in water are high. The reason for monitoring both indicator groups was related to the differences in State and Federal water quality standards. In Missouri, the water quality standard for swimming or other whole body contact is 200 colony forming units (cfu)/100 mL of water based on fecal *coliform* concentrations while the Federal standard is 126 cfu/100 mL based on *E. Coli* concentrations. Note that the whole body contact standards are distinctly different from the maximum contaminant levels allowed in finished drinking water. The U.S. EPA maximum contaminant level for drinking water for either fecal coliform or *E. Coli* is zero cfu/100 mL, which is routinely achieved with disinfection techniques used by drinking water treatment plants.

Over the course of this study, fecal coliform and *E. Coli* data ranged from <10 cfu/100 mL to >5000 cfu/100 mL at all sites. Because of the wide range in the data, statistical analyses were performed on the $\log_{10}$ transformed data. The log-transformed data varies over a narrower range than the raw data and this allows for better discrimination in the statistical analyses. Average log transformed fecal coliform and *E. Coli* data by site are given in Table G.8. Fecal coliform data ranged from 1.72 $\log_{10}$(cfu/100 mL) at Clear Creek to 2.49 $\log_{10}$(cfu/100 mL) at Fox Hollow. The two sites with the highest fecal coliform concentrations, Turkey Creek and Fox Hollow, had statistically greater concentrations than the five sites with the lowest concen-

Table G.8 Average fecal coliform and *E. Coli* concentrations by site.

Site	Fecal Coliform	*E. Coli*
	--------$\log_{10}$(cfu/100 mL)*	-----------
Clear Creek.	1.72	1.54
Gans Creek.	2.07	1.91
Devils Icebox Spring Br.	2.30	2.06
Upper Bonne Femme Creek.	2.17	1.95
Turkey Creek.	2.46	2.38
Hunters Cave	1.93	1.73
Bass Creek.	2.00	1.84
Lower Bonne Femme Creek.	1.97	1.86
Little Bonne Femme Creek.	2.14	1.94
Fox Hollow	2.49	2.26
Average across sites	2.13	1.95
LSD**	0.35	0.35

*Statistical analysis was performed on log transformed data.

**LSD = least significant difference. This value is the minimum difference between sites to be considered statistically different.

trations (Clear Creek., Gans Creek., Bass Creek., Hunters Cave, and Lower Bonne Femme Creek.). Based on statistical differences among sites, the average fecal coliform concentrations fell into three categories: high – Fox Hollow, Turkey Creek., and Devil's Icebox Spring Branch; medium – Upper Bonne Femme Creek., Little Bonne Femme Creek., and Gans Creek; and low – Bass Creek., Lower Bonne Femme Creek., Hunters Cave, and Clear Creek. Average fecal coliform concentrations of the high category sites were equal to or greater than the whole body contact standard (2.30 $\log_{10}$(cfu/100 mL) = 200 cfu/100 mL).

Average *E. Coli* data varied from a low of 1.54 $\log_{10}$(cfu/100 mL) at Clear Creek to a high of 2.38 at $\log_{10}$(cfu/100 mL) at Turkey Creek. On average, *E. Coli* concentrations were about 9% lower than fecal coliform concentrations. The two sites with the highest average *E. Coli* concentrations, Turkey Creek and Fox Hollow, had significantly greater concentrations than every site except the Devil's Icebox Spring Branch (Table G.8). Average *E. Coli* concentrations at the two highest sites also exceeded the Federal whole body contact standard (2.1 $\log_{10}$(cfu/100 mL) = 126 cfu/100 mL). Categorizing the sites based on statistical differences between sites resulted in the following: high – Turkey Creek and Fox Hollow; medium – Devil's Icebox Spring Branch, Upper Bonne Femme Creek, Little Bonne Femme Creek, and Gans Creek; low – Lower Bonne Femme Creek, Bass Creek, Hunters Cave, and Clear Creek. Thus, both sets of indicator bacteria resulted in very similar categories based on statistical differences across sites. The three sub-watersheds with the highest levels of bacterial contamination (Turkey Creek., Fox Hollow, and Devil's Icebox Spring Branch) have consistently greater inputs of fecal bacteria compared to the other sites. Although these data do not indicate the source of the fecal bacteria, there are three likely sources in the Bonne Femme watershed – on-site sewers, livestock, and wildlife.

The U.S. EPA recommends that five approximately equally spaced samples be collected over 30 days when monitoring for compliance with the fecal bacterial whole body contact standards.

Since our scheme was very similar to the recommended scheme (four samples collected at weekly intervals over 28 days), the data were used to assess compliance of the Bonne Femme watershed streams with the State and Federal water quality standards. Another requirement for comparing data against the whole body contact standards is that the geometric mean of a sample set is computed and compared against the standard rather than the arithmetic mean. The geometric mean is computed as $(x_1 X x_2 X x_3 \ldots X x_n)^{1/n}$, where x_1 equals the bacterial concentration of the 1st sample in a set, with up to n samples collected. For our sampling scheme, n equals 4. The geometric mean for data covering a wide range will be less skewed than an arithmetic mean, and therefore, very high or very low bacterial concentrations will not have an undue impact on the geometric mean. This method was used to compute the fecal coliform and *E. Coli* geometric means for each quarterly sample set for the Bonne Femme watershed streams. The data were then grouped by site and the percentage of quarters exceeding the whole body contact standards were graphed (Figure G.2). All sites exceeded the State and Federal standards at least 10% of the time and the three sites with the highest bacterial contamination exceeded both standards >60% of the time. Even Clear Creek., which receives much of its base flow from groundwater pumped from the USGS Environmental Research Center Laboratory, exceeded the standards in a few quarters. Overall, the results showed that the fecal coliform standard (200 cfu/100 mL) used by the State of Missouri was exceeded in 40% of the quarters at seven of the ten sites. However, the Federal standard was shown to be more stringent. The Federal whole body contact standard for *E. Coli* (126 cfu/100 mL) was exceeded in 50% of the quarters at eight of ten sites.

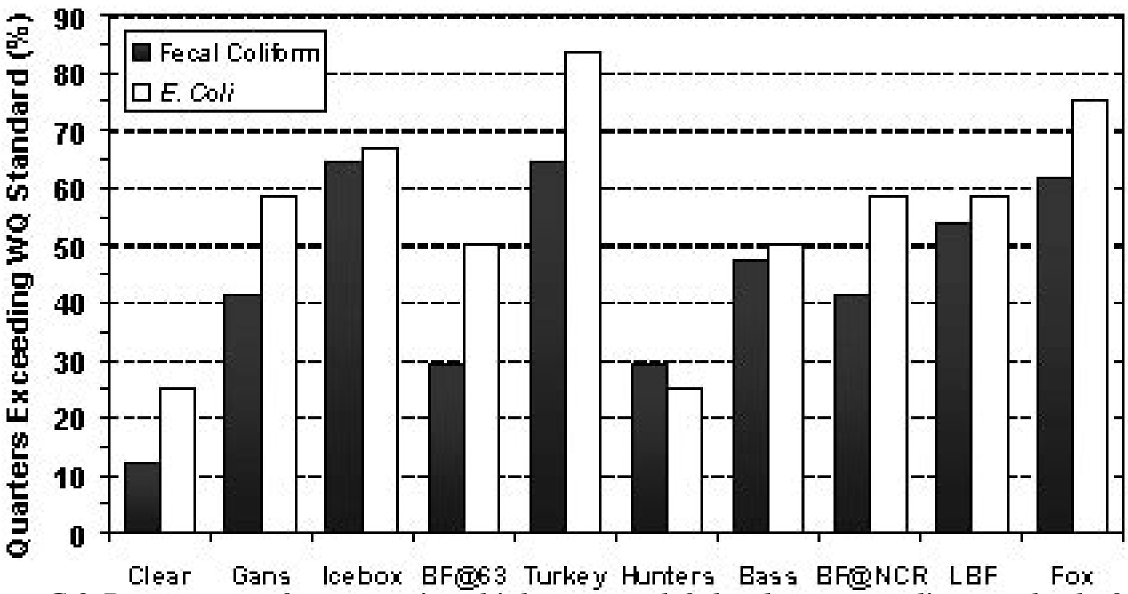

Figure G.2 Percentage of quarters in which state and federal water quality standards for whole body contact were exceeded.

