Appendix A part 2

F. Contaminant Fate and Transport

This section of the ROD addresses the potential routes of contaminant migration through various media in the Welch Creek OU-4 as well as the implications of other site conditions and pilot study findings on contaminant fate and transport. Potential routes of contaminant migration are:

- Contaminant migration from Welch Creek to the Lower Roanoke River during various conditions (whole water sampling results)
- Sediment stability
- Contaminant migration from adjacent wetlands into Welch Creek
- Contaminant migration from the sediment into the surface water (implications of bioavailability)

Other factors that impact contaminant fate and transport under current conditions as well as observations from the pilot tests on site specific factors and conditions that will impact contaminant fate and transport during remedial actions are also presented.

1. Contaminant Migration from the Welch Creek Basin (Whole Water Sampling)

The whole water[2] sampling program was specifically designed to evaluate the physical transport of COPCs from the Welch Creek basin. Sampling events were selected to reflect a range of velocity conditions within Welch Creek since higher velocity conditions in Welch Creek are often associated with sudden decreases in the stage or elevation of the Roanoke River as well as with increased flow from rainfall events. Since the stage drop conditions are more frequent than extreme rainfall events, the impact of increased velocity on mass flux of COPCs from Welch Creek was evaluated by sampling Welch Creek surface water during specific stage drops. The events sampled were those corresponding to typical baseflow conditions, a surge event with a drop in river stage of greater than 1 foot, and two events with a drop in river stage of greater than 2 feet. The four whole water samples were collected just upstream of the railroad bridge near MT-10. This location was chosen because it is near the mouth of Welch Creek and is representative of the transport of COPCs from Welch Creek to the Roanoke River. Discrete samples were collected with an ICSO sampler and then the sample was selected to correspond to the highest measured suspended solids concentration.

The results of the whole water sampling indicate that there is relatively little migration of solids in the Welch Creek system as a result of storm surge events. The concentrations of TSS ranged between approximately 5 mg/L to 10 mg/L during baseflow conditions and typical storm surge events. Of the three events measured, only one event showed elevated TSS concentrations. The maximum TSS concentration of 47 mg/L was observed during the recession of Hurricane Dennis. While the concentration of TSS increases, the peak concentration observed during the hurricane surge event showed relatively limited transport of sediment within Welch Creek.

The results of the whole water sampling also show that the duration of sediment transport events is limited in length. The TSS concentration drops from highs of 47 and 40 mg/L during the rapid recession of Hurricane Dennis to more typical concentrations of 5 to 10 mg/L in four to eight hours. This response is expected because

[2] Whole water is a depth integrated water sample.

the creek velocity slows and typically reverses after an extreme event, further limiting the potential for sediment transport out of the creek. The results of the TSS monitoring support the conclusion that even extreme events do not readily mobilize the deposited wastewater solids.

The results of the analysis of the whole water samples were also used to calculate a loading of dioxin to the Roanoke River. The transport of dioxins and furans is simply presented as a loading of dioxin TEQ (USEPA, 1989). Although it does not represent a true mass flux, this method includes each of the detected congeners in a single, toxicity-weighted, value. The mass loading calculations assumed a frequency of rapid stage recession events with an underlying baseflow and an underlying average annual flow to calculate a range of annual loading of dioxin TEQ. Using this approach, the annual loading of dioxin TEQ from Welch Creek associated with the measured storm surge events is conservatively estimated to be 0.0066 grams to 0.0107 grams based on an underlying baseflow or annual average flow, respectively. A separate sensitivity analysis was done addressing four critical variables: 1) dioxin concentration estimate; 2) effect of precipitation runoff on Roanoke River dioxin TEQ baseload; 3) equal weighting of sample depth intervals; and 4) Toxicity Equivalence Factor (TEF) source - on the mass transfer evaluation. Based upon that evaluation it was concluded that the estimate of the dioxin loading from Welch Creek was made using reasonable and appropriately conservative assumptions.

For comparison, the loading of dioxin TEQ was calculated for the Roanoke River. The average annual Roanoke River flow rate was combined with upstream data from the surface water sampling that was conducted in the Lower Roanoke River (0.0001 ng/L dioxin TEQ) to estimate the dioxin TEQ loading for the Roanoke River. Using this approach, the loading of dioxin TEQ in the Roanoke River upstream from the mill was calculated to be 0.798 grams per year. As a comparison, the annualized loading from Welch Creek baseflow and average annual flow events represents approximately 0.83 to 1.34 percent of the total Roanoke River loading.

2. Sediment Stability

Evaluation of the stability or potential mobility of sediments is important to assess potential contaminant migration and to evaluate remedial alternatives for the Welch Creek study area. Two assessments of sediment transport potential have been done for Welch Creek: one as part of the RI activities and an independent assessment by the USACE in conjunction with other evaluations that they were performing in the Lower Roanoke River. The predicted conditions that would result in sediment migration were based upon hydrologic models with different spatial design. However, a number of similar conclusions were reached. Both analyses indicated that the sediment deposits in Welch Creek are stable or likely to be stable throughout most of the Welch Creek study area under a range of watershed drainage events, including extreme events. Specifically, sediment deposits in the upstream reach were concluded to be more stable than sediments in the midstream reach. After refinement of the modeling assessment by the USACE to incorporate consideration of the effects of Roanoke River stage on more downstream portions of the creek system, both modeling efforts concluded the downstream reach was also more stable than the midstream reach. The reach of the creek most susceptible to mobilization identified by both efforts was the midstream reach (MT-7 to GT-15). This reach generally had shallower water depths and an overall smaller cross-sectional area leading to higher local velocity.

Further evaluation of the migration potential in the midstream reach was conducted as part of the pilot study activities. Specifically, five core samples were collected in this area to review the physical condition of these sediments visually and though grain size analysis. The cores consisted of the top 10 cm from the zone of highest migration potential. The results of grain-size analysis and field observation indicate that the surficial sediments in the area identified with the greatest risk of migration (MT-7 to GT-15) are more granular in texture and have a higher fraction of sand (or greater size) particles than samples immediately upstream or downstream (Table F-1). All of the samples are representative of deposited wastewater solids and not underlying natural soils.

Table F-1
Summary of Grain Size Analyses in Vicinity of Midstream Reach

Location	Percent Sand or Greater Particle	Percent Silt Particle	Percent Clay Particle
Midstream Area (MT-7 to GT-15)	89.9 to 95.2	2.6 to 7.1	2.3 to 3.3
Immediately Upstream and Downstream of Midstream Area	26.9 to 36.0	52.9 to 64.0	9.1 to 11.1
Average MT-6 to MT-10	46	38	17

Another method to assess the potential for sediment migration in the midstream reach was to compare bathymetry profiles over time. During the supplemental data collection, several additional bathymetric surveys were also conducted to assess possible changes in the sediment profile. Measurements of channel cross section performed in 1995 and in 2005 show little change, despite several major hurricanes and many severe storms that have occurred over the past decade. These results indicate that sediment in the midstream reach has been exposed to potentially higher velocities for over 10 years with no evidence of significant sediment migration, and thus, it is expected to remain stable under the foreseeable range of future stream flow events.

3. Contaminant Migration from Adjacent Wetlands

Overbank deposition of mercury, dioxin and chromium is evident from the concentrations measured in wetland soil samples. In general, concentrations of these COPCs generally decrease with increasing distance from Welch Creek although the ability to distinguish the Site related from upstream sources is limited for the metals. A portion of the dioxin congeners (generally 2,3,7,8 TCDD/TCDF) are likely the result of the historical deposition of wastewater solids that occurred when wastewater was discharged to Welch Creek during high stage events, when the wetlands were flooded. During these high stage events, wastewater would continue to be discharged to Welch Creek, spreading out across the adjacent flooded wetlands. The solids contained in the wastewater discharge would have likely settled in the slow-moving waters of the flooded wetlands. More solids would be expected to have been deposited in the lower areas, closer to the creek that were prone to more frequent flooding. However, once deposited in these wetland depressions, there was limited to no ability for these wastewater solids to remobilize.

The aerial distribution of COPCs also suggests that overbank migration from the Site was limited to the wetland area downstream from the Seaboard Coast Railroad. The railroad bed acts as a dam across the wetland area that prevents the spreading of water from the downstream wetlands to the wetlands upstream from the railroad bed.

Stream flow is channeled through the Seaboard Coast bridge that crosses Welch Creek. As evidenced by the small amount of sediment that was identified upstream of the railroad bridge, the railroad bed and bridge were effective in limiting the upstream transport of wastewater solids.

Based upon the facts that there is no longer a direct wastewater discharge to Welch Creek; that the wetland elevations are generally flat as illustrated by the size of the 10-year flood plain; and that the wetland topography is undulating with multiple hollows for water accumulation, it seemed unlikely that the wastewater solids in Welch Creek are a continuing source of COPCs to the adjacent wetlands. A preliminary engineering calculation of velocity based upon slope in the wetlands and one of the storm events suggested that the recession velocity was not erosional.

To further assess this issue, the USACE was requested to evaluate this potential contaminant migration pathway as part of the facilitated meeting discussions held to address technical issues with various stakeholders. Specifically they were to consider possible migration of adjacent wetland soils into the streambed during storms that cause overbanking and the impact of potential future upstream land development. They applied the two dimensional model developed to assess contaminant transport within the Welch Creek channel to the wetlands and concluded that the adjacent wetlands are not of concern for potential erosion of surface soil. They also concluded that the potential for contaminated sediment mobilization from the midstream reach would not be enhanced if the upland drainage basin of Welch Creek were developed.

4. Contaminant Migration from the Sediment into the Surface Water (Implications of Bioavailability)

Potential movement of dioxin from the sediment into the surface water is another potential route of contaminant migration in Welch Creek. During the facilitated meeting process, manageable properties were identified for each reach of the Creek. Those primary manageable properties in the upstream and downstream reaches were identified during the facilitated meetings as surface concentrations and the bioavailability of COCs in these locations. To further understand and manage ecological exposure, surface sediment was defined as the bioactive layer (agreed to be 5 cm in Welch Creek). Thus it was agreed that the extent of contaminant migration from the sediment to the surface water is affected by both the contaminant concentration in the top 5 cm of sediment and its bioavailability.

For mercury in Welch Creek sediment, bioavailability is constrained by binding within the insoluble sulfide complexes. Mercury deposited onto Welch Creek, adjacent wetlands, or onto the overall drainage basin from regional air emissions has been identified as a significant on-going source. New inputs of mercury would tend to be more bioavailable until being bound in the soils or sediments in the system.

For dioxin in Welch Creek, bioavailability will be impacted by its chemical characteristics (low water solubility), the total and black carbon content of the sediment, and the amount of physical mixing of surficial sediment through bioturbation or even decomposition gas entrainment. Many of these different mechanisms have been reviewed and the different contributions assessed to support refinement of the Site Conceptual Model. A summary of the relevant issues affecting dioxin bioavailability follows (see FS for entire discussion).

1. The chemical characteristics of dioxin substantially limit its ability to be transferred through the dissolved phase. The characteristics of the specific chemicals of concern affect the accuracy of extrapolations of individual study results to other systems and compounds. Most of the studies have focused on polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) since these compounds are more prevalent in sediment sites. Table F-3 compares relevant chemical characteristics of PAHs, PCBs, and dioxin. These characteristics reinforce the conclusions that dioxin congener solubilities are orders of magnitude less than PAHs and PCBs. In addition, the partitioning coefficients also reflect at least one to two orders of magnitude difference, with dioxin being significantly less able to chemically desorb or dissolve than other similar organic compounds.

Table F-2
Comparison of Selected Characteristics for Organic Compounds

	Units	Dioxins	PCBs	Aldrin	PAHs
Water solubility	mg/L	$4.8x10^{-4}$ to $7.4x10^{-8}$	5.8 to $1.2 x10^{-6}$	0.011	32 to $5x10^{-4}$
Octanol/Water Partition Coefficient (Log Kow)	---	5.8 to 13	4.5 to 8.3	6.5	3.3 to 6.8
Organic Carbon Normalized Partition Coefficient (Log Koc)	---	5.7 to 12.8	4.4 to 7.7	6.4	3.0 to 6.5
Molecular Weight	g/mo L	322 to 461	189 to 499	365	128 to 278

2. In Welch Creek, bioavailability is more attributable to bioturbation of material into the water column than to the chemical solubility and octanol water partitioning coefficient. This conclusion is based in part upon an estimate of the flux of dioxin caused by groundwater migration (FS Attachment 1D). Groundwater inflow and drainage areas were used to estimate the flux of 2,3,7,8-TCDD transferred from the sediment into the water column. The estimated flux from groundwater was 1.3 percent of the total flux estimated in the creek. The remaining flux was attributed to bioturbation of contaminated sediment by benthic macroinvertebrate surface feeders. This conclusion is consistent with some literature which concluded that bioturbation could significantly increase the rate of contaminant transfer over the dissolved phase. Others took the position that a clean surface layer will limit transfer of contaminants into the food web by isolating the benthic infauna from the contaminated sediment. The implications of gas generation from sediment decomposition with subsequent entrainment of contaminants on the mass of those contaminants transferred to the water column has not been specifically addressed in the reviewed literature.

5. Other Factors

There are also several other conditions in Welch Creek as well as specific observations and findings from the pilot studies that impact contaminant fate and transport as well as remedy selection. These include the following:

- Characteristics of bottom sediments
- Bathymetry and the presence of debris
- The existence and durability of biofilms
- Baseline Flow conditions

In addition, findings from the pilot tests that have implications on the potential for contaminant fate and transport during remedial actions are summarized.

Characteristics of Welch Creek Bottom Sediments

Characterization of bottom sediments along the creek provide physical data on stream features needed to evaluate the remedial alternatives. Bottom probing and sediment core samples were collected at transects positioned through the length of the creek. These data confirmed that the bottom consisted of peat and clay in all locations except MT-1 (at the Highway 64 bridge) where the bottom was sand (see Text Box F-1). The soft peat bottom is prevalent along most of the creek and can be discerned by color and fiberous organic matter from the soft, black wastewater solids deposits. The native clay deposits are distinct from the wastewater solids, both in texture and color. These fine-grained clay and organic particles are likely to remain dispersed in the water column, if disturbed, for an extended period of time (days to weeks).

Bathymetry and the Presence of Debris

Bathymetric surveys of Welch Creek provided physical data on stream features. The generalized bottom profile above the current sediments confirms the presence of steep side slopes (side slopes greater than 3:1 or 33 percent vertical to horizontal) at seven of the ten transects in the upstream reach.

A survey of woody debris along the upstream reach of Welch Creek was done using side-scan sonar. The survey identified an extensive amount of tree fall and other debris in the upstream reach of Welch Creek. Woody debris was visible from the water surface and shore as well as hidden beneath the water surface and contained within the sediments. Ninety debris targets ranging up to 60 feet in length were identified in areas that could be evaluated using the side-scan sonar equipment. Additional debris is expected under the sediment surface and along shorelines less accessible to the survey technique.

