Risks of Atrazine Use to Federally Listed Endangered Alabama Sturgeon
(*Scaphirhynchus suttkusi*)

Pesticide Effects Determination

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1. Executive Summary

The purpose of this assessment is to make an "effects determination" for the Alabama sturgeon (*Scaphirhynchus suttkusi*) by evaluating the potential direct and indirect effects of the herbicide atrazine on the survival, growth, and reproduction of this Federally endangered species. This assessment was completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998), the August 5, 2004 Joint Counterpart Endangered Species Act Section 7 Consultation Regulations specified in 50 CFR Part 402 (USFWS/NMFS, 2004a; FR 69 47732-47762), and procedures outlined in the Agency's Overview Document (U.S. EPA, 2004).

The current range of the Alabama Sturgeon is restricted to a 134-mile reach of the Alabama River channel below the Millers Ferry Lock and Dam, downstream to the mouth of the Tombigbee River. The best available data indicate that the Alabama sturgeon has disappeared from 85 percent of its historic range. Its decline has been associated with construction of dams, flow regulation, navigation channel development, other forms of channel modification, and pollution (USFWS, 2000a). Although the range of the Alabama sturgeon is limited to the area south of the Millers Ferry Lock and Dam, the action area includes the entire Alabama River Basin watershed because drainage from atrazine use sites above the dam flows to areas south of the dam. The action area includes the entire Alabama River Basin watershed because modeled exposure concentrations based on atrazine use exceed the Agency's screening-level LOCs for aquatic plants.

Environmental fate and transport models were used to estimate high-end exposure values as a result of agricultural and non-agricultural atrazine use in accordance with label directions. Modeling was initially performed using the Agency's standard ecological water body, which does not account for flow. The non-flowing nature of the standard water body provides a reasonable estimation of peak exposures for many smaller headwater streams found in agricultural areas; however, it appears to overestimate exposures for longer time periods. Exposure concentrations based on the standard ecological body are likely to overestimate exposure for the Alabama sturgeon because this species requires strong currents in deep water habitats of the main channel of the Lower Alabama River and its major tributaries. Therefore, additional modeling was used together with available monitoring data to refine atrazine exposures in flowing waters. In addition, the estimated agricultural exposure concentrations were refined to consider available land cover data for agricultural crops within the action area. Estimated residential and turf exposure concentrations were also refined, based on impervious surface and land cover data specific to the action area in the Alabama River Basin watershed. The highest overall modeled exposures were predicted to occur from combined agricultural and non-agricultural uses of atrazine, and the highest individual agricultural and non-agricultural modeled exposures were predicted to result from atrazine use on corn and forestry, respectively. Although the available information indicates that atrazine is rarely used on forestry in Alabama (personal communications with K. McNabb, Auburn University School of Forestry, and J. Michael, U.S. Forest Service, Southern Research Station, August 2006), this use pattern was considered as part of the risk description to account for potential changes in current herbicide use practices on forestry, which may include atrazine in the future. The results of the refined analysis indicate that peak atrazine concentrations are expected to be approximately 10 μg/L, while longer-term (weeks) exposures are expected to be in the low μg/L range. Available monitoring data from one sampling location in the defined action area of the Alabama River watershed show that detected concentrations of atrazine are < 1 μg/L.

The assessment endpoints for the Alabama sturgeon include direct toxic effects on the survival, reproduction, and growth of the sturgeon itself, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Direct effects to the Alabama sturgeon are based on toxicity information for freshwater fish. Given that the sturgeon's prey items and habitat requirements are dependant on the availability of freshwater aquatic invertebrates, aquatic plants, and terrestrial plants (i.e., riparian habitat), toxicity information for these taxonomic groups is also discussed. In addition to the registrant-submitted and open literature toxicity information, indirect effects to the Alabama sturgeon, via impacts to aquatic plant community structure and function, are also evaluated based on time-weighted threshold concentrations that correspond to potential aquatic plant community-level effects.

Degradates of atrazine include hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT). Comparison of available toxicity information for the degradates of atrazine indicates lesser aquatic toxicity than the parent for freshwater and estuarine/marine fish, aquatic invertebrates, and aquatic plants. Although degradate toxicity data are not available for terrestrial plants, lesser or equivalent toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the degradates of atrazine may lose efficacy as an herbicide. Because degradates are not of greater toxicological concern than atrazine, concentrations of the atrazine degradates are not assessed further, and the focus of this assessment is parent atrazine.

Risk quotients (RQs) are derived as quantitative estimates of potential high-end risk. Acute and chronic RQs are compared to the Agency's levels of concern (LOCs) to identify instances where atrazine use within the action area has the potential to adversely affect the Alabama sturgeon via direct toxicity or indirectly based on direct effects to their food supply (i.e., freshwater invertebrates) or habitat (i.e., aquatic plants and terrestrial riparian vegetation). When RQs for a particular type of effect are below LOCs, the potential for adverse effects to the Alabama sturgeon is expected to be negligible, leading to a conclusion of "no effect". Where RQs exceed LOCs, a potential to cause adverse effects is identified, leading to a conclusion of "may affect". If a determination is made that use of atrazine within the action area "may affect" the Alabama sturgeon, additional information is considered to refine the potential for exposure and effects, and the best available information is used to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the Alabama sturgeon.

The best available data suggest that atrazine will either have no effect or is not likely to adversely affect the Alabama sturgeon by direct toxic effects or by indirect effects resulting from effects to aquatic plants, aquatic animals, and riparian vegetation. A summary of the risk conclusions and effects determination for the Alabama sturgeon is presented in Table 1.1. Further information on the results of the effects determination is included as part of the Risk Description in Section 5.2.

Table 1.1. Effects Determination Summary for the Alabama Sturgeon

Assessment Endpoint	Effects determination	Basis for Determination
Survival, growth, and reproduction of Alabama sturgeon individuals via direct effects	No effect	No acute and chronic LOCs are exceeded.
Indirect effects to the Alabama sturgeon via reduction of prey (i.e., freshwater invertebrates)	May affect, but not likely to adversely affect	Acute LOCs are exceeded for the forestry use, based on the most sensitive ecotoxicity value for the midge; however RQs for other dietary items (stoneflies and snails) are less than LOCs. Based on the non-selective nature of feeding behavior of the Alabama sturgeon and low magnitude of anticipated individual effects to all evaluated prey species, atrazine is not likely to indirectly affect the Alabama sturgeon via a reduction in freshwater invertebrate food items. This finding is based on insignificance of effects (i.e., effects to freshwater invertebrates are not likely to be extensive over the suite of possible food items to result in “take” of a single Alabama sturgeon).
Indirect effects to the Alabama sturgeon via reduction of habitat and/or primary productivity (i.e., aquatic plants)	May affect, but not likely to adversely affect	Individual aquatic plant species within the Alabama River may be affected. However, refined 14-, 30-, 60-, and 90-day EECs, which consider the impact of flow, are well below the threshold concentrations representing community-level effects. In addition, the available monitoring data for the Alabama River show that all detected concentrations are < 1 μg/L. This finding is based on insignificance of effects (i.e., community-level effects to aquatic plants are not likely to result in “take” of a single Alabama sturgeon).
Indirect effects to the Alabama sturgeon via reduction of terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality and spawning habitat	May affect, but not likely to adversely affect	Riparian vegetation may be affected because terrestrial plant RQs are above LOCs. However, the majority of riparian area adjacent to the current range of the Alabama sturgeon in the Lower Alabama River watershed is forested vegetation, which is not associated with forestry plantation operations. Woody plants are generally not sensitive to environmentally-relevant concentrations of atrazine; therefore, effects on shading, streambank stabilization, and structural diversity of riparian areas in the action area are not expected. Although grassy and herbaceous riparian habitat is expected to be sensitive to atrazine effects, the presence of herbaceous riparian areas in the Lower Alabama River watershed is minimal. Therefore, atrazine-related impacts to riparian habitat are expected to have minimal impact on overall sediment loads in the Lower Alabama River watershed, based on surrounding land use and other sources of sedimentation including forestry management practices and annual dredging of navigational channels. This finding is based on insignificance of effects (i.e., atrazine effects to riparian vegetation in the Lower Alabama River cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where “take” of a single Alabama sturgeon would occur).

2. Problem Formulation

Problem formulation provides a strategic framework for the risk assessment. By identifying the important components of the problem, it focuses the assessment on the most relevant life history stages, habitat components, chemical properties, exposure routes, and endpoints. This assessment was completed in accordance with the August 5, 2004 Joint Counterpart Endangered Species Act (ESA) Section 7 Consultation Regulations specified in 50 CFR Part 402 (USFWS/NMFS, 2004a; FR 69 47732-47762). The structure of this risk assessment is based on guidance contained in U.S. EPA's *Guidance for Ecological Risk Assessment* (U.S. EPA, 1998), the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998) and procedures outlined in the Overview Document (U.S. EPA, 2004).

2.1 Purpose

This ecological risk assessment is a component of the settlement for the *Natural Resources Defense Council, Civ. No: 03-CV-02444 RDB (filed March 28, 2006).* The purpose of this ecological risk assessment is to make an "effects determination," as directed in Section 7(a)(2) of the ESA, for the Alabama sturgeon (*Scaphirhynchus suttkusi*) by evaluating the potential direct and indirect effects resulting from use of the herbicide atrazine (6-chloro-N-ethyl-N-isopropyl-1, 3, 5-triazine-2, 4-diamine) on the survival, growth, and/or reproduction of this Federally endangered species. The Alabama sturgeon was federally listed as an endangered species on May 5, 2000 by the U.S. Fish and Wildlife Service (USFWS or the Service; 65 FR 26437-26461; USFWS, 2000a). USFWS is the branch of the Department of Interior responsible for listing endangered fish, such as the Alabama sturgeon. No critical habitat has been designated for this species.

In this endangered species assessment, direct and indirect effects to the Alabama sturgeon are evaluated in accordance with the screening-level methodology described in the Agency's Overview Document (U.S. EPA, 2004). It should be noted, however, that the indirect effects analysis in this assessment utilizes more refined data than is generally available to the Agency. Specifically, a robust set of microcosm and mesocosm data and aquatic ecosystem models are available for atrazine that allowed the Agency to refine the indirect effects associated with potential aquatic community-level effects (via aquatic plant community structural change and subsequent habitat modification) to the Alabama sturgeon. Use of such information is consistent with the guidance provided in the Overview Document, which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that the Agency finds technically appropriate for risk management objectives" (Section V, page 31 of U.S. EPA, 2004).

As part of the "effects determination", the Agency will reach one of the following three conclusions regarding the potential for atrazine to adversely affect the Alabama sturgeon:

- "No effect";
- "May affect, but not likely to adversely affect"; or
- "Likely to adversely affect".

If the results of the screening-level assessment show no indirect effects and levels of concern (LOCs) for the Alabama sturgeon are not exceeded for direct effects, a "no effect" determination is made based on atrazine's use within the action area. If, however, indirect effects are anticipated and/or exposure exceeds the LOCs for direct effects, the Agency concludes a preliminary "may affect" determination for the Alabama sturgeon.

If a determination is made that use of atrazine within the action area "may affect" the Alabama sturgeon, additional information is considered to refine the potential for exposure at the predicted levels and for effects to the Alabama sturgeon and other taxonomic groups upon which this species depends (i.e., freshwater invertebrates, aquatic plants, riparian vegetation). Based on the refined information, the Agency uses the best available information to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the Alabama sturgeon. This information is presented as part of the Risk Characterization in Section 5.

2.2 Scope

Atrazine is currently registered as a herbicide in the U.S. to control annual broadleaf and grass weeds in corn, sorghum, sugarcane, and other crops. In addition to food crops, atrazine is also used on a variety of non-food crops, forests, residential/industrial uses, golf course turf, recreational areas, and rights-of-way. It is one of the most widely used herbicides in North America (U.S. EPA, 2003a).

The end result of the EPA pesticide registration process is an approved product label. The label is a legal document that stipulates how and where a given pesticide may be used. Product labels (also known as end-use labels) describe the formulation type, acceptable methods of application, approved use sites, and any restrictions on how applications may be conducted. Thus, the use or potential use of atrazine in accordance with the approved product labels is "the action" being assessed.

This ecological risk assessment is for currently registered uses of atrazine in the action area associated with the Alabama sturgeon. Further discussion of the action area for the Alabama sturgeon is provided in Section 2.6.

Degradates of atrazine include hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT). Comparison of available toxicity information for the degradates of atrazine indicates lesser aquatic toxicity than the parent for freshwater fish, aquatic invertebrates, and aquatic plants. Specifically, the available degradate toxicity data for HA indicates that it is not toxic to freshwater fish and invertebrates at the limit of its solubility in water. In addition, no adverse effects were observed in fish or daphnids at DACT concentrations up to 100 mg/L. Acute toxicity values for DIA are 8.5- and 36-fold less sensitive than acute toxicity values for atrazine in fish and daphnids, respectively. In addition, available aquatic plant degradate toxicity data for HA, DEA, DIA, and DACT report non-definitive EC_{50} values (i.e., 50% effect was not observed at the highest test concentrations) at concentrations that are at least 700 times higher than the lowest reported aquatic plant EC_{50} value for parent atrazine. Although degradate toxicity data are not available for terrestrial plants, lesser or equivalent toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the degradates of atrazine may lose efficacy as an herbicide. Therefore, given the lesser toxicity of the degradates, as compared to the parent, and the relatively small proportion of the degradates expected to be in the environment and available for exposure relative to atrazine, the focus of this assessment is parent atrazine. A detailed summary of the available ecotoxicity information for all of the atrazine degradates is presented in Appendix A.

The results of available toxicity data for mixtures of atrazine with other pesticides are presented in Section A.6 of Appendix A. According to the available data, other pesticides may combine with atrazine to produce synergistic, additive, and/or antagonistic toxic effects. Synergistic effects with atrazine have been demonstrated for a number of organophosphate insecticides including diazanon, chlorpyrifos, and methyl parathion, as well as herbicides including alachlor. If chemicals that show synergistic effects with atrazine are present in the environment in combination with atrazine, the toxicity of atrazine may be increased, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggest that the toxic effect of atrazine, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to: (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of atrazine and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (e.g. organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. However, a qualitative discussion of implications of the available pesticide mixture effects data involving atrazine on the confidence of risk assessment conclusions for the Alabama sturgeon is addressed as part of the uncertainty analysis for this effects determination.

2.3 Previous Assessments

The Agency completed a refined ecological risk assessment for aquatic impacts of atrazine use in January 2003 (U.S. EPA, 2003a). This assessment was based on laboratory ecotoxicological data as well as microcosm and mesocosm field studies found in publicly available literature, a substantial amount of monitoring data for freshwater streams, lakes, reservoirs, and estuarine areas, and incident reports of adverse effects on aquatic and terrestrial organisms associated with the use of atrazine. In the refined assessment, risk is described in terms of the likelihood that concentrations in water bodies (i.e., lakes/reservoirs, streams, and estuarine areas) equaled or exceeded concentrations shown to cause adverse effects to aquatic communities and populations of aquatic organisms. The results of the refined aquatic ecological assessment indicated that exposure to atrazine is likely to result in adverse community-level and population-level effects to aquatic communities at concentrations greater than or equal to 10-20 μg/L on a recurrent basis or over a prolonged period of time.

During this time, the Agency extensively reviewed a probabilistic ecological risk assessment submitted by the registrant (Giddings et al., 2000). The Agency's review of Syngenta's probabilistic risk assessment is included in Appendix XVII of the 2003 atrazine IRED. EPA's refined risk assessment incorporates some of the data submitted by the registrant in its probabilistic risk assessment.

The results of the Agency's ecological assessments for atrazine are fully discussed in the January 31, 2003, Interim Reregistration Eligibility Decision (IRED)[1]. Because the Agency had determined that atrazine shares a common mechanism of toxicity with the structurally-related chlorinated triazines, simazine and propazine, a cumulative human health risk assessment for the triazines was necessary before the Agency could make a final determination of reregistration eligibility. However, the Agency issued the interim decision in order to identify risk reduction measures that were necessary to support the continued use of atrazine. The January 2003 IRED requires extensive drinking water monitoring in Community Water Systems (CWSs) where atrazine levels have exceeded or are predicted to have the potential to exceed drinking water levels of concern. In addition, the need for the following information related to potential ecological risks was established: 1) an ecological monitoring program of potentially vulnerable waterbodies in corn, sorghum, and sugarcane use areas; and 2) further information on potential amphibian gonadal developmental responses to atrazine.

EPA issued an addendum on October 31, 2003 that updated the IRED issued on January 31, 2003 (U.S. EPA, 2003b). This addendum describes new scientific developments pertaining to ecological monitoring and mitigation of watersheds and potential effects of atrazine on endocrine-mediated pathways of amphibian gonadal development.

The January 2003 IRED required atrazine registrants to develop a watershed monitoring protocol. The resulting protocol identifies 40 indicator watersheds in corn and sorghum growing areas in which monitoring has been required for a two-year period within each watershed. The first 20 watersheds were monitored in 2004 and 2005. The second set of 20 watersheds was monitored in 2005, and the second year of sampling for these watersheds is currently in progress. The goal of the monitoring is to ascertain the extent to which any of the watersheds have streams with atrazine concentrations that could cause significant changes in aquatic plant community structure, the most sensitive endpoint in the aquatic ecosystem. Streams in watersheds exceeding the Agency's levels of concern will be subject to mitigation consistent with watershed management principles

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[1] The 2003 Interim Reregistration Eligibility Decision for atrazine is available at the following Web site: http://www.epa.gov/oppsrrd1/REDs/0001.pdf.

described by the Agency's Office of Water program requirements (http://www.epa.gov/owow/tmdl/). These monitoring sites are representative of 1,172 watersheds determined to be among the most vulnerable to atrazine surface water loading from use on corn and sorghum. Therefore, the results from the 40 watersheds will be used to determine if further monitoring or remedial efforts are needed in the larger population of watersheds. EPA has selected an atrazine level of concern (LOC) that is based on significant aquatic community effects consistent with those described in the Office of Pesticide Programs (OPP) 2003 ecological risk assessment (U.S. EPA, 2003a and b) and the Office of Water's (OW) draft atrazine aquatic life criteria (U.S. EPA, 2003c). Further discussion of the aquatic community-level LOC is provided in Section 4.2 and Appendix B of this assessment. Aqueous atrazine concentrations obtained from monitoring studies can be interpreted with the LOC to determine if a water body is likely to be significantly affected.

As discussed in the October 2003 IRED, the Agency also conducted an evaluation of the submitted studies regarding the potential effects of atrazine on amphibian gonadal development and presented its assessment in the form of a white paper for external peer review to a FIFRA Scientific Advisory Panel (SAP) in June 2003[2]. In the white paper dated May 29, 2003, the Agency summarized seventeen studies consisting of both open literature and registrant-submitted laboratory and field studies involving both native and non-native species of frogs (U.S. EPA, 2003d). The Agency concluded that none of the studies fully accounted for environmental and animal husbandry factors capable of influencing endpoints that the studies were attempting to measure. The Agency also concluded that the current lines-of-evidence did not show that atrazine produced consistent effects across a range of exposure concentrations and amphibian species tested.

Based on this assessment, the Agency concluded and the SAP concurred that there was sufficient evidence to formulate a hypothesis that atrazine exposure may impact gonadal development in amphibians, but there were insufficient data to confirm or refute the hypothesis (http://www.epa.gov/oscpmont/sap/2003/June/junemeetingreport.pdf). Because of the inconsistency and lack of reproducibility across studies and an absence of a dose-response relationship in the currently available data, the Agency determined that the data did not alter the conclusions reached in the January 2003 IRED regarding uncertainties related to atrazine's potential effects on amphibians. The SAP supported EPA in seeking additional data to reduce uncertainties regarding potential risk to amphibians. Subsequent data collection has followed the multi-tiered process outlined in the Agency's white paper to the SAP (U.S. EPA, 2003d). In addition to addressing uncertainty regarding the potential use of atrazine to cause these effects, these studies are expected to characterize the nature of any potential dose-response relationship. A data call-in for the first tier of amphibian studies was issued in 2005 and studies are on-going; however, as of this writing, results are not available.

[2] The Agency's May 2003 White Paper on Potential Developmental Effects of Atrazine on Amphibians is available at http://www.epa.gov/oscpmont/sap/2003/june/finaljune2002telconfreport.pdf.

2.4 Stressor Source and Distribution

2.4.1 Environmental Fate and Transport Assessment

The following fate and transport description for atrazine was summarized based on information contained in the 2003 IRED (U.S. EPA, 2003a). In general, atrazine is expected to be mobile and persistent in the environment. The main route of dissipation is microbial degradation under aerobic conditions. Because of its persistence and mobility, atrazine is expected to reach surface and ground water. This is confirmed by the widespread detections of atrazine in surface water and ground water. Atrazine is persistent in soil, with a half-life (time until 50% of the parent atrazine remains) exceeding 1 year under some conditions (Armstrong et al., 1967). Atrazine can contaminate nearby non-target plants, soil and surface water via spray drift during application. Atrazine is applied directly to target plants during foliar application, but pre-plant and pre-emergent applications are generally far more prevalent.

The resistance of atrazine to abiotic hydrolysis (stable at pH 5, 7, and 9) and to direct aqueous photolysis (stable under sunlight at pH 7), and its only moderate susceptibility to degradation in soil (aerobic laboratory half-lives of 3-4 months) indicates that atrazine is unlikely to undergo rapid degradation on foliage. Likewise, a relatively low Henry's Law constant (2.6 X 10^{-9} atm-m^3/mol) indicates that atrazine is not likely to undergo rapid volatilization from foliage. However, its relatively low octanol/water partition coefficient (Log K_{ow} = 2 .7), and its relatively low soil/water partitioning (Freundlich K_{ads} values < 3 and often < 1) may somewhat offset the low Henry's Law constant value, thereby possibly resulting in some volatilization from foliage. In addition, its relatively low adsorption characteristics indicate that atrazine may undergo substantial washoff from foliage. It should also be noted that foliar dissipation rates for numerous pesticides have generally been somewhat greater than otherwise indicated by their physical chemical and other fate properties.

In terrestrial field dissipation studies performed in Georgia, California, and Minnesota, atrazine dissipated with half lives of 13, 58, and 261 days, respectively. The inconsistency in these reported half-lives could be attributed to the temperature variation between the studies in which atrazine was seen to be more persistent in colder climate. Long-term field dissipation studies also indicated that atrazine could persist over a year in such climatic conditions. A forestry field dissipation study in Oregon (aerial application of 4 lb ai/A) estimated an 87-day half-life for atrazine on exposed soil, a 13-day half-life in foliage, and a 66-day half-life on leaf litter.

Atrazine is applied directly to soil during pre-planting and/or pre-emergence applications. Atrazine is transported indirectly to soil due to incomplete interception during foliar application, and due to washoff subsequent to foliar application. The available laboratory and field data are reported above. For aquatic environments, reported half-lives were much longer. In an anaerobic aquatic study, atrazine overall (total system), water, and sediment half-lives were given as 608, 578, and 330 days, respectively.

A number of degradates of atrazine were detected in laboratory and field environmental fate studies. Deethyl-atrazine (DEA) and deisopropyl-atrazine (DIA) were detected in all studies, and hydroxy-atrazine (HA) and diaminochloro-atrazine (DACT) were detected in all but one of the listed studies. Deethylhydoxy-atrazine (DEHA) and deisopropylhydroxy-atrazine (DIHA) were also detected in one of the aerobic studies.

All of the chloro-triazine and hydroxy-triazine degradates detected in the laboratory metabolism studies were present at less than the 10% of applied that the Agency uses to classify degradates as “major degradates” (U.S. EPA, 2004); however, several of these degradates were detected at percentages greater than 10% in soil and aqueous photolysis studies. Insufficient data are available to estimate half-lives for these degradates from the available data. The dealkylated degradates are more mobile than parent atrazine, while HA is less mobile than atrazine and the dealkylated degradates.

2.4.2 Mechanism of Action

Atrazine inhibits photosynthesis by stopping electron flow in Photosystem II. Triazine herbicides associate with a protein complex of the Photosystem II in chloroplast photosynthetic membranes (Schulz et al., 1990). The result is an inhibition in the transfer of electrons that in turn inhibits the formation and release of oxygen.

2.4.3 Use Characterization

Atrazine has the second largest poundage of any herbicide in the U.S. and is widely used to control broadleaf and many other weeds, primarily in corn, sorghum and sugarcane (U.S. EPA, 2003a). As a selective herbicide, atrazine is applied pre-emergence and post-emergence**.** Figure 2.1 presents the national distribution of use of atrazine (Kaul et al., 2005).

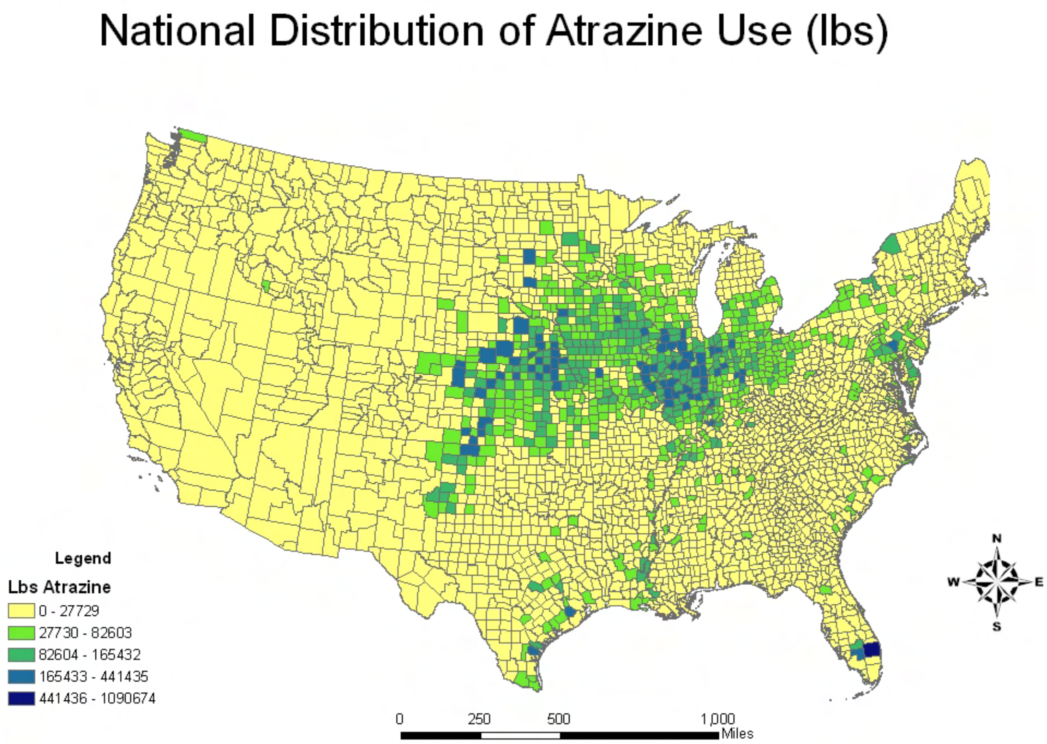

Figure 2.1. **National Extent of Atrazine Use (lbs)**

Atrazine is used on a variety of terrestrial food crops, non-food crops, forests, residential/industrial uses, golf course turf, recreational areas and rights-of-way. Atrazine yields season-long weed control in corn, sorghum and certain other crops. The major atrazine uses include: corn (83 percent of total ai produced per year - primarily applied pre-emergence), sorghum (11 percent of total ai produced), sugarcane (4 percent of total ai produced) and others (2 percent ai produced). Atrazine formulations include dry flowable, flowable liquid, liquid, water dispersible granule, wettable powder and coated fertilizer granule. The maximum registered use rate for atrazine is 4 lbs ai/acre; and 4 lbs ai/acre is the maximum, single application rate for the following uses: sugarcane, forest trees (softwoods, conifers), forest plantings, guava, macadamia nuts, ornamental sod (turf farms), and ornamental and/or shade trees.

Critical to the development of appropriate modeling scenarios and to the evaluation of the appropriate model inputs is an assessment of usage information (Kaul et al., 2005; Kaul and Jarboe, 2006; Zinn and Jones, 2006). Information on the agricultural uses of atrazine in the state of Alabama immediately surrounding the Alabama River and within the Alabama River Watershed as defined in this assessment was gathered (Kaul et al., 2005). In addition, reported atrazine crop use information, application rates (for use in characterization), and methods of application, application timing, and intervals between applications were considered (Kaul and Jarboe, 2006; Zinn and Jones, 2006). Usage information within the Alabama River watershed is utilized to determine which uses should be modeled, while the application methods, intervals, and timing are critical model inputs. While the modeling described in Section 3.2 relies initially on maximum label application rates and numbers of applications, information on typical ranges of application rates and number of applications is also presented to characterize the modeling results. No information is available on non-agricultural uses (residential, rights-of-way, forestry, or turf) of atrazine.

General information on the main agricultural uses of atrazine in Alabama was gathered. Agricultural cropland and atrazine use relative to the Alabama River Basin watershed are depicted in Figures 2.2 and 2.3, respectively.

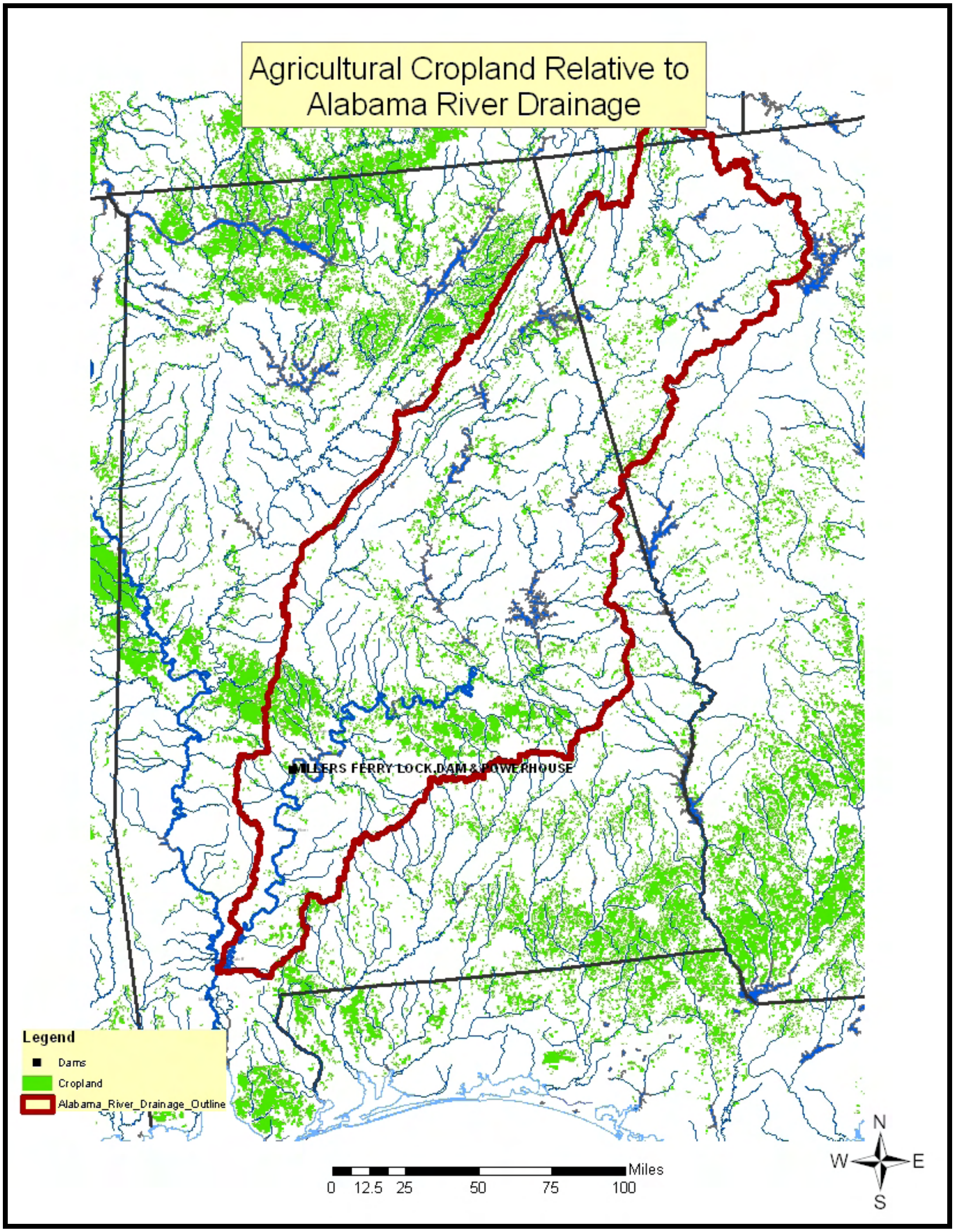

Figure 2.2. Agricultural Cropland Relative to Alabama River

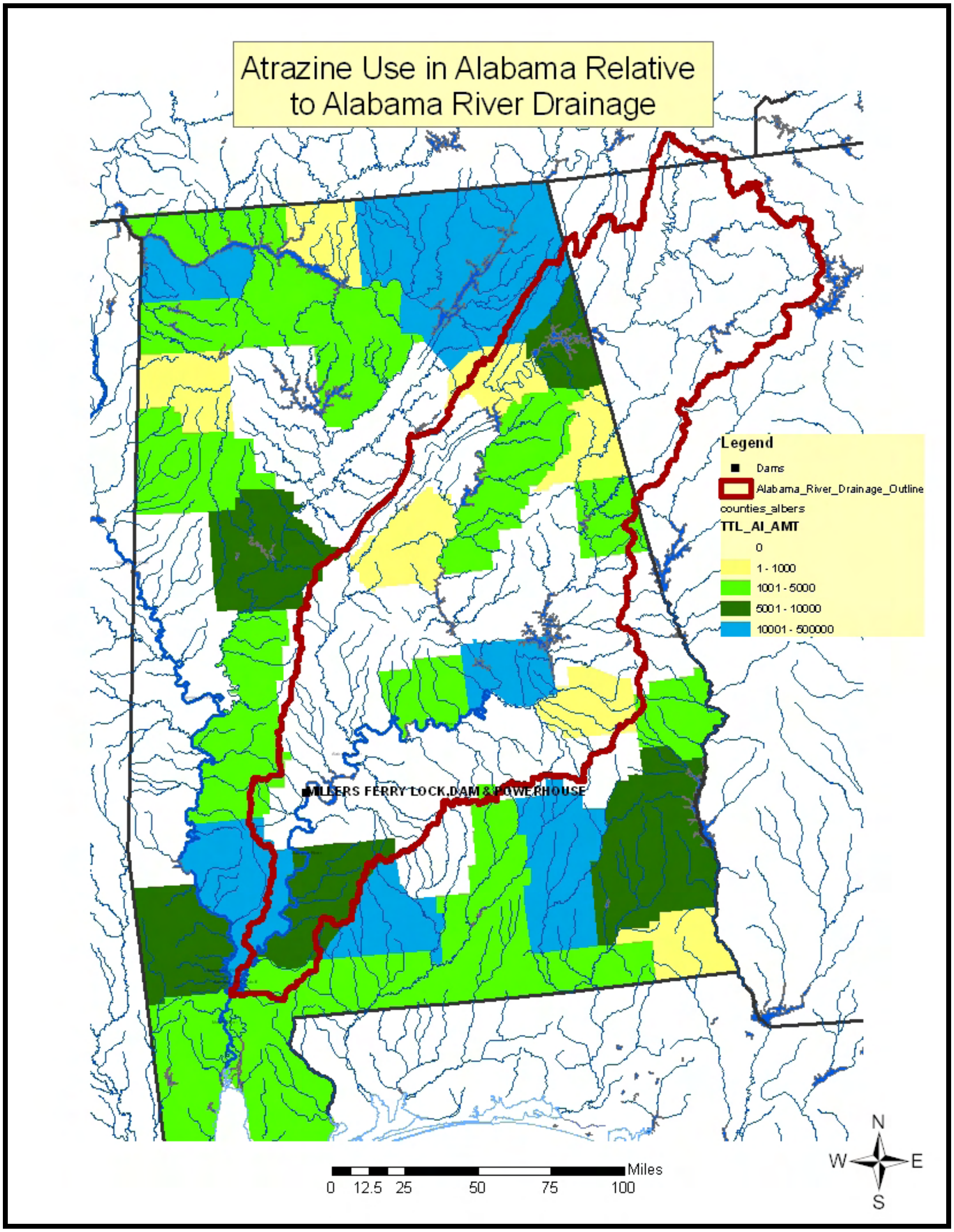

Figure 2.3. Atrazine Use in Alabama Relative to Action Area

Locally, usage information was obtained for agricultural uses of atrazine in the state of Alabama. Only use sites known to be present within the action area are included in this assessment. Agricultural uses that are included in this assessment include corn, sorghum and fallow/idle land in the Conservation Reserve Program (CRP); non-agricultural uses include turf, residential, rights-of-way, and forestry. These uses are discussed in more detail in Section 3.2.

Specifically, county level data for the areas immediately surrounding the Alabama River in southern and central Alabama were used (Kaul et al., 2005). These counties encompass the majority of the action area (defined below) for atrazine relative to the Alabama sturgeon. County level estimates of atrazine use were derived using state level estimates from USDA-NASS and data obtained from Doane (www.doane.com; the full dataset is not provided due to its proprietary nature). State level data from 1998 to 2004 were averaged together and extrapolated down to the county level based on apportioned county level crop acreage data from the 2002 USDA Agriculture of Census (AgCensus). In general, this information suggests that approximately 300,000 lbs of atrazine was used statewide on corn and sorghum. It should be noted, however, that information on non-agricultural use of atrazine is not available.