Data are based on computation of geometric mean of 4 samples/quarter and compared against state and federal water quality standards. Federal Whole Body Contact Standard = 126 cfu/100 mL based on *E. Coli*. Missouri Whole Body Contact Standard = 200 cfu/100 mL based on Fecal Coliforms. Fecal coliform data were based on 17 quarters (1st Q 2001 to 3rd Q 2006); *E. Coli* data were based on 12 quarters (4th Q 2003 to 3rd Q 2006).

<u>Specific Water-Borne Pathogens</u>

Beginning with the 3rd quarter of 2005, additional analyses were conducted by the USDA-Agricultural Research Service for the detection of three specific water-borne pathogens: *E. Coli* O157:H7, *Salmonella*, and *Shigella*. The methods used were based on DNA extraction from water samples collected at each site, followed by addition of a DNA primer that binds to one or more specific gene sequences that are indicative of a particular organism.

Appendix G

In the case of *E. Coli* O157:H7, three separate genes were required for positive identification (Fratamico *et al.*, 1995) whereas a single gene was used to identify *Salmonella* (Aabo *et al.*, 1993) and *Shigella* (Hartman *et al.*, 1990). These methods are qualitative, meaning that they are limited to indicating the presence or absence of the pathogens. These three organisms are known human pathogens capable of causing food-borne gastrointestinal illnesses, but they are also associated with feces and therefore may contaminant streams and lakes, causing disease through oral contact or ingestion of contaminated water (Wikipedia, 2006). *Salmonella* and *Shigella* are genus classifications that can be further categorized into several species, with each species having multiple serotypes (or strains). *E. Coli* O157:H7 is one of hundreds of serotypes of the species *E. Coli*, and it is a common food contaminant associated with the guts of grain-fed cattle. The Centers for Disease Control and Prevention (http://www.cdc.gov/ncidod/dpd/healthywater /factsheets/ ecoli.htm) states that, "*E. Coli* O157:H7 is most commonly found on a small number of cattle farms where the bacteria can live in the intestines of healthy cattle." In addition, *E. Coli* O157:H7 has also been detected in the guts of swine and deer, which may also serve as carriers for the disease. Like fecal coliforms and generic *E. Coli*, these disease causing bacteria can enter surface waters through sewage overflows, polluted storm water runoff, and polluted agricultural runoff.

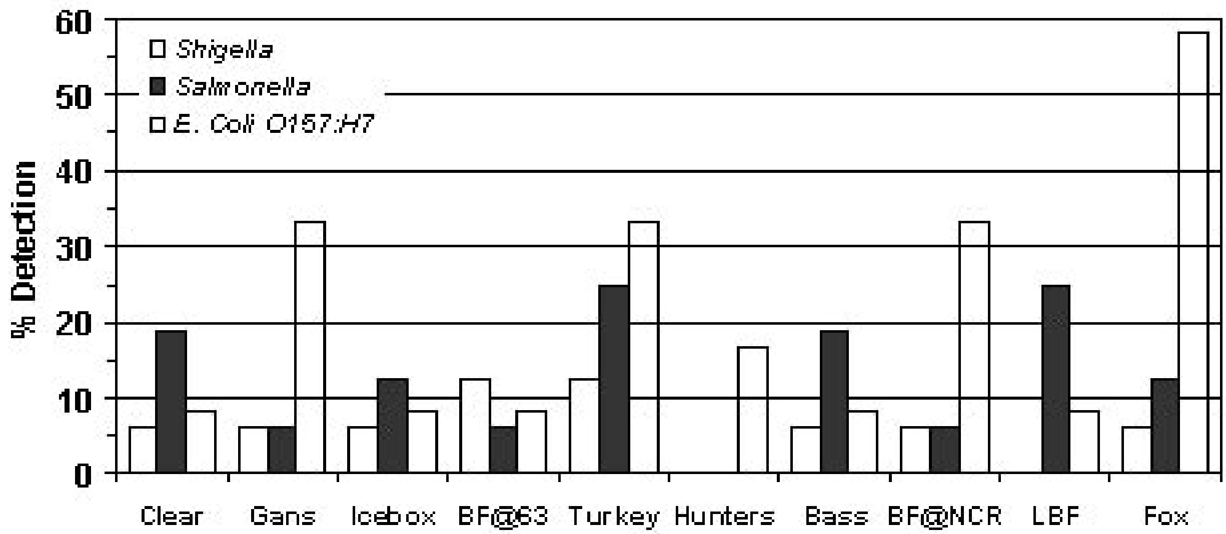

Figure G.3 Detection frequency of specific waterborne pathogens in Bonne Femme watershed.

Data for *Salmonella* and *Shigella* are based on 16 samples per site (3rd quarter 2005 to 2nd quarter 2006); data for *E. Coli* O157:H7 are based on 12 samples per site (4th quarter 2005 to 2nd quarter 2006).

Each of the three pathogens was detected at most of the ten sites monitored (Figure G.3), and at least one pathogen was detected at every site. *Shigella* was detected at eight of ten sites, but generally at lower frequency than *Salmonella* or *E. Coli* O157:H7. *Salmonella* was the most commonly detected pathogen at four of the ten sites, with 33% of the samples collected from Turkey and Little Bonne Femme Creeks testing positive for *Salmonella*. *E. Coli* O157:H7 was the most commonly detected of the pathogens, with at least one detection at every site. Five of the ten sites had multiple detections of *E. Coli* O157:H7. Three sites (Gans Creek, Turkey Creek, and Lower Bonne Femme Creek) had *E. Coli* O157:H7 detected in 33% of their samples, and Fox Hollow had *E. Coli*i O157:H7 detected in 58% of it's samples. These data do not definitively indicate source, but they do point to cattle as a probable source of *E. Coli* O157:H7 at those sites with frequent detections. Of the common carriers of *E. Coli* O157:H7 (cattle, swine, and deer), swine can be eliminated as there are no sizable swine operations within the Bonne Femme watershed. Deer are likely responsible for the widespread nature of the detections, explaining the presence of *E. Coli* O157:H7 at sites with otherwise low fecal contamination, such as Clear Creek and Hunters Cave (Table G.8). Although data on specific numbers of cattle by sub-watershed cannot be reliably compiled, there are major cattle operations in the four watersheds with the highest detection frequency of *E. Coli* O157:H7. Furthermore, the Fox Hollow sampling site is immediately downstream from a large cattle grazing operation (see additional discussion below).

Fecal Bacteria Contamination in Relation to Season, Land Cover, and Stream Properties

The data collected from the monitoring of the Bonne Femme watershed streams showed that fecal bacterial contamination of streams varied significantly across sites and over time. In an effort to explain these differences, several factors were considered to explain the observed variation, including season, land cover (Figure 3.2, p. 47), and general stream water properties (based on data from Table G.5). Statistical analyses were performed to determine if these factors were related to fecal bacterial contamination.