Existence and Durability of Biofilms

Further research and sample observations confirmed that the Welch Creek quiescent environment has likely resulted in the formation of naturally occurring Extra Polymeric Substances (EPS) (Donlan, 2002). EPS increases the cohesion of particles and essentially glues them together into a sediment matrix in-situ. However, when this "fabric" was destroyed, the fine-grained particles dispersed in water and were difficult to reconsolidate under bench-scale conditions. Published literature describes the underlying biofilms formed by benthic organisms (Black, 2002) and algae that create a biological matrix in fine sediments, such as the highly organic Welch Creek sediments. This matrix adds scour resistance and stability to the sediments which can be destroyed through disturbance of surficial sediments such as would occur during bottom fishing or dredging. The

Text Box F-1
Natural Sediment Materials

Clay - The clay varied from a brown to a dark olive brown. The clay ranged from a fat clay (CH) with little or no organic material to a lean clay (CL) containing some or a lot of organic material (plant fibers, pieces of wood, etc.). Organic-rich clay (OL) was also encountered at a few locations. The organic content of the clay ranged from 0.5 to 25 percent, with most samples between 10 to 20 percent.

Peat - Peat was encountered at the surface water/sediment interface and underlying the wastewater solids and natural clay deposits. The peat varied from a yellowish brown to a very dusky red. The peat contained large amounts of debris/organic matter and less inorganic matter.

result of disturbance before the re-forming of biofilm layers would be a loss of strength and stability in disturbed areas and increased likelihood of release of solids to the water column. Thus, it appears biofilm stabilization is an important process in Welch Creek that increases the sediment erosion resistance.

Baseline Flow Conditions

Three Acoustic Velocity Meter (AVM) and surface water monitoring stations were installed along the study area of Welch Creek to assess baseline water quality and flow conditions from July 2004 to November 2005. Specific conditions that impact contaminant transport are summarized as follows:

- **Flow reversals** – Frequent flow reversals occur, measured as far upstream as the Highway 64 bridge. These impact the movement of any mobilized materials and will affect engineering controls and monitoring of potential surface water impacts.
- **Low suspended solids** – Relatively low suspended solid concentrations are observed entering and midstream within the Welch Creek study area with mean concentrations of 5 mg/L and 4.2 mg/L, respectively. Higher concentrations of suspended solids were observed at the downstream station (mean concentration of 10.9 mg/L), and may be a result of surface water runoff from the facility area. Intermittent inflow from the Roanoke River may also contribute to the higher numbers. The relatively low suspended solids loading from the watershed during baseflow conditions indicate that the natural burial of contaminants may take as long as 100 years or more.
- **Large seasonal variations in DO** – Results from the baseline monitoring confirm that there are large seasonal variations in DO. As expected, DO is generally low during the warmer months. When DO levels drop at or below 1 mg/L, adverse impacts to certain fish species are expected. Active remedies that disturb sediment and increase the DO demand need to carefully consider potential impacts to the fishery, and limitations on the available construction season.
- **Sporadic detections of 2,3,7,8-TCDD** – Baseline monitoring and sampling for dioxin showed a lack of consistent, quantifiable dioxin in surface water. The very low detection limit for dioxin is important to recognize during remedy performance monitoring. Sporadic detections of 2,3,7,8 -TCDD are likely to continue to be observed in Welch Creek surface water.

Results from the Pilot Studies and Dewatering Tests

Pilot tests consisting of mini-scale capping and dredging tests, and larger-scale pilot testing of two cap systems, were performed in the upstream reach of Welch Creek. The objectives of these studies included: 1) assessing the short-term effectiveness of the technologies, with focus on evaluating the effects on up and downstream water quality during implementation to assess risk to the fishery; 2) verifying that the capping technologies were effective at isolating the wastewater solids in the natural setting; 3) assessing the engineering feasibility of dredging wastewater solids and dewatering these removed solids prior to disposal; and 4) evaluating impacts of the unusual site conditions (type of wastewater solids and blackwater stream characteristics) on overall remedy effectiveness and implementability.

Key findings and implications from the pilot and mini-scale testing that impact contaminant fate and transport and remedy selection include the following:

- **Thin-layer cap is implementable and effective (short-term)** – A thin-layer sand cap can be supported by the soft wastewater solid deposits in the upstream reach of Welch Creek. Thin-layer capping (1 to 2 cm of sand) resulted in a 74 percent reduction in the surface-area weighted average concentration (SWAC) of dioxin for the pilot test area.

- **Engineered cap will be more difficult to implement on a full-scale basis due to the steep side slopes in the upstream reach of Welch Creek, but is effective (short-term)** – The engineered capping system experienced significant settling and isolated slope failure, even when placed in lifts and allowed to consolidate during construction. These factors will need to be considered during remedy design. However where placed, the engineered capping system (0.5 foot sand over 0.5 foot hogged fuel) resulted in a 78 percent reduction in the SWAC of dioxin for the pilot test area.
- **Cap construction did not adversely impact water quality** – Wastewater solids were not suspended during placement of the capping materials at pilot scale, and minimal impacts to water quality were observed during cap construction.
- **Cap construction did not adversely impact benthic community** – Benthic community surveys conducted before and after pilot-scale capping (both thin-layer and engineered cap systems) indicated a comparable community (density and diversity). It is unclear if this is a result of growth of a remnant population or recolonization of the benthic community.
- **Dredging is likely to adversely impact water quality** – Mini-scale dredging tests used to sample sediments for dewatering studies, indicated that wastewater solids could be suspended and result in elevated dioxin concentrations in the water adjacent to the dredging area. This conclusion is supported by column studies and literature information regarding biofilms on highly organic sediments.
- **Debris removal is likely to adversely impact water quality** – Debris removal caused visual turbidity. The debris broke into smaller pieces during removal and resulted in additional disturbance of the wastewater solids.
- **Engineering controls may not be effective in protecting water quality** – Engineering controls such as silt curtains may improve control of suspended solids migration, but are susceptible to failure in Welch Creek. A full silt curtain failure occurred during one typical Welch Creek storm event during the mini tests.
- **Variation in Benthic Community will impact performance monitoring program design** – Significant annual and seasonal population variations were observed for the benthic community in the reference surveys. This implies that remedy performance monitoring should account for seasonal and year-to-year natural variations, if benthic community surveys are included in the plan.

A bench-scale dewatering study of simulated dredge spoils (both mechanical and hydraulic) was also performed to better understand implications for full-scale dredging operations. Welch Creek sediments and surface water were used to perform the studies, and the resulting filtrate from the dewatering tests was analyzed for dioxin, turbidity, and other COCs. Key findings and implications from this dewatering study include the following:

- **Dewatering characteristics** – Bench scale dewatering test results showed that the removed organic rich wastewater solids are very difficult to dewater. Even the mechanically dredged sediments required large doses of chemical conditioning agents and long cycle times (minimum of 60 minutes) with a filter press for removal of sufficient water to allow landfill disposal.
- **Filtrate quality** – Water treatment will be required to allow discharge of filtrate water back into Welch Creek. The filtrate contained concentrations of 2,3,7,8-TCDD above the existing State of North Carolina water quality standards; so additional water treatment will need to be considered for larger scale applications. The addition of polymers to promote dewatering significantly increased the turbidity of the filtrate, so additional water management will also be needed if polymers are used.

G. Current and Potential Future Land and Resources Uses

The 4.5 mile stretch of Welch Creek which comprises OU-4 is located within the property boundary of the active Domtar (formerly Weyerhaeuser) facility. The OU-4 portion of Welch Creek is bounded by wooded wetlands along the east bank and the non- production Mill facilities (parking areas, green space, wastewater settling ponds) along the west bank. Six bridges span Welch Creek, including three railroad bridges and three bridges for primarily mill-related automobile traffic. The low bridge clearances near the mouth restrict boat access from the river to upper reaches of the creek except for small watercraft. There is one small boat ramp, accessible only from the secured mill property along the central part of OU-4. Upstream near Highway 64, several private residences are located adjacent to the creek but downstream boat access is somewhat limited by natural obstructions. Public boating access to OU-4 from the Lower Roanoke River is limited to the mouth of Welch Creek. Access to the Domtar (formerly Weyerhaeuser) facility property boundary for ambulatory recreational activities along the creek is limited due to the large expanse of dense vegetated wetlands and security fencing along most of the property boundary. The Domtar (formerly Weyerhaeuser) facility is expected to remain an active industrial facility in the future, and site access is expected to continuously be controlled by perimeter fencing and full time security.

Welch Creek is a tributary of the Roanoke River at a point approximately 7 miles from the river's confluence with Albemarle Sound. The Roanoke River is used frequently for recreational fishing. Duck hunters and occasional fisherman use of Welch Creek during the applicable state regulated seasons. Drinking water is not obtained from the surface water in Welch Creek or the Roanoke River downstream of Welch Creek. There are a few residents located where Highway 64 intersects the creek. However, residential development is not expected to occur within the forested wetlands adjacent to the creek given that it is in the flood plain of the Roanoke River. Shallow groundwater in the vicinity of the Welch Creek area is not currently used, and is not expected to be used, as a potable water source due to quality and yield limitations. However, the State of North Carolina considers all groundwater to be potentially potable.

A dioxin fish consumption advisory remains in effect for bottom-feeding fish in Welch Creek. Significant improvements in the dioxin fish tissue concentrations have resulted in the removal of the fish consumption advisory for certain species of fish in Welch Creek.

H. Summary of Site Risks

The baseline Human Health Risk Assessment and the Baseline Ecological Risk Assessment present the results of comprehensive deterministic risk assessments that address potential threats to public health and the environment posed by OU-4 under current and future conditions assuming that no remedial actions take place. Using the collected data and the Site Conceptual Model, these risk assessments help identify contaminants and exposure pathways that need to be addressed by the remedial action.

1. The Baseline Human Health Risk Assessment

The Baseline Human Health Risk Assessment consists of the following sections: identification of chemicals of potential concern; exposure assessment; toxicity assessment; and, risk characterization. A summary of each section is presented below.

a. Chemicals of Potential Concern (COPCs)

The first step involved in the human health risk assessment process is selection of COPCs. The COPC selection identifies site-related chemicals that are present at concentrations that could result in potential adverse effects on human health. The selection of human health COPCs included an initial screening of the detected concentrations relative to USEPA Region III's Risk Based Concentrations (RBCs). The RBCs for noncarinogenic chemicals were adjusted to a level equivalent to a target HQ of 0.1 before being used to select COPCs.

For the purpose of the baseline risk assessment, COPCs for human health, as shown in Table H-1, include the following:

- Sediments: 2,3,7,8-PCDD/PCDFs, chromium and mercury
- Surface Water: 2,3,7,8-PCDD/PCDFs
- Wetland soil: 2,3,7,8-PCDD/PCDFs, chromium and mercury
- Wetland water: 2,3,7,8-PCDD/PCDF

b. Exposure Assessment

The second step of the risk assessment process, the Exposure Assessment, involves identifying the human populations that may be exposed to COPCs in environmental media and the routes by which they may be exposed. The exposure assessment is finalized with the estimate of the daily dose of COPCs to which receptors may be exposed.

The objective of the exposure assessment is to estimate the type and magnitude of potential exposures to COPCs in environmental media associated with Welch Creek. The exposure assessment for Welch Creek follows the guidance in Risk Assessment Guidance for Superfund (RAGS) (USEPA, 1989) and addresses the following:

- Characterization of the exposure setting
- Identification of migration and exposure pathways
- Quantification of exposure

Table H-1
Summary of Human Health and Ecological COPCs for Welch Creek

SUBAREA/MEDIA OF CONCERN	CONSTITUENTS OF POTENTIAL CONCERN	HUMAN HEALTH	ECOLOGICAL	
			DIRECT[1]	MODELED[2]
Welch Creek sediment	2,3,7,8-PCDD/PCDF	X	X	X
	Phenanthrene		X	
	Pyrene		X	
	Chromium	X	X	X
	Copper		X	
	Mercury	X	X	X
	Nickel		X	
	Zinc		X	X
Welch Creek surface water	2,3,7,8-PCDD/PCDF	X	X	X
Wetland soil	2,3,7,8-PCDD/PCDF	X	X	X
	Aroclor 1242		X	
	Aroclor 1260		X	
	Chromium	X	X	X
	Copper		X	
	Mercury	X	X	X
	Nickel		X	
	Zinc		X	X
Wetland water	2,3,7,8-PCDD/PCDF	X	X	X

Notes:
Shading = constituent concentration exceeds screening criteria and is retained as a COPC for further analysis.
(1) Direct ecological COPCs identified based on maximum constituent concentration in excess of a conservative ecological screening value. Retained as a COPC for potential direct toxicity effects to lower trophic level endpoints.
(2) Ecological COPCs identified based on conservative dietary exposure modeling for upper trophic level endpoints as presented in the Screening Ecological Risk Assessment (RMT, 1998). Retained as a COPC for potential dietary toxicity effects to upper trophic level endpoints.

Characterization of Exposure Setting

The location and setting of Welch Creek was presented in Sections A and E. As a component of characterizing the exposure setting for Welch Creek, potential human receptors and their expected types of exposure to the constituents present at the site were identified for current and hypothetical future land use scenarios. Completed exposure pathways are the means by which potentially exposed populations (receptors) come into contact with site-related COPCs. The completed exposure pathways under current land use scenarios evaluated for potential human receptors at the Welch Creek area were as follows:

- Aquatic scientist exposure to COPCs in sediment and surface water
- Recreational fisherman exposure to COPCs in surface water and affected fish

Security fencing located east of Welch Creek along the Weyerhaeuser facility property boundary from U.S. Highway 64 to the confluence of Welch Creek with the Roanoke River along with accessibility limitations in the form of extensive flooded wetlands and site security limit trespasser exposure in the Welch Creek area. In addition, No Trespassing signs have been posted along the banks of Welch Creek. The presence of these physical and administrative controls prevents completed exposure pathways under current land use scenarios for anyone not entering the Welch Creek area by boat. Under the assumption that in-place institutional and physical access restrictions might not be maintained, the baseline risk assessment included evaluation of walk-up fishermen and adolescent trespasser exposures under hypothetical future land use scenarios. The potentially completed exposure pathways evaluated for potential human receptors under hypothetical future land use scenarios at the Welch Creek area were as follows:

- Adolescent trespasser exposure to COPCs in wetland soil, wetland water, and surface water
- Adult trespasser/pedestrian fisherman exposure to COPCs in wetland soil, wetland water, surface water, and affected fish

Identification of Migration and Exposure Pathways

The Welch Creek area conceptual site model (see Figure E-1) is based on characterization of waste sources, the COPC for each affected environmental medium, and the migration and transport potential of this constituent to potential receptors.