Application rates, the number of applications, and application intervals were also estimated at the state level for Alabama (Kaul, et al, 2005, Zinn and Jones, 2006). The information was developed from a combination of USDA and Doane data, and is discussed in further detail as part of the exposure assessment in Section 3.1. Application rates of atrazine are provided at the national level for crops grown in the immediate vicinity of the Alabama River including corn, pasture (as a surrogate for fallow/idle land), and sorghum. Based on data developed for the triazine cumulative risk assessment (U.S. EPA, 2006a; Kaul, et al., 2005), the typical atrazine application rates for corn, sorghum and fallow/idle land in Alabama are 1.1 lbs/acre. Although the 90th percentile of reported application rates is typically used as an upper bound on actual use, data on the 90th percentile is currently unavailable.

In order to refine the exposure assessment, the minimum and typical application intervals are needed when more than one application is made per year on a site. Therefore, registered herbicide/site combinations within Alabama were determined, and sites with the average number of applications greater than one were selected. If the average number of applications equals one, it is assumed that only one application is made, and, therefore, the typical interval is not needed. Only sites with greater than one pesticide application are discussed below. Because typical application interval usage data is not available, crop experts were contacted, label information was reviewed, and other sources, such as previous assessments, were consulted to estimate or otherwise characterize the application intervals.

For corn, most growers apply atrazine only once per season. However, approximately 12 percent of growers apply atrazine more than once, following a pre-emergence application with a post-emergence application (Assessment of Potential Mitigation Measures for

Atrazine, 2003). According to atrazine label information for corn, the minimum application interval is either 14 days or not specified on the label.

For sorghum, atrazine may be applied at various timings. “Atrazine is effective at many application timings including: winter weed control, and pre-plant for control of weeds prior to planting through post-plant as long as weeds are no more than one and one-half inches and sorghum is six to 12 inches tall” (Assessment of Potential Mitigation Measures for Atrazine, 2003). According to atrazine label information for sorghum, the minimum application interval is either 21 days or not specified on the label.

For fallow/idle land use, according the Aatrex® 4L label and some other atrazine labels, only one application of atrazine may be made in fallow period (CDMS search). In addition, the IRED states that only one application per year may be made for chemical fallow applications (U.S. EPA, 2003a).

Typical application rates and number of intervals should be evaluated with caution because these values represent an average, which implies that a significant percentage of the time atrazine is actually being applied at rates higher than those reported as typical.

2.5 Assessed Species

A brief introduction to the Alabama sturgeon, including a summary of habitat, diet, and reproduction data relevant to this endangered species risk assessment is provided below. Further information on the status and life history of the Alabama sturgeon is provided in Appendix C.

The Alabama sturgeon (*Scaphirynchus suttkusi*) is a freshwater fish (Figure C.1 of Appendix C) found in the main stems of the Lower Alabama River from Millers Ferry Lock and Dam, downstream to the mouth of the Tombigbee River (Figure 2.4). The best available data indicate that the Alabama sturgeon has disappeared from 85 percent of its historic range. Its decline has been associated with construction of dams, flow regulation, navigation channel development, other forms of channel modification, and pollution (USFWS, 2000a). Dams in the Alabama River have reduced the amount of riverine habitat, impeded migration of Alabama sturgeon for feeding and spawning needs, and changed the river’s flow patterns. The Alabama sturgeon’s historic range once included about 1,000 miles of the Mobile River system in Alabama. However, recent collection efforts indicate that very low numbers of Alabama sturgeon continue to survive in portions of the 134-mile reach of the Alabama River channel below the Millers Ferry Lock and Dam, downstream to the mouth of the Tombigbee River. The decline of collection records and anecdotal accounts of captures over the past century coincide with construction of dams and the cumulative loss and fragmentation of riverine habitat in the Mobile River Basin over time. These habitat changes, coupled with what is known about life history requirements and life span of other species of river sturgeon, suggest that the Alabama sturgeon is close to extinction (personal communication with Jeff Powell of the USFWS, 2006).

Very little is known about the life history, habitat, or other ecological requirements of the Alabama sturgeon. Observations by Burke and Ramsey (1985) indicate that the species prefers relatively stable gravel and sand substrates in flowing river channels. Verified

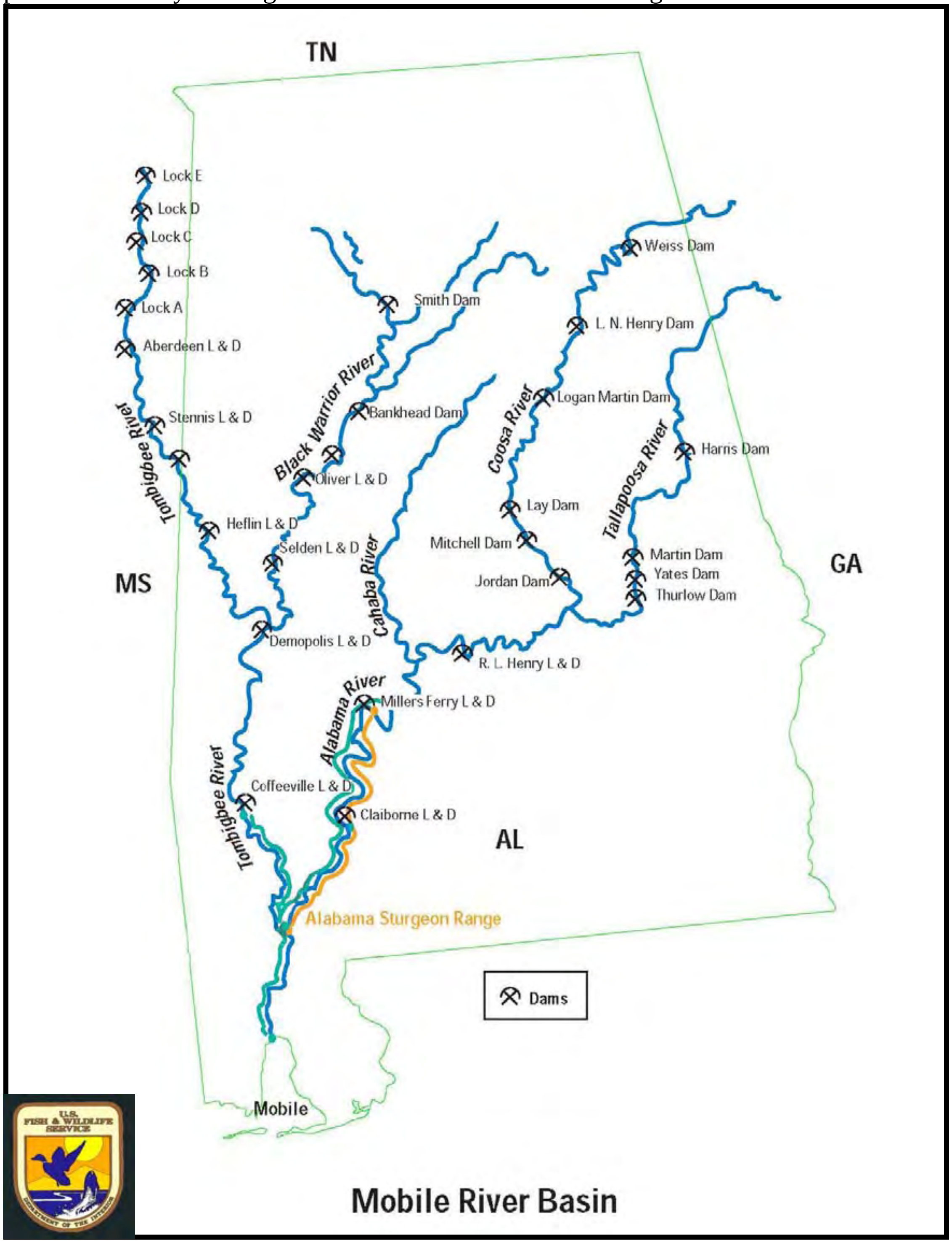

Figure 2.4. Alabama Sturgeon Habitat Range (U.S. Fish and Wildlife Service Daphne, Alabama Field Office, July 2006)

captures of Alabama sturgeon have primarily occurred in large channels of big rivers (Williams and Clemmer, 1991). Examination of Alabama sturgeon stomach contents show that they are opportunistic bottom feeders, preying primarily on aquatic insect larvae (Mayden and Kuhajda, 1996). Alabama sturgeon are likely to migrate upstream during late winter and spring to spawn. Downstream migrations may occur to search for feeding areas and/or deeper, cooler waters during the summer. Although specific locations have not been identified, eggs are likely deposited on hard bottom substrates, such as bedrock, armored gravel, or channel training works (water diversion structures used to direct currents to main channels) in deep water habitats, and possibly tributaries to major rivers (USFWS, 2000a). The eggs are adhesive and require current for proper development. Sturgeon larvae are planktonic, drifting with river currents. Post-larval stages eventually settle on the river bottom. Information from other riverine sturgeon species suggests that the Alabama sturgeon may require some minimum distance of flowing river conditions for development of larval to juvenile stage, and for sustainable recruitment of the species (Powell, personal communication, 2006). Sexual maturity is believed to occur at 5 to 7 years of age. Spawning frequency of both sexes is influenced by food supply and fish condition, and may occur every 1 to 3 years. Although the life span of the Alabama sturgeon is unknown, they may live up to 15 or more years of age (USFWS, 2000a)

2.6 Action Area

For listed species assessment purposes, the action area is considered to be the area affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). It is recognized that the overall action area for the national registration of atrazine uses is likely to encompass considerable portions of the United States based on the large array of both agricultural and non-agricultural uses. Based on the modeling results (discussed further in Section 3.2.3) and the toxicity data for the most sensitive non-vascular aquatic plant, the Agency's LOCs are likely to be exceeded in many watersheds that are in proximity to or downstream of atrazine use sites. Therefore, the overall action area for atrazine is likely to include many watersheds of the United States that co-occur and/or are in proximity to agricultural and non-agricultural atrazine use sites. However, in order to focus this assessment, the scope limits consideration of the overall action area to those geographic portions that may be applicable to the protection of the Alabama sturgeon as they occur within the watershed of the Alabama River. Therefore, the portion of the atrazine action area that is assessed as part of this ESA includes the area within the boundary of the watersheds that drain to the Alabama River.

Modeled concentrations of atrazine for labeled uses expected to occur within the Alabama River watershed exceed Agency established ecological risk levels of concern for aquatic plants, suggesting that adverse effects on components of the environment is possible. The results of the screening level assessment suggest that effects on components of the environment are possible anywhere within the Alabama River. Although the available monitoring data for the Alabama River watershed show that detected concentrations are less than the Agency's screening levels of concern, the dataset is limited to one sampling location, and is, therefore, not considered to be representative of the entire watershed. Therefore, the action area for the Alabama sturgeon is defined as the entire Alabama River watershed and its tributaries. Further information on the definition of the action area for the Alabama sturgeon follows.

The Alabama Sturgeon is known to exist in the Alabama River from the mouth of the confluence with the Tombigbee River near Mobile, Alabama north to Millers Ferry Lock and Dam in Southwestern Alabama in Wilcox County (Figure 2.4). The Alabama River is located principally in southern and central Alabama and drains a watershed roughly 6,000 square miles reaching as far north as northwestern Georgia. Historically, this species ranged much farther north into central Alabama and as far west as Mississippi. Currently, only a few specimens have been found since the mid 1990s in the free flowing portion of the Alabama River in Clarke, Monroe, and Wilcox counties with a single exception north of Claiborne Lock and Dam (USFWS, 2000a). Therefore, the initial definition of the action area for this species is defined by the watershed draining to the stretches of the Alabama River south of Millers Lock and Dam. Although the Millers Lock and Dam may limit the range of the sturgeon northward into central Alabama, the dam does not prevent the flow of water. Therefore, the potential action area includes the entire Alabama River watershed.

In addition, an evaluation of usage information was conducted to determine whether any or all of the area defined by the Alabama River watershed should be included in the action area. As part of this effort, current labels were reviewed and local use information was evaluated to determine which atrazine uses could potentially be present within the defined area. This data suggest that limited agricultural uses are present within the defined area and that non-agricultural uses cannot be precluded from being assessed. Finally, local land cover data and interviews with local agricultural and land use specialists were considered to refine the characterization of potential atrazine use in the areas defined by the Alabama River watershed. The overall conclusion of this analysis was that while certain agricultural uses could likely be excluded and some non-agricultural uses of atrazine were unlikely, no areas could be excluded from the final action area based on usage and land cover data.

The environmental fate properties of atrazine were also evaluated to determine which routes of transport are likely to have impact on the Alabama sturgeon. Review of the environmental fate data as well as physico-chemical properties of atrazine suggest that transport via runoff and spray drift are likely to be the dominant routes of exposure. In addition, long-range atmospheric transport of pesticides could potentially contribute to atrazine concentrations in the aquatic habitat used by the sturgeon. Given the physico-chemical profile for atrazine and the fact that atrazine has been detected in both air and rainfall samples, the potential for long range transport from outside the area defined by the Alabama River watershed cannot be precluded, but is not expected to approach concentrations predicted by modeling (see Section 3.2).

Atrazine has been documented to be transported away from the site of application by both spray drift and volatilization. Spray drift is addressed as a localized route of transport from the application site in the exposure assessment. However, quantitative models are currently unavailable to address the longer-range transport of pesticides from application sites. The environmental fate profile of atrazine, coupled with the available monitoring data, suggest that long-range transport of volatilized atrazine is a possible route of exposure to non-target organisms; therefore, the full extent of the action area could be influenced by this route of exposure. However, given the amount of direct use of atrazine within the immediate area surrounding the species, the magnitude of documented exposures in rainfall at or below available surface water and groundwater monitoring data (as well as modeled estimates for surface water), and the lack of modeling tools to predict the impact of long range transport of atrazine, the extent of the action area is defined by the transport processes of runoff and spray drift for the purposes of this assessment.

Based on this analysis, the action area for atrazine as it relates to the Alabama sturgeon is defined by the entire watershed draining to the Alabama River both above and below the Millers Lock and Dam extending as far as northwestern Georgia. Figure 2.5 presents the action area graphically.

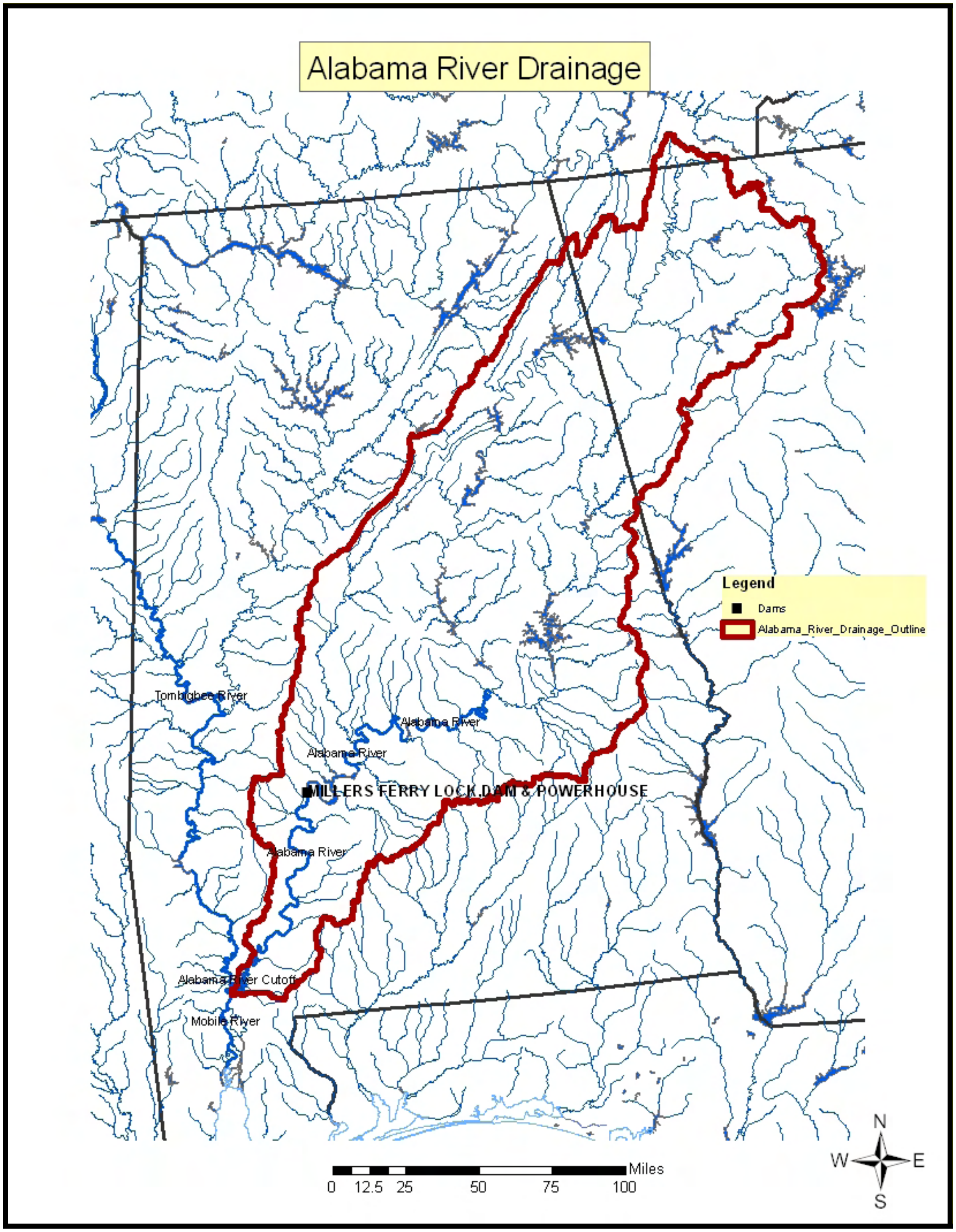

Figure 2.5. Alabama Sturgeon Action Area Defined by Alabama River Watershed

2.7 Assessment Endpoints and Measures of Ecological Effect

Assessment endpoints are defined as "explicit expressions of the actual environmental value that is to be protected."[3] Selection of the assessment endpoints is based on valued entities (i.e., Alabama sturgeon), the ecosystems potentially at risk (i.e., Alabama River), the migration pathways of atrazine (i.e., runoff and spray drift), and the routes by which ecological receptors are exposed to atrazine-related contamination (i.e., direct contact).

Assessment endpoints for the Alabama sturgeon include direct toxic effects on the survival, reproduction, and growth of the sturgeon, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Each assessment endpoint requires one or more "measures of ecological effect," which are defined as changes in the attributes of an assessment endpoint or changes in a surrogate entity or attribute in response to exposure to a pesticide. Specific measures of ecological effect are evaluated based on acute and chronic toxicity information from registrant-submitted guideline tests that are performed on a limited number of organisms. Specific measures of ecological effect are evaluated based on acute and chronic toxicity information from registrant-submitted guideline tests that are performed on a limited number of organisms. Additional ecological effects data from the open literature, including effects data on aquatic freshwater microcosm and mesocosm data, were also considered.

Measures of effect from microcosm and mesocosm data provide an expanded view of potential indirect effects of atrazine on aquatic organisms, their populations and communities in the laboratory, in simulated field situations, and in actual field situations. With respect to the microcosm and mesocosm data, threshold concentrations were determined from realistic and complex time variable atrazine exposure profiles (chemographs) for modeled aquatic community structure changes. Methods were developed to estimate ecological community responses for monitoring data sets of interest based on their relationship to micro- and mescocosm study results, and thus to determine whether a certain exposure profile within a particular use site and/or action area may have exceeded community-level threshold concentrations. Ecological modeling with the Comprehensive Aquatic Systems Model (CASM) (Bartell et al., 2000; Bartell et al., 1999; and DeAngelis et al., 1989) was used to integrate direct and indirect effects of atrazine to indicate changes to aquatic community structure and function.

A complete discussion of all the toxicity data available for this risk assessment, including use of the CASM model and associated aquatic community-level threshold concentrations, and the resulting measures of ecological effect selected for each taxonomic group of concern, is included in Section 4 of this document. A summary of the assessment endpoints and measures of ecological effect selected to characterize potential Alabama sturgeon risks associated with exposure to atrazine is provided in Table 2.1.

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[3] From U.S. EPA (1992). *Framework for Ecological Risk Assessment.* EPA/630/R-92/001.

Table 2.1. Summary of Assessment Endpoints and Measures of Ecological Effect

Assessment Endpoint	Measures of Ecological Effect
1. Survival, growth, and reproduction of Alabama sturgeon individuals via direct effects	1a. Rainbow trout acute LC_{50} 1b. Brook trout chronic NOAEC
2. Survival, growth, and reproduction of Alabama sturgeon individuals via indirect effects on prey (i.e., freshwater invertebrates)	2a. Midge acute EC_{50} 2b. Scud chronic NOAEC 2c. Acute EC/LC_{50} data for freshwater invertebrates that are potential food items for the Alabama sturgeon
3. Survival, growth, and reproduction of Alabama sturgeon individuals via indirect effects on habitat and/or primary productivity (i.e., aquatic plant community)	3a. Vascular plant (duckweed) acute EC_{50} 3b. Non-vascular plant (freshwater algae) acute EC_{50} 3c. Microcosm/mesocosm threshold concentrations showing aquatic primary productivity community-level effects
4. Survival, growth, and reproduction of Alabama sturgeon individuals via indirect effects on terrestrial vegetation (riparian habitat) required to maintain acceptable water quality and spawning habitat	4a. Monocot and dicot seedling emergence EC_{25} 4b. Monocot and dicot vegetative vigor EC_{25}

2.8 Conceptual Model

2.8.1 Risk Hypotheses

Risk hypotheses are specific assumptions about potential adverse effects (i.e., changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (U.S. EPA, 1998). For this assessment, the risk is stressor-linked, where the stressor is the release of atrazine to the environment. Based on the results of the 2003 atrazine IRED (U.S. EPA, 2003a), the following risk hypotheses are presumed for this endangered species assessment:

- Atrazine in surface water and/or runoff/drift from treated areas may directly affect the Alabama sturgeon by causing mortality or adversely affecting growth or fecundity;
- Atrazine in surface water and/or runoff/drift from treated areas may indirectly affect the Alabama sturgeon by reducing or changing the composition of prey populations;
- Atrazine in surface water and/or runoff/drift from treated areas may indirectly affect the Alabama sturgeon by reducing or changing the composition of the aquatic plant community in the Alabama River, thus affecting primary productivity and/or cover; and
- Atrazine in surface water and/or runoff/drift from treated areas may indirectly affect the Alabama sturgeon by reducing or changing the composition of the terrestrial plant community (i.e., riparian habitat) required to maintain acceptable water quality and spawning habitat in the Alabama River.

2.8.2 Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the stressor (atrazine), release mechanisms, abiotic receiving media, biological receptor types, and effects endpoints of potential concern. The conceptual model for the atrazine endangered species assessment for the Alabama sturgeon is shown in Figure 2.6. Exposure routes shown in dashed lines are not quantitatively considered because the resulting exposures are expected to be so low as not to cause adverse effects to the Alabama sturgeon.

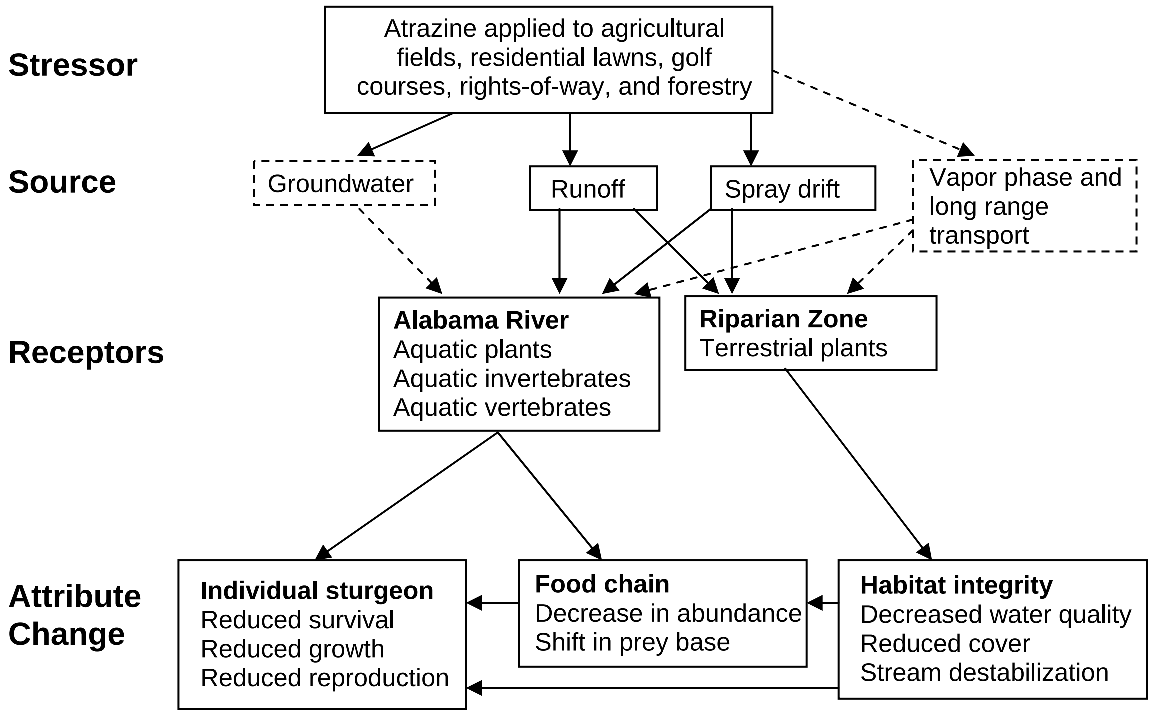

Figure 2.6. Conceptual Model for Alabama Sturgeon

The conceptual model provides an overview of the expected exposure routes for Alabama sturgeon within the atrazine action area previously described in Section 2.6. In addition to freshwater aquatic vertebrates including Alabama sturgeon, other aquatic receptors that may be potentially exposed to atrazine include freshwater invertebrates and aquatic plants. For freshwater vertebrate and invertebrate species, the major routes of exposure are considered to be via the respiratory surface (gills) or the integument. Direct uptake and adsorption are the major routes of exposure for aquatic plants. Direct effects to freshwater invertebrates and aquatic plants resulting from exposure to atrazine may indirectly affect the Alabama sturgeon via reduction in food and habitat availability. The available data indicate that atrazine is not likely to bioconcentrate in aquatic food items, with fish bioconcentration factors (BCFs) ranging from 2 to 8.5 (U.S. EPA, 2003c). Therefore, bioconcentration of atrazine in sturgeon via the diet was not considered as a significant route of exposure.

In addition to aquatic receptors, terrestrial plants may also be exposed to spray drift and runoff from atrazine use in the vicinity of the Alabama River. A significant change in the riparian vegetation adjacent to spawning areas of the sturgeon in the Alabama River may adversely affect sturgeon egg development and reduce the amount of suitable spawning habitat via increased sedimentation.

Individual fish with the greatest potential to experience direct adverse effects from atrazine use are those that occur in surface water with the highest concentrations of atrazine. Individual fish with the greatest potential to experience *indirect* effects are those fish that rely on the sections of the Alabama River that are most vulnerable to atrazine contamination (i.e., those near or adjacent to application areas) for food, shelter, and/or spawning habitat.

The source and mechanism of release of atrazine into surface water are ground and aerial application via foliar spray and coated fertilizer granules to agricultural (i.e., corn, sorghum, and fallow/idle land) and non-agricultural crops (i.e., golf courses, residential lawns, rights-of-way, and forestry). Surface water runoff from the areas of atrazine application is assumed to follow topography, resulting in direct runoff to the Alabama River. Spray drift and runoff of atrazine may also affect the foliage and seedlings of terrestrial plants that comprise the riparian habitat surrounding the Alabama River. Additional release mechanisms include spray drift and atmospheric transport via volatilization, which may potentially transport site-related contaminants to the surrounding air. Atmospheric transport is not considered as a significant route of exposure for this assessment because the magnitude of documented exposures in rainfall are at or below available surface water and monitoring data, as well as modeled estimates of exposure. In addition, modeling tools are not available to predict the potential impact of long range atmospheric transport of atrazine.

3. Exposure Assessment

3.1 Label Application Rates and Intervals

Atrazine labels may be categorized into two types: labels for manufacturing uses (including technical grade atrazine and its formulated products) and end-use products. While technical products, which contain atrazine of high purity, are not used directly in the environment, they are used to make formulated products, which can be applied in specific areas to control weeds. The formulated product labels legally limit atrazine's potential use to only those sites that are specified on the labels.

In the January and October 2003 IREDs (U.S. EPA, 2003a and b), EPA stipulated numerous changes to the use of atrazine including label restrictions and other mitigation measures designed to reduce risk to human health and the environment. Specifically pertinent to this assessment, the Agency entered into a Memorandum of Agreement (MOA) with the atrazine registrants. In the MOA, the Agency stipulated that certain label changes must be implemented on all manufacturing-use product labels for atrazine and on all end-use product labels for atrazine prior to the 2005 growing season including cancellation of certain uses, reduction in application rates, and requirements for harmonization across labels including setbacks from waterways. Specifically, the label changes restrict atrazine use within 50 feet of sinkholes, 66 feet of intermittent and perennial streams, and 200 feet of lakes and reservoirs. It is expected that a setback distance will result in a reduction in loading due to runoff across the setback zone; however, current models do not address this reduction quantitatively. Therefore, these restrictions are not quantitatively evaluated in this assessment. A qualitative discussion of the potential impact of these setbacks on estimated environmental concentrations of atrazine for the Alabama sturgeon is discussed further in Section 3.2.3.1. Table 3.1 provides a summary of label application rates for atrazine uses evaluated in this assessment.

Currently registered non-agricultural uses of atrazine within the action area for the Alabama sturgeon include residential areas such as playgrounds and home lawns, turf (golf courses and recreational fields), rights-of-way, and forestry. Agricultural uses within the action area include corn, sorghum, and fallow/idle land[4]. Other agricultural uses (macadamia nut, guava, and sugarcane) are not present in the action area.

Atrazine is formulated as liquid, wettable powder, dry flowable, and granular formulations. Application equipment for the agricultural uses includes ground application (the most common application method), aerial application, band treatment, incorporated treatment, various sprayers (low-volume, hand held, directed), and spreaders for granular applications. Risks from ground boom and aerial applications are considered in this assessment because they are expected to result in the highest off-target levels of atrazine due to generally higher spray drift levels. Ground boom and aerial modes of application tend to use lower volumes applied in finer sprays than applications coincident with sprayers and spreaders, and thus have a higher potential for off-target movement via spray drift.

[4] Fallow or idle land is defined by the Agency as arable land not under rotation that is set at rest for a period of time ranging from one to five years before it is cultivated again, or land usually under permanent crops, meadows or pastures, which is not being used for that purpose for a period of at least one year. Arable land, which is normally used for the cultivation of temporary crops, but which is temporarily used for grazing, is also included.

Table 3.1. Label Application Information for the Alabama Sturgeon Endangered Species Assessment[1]

Scenario	Maximum Application Rate (lbs/acre)	Maximum Number of Applications	Date of First Application	Formulation	Method of Application	Interval Between Applications
Forestry	4.0	1	June 1	Liquid	Aerial and Ground	NA
Residential	2.0	2	April 1	Granular	Ground	30 days
Residential	1.0	2	April 1	Liquid	Ground	30 days
Rights-of-Way	1.0	1	June 1	Liquid	Ground	NA
Fallow/ Idle land	2.25	1	November 1	Liquid	Ground and Aerial	NA
Corn	2.0	1	April 1	Liquid	Ground and Aerial	NA
Sorghum	2.0	1	April 1	Liquid	Ground and Aerial	NA
Turf	2.0	2	April 1	Granular	Ground	30 days
Turf	1.0	2	April 1	Liquid	Ground	30 days

[1] – Based on 2003 IRED and Label Change Summary Table memorandum dated June 12, 2006 (U.S. EPA, 2006b).

3.2 Aquatic Exposure Assessment

As discussed in Section 2.5 and Appendix C, the Alabama Sturgeon resides principally in the main stem of the Alabama River below the Millers Ferry Lock and Dam. Even though it appears that the dam limits the range of the species northward into central Alabama, the dam does not prevent the flow of water. The potential action area is defined as the entire watershed that drains to the Alabama River both above and below the Millers Ferry Lock and Dam because use sites that drain to the Alabama River and its tributaries above the dam can reach the areas south of the dam.

In general, Alabama sturgeon are found primarily within the confines of the Alabama River and the mouths of the major tributaries. For the purposes of this assessment, the principal location of direct stressor exposure is presumed to be within the Alabama River and the mouths of its tributaries. The rationale for this assumption is discussed further in Appendix C, which details the life history information for the Alabama sturgeon.

For the purposes of this assessment, it is assumed that the highest exposures within the entire Alabama River watershed occur within the areas immediately proximate to the Alabama River including central and southern Alabama and northwestern Georgia. Figure 2.5 shows this location in more detail.

3.2.1 Conceptual Model of Exposure

The general conceptual model of exposure in this assessment is that the highest exposures will occur in the headwater streams adjacent to agricultural fields and other non-agricultural use sites (residential, right-of-way, turf, and forestry). For the most part, these stream segments are far removed from the Alabama River itself. Figure 2.2 depicts the general relationship between agricultural cropland and the Alabama River where the species resides. The Agency's exposure model, Pesticide Root Zone Model/Exposure Analysis Modeling System (PRZM/EXAMS), is generally intended to estimate exposures in headwater streams and not the main stem of major rivers such as the Alabama River. Available Alabama River monitoring data from the United States Geological Survey (USGS) National Water Quality Assessment (NAWQA) Program (http://water.usgs.gov/nawqa/) are also used to refine the typical modeling approach (as specified in the Overview Document; U.S. EPA, 2004) and characterize exposure estimates to the Alabama sturgeon within the Alabama River proper. However, it is expected that the available monitoring data are insufficient to predict all possible exposure in these areas, given the likelihood that significant amounts of atrazine are used in both southern and central areas of Alabama that drain to the Alabama River.

3.2.2 Existing Monitoring Data

Site-specific Alabama River monitoring data were obtained from the USGS NAWQA Program (http://water.usgs.gov/nawqa/). A summary of the data are presented in Figure 3.1. Only one sample location with atrazine detections was located within the current range of the Alabama sturgeon below the Millers Ferry Lock and Dam. This data indicate that atrazine concentrations appear to be consistently below 1 μg/L in the main stem of the Alabama River. It should be noted, however, that two of the higher detected concentrations of 0.12 μg/L coincide with the spawning period of the Alabama sturgeon (April – May). The general location of this sampling station is presented in Figure 3.2. Although other sampling locations are not available, it is anticipated that higher atrazine concentrations may occur both upstream of this location and within the tributaries of the Alabama River. This pattern suggests that an emphasis on predicting exposures in the tributaries is the most conservative approach for assessing both direct and indirect effects to the Alabama sturgeon.

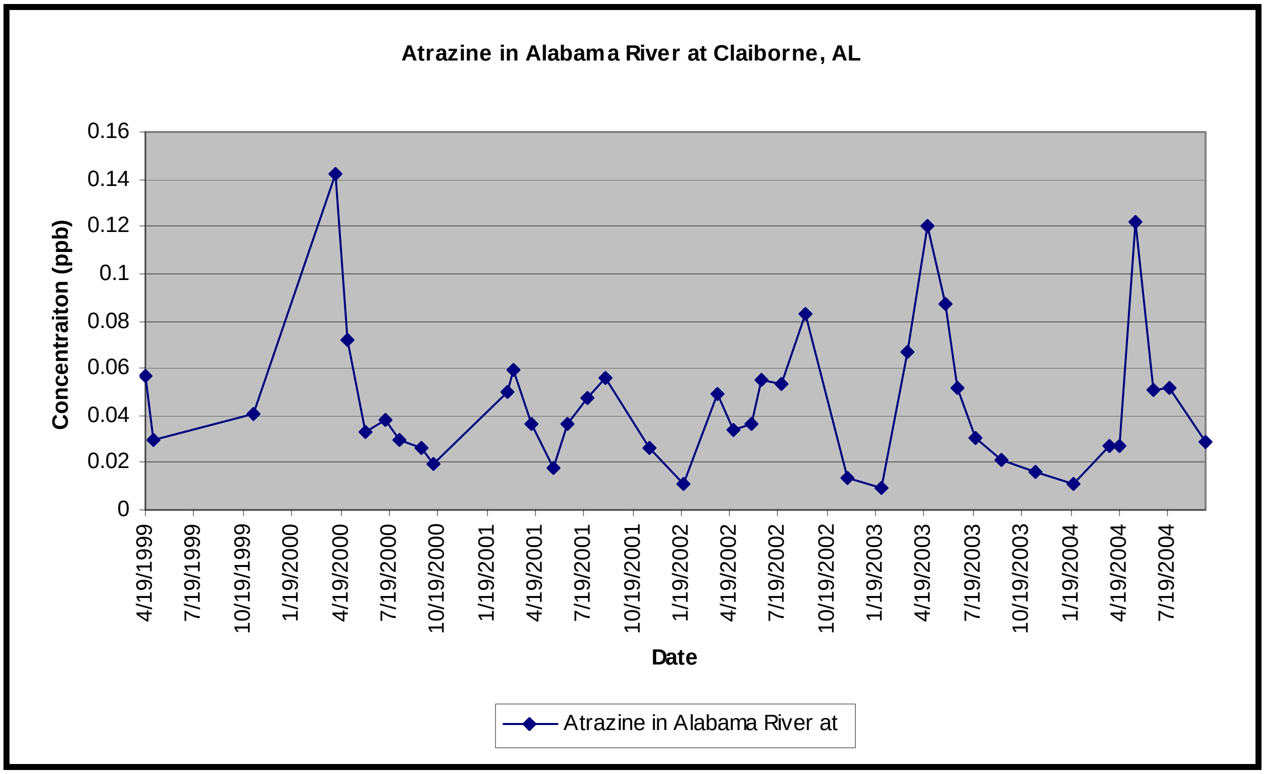

Figure 3.1. Summary of All Available USGS NAWQA Data for Atrazine in the Alabama River

NAWQA groundwater data were evaluated to determine the importance of groundwater on potential loadings to the Alabama River. Groundwater data from Alabama were downloaded from the USGS NAWQA data warehouse (http://water.usgs.gov/nawqa/) on May 11, 2006. A total of 205 well samples were analyzed for atrazine in groundwater between 1993 and 2003. Of these samples, a total of 85 had positive detections of atrazine, with 13 of those estimated at below the limit of quantitation (LOQ). The frequency of detection for all detections was 42%. The maximum concentration detected was 1.8 µg/L in an agricultural setting in Madison County located along the Tennessee state line in north Alabama. Of all detections, only 2 samples had detections greater than 1 µg/L. Overall, the data suggest that atrazine recharge to the waters of the Alabama River watershed is possible; however, surface runoff is expected to be the dominant route of exposure, given the detection frequency, travel times, and magnitude of exposures in the available groundwater data.

