APPENDIX A

EXAMPLE ECOLOGICAL RISK ASSESSMENTS FOR HYPOTHETICAL SITES

INTRODUCTION

Appendix A provides examples of Steps I through 5 of the ecological risk assessment process for three hypothetical sites:

(1) A former municipal landfill from which copper is leaching into a large pond down-gradient of the site (the copper site);

(2) A former chemical production facility that spilled DDT, which has been transported into a nearby stream by surface water runoff (the DDT site); and

(3) A former waste-oil recycling facility that disposed of PCBs in a lagoon from which extensive soil contamination has resulted (the PCB site).

These examples are intended to illustrate key points in Steps 1 through 5 of the ecological risk assessment process. No actual site is the basis for the examples.

The examples stop with Step 5 because the remaining steps (6 through 8) of the ecological risk assessment process and the risk management decisions depend on site-specific data collected during a site investigation. We have not attempted to develop hypothetical data for analysis or the full range of information that a site risk manager would consider when evaluating remedial options.

EXAMPLE 1: COPPER SITE

STEP 1: SCREENING-LEVEL PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

Site history. This is a former municipal landfill located in an upland area of the mid-Atlantic plain. Residential, commercial, and industrial refuse was disposed of at this site in the 1960s and 1970s. Large amounts of copper wire also were disposed at this site over several years. Currently, minimal cover has been placed over the fill and planted with grasses. Terrestrial ecosystems in the vicinity of the landfill include upland forest and successional fields. Nearby land uses include agriculture and residential and commercial uses. The landfill cover has deteriorated in several locations. Leachate seeps have been noted on the slope of the landfill, and several seeps discharge to a five-acre pond down-gradient of the site.

Site visit. A preliminary site visit was conducted and the ecological checklist was completed. The checklist indicated that the pond has an organic substrate; emergent vegetation, including cattail and rushes, occurs along the shore near the leachate seeps; and -the pond reaches a depth of five feet toward the middle. Fathead minnows, carp, and several species of sunfish were observed, and the benthic macroinvertebrate community appeared to be diverse. The pond water was clear, indicating an absence of phytoplankton. The pond appears to function as a valuable habitat for fish and other wildlife using this area. Preliminary sampling indicated elevated copper levels in the seep as well as elevated base cations, total organic carbon (TOC), and depressed pH levels (pH 5.7).

Problem formulation. Copper is leaching from the landfill into the pond from a seep area. EPA's ambient water quality criteria document for copper (U.S. EPA, 1985) indicates that it can cause toxic effects in aquatic plants, aquatic invertebrates, and young fish at relatively low water concentrations. Thus, the seep might threaten the ability of the pond to support macroinvertebrate and fish communities and the wildlife that feed on them. Terrestrial ecosystems do not need to be evaluated because the overland flow of the seeps is limited to short gullies, a few inches wide. Thus, the area of concern has been identified as the five-acre pond and the associated leachate seeps. Copper in surface water and sediments of the pond might be of ecological concern.

Ecological effects evaluation. Copper is toxic to both aquatic plants and aquatic animals. Therefore, aquatic toxicity-based data will be used to screen for ecological risk in the preliminary risk calculation. The screening ecotoxicity value selected for water-column exposure is the U.S. EPA chronic ambient water quality criterion (12 pg/L at a water hardness of 100 mg/L as $CaCO_3$). A screening ecotoxicity value for copper in sediments was identified as 34 mg/kg (U.S. EPA, 1996).

STEP 2: SCREENING-LEVEL EXPOSURE ESTIMATE AND RISK CALCULATION

Exposure estimate. Preliminary sampling data indicate that the leachate contains 53 pg/L copper as well as elevated base cations, elevated TOC, and depressed pH (pH 5.7). Sediment concentrations range from 300 mg/kg to below detection (2 mg/kg), decreasing with distance from the leachate seeps.

Risk calculation. The copper concentration in the seep water (53 ug/L) exceeds the chronic water quality criterion for copper (12 ug/L). The maximum sediment copper concentration of 300 mg/kg exceeds the screening ecotoxicity value for copper in sediments (34 mg/kg). Therefore, the screening-level hazard quotients for both sediment and water exceed one. The decision at the Scientific/Management Decision Point (SMDP) is to continue the ecological risk assessment

Similar screening for the levels of base cations generated hazard quotients below one in the seep water. Although TOC and pH are not regulated under CERCLA, the possibility that those parameters might affect the biota of the pond should be kept in mind if surveys of the pond biota are conducted. Sediment concentrations of chemicals other than copper generated hazard quotients (HQs) of less than one at the maximum concentrations found.

STEP 3: BASELINE RISK ASSESSMENT PROBLEM FORMULATION

Based on the screening-level risk assessment, copper is known to be the only contaminant of ecological concern at the site.

Ecotoxicity literature review. A review of the literature on the ecotoxicity of copper to aquatic biota was conducted and revealed several types of information. Young aquatic organisms are more sensitive to copper than adults (Demayo et al., 1982; Kaplan and Yoh, 1961; Hubschman, 1965). Fish larvae usually are more sensitive than embryos (McKim et al., 1978; Weis and Weis, 1991), and fish become less sensitive to copper as body weight increases (Demayo et al., 1982). Although the exact mechanism of toxicity to fish is unknown, a loss of osmotic control has been noted in some studies (Demayo et al. 1982; Cheng and Sullivan, 1977).

