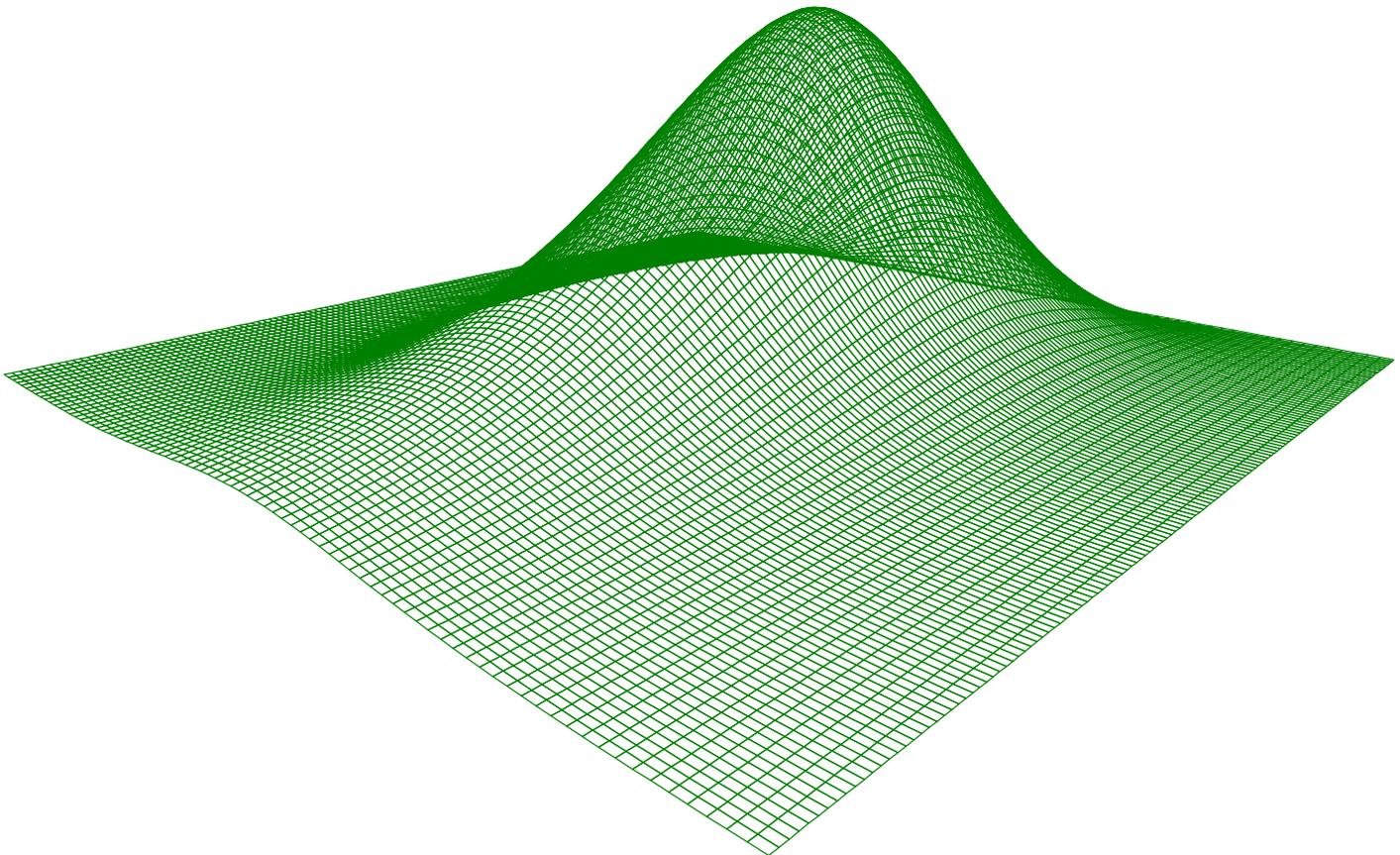


**Environmental Pathway Analysis
Wood Preserving Site
Brunswick, Georgia**

**Georgia Institute of Technology
CEE 4340 Final Report
Jeremy Nichols**



Plume distribution of Beryllium in 1997.