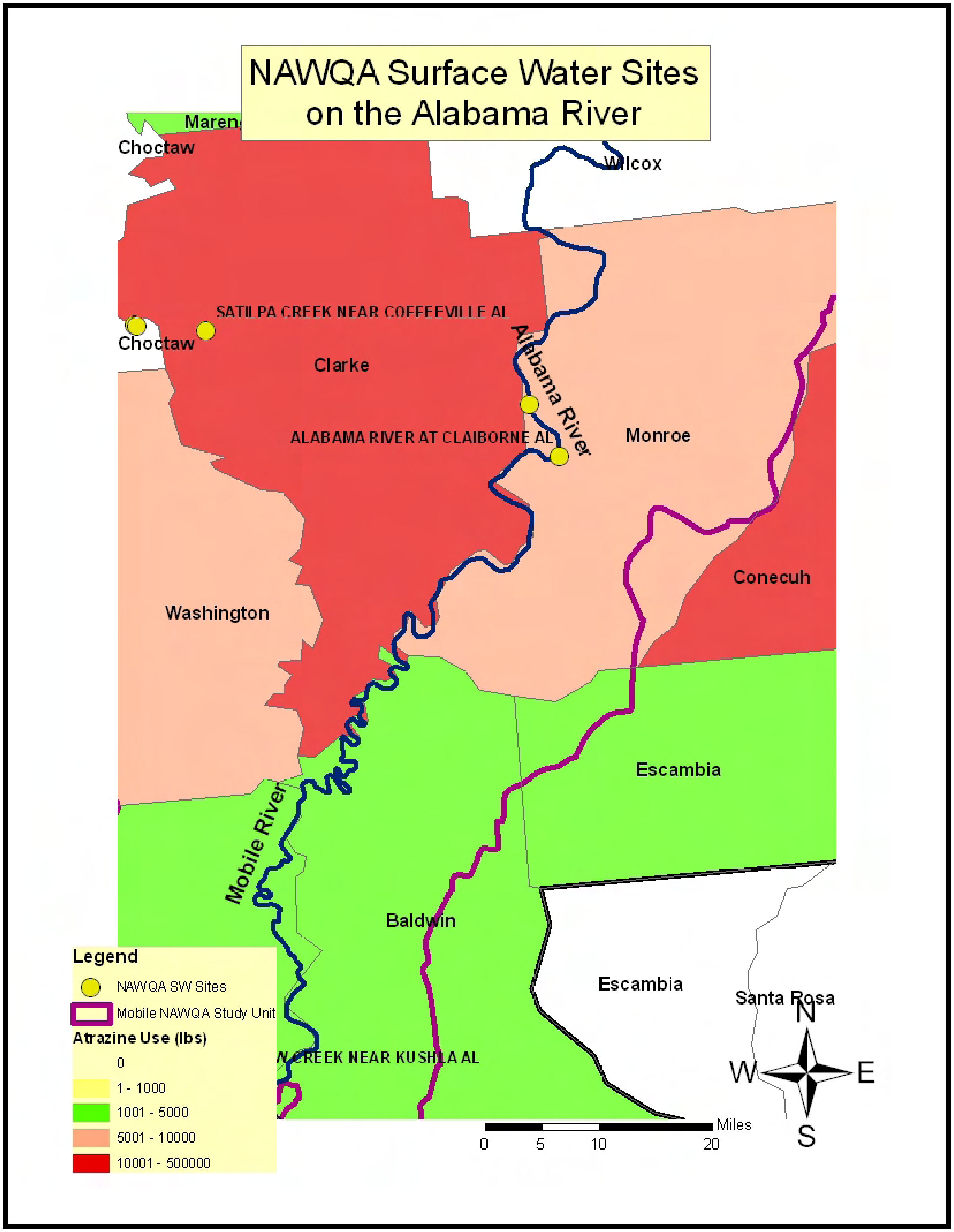

Figure 3.2. **Location of USGS NAWQA Site on Alabama River near Claiborne, Alabama**

3.2.3 Modeling Approach

The analysis of available monitoring data and usage information indicates that the exposure assessment cannot rely exclusively on monitoring data. Although generally of high quality, the USGS NAWQA data available for the Alabama River are limited in that they represent a single location on the river, and the frequency of sampling is not considered sufficient to provide a reasonable upper bound on exposure. The available monitoring data are considered to provide a good estimation of lower bound exposures. In addition, the monitoring data provide context to model predictions, particularly when considering the impact of flow on the modeled predictions.

The modeling approach for this assessment incorporates the standard assessment approach of PRZM/EXAMS scenarios for corn and sorghum with the other scenarios (residential, impervious, rights-of-way, turf, and fallow/idle land) recently developed for use in the Barton Springs salamander endangered species assessment (U.S. EPA, 2006c). In addition, the Oregon Christmas tree scenario (developed for the organophosphate [OP] cumulative assessment; U.S. EPA, 2006d) was used as a surrogate for forestry use. Available usage data (Kaul, et al., 2005; Kaul and Jarboe, 2006; Zinn and Jones, 2006) suggest that the heaviest usage of atrazine is likely to be on corn in south-central Alabama, where agricultural uses are highest. Therefore, all selected modeling scenarios were run using the weather data from the Mobile, Alabama meteorological station that is closest to the high use area and likely to give a higher runoff amount than other nearby weather stations such as Montgomery, Alabama. Each scenario selected as a surrogate for this assessment is considered to be a conservative representation of exposure in the action area because the surrogate scenarios (Mississippi corn, Oregon Christmas tree, and Kansas sorghum) were developed using a hydrologic group C soil with relatively high curve numbers and moderate slopes. These are the most important parameters within a PRZM scenario for generating runoff coupled with rainfall, which is higher within the action area than the areas where the scenarios were originally developed. In addition, the curve numbers and slopes are expected to be higher than those present in the action area, which generally have lower slopes and less runoff prone soils. Further description of the existing PRZM scenarios may be found at the following website.

http://www.epa.gov/oppefed1/models/water/przmenvironmentdisclaim.htm

The non-agricultural scenarios were used within the standard framework of PRZM/EXAMS modeling using the standard graphical user interface (GUI) shell, PE4v01.pl, which may be found at;

http://www.epa.gov/oppefed1/models/water/index.htm#przmexamsshell

Peak concentrations, as well as rolling time-weighted averages of 14 days, 21 days, 30 days, 60 days, and 90 days were derived for comparison with the appropriate ecotoxicity endpoints (including the community-level threshold concentrations) for atrazine. Several of these are non-standard durations of exposure; therefore, the 30 year time series output file was used to recalculate the peak, 14-day, 21-day, 30-day, 60-day, and 90-day rolling averages at the 90th percentile. All model outputs were post-processed manually using Microsoft Excel to provide the equivalent of the standard one in ten year return frequency exposures, as predicted by PRZM/EXAMS. This information is provided in Appendix D. As specified in the Overview Document (USEPA, 2004), it is assumed that a standard water body, of fixed geometry, receives the edge of field runoff. Further discussion of the Agency's standard modeling approach including more detail on PRZM/EXAMS may be found at the following website:

http://www.epa.gov/oppefed1/models/water/index.htm

Additional information on the modeling approach for the non-agricultural residential, rights-of-way, and forestry use scenarios is provided below.

Residential Scenario

The residential scenario was used in tandem with the impervious scenario. It is likely that some overspray does reach the impervious surfaces in the residential setting. In order to account for potential overspray, impervious surfaces were modeled using three separate assumptions. For the purposes of this assessment, it was assumed that 1% of the application rate could reach the impervious surfaces surrounding each residential lot. This amount of overspray is not based on empirical data (i.e. studies on the actual occurrence of overspray are not available); however, the overspray assumption is expected to be reasonable given that the principal drift assumption for ground spray in ecological risk assessments is 1%. In order to test this assumption and address the potential uncertainty associated with the lack of data for overspray, two alternate scenarios were modeled to characterize the effect the 1% assumption. The impervious surface was also modeled assuming 0% and 10% overspray to provide a lower and upper bound of the 1% assumption. The results of these alternate modeling exercises are discussed more fully in Section 3.2.4.1.

In this exercise, it is assumed that 1% overspray is applied to impervious surfaces and 50% of the ¼ acre lot is treated with atrazine. The assumption of 1% overspray may underestimate exposure, given that more overspray of impervious surfaces is possible. However, this impervious scenario represents general impervious surfaces within a watershed that are not part of the ¼ acre lot, and includes roads, parking lots, and buildings where overspray from residential lots is expected to be minimal. The ¼ acre lot by comparison was developed with a curve number reflective of the fact that the lot is covered with both pervious surfaces (grass and landscaped gardens) and impervious surfaces (driveways, sidewalks, and buildings). In this case, the assumption that 50% of the lot is treated likely overestimates the amount of landscaped area treated, but underestimates unintentional overspray of driveways and sidewalks within the lot itself. Overall, these are simplifying assumptions, given the limitations of the modeling approach and lack of empirical data, and are likely to provide a reasonable high-end estimate of exposure. Comparison of modeled exposures with available monitoring data is critical to this evaluation.

In order to justify the assumption of ¼ acre lot as a typical exposure scenario, publicly available data from the United States Census (Census) were reviewed. Specifically, data from 2003 from the American Housing Survey (AHS) were reviewed and are available at the following website:

http://www.census.gov/hhes/www/housing/ahs

The data for all suburban homes available nationally were evaluated. It is assumed that most pesticide applications, particularly herbicide applications, occur in suburban settings. To test the assumption of the ¼ acre lot as the best representation, the AHS data for suburban homes that list total number of houses by lot size and by square footage of house (see Table 1C-3 at the AHS website above) were considered. With a total of 45,552,000 total units reported nationally for all suburban areas, 12,368,000 units (the largest class at 27%) were on lots between 1/8 acre and ¼ acre, while 9,339,000 units (the second largest class at 21%) were on lots between ¼ acre and ½ acre. Overall, the median lot size was 0.37 acre. This analysis suggests that the ¼ acre lot is a reasonable approximation of suburban pesticide use.

It was also assumed in this assessment that 50% of a typical ¼ acre lot would be treated with atrazine. This assumption was based partially on data from the AHS website and partially from professional judgment about typical features and the percentage of a typical lot those features might require. For example, the AHS survey data report that of a total of 43,328,000 single detached homes in suburban areas, 10,124,000 (the largest group at 23%) were between 1,500 and 2,000 square feet, while 7,255,000 (the third largest group at 17%) were between 2,000 and 2,500 square feet, and 9,513,000 (the second largest group at 22%) were between 1,000 and 1,500 square feet. From this data, it was assumed that a typical home is 2,000 square feet with a 1,000 square foot footprint. The lower sized houses less than 1,500 square feet are more likely to represent single floor structures; thus, the 1,000 square foot estimate for a house footprint is reasonable.

In addition to the footprint of the typical house, it was also assumed that a typical house would have a driveway of approximately 25 by 30 feet or 750 square feet and roughly 250 square feet of sidewalk. A typical suburban home was also assumed to have roughly 300 square feet of deck space and 900 square feet of garage. Finally, a substantial portion of the typical home is assumed to be planted in landscaping with an estimate of 2,000 square feet. All of the previous estimates are based on professional judgment and are not derived from the AHS data. All of these areas are assumed to not be treated with a turf herbicide, resulting in a total area not treated with atrazine of 5,200 square feet. Taking a total ¼ acre lot size of 10,890 square feet and subtracting the untreated square footage yields a total remaining area of 5,690, or roughly 50% of the total lot that could be potentially treated.

Assumptions of lot size and percentage of the area that is treated are based on national data and may vary at the local level. Data from the U.S. Census for Alabama (http://www/census.gov/population/censusdata/places/01al.txt) suggest that housing density is typically less than those assumed at a national level (approximately 2,560 lots per square mile); therefore, it is likely that typical lot sizes are greater than the assumed ¼ acre. If the lot sizes are larger, the percentage of a typical lot that is treated may be also be greater than the assumed value of 50%. However, the impact of larger lot sizes and greater percentage of treated area is likely tempered by the fact that central and southern Alabama is largely rural (see Section 3.2.3.2), with fewer housing developments where large-scale homeowner pesticide use is likely to occur. Overall, it is expected that given the generally rural nature of the action area, the impact of residential exposure is over-estimated in this assessment.

Currently two categories of formulations are registered for atrazine use on residential sites. These are granular and liquid formulations (wettable powder and dry flowables). Both formulations are modeled separately because application rates are different (2 lbs/acre for granular and 1 lb/acre for liquid) and the standard assumption for modeling granular formulations is different from liquid formulations. Granular formulations are typically modeled as soil applied (CAM is set to 8 with a minimized incorporation depth of 1 cm) with 0% spray drift, as compared with a foliar application (CAM is set to 2 with a 4-cm depth of incorporation), which assumes the standard spray drift assumption of 1% for ground applications.

For the residential scenarios, it was assumed that some percentage of the watershed is represented by the ¼ acre lot and by impervious surfaces. In order to account for potential variability in impervious surfaces, an analysis of the relative contribution of the impervious and residential scenarios for different portions of the region surrounding the Alabama River Watershed was completed. Figure 3.3 depicts impervious coverage in the area surrounding the Alabama River relative to available atrazine use data. For this screening level exposure assessment, it is assumed that 30% of the area surrounding the watershed is impervious.

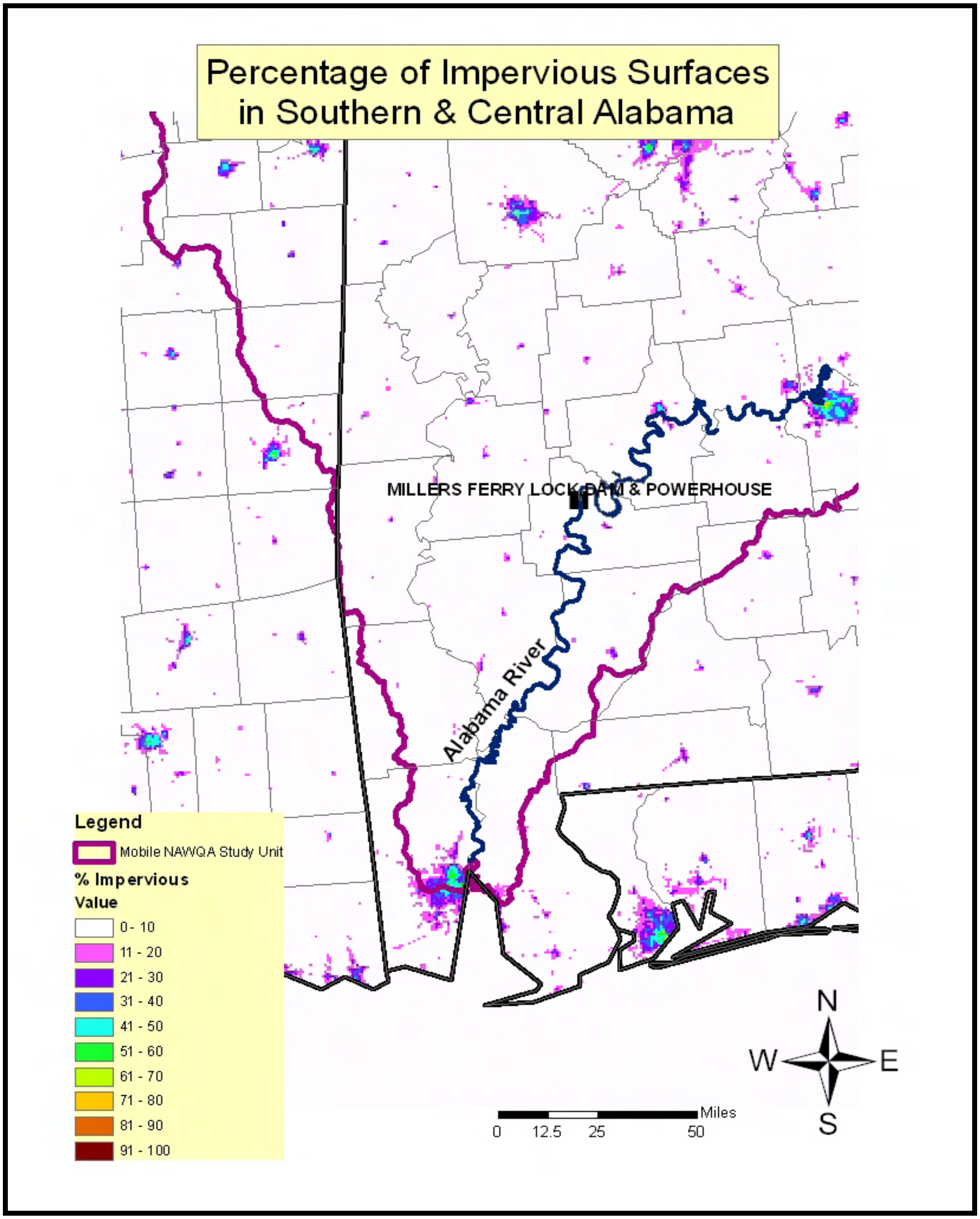

Figure 3.3. Percentage of Impervious Surfaces in Southern and Central Alabama Near the Alabama Sturgeon Action Area

It was also assumed that 50% of the ¼ acre lot is treated with atrazine. The ¼ acre lot was developed with a curve number reflective of the fact that the lot is covered with both pervious surfaces (grass and landscaped gardens) and impervious surfaces (driveways, sidewalks, and buildings). In this case, the assumption that 50% of the lot is treated likely overestimates the amount of landscaped area treated, but underestimates unintentional overspray of driveways and sidewalks, although empirical data to support this assumption are not available.

Rights-of-Way Scenario

For the rights-of-way scenario, it was assumed that rights-of-way consist of 50% impervious and 50% pervious cover. In addition, it was assumed that no single watershed is completely covered by rights-of-way use. This assumption seems reasonable given that rights-of-way (roads, rail and utility lines) are typically long, linear features that traverse a watershed. For the screening level exposure assessment, it was assumed that no more than 10% of the watershed is covered in rights-of-way. However, analysis of spatial data suggests that the 10% assumption is likely an over-estimation of the percentage of the action area covered in rights-of-ways.

In the Barton Springs Assessment (U.S. EPA, 2006c), an evaluation of the local land cover data indicated that a reasonably conservative assumption of the percentage of the area in rights-of-way was 10%. The analysis included land cover types including roads, fence lines, power lines, and railroads. More information on this analysis can be found in Appendix C of the Barton Springs Salamander Assessment for atrazine (U.S. EPA, 2006c). A similar analysis was conducted for this assessment.

In this analysis, national data for roads and railways (http://nationalatlas.gov) and internal EPA data for pipelines were obtained (spatial data for utility easements were not available). The road, rail, and pipeline land cover data were added to a GIS map of the action area (Figure 3.4) and a comparison of the density of the total network of potential use sites was made. Each land cover feature in the GIS map is presented as a line with no width associated. A buffer was applied using the Arc Toolbox within Arc Map in order to account for the potential width of the each linear feature. This assignment of area to each feature was done in order to compare the total area of each feature type (e.g. railways) with the total area of the action area.

For each feature, an assumption was made about the typical width of the feature (e.g. width of the road surface plus shoulders) plus the rights-of-way area adjacent to the feature that could potentially be treated. In each case, a conservative assumption for the width of the feature zone plus the potentially treated area surrounding each was assumed. These assumed feature width estimates, which were based on professional judgment, were skewed to the largest feature in the class. For example, the largest width was assumed for national highways, and this width was also applied to all primary and secondary highways within the action area. This approach is assumed to be conservative

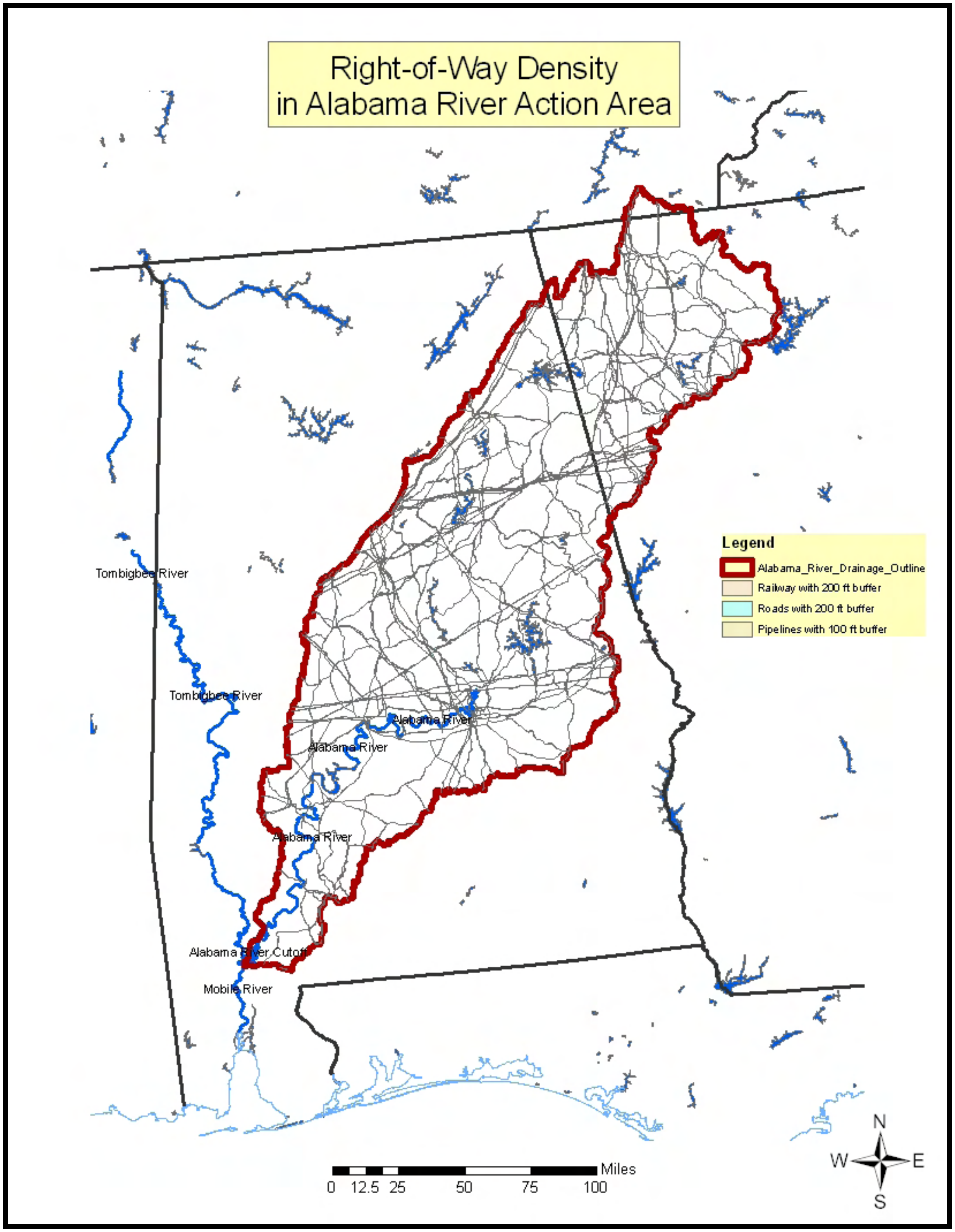

Figure 3.4. Density of Road, Railways, and Pipelines as Surrogate for Rights-of-Way Density in Alabama River Watershed (Action Area)

because it is unlikely that all features will be of similar width, and not all areas will be treated with atrazine (e.g., many areas are likely to be maintained using mechanical methods, such as mowing, or not treated at all). The following assumptions were made for the width of each feature:

- Roads – 200 feet
- Rail – 200 feet
- Pipeline – 100 feet
- Utility Line – 200 feet

Given these assumptions, the percentage of rights-of-way land cover types plus associated buffers for roads, railways, and pipelines within the action area for the Alabama sturgeon is 0.6% of the total area for rail, 1.5% for roads, and 0.6% for pipelines. Locally, it appears that higher percentages occur near more urbanized areas; however, it was assumed that less rights-of-way pesticide application occurs in urbanized areas. The aggregate percentage of land cover in roads and railways of 2.1 % appears to be a reasonable estimate. Additional roads may be present in the action area that are not captured by the available spatial data, and the analysis does not include utilities and pipelines for which no spatial data are available. Therefore, although the assumption of 10% used in this assessment for treated rights-of-way uses may over-estimate exposure, it is expected to be conservative and protective, given the associated uncertainties.

Forestry Scenario

Use of atrazine on commercial forestry operations cannot be precluded as a potential non-agricultural use; however, the available information suggests that atrazine is rarely used on commercial forestry operations in Alabama (McNabb, personal communication, 2006; Michael, personal communication, 2006). However, because this registered use pattern is widely prevalent in Alabama, it has been addressed using the Oregon Christmas tree scenario. This scenario was developed specifically for the OP cumulative assessment recently completed by the Agency (U.S. EPA, 2006d) and represents a vulnerable site based on OP use information intended to represent a commercial nursery operation. Information on the OP cumulative and scenarios used in modeling may be found at:

http://www.epa.gov/pesticides/cumulative/2006-op/index.htm

The Oregon Christmas tree scenario is expected to approximate commercial forestry operations where herbicides are typically applied during the seedling emergence and juvenile growth stages to prevent competition with newly planted trees. The scenario was not modified to represent local conditions but was modeled using local weather data from Mobile, Alabama. Several factors suggest that modeling of forestry uses of atrazine is likely to result in an over-estimation of exposure. As previously mentioned, atrazine use in forestry operations in the state of Alabama is considered to be rare. The available information indicates that the herbicides of choice in Alabama forestry are Roundup®, Oust®, Velpar®, Garlon®, and Arsenal® (Michael, personal communication, 2006). Secondly, modeled estimates represent a one in ten year return frequency using 30 years of modeled output; however, if atrazine were used at all, it would likely be applied for only one or two years during early growth stages. Finally, the available information suggests that most commercial forestry operations are removed from the immediate vicinity of the Alabama River (Michael, personal communication, 2006). Taken together, these facts suggest that the modeled exposures for atrazine forestry use are likely to over-estimate exposure; therefore, these EECs are not used to derive risk quotients. However, they are discussed as part of the risk description in order to account for potential changes in current herbicide use practices in Alabama forestry to include atrazine in the future.

3.2.3.1 Model Inputs

In accordance with the Agency's Overview Document (U.S. EPA, 2004), the estimated water concentrations from surface water sources were calculated using Tier II PRZM (Pesticide Root Zone Model) and EXAMS (Exposure Analysis Modeling System). PRZM is used to simulate pesticide transport as a result of runoff and erosion from a standardized watershed, and EXAMS estimates environmental fate and transport of pesticides in surface waters. The linkage program shell (PE4v01.pl) that incorporates the site-specific scenarios was used to run these models.

As noted above, new and existing scenarios were used in this assessment. Existing scenarios consist of agricultural scenarios for corn and sorghum developed previously for other geographic areas. New scenarios were developed for one agricultural use (fallow/idle land) and several non-agricultural uses including residential, turf, forestry, and rights-of-way. These new scenarios were developed for the Barton Springs Salamander assessment (U.S. EPA, 2006c) and are not specific to Alabama River Watershed. All existing and new scenarios were modeled using local weather data (Mobile, Alabama). Linked use site-specific scenarios and meteorological data were used to estimate exposure as a result of specific use for each modeling scenario. PRZM/EXAMS was used to calculate concentrations using the standard ecological water body scenario in EXAMS. Weather and agricultural practices were simulated over 30 years so that the 1 in 10 year exceedance probability at the site was estimated for the standard ecological water body.

One outcome of the 2003 IRED process was a modification to all existing atrazine labels that requires setback distances around intermittent/perennial streams and lakes/reservoirs. The label changes specify setback distances of 66 feet and 200 feet for atrazine applications surrounding intermittent/perennial streams and lakes/reservoirs, respectively. The Agency incorporated these distances into this assessment and has modified the standard spray drift assumptions accordingly using AgDrift to estimate the impact of a setback distance of 66 feet on the fraction of drift reaching a surface water body. The revised spray drift percentages, which are incorporated into the PRZM/EXAMS modeling, are 0.6% for ground applications and 6.5% for aerial applications.

Models to estimate the effect of setbacks on load reduction for runoff are not currently available. It is well documented that vegetated setbacks can result in a substantial reduction in pesticide load to surface water (USDA, NRCS, 2000). Specifically for atrazine, data reported in the USDA study indicate that well vegetated setbacks have been documented to reduce atrazine loading to surface water by as little as 11% and as much as 100% of total runoff without a setback. It is expected that the presence of a well vegetated setback between the site of atrazine application and receiving water bodies could result in reduction in loading. Therefore, the aquatic EECs presented in this assessment are likely to over-estimate exposure in areas with well-vegetated setbacks. While the extent of load reduction can not be accurately predicted through each relevant stream reach in the action area, data from USDA (USDA, 2000) suggest reductions could range from 11 to 100%.

The appropriate PRZM input parameters were selected from the environmental fate data submitted by the registrant and in accordance with US EPA-OPP EFED water model parameter selection guidelines, Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version 2.3, February 28, 2002. These parameters are consistent with those used in both the 2003 IRED (U.S. EPA, 2003a) and the cumulative triazine risk assessment (U.S. EPA, 2006a) and are summarized in Table 3.2. More detail on these assessments may be found at:

http://www.epa.gov/oppsrrd1/REDs/atrazine_ired.pdf

http://www.epa.gov/pesticides/cumulative/common_mech_groups.htm#chloro

Table 3.2. Summary of PRZM/EZAMS Environmental Fate Data Used for Aquatic Exposure Inputs for Atrazine Endangered Species Assessment for the Alabama Sturgeon

Fate Property	Value	MRID (or source)
Molecular Weight	215.7	MRID 41379803
Henry's constant	2.58 x10 -9	MRID 41379803
Vapor Pressure	3 x 10 -7	MRID 41379803
Solubility in Water	33 mg/l	MRID 41379803
Photolysis in Water	335 days	MRID 42089904
Aerobic Soil Metabolism Half-lives	152 days	MRID 40431301 MRID 40629303 MRID 42089906
Hydrolysis	stable	MRID 40431319
Aerobic Aquatic Metabolism (water column)	304 days	2x aerobic soil metabolism rate constant
Anaerobic Aquatic Metabolism (benthic)	608 days	MRID 40431323

Fate Property	Value	MRID (or source)
Koc	88.78 ml/g	MRID 40431324 MRID 41257901 MRID 41257902 MRID 41257904 MRID 41257905 MRID 41257906
Application Efficiency	95 % for aerial 99 % for ground	default value[2]
Spray Drift Fraction[1]	6.5 % for aerial 0.6 % for ground	default value[2]

[1] – Spray drift not included in final EEC due to edge-of-field estimation approach

[2] – Inputs determined in accordance with EFED "*Guidance for Chemistry and Management Practice Input Parameters for Use in Modeling the Environmental Fate and Transport of Pesticides*" dated February 28, 2002

3.2.3.2 Results

As noted above, a total of eight scenarios were evaluated in this assessment. Of these, three were developed as part of the Barton Springs salamander endangered species assessment (U.S. EPA, 2006c). Two of the Barton Springs scenarios (residential and rights-of-way) were used in tandem with an impervious scenario, while a third (fallow/idle land) is a standard PRZM/EXAMS scenario. The remaining four scenarios (corn, sorghum, Christmas trees as surrogate for forestry, and turf) were taken from existing scenarios developed for other regions of the United States and modeled using weather data from the Mobile, Alabama. No new scenarios were developed for this assessment. In order to address the potential use of atrazine on the labelled use sites within the action area, all of the scenarios were modeled. In addition, the results are characterized to place emphasis on those concentrations actually expected to be present. The results of the modeling are summarized in Table 3.3. An example of the modeling approach and the model input files are provided in Appendix D.

Table 3.3. Summary of PRZM/EXAMS Output EECs for all Modeled Scenarios (Using the Standard Water Body)

Use Site	Application Rate (lbs/acre)	Number of Applications (interval)	First Application Date	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Residential–Granular[1]	2.0	2 (30 days)	April 1	19.9	19.6	19.4	19.2	18.6	17.9
Residential–Liquid[1]	1.0	2 (30 days)	April 1	14.6	14.4	14.2	14.1	13.7	13.4
Right-of-Way[1]	1	1	June 1	2.4	2.4	2.4	2.4	2.3	2.2

Use Site	Application Rate (lbs/acre)	Number of Applications (interval)	First Application Date	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Corn[2]	2	1[3]	April 1	103.2	102	101.3	101.1	98.9	95.9
Sorghum[2]	2	1[3]	May 1	63.6	62.9	62.4	61.7	59.6	57.4
Fallow/idle land[2]	2.25	1	November 15	58.8	58.2	58.0	57.6	56.6	55.6
Turf – Granular	2.0	2 (30 days)	April 1	17.9	17.7	17.7	17.7	17.6	17.1
Turf - Liquid	1.0	2 (30 days)	April 1	14.8	14.6	14.4	14.3	13.7	13.1
Forestry[4]	4.0	1	June 1	46.1	45.2	44.7	44.1	42.2	40.8

1 – Assumes 1% overspray of atrazine to the impervious surfaces. Alternate assumptions of 0% and 10% overspray to impervious surfaces are presented in Section 3.2.4.1.
2 – EECs presented in this table for agricultural crops (corn, sorghum, and fallow) are refined in Table 3.4 to account for an action area specific percent cropped area (PCA) factor. The PCA-adjusted EECs for agricultural crops are used in calculating risk quotients.
3 - Actual labeled maximum rates are 2.0 lb/acre for a single application with no more than 2.5 lbs/acre per year. The rate and number of applications reported in this table are an approximation of the label maximum given the current limitation in the Agency's PRZM/EXAMS graphical user interface PE4v01.pl. Currently, PE4v01.pl allows multiple applications but the rate cannot be varied from one application to the next.
4 - Forestry EECs are not used to derive risk quotients due to uncertainty in the actual use pattern and overestimation of application frequency; however, potential risks to the Alabama sturgeon from forestry uses of atrazine are characterized as part of the risk description in Section 5.2.

Percent Cropped Area (PCA) Adjustment for Agricultural Uses

A GIS analysis of land cover data was completed within the action area for the Alabama River sturgeon. In this analysis, the NLCD (National Land Cover Data) cropland data layer was used to define the extent of all agricultural crops within the action area. The action area was defined using 8-digit HUCs, based on aggregated HUC8 watersheds draining to the Alabama River. The action area for the Alabama River is shown in Figure 2.5.

This analysis indicates that the bulk of the agricultural land in the action area is located in areas far removed from the main stem of the Alabama River where the Alabama sturgeon is known to reside. Typically, the underlying conceptual model for aquatic exposures used in ecological risk assessments is that the water body where the species being assessed lives is adjacent to the treated field. It is also assumed that this treated field represents a small watershed that is 100% treated and drains directly to the water body. Based on the land cover data, it appears that habitat for the Alabama sturgeon is removed from the location where agricultural crops are grown. Therefore, the generic conceptual model discussed above does not apply for agricultural crops modeled in this assessment (corn, sorghum, and fallow/idle land).

Based on the analysis of land cover data, the conceptual model for human health drinking water assessments is considered to be more appropriate for estimating exposures related to agricultural uses of atrazine in the Alabama River where the Alabama sturgeon may reside. In the human health drinking water assessment, it is assumed that some portion, but not all, of the watershed is treated when assessing an agricultural crop use. The Agency has developed a suite of national and regional percent cropped area (PCA) adjustment factors for use in drinking water assessments. Crop-specific PCAs have been developed for corn, sorghum, cotton, and soybeans, and a national default PCA has been identified for all cropland. This national assessment is typically conducted to assess the potential for drinking water exposures in all watersheds in the area of interest that is typically national. The rational for this adjustment and details on how the PCAs were developed can be found at the following website.

http://www.epa.gov/oppfead1/trac/science/reservoir.pdf

In the case of the Alabama sturgeon, exposure concentrations are derived for a single watershed; therefore, use of a watershed-specific PCA is appropriate. As part of this effort, the total area for the entire action area and the cropland portion of the action area was tabulated. This analysis, which is presented graphically in Figure 3.5**,** shows that the bulk of agricultural land is restricted to areas well upstream of the sturgeon's habitat range. The total percentage of cropland within the Alabama River action area is 9.8%. This value has been used to adjust all PRZM/EXAMS predicted EECs for agricultural uses included in this assessment. The PCA-adjusted exposure concentrations for corn, sorghum, and fallow/idle land, which are summarized in Table 3.4, are used for risk estimation. None of the non-agricultural uses were PCA adjusted using this crop-specific PCA. However, the non-agricultural uses (right-of-way, residential, and turf) were adjusted using action area-specific factors for each use.