An exposure pathway is the means by which a constituent moves from a source to a receptor. A completed exposure pathway has the following elements:

1. **Constituent Source** - The primary sources of site-related constituents in environmental media in the Welch Creek area is the wastewater solids that historically accumulated on the bottom of Welch Creek. Wetland concentration levels were also associated with the historical wastewater effluent discharges due to flood events.
2. **Constituent Release and Environmental Transport Mechanism** - The potential constituent release and transport pathways relevant to human health at the Welch Creek area are as follows:
   - Sediment migration within Welch Creek and into adjacent wetlands
   - Partitioning of site-related constituents from sediment to surface water or wetland water

3. **Potential Exposure Routes and Pathways** - Completed exposure pathways are the means by which potentially exposed populations (receptors) come into contact with site-related COPCs. The completed exposure pathways evaluated under current and future land use scenarios for potential human receptors in the Welch Creek area and the exposure routes were as follows:

Current Land Use

Aquatic Scientist exposure to COPCs in sediment and surface water

- Incidental ingestion of surface water and sediment
- Dermal contact with surface water and sediment
- Particulate inhalation of sediment

Recreational fisherman exposure to COPCs in surface water and affected fish

- Incidental ingestion of surface water
- Dermal contact with surface water
- Ingestion of affected fish

Future Land Use

Adolescent trespasser exposure to COPCs in wetland soil, wetland water, and surface water

- Incidental ingestion of wetland soil, wetland water, and surface water
- Dermal contact with wetland soil, wetland water, and surface water
- Particulate inhalation of wetland soil

Adult trespasser/pedestrian fisherman exposure to COPCs in wetland soil, wetland water, surface water, and affected fish

- Incidental ingestion of wetland soil, wetland water and surface water
- Dermal contact with wetland soil, wetland water and surface water
- Particulate inhalation of wetland soil
- Ingestion of affected fish

Quantification of Exposure

The potential exposure to site-related COPCs for each receptor is represented by a chronic daily intake (CDI). The CDI for an individual receptor is estimated from the exposure point concentration of each COPC in each environmental medium.

Exposure Point Concentration

Consistent with Region 4 Supplemental Guidance (USEPA, 1996), the exposure point concentrations used for estimating CDIs are the lesser of the maximum concentration for each COPC or the 95 percent upper confidence limit (95 percent UCL) of the mean concentration assuming a log-normal distribution of the data set. With the exception of individual dioxin/furan congeners, a value equivalent to one-half the quantitation limit was used in the 95 percent UCL exposure point concentration calculations for constituents reported as not detected. For individual dioxin/furan congeners not detected, zero was used in the TEQ derivation. This approach is consistent with North Carolina and U.S. Fish and Wildlife Service (USFWS) practice, as well as historic work performed for the facility under a variety of regulatory frameworks and allows direct comparison of TEQs from past and present evaluations. The exposure point concentrations for the COPCs from the various environmental media are presented in Table H-2. For the purposes of estimating fish fillet concentrations for this Risk Assessment evaluation, dioxin TEQs were based on all detected congeners. TEQs for fish fillet tissues were calculated using two methodologies as follows:

- International Toxicity Equivalence Facor (I-TEF) methodology from USEPA (USEPA, 1989) as published in USEPA Region IV Supplemental Guidance (USEPA, 1996)
- World Health Organization (WHO) TEF methodology for mammalian species as presented in Van den Berg, et al. (1998)

CDI

A CDI is the exposure expressed as the mass of a substance contacted per unit body weight per unit time, averaged over a period of years. The CDIs for COPCs in the Welch Creek area were calculated to represent both the reasonable maximum exposure (RME) and the potential average or central tendency exposure. The RME doses are defined as the "maximum exposure that is reasonably expected to occur at the site" (USEPA, 1989). Several variables that determine the exposure dose for the RME are based on high end (typically 90th percentile or greater) estimates. The RME CDI for any given constituent results from a multiplication of these selected 90th or greater percentile variables. The multiplication of the variables therefore represents a high-end value and a conservative estimate of the actual exposure dose. The average or central tendency exposure doses are defined as representing more typical exposures that are based on 50th percentile exposure estimates. The exposure variables used to calculate the CDI for each potential receptor for both the RME and the potential average or central tendency exposure are outlined in Table H-3. The exposure point concentration relied upon in both the RME and central tendency risk calculations is conservative in that it represents the 95 percent UCL for each media.

c. Toxicity Assessment

There are two purposes of the toxicity assessment: first, to review available information on the potential adverse effects that may result from exposure to the COPC; and second, to quantify the relationship between exposure to these constituents and the likelihood of potential health effects. Toxicity reference values (TRVs) for the COPCs were taken from Integrated Risk Information System (IRIS) and the Health Effect Assessment Summary Table (HEAST).

Toxicity Information for Non-carcinogenic Effects

The USEPA's preferred (USEPA, 1996) toxicity value for evaluating non-carcinogenic effects resulting from chemical exposure is the chronic reference dose (RfD). The chronic RfD is an estimate of a daily exposure level for the human population (including sensitive populations) that should not cause an appreciable risk of harmful effects during a lifetime of exposure. For the Welch Creek area baseline human health risk evaluation, chromium and mercury were quantitatively evaluated for non-carcinogenic health effects.

Table H-2
Exposure Point Concentrations

ENVIRONMENTAL MEDIA	COPC		MAXIMUM OBSERVED CONCENTRATION	CALCULATED 95% UPPER CONFIDENCE LEVEL	EXPOSURE POINT CONCENTRATION
Sediment	Chromium	mg/kg	1840	2049	1840
	Mercury	mg/kg	15.1	42.3	15.1
	Methyl mercury	mg/kg	Not analyzed		
	Dioxin TEQ[(1)]	mg/kg	5.7E-03	5.1E-02	5.7E-03
	Dioxin TEQ[(2)]	mg/kg	5.7E-03	1.2E-01	5.7E-03
Surface water	Chromium	mg/L	ND	ND	ND
	Mercury	mg/L	ND	ND	ND
	Methyl mercury	mg/L	Not analyzed		
	Dioxin TEQ[(1)]	mg/L	9.9E-09	2.4E-08	9.9E-09
	Dioxin TEQ[(2)]	mg/L	9.8E-09	3.8E-08	9.8E-09
Wetland Soil[(3)]	Chromium	mg/kg	333	319	319
	Mercury	mg/kg	5.6	31	5.6
	Methyl mercury	mg/kg	0.0062	0.019	0.0062
	Dioxin TEQ[(1)]	mg/kg	4.1E-03	1.9E-01	4.1E-03
	Dioxin TEQ[(2)]	mg/kg	4.1E-03	5.8E-01	4.1E-03
Wetland Water	Chromium	mg/L	ND	ND	ND
	Mercury	mg/L	ND	ND	ND
	Methyl mercury	mg/L	2.3E-06	8.9E-06	2.3E-06
	Dioxin TEQ[(1)]	mg/L	3.0E-07	1.3E-04	3.0E-07
	Dioxin TEQ[(2)]	mg/L	3.0E-07	2.1E-02	3.0E-07

Notes:
(1) TEQ based on International TEFs (USEPA, 1987)
(2) TEQ based on WHO mammalian TEFs (1997)
(3) Constituent concentrations presented as milligram per kilogram on a dry weight basis.

Table H-2 (continued)
Exposure Point Concentrations

ENVIRONMENTAL MEDIA	COPC[4]		MAXIMUM OBSERVED CONCENTRATION	CALCULATED 95% UPPER CONFIDENCE LEVEL	EXPOSURE POINT CONCENTRATION
Fish Fillet Tissue[3]	Chromium	mg/kg	0.53	8.99	0.53
(All Fish)	Mercury	mg/kg	1.4	6.76	1.4
	Dioxin TEQ[1]	mg/kg	1.0E-05	6.7E-06	6.7E-06[4]
	Dioxin TEQ[2]	mg/kg	1.01E-05	6.8E-06	6.8E-06
Fish Fillet Tissue[3]	Dioxin TEQ[1]	mg/kg	1.55E-06	1.57E-06	1.55E-06
(Gamefish)	Dioxin TEQ[2]	mg/kg	1.55E-06	1.57E-06	1.55E-06
Fish Fillet Tissue[3]	Dioxin TEQ[1]	mg/kg	1.01E-05	1.1E-05	1.01E-05
(Bottom feeders)	Dioxin TEQ[2]	mg/kg	1.01E-05	1.1E-05	1.01E-05

Notes:
(1) TEQ based on International TEFs (USEPA, 1987)
(2) TEQ based on WHO mammalian TEFs (1997)
(3) Refer to Subsection 8.1.3 for basis.
(4) Constituent concentrations presented as milligram per kilogram on a wet weight basis.

Table H-3
RME and Average Exposure Assumptions

EXPOSURE VARIABLE	RME ASSUMPTIONS		AVERAGE EXPOSURE ASSUMPTIONS	
	VALUE	BASIS	VALUE	BASIS
Aquatic Scientist				
Age	Adult		Adult	
Incidental sediment ingestion rate	25 mg/day	Professional Judgment (0.5 times the soil ingestion rate)	25 mg/day	Professional Judgment (0.5 times the soil ingestion rate)
Incidental water ingestion rate	0.01 L/hour	Region IV Guidance(1)	0.01 L/hour	Region IV Guidance(1)
Skin surface area available for dermal contact with sediment and surface water	2,830 cm^2/day	Exposure Factors Handbook(2) Table 6-4 (Maximum)	2,300 cm^2/day	Exposure Factors Handbook(2) Table 6-4 (Mean)
Adherence factor	1.0 mg/cm^2	Region IV Guidance(1)	0.2 mg/cm^2	Dermal Exposure Guidance(3)
Exposure time	4 hours/day	Professional Judgment	2 hours/day	Professional Judgment
Exposure frequency	12 days/year	Professional Judgment(monthly sampling)	12 days/year	Professional Judgment(monthly sampling)
Soil fraction ingested	1.0	Region IV Guidance(1)	1.0	Region IV Guidance(1)
Exposure duration	25 years	Region IV Guidance(1)	9 years	Exposure Factors Handbook(2)
Body weight	70 kg	Region IV Guidance(1)	70 kg	Region IV Guidance(1)

Notes:
(1) Region IV Guidance: Supplemental Guidance to RAGS: Region IV Bulletins – Human Health Risk Assessment (USEPA, 1996).
(2) Exposure Factors Handbook: USEPA/600/P-95/002F (USEPA, 1997).
(3) Dermal Exposure Guidance: Dermal Exposure Assessment: Principles and Applications. Interim Report. USEPA/600/8-91/011B (USEPA, 1992a).

Table H-3 (Continued)
RME and Average Exposure Assumptions

EXPOSURE VARIABLE	RME ASSUMPTIONS		AVERAGE EXPOSURE ASSUMPTIONS	
	VALUE	BASIS	VALUE	BASIS
Recreational – fisherman				
Age	Adult		Adult	
Incidental water ingestion rate	0.01 L/hour	Region IV Guidance[1]	0.01 L/hour	Region IV Guidance[1]
Skin surface area available for dermal contact with surface water	2,490 cm^2/day	Exposure Factors Handbook[2]	1,980 cm^2/day	Exposure Factors Handbook[2]
Adherence factor	1.0 mg/cm^2	Region IV Guidance[1]	0.2 mg/cm^2	Dermal Exposure Guidance
Exposure time	2 hours/day	Professional Judgment	1 hours/day	Professional Judgment
Exposure frequency	24 days/year	Professional Judgment (average twice a month)	24 days/year	Professional Judgment (average twice a month)
Exposure duration	30 years	Region IV Guidance[1]	9 years	Exposure Factors Handbook[2] for time at one residence
Body weight	70 kg	Region IV Guidance[1]	70 kg	Region IV Guidance[1]
Soil fraction ingested	1.0	Region IV Guidance[1]	1.0	Region IV Guidance[1]
Fish ingestion	284 g/meal 21 meals/year 25% of fish ingested are from Welch Creek[5]	Exposure Factors Handbook[2] Chapter 10[4]	85 g/meal 15 meals/year 25% of fish ingested are from Welch Creek[5]	Exposure Factors Handbook[2] Chapter 10[4]

Notes:
(1) Region IV Guidance: Supplemental Guidance to RAGS: Region IV Bulletins – Human Health Risk Assessment (USEPA, 1996).
(2) Exposure Factors Handbook: USEPA/600/P-95/002F (USEPA, 1997).
(3) Dermal Exposure Guidance: Dermal Exposure Assessment: Principles and Applications. Interim Report. USEPA/600/8-91/011B (USEPA, 1992a).
(4) Information on fish meal portion size was taken from Table 10-45, Section 10 of the Exposure Factors Handbook. Information on recreational fish meals per week for all respondents was taken from Table 10-61, Section 10 of the Exposure Factors Handbook.
(5) Percent of total fish ingested sourced from Welch Creek reflects professional judgment with consideration for limited accessibility to Welch Creek (fencing, low bridges/downed trees) and availability of more accessible local fishing venues.

Table H-3 (Continued)
RME and Average Exposure Assumptions

EXPOSURE VARIABLE	RME ASSUMPTIONS		AVERAGE EXPOSURE ASSUMPTIONS	
	VALUE	BASIS	VALUE	BASIS
Adolescent Trespasser				
Age	7 to 16 years	Region IV Guidance[1]	9 to 13 years	Professional judgment
Incidental Soil Ingestion Rate	100 mg/day	Exposure Factors Handbook[2]	100 mg/day	Exposure Factors Handbook[2]
Incidental Water Ingestion Rate	0.01 L/hour	Region IV Guidance[1]	0.01 L/hour	Region IV Guidance[1]
Skin Surface Area Available for Dermal Contact (soil and water)	2,754 cm^2/day	Exposure Factors Handbook[2] Table 6-4 (95th Percentile for arm and hand exposure)	2,232 cm^2/day	Exposure Factors Handbook[2] Table 6-4 (50th Percentile for arm and hand exposure)
Adherence Factor	1.0 mg/cm^2	Region IV Guidance[1]	0.2 mg/cm^2	Dermal Exposure Guidance[3]
Exposure Time	2 hours/visit	Professional judgment	1 hour/visit	Professional judgment
Exposure Frequency	24 visits/year	Professional judgment (twice per month)	12 visits/year	Professional judgment (once per month)
Exposure Duration	10 years	Region IV Guidance[1] based on age range	5 years	Region IV Guidance[1] based on age range
Soil fraction ingested	1.0	Region IV Guidance[1]	1.0	Region IV Guidance[1]
Body Weight	45 kg	Region IV Guidance[1]	40 kg	Exposure Factors Handbook[2] based on age range

Notes:
(1) Region IV Guidance: Supplemental Guidance to RAGS: Region IV Bulletins – Human Health Risk Assessment (USEPA, 1996).
(2) Exposure Factors Handbook: USEPA/600/P-95/002F (USEPA, 1997).
(3) Dermal Exposure Guidance: Dermal Exposure Assessment: Principles and Applications. Interim Report. USEPA/600/8-91/011B (USEPA, 1992a).