Flowthrough toxicity studies in which copper concentrations were measured revealed LC_{50} values ranging from 75 to 790 ug/L for fathead minnows and 63 to 800 pg/L for common carp (U.S. EPA, 1985). Coldwater fish species, such as rainbow trout, can be more sensitive, and species like pumpkinseeds (a sunfish) and bluegills are less sensitive (U.S. EPA, 1985). Although fish fry usually are the most sensitive life stage, this is not always the case; Pickering et al. (1977) determined an LC_{50} of 460 ug/L to 6-month-old juveniles and an LC_{50} of 490 ug/L to 6-week-old fry for fathead minnows. A copper concentration in water of 37 ug/L has been shown to cause a significant reduction in fish egg production (Pickering et al., 1977).

Elevated levels of copper in sediments have been associated with changes in benthic community structure, notably reduced numbers of species (Winner et al., 1975; Kraft and Sypniewski, 1981). Studies also have been conducted with adult *Hyalelia azteca* (an amphipod) exposed to copper in sediments. One of these studies indicated an LC50 of 1,078 mg/kg in the sediment (Cairns et al., 1984); however, a no-observed-adverse-effect level (NOAEL) for copper in sediments was not identified for an early life stage of a benthic invertebrate.

A literature review of the ecotoxicity of copper to aquatic plants, both algae and vascular plants, did not reveal information on the toxic mechanism by which copper affects plants. The review did indicate that exposure of plants to high copper levels inhibits photosynthesis and growth (U.S. EPA, 1985), and cell separation after cell division (Hatch, 1978). Several studies conducted using *Selenastrum capricornutum* indicated that concentrations at 300 ug/L kill algae after 7 days, and a value of 90 pg/l causes complete growth inhibition after 7 days (Bartlett et al., 1974).

The literature indicates that copper does not biomagnify in food chains and does not bioaccumulate in most animals because it is a biologically regulated essential element. Accumulation in phytoplankton and filter-feeding mollusks, however, does occur. The toxicity of copper in water is influenced by water hardness, alkalinity, and pH (U.S. EPA, 1985).

Exposure pathways. A flow diagram was developed to depict the environmental pathways that could result in impacts of copper to the pond's biota (see Exhibit A-1). Direct exposure to copper in the pond water and sediments could cause acute or chronic toxicity in early life stages of fish and/or benthic invertebrates, and in aquatic plants. Risks to filterfeeding mollusks and phytoplankton as well as animals that feed on them are not considered because the mollusks and phytoplankton are unlikely to occur in significant quantities in the pond. The exposure pathways that will be evaluated, therefore, are direct contact with contaminated sediments and water.

Assessment endpoints and conceptual model. Based on the screening-level risk assessment, the ecotoxicity literature review, and the complete exposure pathways, development of a conceptual model for the site is initiated. Copper can be acutely or chronically toxic to organisms in an aquatic community through direct exposure of the organisms to copper in the water and sediments. Threats of copper to higher trophic level organisms are unlikely to exceed threats to organisms at the base of the food chain, because copper is an essential nutrient which is effectively regulated by most organisms if the exposure is below toxic levels. Fish fry in particular can be very sensitive to copper in water.

Based on these receptors and the potential for both acute and chronic toxicity, an appropriate general assessment endpoint for the ecosystem would be the maintenance of the community composition of the pond. A more operational definition of the assessment endpoint would be the maintenance of pond community structure typical for the locality and for the physical attributes of the pond, with no loss of species or community alteration due to copper toxicity.

Risk questions. One question is whether the concentrations of copper present in the sediments and water over at least part of the pond are toxic to aquatic plants or animals. A further question is what concentration of copper in sediments represents a threshold for adverse effects. That level could be used as a preliminary cleanup goal.