Action Area-Specific Adjustment Factors for Non-Agricultural Uses

As previously discussed above, an action area-specific adjustment factor of 10% was assumed for rights-of-way. An additional analysis was conducted to determine the relevance of turf and residential uses within the action area. Evaluation of the impervious surface data and other land cover data suggests that much of the area within the Alabama River watershed is predominantly rural. As such, it is unlikely that 100% of any sub-watershed within the action area is surrounded by residential/turf use sites. In fact, the available information suggests that population density is restricted to only a few isolated urbanized areas. Available data from the U.S. Census (http://factfinder.census.gov) for all Alabama counties in the action area suggest that the average density of housing is 38.3 units per square mile (640 acres). An estimate of the total acreage of residential lots in

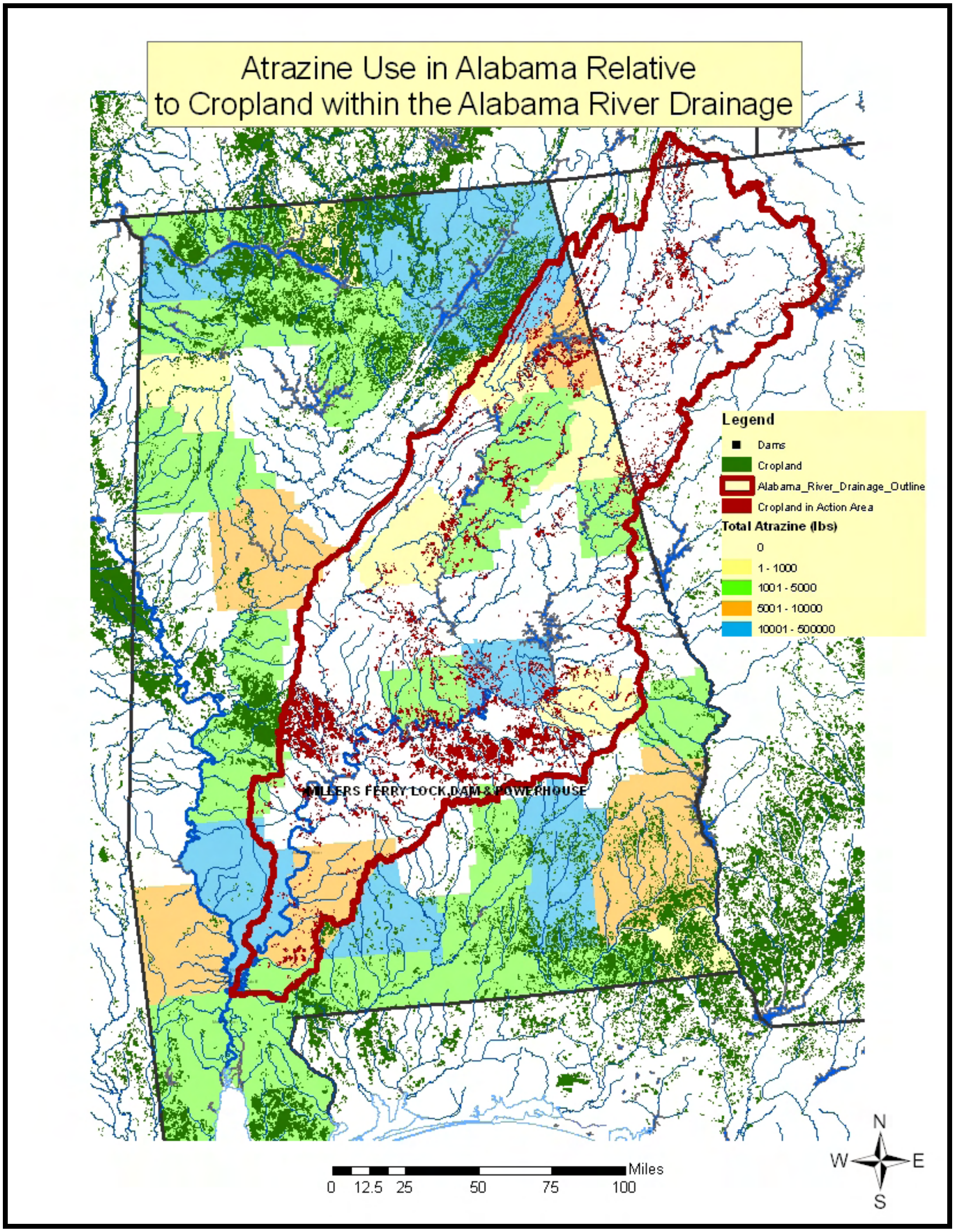

Figure 3.5. Percent Cropped Area (PCA) Analysis in the Alabama River Sturgeon Action Area

the action area was generated using a conservative assumption of 2.5 acres for the maximum lot size (a much higher lot size estimate than used in modeling). Multiplying the average number of lots (38.3) by the assumed lot size (2.5 acres) yields a total of 95.8 acres of residential lots within the action area. This acreage is then divided by the total number of acres per square mile (640 acres) to estimate the percentage of residential area within the action area. The estimated value is 15%. This action area adjustment factor is applied to the residential and turf EECs presented in Table 3.3 to yield adjusted EECs for use in risk estimation. These values are presented along with the PCA-adjusted EECs for the agricultural scenarios in Table 3.4.

Typically, ecological risk exposure assessments assume that 100% of the watershed immediately surrounding the receiving water body is treated. Modeling all potential uses separately and assigning the highest exposure scenario to the risk estimation provides a level of conservativeness to the assessment. If multiple uses were present in the 10 hectare watershed (an unlikely occurrence), the aggregation of these exposures would yield a lower estimate than assuming 100% of the watershed is the maximum use site.

However, in this assessment, a set of action area-specific PCAs were estimated and applied to the modeled individual uses. Use of action area-specific PCAs is appropriate because land cover data analysis suggests that the major use sites (agricultural, residential, rights-of-way, and turf) are not proximate to the species location in the Alabama River. Because these uses are likely removed from the species location, no single use site will dominate exposure, and an aggregation of exposure is necessary to reflect the co-occurrence of agricultural and non-agricultural uses of atrazine within the action area. In order to account for this, each modeled use pattern modeled is assigned a general PCA. For example, three agricultural crops (corn, sorghum, and fallow land) were modeled separately and each assigned a PCA associated with general agricultural land. No detailed land cover information is available to assign crop specific PCA. The concept of aggregating PCA-adjusted EECs is similar to that employed in human health cumulative risk assessments, where the PCA adjustment alters the mass of pesticide reaching a receiving water body that is generally removed from the treated fields. In contrast, the standard conceptual model for ecological risk assessment is that the water body is proximate to the entire treated field. Because, the receiving water body (in this case the portion of the Alabama River) is removed from most treated areas, receives water from a larger drainage area than the standard assumption (10 hectares), and has significant flow, it is similar to the Index Reservoir used in drinking water exposure conceptual models. Exposures were aggregated by selecting the agricultural use pattern that yields the highest exposure (in this case corn), assuming it covers the entire agricultural land cover class, and aggregating it with other non-agricultural use sites from the other general land use types including residential, rights-of-way, and turf. The individual use scenarios that were selected to represent each land class for the aggregate EECs are bolded in Table 3.4.

Similar to the methodology used in human health cumulative risk assessments, the addition of these exposures is likely to be conservative because it assumes that all applications occur at the same time and at the maximum application rate across the entire suite of land cover classes. In reality, aggregated exposure concentrations are expected to be lower than the modeled predicted values because applications are unlikely to occur simultaneously across the landscape at the maximum rate, and not all of the specific use types are likely to be treated (i.e. percent crop treated, or PCT, for corn represents the portion of land in corn that is actually treated). However, no information is available to estimate these factors; therefore, conservative assumptions are used to derive the aggregate EECs. Using the techniques developed for assessing multiple pesticide uses within a watershed, the time series concentrations from each of the four land use classes were added, rather than simply adding the maximum concentrations for each duration of exposure. This analysis accounts for the differences in application timing (still assuming that all applications within a land use class occur at the same time) between land classes. Further detail on the approach used in the cumulative risk assessments for assessing multiple exposures within a watershed may be found at the following website:

http://www.epa.gov/pesticides/cumulative/rra-op/I_E.pdf

The resulting aggregate EECs represent the impact of co-mingling simultaneous agricultural and non-agricultural exposures and account for the diluting effect of non-treated areas as well as the interplay of high and low exposure scenarios. The results of this analysis are presented in Table 3.4

Table 3.4. Revised PRZM/EXAMS EECs for all Modeled Scenarios Using the Action Area-Specific PCA[1]

Use Site	Application Rate (lbs/acre)	Number of Applications (interval)	First Application Date	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Residential–Granular	2.0	2 (30 days)	April 1	3.0	2.9	2.9	2.9	2.8	2.7
Residential–Liquid	1.0	2 (30 days)	April 1	2.2	2.2	2.1	2.1	2.1	2.0
Right-of-Way[2]	1	1	June 1	2.4	2.4	2.4	2.4	2.3	2.2
Corn	2	1	April 1	10.1	10.0	9.9	9.9	9.7	9.4
Sorghum	2	1	May 1	6.2	6.2	6.1	6.0	5.8	5.6
Fallow/idle land	2.25	1	November 15	5.8	5.7	5.7	5.6	5.5	5.4

Use Site	Application Rate (lbs/acre)	Number of Applications (interval)	First Application Date	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Turf – Granular	2.0	2 (30 days)	April 1	2.7	2.7	2.7	2.7	2.6	2.6
Turf - Liquid	1.0	2 (30 days)	April 1	2.2	2.2	2.2	2.1	2.1	2.0
Aggregate EECs from all atrazine land classes in action area[3]				16.3	16.2	16.1	16.1	15.8	15.7

1 – Action area-specific PCA-adjusted EECs are used for risk estimation.
2 – Rights-of-Way EECs from Table 3.3, which incorporate an action area-specific adjustment factor of 10%.
3 – Action Area Weighted EEC estimated by summing the time-series concentrations from each of the general land classes (agricultural land, residential, right-of-way, and turf) assuming 100% of the general class is treated with the highest scenario modeled. Differences in application timing between land classes are considered. For example, general cropland is estimated at 9.8% of the entire action area and therefore, because a distinction cannot be made within the cropland class for specific agricultural crops modeled (corn, sorghum, and fallow land) the highest use scenario modeled (corn) is assumed to represent the entire class, providing a conservative estimate. Similar assumptions are made for the residential and turf uses. This provides an estimation of the impact of co-mingling of atrazine exposures from different application sites at various locations within the action area.

3.2.4 Additional Modeling Exercises Used to Characterize Potential Exposures

A number of uncertainties are associated with the modeling described above. Additional characterization of these results has been completed, including a detailed analysis of monitoring data, alternative modeling assumptions, and characterization of the importance of flowing water on modeled EECs. These analyses are described in the sections that follow.

3.2.4.1 Residential Uses (Impact of Overspray and Impervious Surfaces)

To evaluate the assumption of 1% overspray, alternative variable percentages of overspray that could occur on the impervious surface were modeled. For the residential and rights-of-way scenarios, 1% overspray onto impervious surface was assumed. An alternative modeling exercise was conducted to evaluate the significance of overspray. To account for potential overspray, the impervious scenario (assuming 30% of watershed is impervious and 50% of the ¼ acre lot is treated as above) was modeled by assuming that variable percentages of the application rate could be applied to non-target impervious surfaces. It was assumed that no more than 10% of the intended application rate would be applied to the impervious surface. Given that the impervious scenario is intended to represent non-target surfaces such as roads, parking lots and buildings, the assumption of 10% overspray is likely to result in an over-estimation of exposure. To model overspray, the binding coefficient was set to zero and the aerobic soil metabolism half life was set to stable in lieu of actual data. Thus, it is assumed that non-binding would occur on these surfaces and that limited degradation would occur. The total application rate was then multiplied by the percentage overspray. For the residential scenario, this yielded an application rate on the impervious surface of 0.2 lbs/acre. In addition, the same analysis using an assumption of 0% over spray was modeled.

Comparison of the resulting residential use pattern EECs indicates that with 10% overspray the overall EECs are increased by roughly a factor of two, while assuming 0% overspray only slightly decreases the EECs as compared to 1% overspray. This is not unexpected given the increased runoff, lack of binding, and lack of degradation being assumed. Without actual data for these processes, it is not possible to determine whether these exposures reflect reality; although, it is expected that these assumptions are likely to be conservative (some binding and degradation could occur). The analysis suggests that overspray onto impervious surfaces may be a significant issue when the percentage of overspray is high. The comparison of residential EECs based on varying percentages of overspray is presented in Table 3.5.

Table 3.5. Comparison of Residential EECs (granular w/ 30% impervious surface) Assuming Variable Percentages of Overspray (0, 1, and 10%) onto Impervious Surfaces

Use Site	Application Rate (lbs/acre)	Number of Applications (interval)	First Application Date	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Residential with 1% Overspray	2.0	2 (30 days)	April 1	19.9	19.6	19.4	19.2	18.6	17.9
Residential with 0% Overspray	2.0	2 (30 days)	April 1	17.8	17.5	17.3	17.1	16.5	15.8
Residential with 10% Overspray	2.0	2 (30 days)	April 1	42.4	42.1	41.9	41.6	40.8	39.8

Other assumptions within this assessment, which can have a significant impact on the overall predicted EECs, include the percentage of impervious surfaces and the percentage of ¼ acre lot that is treated. In both instances, the relationship between the assumption and the predicted EEC is linear. In other words, the assumed impervious surface percentage of 30% within the action area of the Alabama River watershed decreases dramatically with increasing distance away from urban areas, such as Mobile or Montgomery, and from the sturgeon's habitat. The available data show that the percentage of impervious surface decreases to less than 10% with increasing distance to the north of Mobile, Alabama, although there are likely to be isolated pockets of urbanized areas with higher percentages of impervious surfaces within the action area (Figure 3.3). The impact of this assumption was evaluated by readjusting the output to reflect the impact of a 5% impervious cover assumption on predicted exposures. In general, peak and longer-term average concentrations generally double as the percentage of impervious surface decreases. The increase in EECs is likely due to the increase in treated area contributing more pesticide mass and a decrease in the impervious surface, which results in a reduction in the amount of non-contaminated runoff. The impact of a higher percentage of impervious surfaces was also modeled by assuming 50% impervious surface that is representative of a core urban setting. The comparison of residential EECs assuming variable percentages of impervious surface is presented in Table 3.6.

Table 3.6. Comparison of Residential EECs (granular w/1% overspray) Assuming Variable Percentages of Impervious Surface (5, 30, and 50%)

Use Site	Percent Impervious	Application Rate (lbs/acre)	Number of Applications (interval)	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Residential	30	2.0	2 (30 days)	19.9	19.6	19.4	19.2	18.6	17.9
Residential near Montgomery, AL	50	2.0	2 (30 days)	16.3	16.0	15.9	15.7	15.3	14.8
Residential in Central Alabama	5	2.0	2 (30 days)	24.5	24.0	23.8	23.6	22.7	21.8

In this assessment, it is assumed that 50% of the ¼ acre lot is treated. In order to test the significance of this assumption, the exposure scenarios were reevaluated using different assumptions of 75% and 10% of the ¼ acre lot are treated. Increasing the percentage of the ¼ acre lot that is treated to 75% of the total area increases the EECs by roughly 50%, while decreasing the percentage treated to 10% of the total area decreases EECs by a factor of roughly four. The results of these analyses are presented in Table 3.7.

Table 3.7. Comparison of Residential (granular) EECs Assuming Various Percentages of Treated ¼ Acre Lot (10, 50, and 75%)

Use Site	Application Rate (lbs/acre)	Number of Applications (interval)	First Application Date	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Residential with 50% of lot treated	2.0	2 (30 days)	April 1	19.9	19.6	19.4	19.2	18.6	17.9
Residential with 75% of lot treated	2.0	2 (30 days)	April 1	28.9	28.3	28.1	27.8	26.8	25.8
Residential with 10% of lot treated	2.0	2 (30 days)	April 1	5.7	5.6	5.6	5.5	5.4	5.2

3.2.4.2 Impact of Flowing Water on Modeled EECs

The Agency's standard ecological assessment for aquatic organisms relies on estimates of exposure derived from PRZM/EXAMS using the standard water body. The standard water body is a 1 hectare pond that is 2 meters deep with a total volume of 20,000,000 liters and is modeled without flow. The standard water body was developed in order to provide an approximation of high end exposures expected in ponds, lakes, and perennial/intermittent streams adjacent to treated agricultural fields. Typically, this has been interpreted as a stream with little, or low flow. For pesticides with low to moderate persistence, the standard water body provides a reasonably high end estimate of exposure in headwater streams and other low flow water bodies for both acute and longer-term exposures. For more persistent compounds, the non-flowing nature of the standard water body provides a reasonable high end estimate of peak exposure for many streams found in agricultural areas; however, it appears to over-estimate exposure for longer time periods in all but the most static water bodies.

The hydrologic landscape of the Alabama River watershed can be generalized by categorizing the stream network into broad classifications. A simplified approach of categorization for this assessment places the streams in the watershed into several broad classifications including headwater streams, upper tributary (relative to the Alabama River) streams, main stem of the tributaries, and the Alabama River itself. The purpose of this classification scheme is to describe the modeled EECs in the context of where these exposures are most representative and where they may be over- or under-estimated. Modeled concentrations derived with the non-flowing standard water body (presented in Table 3.3), are expected to be representative of exposures in headwater streams in areas of low topography. It is also expected that the chronic EECs over-estimate exposure in water bodies with flowing water, including the Alabama River between the Millers Ferry Dam and Lock and the junction with the Tombigbee River, as well as the main tributaries off the Alabama River.

In order to characterize the potential impact of flowing water on the longer-term exposures (14-day, 21-day, 30-day, 60-day, 90-day, and annual average), additional modeling and analysis of available monitoring data was conducted. Alternate approaches to modeling with the standard water body were conducted to provide a general sense of the relative reduction in long term exposure that might be occurring in water bodies where flow is higher than small headwater streams in low topographic regions of central and southern Alabama.

The corn scenario was re-modeled with non-standard assumptions of flow (described below) because it yielded the highest non-PCA-adjusted EECs, based on the input parameters presented in Table 3.2. As previously discussed, the standard EXAMS static ecological water body is typically used as the receiving body for runoff from a 10 hectare field. The standard ecological water body is intended to represent a pond or an ecologically sensitive stream adjacent to an agricultural field. Typically, this is conceptualized as a headwater stream; however, it may also be representative of higher order streams with very low flow rates (e.g. small tidal inlets, oxbow lakes occasionally fed by stream flow only, etc.).

In order to test the effect of flow on predicted EECs, the standard ecological water body described above was used; however, the model was revised to route runoff water from the 10 hectare field through the 1 hectare water body as flow. The net effect of this analysis was to decrease both the peak and longer-term average concentrations by roughly 50% and the annual average by nearly two times. The results of the alternative modeling are presented in Table 3.8.

Further analysis was conducted by pairing the PRZM output from the corn scenario with the Agency's variable volume water model (VVWM), which was developed for the Probabilistic Risk Assessment (PRA) process. The VVWM was developed based on the recommendation of the Scientific Advisory Panel (SAP) to account for the influence of input and output (flow) on model predictions. In this case, the VVWM was used to evaluate the impact of varying volume on the overall EECs. In general, the VVWM yielded EECs less than the standard EXAMS water body EECs, but still above the annual averages from the available monitoring data (see discussion below). Two alternate model runs were conducted with the VVWM. The first was done using standard assumptions and environmental fate parameters generally consistent with the non-flowing standard water body run discussed above. The first model run assumed a 2-meter depth water body that can drop to 0.02 meter and rise to 3 meters before flow occurs. The second model run assumed a larger volume water body that maximizes flow into the water body. This was accomplished by increasing the overall maximum depth of the water body to 10 meters. The net effect of this change is to reduce the original estimates for both peak and long-term exposures with the VVWM by roughly a factor of two to four, depending on water depth. The results are summarized in Table 3.8. Documentation and rationale for the assumptions used in the VVWM may be found at:

http://www.epa.gov/scipoly/sap/2004/index.htm#march

In order to further characterize the impact of larger water bodies with flow, the corn scenario was also modeled using the Index Reservoir as the receiving water body. The Index Reservoir represents a 5.3 hectare water body draining a 172 hectare watershed. In the case of the Index Reservoir, the standard approach is to allow EXAMS to estimate total runoff accumulated from the 172 hectare watershed and route that volume of water as flow through the reservoir while assuming no change in reservoir volume. The predicted peak EECs and flow rates from these alternate approaches assuming flow are similar to those from the static water body with flow and the VVWM and are summarized in Table 3.8. More information on the Index Reservoir may be found at:

http://www.epa.gov/oppfead1/trac/science/reservoir.pdf

The USGS collected flow rates from 196 streams, creeks, and rivers from across Alabama representing the range of physiographic provinces that are typical of stream types found in the Alabama River watershed. Average 7Q10 (7 day average with a return frequency of 10 years that is indicative of base-flow values) flow rates were derived for all gauging stations and for the Alabama River alone (six sites). As shown in Table 3.8, the 7Q10 values indicate that flow varies dramatically both within Alabama and when compared to the Alabama River alone. Although neither flow estimate is an exact representation of flow conditions, they are intended to provide a reasonable range of flow rates. These flow values ranged by nearly one order of magnitude across the state.

Comparison with the modeled flow rates suggests that the PRZM modeling yields significantly lower flow rates than those recorded in Alabama watersheds. Flow data may be found at the following website:

http://waterdata.usgs.gov/nwis/rt

In order to test the influence of these flow data on modeled EECs, a final analysis was conducted with the Index Reservoir by modifying the GUI (PE4v01.pl) that runs PRZM/EXAMS. The STFLO parameter responsible for reporting flow through the receiving water body was modified by using the USGS data for Alabama instead of the runoff volume described above. Two alternate Index Reservoir scenarios were then modeled using the 7Q10 flow rates for the entire Alabama River watershed and Alabama River alone. This exercise was intended to provide a range of possible flow rates and modeled EECs within the Alabama River and its tributaries (streams, creeks, and rivers) where the Alabama sturgeon is expected to occur. The results of this analysis are presented in Table 3.8 and indicate that using both 7Q10 values yields EECs appreciably below those predicted using the static water body.

Table 3.8. Comparison of Alternative PRZM Modeling (assuming flow) with EECs Generated Using the Static Water Body

Scenario	Flow (ft^3/sec)	Peak EEC (µg/L)	96-hour EEC (µg/L)	21-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)	Yearly EEC (µg/L)
AL corn with static water body[1]	0	104.8	104.8	102.8	99.1	95.8	73.1
AL corn with flow thru standard water body	0.033	79.8	78.8	75.7	67.4	61.7	30.1
AL corn with VVWM[2]	0.035	54.1	47.2	46.7	44.8	44.8	33.8
AL corn with VVWM[3]	0.032	30.5	29.5	29.4	29.2	29.2	28.1
AL corn with Index Reservoir[4]	0.574	78.3	76.4	72.0	58.8	50.6	40.3
AL corn (IR) with 7Q10 flow from entire AL River Watershed	274.7[5]	58.5	9.6	2.0	0.70	0.47	0.12
AL corn (IR) with 7Q10 flow from AL River only	5981.3[5]	58.5	9.5	1.9	0.68	0.46	0.11

1 – EECs generated using PE4v01.pl in this table are slightly different from those presented in Table 3.3 due to different duration of exposure and slight differences in the manual estimation technique used in Table 3.3.
2 – VVWM parameters: initial depth = 2 m; minimum depth = 0.02 m; ,maximum depth = 3 m
3 - VVWM parameters: initial depth = 2 m; minimum depth = 0.02 m; ,maximum depth = 10 m
4 – Corn IR scenario EEC reported using percent cropped area (PCA) of 46% for corn
5 – USGS flow data reported as 7Q10 values.

3.2.4.3 Comparison of Modeled EECs with Available Monitoring Data

The second step in the process of characterizing modeled EECs was to compare the modeling results with available surface water monitoring data. Unlike many pesticides, atrazine has a fairly robust data set of surface water monitoring from a variety of sources. Included in this assessment are atrazine data from the USGS NAWQA program (http://water.usgs.gov.nawqa; national, local, and Watershed Regression for Pesticides), and Heidelberg College. These monitoring data were characterized in terms of general statistics including number of samples, frequency of detection, maximum concentration, and mean from all detections. In addition, several sample sites from each data set were selected for further analysis including calculation of annual maximum and annual time weighted mean concentrations by site by year. The sample sites chosen for this additional analysis were based on those locations from the national and local data with the highest detected concentrations of atrazine. Finally, an interpolation of a single year's worth of data from one sample site in the Heidelberg College data was completed in order to estimate 14-day, 30-day, 60-day, and 90-day averages.

USGS NAWQA Data

An analysis of the entire USGS NAWQA data set was completed for atrazine. A data download was conducted from the USGS data warehouse (http://water.usgs.gov/nawqa). Overall, a total of 20,812 samples were analyzed for atrazine. Of these, 16,742 samples had positive detections (including estimated values) yielding a frequency of detection of roughly 80%. The maximum detection from all samples was 201 µg/L from the Bogue Chitto Creek in Alabama near Memphis (outside of the Alabama Sturgeon action area) in 1999. Overall, the average concentration detected was 0.26 µg/L when considering only detections and 0.21 µg/L when considering all detections and non-detections (using the detection limit as the value for estimation).

The top ten sites with the highest atrazine concentrations from the national NAWQA data were selected for refined analysis of the detections. All values from the national data set were ranked and the top ten sites were selected based on maximum concentration. Each location was analyzed separately by year, and the annual maximum and annual time weighted mean concentrations were calculated. The minimum criterion for calculating time weighted means for each sampling station was at least 4 samples in a single year. The equation used for calculating the time weighted annual mean is as follows:

$$[((T_{0+1}-T_0) + ((T_{0+2}-T_{0+1})/2))*C_{t0+1})] + (((T_{i+1}-T_{i-1})/2)*C_i) + [((T_{end}-T_{end-1}) + ((T_{end-1}-T_{end-2})/2)*C_{Tend-1})]/365$$

where: Ci = Concentration of pesticide at sampling time (Ti)
Ti = Julian time of sample with concentration Ci
T_0 = Julian time at start of year = 0
T_{end} = Julian time at end of year = 365

The modeling and national NAWQA monitoring data are not directly comparable because the monitoring data are generally from high atrazine use areas in the Midwest and South vulnerable to runoff, while the modeling was conducted exclusively for the action area of the Alabama River watershed. In the Alabama River watershed, the atrazine use intensity and runoff vulnerability (as identified by Williams et al., 2004) are less than areas in the Midwest and South. The Ecological Exposure in Flowing Water Bodies (Williams, et al., 2004) utilized the WARP model to identify highly vulnerable watersheds for sampling and determined that the top 20% watersheds (based on relative vulnerability) were predominantly located in the Midwest and South, while the watersheds in the immediate vicinity of the Alabama River watershed are in the lower 40th percentile .

Given that the watersheds surrounding the Alabama River are significantly less vulnerable to atrazine runoff than those in the Midwest, a comparison with monitoring data from more vulnerable areas was conducted to provide context on the modeled exposures. Modeled concentrations that exceed monitoring data suggest that the modeling is not conservative for the most vulnerable watersheds (represented by the national monitoring sites), but could still be conservative for less vulnerable sites. Model results that are less than the monitoring data from the highly runoff vulnerable atrazine use areas suggest that modeling is not conservative. In the case of atrazine, the modeling tends to under predict the highest single day concentrations and over predict the annual average concentration from the national NAWQA data. This is not unexpected given that the majority of the high atrazine detections are from the 1990s when labeled application rates were higher and because runoff vulnerability is much lower in the area surrounding the Alabama River. The analysis suggests that modeling in the action area for atrazine provides a reasonable estimate of short term exposure but over-estimates longer term exposure.

Generally, the maximum (peak) values from this analysis are similar to, or above, the model predictions from PRZM/EXAMS, while the annual time weighted mean (TWM) concentrations are roughly an order of magnitude below the static water body model predictions for annual average and are roughly two to four times below the flow influenced model predictions described above. Comparison of these data and model predictions for the intermediate durations exposures (14-day, 30-day, etc.) was not conducted because the NAWQA data generally do not have the frequency needed to conduct a meaningful interpolation between data points. Table 3.9 presents a summary of the annual time weighted mean concentrations, and Table 3.10 presents a summary of the annual maximum concentrations.

Table 3.9. Annualized Time Weighted Mean (TWM) Concentration (µg/L) for the Top Ten NAWQA Surface Water Sites (Ranked by Maximum Concentration Detected)										
	Station Name (ID)									
Year	**Bogue Chitto Creek, near Memphis, TN (02444490)**	**Tributary to S Fork Dry Creek, near Schuyler, NE (06799750)**	**Sugar Creek, New Palestine, IN (394340085524601)**	**Kessinger Ditch, near Monroe City, IN (03360895)**	**LaMoine River @ Colmar, IL (05584500)**	**Sugar Creek @ Milford, IL (05525500)**	**Tensas River @ Tendal, LA (07369500)**	**Maple Creek near Nickerson, NE (06800000)**	**Auglaize River near Ft Jennings, OH (04186500)**	
1991										
1992			0.98					1.32		
1993			0.77	3.80				1.43		
1994			0.87	2.56						
1995			2.28	0.74						
1996			1.30				4.32		2.18	
1997			5.36		3.45		5.55	1.03	2.82	
1998			0.82		1.79		2.94	1.21	1.88	
1999	9.62		0.28				2.50	0.68		
2000	6.49		0.56			1.26		0.15		
2001	1.20		0.83			0.78		0.22	1.28	
2002	2.88		0.51			2.22		1.26	0.80	
2003	2.14	4.46	0.70			7.83		2.23	1.42	
2004	1.77	68.78[1]	0.67			1.24		3.31	1.93	

[1] – TWM concentration likely biased because the first sample on May 8 is the peak sample from this year.

Table 3.10. Maximum Concentration (µg/L) for the Top Ten NAWQA Surface Water Sites (Ranked by Maximum Concentration Detected)										
	Station Name (ID)									
Year	**Bogue Chitto Creek, near Memphis, TN (02444490)**	**Tributary to S Fork Dry Creek, near Schuyler, NE (06799750)**	**Sugar Creek, New Palestine, IN (394340085524601)**	**Kessinger Ditch, near Monroe City, IN (03360895)**	**LaMoine River @ Colmar, IL (05584500)**	**Sugar Creek @ Milford, IL (05525500)**	**Tensas River @ Tendal, LA (07369500)**	**Maple Creek near Nickerson, NE (06800000)**	**Auglaize River near Ft Jennings, OH (04186500)**
1991									
1992			14					25	
1993			8.5	120				11.2	
1994			11	24					
1995			27	2.6					
1996			14.2						18
1997			129		108		92.3	10.3	85.2
1998			7.88		27.7		19.3	30	9.96
1999	201		2.39				13.9	10.7	
2000	136		3.84			23 30		0.87	
2001	4.5		14.4			6.96		1.21	10.4
2002	24.8		4.01			21.3		16.4	2.58
2003	18.8	21.3	10.5			108		34.8	13.4
2004	14.6	191	28.3			10.9		91.9	18.7

USGS Watershed Regression of Pesticides (WARP) Data

The NAWQA data were then compared against the percentiles used to develop the USGS WARP model. Comparison against WARP percentiles was conducted because the WARP model has been reported to be a valuable tool for site selection and assessing overall vulnerability. More information on the WARP model may be found at:

http://pubs.usgs.gov/wri/wri034047/wrir034047.pdf

The WARP data were developed using a subset of the national data described above (all WARP data are included in the national data analysis described above). Data collected between 1992 and 1999 from a total of 113 sample sites were used to create the model. Sample sites were selected based on the robustness of the data available at a given site. The model yields predicted daily exposures at various percentiles of occurrence. The Agency compared the national NAWQA data and the model predictions against the mean and 95th percentile values from the data used. The maximum 95th percentile value from the WARP data was 20.2 μg/L as compared to a maximum of 201 μg/L from all data. The maximum mean value used in the WARP model development data was 3.82 μg/L, which is consistent with the annual TWM values discussed above.

Alabama River Watershed NAWQA Data

The PRZM/EXAMS EECs were compared to surface water data from sites specific to the Alabama River watershed (Figure 3.2). The data from both the entire state of Alabama and from the single sample location on the Alabama River where atrazine was analyzed were evaluated. The data were included in the national assessment described above; however, because the national evaluation focused on all sample sites, some bias was given to higher use areas (even though the highest sample site from NAWQA is from Alabama Bogue Chitto Creek near Memphis and not in the Alabama River watershed). Therefore, the same technique applied to the national data (maximum and TWM) was used for these two data sets to provide a more regionally specific snapshot of the available NAWQA data. Generally, the statewide data were consistent with the national data for maximum exposures with a peak concentration of 201 μg/L, which is the national maximum, while the average concentration from all statewide data was greater with an average for all detections of 1.69 μg/L (compared to national average of 0.21 μg/L) and an average for all data (detects and non-detects) of 1.63 μg/L (compared to national average of 0.21 μg/L). The higher average and peak concentrations are likely biased due to the high concentration of atrazine detected in the Bogue Chitto Creek sample and the limited number of data points in Alabama. Eliminating the Bogue Chitto Creek data from the analysis yields a maximum concentration of 23.6 μg/L and an average for all samples of 0.27 μg/L, indicating that the higher average concentration is significantly influenced by the single site.

The refined analysis for the Alabama River Watershed NAWQA data was completed using the same approach used for the national data. The data were separated by site and year and the annual maximum and TWM concentrations were calculated for the entire

Alabama data set. The results suggest that, with the exception of the Bogue Chitto Creek site, the maximum and TWM concentrations are well below the national analysis. The results of this analysis are presented in Table 3.11.

For data specific to the Alabama River, the results indicate a much lower overall picture of atrazine concentrations relative to both the statewide and national trends. The maximum concentration of atrazine detected in the Alabama River was 0.142 μg/L and the overall average (there were no non-detections) was 0.046 μg/L. The results of the refined analysis indicate that, while statewide results are higher (or similar if the Bogue Chitto Creek site is removed from the data set) than the national average, the site-specific results for the Alabama River are significantly below the national and statewide averages. An analysis of the annual maximum and annual time weighted mean (TWM) concentrations for the data from the Alabama River was also completed. A summary of the monitoring results for the Alabama River is presented in Table 3.12.

Table 3.11. Annual Time Weighted Mean and Annual Maximum Concentration (µg/L) for the Top Six NAWQA Surface Water Sites in Alabama (Ranked by Maximum Concentration Detected)												
Year	**Station ID**											
	THREE MILE BRANCH @ NORTH BLVD AT MONTGOMERY, AL (02419977)		**BOGUE CHITTO CREEK NEAR MEMPHIS, ALABAMA (02444490)**		**TOMBIGBEE R BL COFFEEVILLE L&D NEAR COFFEEVILLE (02469762)**		**FLINT RIVER AT BROWNSBORO, AL (03575100)**		**CAHABA VALLEY CREEK AT CROSS CR RD AT PELHAM, AL. (0242354750)**		**HESTER CREEK @ BUDDY WILLIAMSON ROAD NR PLEVNA, AL (0357479650)**	
	TWM	**Max**	**TWM**	**Max**	**TWM**	**Max**	**TWM**	**Max**	**TWM**	**Max**	**TWM**	**Max**
1999	0.21	1.40	9.62	201.00	0.84	2.86	1.44	3.22	0.04	0.15	0.48	23.60
2000	0.45	1.20	6.49	136.00	0.22	0.49	0.24	6.58	0.05	0.68	0.08	0.36
2001	0.40	4.83	1.20	4.50	0.13	0.57	0.17	1.70	0.04	0.19	0.24	1.99
2002			2.88	24.80	0.15	0.42	0.09	0.62	0.04	0.08	0.09	0.71
2003			2.14	18.80	0.11	0.49	0.21	2.04	0.06	0.19	0.24	2.45
2004			1.77	14.60	0.38	2.56	0.16	1.49	0.06	0.19	0.04	0.22

Table 3.12. Annual Time Weighted Mean and Annual Maximum Concentration (µg/L) for the Top Six NAWQA Surface Water Sites in Alabama (Ranked by Maximum Concentration Detected)

Station ID - 02429500		
Year	**TWM**	**Max**
2000	0.039	0.142
2001	0.036	0.059
2002	0.046	0.083
2003	0.048	0.120
2004	0.042	0.122

Heidelberg College Data

Data from Heidelberg College, which consists of two intensively sampled watersheds (Maumee and Sandusky) in Ohio, were also analyzed. Like the national NAWQA data, the data are outside of the action area but are included in this analysis to provide context to the modeled exposures. More information on the water quality monitoring program at Heidelberg College may be found at the following website:

http://wql-data.heidelberg.edu/

The Heidelberg data were collected more frequently than other data included in this assessment. The study design was specifically established to capture peak and longer term trends in pesticide exposures. Data were collected between 1983 and 1999 and consist of an average of roughly 100 samples per year with several days of multiple sampling.