Statistical analysis of fecal bacterial contamination over time (i.e. quarters of the year) showed significant differences based on the season in which the sample was collected (Table G.9). For both fecal coliforms and *E. Coli*, the 2nd and 3rd quarters of the year had significantly greater levels of fecal bacteria than the 1st and 4th quarters of the year. Given that the input sources (human, cattle, wildlife) do not vary considerably with the season of the year in this watershed, the data indicates that fecal bacterial contamination of the streams was strongly weather related. In the 1st and 4th quarters of the year, colder air and soil temperatures likely resulted in faster die-off of fecal bacteria released to the environment, and therefore, there were fewer bacteria available for transport during fall and winter compared to spring and summer. Additionally, precipitation events in spring and summer are more frequent and more likely to generate runoff than in fall and winter. Thus, the 2nd and 3rd quarters apparently had greater populations of fecal bacteria surviving in the soil environment combined with a greater probability of runoff events capable of transporting fecal bacteria to the streams.

Table G.9 Average fecal coliform and *E. Coli* concentrations by quarter of the year.

Quarter	Fecal Coliform	*E. Coli*
	log10(cfu/100 mL)	
1st	1.53	1.24
2nd	2.50	2.28
3rd	2.47	2.34
4th	1.95	1.86
LSD	0.22	0.21

Of the stream water properties measured (temperature, pH, *specific conductivity*, dissolved oxygen, and turbidity, Table G.5), there were no significant correlations of these parameters to fecal coliform or *E. Coli* concentrations in the streams. However, a much larger data set exists at the two cave sites for the stream water properties and fecal coliform concentrations, with data collected as far back as 1999 and at much greater frequency than was conducted for this project (Lerch *et al*, 2001). Of the general stream water properties measured at the two caves, only turbidity was shown to significantly correlate to the fecal coliform concentrations. At Hunters Cave, 72% of the variation in fecal coliform concentrations could be explained by the turbidity levels of the water. The correlation between turbidity and fecal coliform concentrations at the Devil's Icebox Spring Branch was much lower, but still significant, because high bacterial concentrations were observed even when turbidity was low. Other researchers have reported a significant relationship between fecal bacterial concentrations and turbidity (Rasmussen and Ziegler, 2003) in surface streams, and it is probable that with a more intensive monitoring regime such a relationship also exists for the surface streams in the Bonne Femme watershed. The only other physical parameter that significantly correlated to fecal bacterial concentrations was stream discharge, but this data only exists at the two cave sites. Although both fecal coliform and *E. Coli* concentrations significantly correlated to stream discharge at the caves, *E. Coli* showed a much stronger correlation to discharge than fecal coliforms. The correlations of fecal bacterial concentrations to turbidity and stream discharge indicated that fecal bacterial concentrations, in general, will be greatest for runoff events with high turbidity. These events have enough energy to induce soil erosion, resulting in transport of sediment-bound fecal bacteria to the streams.

None of the major land cover classes (impervious, urban, row crops, grasslands, or forest, Figure 3.2, p. 46) was significantly correlated to either fecal coliform or *E. Coli* concentrations (Table G.8) in the streams. This result suggests multiple sources or fairly uniformly distributed non-point sources of fecal bacteria exist across the sub-watersheds. Given the wide variation in land cover and human population across sub-watersheds (Figure 3.2, p. 46), multiple but different sources apparently exist. Multiple sources seemed to be the cause of contamination in most sub-watersheds (e.g., Turkey Creek, Little Bonne Femme Creek, Upper Bonne Femme Creek, and Gans Creek) while site specific sources of fecal bacteria appear to be responsible for the high levels observed at two sites (Devil's Icebox Spring Branch and Fox Hollow).

The site specific sources in the Devil's Icebox Spring Branch appear to be from private residences within the Pierpont sinkhole plain where on-site sewers discharge to the cave via transport through the sinkholes. Evidence for this is two-fold: 1) the consistently higher levels of fecal bacteria in the Devil's Icebox Spring Branch compared to Upper Bonne Femme Creek, the main source of water to the Devil's Icebox Spring Branch; and 2) frequently observed high concentrations under low-flow conditions. Regarding the first point, the increase in fecal bacterial concentrations between Upper Bonne Femme Creek and the Devil's Icebox Spring Branch (Table G.8) indicates that additional sources are entering the cave between the losing stream reach in Upper Bonne Femme Creek and the cave stream resurgence. The only land area between these points is the sinkhole plain. Moreover, the distance between the losing reach of Upper Bonne Femme Creek and the Devil's Icebox Spring Branch resurgence is at least four miles, and it would be expected that some die-off of the fecal bacteria or dilution from other tributaries to the cave stream would occur along this lengthy flow path if there were no other bacterial inputs. For example, comparison of fecal bacterial concentrations in Hunters Cave to Bass Creek, the main water source to Hunters Cave, showed that the levels in Hunters Cave were consistently lower than Bass Creek (Table G.8). Thus, dilution or die-off occurred along the sub-surface flow path, yet this flow path is much shorter than that of the Devil's Icebox Spring Branch. With regards to the second point, under low flow conditions the Devil's Icebox Spring Branch had 18 of 41 samples with fecal coliform concentrations >200 cfu/ 100 mL compared to only 10 of 39 samples >200 cfu/100 mL at Upper Bonne Femme Creek. For the *E. Coli* data, Devil's Icebox Spring Branch had 21 of 41 samples with concentrations > 126 cfu/100 mL while Upper Bonne Femme Creek had only 9 of 40 samples >126 cfu/100 mL. Since high bacterial inputs were apparent under low flow conditions, this precludes surface runoff from livestock grazing lands or wildlife as the source, and thus, implicates on-site sewers as the probable source of this additional input to the cave. As discussed above, similar trends for TN and NO_3-N were also observed between Upper Bonne Femme Creek and the Devil's Icebox Spring Branch, providing further evidence that on-site sewers in the sinkhole plain have contributed to water quality degradation in the Devil's Icebox Cave Branch.

The other monitoring site with site-specific causes of contamination is Fox Hollow. The monitoring site is immediately downstream of a sizable cattle operation. The cattle have unrestricted stream access (and were frequently observed in the stream) and manure is stored in the open within 100 feet of the stream. In addition, the pasture land adjacent to the stream is overgrazed and there are no riparian management practices employed to stabilize the stream banks or to mitigate fecal bacterial transport. Not coincidentally, this site had the highest fecal coliform levels, 2nd highest *E. Coli* levels, and the highest occurrence of *E. Coli* O157:H7 of the sites monitored.

Significant fecal bacterial contamination occurred at several sites for which no site specific sources of bacteria were apparent, and therefore, multiple sources appeared to be the cause of contamination. This was the case for Turkey Creek, Upper Bonne Femme Creek, Little Bonne Femme Creek, and Gans Creek. For example, Turkey Creek had the highest fecal coliform, *E. Coli*, and occurrence of specific pathogens as any site except for Fox Hollow. Turkey Creek has a very low human population, but 43% of this sub-watershed's area is grasslands with several sizable cattle operations. As was the case in Fox Hollow, many of the grassland areas are overgrazed, cattle have unrestricted access to the streams, and there is little or no riparian management, especially in the upper portions of the sub-watershed. Apparently, multiple cattle operations were the cause of contamination in Turkey Creek. Sub-watersheds with substantial human populations and considerable agricultural land uses, such as Little Bonne Femme Creek and Gans Creek, likely have a combination of human sewage and cattle inputs as the sources of fecal contamination. Sites with the lowest contamination, such as Clear Creek and Hunters Cave, may largely represent background inputs from wildlife with only limited contributions from cattle or on-site sewers.