Table H-3 (Continued)
RME and Average Exposure Assumptions

EXPOSURE VARIABLE	RME ASSUMPTIONS		AVERAGE EXPOSURE ASSUMPTIONS	
	VALUE	BASIS	VALUE	BASIS
Adult trespasser/Pedestrian fisherman				
Age	Adult	Region IV Guidance[1]	Adult	Region IV Guidance[1]
Incidental Soil Ingestion Rate	50 mg/day	Exposure Factors Handbook[2]	50 mg/day	Exposure Factors Handbook[2]
Incidental Water Ingestion Rate	0.01 L/hour	Region IV Guidance[1]	0.01 L/hour	Region IV Guidance[1]
Skin Surface Area Available for Dermal Contact with Water	2,830 cm^2/day	Exposure Factors Handbook[2] Table 6-4 (95th Percentile for arm and hand exposure)	2,300 cm^2/day	Exposure Factors Handbook[2] Table 6-4 (50th Percentile for arm and hand exposure)
Adherence Factor	1.0 mg/cm^2	Region IV Guidance[1]	0.2 mg/cm^2	Dermal Exposure Guidance[3]
Exposure Time	4 hours/day	Professional judgment	2 hours/day	Professional judgment
Exposure Frequency	12 visits/year	Professional judgment	12 visits/year	Professional judgment
Exposure Duration	25 years	Region IV Guidance[1]	9 years	Exposure Factors Handbook[2] for time at one residence
Soil fraction ingested	1.0	Region IV Guidance[1]	1.0	Region IV Guidance[1]
Body Weight	70 kg	Region IV Guidance[1]	70 kg	Region IV Guidance[1]
Fish ingestion	284 g/meal 21 meals/year 100% of fish ingested are from Welch Creek	Exposure Factors Handbook[2] Chapter 10[4]	85 g/meal 15 meals/year 50% of fish ingested are from Welch Creek	Exposure Factors Handbook[2] Chapter 10[4]

Notes:
(1) Region IV Guidance: Supplemental Guidance to RAGS; Region IV Bulletins – Human Health Risk Assessment (USEPA, 1996).
(2) Exposure Factors Handbook: USEPA/600/P-95/002F (USEPA, 1997).
(3) Dermal Exposure Guidance: Dermal Exposure Assessment: Principles and Applications. Interim Report. USEPA/600/8-91/011B (USEPA, 1992a).
(4) Information on fish meal portion size was taken from Table 10-45, Section 10 of the Exposure Factors Handbook. Information on recreational fish meals per week for all respondents was taken from Table 10-61, Section 10 of the Exposure Factors Handbook.

Oral RfDs (RfDO) are published exposure dose estimates derived from ingestion-based studies. RfDO values were used to estimate the potential hazards associated with the incidental ingestion pathway and with modification, the dermal contact pathway. Inhalation RfDs (RfDI) are published exposure dose estimates derived from inhalation based studies and were used to estimate the potential hazard for the inhalation pathway. Tables H-4a and H-4b present a summary of the available quantitative toxicity information for chromium and mercury for non-carcinogenic effects to be used in the estimation of hazard through incidental ingestion, dermal contact, and inhalation exposure pathways.

Toxicity Information for Carcinogenic Effects

Toxicity values for constituents with potential carcinogenic effects are expressed as slope factors (SF). The slope factor is the upper bound estimate of the probability of a response per unit intake of a chemical over a lifetime. It is the value used to define the probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. For the Welch Creek area, baseline human health risk evaluation, dioxin/furans, and chromium were quantitatively evaluated for carcinogenic health effects.

Oral slope factors (SFo) are published exposure dose estimates derived from ingestion based studies. SFo values were used to estimate the potential hazards associated with the incidental ingestion pathway and with modification, the dermal contact pathway. Inhalation slope factors (SFI) are published exposure dose estimates derived from inhalation based studies and were used to estimate the potential hazard for the inhalation pathway. The baseline human health risk estimates include calculation of potential incremental risk from dioxin TEQs. Dioxin TEQs represent the chlorinated dioxins/furans present at a site expressed as toxic equivalents of 2,3,7,8-TCDD and are used to facilitate the toxicity assessment of the chlorinated dioxin/furans. The cancer slope factor of 150,000 (mg/kg-day)-1 was relied upon in incremental risk estimates for the baseline risk assessment. This CSF, published in HEAST, is footnoted in the HEAST citation as under review and subject to change. A discussion of a range of toxicity values for 2,3,7,8-TCDD was presented in the uncertainty analysis portion of the risk assessment . Table H-5a and Table H-5b present a summary of the available quantitative toxicity information for 2,3,7,8-TCDD and chromium. These slope factors were used to estimate the risk resulting from incidental ingestion, dermal contact, and inhalation, where appropriate.

Table H-5a and Table H-5b also show the USEPA Weight of Evidence (WOE) for each of the COPCs that are considered by the USEPA to be potential carcinogenic compounds. WOE is a classification system for characterizing the extent to which the available data indicate that an agent is a human carcinogen. Group A chemicals are listed as "known human carcinogenic compounds" by the USEPA. Group B1 chemicals are listed as "probable human carcinogenic compounds" based on limited evidence of carcinogenicity in humans. Group B2 chemicals are called "probable human carcinogenic compounds" based on evidence of carcinogenicity in animals; human evidence is inadequate. Group C chemicals are "possible human carcinogenic compounds" based on limited

Table H-4a
Summary of Noncarcinogenic Toxicity Data – Oral/Dermal

CONSTITUENT OF POTENTIAL CONCERN	CHRONIC/ SUBCHRONIC	ORAL RfD VALUE (mg/kg-day)	ORAL TO DERMAL ADJUSTMENT FACTOR[1]	ADJUSTED DERMAL RfD (mg/kg-day)	COMBINED UNCERTAINTY/ MODIFYING FACTORS	SOURCES OF RfD	DATES OF RfD[2] (mm/dd/yy)
Chromium, trivalent	Chronic	1.5E+00	0.2	3.0E-01	1000	IRIS	05/07/01
Mercury, elemental[3]	Subchronic	3.0E-04	0.2	6.0E-05	1000	IRIS	07/19/00
Mercury, elemental	NA	NA	NA	NA	NA	IRIS	12/10/99
Methyl mercury	Chronic	1E-04	1.0	1E-04	10	IRIS	12/10/99
2,3,7,8-TCDD	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes:
[1] Supplemental Guidance to RAGS (USEPA, 1996).
[2] For IRIS values, date IRIS Internet database was searched.
[3] Based on the toxicity values for mercuric chloride.
N/A = not available.

Table H-4b
Summary of Noncarcinogenic Toxicity Data – Inhalation

CONSTITUENT OF POTENTIAL CONCERN	CHRONIC/ SUBCHRONIC	INHALATION RfC[3] VALUE (mg/m^3)	ADJUSTED INHALATION RfD[1] (mg/kg-day)	COMBINED UNCERTAINTY/ MODIFYING FACTORS	SOURCES OF RfC[3]:RfD	DATES[2] (mm/dd/yy)
Chromium, trivalent	NA	NA	NA	NA	IRIS	05/07/01
Mercury, elemental	Subchronic	3.0E-04	8.6E-05	30	IRIS	12/10/99
Methyl mercury	N/A	N/A	N/A	N/A	IRIS	12/10/99
2,3,7,8-TCDD	N/A	N/A	N/A	N/A	N/A	N/A

Notes:
[1] For noncarcinogenic compounds: Inhalation RfD (mg/kg-day) = RfC (mg/m^3) x $(70\ kg)^{-1}$ x 20 m^3/day, Supplemental Guidance to RAGS (USEPA, 1996).
[2] For IRIS values, date IRIS Internet database was searched.
[3] Inhalation reference concentration
N/A = not available.

Table H-5a
Summary of Carcinogenic Toxicity Data – Oral/Dermal

CONSTITUENT OF POTENTIAL CONCERN	ORAL CANCER SLOPE FACTOR $(mg/kg\text{-}day)^{-1}$ [(1)]	ORAL TO DERMAL ADJUSTMENT FACTOR	ADJUSTED DERMAL CANCER SLOPE FACTOR $(mg/kg\text{-}day)^{-1}$ [(1)]	WEIGHT OF EVIDENCE/ CANCER GUIDELINE DESCRIPTION	INFORMATION SOURCE	DATES OF RID[(2)] (mm/dd/yy)
Chromium, trivalent	N/A	N/A	N/A	D	IRIS	12/10/99
Mercury, elemental	N/A	N/A	N/A	D	IRIS	12/10/99
Methyl mercury	N/A	N/A	N/A	C	IRIS	12/10/99
2,3,7,8-TCDD	1.5E+05	1.0	1.5E+05	B2	HEAST	1997

Notes:
(1) Supplemental Guidance to RAGS, USEPA 1996
(2) For IRIS values, date IRIS Internet database was searched. For HEAST values, date of HEAST publication.
N/A = not available.

Table H-5b
Summary of Carcinogenic Toxicity Data – Inhalation

CONSTITUENT OF POTENTIAL CONCERN	INHALATION UNIT RISK $(\mu g/m^3)$	INHALATION CANCER SLOPE FACTOR[(1)] (mg/m^3)	WEIGHT OF EVIDENCE/ CANCER GUIDELINE DESCRIPTION	INFORMATION SOURCE	DATES[(2)] (mm/dd/yy
Chromium, trivalent	NA	NA	NA	IRIS	12/10/99
Mercury, elemental	N/A	N/A	D	IRIS	12/10/99
Methyl mercury	N/A	N/A	C	IRIS	12/10/99
2,3,7,8-TCDD	N/A	1.5E+05	B2	HEAST	1997

Notes:
(1) For carcinogenic compounds: Inhalation CSF $(mg/kg\text{-}day)^{-1}$ = Unit Risk $(\mu g/m^3) \times (70\ kg)^{-1} \times 20\ (m^3/day)^{-1}$, Supplemental Guidance to RAGS, USEPA 1996
(2) For IRIS values, date IRIS HEAST database was searched. For HEAST values, date of HEAST publication.
N/A = not available.

evidence of carcinogenicity in animals; human evidence is inadequate. Group D chemicals are not classifiable as to human carcinogenicity. Group E chemicals show no evidence of carcinogenicity in humans.

Absorbed Doses

Reference doses and slope factors are typically calculated based on toxicity testing that involves ingestion of the constituent being evaluated. For the dermal route of exposure, toxicity values that are expressed as an administered dose must be adjusted to reflect an absorbed dose. To utilize oral toxicity values (RfDO or SFO) in estimation of hazard associated with dermal contact exposures, it is necessary to apply a dermal correction factor to the RfDOs (or SFOs) when they are used in the evaluation of absorbed intake values. For compounds that have poor oral absorption efficiencies, the dermally adjusted RfD would be expected to be lower and the dermally-adjusted SF would be expected to be higher. Consistent with guidance, appropriate published data on oral absorption of specific chemicals should be used to make the administered/ absorbed dose adjustment, where available. The individual Agency for Toxic Substance and Disease Registry (ATSDR) Toxicological Profiles were utilized as the source of the chemical- specific absorption efficiencies, where available. A dermal correction factor of 100 percent was utilized for dioxin TEQ (ATSDR, page 286, 1997). A dermal correction factor of 100 percent was utilized for methyl mercury (ATSDR, page 220, 1999). The Region 4 default oral absorption efficiency value for inorganics of 20 percent was utilized for chromium and inorganic mercury (as mercuric chloride) (USEPA, 1996).

d. Human Health Exposure and Risk Calculations

In the baseline risk characterization, the results of the toxicity and exposure assessments are summarized and integrated into quantitative and qualitative expressions of potential risk for carcinogenic compounds and into a HI for non-carcinogenic compounds. The baseline risk characterization presents RME and average/central tendency exposures to baseline site conditions in the absence of additional site controls or remediation.

Non-carcinogenic Hazard

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specified time period (*e.g.*, life-time) with a reference dose (RfD) derived for a similar exposure period. A RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a hazard quotient (HQ). An HQ<1 indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic non- carcinogenic effects from that chemical are unlikely. The Hazard Index (HI) is generated by adding the HQs for all chemicals of concern that affect the same target organ (*e.g.*, liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. An HI<1 indicates that, based on the sum of all HQs from different contaminants and exposure routes, toxic non carcinogenic effects from all contaminants are unlikely. An HI >1 indicates that site-related exposures may present a risk to human health.

The HQ is calculated as follows:

Non-cancer HQ = CDI/RfD

Where: CDI = chronic daily intake
RfD = reference dose

CDI and RfD are expressed in the same units and represent the same exposure period (*e.g.*, chronic, sub-chronic, or short-term).

The HQs and HI for the aquatic scientist, recreational fisherman and adolescent trespasser were below 1 for both the RME scenarios and the average or central tendency scenarios. For the adult trespasser/pedestrian fisherman, the calculated total hazard index is slightly above 1.0. The potential hazard index is primarily attributable to ingestion of mercury in fish tissue (HI = 1.09).

The HQs and calculated total HIs for potential receptors under the current and future land use scenarios representing an average/central tendency exposure for the aquatic scientist, recreational fisherman, adult trespasser/pedestrian fisherman, and the adolescent trespasser, were well below 1.0.

Carcinogenic Risk

For carcinogens, risks are generally expressed as the incremental probability of an individual's developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk is calculated from the following equation:

Risk = CDI x SF

Where: risk = a unit less probability (e.g., 2 x 10^{-5}) of an individual's developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
SF = slope factor, expressed as (mg/kg-day)-1.

These risks are probabilities that are expressed in scientific notation (*e.g.*, 10^{-6}). An excess lifetime cancer risk of 1 x 10^{-6} indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime cancer risk" because it would be in addition to the risks of cancer individuals face from other causes such as smoking or exposure to too much sun. The chances of an individual's developing cancer from all other causes has been estimated to be as high as one in three. The USEPA's acceptable risk range for excess lifetime cancer risk from site-related exposure is 10^{-4} to 10^{-6}.

Carcinogenic risk for each individual receptor pathway which was modeled in the risk assessment as presented in the following sections.

Aquatic Scientist

The total estimated RME risk for the aquatic scientist is 7.7 x 10^{-6}. The potential incremental risk is primarily attributable to incidental exposure to dioxins in sediment (7.6 x 10^{-6}).

The total estimated risk for the aquatic scientist based on central tendency exposure assumptions is 1.5 x 10^{-6}. The potential incremental risk is primarily attributable to incidental exposure to dioxins in sediment (1.5 x 10^{-6}).

Recreational Fisherman

The total estimated potential RME risk for the recreational fisherman is 2.1 x 10^{-5}. The primary pathway contributing to the receptor risk is ingestion of dioxin in fish (2.1 x 10^{-5}).

The total estimated risk for the recreational fisherman based on central tendency exposure assumptions is 1.6 x 10^{-6}. The potential incremental risk is primarily attributable to ingestion of dioxin in fish (1.6 x 10^{-6}).