For the Sandusky watershed, a total of 1,597 samples were collected with 1,444 detections of atrazine (90.4% frequency of detection). The maximum concentration detected in the Sandusky watershed was 52.2 µg/L, and the overall average concentration was 4.5 µg/L. For the Maumee watershed, a total of 1,437 samples were collected with 1,305 detections of atrazine (90.8% frequency of detection). The maximum concentration detected in the Maumee watershed was 38.7 µg/L with an overall average concentration of 3.7 µg/L.

This analysis was further refined by deriving the annual TWM and maximum concentrations by sampled watershed by year. The results of this analysis are presented in Table 3.13. The results show a consistent pattern with that seen in other data collected from high atrazine use areas with general TWM concentrations between 1 and 3 µg/L.

Table 3.13. Annual Time Weighted Mean and Maximum Concentrations (µg/L) for Atrazine in Two Ohio Watersheds from the Heidelberg College Data

Year	Sandusky Watershed		Maumee Watershed	
	TWM	Max	TWM	Max
1983	1.34	7.97	0.98	5.42
1984	1.08	8.73	1.27	11.71
1985	1.83	19.46	1.00	6.21
1986	3.32	24.61	1.64	10.01
1987	1.76	16.45	1.80	9.92
1988	0.41	1.53	0.43	2.15
1989	1.30	15.71	1.07	8.49
1990	1.96	19.31	1.69	14.78
1991	1.49	20.59	2.044	21.45
1992	0.39	40.53	0.51	7.35
1993	1.27	26.34	1.21	22.66
1994	0.86	10.10	0.82	4.02
1995	1.39	15.46	1.30	14.06
1996	1.56	23.40	1.19	16.19
1997[1]	**2.16**	**53.21**	2.09	38.74
1998	1.49	40.03	1.41	27.62
1999	1.57	17.11	1.88	19.37

[1] Sample year 1997 from Sandusky selected for data infilling by interpolation in order to calculate CASM duration exposure values.

Unlike other data sets included in this assessment, an effort at interpolation between data points was completed in order to estimate 14-day, 30-day, 60-day, and 90-day average concentrations. A final analysis of the data was completed by selecting one years worth of data from the Heidelberg data. The 1997 sampling year was selected because it was one of the more recent data sets and because the maximum and TWM concentrations were higher than most other year's data. To process this data, it was necessary to "fill in the gaps". A total of 126 samples were collected during 1997 with 50 days with multiple samples yielding a time series of roughly 75 days. A step-wise approach was used to estimate daily concentrations between sampling dates that consisted of simply extending an analytical result from the date of analysis to the next date. For example, on January 6, 1997, atrazine was detected at a concentration of 0.475 µg/L. On the next sample date of January 20, 1997, no atrazine was detected (0 µg/L). In the step-wise interpolation, all dates between January 6 and January 20 were assigned the concentration of 0.475 µg/L. Also, because January 6 was the first sample date of the year, all previous days were also assigned a value of 0.475 µg/L. This process was repeated throughout the year to fill in the time series and yield 365 days worth of data. In addition, where multiple samples were analyzed on any given day, the highest of the values on that day was assigned. There is significant uncertainty with this type of interpolation because there is no information to suggest whether the interpolated value represents actual exposure. For example, where a significant gap in time exists between two samples, it is unlikely that a continuous concentration exists. It is more likely that there are upward and downward fluctuations in exposure, with a greater likelihood that higher exposures are missed between sample times with larger gaps in data points. The greatest fluctuations are likely to occur either before, or well after, an application of atrazine. It is expected that variation in concentration is less pronounced immediately after application due to the persistence of atrazine.

Table 3.14 presents the results of this analysis. The analysis suggests that, for the Sandusky watershed, in 1997, the estimated longer-term exposures are less than the modeled estimates for the Alabama River by a factor of two to three.

Table 3.14. Magnitude and Duration Estimates (µg/L) from the 1997 Data from Sandusky Watershed Using Stepwise Interpolation Between Samples

	14 day	21 day	30 day	60 day	90 day
Maximum	28.26	21.11	18.30	12.38	8.89
90th Percentile	7.55	7.08	7.82	10.23	8.22

Summary of Open Literature Sources of Monitoring Data for Atrazine

Atrazine is likely to be persistent in ground water and in surface waters with relatively long hydrologic residence times (such as in some reservoirs) where advective transport (flow) is limited. The reasons for atrazine's persistence are its resistance to abiotic hydrolysis and direct aqueous photolysis, its only moderate susceptibility to biodegradation, and its limited volatilization potential as indicated by a relatively low Henry's Law constant. Atrazine has been observed to remain at elevated concentrations longer in some reservoirs than in flowing surface water or in other reservoirs with presumably much shorter hydrologic residence times in which advective transport (flow) greatly limits its persistence.

A number of open literature studies have been cited in the 2003 IRED (U.S. EPA, 2003a), which document the occurrence of atrazine and its degradates in both surface water and groundwater. These data support the general conclusion that higher exposures tend to occur in the most vulnerable areas in the Midwest and South and that the most vulnerable water bodies tend to be headwater streams and water bodies with little or no flow.

The analysis in the IRED also documents the occurrence of atrazine in the atmosphere. The data indicate that atrazine can enter the atmosphere via volatilization and spray drift. The data also suggest that atrazine is frequently found in rain samples and tends to be seasonal, related to application timing. Finally, the data suggest that although frequently detected, atrazine concentrations detected in rain samples are less than those seen in the monitoring data and modeling conducted as part of this assessment and support the contention that runoff and spray drift are the principal routes of exposure. More details on these data can be found in the 2003 IRED (U.S. EPA, 2003a).

3.2.5 Modeling with Typical Usage Information

As previously discussed, agricultural use information within the state of Alabama was taken from the data prepared for the cumulative triazine risk assessment (Kaul, et al., 2005). This information does not include analysis of non-agricultural uses such as residential, turf, rights-of-way, and forestry. However, this information does provide a sense of actual atrazine use on sites similar to those assessed including corn, sorghum, and fallow/idle land. This data suggest that the typical application rates (equivalent to the average of the available data) and number of applications are less than the maximum rates on the labels used above. Table 3.15 summarizes the typical rates and number of applications relative to those used in this assessment. Clearly, if these lower application rates were used, the overall exposure predicted for these uses would be decreased by at least a factor of two for all three uses.

Table 3.15. Comparison of Maximum Labeled Use Information with Typical Rates and Number of Applications

Scenario	Maximum Application Rate (lbs/acre)	Maximum Number of Applications	Typical Application Rate (lbs/acre)	Typical Number of Applications
Corn	2.0	1	1.1	1.5[1]
Sorghum	2.0	1	1.0	1.7[1]
Fallow/ Idle land	2.25	1	1.0	0.9

[1] – Typical number of applications greater than 1 reflect the impact of multiple applications at less than the single maximum rate of 2 lbs/acre. An example would be when atrazine is applied as a mixture with another herbicide but at less than the labeled maximum.

Alternative modeling of the corn scenario using the typical application rate information was completed (corn yielded the highest non-PCA-adjusted EECs using maximum application rates specified on the atrazine label). The rates and number of applications are similar with a typical application rate of 1 lb/acre and 1.1 applications per growing season (Kaul, et al., 2005). Data reported with 1.1 applications represent an average of multiple applications applied at lower than maximum rates and are interpreted in this analysis as a single application. In order to simplify this part of the assessment, the refined application rate was modeled at 1 lb/acre with one application. Data on 90th percentile use rates were not available for this assessment. Comparison of typical applications rates (essentially equivalent to the average of all available reported data) with monitoring data and modeling with labeled maximum rates is used for characterization only because a typical, or average, rate implies that a substantial number of applications may occur above this value. Given the site-specific nature of an endangered species assessment, it is impossible to rule out the possibility that some percentage of actual applications are occurring in proximity to the Alabama sturgeon. However, the results of this analysis show that use of atrazine at the typical application rates results in a reduction of EECs across the board by a factor of two. The results of this analysis are summarized in Table 3.16.

Table 3.16. Comparison of Non-PCA-Adjusted Corn EECs Using Maximum and Typical Application Rates

Use Site	Application Rate (lbs/acre)	Number of Applications (interval)	First Application Date	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
Corn	2	1	April 1	103.2	102	101.3	101.1	98.9	95.9
Corn	1	1	April 1	51.8	51.0	50.7	50.5	49.5	48.0

3.2.6 Summary of Modeling vs. Monitoring Data

Overall, comparison of the monitoring data with the modeling indicates that, in general, the peak concentrations are reasonably well predicted by modeling with PRZM/EXAMS for all scenarios and iterations of the modeling; however, the longer-term average concentrations are over-estimated. For this analysis, only the peak and annual average (approximated by averaging across the sample range from the monitoring data) from the monitoring data were comparable to the model output, with the exception of the analysis from the Heidelberg data. The Heidelberg analysis, although highly uncertain due to the nature of the interpolation necessary, suggests that in a highly vulnerable watershed, the longer-term exposures will be less than model predictions for streams and rivers with even moderate flow rates.

3.3 Terrestrial Plant Exposure Assessment

Terrestrial plants in riparian areas may be exposed to atrazine residues carried from application sites via surface water runoff or spray drift. Exposures can occur directly to seedlings breaking through the soil surface and through root uptake or direct deposition onto foliage to more mature plants. Riparian vegetation is important to the Alabama sturgeon water and stream quality because it serves as a buffer and filters out sediment, nutrients, and contaminants before they enter the Alabama River watershed. Riparian vegetation has been shown to be essential in the maintenance of a stable stream (Rosgen, 1996). Destabilization of the stream can have a severe effect on sturgeon habitat quality by increasing sedimentation within the watershed.

Concentrations of atrazine on the riparian vegetation were estimated using OPP's TerrPlant model (U.S. EPA, 2005; Version 1.2.1), considering use conditions likely to occur in the Alabama River watershed. The TerrPlant model evaluates exposure to plants via runoff and spray drift and is EFED's standard tool for estimating exposure to non-target plants. The runoff loading of TerrPlant is estimated based on the solubility of the chemical and assumptions about the drainage and receiving areas. The spray drift component of TerrPlant assumes that 1% and 5% of the application rate deposits in the receiving area for ground boom and aerial applications, respectively.

Although TerrPlant calculates exposure values for terrestrial plants inhabiting two environments (i.e., dry adjacent areas and semi-aquatic areas), only the exposure values from the dry adjacent areas are used in this assessment. The 'dry, adjacent area' is considered to be representative of a slightly sloped area that receives relatively high runoff and spray drift levels from upgradient treated fields. In this assessment, the 'dry, adjacent area' scenario is used to estimate screening-level exposure values for terrestrial plants in riparian areas. The 'semi-aquatic area' is considered to be representative of depressed areas that are ephemerally flooded, such as marshes, and, therefore, is not used to estimate exposure values for terrestrial riparian vegetation.

The following input values were used to estimate terrestrial plant exposure to atrazine from all uses: solubility = 33 ppm; minimum incorporation depth = 0 (from product labels); application methods: ground boom, aerial, and granular (from product labels). The following agricultural and non-agricultural scenarios were modeled: ground/aerial application to fallow/idle land at 2.25 lbs ai/A and corn/sorghum at 2.0 lb ai/A, and granular application to residential lawns at 2 lbs ai/A. Although atrazine is also labeled for forestry use on conifers at an application rate of 4 lb ai/A, EECs for this use were not modeled because the best available information indicates that atrazine is rarely used in forestry in Alabama (see Section 3.2.3). However, potential impacts to riparian vegetation resulting from atrazine use on forestry (should herbicide use patterns on Alabama forestry change in the future) are discussed as part of the risk description in Section 5.2.4.

Terrestrial plant EECs for non-granular and granular formulations are summarized in Table 3.17**.** EECs resulting from spray drift are derived for non-granular applications only.

Table 3.17. Screening-Level Exposure Estimates for Terrestrial Plants to Atrazine

Use/ App. Rate (lbs/acre)	Application Method	Total Loading to Dry Adjacent Areas (lbs/acre)	Drift EEC (lbs/acre)
Fallow/idle land / 2.25	Aerial	0.16	0.14
	Ground	0.07	0.02
Corn and Sorghum / 2.0	Aerial	0.14	0.10
	Ground	0.06	0.02
Residential / 2.0	Granular	0.04	NA

For non-granular applications of atrazine, the highest off-target loadings of atrazine predicted by TerrPlant are approximately 7% of the application rate for dry adjacent areas. As expected, resulting exposure estimates for terrestrial plants are higher for aerial than ground boom applications. Granular applications associated with residential use of atrazine result in estimated exposures, as a percentage of the associated application rate, of 2% for adjacent areas.

4. Effects Assessment

This assessment evaluates the potential for atrazine to adversely affect the Alabama sturgeon. As previously discussed in Section 2.7, assessment endpoints for the Alabama sturgeon include direct toxic effects on the survival, reproduction, and growth of the sturgeon itself, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Direct effects to the Alabama sturgeon, a freshwater species, are based on toxicity information for freshwater fish. Given that the Alabama sturgeon's prey items and habitat requirements are dependent on the availability of freshwater aquatic invertebrates and aquatic plants, toxicity information for various freshwater aquatic invertebrates and plants is also discussed. In addition, terrestrial plant data are used to evaluate indirect effects on the sturgeon via direct effects to terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality and spawning habitat.

Acute (short-term) and chronic (long-term) effects toxicity information is characterized based on registrant-submitted studies and a comprehensive review of the open literature on atrazine. In addition to registrant-submitted and open literature toxicity information, indirect effects to the Alabama sturgeon, via impacts to aquatic plant community structure and function are also evaluated based on community-level threshold concentrations. Other sources of information, including use of the acute probit dose response relationship to establish the probability of an individual effect and reviews of the Ecological Incident Information System (EIIS), are conducted to further refine the characterization of potential ecological effects associated with exposure to atrazine. A summary of the available freshwater and terrestrial plant ecotoxicity information, the community-level endpoints, use of the probit dose response relationship, and the incident information for atrazine are provided in Sections 4.1 through 4.4, respectively.

With respect to atrazine degradates, including hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT), it is assumed that each of the degradates are less toxic than the parent compound. As shown in Table 4.1, comparison of available toxicity information for HA, DIA, and DACT indicates lesser aquatic toxicity than the parent for freshwater fish, invertebrates, and aquatic plants.

Table 4.1 Comparison of Acute Freshwater Toxicity Values for Atrazine and Degradates

Substance Tested	Fish LC_{50} (µg/L)	Daphnid EC_{50} (µg/L)	Aquatic Plant EC_{50} (µg/L)
Atrazine	5,300	3,500	1
HA	>3,000 (no effects at saturation)	>4,100 (no effects at saturation)	>10,000
DACT	>100,000	>100,000	No data
DIA	17,000	126,000 (NOAEC: 10,000)	2,500
DEA	No data	No data	1,000

Although degradate toxicity data are not available for terrestrial plants, lesser or equivalent toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the atrazine degradates are expected to lose efficacy as an herbicide.

Therefore, given the lesser toxicity of the degradates, as compared to the parent, concentrations of the atrazine degradates are not assessed, and the focus of this assessment is limited to parent atrazine. The available information also indicates that aquatic organisms are more sensitive to the technical grade (TGAI) than the formulated products of atrazine; therefore, the focus of this assessment is on the TGAI. A detailed summary of the available ecotoxicity information for all atrazine degradates and formulated products is presented in Appendix A.

As previously discussed in the problem formulation, the available toxicity data show that other pesticides may combine with atrazine to produce synergistic, additive, and/or antagonistic toxic interactions. The results of available toxicity data for mixtures of atrazine with other pesticides are presented in Section A.6 of Appendix A. Synergistic effects with atrazine have been demonstrated for a number of organophosphate insecticides including diazanon, chlorpyrifos, and methyl parathion, as well as herbicides including alachlor. If chemicals that show synergistic effects with atrazine are present in the environment in combination with atrazine, the toxicity of the atrazine mixture may be increased relative to the toxicity of each individual chemical, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggest that the toxic effect of atrazine, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of atrazine and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (e.g. organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. However, a qualitative discussion of implications of the available pesticide mixture effects data involving atrazine on the confidence of risk assessment conclusions for the Alabama sturgeon is addressed as part of the uncertainty analysis for this effects determination.

4.1 Evaluation of Aquatic Ecotoxicity Studies

Toxicity endpoints are established based on data generated from guideline studies submitted by the registrant, and from open literature studies that meet the criteria for inclusion into the ECOTOX database maintained by EPA/Office of Research and Development (ORD) (U.S. EPA, 2004). Open literature data presented in this assessment were obtained from the 2003 atrazine IRED as well as ECOTOX information obtained on February 16, 2006. The February 2006 ECOTOX search included all open literature data for atrazine (i.e., pre- and post-IRED). In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

(1) the toxic effects are related to single chemical exposure;
(2) the toxic effects are on an aquatic or terrestrial plant or animal species;
(3) there is a biological effect on live, whole organisms;
(4) a concurrent environmental chemical concentration/dose or application rate is reported; and
(5) there is an explicit duration of exposure.

Data that pass the ECOTOX screen are evaluated along with the registrant-submitted data, and may be incorporated qualitatively or quantitatively into this endangered species assessment. In general, effects data in the open literature that are more conservative than the registrant-submitted data are considered. Based on the results of the 2003 IRED for atrazine, potential adverse effects on sensitive aquatic plants and non-target aquatic organisms including their populations and communities, are likely to be greatest when atrazine concentrations in water equal or exceed approximately 10 to 20 μg/L on a recurrent basis or over a prolonged period of time (U.S. EPA, 2003a). Given the large amount of microcosm/mesocosm and field study data for atrazine, only effects data that are less than or more conservative than the 10 μg/L aquatic-community effect level identified in the 2003 atrazine IRED were considered. The degree to which open literature data are quantitatively or qualitatively characterized is dependent on whether the information is relevant to the assessment endpoints (i.e., maintenance of Alabama sturgeon survival, reproduction, and growth) identified in the problem formulation. For example, endpoints such as behavior modifications are likely to be qualitatively evaluated, because it is not possible to quantitatively link these endpoints with reduction in species survival, reproduction, and/or growth (e.g., the magnitude of effect on the behavioral endpoint needed to result in effects on survival, growth, or reproduction is not known).

Citations of all open literature not considered as part of this assessment because it was either rejected by the ECOTOX screen or accepted by ECOTOX but not used (e.g., the endpoint is less sensitive and/or not appropriate for use in this assessment) are included in Appendix G. Appendix G also includes a rationale for rejection of those studies that did not pass the ECOTOX screen and those that were not evaluated as part of this ESA.

As described in Agency's Overview Document (U.S. EPA, 2004), the most sensitive endpoint for each taxa is evaluated. For this assessment, evaluated taxa include freshwater fish, freshwater aquatic invertebrates, freshwater aquatic plants, and terrestrial plants. Table 4.2 summarizes the most sensitive ecological toxicity endpoints for the Alabama sturgeon, based on an evaluation of both the submitted studies and the open literature, as previously discussed. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment for the Alabama sturgeon is presented below. Additional information is provided in Appendix A. It should be noted that Appendix A also includes ecotoxicity data for taxonomic groups that are not relevant to this assessment (i.e., birds, estuarine/marine fish and invertebrates) because the Agency is completing endangered species assessments for other species concurrently with this assessment.

Table 4.2. Freshwater Aquatic and Terrestrial Plant Toxicity Profile for Atrazine

Assessment Endpoint	Species	Toxicity Value Used in Risk Assessment	Citation MRID # (Author & Date)	Comment
Acute Direct Toxicity to Sturgeon	Rainbow trout[1]	96-hour LC_{50} = 5,300 µg/L Probit slope = 2.72	000247-16 (Beliles and Scott, 1965)	Acceptable
Chronic Direct Toxicity to Sturgeon	Brook trout[1]	NOAEC = 65 µg/L LOAEC = 120 µg/L	000243-77 (Macek et al., 1976)	Acceptable: 7.2% reduction in length; 16% reduction in weight
Indirect Toxicity to Sturgeon via Acute Toxicity to Freshwater Invertebrates (i.e. prey items)	Midge	48-hour LC_{50} = 720 µg/L Probit slope unavailable	000243-77 (Macek et al., 1976)	Supplemental: raw data unavailable
Indirect Toxicity to Sturgeon via Chronic Toxicity to Freshwater Invertebrates (i.e. prey items)	Scud	NOAEC = 60 µg/L LOAEC = 120 µg/L	000243-77 (Macek et al., 1976)	Acceptable: 25 % reduction in development of F_1 to seventh instar
Indirect Toxicity to Sturgeon via Acute Toxicity to Non-vascular Aquatic Plants	4 species of freshwater algae	1-week EC_{50} = 1 µg/L	000235-44 (Torres & O'Flaherty, 1976)	Supplemental: 41 to 98% reduction in chlorophyll production; raw data unavailable
Indirect Toxicity to Sturgeon via Acute Toxicity to Vascular Aquatic Plants	Duckweed	14-day EC_{50} = 37 µg/L	430748-04 (Hoberg, 1993)	Supplemental: 50% reduction in biomass; NOAEC not determined
Indirect Toxicity to Sturgeon via Acute Toxicity to Terrestrial Monocot Plants	Oat	Tier II Seedling Emergence EC_{25} = 0.004 lb ai/A	420414-03 (Chetram, 1989)	Acceptable: 25% reduction in dry weight
Indirect Toxicity to Sturgeon via Acute Toxicity to Terrestrial Dicot Plants	Carrot	Tier II Seedling Emergence EC_{25} = 0.003 lb ai/A	420414-03 (Chetram, 1989)	Acceptable: 25% reduction in dry weight

[1] Used as a surrogate for the Alabama sturgeon.

Toxicity to aquatic fish and invertebrates is categorized using the system shown in Table 4.3 (U.S. EPA, 2004). Toxicity categories for aquatic plants have not been defined.

Table 4.3. Categories of Acute Toxicity for Aquatic Organisms

LC_{50} (ppm)	Toxicity Category
< 0.1	Very highly toxic
> 0.1 - 1	Highly toxic
> 1 - 10	Moderately toxic
> 10 - 100	Slightly toxic
> 100	Practically nontoxic

4.1.1 Toxicity to Freshwater Fish

Freshwater fish toxicity data were used to assess potential direct effects of atrazine to the Alabama sturgeon. A summary of acute and chronic freshwater fish data, including data from the open literature, is provided below in Sections 4.1.1.1 through 4.1.1.3.

4.1.1.1 Freshwater Fish: Acute Exposure (Mortality) Studies

Freshwater fish acute toxicity studies were used to assess potential direct effects to the Alabama sturgeon because the observed range of this species occurs within freshwater of the Alabama River. Atrazine toxicity has been evaluated in numerous freshwater fish species, including rainbow trout, brook trout, bluegill sunfish, fathead minnow, tilapia, zebrafish, goldfish, and carp, and the results of these studies demonstrate a wide range of sensitivity. The range of acute freshwater fish LC_{50} values for atrazine spans one order of magnitude, from 5,300 to 60,000 μg/L; therefore, atrazine is categorized as moderately (>1,000 to 10,000 μg/L) to slightly (>10,000 to 100,000 μg/L) toxic to freshwater fish on an acute basis. The freshwater fish acute LC_{50} value of 5,300 μg/L is based on a static 96-hour toxicity test using rainbow trout (*Oncorhynchus mykiss*) (MRID # 000247-16). No sublethal effects were reported as part of this study. A complete list of all the acute freshwater fish toxicity data for atrazine is provided in Table A-8 of Appendix A.

4.1.1.2 Freshwater Fish: Chronic Exposure (Growth/Reproduction) Studies

Chronic freshwater fish acute toxicity studies were used to assess potential direct effects via growth and reproduction to the Alabama sturgeon. Freshwater fish full life-cycle studies for atrazine are available and summarized in Table A-12 of Appendix A. Following 44 weeks of exposure to atrazine in a flow-through system, statistically significant reductions in brook trout mean length (7.2%) and body weight (16%) were observed at a concentration of 120 μg/L, as compared to the control (MRID # 000243-77). The corresponding NOAEC for this study is 65 μg/L. Although the acute toxicity data for atrazine show that rainbow trout are the most sensitive freshwater fish, available chronic rainbow trout toxicity data indicate that it is less sensitive to atrazine, on a chronic exposure basis, than the brook trout, with respective LOAEC and NOAEC values of 1,100 μg/L and 410 μg/L. Further information on chronic freshwater fish toxicity data for atrazine is provided in Section A.2.2 of Appendix A.

4.1.1.3 Freshwater Fish: Sublethal Effects and Additional Open Literature Information

In addition to submitted studies, data were located in the open literature that report sublethal effect levels to freshwater fish that are less than the selected measures of effect summarized in Table 4.2. Although these studies report potentially sensitive endpoints, effects on survival, growth, or reproduction were not observed in the four available full life-cycle studies at concentrations that induced the reported sublethal effects described below and in Appendix A.

Reported sublethal effects in rainbow trout show increased plasma vitellogenin levels in both female and male fish and decreased plasma testosterone levels in male fish at atrazine concentrations of approximately 50 μg/L (Wieser and Gross, 2002 [MRID 456223-04]). Vitellogenin (Vtg) is an egg yolk precursor protein expressed normally in female fish and dormant in male fish. The presence of Vtg in male fish is used as a molecular marker of exposure to estrogenic chemicals. It should be noted, however, that there is a high degree of variability with the Vtg effects in these studies, which confounds the ability to resolve the effects of atrazine on plasma steroids and vitellogenesis.

Effects of atrazine on freshwater fish behavior, including a preference for the dark part of the aquarium following one week of exposure (Steinberg et al., 1995 [MRID 452049-10]) and a reduction in grouping behavior following 24-hours of exposure (Saglio and Trijase, 1998 [MRID 452029-14]), have been observed at atrazine concentrations of 5 μg/L. In addition, alterations in rainbow trout kidney histology have also been observed at atrazine concentrations of 5 μg/L and higher (Fischer-Scherl et al., 1991 [MRID 452029-07]).

In salmon, atrazine effects on gill physiology and endocrine-mediated olfactory functions have been studied. Data from Waring and Moore (2004; ECOTOX #72625) suggest that salmon smolt gill physiology, represented by changes in Na-K-ATPase activity and increased sodium and potassium levels, was altered at 1 μg/L atrazine and higher. However, the Alabama sturgeon occurs in freshwater habitats of the Alabama River; therefore, seawater survival is not a relevant endpoint for potential host fish. Moore and Lower (2001; ECOTOX #67727) reported that endocrine-mediated functions of male salmon parr were affected at 0.5 μg/L atrazine. The reproductive priming effect of the female pheromone prostaglandin $F_{2\alpha}$ on the levels of expressible milt in males was reduced after exposure to atrazine at 0.5 μg/L. Although the hypothesis was not tested, the study authors suggest that exposure of smolts to atrazine during the freshwater stage may potentially affect olfactory imprinting to the natal river and subsequent homing of adults. However, no quantitative relationship is established between reduced olfactory response of male epithelial tissue to the female priming hormone in the laboratory and reduction in salmon reproduction (i.e., the ability of male salmon to detect, respond to, and mate with ovulating females). A negative control was not included as part of the study design; therefore, potential solvent effect cannot be evaluated. Furthermore, the study did not determine whether the decreased response of olfactory epithelium to specific chemical stimuli would likely impair similar responses in intact fish.

Although these studies raise questions about the effects of atrazine on plasma steroid levels, behavior modifications, gill physiology, and endocrine-mediated functions in freshwater and anadromous fish, it is not possible to quantitatively link these sublethal effects to the selected assessment endpoints for the Alabama sturgeon (i.e., survival, growth, and reproduction of individuals). Also, effects on survival, growth, or reproduction were not observed in the four available full life-cycle studies at concentrations that induced these reported sublethal effects. Therefore, potential sublethal effects on fish are evaluated qualitatively in Section 5.2 and not used as part of the quantitative risk characterization. Further detail on sublethal effects to fish is provided in Sections A.2.4a and A.2.4b of Appendix A.

4.1.2 Toxicity to Freshwater Invertebrates

Freshwater aquatic invertebrate toxicity data were used to assess potential indirect effects of atrazine to the Alabama sturgeon. Direct effects to freshwater invertebrates resulting from exposure to atrazine may indirectly affect the Alabama sturgeon via reduction in available food. As previously discussed in Section 2.5, the Alabama sturgeon is a benthic omnivore, feeding primarily on freshwater invertebrates including aquatic insect larvae. A summary of acute and chronic freshwater invertebrate data, including data published in the open literature, is provided below in Sections 4.1.2.1 through 4.1.2.3.

4.1.2.1 Freshwater Invertebrates: Acute Exposure Studies

Atrazine is classified as highly toxic to slightly toxic to aquatic invertebrates. There is a wide range of EC_{50}/LC_{50} values for freshwater invertebrates with values ranging from 720 to >33,000 μg/L. The freshwater LC_{50} value of 720 μg/L is based on an acute 48-hour static toxicity test for the midge, *Chironomus tentans* (MRID # 000243-77). Further evaluation of the available acute toxicity data for the midge shows high variability with the LC_{50} values, ranging from 720 to >33,000 μg/L. With the exception of the midge, reported acute toxicity values for the other five freshwater invertebrates (including the water flea, scud, stonefly, leech, and snail) are 3,500 μg/L and higher. All of the available acute toxicity data for freshwater invertebrates are provided in Section A.2.5 and Table A-18 of Appendix A. The LC_{50}/EC_{50} distribution for freshwater invertebrates is graphically represented in Figure 4.1. The columns represent the lowest reported value for each species, and the positive y error bar represents the maximum reported value. Values in parentheses represent the number of studies included in the analyses.

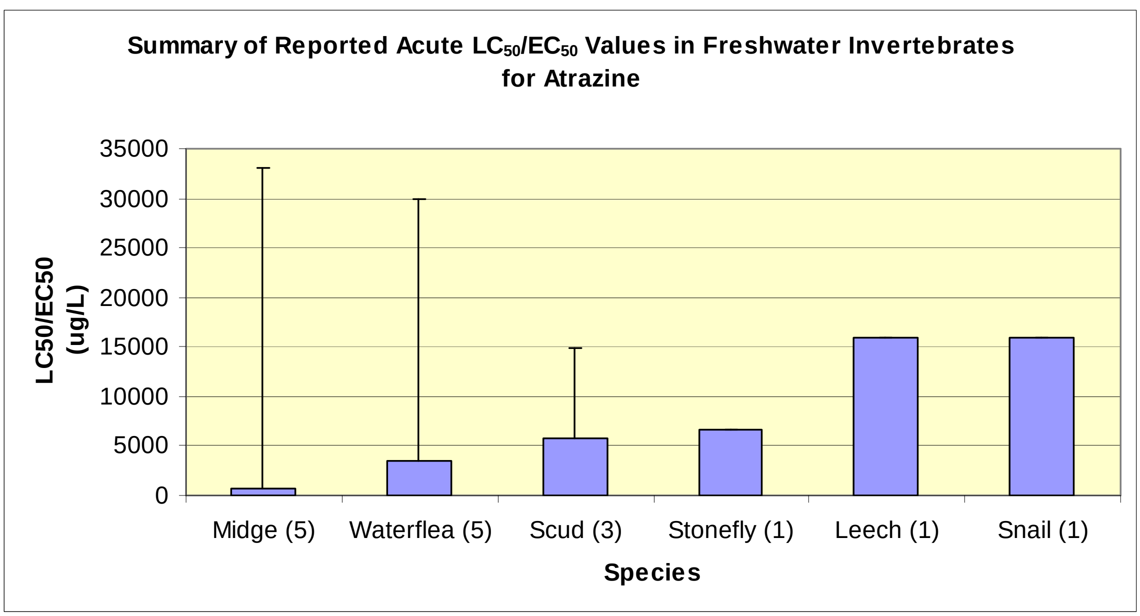

Figure 4.1. Summary of Reported Acute LC_{50}/EC_{50} Values in Freshwater Invertebrates for Atrazine

4.1.2.2 Freshwater Invertebrates: Chronic Exposure Studies

The most sensitive chronic endpoint for freshwater invertebrates is based on a 30-day flow-through study on the scud (*Gammarus fasciatus*), which showed a 25% reduction in the development of F_1 to the seventh instar at atrazine concentrations of 140 µg/L; the corresponding NOAEC is 60 µg/L (MRID # 000243-77). Although the acute toxicity data for atrazine show that the midge (*Chironomus tentans*) is the most sensitive freshwater invertebrate, available chronic midge toxicity data indicate that it is less sensitive to atrazine, on a chronic exposure basis, than the scud, with respective LOAEC and NOAEC values of 230 µg/L and 110 µg/L. Additional information on the chronic toxicity of atrazine to freshwater invertebrates is provided in Section A.2.6 and Table A-20 of Appendix A.

4.1.2.3 Freshwater Invertebrates: Open Literature Data

One additional acute study for an underrepresented taxon of freshwater mussels was located in the open literature. The results of the study by Johnson et al. (1993) suggest that 48-hour exposures at atrazine concentrations up to 60 mg/L do not affect the survival of juvenile and mature freshwater mussels, *Anodonta imbecilis*; therefore, *A. imbecilis* is less acutely sensitive to atrazine than other freshwater invertebrates.

4.1.3 Toxicity to Aquatic Plants

Aquatic plant toxicity studies were used as one of the measures of effect to evaluate whether atrazine may affect primary production. In the Alabama River, primary productivity is essential for indirectly supporting the growth and abundance of the Alabama sturgeon.

Two types of studies were used to evaluate the potential of atrazine to affect primary productivity. Laboratory studies were used to determine whether atrazine may cause direct effects to aquatic plants. In addition, the threshold concentrations, described in Section 4.2, were used to further characterize potential community level effects to Alabama sturgeon resulting from potential effects to aquatic plants. A summary of the laboratory data for aquatic plants is provided in Section 4.1.3.1. A description of the threshold concentrations used to evaluate community-level effects is included in Section 4.2.

4.1.3.1 Aquatic Plants: Laboratory Data

Numerous aquatic plant toxicity studies have been submitted to the Agency. A summary of the data for freshwater vascular and non-vascular plants is provided below. Section A.4.2 and Tables A-40 and A-41 of Appendix A include a more comprehensive description of these data.

The Tier II results for freshwater aquatic plants indicate that atrazine causes a 41 to 98% reduction in chlorophyll production of freshwater algae; the corresponding EC_{50} value for four different species of freshwater algae is 1 µg/L, based on data from a 7-day acute study (MRID # 000235-44). Vascular plants are less sensitive to atrazine than freshwater non-vascular plants with an EC_{50} value of 37 µg/L, based on reduction in duckweed growth (MRID # 430748-04).

Comparison of atrazine toxicity levels for three different endpoints in algae suggests that the endpoints in decreasing order of sensitivity are cell count, growth rate and oxygen production (Stratton, 1984). Walsh (1983) exposed *Skeletonema costatum* to atrazine and concluded that atrazine is only slightly algicidal at relatively high concentrations (i.e., 500 and 1,000 µg/L). Caux et al. (1996) compared the cell count IC_{50} and fluorescence LC_{50} and concluded that atrazine is algicidal at concentrations affecting cell counts. Abou-Waly et al. (1991) measured growth rates on days 3, 5, and 7 for two algal species. The pattern of atrazine effects on growth rates differs sharply between the two species. Atrazine had a strong early effect on *Anabaena flos-aquae* followed by rapid recovery in clean water (i.e., EC_{50} values for days 3, 5, and 7 are 58, 469, and 766 µg/L, respectively). The EC_{50} values for *Selenastrum capricornutum* continued to decline from day 3 through 7 (i.e., 283, 218, and 214 µg/L, respectively). Based on theses results, it appears that the timing of peak effects for atrazine may differ depending on the test species.

It should be noted that recovery from the effects of atrazine and the development of resistance to the effects of atrazine in some vascular and non-vascular aquatic plants have been reported and may add uncertainty to these findings. However, reports of recovery are often based on differing interpretations of recovery. Thus, before recovery can be considered as an uncertainty, an agreed upon interpretation is needed. For the purposes of this assessment, recovery is defined as a return to pre-exposure levels for the *affected population*, not for a replacement population of more tolerant species. Further research is needed to quantify the impact that recovery and resistance would have on aquatic plants.

4.1.4 Freshwater Field Studies

Microcosm and mesocosm studies with atrazine provide measurements of primary productivity that incorporate the aggregate responses of multiple species in aquatic plant communities. Because plant species vary widely in their sensitivity to atrazine, the overall response of the plant community may be different from the responses of the individual species measured in laboratory toxicity tests. Mesocosm and microcosm studies allow observation of population and community recovery from atrazine effects and of indirect effects on higher trophic levels. In addition, mesocosm and microcosm studies, especially those conducted in outdoor systems, incorporate partitioning, degradation, and dissipation, factors that are not usually accounted for in laboratory toxicity studies, but that may influence the magnitude of ecological effects.

Atrazine has been the subject of many mesocosm and microcosm studies in ponds, streams, lakes, and wetlands. The durations of these studies have ranged from a few weeks to several years at exposure concentrations ranging from 0.1 µg/L to 10,000 µg/L. Most of the studies have focused on atrazine effects on phytoplankton, periphyton, and macrophytes; however, some have also included measurements on animals.

As described in the 2003 IRED for atrazine (U.S. EPA, 2003a), potential adverse effects on sensitive aquatic plants and non-target aquatic organisms including their populations and communities are likely to be greatest when atrazine concentrations in water equal or exceed approximately 10 to 20 µg/L on a recurrent basis or over a prolonged period of time. A summary of all the freshwater aquatic microcosm, mesocosm, and field studies that were reviewed as part of the 2003 IRED is included in Section A.2.8a and Tables A-22 through A-24 of Appendix A. Given the large amount of microcosm and mesocosm and field study data for atrazine, only effects data less than or more conservative than the 10 µg/L aquatic community effect level identified in the 2003 IRED were considered as part of the open literature search that was completed in February 2006. Based on the selection criteria for review of new open literature, all of the available studies show effects levels to freshwater fish, invertebrates, and aquatic plants at concentrations greater than 10 µg/L.