Conclusions

The following general conclusions can be reached from the monitoring study:

- General stream water properties indicate no acute contamination, with all five properties measured falling within typical ranges for carbonate bedrock streams, and dissolved oxygen levels above the State minimum standard of 5 mg/L;
- Nutrient levels were similar to or less than streams in other agricultural watersheds of northern Missouri. There was no evidence of acute contamination at any site;
- The combination of dissolved oxygen, turbidity, nutrient levels, and field observations indicated that all sites have some level of nuisance algal growth and presumed loss of macroinvertebrate diversity, but eutrophication conditions have not occurred at any site;
- At least one herbicide or *metabolite* was detected in every sample at all sites, but typically at low levels. Atrazine and its metabolites had the highest average concentrations at all sites;
- Fecal bacterial contamination was widespread with significant differences observed across sites and over seasons. Concentrations of fecal bacteria were highest in spring and summer;
- Whole body contact standards for fecal bacteria were commonly exceeded. Seven of ten sites exceeded the State fecal coliform standard 40% of the time. Eight of ten sites exceeded the Federal *E. Coli* standard 50% of the time;
- Frequency of detection of specific pathogens was in the following order: *E. Coli* O157:H7 > *Salmonella*> *Shigella*. The pattern of *E. Coli* O157:H7 detections indicated that cattle were the probable source;

• Of the general stream water properties measured, concentrations of fecal bacteria were significantly correlated only to turbidity and stream discharge (based only on the two cave sites);
• Land cover classes did not significantly correlate to the concentrations of fecal bacteria;
• Multiple sources apparently were the cause of contamination in most sub-watersheds while site specific sources of fecal bacteria appear to be responsible for the high levels observed at the Devil's Icebox Spring Branch (most likely from on-site sewage) and Fox Hollow (most likely from cattle).

G.4 Bonne Femme Dye Traces

Introduction

The following information is summarized from "Bonne Femme Watershed Project Dye Trace Final Report" (Frueh and Lerch, 2006).

Groundwater recharge in karst systems is highly vulnerable to pollution since there is little-to-no filtering of surface water as it enters subterranean conduits. Nonpoint source (NPS) pollutants are transported to streams and sinkholes dissolved in water and bound to sediments suspended in surface runoff. This pollution poses a special threat to karst systems, in part because it is spread throughout a watershed and therefore is harder to control, and in part because aquatic life in karst systems tend to be especially vulnerable to pollution. Thus, it is important to know the recharge area (the land area that contributes water to a cave) of a cave stream in order to determine the sources of water and their associated land uses. This delineation of the recharge area of a cave system provides the basic information required to protect organisms living in its water. Dye tracing is a method frequently used to determine hydrogeological flow characteristics of an area, and it is the primary tool available for delineating recharge areas.

Two dye trace experiments were performed by the Bonne Femme Watershed Project. The first dye trace, carried out during winter 2003-2004, confirmed that the reach of Bonne Femme Creek downstream of Highway 163 loses water to the Devil's Icebox Cave Branch. This approximately one-mile-long reach was previously determined to be losing continuously along the reach (St. Ivany, 1988), and thus is presumed to lose flow to Devil's Icebox Cave Branch down to the point where elevation precludes transmission of water to the cave (estimated to be 700 feet above sea level). The results of this dye trace allowed us to add approximately 2.0 square miles (5.2 square kilometers) to the known Devil's Icebox recharge area (Frueh and Lerch, 2006). The second dye trace, carried out in the summer of 2004, indicated that Gans Creek does not lose any water out of the stream channel to any springs during low flow conditions, although further study is needed to confirm these results. However, it is important to note that St. Ivany (1988) found that Gans did lose a portion of its water during normal flows to a spring located in the Gans Creek floodplain, but Gans Creek did not lose water to the Devil's Icebox Cave Branch under low and normal flow conditions.

Appendix G

Previous Karst Studies

Devil's Icebox Cave Branch

Previous studies established that surface water flows from both the upper Bonne Femme Creek and the Pierpont Sinkhole Plain to the Devil's Icebox Cave Branch (DI). Work completed in the 1980s showed that the reach of Bonne Femme Creek between Highways 63 and 163 loses water that flows to DI (St. Ivany, 1988). The water is lost via a swallow hole (a sinkhole located in the stream bed) and other cracks in the bedrock of the stream channel within this reach. The 'lost' water flows through sub-surface conduits to DI. The initial recharge area delineation for DI was based on these studies in combination with surface water drainage patterns and topography, giving an estimated recharge area of 11.1 square miles (26.4 square kilometers).

St. Ivany postulated that the reach of Bonne Femme Creek downstream of Highway 163 loses to DI because flow continued to decrease in the reach proceeding downstream from the Highway 163 bridge (St. Ivany, 1988). Its flow decreased enough to meet the standard for classifying it as a losing stream according to Missouri Department of Natural Resources rules. The drainage area of this section that could flow to DI, excluding the area upstream from the bridge, is approximately 2.0 square miles (5.2 square kilometers) in size. However, St. Ivany did not perform the dye tracing studies to confirm that this flows to DI.

Clear and Gans Creeks were confirmed to be gaining streams (and therefore are not losing to DI nor other cave systems) (St. Ivany, 1988). A gaining stream's flow increases when moving downstream due to small tributaries contributing flow, and shallow groundwater being added from the channel banks and channel bottom. St. Ivany did note that Gans Creek seemed to lose some water in one reach, but he showed that this lost water remains in the main stream valley. The lost water flows down through the upper unit of the Burlington Limestone, then flows laterally when it reaches the middle unit of the Burlington Limestone to re-surface further downstream in both Gans Creek and a spring (located in the Gans Creek floodplain) that flows into Gans Creek.

Hunter's Cave

Although Hunters Cave (HC) is not directly related to the dye traces described here, brief discussion of its study is warranted because it is in the Bonne Femme watershed, and it is in close proximity to the traces. Lerch et al. (2005) used dye tracing to delineate the HC recharge area. They found that most of its recharge comes from Bass Creek. This creek loses water to Hunters Cave several hundred yards upstream from its entrance, with its water entering the cave at Angel Spring. In addition, two tributaries to Turkey Creek on its south side were confirmed to lose to HC, although the main channel of Turkey does not. These two tributaries lose at a geologic fault along which HC is formed. The contributing recharge area for HC is approximately 12.9 square miles (33.4 square kilometers) and includes portions of the City of Ashland and the Columbia Regional Airport (Figure G.4).