Adolescent Trespasser

The total estimated RME risk for the adolescent trespasser is 1.7 x 10^{-5}. The potential incremental risk is primarily attributable to incidental exposure to dioxins in wetland soil (1.6 x 10^{-5}). The total estimated risk for the adolescent trespasser based on central tendency exposure assumptions is 4.5 x 10^{-6}. The potential incremental risk is primarily attributable to incidental exposure to dioxins in wetland soil (4.4 x 10^{-6}).

Adult Trespasser/Pedestrian Fisherman

The total estimated RME risk for the adult trespasser/pedestrian fisherman is 9.4 x 10^{-5}. The potential incremental risk is primarily attributable to ingestion of dioxin in fish tissue (8.5 x 10^{-5}). The total estimated risk for the adult trespasser/pedestrian fisherman based on central tendency exposure assumptions is 5.4 x 10^{-6}. The potential incremental risk is primarily attributable to ingestion of affected fish (3.3 x 10^{-6}).

e. Summary of Risk Characterization

The non-carcinogenic HIs and the incremental carcinogenic risk for each media and receptor are presented in Table H-6 for the RME and Table H-7 for the central tendency. The total HIs derived using RME exposure assumptions for the aquatic scientist and the recreational fisherman, under current land use, and the adolescent trespasser, under hypothetical future land use, were less than 1.0. A HI below 1.0 indicates that these receptors are not expected to experience adverse non-carcinogenic health effects under the exposure evaluated. The total HI derived using RME exposure assumptions for the adult trespasser/pedestrian fisherman, under hypothetical future land use, was slightly above 1.0 (HI = 1.09).

The USEPA has established a range of 1 x 10^{-4} to 1 x 10^{-6} as acceptable maximum limits for excess lifetime carcinogenic risks. The estimated incremental potential risks using RME exposure assumptions for the aquatic scientist and the recreational fisherman for the current land use were greater than the conservative end (1×10^{-6}) of the acceptable risk range. The risk is mainly attributable to sediment exposure for the aquatic scientist and ingestion of affected fish for the fisherman.

Under hypothetical future land use, the estimated incremental potential risks using RME exposure assumptions for the adult trespasser/pedestrian fisherman and the adolescent trespasser were greater than the conservative end (1×10^{-6}) of the acceptable risk range. The risk is mainly attributable to ingestion of affected fish for the adult trespasser/pedestrian fisherman and exposure to wetland soil for the adolescent trespasser.

The total HIs derived using average/central tendency exposure assumptions under both current and hypothetical future land uses for the aquatic scientist, recreational fisherman, adult trespasser/ pedestrian fisherman, and adolescent trespasser were less than 1.0. A HI below 1.0 indicates that these receptors are not expected to experience adverse noncarcinogenic health effects under the exposure evaluated. Potential risk estimates prepared using the average/central tendency exposure assumptions for the aquatic scientist and the recreational fisherman for the current land use scenario resulted in an incremental cancer risk greater than 1×10^{-6}. The risk is mainly attributable to ingestion of affected fish for the recreational fisherman and exposure to sediment for the aquatic scientist. Potential risk estimates prepared using the average/central tendency exposure assumptions for the adult trespasser/pedestrian fisherman and the adolescent trespasser for the future land use scenario resulted in an incremental cancer risk greater than 1×10^{-6}. The risk is mainly attributable to ingestion of affected fish for the adult trespasser/pedestrian fisherman and exposure to wetland soil for the adolescent trespasser.

While the risk assessment calculations did not indicate an unacceptable risk for people, including an adult recreational fisherman, the State of North Carolina has issued notices advising that people limit their consumption of some fish from this area. USEPA recommends that people continue to follow the fish consumption advisories that have been issued by State of North Carolina. The advisory notes that catfish and carp from these waters may contain low levels of dioxins. Women of childbearing age and children should not eat any catfish or carp from this area until further notice. All other persons should eat no more than one meal per month of catfish and carp from this area. The North Carolina State Health Director uses a concentration of 3×10^{-6} mg/kg total dioxins in fish tissues for issuing fish consumption advisories.

Table H-6
Hazard and Incremental Risk Summary by Media for Reasonable Maximum Exposure Scenario

RECEPTOR/ MEDIA OF CONCERN	WELCH CREEK HAZARD	WELCH CREEK INCREMENTAL RISK
	REASONABLE MAXIMUM EXPOSURE	REASONABLE MAXIMUM EXPOSURE
Current Land Use		
Aquatic Scientist		
Sediment	0.00097	**7.6×10^{-6}**
Surface water	NC	2.1×10^{-8}
Total Receptor Risk	0.00097	**7.7×10^{-6}**
Recreational Fisherman		
Surface water	NC	2.4×10^{-8}
Fish tissue	0.27	**2.6×10^{-5}**
Total Receptor Risk	0.27	**2.6×10^{-5}**
Future Land Use		
Adolescent Trespasser		
Wetland soil	0.003	**1.6×10^{-5}**
Wetland water	0.000001	3.9×10^{-7}
Surface water	NC	1.3×10^{-8}
Total Receptor Risk	0.003	**1.7×10^{-5}**
Adult Trespasser/Pedestrian Fisherman		
Wetland soil	0.0006	**8.1×10^{-6}**
Wetland water	0.0000007	6.4×10^{-7}
Surface water	NC	2.1×10^{-8}
Fish tissue	**1.09**	**8.5×10^{-5}**
Total Receptor Risk	**1.09**	**9.4×10^{-5}**

Notes:
NC = not calculated—noncarcinogenic COPCs not detected in this media.
Risk estimates presented in **bold face type** exceed the conservative end of USEPA's risk range (*i.e.*, 1×10^{-6}) or the target Hazard Index of 1.0.

Table H-7
Hazard and Incremental Risk Summary by Media for
Central Tendency Exposure Scenario

RECEPTOR/ MEDIA OF CONCERN	WELCH CREEK HAZARD	WELCH CREEK INCREMENTAL RISK
	CENTRAL TENDENCY EXPOSURE	CENTRAL TENDENCY EXPOSURE
Current Land Use		
Aquatic Scientist		
Sediment	0.00066	**1.5×10^{-6}**
Surface water	NC	3.4×10^{-9}
Total Receptor Risk	0.00066	**1.5×10^{-6}**
Recreational Fisherman		
Surface water	NC	3.2×10^{-9}
Fish tissue	0.058	**1.6×10^{-6}**
Total Receptor Risk	0.058	**1.6×10^{-6}**
Future Land Use		
Adolescent Trespasser		
Wetland soil	0.0017	**4.4×10^{-6}**
Wetland water	0.00000027	5.0×10^{-8}
Surface water	NC	1.65×10^{-9}
Total Receptor Risk	0.0017	**4.5×10^{-6}**
Adult Trespasser/Pedestrian Fisherman		
Wetland soil	0.00047	**2.0×10^{-6}**
Wetland water	0.0000003	1.0×10^{-7}
Surface water	NC	3.4×10^{-9}
Fish tissue	0.12	**3.3×10^{-6}**
Total Receptor Risk	0.12	**5.4×10^{-6}**

Notes:
NC = not calculated—noncarcinogenic COPCs not detected in this media.
Risk estimates presented in **bold face type** exceed the conservative end of USEPA's risk range (*i.e.*, 1×10^{-6}) or the target Hazard Index of 1.0.

f. Uncertainty Analysis

The primary goal of the uncertainty analysis is to provide a discussion of the key assumptions made in the risk assessment that may significantly influence the estimate of potential risk. A discussion of the sources of uncertainty contributing to the potential risk and the associated effects (overestimation or underestimation of risk) of these factors as presented in the RI.

In the absence of empirical- or site-specific data, assumptions are developed based on best estimates of exposure or dose-response relationships. To assist in the development of these estimates, the USEPA (1989, 1991) recommends the use of guidelines and standard factors in risk assessments conducted under CERCLA. The use of these standard factors is intended to promote consistency among risk assessments where assumptions must be made. Although the use of standard factors undoubtedly promotes comparability, their usefulness in accurately predicting potential risk is directly related to their applicability to the actual site-specific conditions.

The potential non carcinogenic hazard and carcinogenic risk estimates for the site are based on a number of assumptions that incorporate varying degrees of uncertainty resulting from many sources, including the following:

- Environmental monitoring and data evaluation
- Assumptions in the selection of exposure pathways and scenarios
- Assumptions in the expression of potential non carcinogenic hazard and carcinogenic risk
- Estimation of the magnitude of exposure under selected exposure scenarios

Several factors introduced in the risk assessment may contribute to the uncertainty of the potential risk estimates, including the following:

- Sampling concentrated in areas at the site believed to be affected by constituents (biased sampling) is likely to overestimate exposure.
- Use of environmental data qualified as estimated potentially biases the actual value low or high.
- Using toxicity values with low confidence ratings and high uncertainty factors could potentially overestimate the risk calculated.
- Using toxicity values that are largely based on animal studies and extrapolated to humans could potentially overestimate or underestimate the risk calculated.
- Not quantitatively evaluating constituents that do not have toxicity data may underestimate actual risk.
- Not quantitatively evaluating synergistic or cumulative toxicity effect associated with the co-occurrence of COPCs in environmental media may underestimate actual risk.
- Compounding conservative assumptions in the risk assessment yield extremely conservative (overestimated) potential risk estimates.
- Assuming constituents present in the stream sediment have a significant tendency to desorb from the soil and pass through the skin is likely to overestimate exposure.

- Using 95 percent UCL and maximum concentrations is likely to overestimate intakes since actual exposure is probably at lower concentrations.
- The assumption that aquatic scientists spend their entire workdays within the localized affected areas of the site overestimates exposure.

Several factors were identified in the risk assessment as factors that may contribute to the uncertainty of the potential risk estimates. A detailed discuss of the key assumptions and uncertainties in each phase of the risk assessment that resulted in a significant contribution to total potential risk was included in the RI. A brief summary of the key assumptions and uncertainties is included below.

Characterization of Affected Media

The intent of the RI conducted in the Welch Creek area was to characterize the nature and extent of the COPCs in various media due to the suspected and known releases that have occurred at the Welch Creek area. To achieve this goal in a timely, cost-effective manner, the investigation focused on those areas of the site that were known or suspected to be affected by chemical releases. In the absence of a representative sample population (*i.e.,* an equally distributed number of data points from all portions of the site), the available data used in the baseline risk assessment were assumed to be representative of the entire Welch Creek area. For the aquatic scientist, this assumption is more likely to overestimate risk than to underestimate it, since potential receptors may spend less time in the sampled areas than the site as a whole.

For the Welch Creek area, the calculated exposure point concentrations for sediment and surface water are biased high due to the presence of elevated dioxin concentrations in localized areas. The conservative baseline risk assessment process assumes that the elevated exposure point concentration is equally distributed over the Welch Creek area and equally accessible to the receptors being evaluated.

Exposure Assessment

There are numerous assumptions made in the exposure assessment, including the selection of exposure routes, scenarios, and factors (*e.g.,* contact rates, exposure frequency, body weight) used to estimate exposure doses. The RME was used to develop exposure doses and is defined as the "maximum exposure that is reasonably expected to occur at the site (USEPA, 1989)." Several variables that determine the exposure dose for the RME are based on high-end (typically 90th percentile or greater) estimates. These variables include exposure concentrations, intake rate, exposure frequency, exposure duration and fraction ingested.

Therefore, the calculated RME dose for any given constituent, which results from a multiplication of these selected variables, represents a high-end value and a conservative estimate of the actual exposure dose. The use of this exposure dose, coupled with conservative estimates of toxicity, will yield a potential risk result that represents a high-end estimate of the likelihood of non-carcinogenic effects.

The exposure assessment for the Welch Creek area incorporated a number of existing physical, legal and administrative access control measures into the development of the reasonably exposed individual. Those measures included:

- Property line security fencing for the mill, inclusive of Welch Creek
- Posted and enforced "No Trespassing" provisions for the mill property, inclusive of the lands surrounding Welch Creek
- Posted North Carolina advisory on consumption of fish from Welch Creek

Toxicity Assessment

In order for a potential risk to be present, both exposure to the COC and toxicity at the predicted exposure levels must exist. The toxicological uncertainties primarily relate to the methodology by which carcinogenic and non-carcinogenic criteria (*i.e.*, CSFs and Rfds) are developed. The toxicity values developed by the USEPA are designed to represent a conservative position, may not reflect the current scientific consensus, and in most instances, will result in an overestimation of potential hazards. As previously presented, there is considerable scientific debate regarding the nature of dioxin toxicity. In light of the uncertainty associated with the health effects of dioxin TEQ exposures, a range of CSFs were quantitatively evaluated in the uncertainty analysis. Table H-8 presents a range of alternate CSFs for dioxin TEQ and a summary of derivation and implications for the human health risk evaluation.

For dermal contact exposures in this baseline risk assessment, oral slope factors and reference doses adjusted for dermal exposure are used. The adjustments are based on studies on each individual parameter when available. However, the uncertainty involved in this adjustment method is high.

The assumptions of the exposure assessment are conservative, and in general, result in overestimates of exposure. In the face of uncertainties, the assumptions of the exposure assessment are purposely conservative (high-end). This conservative risk and hazard estimate approach, dealing with uncertainties for exposure, conforms to USEPA guidance provided in RAGS (USEPA, 1989).

g. Constituent of Concern Determination

Constituents of concern (COCs) are the COPCs that significantly contribute to a pathway in a current land use scenario for either the aquatic scientist or the recreational fisherman or in a future land use scenario for either the adolescent trespasser or the adult trespasser/pedestrian fisherman that either exceeds a 1×10^{-4} cumulative site cancer risk; or exceeds a non-carcinogenic HI of 1.