Community-level effects to aquatic plants that are likely to result in indirect effects to the rest of the aquatic community, including the Alabama sturgeon, are evaluated based on threshold concentrations. These screening threshold concentrations, which are discussed in greater detail in Section 4.2 and Appendix B, incorporate the available micro- and mesocosm data included in the 2003 IRED (U.S. EPA, 2003a) as well as additional information gathered following completion of the 2003 atrazine IRED (U.S. EPA, 2003e).

4.1.5 Toxicity to Terrestrial Plants

Terrestrial plant toxicity data are used to evaluate the potential for atrazine to affect riparian zone vegetation within the action area for the Alabama sturgeon. Riparian zone effects may result in increased sedimentation, which may impact the spawning habitat of the Alabama sturgeon. As previously discussed in Section 2.5, Alabama sturgeon require strong currents in deep waters over relatively stable substrates for feeding and spawning.

Plant toxicity data from both registrant-submitted studies and studies in the scientific literature were reviewed for this assessment. Registrant-submitted studies are conducted under conditions and with species defined in EPA toxicity test guidelines. Sub-lethal endpoints such as plant growth, dry weight, and biomass are evaluated for both monocots and dicots, and effects are evaluated at both seedling emergence and vegetative life stages. Guideline studies generally evaluate toxicity to ten crop species. A drawback to these tests is that they are conducted on herbaceous crop species only, and extrapolation of effects to other species, such as the woody shrubs and trees and wild herbaceous species, contributes uncertainty to risk conclusions. However, atrazine is labeled for use on conifers and softwoods; therefore, effects to evergreens would not be anticipated. In addition, preliminary data submitted to the Agency (discussed below) suggests that sensitive woody plant species exist; however, damage to most woody species at labeled application rates is not expected.

Commercial crop species have been selectively bred, and may be more or less resistant to particular stressors than wild herbs and forbs. The direction of this uncertainty for specific plants and stressors, including atrazine, is largely unknown. Homogenous test plant seed lots also lack the genetic variation that occurs in natural populations, so the range of effects seen from tests is likely to be smaller than would be expected from wild populations.

Based on the results of the submitted terrestrial plant toxicity tests, it appears that emerged seedlings are more sensitive to atrazine via soil/root uptake exposure than emerged plants via foliar routes of exposure. However, all tested plants, with the exception of corn in the seedling emergence and vegetative vigor tests and ryegrass in the vegetative vigor test, exhibited adverse effects following exposure to atrazine. Tables 4.4 and 4.5 summarize the respective seedling emergence and vegetative vigor terrestrial plant toxicity data used to derive risk quotients in this assessment.

In Tier II seedling emergence toxicity tests, the most sensitive monocot and dicot species are oats and carrots, respectively. EC_{25} values for carrots and oats, which are based on a reduction in dry weight, are 0.003 and 0.004 lb ai/A, respectively; NOAEC values for both species are 0.0025 lb ai/A.

For Tier II vegetative vigor studies, the most sensitive dicot and monocot species are the cucumber and onion, respectively. In general, dicots appear to be more sensitive than monocots via foliar routes of exposure with all tested dicot species showing a significant reduction in dry weight at EC_{25} values ranging from 0.008 to 0.72 lb ai/A. In contrast, two of the four tested monocots showed no effect to atrazine (corn and ryegrass), while EC_{25} values for onion and oats were 0.61 and 2.4 lb ai/A, respectively.

Table 4.4. Non-target Terrestrial Plant Seedling Emergence Toxicity (Tier II) to Atrazine

Surrogate Species	% ai	EC_{25} / NOAEC (lbs ai/A) Probit Slope	Endpoint Affected	MRID No. Author/Year	Study Classification
Monocot - Corn (*Zea mays*)	97.7	> 4.0 / > 4.0	No effect	420414-03 Chetram 1989	Acceptable
Monocot - Oat (*Avena sativa*)	97.7	**0.004 / 0.0025**	red. in dry weight	420414-03 Chetram 1989	Acceptable
Monocot - Onion (*Allium cepa*)	97.7	0.009 / 0.005	red. in dry weight	420414-03 Chetram 1989	Acceptable
Monocot - Ryegrass (*Lolium perenne*)	97.7	0.004 / 0.005	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Root Crop - Carrot (*Daucus carota*)	97.7	**0.003 / 0.0025**	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Soybean (*Glycine max*)	97.7	0.19 / 0.025	red. in dry weight	420414-03 Chetram 1989	Acceptable

Surrogate Species	% ai	EC_{25} / NOAEC (lbs ai/A) Probit Slope	Endpoint Affected	MRID No. Author/Year	Study Classification
Dicot - Lettuce (*Lactuca sativa*)	97.7	0.005 / 0.005	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Cabbage (*Brassica oleracea alba*)	97.7	0.014 / 0.01	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Tomato (*Lycopersicon esculentum*)	97.7	0.034 / 0.01	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Cucumber (*Cucumis sativus*)	97.7	0.013 / 0.005	red. in dry weight	420414-03 Chetram 1989	Acceptable

Table 4.5. Non-target Terrestrial Plant Vegetative Vigor Toxicity (Tier II) to Atrazine

Surrogate Species	% ai	EC_{25} / NOAEC (lbs ai/A)	Endpoint Affected	MRID No. Author/Year	Study Classification
Monocot - Corn	97.7	> 4.0 / > 4.0	No effect	420414-03 Chetram 1989	Acceptable
Monocot - Oat	97.7	2.4 / 2.0	red. in dry weight	420414-03 Chetram 1989	Acceptable
Monocot - Onion	97.7	**0.61 / 0.5**	red. in dry weight	420414-03 Chetram 1989	Acceptable
Monocot - Ryegrass	97.7	> 4.0 / > 4.0	No effect	420414-03 Chetram 1989	Acceptable
Dicot - Carrot	97.7	1.7 / 2.0	red. in plant height	420414-03 Chetram 1989	Acceptable
Dicot - Soybean	97.7	0.026 / 0.02	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Lettuce	97.7	0.33 / 0.25	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Cabbage	97.7	0.014 / 0.005	red. in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Tomato	97.7	0.72 / 0.5	red. in plant height	420414-03 Chetram 1989	Acceptable
Dicot - Cucumber	97.7	**0.008 / 0.005**	red. in dry weight	420414-03 Chetram 1989	Acceptable

In addition, a report on the toxicity of atrazine to woody plants (Wall et al., 2006; MRID 46870400-01) was reviewed by the Agency. A total of 35 species were tested at application rates ranging from 1.5 to 4.0 lbs ai/A. Twenty-eight species exhibited either no or negligible phytotoxicity. Seven of 35 species exhibited >10% phytotoxicity. However, further examination of the data indicate that atrazine application was clearly associated with severe phytotoxicity in only one species (Shrubby Althea). These data suggest that, although sensitive woody plants exist, atrazine exposure to most woody plant species at application rates of 1.5 to 4.0 lbs ai/A is not expected to cause adverse effects. A summary of the available woody plant data is provided in Table A-39b of Appendix A.

4.2 Community-Level Endpoints: Threshold Concentrations

In this endangered species assessment, direct and indirect effects to the Alabama sturgeon are evaluated in accordance with the screening-level methodology described in the Agency's Overview document (U.S. EPA, 2004). If aquatic plant RQs exceed the Agency's non-listed species LOC (because the sturgeon does not have an obligate relationship with any one particular plant species, but rather relies on multiple plant species), based on available EC_{50} data for vascular and non-vascular plants, risks to individual aquatic plants are assumed.

It should be noted, however, that the indirect effects analysis in this assessment is unique, in that the best available information for atrazine-related effects on aquatic communities is significantly more extensive than for other pesticides. Hence, atrazine effects determinations can utilize more refined data than is generally available to the Agency. Specifically, a robust set of microcosm and mesocosm data and aquatic ecosystem models are available for atrazine that allowed EPA to refine the indirect effects associated with potential aquatic community-level effects (via aquatic plant community structural change and subsequent habitat modification) to the Alabama sturgeon. Use of such information is consistent with the guidance provided in the Overview Document (U.S. EPA, 2004), which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that EPA finds technically appropriate for risk management objectives" (Section V, page 31 of EPA, 2004). This information, which represents the best scientific data available, is described in further detail below and in Appendix B.

As previously mentioned in Section 2.3, the Agency has selected an atrazine level of concern (LOC) in the 2003 IRED (U.S. EPA, 2003a and b) that is consistent with the approach described in the Office of Water's (OW) draft atrazine aquatic life criteria (U.S. EPA, 2003c). Through these previous analyses (U.S. EPA, 2003a, b, and c), which reflect the current best available information, predicted or monitored aqueous atrazine concentrations can be interpreted to determine if a water body is likely to be significantly affected via indirect effects to the aquatic community. Potential impacts of atrazine to plant community structure and function that are likely to result in indirect effects to the rest of the aquatic community, including the Alabama sturgeon, are evaluated as described below.

As described further in Appendix B, responses in microcosms and mesocosms exposed to atrazine were evaluated to differentiate no or slight, recoverable effects from significant, generally non-recoverable effects (U.S. EPA, 2003e). Because effects varied with exposure duration and magnitude, there was a need for methods to predict relative differences in effects for different types of exposures. The Comprehensive Aquatic Systems Model (CASM) (Bartell et al., 2000; Bartell et al., 1999; DeAngelis et al., 1989) was selected as an appropriate tool to predict these relative effects, and was configured to provide a simulation for the entire growing season of a 2nd and 3rd order Midwestern stream as a function of atrazine exposure. CASM simulations conducted for the concentration/duration exposure profiles of the micro- and mesocosm data showed that

CASM seasonal output, represented as an aquatic plant community similarity index, correlated with the micro- and mesocosm effect scores, and that a 5% change in this index reasonably discriminated micro- and mesocosm responses with slight versus significant effects. The CASM-based index was assumed to be applicable to more diverse exposure conditions beyond those present in the micro- and mesocosm studies.

To avoid having to routinely run the CASM model, simulations were conducted for a variety of actual and synthetic atrazine chemographs to determine 14-, 30-, 60-, and 90-day average concentrations that discriminated among exposures that were unlikely to exceed the CASM-based index (i.e., 5% change in the index). It should be noted that the average 14-, 30-, 60-, and 90-day concentrations were originally intended to be used as screening values to trigger a CASM run (which is used as a tool to identify the 5% index change LOC), rather than actual thresholds to be used as an LOC (U.S. EPA, 2003e). The following threshold concentrations for atrazine were identified (U.S. EPA, 2003e):

- 14-day average = 38 μg/L
- 30-day average = 27 μg/L
- 60-day average = 18 μg/L
- 90-day average = 12 μg/L

Effects of atrazine on aquatic plant communities that have the potential to subsequently pose indirect effects to the Alabama sturgeon are best addressed using the robust set of micro- and mesocosm studies available for atrazine and the associated risk estimation techniques (U.S. EPA, 2003a, b, c, and e). The 14-, 30-, 60-, and 90-day threshold concentrations developed by EPA (2003e) are used to evaluate potential indirect effects to aquatic communities for the purposes of this endangered species assessment. Use of these threshold concentrations is considered appropriate because: (1) the CASM-based index meets the goals of the defined assessment endpoints for this assessment; (2) the threshold concentrations provide a reasonable surrogate for the CASM index; and (3) the additional conservatism built into the threshold concentration, relative to the CASM-based index, is appropriate for an endangered species risk assessment (i.e., the threshold concentrations were set to be conservative, producing a low level (1%) of false negatives relative to false positives). Therefore, these threshold concentrations are used to identify potential indirect effects (via aquatic plant community structural change) to the Alabama sturgeon. If modeled atrazine EECs exceed the 14-, 30-, 60- and 90-day threshold concentrations following refinements of potential atrazine concentrations with available monitoring data, the CASM model could be employed to further characterize the potential for indirect effects. A step-wise data evaluation scheme incorporating the use of the screening threshold concentrations is provided in Figure 4.2. Further information on threshold concentrations is provided in Appendix B.

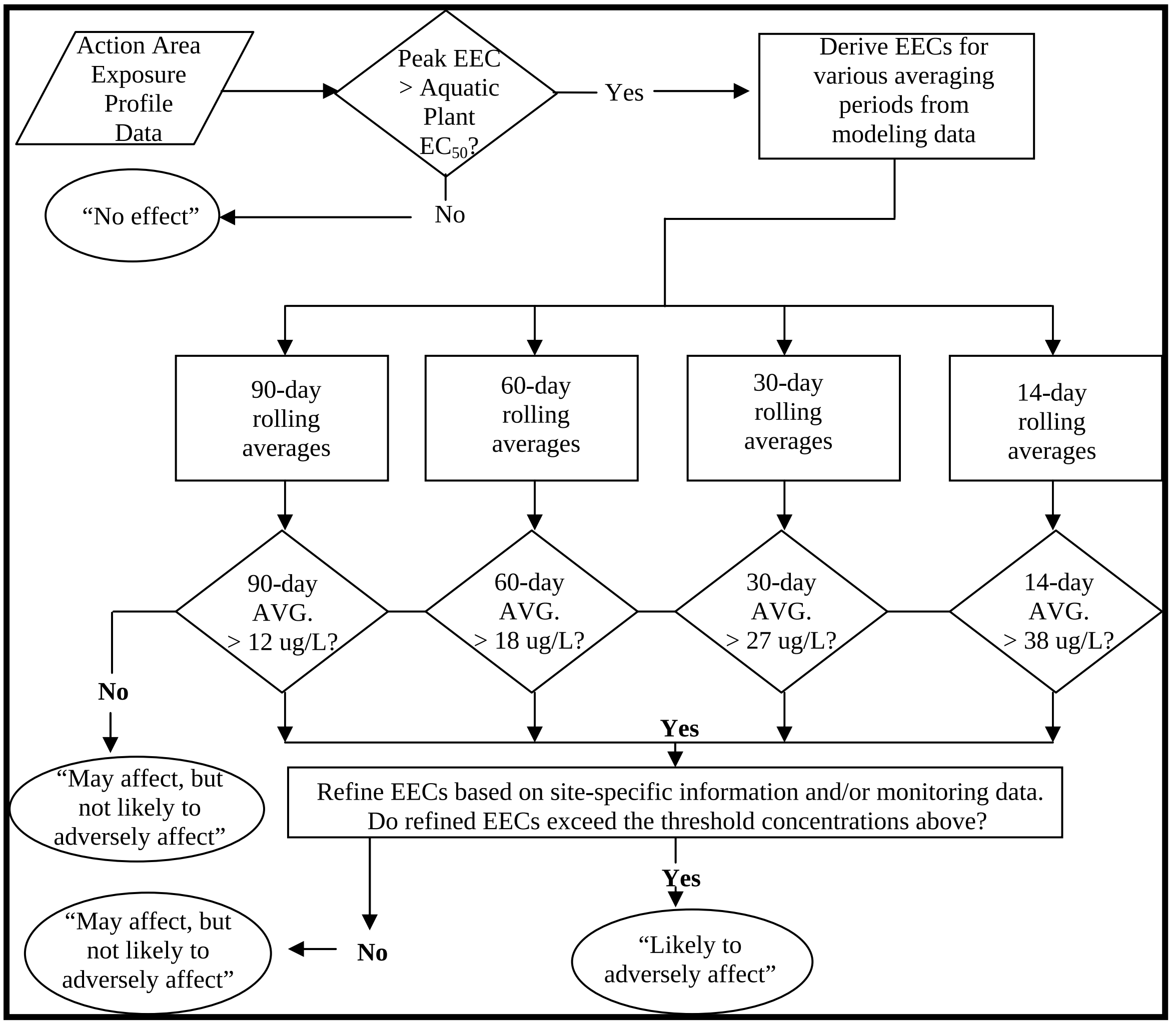

Figure 4.2. Use of Threshold Concentrations in Endangered Species Assessment

4.3 Use of Probit Slope Response Relationship to Provide Information on the Endangered Species Levels of Concern

The Agency uses the probit dose response relationship as a tool for providing additional information on the potential for acute direct effects to individual listed species and aquatic animals that may indirectly affect the listed species of concern (U.S. EPA, 2004). As part of the risk characterization, an interpretation of acute RQ for listed species is discussed. This interpretation is presented in terms of the chance of an individual event (i.e., mortality or immobilization) should exposure at the EEC actually occur for a species with sensitivity to atrazine on par with the acute toxicity endpoint selected for RQ calculation. To accomplish this interpretation, the Agency uses the slope of the dose response relationship available from the toxicity study used to establish the acute toxicity measures of effect for each taxonomic group that is relevant to this assessment (i.e., freshwater fish used as a surrogate for aquatic-phase amphibians and freshwater invertebrates). The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship. In addition to a single effects probability estimate based on the mean, upper and lower estimates of the effects probability are also provided to account for variance in the slope, if available. The upper and lower bounds of the effects probability are based on available information on the 95% confidence interval of the slope. A statement regarding the confidence in the estimated event probabilities is also included. Studies with good probit fit characteristics (i.e., statistically appropriate for the data set) are associated with a high degree of confidence. Conversely, a low degree of confidence is associated with data from studies that do not statistically support a probit dose response relationship. In addition, confidence in the data set may be reduced by high variance in the slope (i.e., large 95% confidence intervals), despite good probit fit characteristics.

Individual effect probabilities are calculated based on an Excel spreadsheet tool IECV1.1 (Individual Effect Chance Model Version 1.1) developed by the U.S. EPA, OPP, Environmental Fate and Effects Division (June 22, 2004). The model allows for such calculations by entering the mean slope estimate (and the 95% confidence bounds of that estimate) as the slope parameter for the spreadsheet. In addition, the acute RQ is entered as the desired threshold.

4.4 Incident Database Review

A number of incidents have been reported in which atrazine has been associated with some type of environmental effect. Incidents are maintained and catalogued by EFED in the Ecological Incident Information System (EIIS). Each incident is assigned a level of certainty from 0 (unrelated) to 4 (highly probable) that atrazine was a causal factor in the incident. As of the writing of this assessment, 358 incidents are in EIIS for atrazine spanning the years 1970 to 2005. Most (309/358, 86%) of the incidents involved damage to terrestrial plants, and most of the terrestrial plant incidences involved damage to crops treated directly with atrazine. Of the remaining 49 incidents, 47 involved aquatic animals and 2 involved birds. Because the species included in this effects determination are aquatic species, incidents involving aquatic animals assigned a certainty index of 2 (possible) or higher (N=33) were re-evaluated. Results are summarized below, and additional details are provided in Appendix E. The 33 aquatic incidents were divided into three categories:

1. Aquatic incidents in which atrazine concentrations were confirmed to be sufficient to either cause or contribute to the incident, including directly via toxic effects to aquatic organisms or indirectly via effects to aquatic plants, resulting in depleted oxygen levels;
2. Aquatic incidents in which insufficient information is available to conclude whether atrazine may have been a contributing factor – these may include incidents where there was a correlation between atrazine use and a fish kill, but the presence of atrazine in the affected water body was not confirmed; and
3. Aquatic incidents in which causes other than atrazine exposure are more plausible (e.g., presence of substance other than atrazine confirmed at toxic levels).

The presence of atrazine at levels thought to be sufficient to cause either direct or indirect effects was confirmed in 3 (9%) of the 33 aquatic incidents evaluated. Atrazine use was also correlated with 11 (33%) additional aquatic incidents where its presence in the affected water was not confirmed, but the timing of atrazine application was correlated with the incident. Therefore, a definitive causal relationship between atrazine use and the incident could not be established. The remaining 19 incidents (58%) were likely caused by some factor other than atrazine. Other causes primarily included the presence of other pesticides at levels known to be toxic to affected animals. Although atrazine use was likely associated with some of the reported incidents for aquatic animals, they are of limited utility to this assessment for the following reasons:

- No incidents in which atrazine is likely to have been a contributing factor have been reported after 1998. A number of label changes, including cancellation of certain uses, reduction in application rates, and harmonization across labels to require setbacks for applications near waterbodies, have occurred since that time. For example, several incidents occurred in ponds that are adjacent to treated fields. The current labels require a 66-foot buffer between application sites and water bodies.

- The habitat of the assessed species is not consistent with environments in which incidents have been reported. For example, no incidents in streams or rivers were reported.

Although the reported incidents suggest that high levels of atrazine may result in impacts to aquatic life in small ponds that are in close proximity to treated fields, the incidents are of limited utility to the current assessment. However, the lack of recently reported incidents in flowing waters does not indicate that effects have not occurred. Further information on the atrazine incidents and a summary of uncertainties associated with all reported incidents are provided in Appendix E.

5. Risk Characterization

Risk characterization is the integration of the exposure and effects characterizations to determine the potential ecological risk from varying atrazine use scenarios within the action area and likelihood of direct and indirect effects on the Alabama sturgeon. The risk characterization provides an estimation and a description of the likelihood of adverse effects; articulates risk assessment assumptions, limitations, and uncertainties; and synthesizes an overall conclusion regarding the likelihood of adverse effects to the Alabama sturgeon and/or its habitat (i.e., “no effect,” “likely to adversely affect,” or “may affect, but not likely to adversely affect”).

5.1 Risk Estimation

Risk was estimated by calculating the ratio of the estimated environmental concentration (Table 3.4) and the appropriate toxicity endpoint (Table 4.2). This ratio is the risk quotient (RQ), which is then compared to pre-established acute and chronic levels of concern (LOCs) for each category evaluated (Appendix F). Screening-level RQs are based on the most sensitive endpoints and the following surface water concentration scenarios for atrazine:

- residential granular use @ 2 lb ai/A; 2 applications with 30 days between applications (assumes 1% over-application of atrazine granules to impervious surfaces)
- residential liquid use @ 1 lb ai/A; 2 applications with 30 days between applications (assumes 1% over-spray of atrazine to impervious surfaces)
- turf granular use @ 2 lb ai/A; 2 applications with 30 days between applications
- turf liquid use @ 1 lb ai/A; 2 applications with 30 days between applications
- rights-of-way liquid use @ 1 lb ai/A; 1 application (assumes 1% over-spray of atrazine to impervious surfaces)
- fallow/idle land use @ 2.25 lb ai/A; 1 application
- corn use @ 2 lbs ai/A; 1 application
- sorghum use @ 2 lbs ai/A; 1 application
- aggregate EEC based on combined agricultural, residential, turf, and rights-of-way atrazine uses

As previously discussed in Section 3.2.3, RQs were not derived for the forestry use because available information indicates that atrazine is rarely used on forestry in Alabama (personal communications with K. McNabb, Auburn University School of Forestry, and J. Michael, U.S. Forest Service, Southern Research Station, August 2006). Although the forestry EECs are not used to derive risk quotients, this use pattern is considered as part of the risk description in Section 5.2 to account for potential changes in current herbicide use practices on forestry, which may include atrazine in the future.

In cases where the screening-level RQ exceeds one or more LOCs, additional factors, including Alabama sturgeon life history characteristics, refinement of the EECs using available monitoring data, and consideration of community-level threshold concentrations, are considered and used to characterize the potential for atrazine to result in a "likely to adversely affect" determination for the Alabama sturgeon. Risk estimations of direct and indirect effects of atrazine to the Alabama sturgeon are provided in Sections 5.1.1 and 5.1.2, respectively.

As previously discussed in the effects assessment, the toxicity of the atrazine degradates has been shown to be less than the parent compound based on the available toxicity data for freshwater fish, invertebrates, and aquatic plants; therefore, the focus of the risk characterization is parent atrazine (i.e., RQ values were not derived for the degradates).

5.1.1 Direct Effects

Direct effects associated with acute and chronic exposure to atrazine are not expected to occur for the Alabama sturgeon. RQs used to estimate direct effects to the Alabama sturgeon are provided in Table 5.1 below. RQs were calculated only for the use that resulted in the highest EEC (aggregate agricultural and non-agricultural uses) because none of the acute or chronic LOCs were exceeded. These RQs are further characterized in Section 5.2.1.

Table 5.1. Summary of Direct Effect RQs for the Alabama Sturgeon

Effect to Alabama sturgeon	Surrogate Species	Toxicity Value (µg/L)	EEC (µg/L)	RQ	Probability of Individual Effect	LOC Exceedance and Risk Interpretation
Acute Direct Toxicity	Rainbow trout	LC_{50} = 5,300	Peak: 16.3	0.003	1 in 3.0E+11 (1 in 24,100 to 1 in 2.0E+22)[a]	No[b]
Chronic Direct Toxicity	Brook trout	NOAEC = 65	60-day: 15.8	0.24	Not calculated for chronic endpoints	No[c]

[a] Based on a probit slope of 2.72 for the rainbow trout with 95% confidence intervals of 1.56 and 3.89 (MRID # 000247-16).
[b] RQ < acute endangered species LOC of 0.05.
[c] RQ < chronic LOC of 1.0.

5.1.2 Indirect Effects

Pesticides have the potential to exert indirect effects upon listed species by inducing changes in structural or functional characteristics of affected communities. Perturbation of forage or prey availability and alteration of the extent and nature of habitat are examples of indirect effects.

In conducting a screen for indirect effects, direct effects LOCs for each taxonomic group (i.e., freshwater fish, invertebrates, aquatic plants, and terrestrial plants) are employed to make inferences concerning the potential for indirect effects upon listed species that rely upon non-listed organisms in these taxonomic groups as resources critical to their life cycle (U.S. EPA, 2004). This approach used to evaluate indirect effects to listed species is endorsed by the Services (USFWS/NMFS, 2004b). If no direct effect listed species LOCs are exceeded for non-endangered organisms that are critical to the Alabama sturgeon's life cycle, the concern for indirect effects to the Alabama sturgeon is expected to be minimal.

If LOCs are exceeded for freshwater invertebrates that are prey items of the Alabama sturgeon, there is a potential for atrazine to indirectly affect the sturgeon by reducing available food supply. In such cases, the dose response relationship from the toxicity study used for calculating the RQ of the surrogate prey item is analyzed to estimate the probability of acute effects associated with an exposure equivalent to the EEC. The greater the probability that exposures will produce effects on a taxa, the greater the concern for potential indirect effects for listed species dependant upon that taxa (U.S. EPA, 2004).

As an herbicide, indirect effects to the Alabama sturgeon from potential effects on primary productivity of aquatic plants are a principle concern. If plant RQs fall between the endangered species and non-endangered species LOCs, a no effect determination for listed species that rely on multiple plant species to successfully complete their life cycle (termed plant dependent species) is determined. If plant RQs are above non-endangered species LOCs, this could be indicative of a potential for adverse effects to those listed species that rely either on a specific plant species (plant species obligate) or multiple plant species (plant dependant) for some important aspect of their life cycle (U.S. EPA, 2004). Based on the information provided in Appendix C, the Alabama sturgeon does not rely on a specific plant species (i.e., the sturgeon does not have an obligate relationship with a specific species of aquatic plant).

Direct effects to riparian zone vegetation may also indirectly affect the Alabama sturgeon by reducing the amount of available spawning habitat via increased sedimentation. Direct impacts to the terrestrial plant community (i.e., riparian habitat) are evaluated using submitted terrestrial plant toxicity data. If terrestrial plant RQs exceed the Agency's LOC for direct effects to non-endangered plant species, based on EECs derived using EFED's Terrplant model (Version 1.2.1) and submitted guideline terrestrial plant toxicity data, a conclusion that atrazine may affect the Alabama sturgeon via potential indirect effects to the riparian habitat (and resulting impacts to spawning habitat due to increased sedimentation) is made. Further analysis of the potential for atrazine to affect the Alabama sturgeon via reduction in riparian habitat includes consideration of the land use and types of riparian buffers surrounding the Alabama River action area (i.e., forested versus grassy), toxicity of atrazine to woody plant species, and the relative contribution of other factors which are likely to cause sedimentation in areas that the sturgeon could potentially use as spawning habitat.

In summary, the potential for indirect effects to the Alabama sturgeon was evaluated using methods outlined in U.S. EPA (2004) and described below in Sections 5.1.2.1 through 5.1.2.3.

5.1.2.1 Evaluation of Potential Indirect Effects via Reduction in Food Items (Freshwater Invertebrates)

Alabama sturgeon feed on a wide range of freshwater insect larvae, as well as oligochaetes, mollusks, and small fish. The most prevalent larval insect families found in stomach contents from a limited number of adult Alabama sturgeon specimens were midges, mayflies, stoneflies, damselflies, dragonflies, and netspinners (Haynes et al., 2005). Although data on the relative percentage of each type of aquatic invertebrate in the sturgeon's diet are unavailable, the available information indicates that they are opportunistic bottom feeders, preying primarily on aquatic insect larvae (Mayden and Kuhajda, 1996). Potential indirect effects from direct effects on animal food items (i.e., freshwater invertebrates) were evaluated by considering the diet of the Alabama sturgeon and the effects data for the most sensitive food item (i.e., the midge). The RQs used to characterize potential indirect effects to the Alabama sturgeon from direct acute and chronic effects on freshwater invertebrate food sources are provided in Table 5.2.

Table 5.2. Summary of Acute and Chronic RQs Used to Estimate Indirect Effect to the Alabama Sturgeon via Direct Effects on Dietary Items

Indirect Effect to Alabama Sturgeon	Surrogate Species	Toxicity Value (µg/L)	EEC (µg/L)	RQ	Probability of Individual Effect	LOC Exceedance and Risk Interpretation
Reduced Food Supply via Acute Direct Toxicity to Invertebrates	Midge	EC_{50} = 720	Peak: 16.3	0.023	1 in 3.5E+12[a]	No[b]
Reduced Food Supply via Chronic Direct Toxicity to Invertebrates	Scud	NOAEC = 60	21-day: 16.1	0.27	Not calculated for chronic endpoints	No[c]

[a] Slope information on the toxicity study that was used to derive the RQ for freshwater invertebrates is not available. Therefore, the probability of an individual effect was calculated using a probit slope of 4.4, which is the only technical grade atrazine value reported in the available freshwater invertebrate acute studies; 95% confidence intervals could not be calculated based on the available data (Table A-18). Use of a probit slope of 4.4 would result in a more conservative estimation of the probability of an individual effect than the default slope recommended in U.S. EPA (2004a) of 4.5.
[b] RQ < acute endangered species LOC of 0.05.
[c] RQ < chronic LOC of 1.0.

Indirect effects to the Alabama sturgeon based on direct acute and chronic effects to dietary items are not expected to occur. As shown in Table 5.2, acute and chronic LOCs are not exceeded for freshwater invertebrates, based on the use that results in the highest EECs (aggregate agricultural and non-agricultural uses) and the most sensitive food item of the Alabama sturgeon. These risk quotients are further characterized in Section 5.2.2.

5.1.2.2 Evaluation of Potential Indirect Effects via Reduction in Habitat and/or Primary Productivity (Freshwater Aquatic Plants)

Potential indirect effects from effects on habitat and/or primary production were assessed using RQs from freshwater aquatic vascular and non-vascular plant data as a screen. If aquatic plant RQs exceed the Agency's non-endangered species LOC (because the Alabama sturgeon relies on multiple plant species), potential community-level effects are evaluated using the threshold concentrations, as described in Section 4.2. RQs used to estimate potential indirect effects to the Alabama sturgeon from effects on aquatic plant primary productivity are summarized in Table 5.3.

Table 5.3. Summary of RQs Used to Estimate Indirect Effects to the Alabama Sturgeon via Direct Effects on Aquatic Plants

Indirect Effect to Alabama Sturgeon	Use (appl. Method; rate; # appl.; interval between appl.)	Peak EECs (µg/L)	Non-vascular plant RQ (EC_{50} = 1 µg/L[a])	Vascular plant RQ (EC_{50} = 37 µg/L[b])	LOC Exceedance and Risk Interpretation
Reduced Habitat and/or Primary Productivity via Direct Toxicity to Aquatic Plants	Aggregate agricultural and non-agricultural uses	16.3	**16.3**	0.44	Yes[c]
	Corn (aerial liquid; 2 lb ai/A; 1 appl.)	10.1	**10.1**	0.27	Yes[c]
	Sorghum (aerial liquid; 2 lb ai/A; 1 appl.)	6.2	**6.2**	0.17	Yes[c]
	Fallow/Idle land (aerial liquid; 2.25 lb ai/A; 1 appl.)	5.8	**5.8**	0.16	Yes[c]
	Residential (granular; 2 lb ai/A; 2 appl.; 30 d interval)	3.0	**3.0**	0.08	Yes[c]
	Turf (granular; 2 lb ai/A; 2 appl.; 30 d interval)	2.7	**2.7**	0.07	Yes[c]
	Residential and Turf (ground liquid; 1 lb ai/A; 2 appl.; 30 d interval)	2.2	**2.2**	0.06	Yes[c]
	Rights-of-Way (liquid; 1 lb ai/A; 1 appl.)	2.4	**2.4**	0.06	Yes[c]

[a] Based on 1-week EC_{50} value of 1 µg/L for four species of freshwater algae (MRID # 000235-44).
[b] Based on 14-day EC_{50} value of 37 µg/L for duckweed (MRID # 430748-08).
[c] RQ > non-endangered aquatic plant species LOC of 1.0 for non-vascular plants; RQ < non-endangered plant species LOC of 1.0 for vascular plants. Direct effects to non-vascular aquatic plants are possible. Further evaluation of the EECs relative to the threshold concentrations (for community-level effects) is necessary.

Based on the results shown in Table 5.3, LOCs for direct effects to aquatic non-vascular plants are exceeded for all modeled atrazine use scenarios; however, RQs for aquatic vascular plants are less than LOCs for all use scenarios. Therefore, atrazine may indirectly affect the Alabama sturgeon via direct effects on non-vascular aquatic plants for all modeled use scenarios. However, this screening-level analysis was based on the most sensitive EC_{50} value from all of the available freshwater non-vascular plant toxicity information. No known obligate relationship exists between the Alabama sturgeon and any single freshwater non-vascular plant species; therefore, endangered species RQs using the NOAEC/EC_{05} values for aquatic plants were not derived. Further analyses of the 14-, 30-, 60-, and 90-day time-weighted EECs relative to their respective threshold concentrations was completed to determine whether effects to individual non-vascular plant species would likely result in community-level effects to the Alabama sturgeon. This analysis is presented as part of the risk description in Section 5.2.3.

5.1.2.3 Evaluation of Potential Indirect Effects via Reduction in Terrestrial Plant Community (Riparian Habitat)

Potential indirect effects to the Alabama sturgeon resulting from direct effects on riparian vegetation were assessed using RQs from terrestrial plant seedling emergence and vegetative vigor EC_{25} data as a screen. Based on the results of the submitted terrestrial plant toxicity tests, it appears that emerging seedlings are more sensitive to atrazine via soil/root uptake than emerged plants via foliar routes of exposure. However, all tested plants, with the exception of corn in the seedling emergence and vegetative vigor tests, and ryegrass in the vegetative vigor test, exhibited adverse effects following exposure to atrazine. The results of these tests indicate that a variety of terrestrial plants that may inhabit riparian zones may be sensitive to atrazine exposure. RQs used to estimate potential indirect effects to the Alabama sturgeon from seedling emergence and vegetative vigor effects on terrestrial plants within riparian areas are summarized in Tables 5.4 and 5.5, respectively.

Table 5.4. Non-target Terrestrial Plant Seedling Emergence RQs

Surrogate Species	**EC_{25} (lbs ai/A)[1]**	**EEC Dry adjacent areas**	**RQ Dry adjacent areas**
Monocot - Corn	> 4.0	Aerial: 0.16 Ground: 0.07 Granular: 0.04	<LOC
Monocot - Oat	0.004	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 40** **Ground: 18** **Granular: 10**
Monocot - Onion	0.009	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 18** **Ground: 7.8** **Granular: 4.4**
Monocot - Ryegrass	0.004	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 40** **Ground: 18** **Granular: 10**
Dicot - Carrot	0.003	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 53** **Ground: 23** **Granular: 13**
Dicot - Soybean	0.19	Aerial: 0.16 Ground: 0.07 Granular: 0.04	<LOC
Dicot - Lettuce	0.005	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 32** **Ground: 14** **Granular: 8**
Dicot - Cabbage	0.014	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 11** **Ground: 5** **Granular: 2.9**
Dicot - Tomato	0.034	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 4.7** **Ground: 2.1** **Granular: 1.2**
Dicot - Cucumber	0.013	Aerial: 0.16 Ground: 0.07 Granular: 0.04	**Aerial: 12** **Ground: 5.4** **Granular: 3.1**

[1] From Chetram (1989); MRID 420414-03.

As shown in Table 5.4, terrestrial plant RQs are above the Agency's LOC for all species except corn and soybeans. For species with LOC exceedances, RQ values based on aerial application of atrazine to fallow/idle land at 2.25 lb ai/A range from 4.7 to 53; RQ values based on an equivalent ground application rate range from 2.1 to 23, a two-fold reduction as compared to aerial applications. Granular application of atrazine to residential lawns at 2.0 lb ai/A is also likely to impact terrestrial plants with RQs ranging from <1 (corn and soybeans) to 13 (carrots). Monocots and dicots show similar sensitivity to atrazine; therefore, RQs are similar across both taxa.