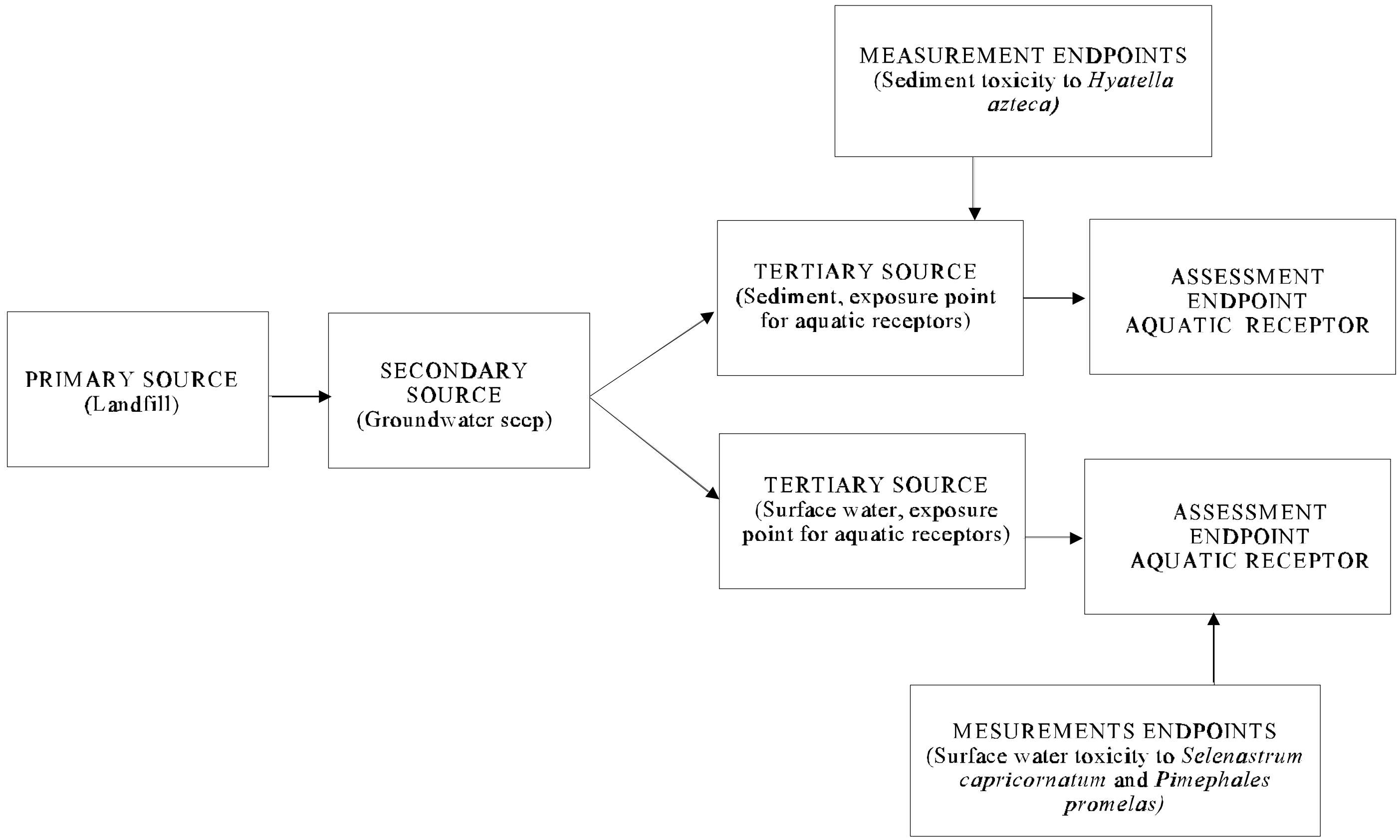
STEP 4: MEASUREMENT ENDPOINTS AND STUDY DESIGN

To answer the hypothesis identified in Step 3, lines of evidence were considered when selecting measurement endpoints: (1) whether the ambient copper levels are higher than levels known to be directly toxic to aquatic organisms likely or known to be present in the pond; (2) whether water and sediments taken from the pond are more toxic to aquatic organisms than water and sediments from a reference pond; and (3) whether the aquatic community structure in the site pond is simplified relative to a reference pond.

Measurement endpoints. Since the identified assessment endpoint is maintaining a typical pond community structure, the possibility of directly measuring the condition of the plant, fish, and macroinvertebrate communities in the pond was considered. Consultation with experts on benthic macroinvertebrates suggested that standard measures of the pond benthic invertebrate community probably would be insensitive measures of existing effects at this particular site because of the high spatial variation in benthic communities within and among ponds of this size. Measuring the fish community also would be unsuitable, due to the limited size of the pond and low diversity of fish species anticipated. Since copper is not expected to bioaccumulate or biomagnify in this pond, direct toxicity testing was selected as appropriate. Because early life stages tend to be more sensitive to the toxic effects of copper than older life stages, chronic toxicity would be measured on early life stages. For animals, toxicity is defined as a statistically significant decrease in survival or juvenile growth rates (measurement endpoints) of a test group exposed to water or sediments from the site compared with a test group exposed to water or sediments from a reference site. For plants, toxicity is defined as a statistically significant decrease in growth rate (measurement endpoint) with the same comparison.

One toxicity test selected is a 10-day (i.e., chronic) solid-phase sediment toxicity test using an early life stage of *Hyalella azteca.* The measures of effects for the test are mortality rates and growth rates (measured as length and weight increases). Two water-column toxicity tests will be used: (1) a 7-day test using the alga *Selenastrum capricornutum* (growth test) and (2) a 7-day larval fish test using *Pimephales promelas* (mortality and growth endpoints). The *H. azteca and P. promelas* toxicity tests will be used to determine the effects of copper on early life stages of invertebrates and fish in sediment and the water column, respectively. The test on *S. capricornutum* will be used to determine the phytotoxicity of copper in the water column.

EXHIBIT A-1
Conceptual Model for the Copper Site



Study design. To answer the questions stated in the problem formulation step, the study design specified in the following. The water column tests will be run on 100 percent seep water, 100 percent pond water near the seep, 100 percent reference-site water, and the laboratory control. U.S. EPA test protocols will be followed. Five sediment samples will be collected from the pond bottom at intervals along the observed concentration gradient, from a copper concentration of 300 mg/kg at the leachate seeps down to approximately 5 mg/kg near the other end of the pond. The sediment sampling locations will transect the pond at equidistant locations and include the point of maximum pond depth. All sediment samples will be split so that copper concentrations can be measured in sediments from each sampling location. A reference sediment will be collected and a laboratory control will be run. Test organisms will not be fed during the test; sediments will be sieved to remove native organisms and debris. Laboratory procedures will follow established protocols and will be documented and reviewed prior to initiation of the test. For the water-column test, statistical comparisons will be made between responses to each of the two pond samples and the reference site, as well as the laboratory control. Statistical comparisons also will be made of responses to sediments taken from each sampling location and responses to the reference sediment sample.