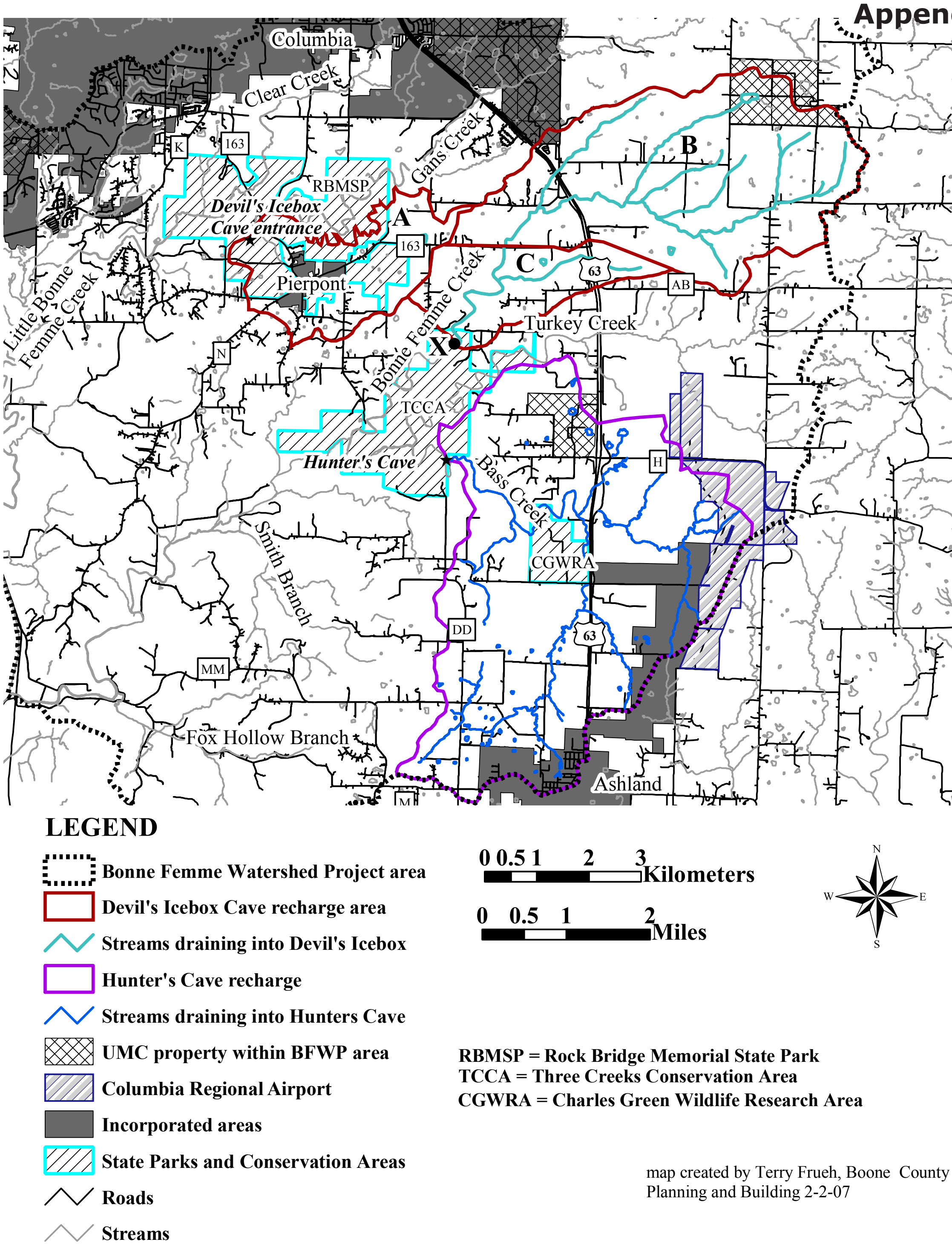

Figure G.4 Devil's Icebox Recharge area.

Appendix G

Methodology

Both of the Bonne Femme Watershed Project dye traces used standard dye tracing techniques, involving the introduction of fluorescent dyes into stream channels and their subsequent *adsorption* from the water by activated carbon samplers (Aley, 1999). These samplers adsorb dye continuously while they are in place, thereby giving a total amount of dye collected integrated over time. In order to avoid the potential for cross-contamination between the two traces, two distinct dyes were used (fluorescein dye in the Bonne Femme Creek trace, and rhodamine WT dye in the Gans Creek trace). The Bonne Femme Creek and Gans Creek trace samplers were placed at 3 and 5 locations, respectively. The specific location for dye injections and locations of activated carbon samplers are given in Figure G.5. It is important to place samplers at all locations where they could potentially catch dye. They were placed downstream from all dye introduction points, and at lower elevations. In addition, they were placed in other locations that could potentially have a hydrogeological connection (i.e. in adjacent basins in order to assess the possibility of inter-basin transfer, and springs within the same subwatershed). The dye was released into the middle of flowing water to ensure it mixed in well with the flowing portion of the stream. In addition, the person who released the dye ensured that no dye splashed on them in order to avoid the possibility of inadvertently contaminating samplers.

Carbon samplers were in place for 3-7 days prior to each injection in order to determine if there was already dye present in the system before releasing the dye into the stream. These background measurements are important in order to determine that any samplers that detected dye were not contaminated by pre-existing dye in the system. Samplers were typically collected and replaced at weekly intervals for up to 2 months following dye introduction. For example, the first sampler, labeled 3 DAI (Days After Injection) was left in place from the day of injection until 3 DAI, and the second sampler, labeled 7 DAI, was in place for the period 4-7 DAI. For more details, see Frueh and Lerch (2006).

Results and Discussion

Bonne Femme Creek dye injection

In Bonne Femme Creek, the largest volume of fluorescein dye appeared in the sampler collected 3 DAI, with a much smaller volume of dye found in the sampler collected at 17 DAI, and virtually no dye at 30 DAI. These results are expected since one would assume that under high flow conditions at least some water would stay in the main channel into which it was introduced. The results also indicate the dye is flushed through the channel relatively quickly. For DI, the sampler collected at 3 DAI had a similar volume of dye as that of the Bonne Femme Creek collected the same day. However, the DI samplers collected at 7 and 17 DAI also had large volumes of dye collected (approximately 1/5 of that from 3 DAI), in contrast to that of Bonne Femme Creek for the same DAI, which had only a barely perceptible amount of dye collected. These elevated volumes of dye indicate that the water moves through DI quickly