Table 5.5. Non-target Terrestrial Plant Vegetative Vigor Toxicity RQs

Surrogate Species	EC_{25} (lbs ai/A)[1]	Drift EEC (lbs ai/A)	Drift RQ
Monocot - Corn	> 4.0	Aerial: 0.11 Ground: 0.02	<LOC
Monocot - Oat	2.4	Aerial: 0.11 Ground: 0.02	<LOC
Monocot - Onion	0.61	Aerial: 0.11 Ground: 0.02	<LOC
Monocot - Ryegrass	> 4.0	Aerial: 0.11 Ground: 0.02	<LOC
Dicot - Carrot	1.7	Aerial: 0.11 Ground: 0.02	<LOC
Dicot - Soybean	0.026	Aerial: 0.11 Ground: 0.02	**Aerial: 4.2** Ground: 0.77
Dicot - Lettuce	0.33	Aerial: 0.11 Ground: 0.02	<LOC
Dicot - Cabbage	0.014	Aerial: 0.11 Ground: 0.02	**Aerial: 7.8** **Ground: 1.4**
Dicot - Tomato	0.72	Aerial: 0.11 Ground: 0.02	<LOC
Dicot - Cucumber	0.008	Aerial: 0.11 Ground: 0.02	**Aerial: 14** **Ground: 2.5**

1 From Chetram (1989); MRID 420414-03.

Vegetative vigor studies indicate that terrestrial plants are generally less sensitive to foliar exposure of atrazine as compared to soil/root uptake. As shown in Table 5.5, vegetative vigor RQs exceed the Agency's LOC for only three dicot species (soybeans, cabbage, and cucumber), based on aerial application of atrazine at 2.25 lb ai/A, with RQs ranging from 4.2 to 14. For ground applications, LOCs are exceeded for two dicot species, cabbage and cucumber, with RQs ranging from 1.4 to 2.5. Vegetative vigor RQs do not exceed LOCs for any of the tested monocot species.

Further analysis of the potential for atrazine to affect the Alabama sturgeon via reduction in riparian habitat, including consideration of the land use and types of riparian buffers surrounding the Alabama River action area (i.e., forested versus grassy), toxicity of atrazine to woody plant species, and the relative contribution of other factors which are likely to cause sedimentation in areas that the sturgeon could potentially use as spawning habitat, are discussed in Section 5.2.4.

5.2 Risk Description

The risk description synthesizes an overall conclusion regarding the likelihood of adverse impacts leading to an effects determination (i.e., “no effect,” “may affect, but not likely to adversely affect,” or “likely to adversely affect”) for the Alabama sturgeon.

If the RQs presented in the Risk Estimation (Section 5.1) show no indirect effects and LOCs for the Alabama sturgeon are not exceeded for direct effects, a “no effect” determination is made, based on atrazine’s use within the action area. If, however, indirect effects are anticipated and/or exposure exceeds the LOCs for direct effects, the Agency concludes a preliminary “may affect” determination for the Alabama sturgeon.

Following a “may affect” determination, additional information is considered to refine the potential for exposure at the predicted levels based on additional modeling and monitoring data, the life history characteristics (i.e., habitat range, feeding preferences, etc.) of the Alabama sturgeon, and potential community-level effects to aquatic plants. Based on the best available information, the Agency uses the refined evaluation to distinguish those actions that “may affect, but are not likely to adversely affect” from those actions that are “likely to adversely affect” the Alabama sturgeon.

The criteria used to make determinations that the effects of an action are “not likely to adversely affect” the Alabama sturgeon include the following:

- Significance of Effect: Insignificant effects are those that cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where “take” occurs for even a single individual. “Take” in this context means to harass or harm, defined as the following:

    - Harm includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.

    - Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering.

- Likelihood of the Effect Occurring: Discountable effects are those that are extremely unlikely to occur. For example, use of dose-response information to estimate the likelihood of effects can inform the evaluation of some discountable effects.

- Adverse Nature of Effect: Effects that are wholly beneficial without any adverse effects are not considered adverse.

A description of the risk and effects determination for each of the established assessment endpoints for the Alabama sturgeon is provided in Sections 5.2.1 through 5.2.4.

5.2.1 Direct Effects to the Alabama Sturgeon

Respective acute and chronic RQs of 0.003 and 0.24 (based on aggregate EECs from the combined agricultural and non-agricultural use scenario) are well below the Agency's acute and chronic risk LOCs for all modeled uses of atrazine within the action area.

Additional modeling of the residential scenario was completed to account for potential variability in overspray (1 vs. 10%), percentage of impervious surface (30 vs. 5%), and percentage of lot treated (50 vs. 75%) (Section 3.2.4.1). The results of the additional modeling show that overall EECs are increased by no more than a factor of two, when accounting for overspray, impervious surface, and treated area variability. Assuming peak and 60-day EECs of 6.0 and 5.6 μg/L (derived by multiplying the residential granular EECs in Table 3.4 by two), respective acute and chronic RQs of 0.001 and 0.09 are also well below the Agency's LOCs.

As previously discussed in Section 3.2.3, RQs for labeled uses of atrazine related to forestry were not derived as part of the risk estimation because its use within the action area is considered unlikely, given the available information. However, the forestry use is considered as part of the risk description in order to characterize an upper bound of potential exposure, should herbicide forestry use patterns within the action change in the future. Based on modeled EECs from Table 3.3 for forestry use of atrazine at an application rate of 4.0 lb ai/A (peak EEC = 46.1 μg/L; 60-day EEC = 42.2 μg/L), respective acute and chronic RQs of 0.009 and 0.65 are also less than the Agency's LOCs.

The Agency, consistent with the Overview Document (U.S. EPA, 2004) and the alternative consultation agreement with the Services (USFWS/NMFS, 2004a and b), interprets RQs below the endangered species LOC to be consistent with a finding of no effect for direct effects on the listed species for the taxa being assessed. To provide additional information, the probability of an individual mortality to the Alabama sturgeon was calculated for the acute RQ of 0.003, based on the dose response curve slope from the acute toxicity study for the rainbow trout of 2.72 (MRID # 000247-16). The corresponding estimated chance of an individual acute mortality to the Alabama sturgeon at an RQ level of 0.003 (based on the acute toxic endpoint for surrogate freshwater fish) is 1 in 300 billion. It is recognized that extrapolation of very low probability events is associated with considerable uncertainty in the resulting estimates. In order to explore the possible bounds to such estimates, the upper and lower default values for the rainbow trout dose response curve slope estimate (95% C.I.: 1.56 to 3.89) were used to calculate upper and lower estimates of the effects probability associated with the acute RQ. The respective lower and upper effects probability estimates are 1 in 24,100 (0.004%) and 1 in 2.0E+22 (~5E-21%).

As discussed in Section 4.1.1.3, several open literature studies raise questions about sublethal effects of atrazine on plasma steroid levels, behavior modifications, gill physiology, and endocrine-mediated functions in freshwater fish and anadromous fish. Consideration of the sublethal data indicates that effects associated with alteration of gill physiology and endocrine-mediated olfactory functions may occur in anadromous fish including salmon at atrazine concentrations as low as 0.5 µg/L (Waring and Moore, 2004; Moore and Lower, 2001). However, there are a number of limitations in the design of these studies, which are addressed in detail in Sections A.2.4 of Appendix A, that preclude quantitative use of the data in this risk assessment. For example, Moore and Lower (2001) exposed epithelial tissue (after removal of skin and cartilage) and not intact fish to atrazine, and potential solvent effects could not be reconciled (i.e., no negative control was tested). Furthermore, no quantitative relationship is established between reduced olfactory response (measured as electrophysiological response) of male epithelial tissue to the female priming hormone in the laboratory and reduction in salmon reproduction (i.e., the ability of male salmon to recognize and mate with ovulating females). Other sublethal effects observed in fish studies have included behavioral modifications, alterations of plasma steroid levels, and changes in kidney histology at atrazine concentrations ranging from 5 to 35 µg/L (see Section 4.1.2.3). However, a number of uncertainties were also identified with each of the studies, which are discussed in Section A.2.4 of Appendix A.

In summary, it is not possible to quantitatively link the sublethal effects to the selected assessment endpoints for the Alabama sturgeion (i.e., survival, growth, and reproduction of individuals). Also, effects to reproduction, growth, and survival were not observed in the four submitted fish life-cycle studies at levels that produced the reported sublethal effects (Appendix A). In addition, there are a number of limitations in the design of these studies, which are addressed in detail in Sections A.2.4a and A.2.4b of Appendix A, that preclude quantitative use of the data in risk assessment.

In summary, the Agency concludes a “no effect” determination for direct effects to the Alabama sturgeon, via mortality, growth, or fecundity, based on all available lines of evidence.

5.2.2 Indirect Effects via Reduction in Food Items (Freshwater Invertebrates)

Respective acute and chronic RQs for freshwater invertebrates of 0.023 and 0.27 (based on the modeled aggregate EECs from the combined agricultural and non-agricultural use scenario) are well below the Agency’s acute and chronic risk LOCs for all modeled uses of atrazine within the action area. In addition, acute and chronic RQs based on residential EECs considering upper bound assumptions of overspray (10%), impervious surface (5%), and treated area (75%) (peak EEC = 6.0 µg/L and acute RQ = 0.008; 21-day EEC = 5.9 µg/L and chronic RQ = 0.98) are also below the Agency’s LOCs.

Based on an upper bound assumption of forestry use EECs (peak EEC = 46.1 µg/L; 21-day EEC = 44.7 µg/L), respective acute and chronic RQs are 0.06 and 0.75. While the chronic RQ, based on the forestry use, is less than the Agency’s LOC, the acute RQ exceeds the endangered species LOC of 0.05. Although the available information indicates that atrazine is not used on forestry within the action area of the Alabama sturgeon, current usage patterns may change in the future. Therefore, if future use of atrazine within the action area is modified to include forestry, this use may have the potential to indirectly affect the Alabama sturgeon via reduction in the availability of sensitive aquatic invertebrate food items.

However, this analysis was based on the lowest LC_{50} value of 720 µg/L for the midge (*Chironomus* spp.). Consideration of all acute toxicity data for the midge shows a wide range of sensitivity within and between species of the same genus (2 orders of magnitude) with values ranging from 720 to >33,000 µg/L. Although the midge is a component of the Alabama sturgeon's diet, this species reportedly consumes a wide range of freshwater invertebrates that also include oligochaetes, mollusks (Williams and Clemmer, 1991; USFWS, 2000a), as well as aquatic insect larvae including mayflies, stoneflies, damselflies and dragonflies, and common netspinners (Haynes et al., 2005). Although reported acute atrazine toxicity data are not available for many of these food items, the available information for other freshwater invertebrates that are included in the Alabama sturgeon's diet (stoneflies and snails) are 6,700 µg/L and higher.

The potential for atrazine to elicit indirect effects to the Alabama sturgeon via effects on food items is dependent on several factors including: (1) the potential magnitude of effect on freshwater invertebrate individuals and populations; and (2) the number of prey species potentially affected relative to the expected number of species needed to maintain the dietary needs of the Alabama sturgeon. Together, these data provide a basis to evaluate whether the number of individuals within a prey species is likely to be reduced such that it may indirectly affect the Alabama sturgeon. Table 5.6 presents acute RQs and the probability of individual effects for dietary items of the Alabama sturgeon including stoneflies and snails. The species sensitivity distribution of all acute toxicity data for freshwater aquatic invertebrates tested is represented in Figure 4.1. This analysis considers only acute risk to aquatic invertebrate food items because chronic RQs for invertebrates were less than the Agency's LOC, based on EECs assuming forestry use of atrazine at 4.0 lb ai/A.

Table 5.6. Summary of RQs Used to Assess Potential Risk to Freshwater Invertebrate Food Items of the Alabama Sturgeon Based on Forestry Use of Atrazine

Alabama Sturgeon Food Item Species	Acute Toxicity Value Range (µg/L) (No. of Studies)	RQ Range (based on an EEC of 46.1 µg/L)	Probability of Individual Effect*	Risk Interpretation
Midge	720 - >33,000 (5)	<0.01 - 0.06	Up to 1 in 1.34E+07	Atrazine may affect sensitive food items, such as the midge; however the low probability of an individual effect to the midge is not likely to indirectly affect the Alabama sturgeon via reduction in midge prey items.

Stonefly	6,700 (1)	<0.01	Up to 1 in 1.4E+21	RQs are well below acute LOCs, which are interpreted to represent no direct effect; therefore, atrazine is not likely to indirectly affect the Alabama sturgeon via reduction in stonefly or snail prey items.
Snail	>16,000 (1)			

*The probability of an individual effect was calculated using a probit slope of 4.4, which is the only technical grade atrazine value reported in the available freshwater invertebrates studies; 95% confidence intervals could not be calculated based on the available data (Table A-18).

As shown in Table 5.6, the listed species LOC, based on forestry use of atrazine, is exceeded for the midge (RQ = 0.06), based on the LC_{50} value of 720 μg/L. However, acute RQs based on the other acute toxicity data for the midge are <0.05, less than the acute risk to endangered species LOC. Sufficient dose-response information was not available to allow for an estimation of the probability of an individual effect on the midge. Therefore, the probability of an individual effect was calculated using a probit dose response curve slope of 4.4; this is the only slope for technical grade atrazine reported in available ecotoxicity data for freshwater invertebrates (MRID # 452029-17). Based on a probit slope of 4.4, the probability of an individual mortality to the midge at an RQ of 0.06 is approximately 1 in 13.4 million (7.46E-06%).

Acute LOCs are not exceeded for other dietary items of the Alabama sturgeon including the stonefly and snail, based on the forestry use of atrazine. As previously discussed, the upper bound forestry use EEC, upon which the acute LOC exceedance is based, is likely to overestimate exposure; therefore, use of this EEC to derive RQs is also likely to result in overestimation of risk to potential food items of the Alabama sturgeon.

Based on the non-selective nature of feeding behavior in the Alabama sturgeon, the low magnitude of anticipated individual effects to all evaluated prey species, and the likelihood that EECs assuming forestry use of atrazine overestimate exposure, atrazine is not likely to indirectly affect the Alabama sturgeon via a reduction in freshwater invertebrate food items. This finding is based on insignificance of effects (i.e., effects to freshwater invertebrates are not likely to result in "take" of a single Alabama sturgeon). Therefore, the effects determination for the assessment endpoint of indirect effects on the Alabama sturgeon via direct effects on prey (i.e., freshwater invertebrates) is "may affect, but not likely to adversely affect."

5.2.3 Indirect Effects via Reduction in Habitat and/or Primary Productivity (Freshwater Aquatic Plants)

Direct adverse effects to non-vascular aquatic plants are possible, based on all modeled atrazine uses within the action area. Based on these direct effects, atrazine may indirectly affect the Alabama sturgeon via direct effects on aquatic plants. Therefore, the time-weighted EECs (for 14-day, 30-day, 60-day, and 90-day averages) were compared to their respective time-weighted threshold concentrations to determine whether potential effects to individual plant species would likely result in community level effects. As discussed in Section 4.2, concentrations of atrazine from the exposure profile at a particular use site and/or action area that exceed any of the following time-weighted threshold concentrations indicate that changes in the aquatic plant community structure could be affected:

- 14-day average = 38 µg/L
- 30-day average = 27 µg/L
- 60-day average = 18 µg/L
- 90-day average = 12 µg/L

A comparison of the 14-, 30-, 60-, and 90-day EECs for the Alabama sturgeon with the atrazine threshold concentrations representing potential aquatic community-level effects is provided in Table 5.7.

Table 5.7. Summary of Modeled Scenario Time-Weighted EECs with Threshold Concentrations for Potential Community-Level Effects

Use Scenario	14-day		30-day		60-day		90-day	
	EEC (µg/L)	Threshold Conc. (µg/L)	EEC (µg/L)	Threshold Conc. (µg/L)	EEC (µg/L)	Threshold Conc. (µg/L)	EEC (µg/L)	Threshold Conc. (µg/L)
Aggregate agricultural and non-agricultural uses	16.2	38	16.1	27	15.8	18	**15.7**	12
Corn	10.0		9.9		9.7		9.4	
Sorghum	6.2		6.0		5.8		5.6	
Fallow / idle land	5.7		5.6		5.5		5.4	
Res. (granular) (1% OS / 10% OS)	2.9 / 5.8		2.9 / 5.8		2.8 / 5.6		2.7 / 5.4	
Res. and Turf (liquid)	2.2		2.1		2.1		2.0	
Turf (granular)	2.7		2.7		2.6		2.6	
Rights-of-Way	2.4		2.4		2.3		2.2	
Forestry	**45.2**		**44.1**		**42.2**		**40.8**	

OS = overspray

Based on the results of this comparison, predicted 14-, 30-, 60-, and 90-day EECs for all modeled individual uses (including residential scenarios that consider overspray) are less than their respective threshold concentrations, with the exception of the forestry use and 90-day EECs for the combined agricultural and non-agricultural uses. Although predicted EECs for the forestry and aggregate scenarios exceed thresholds of concern for community level effects, these EECs were estimated using PRZM/EXAMS and the non-flowing standard water body scenario, which is intended to be representative of exposures in headwater streams. As previously discussed in Section 3.2.4.2, these chronic EECs are expected to over-estimate exposure in water bodies with flowing water, including the current range of the Alabama sturgeon in the Alabama River between the Millers Ferry Dam and Lock and the junction with the Tombigbee River, as well as the main tributaries of the Alabama River. Alabama sturgeon require strong currents in deep waters over relatively stable substrates for feeding and spawning (Appendix C); therefore, chronic EECs based on a non-flowing water body are expected to over-estimate actual exposure concentrations of atrazine for the sturgeon in its expected range. Additional information on the impact of flowing water on the modeled EECs, including available monitoring data, was used to refine exposure concentrations of atrazine for the Alabama sturgeon, relative to those presented for the standard water body scenario. This analysis was presented in detail in Sections 3.2.4.2 and 3.2.4.3 and is summarized below in Section 5.2.3.1 for the Alabama sturgeon.

5.2.3.1 Additional Characterization of EECs in Flowing Streams and Rivers

Given that the range of the Alabama sturgeon is reported to occur in the flowing waters of the Alabama River and its main tributaries between the Millers Ferry Dam and Lock and the junction with the Tombigbee River, EECs derived from the standard ecological water body are not likely to be representative of actual chronic exposure concentrations. Chronic exposure concentrations estimated using the standard ecological water body pond are not representative of the Alabama River and its main tributaries because the River and its main tributaries are flowing water bodies, subject to extensive mixing and dilution. In contrast, the standard ecological water body is a static water body.

As described in Section 3.2.4.2, the Agency performed a number of additional modeling exercises to allow for characterization of potential effects of flow rate on the EECs. This analysis, together with monitoring data (presented in Section 3.2.4.3), was used to further characterize and refine potential exposures associated with future forestry use of atrazine to the Alabama sturgeon.

First, the Agency's variable volume water model (VVWM) was used to account for the influence of input and output (flow) on model predictions. The Agency conducted two alternate model runs with the VVWM. The first was conducted using standard assumptions and environmental fate parameters that are generally consistent with the non-flowing standard water body. The second assumption was designed to represent a larger volume water body that maximizes flow into the water body.

Second, the impact of various flow rates was characterized using the Index Reservoir (IR) as the receiving water body. Standard and non-standard flow assumptions considered representative of the Alabama River watershed where the sturgeon is located were used to derive alternative EECs based on the IR approach.

The net effect of the additional VVWM modeling was to reduce the longer-term average exposure concentrations by approximately 4 times, based on a water depth of 10 meters. Refined long-term average EECs, based on the IR modeling and 7Q10 flow rates for the Alabama River watershed, are reduced by approximately 50 to 200 times, as compared to EECs derived using the static water body model (see Table 4.9).

In addition to the modeling exercises, The Agency used existing monitoring data to further characterize atrazine concentrations in the Alabama River. For data specific to the Alabama River, the results indicate a much lower overall atrazine concentration picture relative to both the statewide and national trends. The maximum concentration of atrazine detected in the Alabama River was 0.142 μg/L and the overall average was 0.046 μg/L. A detailed description of these data is provided in Section 3.2.4.3.

A summary of the refined EECs, which consider both flowing water bodies and the available monitoring data, relative to the community-level effect threshold concentrations is provided in **Table 5.8.**

Table 5.8. Summary of Alternative Modeling (assuming flow) and Available Monitoring Data

Analysis	Results
Modeling using VVWM	Refined 14-, 30-, 60-, and 90-day EECs for the forestry use scenario (EECs are reduced by a factor of approximately four) are less than their respective community-level threshold concentrations.
Modeling using Index Reservoir and various flow rates	EECs decrease as flow rate increases. Flow rates representative of the Alabama River result in EECs that are well below the community-level threshold concentrations.
Monitoring data, Alabama River	The maximum atrazine concentration detected in the Alabama River was 0.142 μg/L and the overall average was 0.046 μg/L, well below the community-level threshold concentrations.
Monitoring, other representative water bodies	High peak atrazine concentrations have been observed; however, longer-term (14- to 90-day) exposure durations (when the data allow for calculation) are in the low μg/L range, well below the community-level threshold concentrations.

Collectively, the refined modeling considering flow and the available monitoring data for the Alabama River suggest that atrazine concentrations in the River and its main tributaries are expected to be in the low μg/L range, well below the 14-, 30-, 60-, and 90-day threshold concentrations for community-level effects.

Although atrazine use may directly affect individual aquatic non-vascular plants in the Alabama River, its use within the action area is not likely to adversely affect the Alabama sturgeon via indirect community-level effects to aquatic vegetation. This finding is based on insignificance of effects (i.e., community-level effects to aquatic plants are not likely to result in "take" of a single Alabama sturgeon). Therefore, the effects determination for the assessment endpoint of indirect effects on the Alabama sturgeon via direct effects on habitat and/or primary productivity of aquatic plants is "may affect, but not likely to adversely affect."

5.2.4 Indirect Effects via Alteration in Terrestrial Plant Community (Riparian Habitat)

As shown in Tables 5.4 and 5.5, seedling emergence and vegetative vigor RQs exceed LOCs for a number of the tested plant species. Based on exceedance of the seedling emergence LOCs for all species tested except corn and soybeans, the following general conclusions can be made with respect to potential harm to riparian habitat via runoff exposures:

- Atrazine may enter riparian areas via runoff where it may be taken up through the root system of sensitive plants.

- Comparison of seedling emergence EC_{25} values to EECs estimated using TERRPLANT suggests that existing vegetation may be affected, or inhibition of new growth may occur. Inhibition of new growth could result in degradation of high quality riparian habitat over time because as older growth dies from natural or anthropogenic causes, plant biomass may be prevented from being replenished in the riparian area. Inhibition of new growth may also slow the recovery of degraded riparian areas that function poorly due to sparse vegetation because atrazine deposition onto bare soil would be expected to inhibit the growth of new vegetation.

- Because LOCs were exceeded for most species tested (8/10) in the seedling emergence studies, it is likely that many species of herbaceous plants may be potentially affected by exposure to atrazine in runoff.

A number of dicots in riparian habitats may also be impacted via foliar exposure from atrazine in spray drift as evidenced by vegetative vigor LOC exceedances in three dicots. Therefore, riparian habitats comprised of herbaceous plants sensitive to atrazine may be adversely affected by spray drift. However, comparison of the seedling emergence and vegetative vigor RQs indicates that runoff, and not spray drift, is a larger contributor to potential risk for riparian vegetation. Vegetative vigor risk quotients were not exceeded for monocots; therefore, drift would not be anticipated to affect riparian zones comprised primarily of monocot species such as grasses.

Because RQs for terrestrial plants are above the Agency's LOCs, atrazine use is considered to have the potential to directly impact plants in riparian areas, potentially resulting in degradation of stream water quality via sedimentation and loss of available spawning habitat. Therefore, an analysis of the potential for habitat degradation to affect the sturgeon is necessary. In addition, if forestry uses of atrazine are considered (at an application rate of 4.0 lb ai/A), the RQ values shown in Tables 5.4 and 5.5 would be expected to increase by a factor of approximately two.

Riparian plants beneficially affect water and stream quality in a number of ways (discussed below) in both adjacent river reaches and areas downstream of the riparian zone. Atrazine use in the area of the Alabama sturgeon's range, below the Millers Ferry Lock and Dam, downstream to the mouth of the Tombigbee River (Figure 2.4), may potentially affect the sturgeon by impacting riparian vegetation and subsequently causing sedimentation that results in degraded water quality and reduction of available spawning habitat. Although the watershed above the Millers Ferry Lock and Dam is included in the action area for this assessment, the focus of impacts to riparian vegetation is limited to the areas adjacent to the Lower Alabama River, downstream of the dam. Given the presence of the Millers Ferry Lock and Dam, sedimentation resulting from impacts to riparian areas is likely to be limited to the area downstream of the dam in the area of the Alabama sturgeon's range.

As shown in Figure 2.2, the majority of agricultural cropland in the Alabama River Basin watershed is restricted to areas well upstream from the range of the Alabama sturgeon. The land adjacent to the Lower Alabama River surrounding the habitat range of the Alabama sturgeon contains only a small percentage of area devoted to cropland, and available information indicates that cropped riparian zones do not exist in the Lower Alabama River watershed (Michael, personal communication, 2006). Within the entire action area for the Alabama sturgeon (including upstream and downstream of the Millers Ferry Lock and Dam), the total percentage of cropland is approximately 9.8%. Therefore, atrazine is not likely to impact cropped riparian zones because they are unlikely to occur on land adjacent to the Lower Alabama River watershed. According the Alabama River Basin Management Plan (Kleinschmidt, 2005), land use in the Alabama River Basin watershed is dominated by forests (67%), with pastureland at 17% and cropland at 9%. Approximately 98 to 99% of land use in the Lower Alabama River Basin is rural in nature.

A general discussion of riparian habitat and its relevance to the Alabama sturgeon is discussed in Section 5.2.4.1. Forested riparian zones that may be potentially impacted by atrazine use in the Alabama River are discussed in Section 5.2.4.2, and sediment loading in the Lower Alabama River watershed and the potential risks to the Alabama sturgeon caused by atrazine-related impacts to riparian vegetation are discussed in Section 5.2.4.3.

5.2.4.1 Importance of Riparian Habitat to the Alabama Sturgeon

Riparian vegetation provides a number of important functions in the stream/river ecosystem, including the following:

- serves as an energy source;
- provides organic matter to the watershed;
- provides shading, which ensures thermal stability of the stream; and
- serves as a buffer, filtering out sediment, nutrients, and contaminants before they reach the stream.

The specific characteristics of a riparian zone that are optimal for the Alabama sturgeon are expected to vary with developmental stage, the use of the reach adjacent to the riparian zone, and the hydrology of the watershed. Criteria developed by Fleming et al. (2001) have been used to assess the health of riparian zones and their ability to support fish habitat. These criteria, which include the width of vegetated area (i.e. distance from cropped area to water), structural diversity of vegetation, and canopy shading, are summarized in Table 5.9.

Table 5.9. Criteria for Assessing the Health of Riparian Areas to Support Aquatic Habitats (adapted from Fleming et al. 2001)

Criteria	Quality			
	Excellent	**Good**	**Fair**	**Poor**
Buffer width	>18m	12 - 18m	6 - 12m	<6m
Vegetation diversity	>20 species	15 - 20 species	5 - 14 species	<5 species
Structural diversity	3 height classes grass/shrub/tree	2 height classes	1 height class	sparse vegetation
Canopy shading	mixed sun/shade	sparse shade	90% sun	no shade

To maintain at least "good" water quality for fish in general, riparian areas should contain at least a 12 m (~40 feet) wide vegetated area, 15 plant species, vegetation of at least two height classes, and provide at least sparse shade (>10% shade). In general, higher quality riparian zones (wider vegetated areas with greater plant diversity) are expected to have a lower probability of being significantly affected by atrazine than poor quality riparian areas (narrower areas with less vegetation and little diversity).

The following three attributes of riparian vegetation habitat quality were evaluated for this assessment: water temperature, stream bank stability, and sediment loading. Each of these attributes is discussed briefly below.

<u>Streambank Stabilization:</u> Riparian vegetation typically consists of three distinct types of plants, which include a groundcover of grasses and forbs, an understory of shrubs and young trees, and an overstory of mature trees. These plants serve as structural components for streams, with the root systems helping to maintain stream stability, and the large woody debris from the mature trees providing instream cover. Riparian vegetation has been shown to be essential to maintenance of a stable stream (Rosgen, 1996). Destabilization of the stream can have a severe impact on aquatic habitat quality. Following a disturbance, the stream may widen, releasing sediment from the stream banks and scouring the stream bed. Destabilization of the stream can have severe effects aquatic habitat quality by increasing sedimentation within the watershed. The effects of sedimentation are summarized below.

<u>Sedimentation:</u> Sedimentation refers to the deposition of particles of inorganic and organic matter from the water column. Increased sedimentation is caused primarily by

disturbances to river bottoms and streambeds and by soil erosion. Riparian vegetation is important in moderating the amount of sediment loading from upland sources. The roots and stems of riparian vegetation can intercept eroding upland soil (USDA NRCS, 2000), and riparian plant foliage can reduce erosion from within the riparian zone by covering the soil and reducing the impact energy of raindrops onto soil (Bennett, 1939).

According to the USFWS *Recovery Plan of the Mobile River Basin Aquatic Ecosystem* (USFWS, 2000b), sedimentation is considered the greatest factor threatening the aquatic ecosystems across the basin. Sediment loading alters streambeds, transports pollutants and nutrients, smothers and kills benthic plants and animals, and eliminates suitable breeding and foraging habitat for mobile species (e.g., fish, turtles, snails) (USFWS, 2000b). Increased sedimentation may affect spawning by settling on spawning gravel and reducing flow of water and dissolved oxygen to the eggs and fry (Everest et al., 1987). In addition, fine particles settling on the streambed can also disrupt the food chain by reducing habitat quality for aquatic invertebrates, and adversely affect groundwater-surface water interchange (Nelson et al., 1991). Increased turbidity from sediment loading may also reduce light transmission, potentially affecting aquatic plants (Cloern, 1987; Weissing and Huisman, 1994) that are important for shelter and food.

<u>Thermal stability</u>. Riparian habitat provides stream shading resulting in thermal stability. While thermal stability is generally considered to be an important variable for most river sturgeons (*Scaphirhynchus* spp.) (USFWS, 2000a), the sensitivity of the Alabama sturgeon to fluctuations in temperature is unknown.

5.2.4.2 Sensitivity of Forested Riparian Zones to Atrazine

Available land use information from the Alabama Soil and Water Conservation Committee (SWCC), as shown in Figure 5.1, indicates that the majority of land surrounding the Lower Alabama River watershed is forestland. The area defined as "forestland" is expected to include land that is commercially harvested (i.e., plantations), as well as undisturbed forested areas that are not harvested. As shown in Figure 5.2, forested land cover data for the Lower Alabama River watershed shows that the land adjacent to the current range for the Alabama sturgeon is dominated by forested wetlands and deciduous and evergreen forest, with very little herbaceous riparian area (USGS, 2004).

As previously summarized in Table 5.9, the parameters used to assess riparian quality include buffer width, vegetation diversity, vegetation cover, structural diversity, and canopy shading. Buffer width, vegetation cover, and/or canopy shading may be reduced if atrazine exposure impacts plants in the riparian zone or prevents new growth from emerging. Plant species diversity and structural diversity may also be affected if only sensitive plants are impacted (Jobin et al., 1997; Kleijn and Snoeijing, 1997), leaving non-sensitive plants in place. Atrazine may also affect the long term health of high quality riparian habitats by affecting seed germination. Thus, if atrazine exposure impacted these riparian parameters, water quality within the Lower Alabama River watershed could be affected.

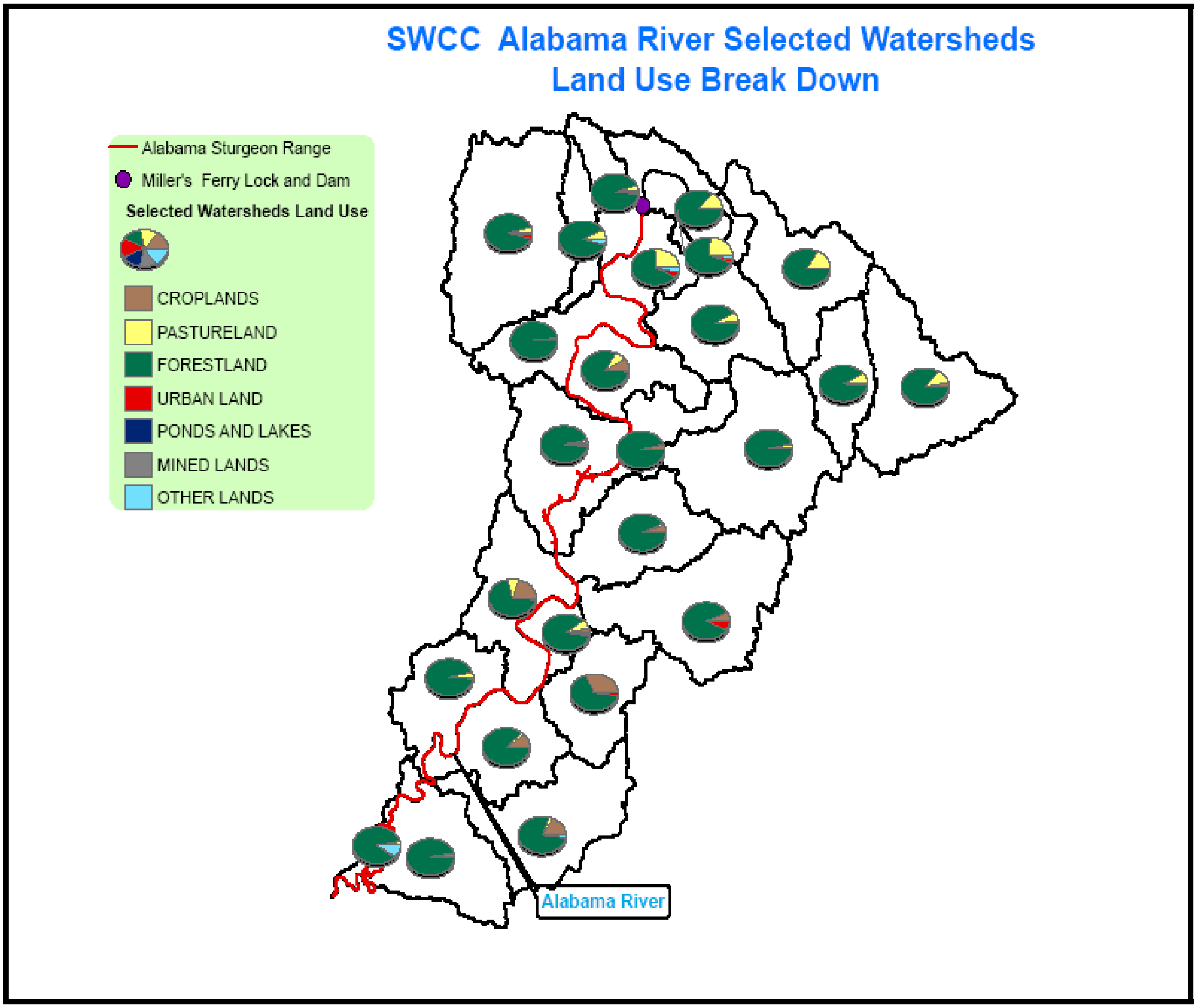

Figure 5.1. Land Use Within the Range of the Alabama Sturgeon

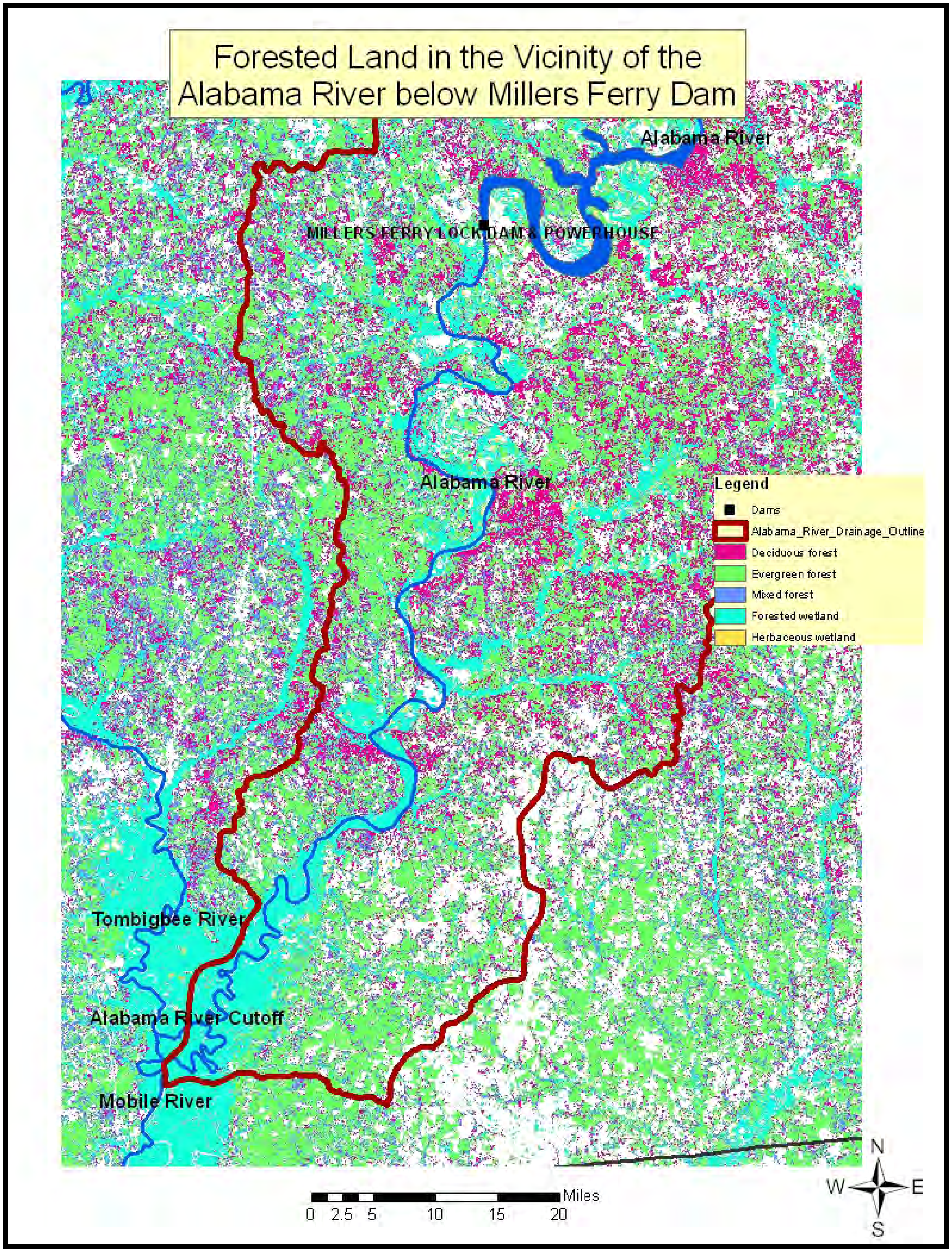

Figure 5.2. Forested Land Cover in the Lower Alabama River Watershed

Because woody plants are generally not sensitive to environmentally-relevant atrazine concentrations (MRID 46870400-01), effects on shading, streambank stabilization, and structural diversity (height classes) of woody forested vegetation are not expected. Effects are expected to be limited to herbaceous (non-woody) plants, which are not generally associated with shading or considered to represent vegetation of higher height classes. Therefore, plant diversity, vegetation cover, and buffer width are expected to be the most sensitive riparian quality criteria for herbaceous plants.