Because leachate seeps can be intermittent (depending on rainfall), the study design specifies that a pre-sampling visit is required to confirm that the seep is flowing and can be sampled. The study design also specifies that both sediments and water will be sampled at the same time at each sampling location.

As the work plan (WP) and sampling and analysis plan (SAP) were finished, the ecological risk assessor and the risk manager agreed on the site conceptual model, assessment endpoints, and study design (SMDP).

STEP 5: FIELD VERIFICATION OF STUDY DESIGN

A site assessment was conducted two days prior to the scheduled initiation of the site investigation to confirm that the seep was active. It was determined that the seep was active and that the site investigation could be initiated.

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EXAMPLE 2: DDT SITE

STEP 1: SCREENING-LEVEL PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

Site history. This is the site of a former chemical production facility located adjacent to a stream. The facility manufactured and packaged dichlorodiphenyltrichloroethane (DDT). Due to poor storage practices, several DDT spills have occurred.

Site visit A preliminary site visit was conducted and the ecological checklist was completed. Information gathered indicates that surface water drainage from the site flows through several drainage swales toward an unnamed creek. This creek is a second-order stream containing riffle-run areas and small pools. The stream substrate is composed of sand and gravel in the pools with some depositional areas in the backwaters and primarily cobble in the riffles.

Problem formulation. Previous sampling efforts indicated the presence of DDT and its metabolites in the stream's sediments over several miles at concentrations up to230 mg/kg. A variety of wildlife, especially piscivorous birds, use this area for feeding. Many species of minnow have been noted in this strewn. DDT is well known for its tendency to bioaccumulate and biomagnify in food chains, and available evidence indicates that it can cause reproductive failure in birds due to eggshell thinning.

The risk assessment team and risk manager agreed that the assessment endpoint is adverse effects on reproduction of high-trophic-level wildlife, particularly piscivorous birds.

Ecological effects evaluation. Because DDT is well studied, a dietary concentration above which eggshell thinning might occur was identified in existing U.S. EPA documents on the ecotoxicity of DDT. Moreover, a no-observed-adverse-effect-level (NOAEL) for the ingestion route for birds also was identified.

STEP 2: SCREENING-LEVEL EXPOSURE ESTIMATE AND RISK CALCULATION

Exposure estimate. For the screening-level exposure estimate, maximum concentrations of DDT identified in the sediments were used. To estimate the concentration of DDT in forage fish, the maximum concentration in sediments was multiplied by the highest DDT bioaccumulation factor relating forage fish tissue concentrations to sediment concentrations reported in the literature. Moreover, it was assumed that the piscivorous birds obtain 100 percent of their diet from the contaminated area.

Risk calculation. The predicted concentrations of DDT in forage fish were compared with the dietary NOAEL for DDT in birds. This risk screen indicated that DDT concentrations measured at this site might be high enough to cause adverse reproductive effects in birds. Thus, transfer of DDT from the sediments to the stream and biota are of concern at this site.

STEP 3: BASELINE RISK ASSESSMENT PROBLEM FORMULATION

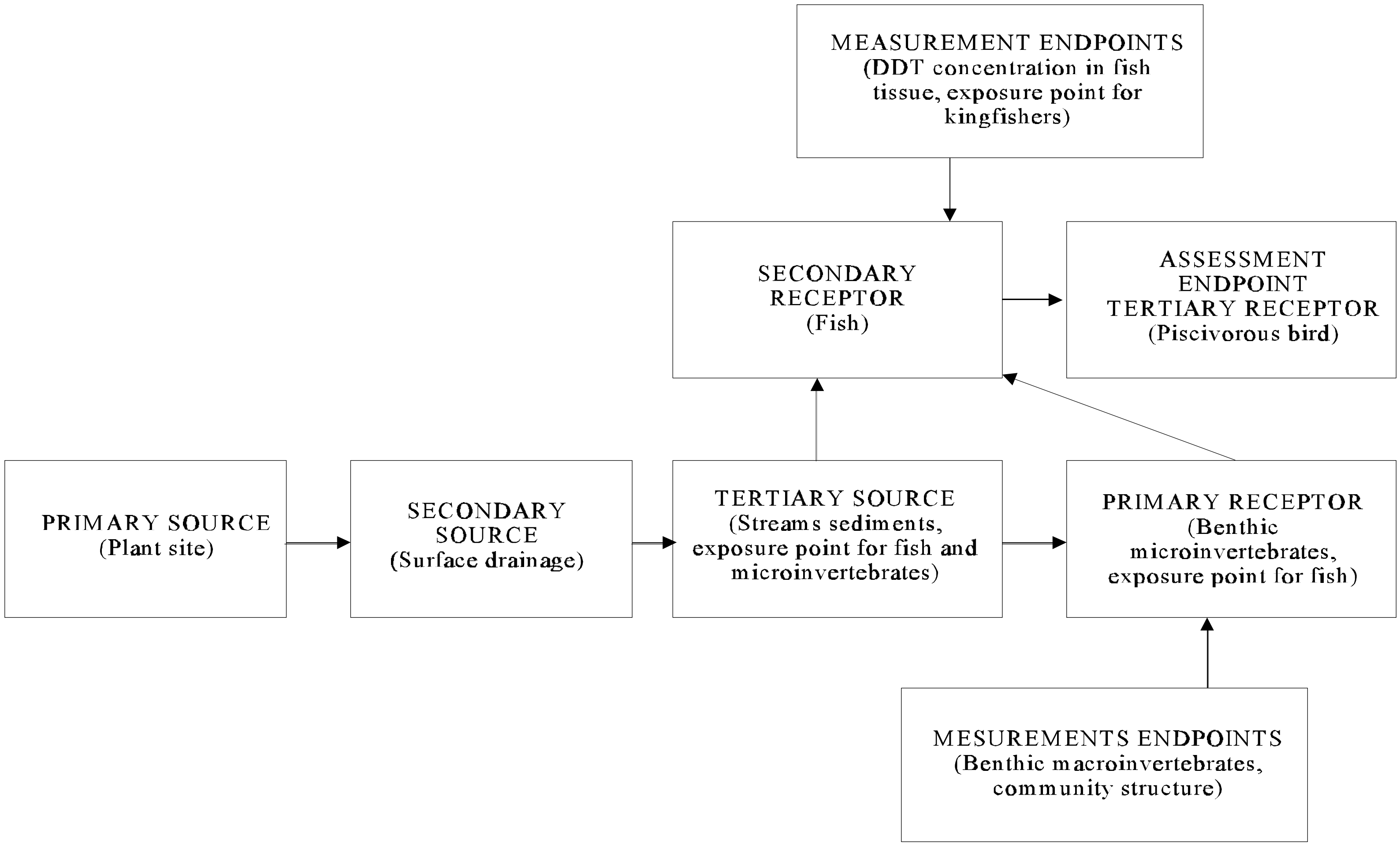
Based on the screening-level risk assessment, potential bioaccumulation of DDT in aquatic food chains and effects of DDT on reproduction in piscivorous birds are known concerns. During refinement of the problem, the potential for additional ecological effects of DDT was examined.