Generally, a 1×10^{-4} cumulative site risk level and an HI of 1 are guides for potential use as remediation "triggers." The exact level used as the "trigger" is at the discretion of the risk manager. Constituents are considered as significant contributors to risk and therefore included as COCs if their individual carcinogenic risk contribution is greater than 1×10^{-6} and their noncarcinogenic HQ is greater than 0.1. No total receptor risks exceed the 1×10^{-4} cumulative site risk level. Although no total receptor risk

Table H-8
Alternate Dioxin CSFs - Effects on Total Receptor Risk

DIOXIN CSFs (mg/kg-day)$^{-1}$	DERIVATION	TOTAL RME RECEPTOR RISK			
		AQUATIC SCIENTIST	RECREATIONAL FISHERMAN	ADULT TRESPASSER/ PEDESTRIAN FISHERMAN	ADOLESCENT TRESPASSER
150,000	– Based an alternate interpretation of Kociba *et al.* (1978) study results. – Relied upon by USEPA for risk assessments under CERCLA framework – Reflects CSF published in HEAST – This citation is currently under review and subject to change	**7.7 x 10^{-6}**	**2.6 x 10^{-5}**	**9.4 x 10^{-5}**	**1.7 x 10^{-5}**
ALTERNATE DIOXIN CSFs (mg/kg-day)$^{-1}$					
9,000	– Based an alternate interpretation of Kociba *et al.* (1978) study results. Based on reanalysis of the pathology results of the study by the Pathology Working Group (PWG, 1990a; 1990b) and different data interpretation and body scaling methodologies. – Supported by Food and Drug Administration as the best estimate of upper bound lifetime risk from 2,3,7,8-TCDD (FDA, 1994). – Previously approved for use by North Carolina Department of Health and Human Services Division of Epidemiology	4.6 x 10^{-7}	**1.6 x 10^{-6}**	**5.6 x 10^{-6}**	**1.0 x 10^{-6}**
52,000	– Based on an alternate interpretation of Kociba *et al.* (1978) study results. Based on different data interpretation and body scaling methodologies.	**2.7 x 10^{-6}**	**9.0 x 10^{-6}**	**3.3 x 10^{-5}**	**5.9 x 10^{-6}**
62,000	– Based on CSF for hexachlorodibenzo-p-dioxin (HxCDD) reported in IRIS, modified with a 10x TEF – This 10x TEF is consistent with both International TEF and WHO TEF – Based on primary toxicology reference (IRIS) and consensus TEFs	**3.2 x 10^{-6}**	**1.1 x 10^{-5}**	**3.9 x 10^{-5}**	**7.0 x 10^{-6}**

Note: Risk estimates presented in **bold face type** exceed the conservative end of USEPA's risk range (*i.e.*, 1 x 10^{-6})

exceeds the 1 x 10^{-4} cumulative site risk level, dioxin TEQ (USEPA, 1989 and WHO, 1997) exceeds individual carcinogenic risk contribution of greater than 1 x 10^{-6} for the evaluated receptors.

Under the hypothetical future use exposure scenario for the adult trespasser/pedestrian fisherman, mercury in fish tissue is also identified as a COC. A constituent may also be retained as a COC for a medium if the observed concentration exceeds a state or federal chemical-specific ARAR. 2,3,7,8-TCDD was maintained as COC for surface water based on a maximum observed concentration above the North Carolina water quality standard.

There are no chemical-specific applicable or relevant and appropriate requirements (ARARs) for 2,3,7,8-PCDD/PCDF in sediment or soils. Although standards for dioxin TEQ in soils are not promulgated, OSWER guidance (OSWER Directive 9200.4-26) is available which identifies cleanup target ranges of 5 ug/kg to 20 ug/kg dioxin TEQ for industrial facilities and 1 ug/kg dioxin TEQ for residential soils. The North Carolina State Health Director uses a concentration of 3 x 10^{-6} mg/kg total dioxins in fish tissues for issuing fish consumption advisories.

2. The Baseline Ecological Risk Assessment (BERA)

A BERA report was prepared concurrently with the RI report for the Welch Creek Area which documents biological data gathering and ecological risk characterization activities. To assess the ecological health of the macroinvertebrate community in the Welch Creek area, toxicity testing was conducted. In addition, the data gathering included analysis of forage materials and prey items for COPCs in support of exposure modeling to evaluate potential effects in upper trophic level endpoints. Additional site-specific information was incorporated into the FS as part of the continued refinement of the ecological site conceptual model.

a. Problem Formulation

The problem formulation step focused on the defined project objectives and incorporated the existing ecological information to arrive at a conceptual model that could be tested. As part of the problem formulation step, the site-related ecosystem was characterized, the site-related COPC and assessment endpoints were identified, and a preliminary conceptual model was formulated. The conceptual model serves as the foundation for the subsequent ecological study design and BERA. The preliminary ecological conceptual site model for the Welch Creek Area was further refined as part of the FS. The refined ecological conceptual site model is presented in Figure E-1.

Conceptual Migration and Exposure Model

The ecological migration and exposure model identifies wastewater treatment solids present in Welch Creek as the suspected primary source of site-related chemicals that may affect the Welch Creek ecosystem. These wastewater treatment solids potentially result in secondary sources of COPCs in the Welch Creek surface water and sediment or adjacent wetland areas. Welch Creek and its adjacent wetlands provide a potential habitat for swamp stream-adapted aquatic, avian, and terrestrial species. Potential primary receptors include benthic macroinvertebrates, emergent and terrestrial insects, fish, and aquatic/wetlands plants. Predator species are exposed to COPCs primarily through the ingestion of prey and forage species (macroinvertebrates, insects, fish, and plants) that may have sequestered dioxins and mercury in their lipid and muscle tissue. It is primarily by this mechanism that bioaccumulative constituents, such as dioxins and mercury, are transferred to the members of the upper trophic levels of an ecosystem.

Potential pathways for environmental receptors for the Welch Creek and area are as follows:

- Swamp stream-adapted aquatic biota, which may be exposed to site-related COPCs in surface water and sediment through ingestion, respiration, and dermal contact
- Terrestrial biota, which may be directly exposed to COPCs in creek or wetland water and wetland soil through ingestion or dermal contact
- Avian biota, which may be exposed to creek or wetland water and wetland soil through ingestion and dermal contact
- Terrestrial and avian receptors, which may also be exposed to contaminants through the ingestion of affected flora and fauna at lower trophic levels

Assessment and Measurement Endpoints

USEPA guidance states "Assessment endpoints are explicit expressions of the actual environmental value that is to be protected" (USEPA, 1998). Assessment endpoints representing swamp stream-adapted aquatic and terrestrial ecosystems were selected for evaluation of Welch Creek and its environs. Assessment endpoints were selected with consideration for ecological effects to both the aquatic and terrestrial ecosystem components, which result from direct exposure to COPCs in surface water and sediments and from transfer through dietary exposure interactions.

Assessment endpoints were selected to focus primarily on upper trophic level receptors in consideration of the bioaccumulative properties of selected COPCs (dioxin/furans, PCBs, mercury and selenium). Upper trophic level mammalian and avian receptors may be exposed to site-related COPCs through ingestion of forage materials (plants, terrestrial/wetland invertebrates, and small mammals) that have accumulated COPCs in tissues or through incidental ingestion of affected environmental media. For ecological risk assessments, actual measurement of impacts to whole site-specific animal communities and populations and any associated habitats is difficult in part due to the complex interactions both within and between the animal communities and populations that compose an ecosystem and the likely absence of community or population based toxicological data for the site-specific assessment endpoints. .As such, measurement endpoints are chosen to represent the assessment endpoints.

Assessment endpoints identified for Welch Creek and its adjacent wetlands include the following:

- Maintenance of ecological health of the fresh water macroinvertebrate community, specifically in terms of structure and function in support of upper trophic levels
- Protection of long-term health and reproductive capacity of the fishery resources in support of upper trophic levels
- Protection of long-term health and reproductive capacity of predominately piscivorous mammalian species utilizing Welch Creek and its adjacent wetlands (represented by the River otter)

- Protection of long-term health and reproductive capacity of predominately piscivorous avian species utilizing Welch Creek and its adjacent wetlands (represented by the Great Blue Heron)
- Protection of long-term health and reproductive capacity of predominately herbivorous/ insectivorous avian species utilizing Welch Creek and its adjacent wetlands (represented by the wood duck)
- Protection of long-term health and reproductive capacity of predominately insectivorous avian species utilizing Welch Creek and its adjacent wetlands (represented by the swallow)

Measurement endpoints were selected to conservatively estimate the effects to the upper trophic levels of the different biotic communities that compose the ecosystem of the Welch Creek area. For the upper trophic level endpoints, the measurement endpoint was selected to establish the relative effects of ingestion of modeled COPCs in forage materials and prey species on growth, survival, and reproductive success of the endpoint. Three basic types of effects data are available to serve as measurement endpoints for the lower trophic level endpoints (Assessment Endpoint # 1- Maintenance of ecological health of the fresh water macroinvertebrate community and #2 - Protection of long-term health and reproductive capacity of the fishery resources). In general, these measurement endpoints, in increasing weight of evidence order, include:

- Comparison of observed water and sediment quality results with existing toxicity information from the literature
- Toxicity testing performed on environmental media from Welch Creek and the adjacent wetlands as well as Conaby Creek (reference creek)
- Community survey results for Welch Creek and Conaby Creek

For the upper trophic level endpoints (Assessment Endpoints # 3 through #6), the measurement endpoint was selected to establish the relative effects of ingestion of COPCs in forage materials and prey species on growth, survival, and reproductive success of the endpoint. The measurement endpoint for each of the upper trophic level assessment endpoints involves comparison of modeled dietary intakes for each ecological COPC to chronic toxicity thresholds.

As outlined in the Ecological Risk Assessment Study Design (RMT, 1999), the modeled risk characterizations incorporate two approaches into the estimation of potential exposures to ecological receptors at the Welch Creek area. The conservative approach reflects exposure assumptions identified by the USEPA as appropriate for a conservative and baseline ecological risk evaluation using general default values for all parameters. The alternative approach includes alternate exposure and toxicity information, reflective of central tendency (average) assumptions reported in the literature and site-specific information, where available. Table H-9 presents data gathering conducted in support of the measurement endpoints for the Welch Creek area.

b. Ecological Chemicals of Potential Concern

Preliminary direct ecological COPCs were selected by comparing the maximum detected concentration of each constituent to the appropriate USEPA Region 4 ecological screening value for each media tested. The COPCs were further refined based on dietary exposure modeling for the selected upper

Table H-9
Summary of Assessment and Measurement Endpoints

ASSESSMENT ENDPOINT	MEASUREMENT ENDPOINT
1. Ecological health of the fresh water macroinvertebrate community	– Performance of sediment biotoxicity testing for Welch Creek and the adjacent wetlands
	– Assessment and confirmation of macroinvertebrate species population density and diversity in Welch Creek
	– Current water quality/indicator data
	– Current analytical data for creek and wetland sediment
2. Long-term health and reproductive capacity of the fishery resources	– Performance of surface water biotoxicity testing with fathead minnows for Welch Creek
	– Confirmation of fish species diversity within Welch Creek
	– Current water quality/indicator data
	– Current analytical data for creek and wetland surface water
3. Long-term health and reproductive capacity of piscivorous mammalian species (either semiaquatic or terrestrial) utilizing Welch Creek and its adjacent wetlands	– Evaluation of body burdens of fish species in support of dietary exposure models
	– Current analytical data for creek and wetland surface water and sediment
4. Long-term health and reproductive capacity of predominately piscivorous avian species utilizing Welch Creek and its adjacent wetlands.	– Evaluation of body burdens of fish species in support of dietary exposure models
	– Current analytical data for creek and wetland surface water and sediment
5. Long-term health and reproductive capacity of predominately herbivorous/ insectivorous avian species utilizing Welch Creek and its adjacent wetlands	– Evaluation of forage plant tissues for COPC concentrations in support of dietary exposure models
	– Evaluation of benthic macroinvertebrates and terrestrial insects for COPC concentrations in support of dietary exposure models
	– Current analytical data for creek and wetland surface water and sediment
6. Long-term health and reproductive capacity of insectivorous avian species utilizing Welch Creek	– Evaluation of emergent insects for COPC concentrations in support of dietary exposure models
	– Current analytical data for creek and wetland surface water and sediment

trophic endpoint receptors which was performed in the Screening Ecological Risk Assessment. The ecological COPCs for each environmental media in the Welch Creek area are shown in Table H-10.

c. Biological Tissue Characterizations

Tissue samples of fish, terrestrial invertebrates, benthic invertebrates, emergent insects, and plants were collected for analysis from the Welch Creek area in order to provide modeled COPC concentrations in forage species for dietary exposure model inputs. Tissue samples were collected from three Master Transect sampling locations and analyzed for COPCs. The exposure point concentrations used in the BERA dietary exposure modeling, which were derived from the biological tissue sampling results, are presented in Table H-11a and Table H-11b.

d. Exposure Characterization

The objective of the exposure assessment is to estimate the types and magnitude of potential exposures to ecological COPCs in the environmental media and forage/prey species associated with the Welch Creek area. Exposure can be expressed as the temporal and spatial co-occurrence (*i.e.*, contact) of stressors (*i.e.*, COPCs) with the ecological receptors of an ecosystem (USEPA, 1992). Within the context of an ecological risk assessment, the estimation of exposure focuses on the measurement endpoints that represent the variety of species within the site-related ecosystem.

The Welch Creek conceptual site model for ecological risk. Figure E-1 is based on characterization of waste sources, the ecological COPC for each affected environmental medium, and the migration and transport potential of this constituent to potential ecological receptors. The ecological migration and exposure model identifies wastewater treatment solids present in Welch Creek as the suspected primary source of site-related chemicals that may affect the Welch Creek ecosystem. The potential constituent release and transport pathways at the Welch Creek area are as follows:

- Sediment migration within Welch Creek
- Historic deposition of wastewater solids in the adjacent wetlands during high creek stage
- Partitioning of site-related constituents from sediment to surface water
- Food chain bioaccumulation by predator-prey interaction initiated by direct uptake from surface water or sediment by plant and animal species

Exposure of the endpoints to COPCs associated with Welch Creek and the adjacent wetlands were estimated using a dietary exposure model. The direct toxicity characteristics of the COPCs and their bioaccumulative properties were accounted for by incorporating the COPC concentrations in various environmental media and key food species of each endpoint species in the dietary exposure model.

The ecological risk characterization incorporated two approaches into the estimation of potential exposures to ecological receptors at the Welch Creek area. One approach reflects exposure assumptions identified by the USEPA as appropriate for a conservative and comparable baseline ecological risk evaluation on a general basis. The other approach included alternate exposure and toxicity information, reflective of site-specific information, where appropriate.