Abstract

A contaminated site was selected for computational simulation of hazardous material pathways in the environment, and analysis conducted for the potential exposure risk of these chemicals. The Brunswick Wood Processing site was designated as an EPA Superfund site due to the high levels of hydrocarbons and heavy metals persisting after the discontinuation of operations in 1991. A solution domain which encompassed the nearby estuarine tributary was determined to be applicable, and potentiometric contours and well locations were used to inform the calibration of the model. Realistic values for the physical properties of the soil at the site were determined using a map of the soil profiles at the site and literature pertaining to coastal sands and aquifer parameters. Probable initial concentrations of the contaminants of concern were back calculated using the calibrated model and reported concentration values in 1997. These values were then used to determine the probabilistic concentrations reaching the creek in three time periods: 1990, during operation of the facility; 1997, the year the site was designated a Superfund location; and 2015 to predict the current concentrations of contaminant reaching the stream. It was found that although certain heavy metals had exceeded EPA standards in the past, there are currently no violations of maximum concentration level guidelines reaching the creek. The hydrocarbons that were detected in 1997 all experience higher rates of decay than the heavy metals, and as such are less likely to continue to be hazards at the site. Although the model does not fully describe all of the variables that contributed to the pollution of the site, the groundwater transport route is reasonably simulated. Remediation efforts at the site have also diminished the possibility of continued negative health effects due to the compounds originally released into the environment.

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Introduction

To demonstrate and utilize the topics covered in the course *Environmental Modeling and Health Risk Analysis*, a contaminated site was chosen for which a transportation pathway analysis would be performed. Using principles of the fields of fluid mechanics, geotechnical engineering, and environmental systems design, parameters were defined for the site for use in the Analytical Contaminant Transport Systems software (ACTS). Using available information regarding the nature of the contamination at the site, as well as published specifications for the physical properties of the soil and subsurface water systems in the area immediately surrounding and contained within the analyzed domain, a model was created using the ACTS software that presented results both deterministically and probabilistically. These results were then compared to reported findings by the agencies responsible for the official site analysis and remediation procedures. Further discussion and conclusions were drawn as to the effectivity of this process and areas of potential refinement and improvement identified.

Background

A designated Environmental Protection Agency (EPA) Superfund site, the grounds of an abandoned wood processing facility in Brunswick Georgia have presented numerous environmental concerns for nearby residents decades after the cessation of operations at the site. Surface and ground water contamination has led to instances of health advisories regarding consumption of seafood sourced from nearby rivers and estuarine systems as recently as August, 2014 (Sanchez 2014).

The Brunswick Wood Preserving (BWP) facility is located off of Perry Lane in Glynn County, Georgia, between Interstate 95 and Highway 341. The property occupies approximately 80 acres of land, bounded by Perry Lane to the North, railroad tracks to the East, and private residential areas to the South. Located to the West of the property is Burnett Creek, a small tidal stream that feeds into the Brunswick River estuary system. Beginning operations in 1958 by the Escambia Treating Company, the facility was active until 1991 when the current owner Brunswick Treating Company filed for bankruptcy following a fire at the location. (“Brunswick Wood Preserving Superfund National Priorities List Site”).

While operating, the preservation process utilized the most common oil based preservative creosote in addition to pentachlorophenol (PCP) and chromated copper arsenate (CCA). The treatment process generates large amounts of wastewater contaminated with these chemicals and their byproducts. The wastewater was treated on site before being released into the facilities above ground impoundments or the nearby Burnett Creek. Common practice of the era did not include the placement of concrete slab foundations under processing, drying, or storage areas leading to direct infiltration of the soil with the preserving compounds (Moore and Balir 1997).

The same year that the facility closed, the EPA began conducting subsurface soil and water sampling of the area and initial abatement of the contamination was conducted. It was determined that elevated levels of the chemicals used in the preserving process were present at depths up to 9 feet below the surface; the main compounds of concern were identified as PCP and one of its impurities dioxin, polycyclic aromatic hydrocarbons (PAHs), arsenic, and

chromium. During this initial phase of cleanup, over 127,000 tons of contaminated soil were excavated and stored on site in lined and covered receptacles (Moore and Balir 1997).

The location was officially added the EPA's National Priorities List (NPL) as a Superfund site in 1997. Final remediation began in 2007 according to the 2002 cleanup plan with the removal of contaminated soil and settlements from the impoundment pond and replacement with backfill soil. Further efforts to contain the pollution included the construction of engineered caps on top of containment cells, and the installation of subsurface barrier walls. Groundwater treatment was conducted on site from 2011 to 2013, with ongoing study of the containment cells intended to identify any concerns with the effectiveness of remediation. Further remediation of creosote contamination is planned and expected to be completed by 2016 (EPA Superfund 2015).

Methodology

The Brunswick Wood Preserving site was chosen due primarily to the author's knowledge of the surrounding area and current work regarding on coastal Georgia's habitat and circumstances. The site has long been source of concern for residents of the affected area and has been on the EPA's National Priorities List since 1997, remediation efforts at the location continue, as the locus currently exists as an unused brown field with the EPA considering the contaminated ground water status 'Not Under Control,' although the human exposure status is listed as 'Under Control.' (EPA Superfund 2015).