Ecotoxicity literature review. In freshwater systems, DDT can have direct effects on animals, particularly aquatic insects. A literature review of the aquatic toxicity of DDT was conducted, and a NOAEL and LOAEL identified for the toxicity of DDT to aquatic insects. Aquatic plants are not affected by DDT. Additional quantitative information on effects of DDT on birds was reviewed, particularly to identify what level of eggshell thinning is likely to reduce reproductive success. A number of studies have correlated DDT residues measured in eggs of birds to increased eggshell thinning and egg loss due to breakage. Eggshell thinning of more than 20 percent appears to result in decreased hatching success due to eggshell breakage (Anderson and Hickey, 1972; Dilworth et al., 1972). Information was not available for any piscivorous species of bird. Lincer (1975) conducted a I laboratory feeding study using American kestrels. Females fed a diet of 6 mg/kg DDE (1.1 mg/kgBW-day) produced eggs with shells which were 25.5 percent thinner than archived eggshells collected prior to widespread use of DDT. Based on this information, a LOAEL of 1.1 mg/kgBW-day was selected to evaluate the effects of DDT on piscivorous birds.

Exposure pathways, assessment endpoints, and conceptual model. Based on knowledge of the fate and transport of DDT in aquatic systems and the ecotoxicity of DDT to aquatic organisms and birds, a conceptual model was initiated. DDT buried in the sediments can be released to the water column during resuspension and redistribution of the sediments. Some diffusion of DDT to the water column from the sediment surface also will occur. The benthic community would be an initial receptor for the DDT in sediments, which could result in reduced benthic species abundance and DDT accumulation in species that remain. Fish that feed on benthic organisms might be exposed to DDT both in the water column and in their food. Piscivorous birds would be exposed to the DDT that has accumulated in the fish, and could be exposed at levels sufficiently high to cause more than 20 percent eggshell thinning. Based on this information, two assessment endpoints were identified: (1) maintaining stream community structure typical for the stream order and location, and (2) protecting piscivorous birds from eggshell thinning that could result in reduced reproductive success.

DDE is a degradation product of DDT; typically, field measures of DDT are reported as the sum of the concentrations of DDT, DDE, and DDD (another deVWation product).

EXHIBIT A-2
Conceptual Model for the Stream DDT Site



A flow diagram of the exposure pathways for DDT was added to the conceptual model (Exhibit A-2). The diagram identifies the primary, secondary, and tertiary sources of DDT at the site, as well as the primary, secondary, and tertiary types of receptors that could be exposed.

Risk questions. Two questions were developed: (1) has the stream community been affected by the DDT, and (2) have food-chain accumulation and transfer of DDT occurred to the extent that 20 percent or more eggshell thinning would be expected in piscivorous birds that use the area.

STEP 4: MEASUREMENT ENDPOINTS AND STUDY DESIGN

Measurement endpoints. For the assessment endpoint of protecting piscivorous birds from eggshell thinning, the conceptual model indicated that DDT in sediments could reach piscivorous birds through forage fish. Belted kingfishers are known to feed in the stream. They also have the smallest home range of the piscivorous birds in the area, which means that more kingfishers can forage entirely from the contaminated stream area than can other species of piscivorous birds. Thus, one can conclude that, if the risk assessment shows no threat of eggshell g to the kingfisher, there should be minimal or no threat to other piscivorous birds that might utilize the site. Eggshell thinning in the belted kingfisher therefore was selected as the measure of effect.