Table H-10
Area-Specific Ecological COPCs for Welch Creek
Identified in RI/FS Workplanning

SUBAREA/MEDIA OF CONCERN	ECOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN	
Welch Creek Sediments	Dioxin/Furans	Chromium
	Phenanthrene	Copper
	Pyrene	Nickel
	Mercury	Zinc
Welch Creek Surface Water	Dioxin/Furans	
Wetland Soils	Dioxin/Furans	Copper
	PCBs (Aroclor 1242 and 1260)	Nickel
	Mercury	Zinc
	Chromium	
Wetland Water	Dioxin/Furans	Chromium
	Mercury	

Table H-11a
Range of Exposure Point Concentrations for Dioxin TEQ in Environmental Media and Key Forage/Prey Items

SAMPLE DESCRIPTION	DIOXIN TEQ I-TEF(USEPA, 1989) mg/kg[1]			DIOXIN TEQ WHO-TEF-Avian (1998) mg/kg[1]			DIOXIN TEQ WHO-TEF-Mammalian (1998) mg/kg[1]		
	Average	Maximum	95%UCL	Average	Maximum	95%UCL	Average	Maximum	95%UCL
Sediment	1.2E-03	5.7E-03[2]	5.7E-03	5.2E-03	2.6E-02[2]	2.6E-02	1.2E-03	5.7E-03[2]	5.7E-03
Surface Water[3]	2.6E-09	9.9E-09	9.9E-09	1.5E-08	3.3E-08	3.3E-08	2.5E-09	9.8E-09	9.8E-09
Wetland Soil	8.7E-04	4.1E-03	4.1E-03	3.2E-03	1.3E-02	1.3E-02	8.6E-04	4.1E-03	4.1E-03
Wetland Water[3]	4.6E-08	3.0E-07	3.0E-07	1.9E-07	1.2E-06	1.2E-06	4.5E-08	3.0E-07	3.0E-07
Benthic – All	7.4E-06	2.1E-05	2.1E-05	3.4E-05	1.0E-04	8.9E-05			
Chironomids/ Oligochaetes	1.1E-05	2.1E-05	2.1E-05	5.2E-05	1.0E-04	1.0E-04			
Insecta/Mollusca and Crustaceans	5.6E-06	1.1E-05	1.1E-05	2.5E-05	5.1E-05	5.1E-05			
Fish – All	1.7E-05	5.0E-05	2.2E-05	4.3E-05	1.8E-04	5.5E-05	1.7E-05	5.0E-05	2.2E-05
Predators/ Bottom Feeders	1.6E-05	4.4E-05	2.7E-05	4.7E-05	1.8E-04	7.1E-05	1.6E-05	4.4E-05	2.7E-05
Predators	1.9E-05	4.4E-05	2.9E-05	4.6E-05	7.1E-05	6.2E-05	1.9E-05	4.4E-05	2.9E-05
Bottom Feeders	1.2E-05	3.7E-05	3.7E-05	4.8E-05	1.8E-04	1.4E-04	1.2E-05	3.7E-05	3.7E-05
Large/Small Forage	1.8E-05	5.0E-05	2.6E-05	3.9E-05	9.3E-05	5.5E-05	1.8E-05	5.0E-05	2.6E-05
Large Forage	2.5E-05	5.0E-05	4.6E-05	4.9E-05	9.3E-05	8.8E-05	2.5E-05	5.0E-05	4.6E-05
Small Forage	1.0E-05	1.6E-05	1.5E-05	2.9E-05	4.5E-05	4.5E-05	9.9E-06	1.6E-05	1.5E-05
Terrestrial Insects-All	1.9E-06	3.5E-06	3.5E-06	7.4E-06	1.2E-05	1.2E-05			
Beetles	1.6E-06	2.5E-06	2.5E-06	7.1E-06	1.2E-05	1.2E-05			
Terrestrial Insects	2.1E-06	3.5E-06	3.5E-06	7.7E-06	1.1E-05	1.1E-05			
Emergent Insects	2.2E-05	2.6E-05	2.5E-05	1.2E-04	1.4E-04	1.3E-04			
Plants - All	4.6E-06	3.6E-05	1.6E-05	2.1E-05	1.7E-04	1.7E-04			
Submerged Aquatic	9.3E-06	3.6E-05	3.6E-05	4.3E-05	1.7E-04	1.7E-04			
Floating Aquatic	ND	ND	NC	ND	ND	NC			
Mast	4.8E-07	9.3E-07	9.3E-07	1.8E-06	3.9E-06	3.9E-06			

ND Not Detected - Constituent not detected in biological tissue sample.
NC Not Calculated - 95%UCL not calculated given that constituent not detected in biological tissue samples.
95%UCL The lesser of the maximum detected concentration for each COPC or the 95% UCL.
(1) Environmental media concentrations in mg-kg-dry weight, unless otherwise noted; Biological tissues concentrations in mg/kg-wet weight.
(2) TEQs Calculated using only 2,3,7,8-TCDD and 2,3,7,8-TCDF Congeners
(3) Units for surface water and wetland water are mg/L.

Table H-11b
Range of Exposure Point Concentrations Inorganic COPCs in Environmental Media and Key Forage/Prey Items

SAMPLE DESCRIPTION	CHROMIUM mg/kg(1)			MERCURY mg/kg(1)			ZINC mg/kg(1)		
	Average	Maximum	95%UCL	Average	Maximum	95%UCL	Average	Maximum	95%UCL
Sediment	375	1840	840	4.4	15.1	15.1	169	399	382
Surface Water(2)	ND	ND	NC	3.4E-06	4.1E-06	4.1E-06	0.0028	0.0081	0.0034
Wetland Soil	68.4	333	319	0.88	5.6	5.6	83.7	207	123
Wetland Water(2)	ND	ND	NC	ND	ND	NC			
Benthic – All	0.51	1.8	0.72	0.042	0.069	0.060	16	31	17.4
Chironomids/ Oligochaetes	0.90	1.8	1.8	0.032	0.048	0.048	13	15	13.6
Insecta/Mollusca and Crustaceans	0.31	0.74	0.41	0.047	0.069	0.069	18	31	19.6
Fish – All	0.34	0.94	0.40	0.40	1.3	0.62			
Predators/ Bottom Feeders	0.35	0.94	0.46	0.35	1.3	0.80			
Predators	0.40	0.94	0.63	0.61	1.3	0.84			
Bottom Feeders	0.29	0.44	0.44	0.10	0.29	0.16			
Large/Small Forage	0.32	0.54	0.42	0.45	0.91	0.70			
Large Forage	0.36	0.47	0.47	0.69	0.91	0.77			
Small Forage	0.29	0.54	0.46	0.21	0.42	0.29			
Terrestrial Insects–All	ND	ND	NC	0.066	0.1	0.08	45.8	75	51.4
Beetles	ND	ND	NC	0.073	0.088	0.088	36.4	44	38.4
Terrestrial Insects	ND	ND	NC	0.060	0.1	0.09	55.1	75	63.9
Emergent Insects	0.27	0.64	0.42	0.028	0.039	0.039	39.8	51	43.6
Plants- All	ND	ND	NC	ND	ND	NC	21.2	160	30.9
Submerged Aquatic	ND	ND	NC	ND	ND	NC	8.9	23	23
Floating Aquatic	ND	ND	NC	ND	ND	NC	46.9	160	160
Mast	ND	ND	NC	ND	ND	NC	7.9	11	10.6

ND Not Detected - Constituent not detected in biological tissue sample.
NC Not Calculated - 95%UCL not calculated given that constituent not detected in biological tissue samples.
95%UCL The lesser of the maximum detected concentration for each COPC or the 95% UCL.
(1) Environmental media concentrations in mg-kg-dry weight, unless otherwise noted; Biological tissues concentrations in mg/kg-wet weight.
(2) Units for surface water and wetland water are mg/L.

The estimated daily exposure derived from dietary exposure modeling was compared with relevant and appropriate toxicity data from existing laboratory studies to arrive at numerical estimates of potential risk. These numerical risk estimates, in consideration for appropriate uncertainties, were used to assess whether the upper trophic level endpoints associated with Welch Creek are potentially at risk.

e. Direct Ecological Effects Characterization

Direct ecological effects characterization activities were conducted for the Welch Creek area. The direct ecological effects characterization activities included:

- Assessment of macroinvertebrate population density and diversity in Welch Creek sediments relative to local reference environments to augment 1995 Welch Creek study observations
- Assessment of fish population density and diversity in Welch Creek relative to Conaby Creek
- A habitat assessment conducted in Welch Creek during the RI activities
- Performance of sediment and surface water biotoxicity testing to augment 1995 Welch Creek study observations
- Comparison of observed fish tissue and surface water concentrations to literature benchmarks

The following sections summarize the results of the direct effects characterization activities conducted in Welch Creek.

Benthic Macroinvertebrate Community Survey

Confirmational benthic macroinvertebrate surveys were conducted for Welch Creek during the RI/FS data gathering activities. Organism density and diversity were comparable in littoral zone samples collected in Welch Creek and the reference Conaby Creek. A total of 45 taxa were collected from the two stations in Conaby Creek and a total of 64 taxa from the three stations in Welch Creek. At Conaby Creek, the number of taxa ranged from 31 at Station CC-8 to 34 at Station CC-6. At Welch Creek, the number of taxa was the same or higher than in Conaby Creek (reference creek) ranging from 31 at MT-8 to 45 at MT-1. Organism density and diversity was also comparable in sediment samples collected in Welch Creek and the reference Conaby Creek. A total of 31 taxa were collected from the two stations in Conaby Creek and 50 taxa from the three stations in Welch Creek. Both creeks are dominated by either phantom midges or chironomid midges and oligochaete worms. For both littoral zone and sediment samples, individual differences in benthic community between Conaby Creek and Welch Creek are likely a function of location, habitat, or other conditions not related to water quality differences between the creeks. The number of taxa collected in littoral zone samples was similar in magnitude but different between years at each station. Compared to 1995 survey results, the number of taxa were higher at all stations in the 1999 petite ponar samples.

Benthic communities at all sites were comprised primarily of moderately tolerant to tolerant dipterans, worms and fingernail clams, and many of the respective numerically dominant taxa were represented and relatively abundant at the other sites. Overall, Conaby and Welch Creek data do not indicate much difference between the sites, in terms of macroinvertebrate community metrics or their implied water quality ratings. It does not appear that water quality or sediment related stress, as indicated by indigenous macroinvertebrate communities, in Welch Creek are substantially different from those conditions in Conaby Creek; NCBI suggests very similar conditions at CC-6 and MT-6 and at CC-8 and MT-8.

An independent review of the methodologies, results and conclusions of the benthic survey was performed by local experts within the NC DENR Division of Water Quality (NC DWQ). The reviewer concluded that the general study design is adequate to compare the benthic communities of Welch Creek and Conaby Creek. The reviewer concluded that there are some significant differences between Welch Creek and Conaby Creek, but they should not interfere with the objectives of the study. Furthermore, the reviewer concluded that the invertebrate communities in both creeks are strongly influenced by periods of low dissolved oxygen.

Fish Community Survey

Fish diversity surveys were conducted for Welch Creek during the RI/FS data gathering activities. Observed fish population density and species diversity were similar between Welch Creek and the reference Conaby Creek. A total of 29 species of fish (plus several hybrid sunfish) were collected in Conaby and Welch Creeks during the 1999 survey. A total of 25 species were collected by either electrofishing or gillnetting in Welch Creek, and a total of 22 species of fish were collected by electrofishing only in Conaby Creek. The total number of species for Welch Creek is the same as that for Conaby Creek for electrofishing only data with 22 species being collected from each creek. Eighteen fish species collected were common to both Conaby and Welch Creeks. No Deformities, Erosions, Lesions, and Tumors (DELT) anomalies were observed externally on fish collected from the three Welch Creek locations.

Habitat Assessment

Habitat assessments were conducted for Welch Creek during the RI/FS data gathering. Sampling stations at Conaby and Welch Creeks were surrounded by forested wetland consisting primarily of cypress, black gum, maple, ash, and alder. The creeks ranged in width from 100 feet to 160 feet (30 meters to 50 meters) and were 10 feet to 16 feet (3 meters to 5 meters) in depth at mid-channel. The bottom substrate in both creeks consisted of coarse particulate organic matter, muck and silt. Some stations also had a component of fine sand or clay.

Aquatic plants observed included duckweed, Lemna, and the yellow pond lily, Nuphar, at most stations and a small amount of bladderwort, Utricularia, at MT-6 and MT-8. Water snakes and turtles were common in Welch Creek. Birds that were observed at Conaby and Welch Creeks included great blue heron and wood ducks. Other bird species observed included pileated woodpecker, Canada geese, mallard ducks, kingfishers, and osprey. Mammals observed included beaver, muskrat and white-tailed deer. Other observations included the occurrence of relic unionid clam shells on the banks of Welch Creek.

Habitat quality was evaluated at each sampling station using the NC DENR habitat assessment form for Coastal Plain streams (NC DENR, 1997). The habitat scores were broken down into three classification groups: 80 and higher were good; 79 to 60 were fair; and <60 were poor. Scores for the five locations were as follows:

LOCATION	SCORE
MT-1	82
MT-6	47
MT-8	69
CC-6	68
CC-8	68

Habitat quality in Welch Creek was assessed as relatively good at MT-1 (total score of 82) where the stream is narrow and sinuous with a nearly complete canopy and abundant near-bank cover (*e.g.*, over-hanging vegetation, instream woody debris, and macrophytes). Downstream, natural changes in the creek, such as a broadened channel, more open canopy, and less instream cover all contributed to the relatively lower scores at MT-6 (47) and MT-8 (69). In addition, industrial modification on the north bank at MT-6 (*e.g.*, leveed and canopy removal) also contributed to the lower score at that station. Habitat quality at MT-8 improved relative to MT-6 and was virtually identical to the two Conaby Creek locations.

Direct Effects Toxicity Testing

The following confirmatory toxicity testing was performed as a component of the 1999 RI:

- Performance of confirmational sediment biotoxicity testing for Welch Creek sediment and wetland soil with Hyalella azteca
- Performance of supplemental/confirmational surface water biotoxicity testing for Welch Creek surface water and wetland water with fathead minnows

The sediment toxicity testing results indicate that sediment at MT-1 and wetland soil at all Welch Creek locations tested do not exhibit a detrimental effect on growth or survival of Hyalella azteca. Sediment from MT-6 and MT-8 did not adversely affect Hyalella survival, but did exhibit an adverse effect on organism growth (as evidenced by lower dry weights at test completion).

The surface water and wetland water toxicity testing results indicate that water from the locations tested does not exhibit a detrimental effect on growth or survival of fathead minnows (P. promelas). These results are consistent with surface water toxicity testing performed with fathead minnows during the 1995 Welch Creek Study.

Comparison to Benchmarks

Dioxin TEQs (WHO-fish) in Welch Creek fish tissues and surface water and wetland water were compared to effects benchmarks available in the literature. Dioxin TEQs(WHO-fish) in whole fish tissues collected in Welch Creek were compared to effects benchmarks available in "Linkage of effects to tissue residues: development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals" (Jarvinen and Ankley, 1999). The average and maximum observed dioxin TEQs (WHO-fish) in Welch Creek fish tissues were below the effect level benchmark ranges (143 to 530 ng/kg).

Dioxin TEQs (WHO-fish) in surface water were also compared to effects benchmarks available in Jarvinen and Ankley (1999). The average and maximum observed dioxin TEQs (WHO-fish) in Welch Creek surface water and the average observed dioxin TEQs (WHO-fish) in wetland water are below the benchmark no effect level (0.038 ng/L). Only the maximum observed dioxin TEQs (WHO-fish) in wetland water was above this benchmark.

f. Modeled Risk Characterization

The risk characterization step of the ecological assessment relies on the integration of data on exposure and effects to arrive at findings and conclusions relative to risks posed to the selected ecological receptors. The result of this characterization determines whether there are potential unacceptable risks posed to ecological receptors by site-related constituents. The risk characterization includes both qualitative and quantitative presentations of the risk results relative to each assessment endpoint. Consistent with USEPA guidance (USEPA, 1997), the ecological risk characterization relies on the Hazard Quotient (HQ) method as an indicator of the risks posed to the ecological endpoint.