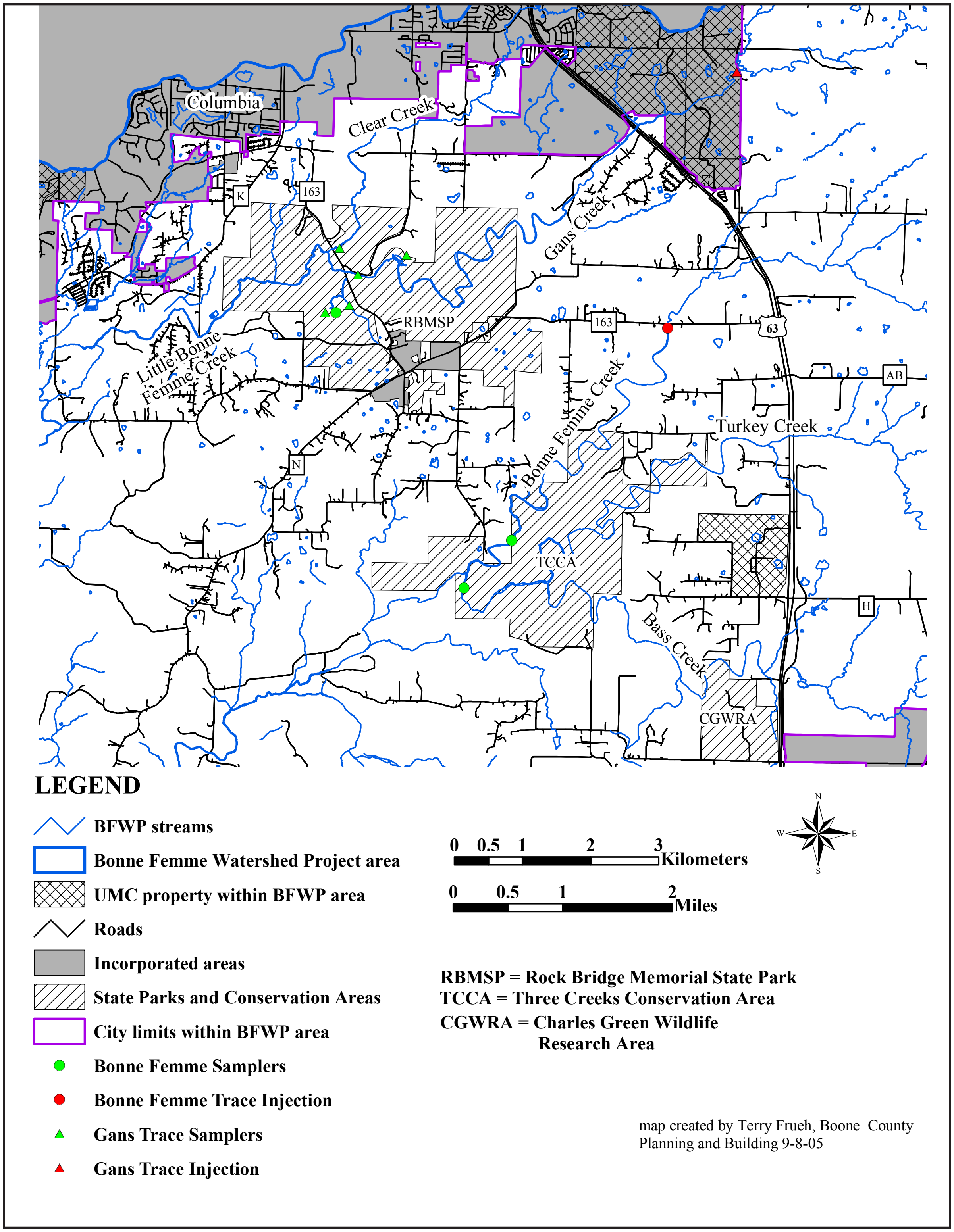

Figure G.5 Dye Trace Locations

(as evidenced by the high volume at 3 DAI), but some of it is also moves through slowly (as evidenced by the moderate volumes at 7 and 17 DAI). Turkey Creek samplers detected no dye. None of the samplers detected the dye used for the other trace, rhodamine WT.

The reach of Bonne Femme Creek downstream from Highway 163 is verified to lose to DI, thereby confirming what St. Ivany (1988) hypothesized was occurring within this reach. The trace also indicates that this reach of Bonne Femme Creek loses no water to Turkey Creek.

The drainage area that contributes to the losing section of Bonne Femme Creek confirmed in this trace is approximately 2.0 square miles (5.2 square kilometers) (Figure G.4, area C). The two recharge areas; the Pierpont Sinkhole Plain (Fig. G.4, area A), and the upper Bonne Femme Creek subwatershed (Fig. G.4, area B); that were found to be losing in previous studies (King and Hargrove, 1973; St. Ivany, 1988) have areas of 3.6 square miles (9.3 square kilometers) and 7.5 square miles (19.4 square kilometers), respectively. Therefore the total identified DI recharge area is approximately 13.1 square miles (34.0 square kilometers). This recharge area contains portions of the recently-formed village of Pierpont, unincorporated Boone County, University of Missouri's Bradford Research Farm, Rock Bridge Memorial State Park and Three Creeks Conservation Area.

Gans Creek dye injection

The only detection of dye for this trace was a small volume of rhodamine WT dye that occurred in Gans Creek, which occurred for the sampler picked up at 30 DAI; all of the other samplers had no detection of either dye. The fact that the only detect was for the period 14-30 DAI indicates water moved slowly through the system. Its low volume means there was very little dye in the water column. As dye was not found in any other locations (and therefore no dye was lost from the system), the weak detect suggests the dye was broken down by *photolysis*; this hypothesis is further supported by the long travel time, thereby allowing ample time for breakdown from sunlight to occur. Also, at this time of year, the days are long and the sun is at a high angle in the sky, giving more time and energy for this breakdown to occur.

The lack of any dye detection at Gans Creek Spring runs counter to St. Ivany's work (1988), although the results for this trace from Frueh and Lerch need further confirmation (2006). St. Ivany (1988) found that dye was detected at this spring 3 weeks after injection, indicating a slow movement through the gravel in the alluvial plain, and possibly through a minor fracture in the bedrock. His hypothesis was further supported by his observation that the spring stopped flowing when Gans Creek stopped flowing during summer months. He also found that under low and normal flows, water did not leave the Gans Creek Valley to enter the Devil's Icebox Cave Branch or other watersheds. Upon analyzing the geology, surface water flow measurements, and dye traces, St. Ivany concludes Gans Creek's water stays within its valley. The lack of dye detection in Gans Creek Spring for this dye trace could be due to the low flow conditions causing sunlight-induced breakdown of dye. In addition, it is possible that flow in the creek was not high enough to allow water with dissolved dye to enter karst conduits that flow to Gans Creek Spring.

G.5 Subwatershed Sensitivity Analysis, a Planning Tool

The Steering Committee wanted to have an independent, scientifically-based decision-support tool created to help the Stakeholders in their planning effort. It was decided to hire a consultant who had experience doing hydrologic analysis, who could use the latest technologies to create *GIS* data layers, and who could create an interactive model for forecasting future stream conditions.

Formed by the Steering Committee, a group of technical experts wrote a Request for Proposals (RFP) to complete a Subwatershed Sensitivity Analysis of the Bonne Femme Watershed that would serve as a decision-support tool for the Stakeholder Committee. Writing the RFP was challenging because the group had never seen an analysis completed at a similar scale and depth of study that combined hydrological modeling and a natural resource assessment. Therefore, they could not precisely state how the goals of the RFP were to be met. Thus, the RFP requested a creative approach to analyzing the streams within the watershed. Three consultants responded to the RFP, of which Applied Ecological Services (AES) was selected since they had the response that best fit the Project's needs. Following is a brief description of the Subwatershed Sensitivity Analysis they completed.

In this analysis, a variety of techniques were used to obtain a more comprehensive assessment of the watershed. Three different models were used to assess stream conditions.

The following is excerpted from the Subwatershed Sensitivity Analysis:

> Stream Carrying Capacity Model
>
> The Stream Carrying Capacity Model uses soil permeability, topography and land use to assess existing stormwater runoff and predict future stormwater runoff. In the model, future runoff is based on projected changes in permeability as a result of predicted land use changes. This model indicates that existing runoff in the upper reaches of the watershed has already resulted in the degradation of streams in lower reaches. This concurs with field observations. The model also indicates that stream channels are stable ("acceptable") in the Upper Bonne Femme, Turkey Creek, Turkey/Bass Confluence and Bass Creek subwatersheds. However, observations in the field indicated that these "acceptable" subwatersheds are relatively unstable in the upper reaches due primarily to poor land management practices and loess or sandy soils, and relatively stable in the lower reaches where the creek bed and bank consists of large rock and cobble. The instability in the upper reaches is a concern most notably for the karst recharge areas that comprise most of the Upper

Bonne Femme and Bass Creek subwatersheds. If sediment or other material is actively being transported into these conduits, this could be detrimental to sensitive cave *ecosystems*.

Stream Sensitivity Model

The Stream Sensitivity Model uses existing and projected impervious surfaces as modified by field criteria to measure the vulnerability of streams to degradation. This analysis is based on observations that watersheds with less than 10% impervious cover remain healthy; watersheds with 10-25% impervious cover are "impacted" and somewhat degraded; and watersheds with more than 25% impervious cover are highly degraded and difficult to restore.

This model indicates that subwatersheds around Columbia and Ashland are currently "impacted." This trend is expected to continue during projected build out conditions with downstream subwatersheds degrading further. Subwatersheds contiguous to Columbia and Ashland are restorable with the implementation of new and remedial BMPs discussed in a subsequent section.

Landscape Function Model

This model uses ecological communities as defined by National Land Cover Data (NLCD) as a surrogate for how well the landscape functions. This model indicates that landscape function is most degraded around Columbia and Ashland due to development pressure and within the upper reaches of the watershed where the native prairie has been converted to agricultural land uses where poor management practices are employed. Floodplains along the lower reaches of the watershed that have been converted from bottomland forest to agricultural land with poor management practices also are rated poorly. Highest quality landscape functions exist in the remnant woodlands along steep and rugged terrain.

Watershed Trends and Implications of the Models

1. In the upper reaches of the watershed, the conversion of native prairie to agricultural uses without appropriate BMPs in place has resulted in increased stormwater runoff and decreased soil stability. As a result, streams in the upper reaches are downcut and eroding. Increased flows in the upper reaches also have led to stream degradation in the lowest reaches of the watershed.