Data from the literature suggest that DDT can have a bioaccumulation factor in surface water systems as high as six orders of magnitude (10^6); however, in most aquatic ecosystems, the actual bioaccumulation of DDT from the environment is lower, often substantially lower. Many factors influence the actual accumulation of DDT in the environment. There is considerable debate over the parameters of any proposed theoretical bioaccumulation model; therefore, it was decided to measure tissue residue levels in the forage fish at the site instead of estimating the tissue residue levels in forage fish using a bioaccumulation factor (BAF).

Existing information on the distribution of DDT in the stream indicates that a general gradient of DDT concentrations exists in the sediments, and five locations could be identified that corresponded to a range of DDT concentrations in sediments. Based on information available on fish communities in streams similar to the one in the site area, creek chub *(Semotilus afromaculatus)* were selected to measure exposure levels for kingfishers. Creek chub feed on benthic invertebrates, which are in direct contact with the contaminated sediments. Adult creek chub average 10 inches and about 20 grams, allowing for analysis of individual fish. Creek chub also have small home ranges during the spring and summer, and thus it should be possible to relate DDT levels in the chub to DDT levels in the sediments.

For the assessment endpoint of maintaining stream community structure, the selected measurement endpoints were several metrics describing the abundance and trophic structure of the stream benthic macroinvertebrate community.

Study design. The study design specified that creek chub would be collected at several locations with known DDT concentrations in sediments. The fish would be analyzed for body burdens of DDT, and the relationship between DDT levels in the sediments and in the creek chub would be established. The fish DDT concentrations would be used to evaluate the DDT threat to piscivorous birds feeding on the fish at each location. Using the DDT concentrations measured in fish that correspond to a LOAEL and NOAEL for adverse effects in birds, the corresponding sediment contamination levels would be determined. Those sediment DDT levels then could be used to derive a cleanup level that would reduce threats of eggshell thinning to piscivorous birds.

The study design for measuring DDT residue levels in creek chub specified that 10 creek chub of the same size and sex would be collected at each location and that each creek chub be at least 20 grams, so that individuals could be analyzed. In addition, at one location, QA/QC requirements dictated that an additional 10 fish be collected. In this example, it was necessary to verify in the field that sufficient numbers of creek chub of the specified size were present to meet the tissue sampling requirements. In addition, the stream conditions needed to be evaluated to determine what fish sampling techniques would work best at the targeted locations.

The study design and methods for benthic macroinvertebmte collection followed the Rapid Bioassessment Protocol (RBP) manual for level three evaluation (U.S. EPA, 1989). Benthic macroinvertebmte samples were co-located with sampling for fish tissue residue levels so that one set of co-located water and sediment samples for analytic chemistry could serve for comparison with both tissue analyses.

The study design also specified that the hazard quotient (HQ) method would be used to evaluate the effects of DDT on the kingfisher during risk characterization. To determine the HQ, the estimated daily dose of DDT consumed by the kingfishers is divided by a LOAF-L of 1. I mg/kgBW-day for kestrels. To estimate the DDT dose to the kingfisher, the DDT concentrations in the chub is multiplied by the fish ingestion rate for kingfishers and divided by the body weight of kingfishers. This dose is adjusted by the area use factor. The area use factor corresponds to the proportion of the diet of a kingfisher that would consist of fish from the contaminated area. The area use factor is a function of the home range size of kingfishers relative to the area -of contamination. The adjusted dose is compared to the LOAEL. A HQ of greater than one implies that impaired reproductive success in kingfishers due to site contamination is likely, and an HQ of less than one implies impacts due to site contaminants are unlikely (see text Section 2.3 for a description of HQs).

STEP 5: FIELD VERIFICATION OF STUDY DESIGN

A field assessment was conducted and several small fish collection techniques were used to determine which technique was the most effective for capturing creek chub at the site. Collected chub were examined to determine the size range available and to determine if individuals could be sexed.

Seine netting the areas targeted indicated that the creek chub might not be present in sufficient numbers to provide the necessary biomass for chemical analyses. Based on these findings, a contingency plan was agreed to (SMDP), which stated that both the creek chub and the longosed dace *(Rhinichthys cataractae)* would be collected. If the creek chub were collected at all locations in sufficient numbers, those samples would be analyzed and the dace would be released. If sufficient creek chub could not be collected but sufficient longosed dace could, the longosed dace would be analyzed and the creek chub released. If neither species could be collected at all locations in sufficient numbers, then a mix of the two species would be used; however, for any given site only one species would be analyzed. In addition, at one location, preferably one with high DDT levels in the sediment, sufficient numbers of approximately 20 gram individuals of both species would be collected to allow comparison (and calibration) of the accumulation between the two species. If necessary to meet the analytic chemistry needs, similarly-sized individuals of both sexes of creek chub would be pooled. Pooling two or more individuals would be necessary for the smaller dace. The risk assessment team decided that the fish samples would be collected by electro-shocking. Field notes for all samples would document the number of fish per sample pool, sex, weight, length, presence of parasites or deformities, and other measures and might help to explain any anomalous data.

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EXAMPLE 3: PCB SITE

STEP 1: SCREENING-LEVEL PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

Site history. This is a former waste-oil recycling facility located in a remote area. Oils contaminated with polychlorinated biphenyl compounds (PCBs) were disposed of in a lagoon. The lagoon was not lined, and the soil is composed mostly of sand. Oils contaminated with PCBs migrated through the soil and contaminated a wide area adjacent to the site.