The HQ method compares an estimated exposure level or daily dose to reference values (TRVs) for each modeled ecological COPC under consideration. The BERA for the Welch Creek area incorporated two approaches (conservative and alternative) to HQ estimation based on the dietary exposure modeling for upper trophic level receptors, as indicated below.

Conservative Exposure Scenario

DESIGNATION	EXPOSURE LEVEL	TOXICITY VALUE
$HQ_{max\text{-}NOAEL}$	Maximum Concentrations	NOAEL
$HQ_{avg\text{-}NOAEL}$	Average Concentrations	NOAEL
$HQ_{max\text{-}LOAEL}$	Maximum Concentrations	LOAEL
$HQ_{avg\text{-}LOAEL}$	Average Concentrations	LOAEL

Alternative Exposure Scenario

DESIGNATION	EXPOSURE LEVEL	TOXICITY VALUE
$HQ_{95\%UCL\text{-}NOAEL}$	95% UCL of Mean Concentrations	NOAEL
$HQ_{avg\text{-}NOAEL}$	Average Concentrations	NOAEL
$HQ_{95\%UCL\text{-}LOAEL}$	95% UCL of Mean Concentrations	LOAEL
$HQ_{avg\text{-}LOAEL}$	Average Concentrations	LOAEL

Table H-12 presents a summary of final ecological COCs for the Welch Creek area by assessment endpoints. For the Welch Creek area, COCs identified from dietary exposure modeling, based on at least one estimated HQ greater than 1.0, were dioxin TEQ and mercury.

Table H-12
Summary of Ecological COCs and Primary Sources of Risk for the Welch Creek Area

COC	PISCIVOROUS MAMMAL (RIVER OTTER)		PISCIVOROUS BIRD (GREAT BLUE HERON)		HERBIVOROUS/ INSECTIVOROUS BIRD (WOOD DUCK)		INSECTIVOROUS BIRD (BARN SWALLOW)	
	CONSERVATIVE	ALTERNATIVE	CONSERVATIVE	ALTERNATIVE	CONSERVATIVE	ALTERNATIVE	CONSERVATIVE	ALTERNATIVE
Dioxin TEQ[1]	**Yes.** Fish	**Yes.** Fish	**Yes.** Fish and sediment but only when using the chronic adjusted TRVs	**Yes.** Fish and sediment but only when the maximum concentration is compared to the chronic adjusted NOAEL	**Yes.** Sediment, plants, and invertebrates but only when using the chronic adjusted NOAEL	**Yes.** Sediment, plant, and invertebrates but only when the maximum concentration is compared to the chronic adjusted NOAEL	**Yes.** Emergent insects but only when using the chronic adjusted NOAEL	**Yes.** Emergent insects but only when using the chronic adjusted NOAEL
Dioxin TEQ[2]	**Yes.** Fish	**Yes.** Fish	**Yes.** Fish and sediment	**Yes.** Fish and sediment but only when the maximum concentration is compared to the chronic adjusted NOAEL	**Yes.** Sediment, plants, and invertebrates	**Yes.** Sediment, plant, and invertebrates but only when the maximum concentration is compared to the chronic adjusted NOAEL	**Yes.** Emergent insects	**Yes.** Emergent insects
Chromium								
Mercury	**Yes.** Fish[3]	**Yes.** Fish[3] but only when compared to the NOAEL	**Yes.** Fish[3]	**Yes.** Fish[3] but only when compared to the NOAEL	**Yes.** Sediment and invertebrates but only when compared to the NOAEL		**Yes.** Emergent insects but only when the maximum concentration is compared to the NOAEL	**Yes.** Emergent insects but only when the maximum concentration is compared to the NOAEL
Zinc								

(1) Dioxin TEQs calculated using USEPA I-TEFs (USEPA 1989)
(2) Dioxin TEQs calculated using WHO mammalian or avian TEFs, as appropriate (WHO 1998)
(3) Background concentrations for both Conaby Creek and Roanoke River would also result in a modeled risk for selected endpoint in excess of threshold (HQ=1.0).

g. Uncertainty Analysis

The primary goal of the uncertainty analysis is to provide a discussion of the key assumptions made in the risk assessment that significantly influence the estimate of risk. The ecological risk estimates for the site is based on a number of assumptions that incorporate varying degrees of uncertainty resulting from many sources. The ecological risk characterization for the upper trophic level species presented in the BERA relies on a deterministic "HQ" method (*i.e.*, point estimates of risk derived from ratios of modeled exposure concentrations and toxicity reference values believed to be potentially harmful to organisms). Such screening-level data and models are designed to be conservative, to minimize the possibility that any potential adverse effects are missed in the risk assessment. The deterministic methods generally overstate the actual effects of chemicals at most sites, focus too narrowly on individual versus population effects, and limit appropriate reflection of variability and uncertainty inherent in the natural system. As an example, for each endpoint species evaluated, the conservative exposure scenarios presented in the risk assessment compound conservative dietary assumptions, namely, maximum ingestion rate and minimum body weight, to yield a conservative (overestimated) exposure estimate (on a dose per body weight basis). In reality, both these critical dietary exposure variables are proportional to each other and are likely represented in a normal distribution in the ecosystem.

Uncertainties in exposure level in the conservative exposure scenario were bracketed by considering the maximum observed concentration and the average observed concentration as estimates of the exposure point concentration for environmental media and forage materials. Uncertainties in exposure level in the alternative exposure scenario were bracketed by considering the 95 percent UCL of the mean concentration and the average observed concentration as estimates of the exposure point concentrations. Uncertainties in toxicity/exposure-response were bracketed by calculating hazard quotients using both the NOAEL and the LOAEL. Specific to dioxins, the additional uncertainties related to estimating the hazard to avian species were further refined by utilizing a range of NOAEL and LOAEL avian dioxin toxicity values. The relative differences between the hazard quotients calculated with each set of assumptions provide an indication of the relative extent to which the spatial variability in the detected concentrations versus the sensitivity of the dose-response is influencing the hazard quotient calculations. In interpretation of the modeled HQs as a potential indicator of ecosystem effects, higher weighting was assigned to LOAEL-based HQs. Comparison of reasonably conservative exposure estimates (*i.e.*, average observed concentrations and maximum exposure assumptions or upper bound limits [95 percent UCL] on observed concentrations and central tendency exposure assumptions) to LOAELs were considered to most appropriately characterize the potential for adverse ecological effects.

h. Preliminary Ecological Remedial Goal Options (RGOs)

One of the objectives for the ecological risk assessment activities for Welch Creek was to provide the information necessary to support risk management decisions concerning the practical need for, and the extent of remedial actions in the Welch Creek area. Preliminary numerical RGOs were established for Welch Creek media reflecting ecological exposure considerations for the populations resulting in a modeled HQ greater than 1.0. Based on the results of the modeled ecological risk characterization, dioxin/furans and mercury are appropriate for consideration in risk-based decision making for the

Welch Creek area. Development of preliminary numerical RGOs were evaluated for both COCs in the BERA.

The RGO represents a specific media concentration that is modeled to not exceed a HQ of 1.0. Inherent in this calculation is the assumption that the concentration of a COC in a specific medium actually produces the hazard in the endpoint. It is also assumed that the relationship between concentration and hazard is linear. The preliminary RGOs developed for dioxin and mercury are discussed below.

Dioxins

Preliminary ecological RGOs for dioxin, reflective of site-specific ecological exposures to COCs in the Welch Creek area, for a target HQ of 1.0 were calculated in the BERA. The range of preliminary RGOs are presented in Table H-13.

The term "RGO" was used to identify a dioxin concentration (as I-TEQ) quantified in surficial sediment that defines areas for evaluation in the Welch Creek FS. This distinction is important since the former definition implies a numeric cleanup goal, whereas the Welch Creek definition and application of the RGO defines an area of the creek for detailed FS evaluations. The USEPA specifically identified the target RGO as 410 ppt I-TEQ for dioxin found in surficial sediment deposits. This concentration, from the Welch Creek BERA, is based upon protection of the river otter at the no adverse effect level (NOAEL) for food chain modeling and is the lowest concentration presented in the approved Welch Creek BERA. This delineation concentration of 410 ppt dioxin (I-TEQ), incorporates the conservative assumptions embedded in the risk assessment and utilizes the no adverse effects concentration in contrast to the low adverse effects concentrations (the LOAEL based numbers are typically considered a more probable effects concentrations). This concentration thus provided sufficient conservatism for use in delineation of areas for the FS without modification to address uncertainty or variations in bioavailability. Application of this delineation number was applied to all three reaches of Welch Creek (see Section I of this ROD). As noted in later sections, USEPA ultimately selected a final cleanup level for dioxin in sediment of 1.0 ppb which was well within the range of protective calculated RGOs in the BERA.

Mercury

As presented in the Welch Creek BERA, the assumption that there is a linear relationship between environmental media and biological tissues may be inappropriate for those anthropogenic constituents that have significant non-point sources to the environment and where biogeochemical transformations complicate relationships in the ecological system. Mercury is pervasive in the environment and has multiple sources in the complex ecosystem of Welch Creek. This is further discussed in the Welch Creek FS (RMT, 2007). Additional data and information regarding

Table H-13
Range of Ecological RGOs for Welch Creek Area Sediments

COC	CONSERVATIVE			ALTERNATIVE		
	NOAEL-BASED RGO (mg/kg)	GM-BASED RGO (mg/kg)	LOAEL-BASED RGO (mg/kg)	NOAEL-BASED RGO (mg/kg)	GM-BASED RGO (mg/kg)	LOAEL-BASED RGO (mg/kg)
Dioxin TEQ [1]	0.00041 to 0.0041 mg/kg			0.0010 to 0.010 mg/kg		
River Otter	0.00041	0.0013	0.0041	0.0010	0.0032	0.010
Dioxin TEQ [2]	0.00041 to 0.2 mg/kg			0.001 to 0.39 mg/kg		
River Otter	0.00041	0.0013	0.0041	0.0010	0.0032	0.010
Great Blue Heron *Unadjusted TRVs*	0.0087	0.028	0.087	0.025	0.078	0.25
Adjusted TRVs	0.00087	0.0028	0.0087	0.0025	0.0078	0.025
Barn Swallow *Unadjusted TRVs*	0.020	0.063	0.20	0.015	0.046	0.15
Adjusted TRVs	0.0020	0.0063	0.020	0.0015	0.0046	0.015
Wood Duck *Unadjusted TRVs*	0.0063	0.020	0.063	0.039	0.12	0.39
Adjusted TRVs	0.00063	0.0020	0.0063	0.0039	0.012	0.039

(1) Dioxin TEQs calculated using USEPA I-TEFs (USEPA 1989)
(2) Dioxin TEQs calculated using WHO mammalian or avian TEFs, as appropriate (WHO 1998)
Shaded rows indicate the use of the more conservative adjusted NOAEL (1×10^{-6} mg/kg-day) and LOAEL (1×10^{-5} mg/kg-day).
NOAEL No Observed Adverse Effects Level.
GM Geometric mean of the NOAEL and LOAEL.
LOAEL Lowest Observed Adverse Effects Level.

mercury bioavailability was incorporated into a revised site conceptual model for the site (Figure E-1). Site-specific data collected from both Welch and Conaby Creeks confirmed that mercury concentrations in biological tissue do not correlate with co-located mercury concentrations in sediment. However, Welch Creek fish tissue concentrations were higher than those measured in Conaby Creek. Upon review of additional fish tissue trend information for the region, Welch Creek mercury fish concentrations were comparable to fish from other water bodies in the region (as discussed in Attachment 2B of the Welch Creek FS). Therefore, due to the presence of well documented on-going air sources of mercury, the ability of sulfides in the sediment to reduce the availability of mercury in that media, and the overall complexity of mercury processing in the wetlands and creek environment (see Attachment 2A of the Welch Creek FS), a preliminary RGO for mercury was developed based upon fish tissue concentrations and comparison to background fish tissue levels, rather than sediment concentrations. Thus, mercury sediment concentrations were not used to establish areas of Welch Creek sediment for remedy consideration in the Welch Creek FS. A mercury RGO of 0.15 mg/kg for bluegill whole fish tissue was proposed based on recommendation by USEPA in their response to the Welch Creek BERA text revisions and ecological risk assessment discussion items, agreements, and action items letter dated April 3, 2003. The RGO is based on a No Observed Effects Concentration (NOEC). Since mercury concentrations in background fish may change overtime, the proposed RGO will be reassessed periodically using updated background information.

I. Remedial Action Objectives

Remedial Action Objectives (RAOs) for the Welch Creek area were developed based on the requirements of the National Contingency Plan (40 CFR §300.430[e][2][i]), which defines remedial action objectives as a listing of the COCs and media of concern, potential exposure pathways and remediation goals. Specific RAOs were developed from a review of the results of site characterization activities, site-specific risk and fate and transport evaluations, and an initial review of ARARs. In addition, RAOs were developed during portions of the facilitated meetings which were held with USEPA, NC DENR, USFWS, NOAA, USACE and Weyerhaeuser. These stakeholders identified and discussed their desired outcomes for the Welch Creek remedial action. This stakeholder input was used to finalize the Welch Creek RAOs, which were documented in a memorandum dated May 21, 2004, as Action Item No. 35. The following agreed upon RAOs for Welch Creek include goals for the protection of human health and the environment and for the management of migration potential.

Human Health Remedial Action Objectives

- Maintain acceptable levels of potential risk to site-specific human receptors.
- Continue progress toward removal of remaining fish consumption advisory in Welch Creek.

Ecological Remedial Action Objectives

- Protect the health of local populations and communities of biota.
- Reduce the dioxin concentrations in whole fish tissues over time, to the extent practicable.
- Achieve surface water concentrations at or below surface water standards, to the extent practicable.
- Limit biological uptake of COCs from the sediment in areas with excess potential risk, to the extent practicable.
- Minimize the adverse effects of remediation activities on the existing aquatic environment and/or wetland habitat, to the extent practicable.

Management of Migration Potential

- Minimize significant migration of COC-containing sediment in delineated areas of concern, to the extent practicable.

Application of Remedial Goal Options

For the Welch Creek, the term Remedial Goal Option (RGO) was used to identify a dioxin concentration (as I-TEQ) quantified in surficial sediment that defines areas for evaluation in the Welch Creek FS. The USEPA specifically directed the target RGO as 0.41 ppb I-TEQ for dioxin found in surficial sediment deposits. The range of calculated RGOs varied from 0.41 ppb to 4.1 ppb in the approved Welch Creek BERA. This range of RGOs was for protection of the river otter based upon food chain modeling. These RGOs for the otter were the most conservative (lowest) of all the cleanup levels evaluated for mammals and birds.

USEPA selected a sediment cleanup goal from within the range of RGOs. One consideration in choosing within such a range is to use a statistical measure – the geometric mean. In this case, the geometric mean of the cleanup levels is 1.3 ppb. An additional consideration was USEPA guidance (OSWER Directive 9200.4-26)