The riparian health criteria described in Fleming et al. (2001; Table 5.9) and the characteristics associated with effective vegetative buffer strips suggest that healthy riparian zones would be less sensitive to the impacts of atrazine runoff than poor riparian zones. Although riparian zones rich in species diversity and woody species may contain sensitive species, it is unlikely that they would consist of a high proportion of very sensitive plants. Wider buffers have more potential to reduce atrazine residues over a larger area, resulting in lower levels. In addition, trees and woody plants in a healthy riparian area act to filter spray drift (Koch et al., 2003) and push spray drift plumes over the riparian zone (Davis et al., 1994), thus reducing exposure to herbaceous plants, which tend to be more sensitive. Therefore, high quality riparian zones are expected to be less sensitive to atrazine than riparian zones that are narrow, low in species diversity, and comprised of young herbaceous plants or unvegetated areas. The available data suggest that riparian zones comprised largely of herbaceous plants and grasses would likely be most sensitive to atrazine effects. However, as shown in Figure 5.2, there is little, if any, riparian area that is composed predominantly of herbaceous vegetation located adjacent to the Lower Alabama River watershed. Bare ground riparian areas could also be adversely affected by prevention of new growth of grass, which can be an important component of riparian vegetation for maintaining water quality.

Although atrazine is rarely used in commercial forestry in Alabama (Michael, personal communication, 2006; McNabb, personal communication, 2006), its use within the Lower Alabama River watershed and potential impacts to riparian vegetation are qualitatively evaluated. Herbicides are used in forest management primarily to enhance reforestation on areas that have been recently harvested. As part of site preparation, herbicide treatments are applied to bare ground after harvest and before trees are planted (or naturally regenerated) to control woody vegetation and fast-growing herbaceous plants that can kill or suppress the growth of planted tree seedlings (Wagner et al., 2004).

If atrazine is applied to bare pine plantation areas (as part of site preparation) that are in close proximity to the Lower Alabama River watershed, water quality could be impacted. The best available information indicates that riparian areas adjacent to the watershed are forested; however, the forested vegetation within these areas is not harvested as part of forestry operations (i.e., plantations) (Michael, personal communication, 2006). The forest land cover map (Figure 5.2), which shows that the area directly adjacent to the watershed is predominantly forested wetland, provides additional evidence that areas directly adjacent to the watershed are not harvested. In addition, Best Management Practices (BMPs), specified by the Alabama Forestry Commission, recommend streamside management zones (SMZs) for forestry in Alabama. A SMZ is a strip of land (approximately 35 to 100 feet wide) immediately adjacent to a water of the state where soils, organic matter, and vegetation are managed to protect the physical, chemical, and biological integrity of the surface water adjacent to and downstream from forestry operations (Alabama Forestry Commission, 1993). SMZs are used to: 1) reduce channel and floodplain erosion, 2) control deposition of pollutants directly into waters of the state, 3) maintain biological integrity of aquatic ecosystems, and 4) retain the capability of the forest floor to filter out pollutants from upland runoff (Alabama Forestry Commission, 1993). In its BMP guidance document, the Alabama Forestry Commission (1993) specifies that herbicides should not be used within SMZs. Although SMZs are not legally required within the state of Alabama, use of this BMP within forestry plantation management is generally followed in areas surrounding the Alabama River Basin watershed (Michael, personal communication, 2006). In addition, labeling requirements for atrazine specify no use within 66 feet of intermittent and perennial streams.

Given the forested nature of the riparian zone adjacent to the Lower Alabama River watershed, the low sensitivity of woody plants to atrazine, the existence of recommended BMPs (i.e., SMZs) adjacent to the watershed, and existing atrazine labels requiring setbacks for applications near water bodies, it is unlikely that atrazine will adversely affect forested vegetation in the area of the Lower Alabama River watershed.

5.2.4.3 Sediment Loading in the Lower Alabama River Watershed and the Potential for Atrazine to Affect the Alabama Sturgeon via Effects on Riparian Vegetation

It is difficult to estimate the magnitude of potential impacts of atrazine use on riparian habitat and the magnitude of potential effects on stream water quality from such impacts as they relate to survival, growth, and reproduction of the Alabama sturgeon. The level of exposure and any resulting magnitude of effect on riparian vegetation are expected to be highly variable and dependent on many factors. The extent of runoff and/or drift into stream corridor areas is affected by the distance the atrazine use site is offset from the stream, local geography, weather conditions, and quality of the riparian buffer itself. The sensitivity of the riparian vegetation is dependent on the susceptibility of the plant species present to atrazine and composition of the riparian zone (e.g. vegetation density, species richness, height of vegetation, width of riparian area).

Quantification of risk to the Alabama sturgeon is precluded by the following factors:

- Locations of Alabama sturgeon spawning habitat within the Lower Alabama River watershed are not known;

- The relationship between distance of soil input into the river and sediment deposition in spawning areas critical to survival and reproduction of the Alabama sturgeon is not known; and

- Riparian areas are highly variable in their composition and location with respect to atrazine use; therefore, their sensitivity to potential damage is also variable.

In addition, even if plant community structure was quantifiably correlated with riparian function, it may not be possible to discern the effects of atrazine on species composition separate from other agricultural actions or determine if atrazine is a significant factor in altering community structure. Plant community composition in agricultural field margins is likely to be modified by many agricultural management practices. Vehicular impact and mowing of field margins and off-target movement of fertilizer and herbicides are all likely to cause changes in plant community structure of riparian areas adjacent to agricultural fields (Jobin et al., 1997; Kleijn and Snoeijing, 1997; Schippers and Joenje, 2002). Although herbicides are commonly identified as a contributing factor to changes in plant communities adjacent to agricultural fields, some studies identify fertilizer use as the most important factor affecting plant community structure near agricultural fields (e.g. Schippers and Joenje, 2002) and community structure is expected to be affected by a number of other factors (de Blois et al., 2002). Specifically, the construction of dams and locks in the Alabama River watershed is a critical factor that impacts water quality for the Alabama sturgeon. Thus, the effect of atrazine on riparian community structure would be expected to be one influence complicated by a myriad of other factors. Although the data do not allow for a quantitative estimation of risk from potential riparian habitat alteration, a qualitative discussion is presented below.

The magnitude of potential impacts of atrazine use on riparian habitat within the Lower Alabama River watershed and resulting indirect effects to Alabama sturgeon water quality via sedimentation and destruction of available spawning habitat are evaluated by considering the dominant forestry land use within the area, available data on sediment loading contributions from all potential sources of erosion within the Lower Alabama River watershed, and a study of the potential impact of annual dredging activities on the Alabama sturgeon.

Data on sediment loading estimates (in units of tons per year) are available from the Alabama SWCC database that is published on the web (www.swcc.state.al.us/watershedmenu.htm; July 31, 2006). Alabama Department of Environmental Management data for 2002 indicate that woodlands are the dominant source of sediment (27%) to the Lower Alabama River Basin, followed by cropland (18%), dirt roads and road banks (15%), and sand and gravel pits (13%). Estimated sources of sediment loading into the Lower Alabama River watershed, based on data compiled by the Alabama SWCC, are depicted in Figure 5.3. SWCC data on each of the subwatersheds of the Lower Alabama River show that the management practices associated with woodlands/forestry account for the majority of sedimentation (>75%) into the Lower Alabama River. Intensive forest management practices, particularly road building, harvesting and mechanical site preparation, result in the greatest increases in erosion from forest sites. The most used type of mechanical site preparation is shear and pile (Prince, 2003). In this method, a tractor is used to cut down residual tree stands, using a shear blade, followed by a second tractor that uses a root rake to move the residue into piles or windrows. The available studies on the impact of mechanical versus chemical (i.e., herbicide) site-preparation for forestry show that use of mechanical site preparation methods result in 20 to 400% more sediment than observed on paired sites

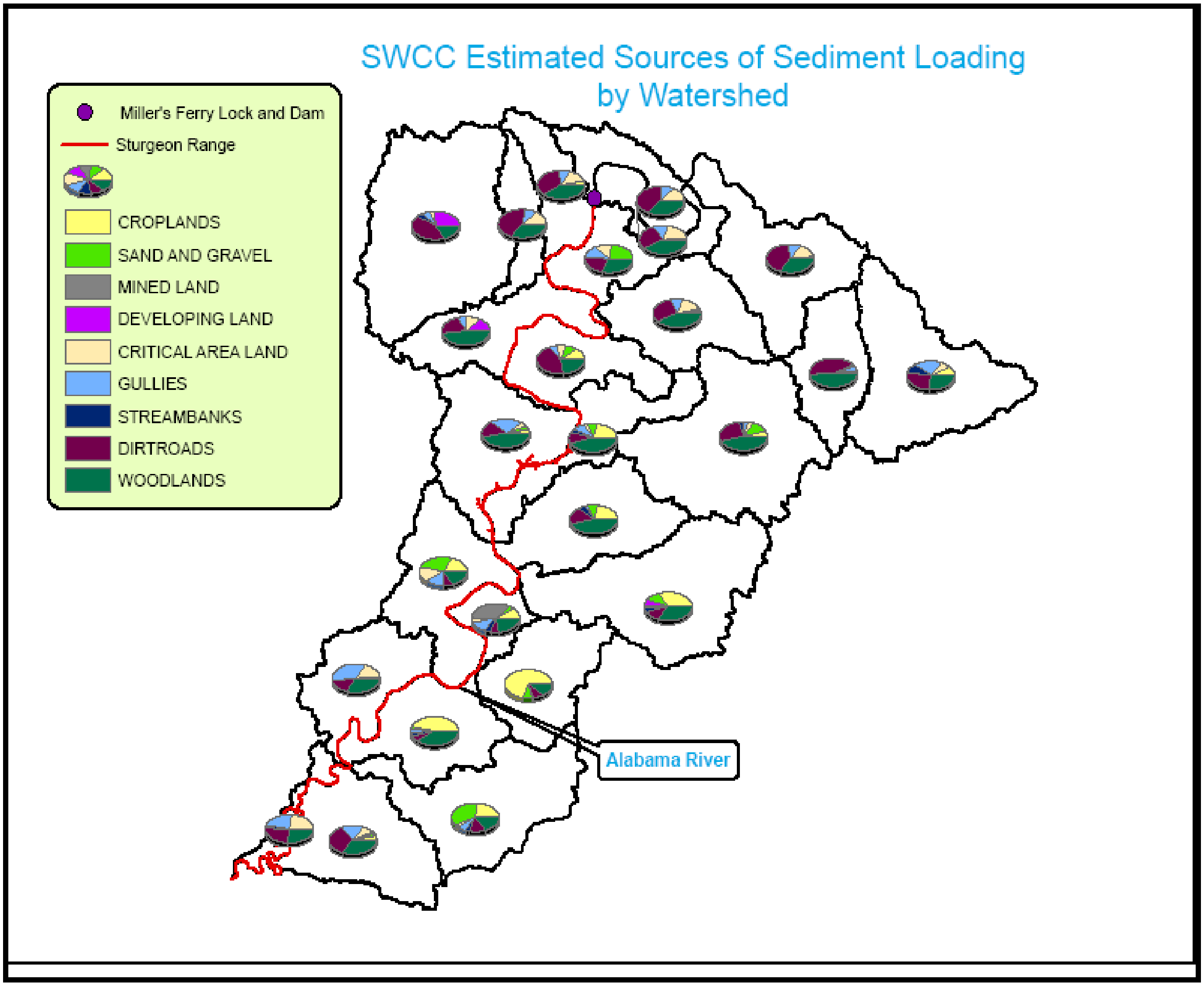

Figure 5.3. Estimated Sources of Sediment Loading into the Lower Alabama River

which are prepared with herbicides (Michael et al., 2000). Therefore, the best available information shows that the primary source of sedimentation into the Lower Alabama River is from woodland and forestry management practices, consistent with the majority of land use for the surrounding area.

Although forestry management practices are likely to contribute the largest percentage of sediment loads from land-based activities, the impacts of dredging on potential sedimentation loading to the Lower Alabama River within the habitat range of Alabama sturgeon are also evaluated.

In 1994, the Services and the U.S. Army Corp of Engineers reviewed the anticipated impacts of a variety of activities in the Lower Alabama River to the Alabama sturgeon in a document that has become widely known as the White Paper (Biggins, 1994). Specifically, the impact of annual dredging required to maintain navigation channels in the Lower Alabama River was evaluated. Maintenance dredging continues to be necessary to remove the accumulated material (i.e., unconsolidated substrates) that settles in slower current depositional areas in the Lower Alabama River. Based on the findings of 1994 White Paper, maintenance dredging and disposal activities in the Lower Alabama River had no effect on the Alabama sturgeon. The available information indicates that Alabama sturgeon require strong currents over relatively stable substrates for feeding and spawning (USFWS, 2000a). As such, they are not likely to be present in shallow, slower current areas with unconsolidated substrates, where dredging occurs annually to maintain navigation. Therefore, removal and disposal of unconsolidated materials is not perceived as a threat to the sturgeon or to its feeding or spawning habitat. Furthermore, the following activities, which do not include labeled pesticide use, are listed in the 1994 White Paper as having the potential to result in a “take” of the Alabama sturgeon:

1. Illegal collection of the Alabama sturgeon;
2. Unlawful destruction or alteration of the Alabama sturgeon’s habitat (e.g., un-permitted instream dredging, channelization, discharge of fill material); and
3. Illegal discharge or dumping of toxic chemicals or other pollutants into waters supporting the Alabama sturgeon.

Despite the findings of the 1994 White Paper, the USFWS maintains that dredging activities have the potential to permanently alter or degrade habitat quality for the Alabama sturgeon (USFWS, 2000b). More importantly, the construction of dams and locks is recognized as the major contributing factor to the extinction and imperilment of listed aquatic species, including the Alabama sturgeon, in the Alabama River Basin (USFWS, 2000b). Impoundments fragment habitat, change flow regimes, increase sedimentation, and limit the movement of species within the ecosystem. Other activities that permanently alter or degrade habitat quality include channelization of streams, in-stream mining, and point source wastewater discharges. Lastly, any increases in intensive land-based activities that promote erosion (e.g., deforestation, road and building construction, mining) exacerbate sedimentation in streams and rivers and may potentially lead to habitat degradation for the Alabama sturgeon (Kleinschmidt, 2005).

As previously discussed, the potential for atrazine to affect the Alabama sturgeon via impacts on riparian vegetation depends primarily on the extent of sensitive (herbaceous and grassy) riparian zones and its impact on water quality in the Lower Alabama River watershed. The extent to which herbaceous or grassy riparian areas are present in the area surrounding the Alabama sturgeon’s range is expected to be minimal (see Figure 5.2). Forested riparian areas are more prevalent, given the dominant forested land use surrounding the watershed. Because woody plants are generally not sensitive to atrazine, impacts to forested riparian vegetation adjacent to atrazine use areas (and resulting sedimentation) are unlikely to occur In addition, the majority of sediment loading into the Lower Alabama River watershed is associated with forestry practices, and the smaller percentage of sediment loading that is attributed to cropland is likely to be associated with related management practices (such as soil disturbance), rather than atrazine-related impacts to riparian vegetation. Therefore, potential impacts on herbaceous riparian habitat from atrazine use are expected to result in negligible effects on overall sediment loading into the Lower Alabama River adjacent to potential habitat for the Alabama sturgeon, as compared to other sources of sedimentation including forestry management practices and annual dredging of navigational channels.

In summary, terrestrial plant RQs are above LOCs; therefore, riparian vegetation may be affected. However, woody plants are generally not sensitive to environmentally-relevant atrazine concentrations; therefore, effects on shading, streambank stabilization, and structural diversity (height classes) of vegetation are not expected. In addition, the best available data on surrounding land use (i.e., forested) and the relative contribution of sediment loading from a variety of sources suggest that atrazine is not likely to adversely affect the Alabama sturgeon from potential reduction in riparian habitat and resulting sedimentation to available spawning habitat. This finding is based on insignificance of effects (i.e., effects to riparian vegetation in the Lower Alabama River watershed cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where "take" of a single Alabama sturgeon would occur). Therefore, the effects determination for the assessment endpoint of indirect effects on the Alabama sturgeon via direct effects on terrestrial vegetation (riparian habitat) required to maintain acceptable water quality and spawning habitat is "may affect, but not likely to adversely affect." A graphic representation of the effects determination for this assessment endpoint, based on evaluation of the sedimentation, streambank stability, and thermal stability attributes for riparian vegetation is provided in Figure 5.4.

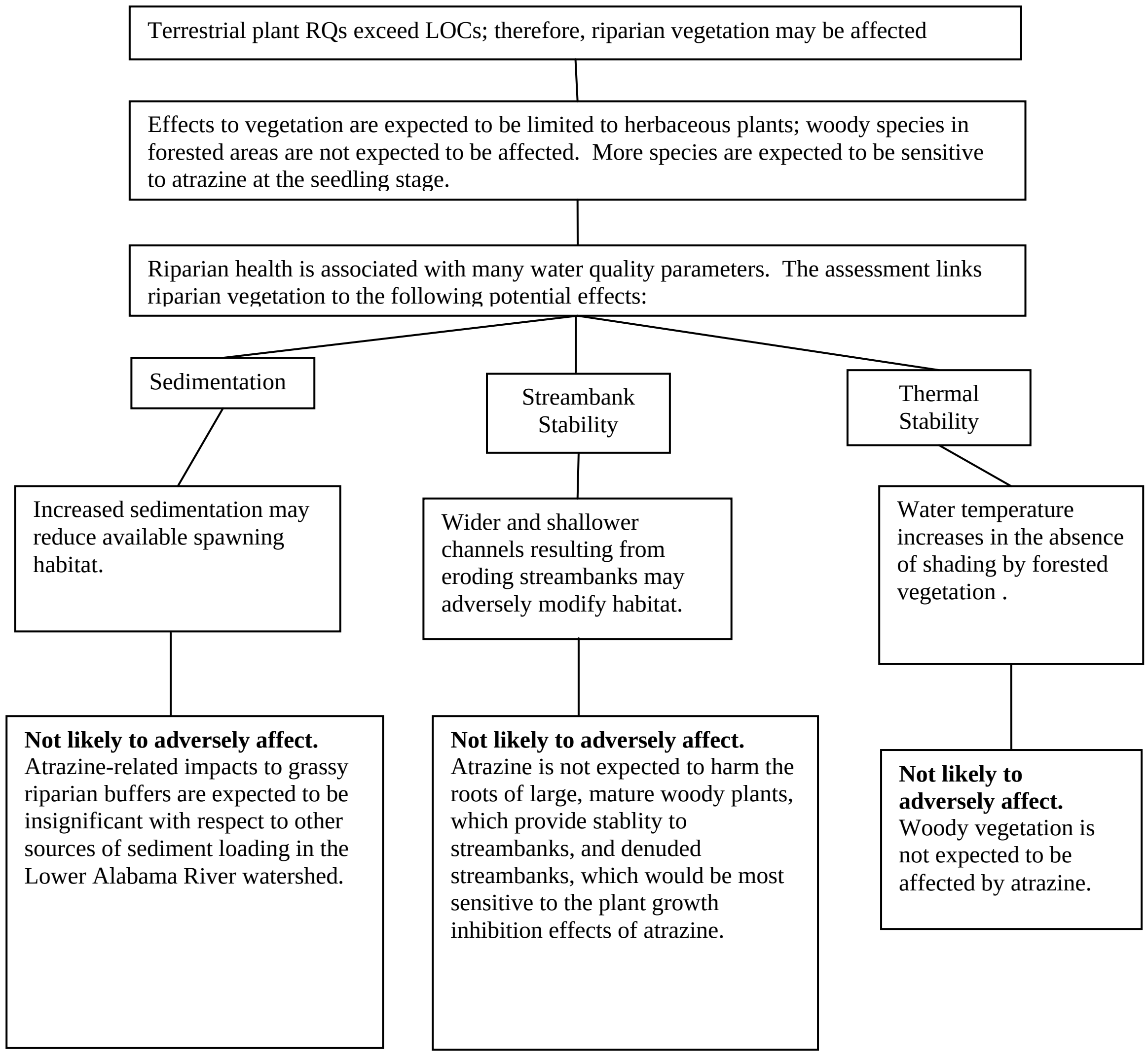

Figure 5.4. Summary of the Potential of Atrazine to Affect the Alabama Sturgeon via Riparian Habitat Effects

6. Uncertainties

6.1 Exposure Assessment Uncertainties

Overall, the uncertainties inherent in the exposure assessment tend to result in over-estimation of exposures. This is apparent when comparing modeling results with monitoring data. In particular, peak exposures are generally several orders of magnitude above the highest detection found in any of the samples collected from the Alabama River. In general, the monitoring data should be considered a lower bound on exposure, while modeling represents an upper bound. Factors influencing the over-estimation of exposure include the assumption of no flow in the modeled water body. Analysis indicates that increasing flow will result in significant reduction in exposure, particularly for longer-term durations of exposure (14-day, 30-day, etc.). In addition, many of the atrazine use sites are likely to be far removed from the Alabama River; thus, significant dilution is likely to occur between modeled EECs that are representative of headwater streams immediately adjacent to agricultural fields and exposure concentrations expected to occur in the Alabama River below Millers Ferry Dam. Furthermore, the impact of setbacks on runoff estimates has not been quantified, although well-vegetated setbacks are likely to result in significant reduction in runoff loading of atrazine.

6.1.1 Modeling Assumptions

Overall, the uncertainties addressed in this assessment cannot be quantitatively characterized. However, given the available data and the tendency to rely on conservative modeling assumptions, it is expected that the modeling results in an over-prediction in exposure. In general, the simplifying assumptions used in this assessment appear from the characterization in Section 3.2.4 to be reasonable given the analysis completed and the available monitoring data. There are also a number of assumptions that tend to result in over-estimation of exposure. Although these assumptions cannot be quantified, they can be qualitatively described. For instance, modeling in this assessment for each use site assumes that all applications have occurred concurrently on the same day at the exact same application rate. This is unlikely to occur in reality, but is a reasonable conservative assumption in lieu of actual data.

6.1.2 Impact of Vegetative Setbacks on Runoff

Unlike spray drift, tools are currently not available to evaluate the effectiveness of a vegetative setback on runoff and loadings. The effectiveness of vegetative setbacks is highly dependent on the condition of the vegetative strip. For example, a well-established, healthy vegetative setback can be a very effective means of reducing runoff and erosion from agricultural fields. Alternatively, a setback of poor vegetative quality or a setback that is channelized can be ineffective at reducing loadings. Until such time as a quantitative method to estimate the effect of vegetative setbacks on various conditions on pesticide loadings becomes available, the aquatic exposure predictions are likely to overestimate exposure where healthy vegetative setbacks exist and underestimate exposure where poorly developed, channelized, or bare setbacks exist.

6.1.3 PRZM Modeling Inputs and Predicted Aquatic Concentrations

In general, the linked PRZM/EXAMS model produces estimated aquatic concentrations that are expected to be exceeded once within a ten-year period. The Pesticide Root Zone Model (PRZM) is a process or "simulation" model that calculates what happens to a pesticide in a farmer's field on a day-to-day basis. It considers factors such as rainfall and plant transpiration of water, as well as how and when the pesticide is applied. It has two major components: hydrology and chemical transport. Water movement is simulated by the use of generalized soil parameters, including field capacity, wilting point, and saturation water content. The chemical transport component can simulate pesticide application on the soil or on the plant foliage. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar wash-off, advection, dispersion, and retardation.

Uncertainties associated with each of these individual components add to the overall uncertainty of the modeled concentrations. Additionally, model inputs from the environmental fate degradation studies are chosen to represent the upper confidence bound on the mean, values that are not expected to be exceeded in the environment 90 percent of the time. Mobility input values are chosen to be representative of conditions in the environment. The natural variation in soils adds to the uncertainty of modeled values. Factors such as application date, crop emergence date, and canopy cover can also affect estimated concentrations, adding to the uncertainty of modeled values. Factors within the ambient environment such as soil temperatures, sunlight intensity, antecedent soil moisture, and surface water temperatures can cause actual aquatic concentrations to differ for the modeled values.

Additionally, the rate at which atrazine is applied and the percent of crops that are actually treated with atrazine may be lower than the Agency's default assumption of the maximum allowable application rate being used and the entire crop being treated. The geometry of a watershed and limited meteorological data sets also add to the uncertainty of estimated aquatic concentrations.

6.2 Effects Assessment Uncertainties

6.2.1 Age Class and Sensitivity of Effects Thresholds

It is generally recognized that test organism age may have a significant impact on the observed sensitivity to a toxicant. The acute toxicity data for fish are collected on juvenile fish between 0.1 and 5 grams. Aquatic invertebrate acute testing is performed on recommended immature age classes (e.g., first instar for daphnids, second instar for amphipods, stoneflies, mayflies, and third instar for midges).

Testing of juveniles may overestimate toxicity at older age classes for pesticidal active ingredients, such as atrazine, that act directly (without metabolic transformation) because younger age classes may not have the enzymatic systems associated with detoxifying xenobiotics. In so far as the available toxicity data may provide ranges of sensitivity information with respect to age class, this assessment uses the most sensitive life-stage information as measures of effect for surrogate aquatic animals, and is therefore, considered as protective of the Alabama sturgeon.

6.2.2 Use of Acute Freshwater Invertebrate Toxicity Data for the Midge

The initial acute risk estimate for freshwater invertebrates was based on the lowest toxicity value from *Chironomus* studies, which showed a wide range of sensitivity within and between species of the same genus (2 orders of magnitude). Therefore, acute RQs based on the most sensitive toxicity endpoint for freshwater invertebrates may represent an overestimation of potential direct risks to freshwater invertebrates and indirect effects to the Alabama sturgeon via a reduction in available food.

6.2.3 Extrapolation of Long-term Environmental Effects from Short-Term Laboratory Tests

The influence of length of exposure and concurrent environmental stressors to the Alabama sturgeon (i.e., construction of dams and locks, fragmentation of habitat, change in flow regimes, increased sedimentation, degradation of quantity and quality of water in the Alabama River watershed, predators, etc.) will likely affect the species response to atrazine. Additional environmental stressors may decrease the Alabama sturgeon's sensitivity to the herbicide, although there is the possibility of additive/synergistic reactions. Timing, peak concentration, and duration of exposure are critical in terms of evaluating effects, and these factors will vary both temporally and spatially within the action area. Overall, the effect of this variability may result in either an overestimation or underestimation of risk. However, as previously discussed, the Agency's LOCs are intentionally set very low, and conservative estimates are made in the screening level risk assessment to account for these uncertainties.

6.2.4 Use of Threshold Concentrations for Community-Level Endpoints

For the purposes of this endangered species assessment, threshold concentrations are used to predict potential indirect effects (via aquatic plant community structural change) to the Alabama sturgeon. The conceptual aquatic ecosystem model used to develop the threshold concentrations is intended to simulate the ecological production dynamics in a 2^{nd} or 3^{rd} order Midwestern stream; however, the model has been correlated to the micro- and mesocosm studies, which were derived from a wide range of experimental studies (i.e., jar studies to large enclosures in lentic and lotic systems), that represent the best available information for atrazine-related community-level endpoints.

The threshold concentrations are predictive of potential atrazine-related community-level effects in aquatic ecosystems, such as the Alabama River, where the species composition may differ from those included in the micro- and mesocosm studies. Although it is not possible to determine how well the responses observed in the micro- and mesocosm studies reflect the Alabama River Basin aquatic community, estimated chronic atrazine exposure concentrations in the action area (from modeled EECs assuming flow) are predicted to be between 2 to 5 times lower than the community-level threshold concentrations, depending on the modeled atrazine use and averaging period. An evaluation of monitoring data suggests that concentrations of atrazine could be even further removed from these threshold concentrations. Given that threshold concentrations were derived based on the best available information from available community-level data for atrazine, these values are intended to be protective of the aquatic community, including the Alabama sturgeon. Additional uncertainties associated with use of the screening thresholds to estimate community-level effects are discussed in Section B.8 of Appendix B.

6.2.5. Sublethal Effects

The assessment endpoints used in ecological risk assessment include potential effects on survival, growth, and reproduction of the Alabama sturgeon. A number of studies were located that evaluated potential sublethal effects to fish from exposure to atrazine. Although many of these studies reported toxicity values that were less sensitive than the submitted studies, they were not considered for use in risk estimation. In particular, fish studies were located in the open literature that reported effects on endpoints other than survival, growth, or reproduction at concentrations that were considerably lower than the most sensitive endpoint from submitted studies.

Upon evaluation of the available studies, however, the most sensitive NOAEC from the submitted full life-cycle studies was considered to be the most appropriate chronic endpoint for use in risk assessment. In the full life cycle study, fish are exposed to atrazine from one stage of the life cycle to at least the same stage of the next generation (e.g. egg to egg). Therefore, exposure occurs during the most sensitive life stages and during the entire reproduction cycle. Four life cycle studies have been submitted in support of atrazine registration. Species tested include brook trout, bluegill sunfish, and fathead minnows. The most sensitive NOAEC from these studies was 65 µg/L.

Reported sublethal effects including changes in hormone levels, behavioral effects, kidney pathology, gill physiology, and potential olfaction effects have been observed at concentrations lower than 65 µg/L (see Appendix A and Section 4.1.2.). These studies were not considered appropriate for risk estimation in place of the life cycle studies because quantitative relationships between these effects and the ability of fish to survive, grow, and reproduce has not been established. The magnitude of the reported sublethal effect associated with reduced survival or reproduction has not been established; therefore it is not possible to quantitatively link sublethal effects to the selected assessment endpoints for this ESA. In addition, in the fish life cycle studies, no effects were observed to survival, reproduction, and/or growth at levels associated with the sublethal effects. Also, there were limitations to the studies that reported sublethal effects that preclude their quantitative use in risk assessment (see Appendix A and Section 4.2.1). Nonetheless, if future studies establish a quantitative link between the reported sublethal effects and fish survival, growth, or reproduction, the conclusions with respect to potential effects to the Alabama sturgeon may need to be revisited.

6.2.6. Exposure to Pesticide Mixtures

This assessment considered only the single active ingredient of atrazine. However, the Alabama sturgeon may be exposed to multiple pesticides simultaneously. Interactions of other toxic agents with atrazine could result in additive effects ($1/LC50_{mix} = 1/LC50_{Pesticide\_A} + 1/LC50_{Pesticide\_B}\ldots$), synergistic effects ($1/LC50_{mix} = 1/LC50_{Pesticide\_A} + 1/LC50_{Pesticide\_B}\ldots x\ Y$; where $Y > 1$) or antagonistic effects ($1/LC50_{mix} = 1/LC50_{Pesticide\_A} + 1/LC50_{Pesticide\_B}\ldots\ x\ Y$; where $Y < 1$). Conceptually, the combined effect of the mixture is equal to the sum of the effects of each stressor (1 + 1 = 2) for additive toxicity. Synergistic effects occur when the combined effect of the mixture is greater than the sum of each stressor (1 + 1 >2), and antagonistic effects occur when the combined effect of the mixture is less than the sum of each stressor (1 + 1 <2).

The available data suggest that pesticide mixtures involving atrazine may produce either synergistic, additive, or antagonistic effects. Mixtures that have been studied include atrazine with insecticides such as organophosphates and carbamates or with herbicides including alachlor and metolachlor. Additive or synergistic effects have been reported in several taxa including fish, amphibians, invertebrates, and plants.

As previously discussed, evaluation of pesticide mixtures is beyond the scope of this assessment because of the myriad of factors that cannot be quantified based on the available data. Those factors include identification of other possible co-contaminants and their concentrations, differences in the pattern and duration of exposure among contaminants, and the differential effects of other physical/chemical characteristics of the receiving waters (e.g. organic matter present in sediment and suspended water). Evaluation of factors that could influence additivity/synergism is beyond the scope of this assessment and is beyond the capabilities of the available data to allow for an evaluation. However, it is acknowledged that not considering mixtures could over- or under-estimate risks depending on the type of interaction and factors discussed above.

6.3 Assumptions Associated with the Acute LOCs

The risk characterization section of this endangered species assessment includes an evaluation of the potential for individual effects. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship for the effects study corresponding to the taxonomic group for which the LOCs are exceeded.

Sufficient dose-response information was not available to estimate the probability of an individual effect on the midge (one of the dietary food items of the Alabama sturgeon). Acute ecotoxicity data from the midge were used to derive RQs for freshwater invertebrates. Based on a lack of dose-response information for the midge, the probability of an individual effect was calculated using the only probit dose response curve slope value reported in available freshwater invertebrate ecotoxicity data for technical grade atrazine. Therefore, a probit slope value of 4.4 for the amphipod was used to estimate the probability of an individual effect on the freshwater invertebrates. It is unclear whether the probability of an individual effect for freshwater invertebrates other than amphipods would be higher or lower, given a lack of dose-response information for other freshwater invertebrate species. However, the assumed probit dose response slope for freshwater invertebrates of 4.4 would have to decrease to approximately 1 to 2 to cause an effect probability ranging between 1 in 10 and 1 in 100, respectively, for freshwater invertebrates.

7. Summary of Direct and Indirect Effects to the Alabama Sturgeon

In fulfilling its obligations under Section 7(a)(2) of the Endangered Species Act, the information presented in this endangered species risk assessment represents the best data currently available to assess the potential risks of atrazine to the Alabama sturgeon. The best available data suggest that atrazine will either have no effect or is not likely to adversely affect the Alabama sturgeon by direct toxic effects or by indirect effects resulting from effects to aquatic plants, aquatic animals, and riparian vegetation. A summary of the risk conclusions and effects determination for the Alabama sturgeon, given the uncertainties discussed in Section 6, is presented in Table 7.1.

Table 7.1. Effects Determination Summary for the Alabama Sturgeon

Assessment Endpoint	Effects determination	Basis for Determination
Survival, growth, and reproduction of Alabama sturgeon individuals via direct effects	No effect	No acute and chronic LOCs are exceeded.
Indirect effects to the Alabama sturgeon via reduction of prey (i.e., freshwater invertebrates)	May affect, but not likely to adversely affect	Acute LOCs are exceeded for the forestry use, based on the most sensitive ecotoxicity value for the midge; however RQs for other dietary items (stoneflies and snails) are less than LOCs. Based on the non-selective nature of feeding behavior of the Alabama sturgeon and low magnitude of anticipated individual effects to all evaluated prey species, atrazine is not likely to indirectly affect the Alabama sturgeon via a reduction in freshwater invertebrate food items. This finding is based on insignificance of effects (i.e., effects to freshwater invertebrates are not likely to be extensive over the suite of possible food items to result in “take” of a single Alabama sturgeon).
Indirect effects to the Alabama sturgeon via reduction of habitat and/or primary productivity (i.e., aquatic plants)	May affect, but not likely to adversely affect	Individual aquatic plant species within the Alabama River may be affected. However, refined 14-, 30-, 60-, and 90-day EECs, which consider the impact of flow, are well below the threshold concentrations representing community-level effects. In addition, the available monitoring data for the Alabama River show that all detected concentrations are < 1 μg/L. This finding is based on insignificance of effects (i.e., community-level effects to aquatic plants are not likely to result in “take” of a single Alabama sturgeon).
Indirect effects to the Alabama sturgeon via reduction of terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality and spawning habitat	May affect, but not likely to adversely affect	Riparian vegetation may be affected because terrestrial plant RQs are above LOCs. However, the majority of riparian area adjacent to the current range of the Alabama sturgeon in the Lower Alabama River watershed is forested vegetation, which is not associated with forestry plantation operations. Woody plants are generally not sensitive to environmentally-relevant concentrations of atrazine; therefore, effects on shading, streambank stabilization, and structural diversity of riparian areas in the action area are not expected. Although grassy and herbaceous riparian habitat is expected to be sensitive to atrazine effects, the presence of herbaceous riparian areas in the Lower Alabama River watershed is minimal. Therefore, atrazine-related impacts to riparian habitat are expected to have minimal impact on overall sediment loads in the Lower Alabama River watershed, based on surrounding land use and

		other sources of sedimentation including forestry management practices and annual dredging of navigational channels. This finding is based on insignificance of effects (i.e., atrazine effects to riparian vegetation in the Lower Alabama River cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where “take” of a single Alabama sturgeon would occur).

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