Site visit During the preliminary site visit, the ecological checklist was completed. Most of the habitat is upland forest, old field, and successional terrestrial areas. Biological surveys at this site have noted a variety of small mammal sips. In addition, red-tailed hawks were observed.

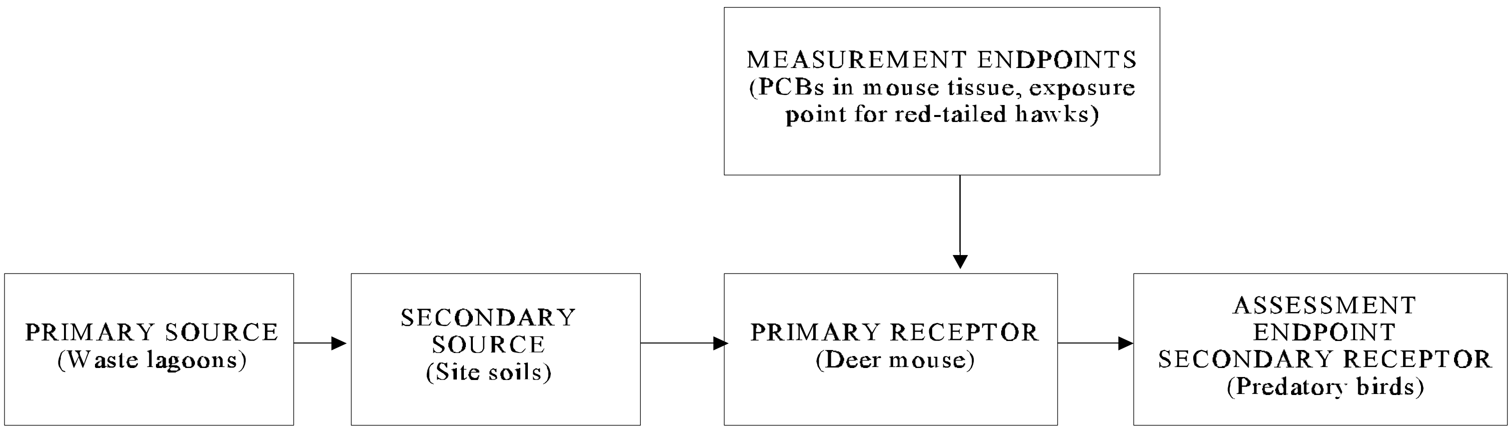
Problem formulation. At least 10 acres surrounding the site are known to be -contaminated with PCBS. Some PCBs are reproductive toxins in mammals (Ringer et al.,' 1972; Aulerich et al., 1985; Wren, 1991; Kamrin and Ringer, 1996). When ingested, they induce (i.e., increase concentrations and activity of) enzymes in the liver, which might affect the metabolism of some steroid hormones (Rice and O'Keefe, 1995). Whatever the mechanism of action, several physiological functions that are controlled by steroid hormones can be altered by exposure of mammals to PCBS, and reproduction appears to be the most sensitive endpoint for PCB toxicity in mammals (Rice and O’Keefe, 1995). Given this information, the screening ecological risk assessment should include potential exposure pathways for mammals to PCBS.

Several possible exposure pathways were evaluated for mammals. PCBs are not highly volatile, so inhalation of PCBs by animals would not be an important exposure pathway. PCBs in soils generally are not taken up by most plants, but are accumulated by soil macroinvertebrates. Thus, herbivores, such as votes and rabbits, would not be exposed to PCBs in most of their diets; whereas insectivores, such as shrews, or omnivores, such as deer n-Lice, could be exposed to accumulated PCBs in their diets. PCBs also are known to biomagnify in terrestrial food chains; therefore, the ingestion exposure route needs evaluation, and shrews and/or deer mice would be appropriate mammalian receptors to evaluate in this exposure pathway.

Potential reproductive effects on predators that feed on shrews or mice also would be important to evaluate. The literature indicated that exposure to PCBs through the food chain could cause reproductive 'unpai nt in predatory birds through a similar mechanism as in mammals. The prey of red-tail hawks include votes, deer mice, and various insects. Thus, this raptor could be at risk of adverse reproductive effects.

Ecological effects evaluation. No-observed-adverse-effect levels (NOAELS) for the effects of PCBs and other contaminants at the site on mammals, birds, and other biota were identified in the literature.

EXHIBIT A-3
Conceptual Model for the Terrestrial PCB Site



STEP 2: SCREENING-LEVEL EXPOSURE ESTIMATE AND RISK CALCULATION

Exposure estimate. For the screening-level risk calculation, the highest PCB and other contaminant levels measured on site were used to estimate exposures.

Risk calculation. The potential contaminants of concern were screened based on NOAELs for exposure routes appropriate to each contaminant. Based on this screen, PCBs were confirmed to be the only contaminants of concern to small mammals, and possibly to birds, based on the levels measured at this site. Thus, at the SMDP, the risk manager and lead risk assessor decided to continue to Step 3 of the ecological risk assessment process.

STEP 3: BASELINE RISK ASSESSMENT PROBLEM FORMULATION

The screening-level ecological risk assessment confirmed that PCBs are of concern to small mammals based on the levels measured at the site and suggested that predatory birds might be at risk from PCBs that accumulate in some of their mammalian prey.