2. In the lower reaches of the watershed, the conversion of floodplain bottomland forest to agricultural uses without appropriate BMPs in place has also led to increased runoff and decreased soil stability. Most of the streams

in the lower reaches are entrenched, shear, unstable and disconnected from the floodplain during channel forming (one to two year storm events) storm events. These conditions become exacerbated as flows continue to increase with projected development.

3. Most of the groundwater recharge to Devil's Ice Box and Hunters Cave occurs in the upper reaches of the watershed. Streams within the recharge zones occur on highly erosive loess and sandy soils, making the recharge zones highly vulnerable to erosion, streambank degradation, reduced water quality, and sedimentation impacts to sensitive cave systems.

4. Karst topography plays a major role in hydrology of the watershed. The two largest caves are mapped and their recharge areas are fairly well delineated. While the scientific community understands how karst topography affects hydrology, generally more education is needed for the lay public, especially since they have the greatest influence on how land is managed.

5. Channel instability issues appear to be migrating upstream, especially in the Northern Little Bonne Femme subwatershed. This is a common and expected phenomenon in downcutting streams as the stream seeks a flatter, more stable grade.

6. Subwatersheds most vulnerable to degradation based on the impervious cover and field indicators are clustered around Columbia and Ashland. Upper Bonne Femme and subwatersheds downstream from Upper Bonne Femme are the next most vulnerable group of subwatersheds. Most of the recharge for Devil's Ice Box occurs in Upper Bonne Femme, a "moderately" vulnerable subwatershed. Most of the recharge for Hunters Cave occurs in the Bass Creek subwatershed, which is ranked as "vulnerable."

7. All subwatersheds are considered restorable, though the greatest restoration challenges will occur, in order of difficulty, in the North Branch Little Bonne Femme, Clear Creek and Bass Creek subwatersheds.

8. When assessed collectively, the three models indicate that there are regions within the watershed that should be prioritized for protection and remediation, namely the urbanizing regions around Columbia and Ashland, and the agricultural headwater region in the eastern portion of the watershed.

Appendix G

Best Management Practices (BMPs)

Best Management Practices (BMPs) are watershed restoration and management techniques that, if implemented, can improve water quality, reduce runoff and flooding, and protect or restore natural resources. BMPs can include preventative measures to reduce the likelihood of new problems occurring, remedial measures that attempt to solve an existing problem, and maintenance measures that can be either preventative or remedial, depending on the circumstances.

The selection of a BMP or suite of BMPs should be based on the efficacy of each specific BMP to achieve the desired result in a given landscape. The suite of BMPs used in a row crop setting, for example, would be different from the suite of BMPs used in a new urban development, though there would certainly be some overlap.

BMP Zones

Five discrete zones were identified within the watershed that would benefit from a specialized suite of BMPs: Headwater Pasture, Wooded/Karst Slope, Bottomland/River Valley Floodplain, Transitional Fringe, and Urban Developed. Zones were categorized using a combination of GIS data layers and attributes.

See Table G.10 for the BMPs they recommend in different zones.

The Subwatershed Sensitivity Analysis report makes a series of recommendations. Their inclusion here is for informational purposes only and do not necessarily reflect the opinion of the Stakeholder Committee. Following are the Subwatershed Sensitivity Analysis report policy recommendations.

It is recommended that Boone County and the cities of Ashland, Columbia, and Pierpont (hereafter, the Watershed's local governments) take the following actions to improve stormwater and groundwater management for protection of natural resources and restoration of degraded areas. At a minimum, Boone County and its municipalities could adopt the latest version of American Public Works Association (APWA) Section 5600 stormwater design criteria and BMP Manual (APWA 2003). These manuals were written specifically for the Kansas City metro region, and therefore would be easy to adapt to conditions in Boone County. Other recommendations build on these documents, including public education, incentive programs, and water resource protection and restoration recommendations.

Table G.10 BMP Summary Implementation and Benefit Table

Recommended Best Management Practice	Recommended Implementation Zone within the Watershed	Attributes Protected or Enhanced				
		Water Quality	Biodiversity	Groundwater Recharge/Infiltration	Flood Protection	Wildlife Habitat
Exclusion of livestock from riparian corridors.	Headwater Pasture, Wooded/ Karst Slope, Bottomland/ River Valley Floodplain	x		x	x	
Restoration of riparian buffers along channels.	All zones.	x	x	x	x	x
Culvert resizing and/or reshaping.	Headwater Pasture, Wooded/ Karst Slope, Bottomland/ River Valley Floodplain				x	
Restore drained wetlands.	Headwater Pasture, Wooded/ Karst Slope, Bottomland/ River Valley Floodplain	x	x	x	x	x
Convert intensively used open space to natural plant communities.	All zones	x	x	x	x	x
Repair rills and gullies caused by concentrated discharges of water fromhomes, farmsteads, and pastures. Provide for dispersion of future discharges.	Headwater Pasture, Wooded/ karst Slope	x			x	
Complete more extensive mapping of areas tributary to karst features including sinkholes and losing streams. Restore these ares where appropriate and to the greatest extent practical	Wooded/Karst Slope	x		x		x
Minimize soil loss in steep areas during road repair and construction, residential and commercial development, and within ares used for agricultural purposes.	Headwater Pasture, Wooded/ Karst slope, Urban/Developed	x				
Remove farm fences obstructing channels.	Headwater Pasture, Wooded/ Karst Slope				x	
Buffer and/or expand protected lands and listed species habitat.	Wooded/Karst Slope		x			x
Localized land planning should occur to protect areas most vulnerable to erosion and sedimentation	Urban/Developed	x				
Implement the use of decreased road widths, detention ponds, silt fences, minimization of mass grading, and/or inlet protection during construction.	Urban/Developed	x		x	x	
Retrofit existing ponds and lakes to detain more water by restricting the outlet, increasing the elevation of the berm/dam, or both	Urban/Developed	x		x	x	
A channel restoration and maintenance plan should be developed to prioritize creeks for restoration and for regular removal of debris jams.	All Zones.	x	x		x	x

Excerpted from the Subwatershed Sensitivity Analysis.

Appendix G

1. Adopt APWA 5600 Storm Drainage Systems and Facilities stormwater design criteria.

APWA 5600 specifies application and design criteria for stormwater management, conveyance, detention, and natural stream protection. In particular, APWA 5600 includes guidance that will address problems noted in Boone County, including:

a. Limiting stormwater discharges from developments to rates, volumes, and frequencies that prevent future flooding, limit erosion, and protect stream stability.

b. Providing stream assessment guidance to quantify stream stability and potential impacts.

c. Requiring developers to maintain stable stream channels and banks by designing stormwater outlets that will not destabilize stream channels and banks and by maintaining predevelopment discharge rate, energy, and flowlines. In addition, APWA 5600 provides guidance for designing non-erosive indirect discharges into stream buffers. The Watershed's local governments should specify that this is the preferred practice.

d. Recommending a systematic riparian buffer program with buffers planted with appropriate native vegetation that vary from 40 to 120 feet, from the ordinary high water mark on both sides of the stream, depending on the size of the contributing drainage area.

e. Requiring that bridge utilities cross at locations and in a manner that preserves stream meander geometry and cross-sectional areas.

f. Minimizing changes to existing channel and floodplain cross-sections and conveyance capacity.

g. Maintaining channel roughness and energy dissipation (and habitat) with preserved or established native vegetation.

h. Maintaining sediment transport capacity necessary for channel equilibrium.

i. Specifying low-impact grade controls, flowing water energy management, and bioengineering to maintain channel plan and profile, and to protect and restore stream stability when infrastructure has or will otherwise impact stream stability.

j. Allowing and encouraging low-impact design, such as conservation subdivisions and other "smart growth" practices, to minimize runoff as an alternative to detention basins.