Ecotoxicity literature review. A literature review was conducted to evaluate potential reproductive effects in birds. PCBs have been implicated as a cause of reduced reproductive success of piscivorous birds (e.g., cormorants, terns) in the Great Lakes (Kubiak et al., 1989; Fox et al., 1991). Limited information was available on the effects of PCBs to red-tailed hawks. A study on American kestrel indicated that consumption of 33 mg/kgBWday PCBs resulted in a significant decrease in sperm concentration in male kestrels (Bird et al ., 1983). Implications of this decrease for mating success in kestrels was not evaluated in the study, but studies on other bird species indicate that it could increase the incidence of infertile eggs and therefore reduce the number of young fledged per pair. The Great Lakes International Joint Commission (IJC) recommends 0.1 mg/kg total PCBs as a prey tissue level that will protect predatory birds and mammals (IJC, 1988). (This number is used as an illustration and not to suggest that this particular level is appropriate for a given site.)

Exposure pathways. The complete exposure pathways identified during Steps I were considered appropriate for the baseline ecological risk assessment as well.

Assessment endpoints and conceptual model. Based on the screening-level risk assessment for small mammals and the results of the ecotoxicity literature search for birds, a conceptual model was initiated for the site, which included consideration of predatory birds (e.g., red-tailed hawks) and their prey. The ecological risk assessor and the risk manager agreed (SMDP) that assessment endpoints for the site would be the protection of small mammals and predatory birds from reproductive impairment caused by PCBs that had accumulated in their prey.

An exposure pathway diagram was developed for the conceptual model to identify the exposure pathways by which predatory birds could be exposed to PCBs originating in the soil at the site (see Exhibit A-3). While votes may be prevalent at the site, they are not part of the exposure pathway for predators because they are herbivorous and PCBs do not accumulate in plants. Deer mice *(Peromyscus maniculatus)*, on the other hand, also are abundant at the site and, being omnivorous, are likely to be exposed to PCBs that have accumulated in the insect component of their diet. Preliminary calculations indicated that environmental levels likely to cause reproductive effects in predatory birds are lower than those likely to cause reproductive effects in mice because mice feed lower in the food chain than do raptors. The assessment endpoint was therefore restricted to reproductive impairment in predatory birds.

Risk questions. Based on the conceptual model, one question was whether predatory birds could consume a high enough dose of PCBs in their diet to impair their reproduction. Given the presence of red-tailed hawks on site, the question was refined to ask whether that species could consume sufficient quantities of PCBs in their diet to affect reproduction.

STEP 4: MEASUREMENT ENDPOINTS AND STUDY DESIGN

Measurement endpoints. To determine whether PCB levels in prey of the redtailed hawk exceed levels that might impair their reproduction, PCB levels would be measured in deer mice taken from the site (of all of the species in the diet of the red-tailed hawk, deer mice are assumed to accumulate the highest levels of PCBS). Based on estimated prey ingestion rates for red-tailed hawks, a total PCB dose would be estimated from the measured PCB concentrations in the mice.

Study design. The available measures of PCB concentrations in soil at the site indicated a gradient of decreasing PCB concentration with increasing distance from the unlined lagoon. Three locations along this gradient were selected to measure PCB concentrations in deer mice. The study design specified that eight deer mice of the same size and sex would be collected at each location. Each mouse should be approximately 20 grams so that contaminant levels can be measured in individual mice. With concentrations measured in eight individual mice, it is possible to estimate a mean concentration and an upper confidence limit of the mean concentration in deer mice for the location. In addition, QA/QC requirements dictate that an additional eight deer mice should be collected at one location.

For this site, it was necessary to verify that sufficient numbers of deer mice of the specified size would be present to meet the sampling requirements. In addition, habitat conditions needed to be evaluated to determine what trapping techniques would work at the targeted locations.

The study design specified further that the hazard quotient (HQ) method would be used to estimate the risk of reproductive impairment in the red-tailed hawk from exposure to PCBs in their prey. To determine the HQ, the measured DDT concentrations in deer mice is divided by the LOAEL of 33 mg/kgBW-day for a decrease in sperm concentration in kestrels. To estimate the dose to the red-tailed hawk, the PCB concentrations in deer mice is multiplied by the quantity of deer mice that could be ingested by a red-tailed hawk each day and divided by the body weight of the hawk. This dose is adjusted by a factor that corresponds to the proportion of the diet of a red-tailed hawk that would come from the contaminated area. This area use factor is a function of the home range size of the hawks relative to the area of contamination. A HQ of greater than one implies that impacts due to site contamination are likely, and an HQ of less than one implies impacts due to site contaminants are unlikely.

STEP 5: FIELD VERIFICATION OF STUDY DESIGN

A field assessment using several trapping techniques was conducted to determine (1) which technique was most effective for capturing deer mice at the site and (2) whether the technique would yield sufficient numbers of mice over 20 grams to meet the specified sampling design. On the first evening of the field assessment, two survey lines of 10 live traps were set for deer mice in typical old-field habitat in the area believed to contain the desired DDT concentration gradient for the study design. At the beginning of the second day, the traps were retrieved. Two deer mice over 20 grams were captured in each of the survey lines. These results indicated that collection of deer mice over a period of a week or less with this number and spacing of live traps should be adequate to meet the study objectives.

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