2. Adopt the APWA Manual of Best Management Practices for Stormwater Quality (BMP Manual)

The BMP Manual would provide the Watershed's local governments with the tools to prevent future flooding and protect water quality, including a flexible framework for developers to estimate potential water quality impacts and increased runoff from development plans. The BMP Manual would also design a comprehensive stormwater management system that includes site design and dispersed, structural and non-structural best management practices (BMPs) for residential, commercial, and industrial developments. The "Level of Service Method" can be used to maintain or reduce predevelopment runoff volumes and pollutant loads by:

a. Encouraging and specifying preservation of upland and bottomland vegetation and infiltration capacity, through the use of riparian buffers and other practices.

b. Minimizing impervious surfaces and encouraging rainfall infiltration through the preservation or restoration of native vegetation and soil profiles.

c. Providing incentives to disconnect impervious surfaces in stormwater conveyance systems.

d. Infiltrating stormwater runoff at the source through engineered BMPs, which maintain groundwater hydrology and are highly effective pollutant filters.

e. Filtering runoff that cannot be infiltrated through dispersed filtration BMPs.

f. Presenting multiple wet detention options, including wet ponds, wetlands, and extended detention wetlands.

g. Providing detailed design guidance for structural and non-structural BMPs including standard specifications and details for common BMPs, and detailed planting and vegetation management guidance.

h. Specifying native vegetation for all BMPs to enhance pollutant removal through filtration and evapotranspiration.

i. Specifying holding times for further pollutant settling and evaporative water losses.

3. Adopt Additional Stormwater Management and Development Policies

APWA Section 5600 criteria may not be sufficient in all circumstances to stabilize stream channels and manage water quality, rates, and volumes entering streams and other water bodies. AES recommends the Watershed's local governments adopt the following "Technical Policy Guideline for Stormwater Management" in all developments:

a. Require any post-development release rates do not exceed the ne-year predevelopment release rates for all storms with a frequency of greater than 10 years. And, rare events such as the 100-year storm should be released at no greater than the 10-year predevelopment release rates.

b. Enact a stream setback ordinance to codify the comprehensive buffer system recommended in APWA 5600. Design the setback zones in accordance with APWA 5600 and the BMP Manual but increase the maximum setback to 150 feet from the ordinary high water mark.

c. Add a Conservation Development classification to the zoning ordinance that specifies Conservation Development planning principles, and encourage alternative stormwater management systems by requiring developments to provide a higher "Level of Service" than the recommendation in the BMP Manual.

d. Develop a stream restoration and maintenance program including floodplain restoration, stream buffers, and restoration practices, to reduce down cutting and to stabilize streambanks throughout the County. Restoration and maintenance practices could be adopted from APWA 5600, the BMP Manual, and other sources.

e. Enact a new zoning classification to preserve upland environments and other off-channel locations with the potential for stormwater detention. Protect hydric soil units (historic wetlands) and naturally occurring depressional storage areas from development and specify natural stormwater management facilities as permitted uses. Natural detention systems should be designed in accordance with the BMP Manual and linked to natural drainage ways or the man-made conveyance system as specified in APWA 5600 and the BMP Manual.

f. Develop cooperative agreements for municipalities within the County to effectively manage stormwater that flows in to or out of shared watersheds within the framework of a single watershed plan, using the criteria in recommendations 1, 2, and 3a for stormwater management and natural resource protection and restoration.

4. Public Education and Incentives

Public education and incentive programs could build support for new policies and help landowners and developers meet their obligations under the policies.

AES recommends the following education efforts and incentive programs:

a. Use an annual "developers' forum" or other methods to educate landowners and developers about:

- comprehensive buffer systems or ordinances and their own buffer requirements;
- watershed-sensitive development strategies and how they can protect the area's valuable land and water resources; and
- alternative stormwater management designs in the BMP Manual and other references that may eliminate the need for stormwater sewers and other costly infrastructure.

b. Promote awareness of natural resources and critical resource issues in the watershed through public education, volunteer stewardship activities in public parks, and through collaboration and partnership with local landowners, conservation groups, agencies, local colleges, and other stakeholders.

c. Establish a County-wide environmental stewardship and stormwater real estate transaction surcharge fee to generate an Environmental Stewardship Fund. This fund should be used, along with other revenue sources (e.g. capital investment funds, taxes, etc) to create private-public partnerships with landowners to help restore, protect, and repair natural resources areas (streams, woodlands, wetlands, etc). AES recommends a transaction fee of 0.05 percent to 0.2 percent of all real estate transactions in the County to establish this fund. The fund could be managed for "interest generation", as a professionally managed fund, and could be used to leverage other funds, land owner participation in land protection, stewardship, restoration and repair.

d. Consider creating other incentives, including stormwater credits for developments that exceed stormwater management requirements.

e. Provide incentives for private landowners to designate conservation, riparian corridor and drainage easements, and other land protection tools. One option is a density credit system that would reward Conservation Developments by allowing developers to transfer density to other more appropriate developments. The Watershed's local governments could also reduce impact fees for developments that employ BMPs and alternative stormwater management practices.

f. Provide training for financing of development to give the confidence that conservation developments are a good investment.

g. Provide training and planning on how to do conservation design, alternative stormwater management, and natural channel restoration for engineers.

5. Habitat and Biodiversity Preservation

Finally, many of the measures described above would preserve or restore scarce habitat as well as protect streams. AES recommends that the Watershed's local governments take the following additional measures that would further enhance habitat protection and biodiversity in the County:

a. Specify that development applications include a conservation plan that protects sensitive habitats and lands and provides land management and ecological restoration recommendations.

b. Require a Natural Resource Inventory with every development application, as commonly required in many municipalities throughout the U.S.

c. At minimum, require proof of wetland delineations where required by U.S. Army Corps of Engineers, and require identification and mapping of drained hydric soils, moderate to highly permeability top and subsoil areas (>10-4 cm-sec or .5 gallons/square foot/hour), and depressional areas that may be valuable stormwater management sites. Set the threshold for identification of these soils and depressional areas as being any site that provides greater than 0.1 acre-foot of storage.

d. Require applicants to delineate forests, prairies, steep slopes (12 percent grade or more), and erosive soils; e.g. loess and silty and sandy loams.

e. Require applicants to submit map overlays that may be combined with other environmental layers such as archeological and cultural resource mapping, water table depth (in locations with high water tables), drainage features, and hydrology.

f. Wildlife habitat delineation may be optional as well.

g. Establish a "Core Natural Area Protection Plan" for the County. Map "Core Natural Areas" that would be the highest priority areas for protection. Include all drainage areas, forested blocks, prairies, wetlands, restorable wetlands, and other key natural communities.

h. Initiate or work with a local land trust to work with private landowners to protect Core Natural Areas on their land and to help landowners realize tax benefits for protecting their lands. The land trust could be partially funded with the environmental stewardship and stormwater real estate transaction surcharge fee described.

i. Design and implement demonstration projects to show functioning stream buffers and riparian corridors, Conservation Developments, alternative stormwater management practices, and ecological restoration programs.

Provide cost and performance data on these projects for use by others in the watershed and in the region.

j. Design proper and adequate training and funding for the Watershed's local governments so that staff are better able to assess the aforementioned measures.

Bonne Femme Watershed Plan
completed by the Bonne Femme Stakeholder Committee
February, 2007

Bonne Femme Watershed Project
www.CaveWatershed.org

U.S. Environmental Protection Agency Region 7, through the Missouri Department of Natural Resources, has provided partial funding for this project under Section 319 of the Clean Water Act.