Documents sourced from the Agency for Toxic Substances and Disease Registry (ASTDR) include maps highlighting the monitoring wells placed on the facility grounds as well as the location of the main wastewater impoundment in addition to maps detailing the broader topography of the area. These maps were georeferenced using GIS software and current aerial photography, allowing for fine grained calculation of necessary physical parameters of the site including grid referenced well locations and estimated flow lines. Figure 1 below illustrates these well locations and shows the given potentiometric gradient at the site, from which the general flow direction was determined.

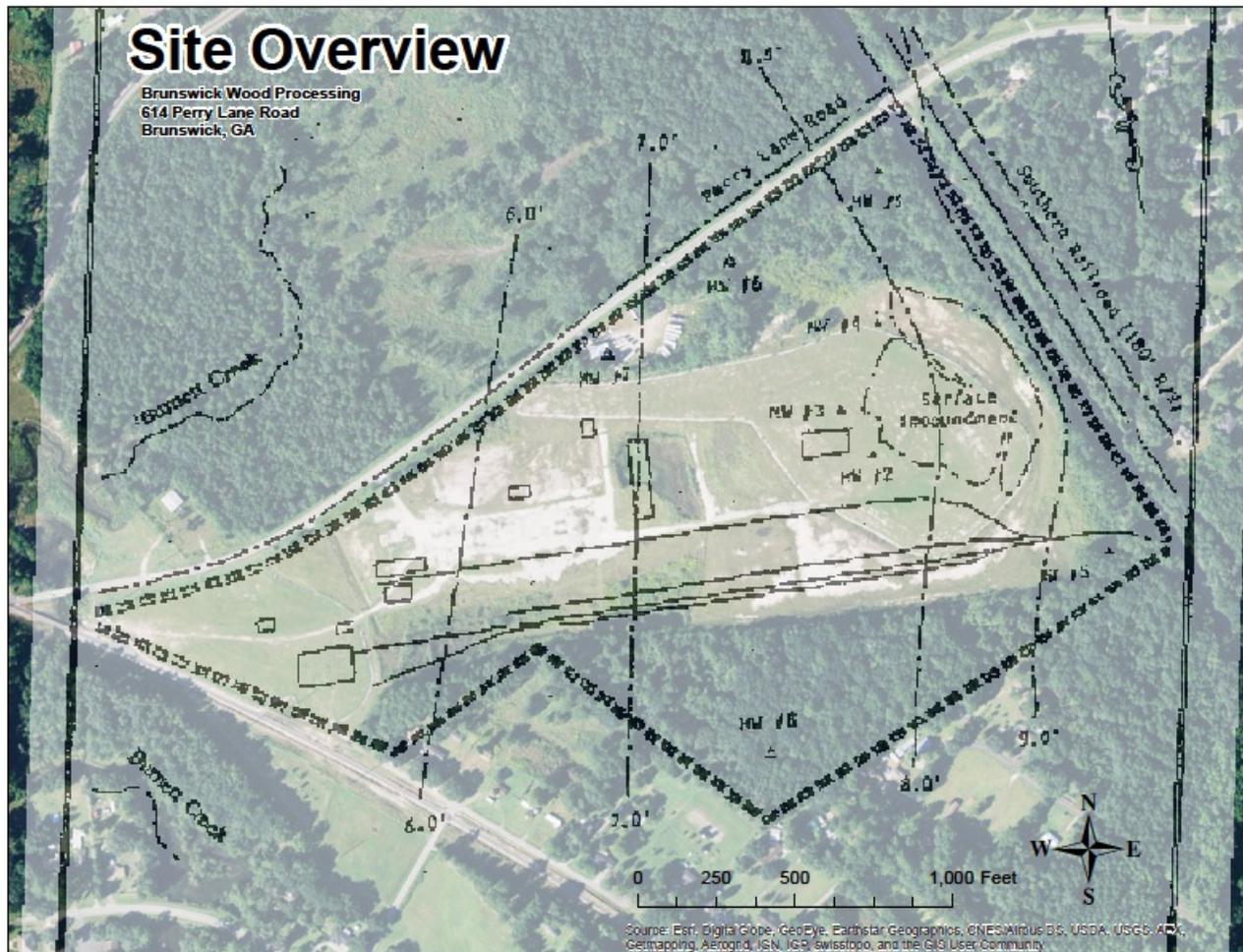


Figure 1: Brunswick Wood Processing Site Overview. Original ASTDR map referenced spatially to aerial photography of the region. The original map can be found in the Appendix.

After the solution domain had been determined using the available geospatial data, physical parameters of the soil were found using USGS maps of the locality and a profile for the most likely dominant substrate built. The soil at the site is largely silty sand and sandy loam, with a patchwork of specific soil types lying between the large impoundment and the nearby Burnett Creek. Figure 2 provides the visual distribution of soil types that dominant the area, with the solution domain, flow direction, and well locations superimposed.

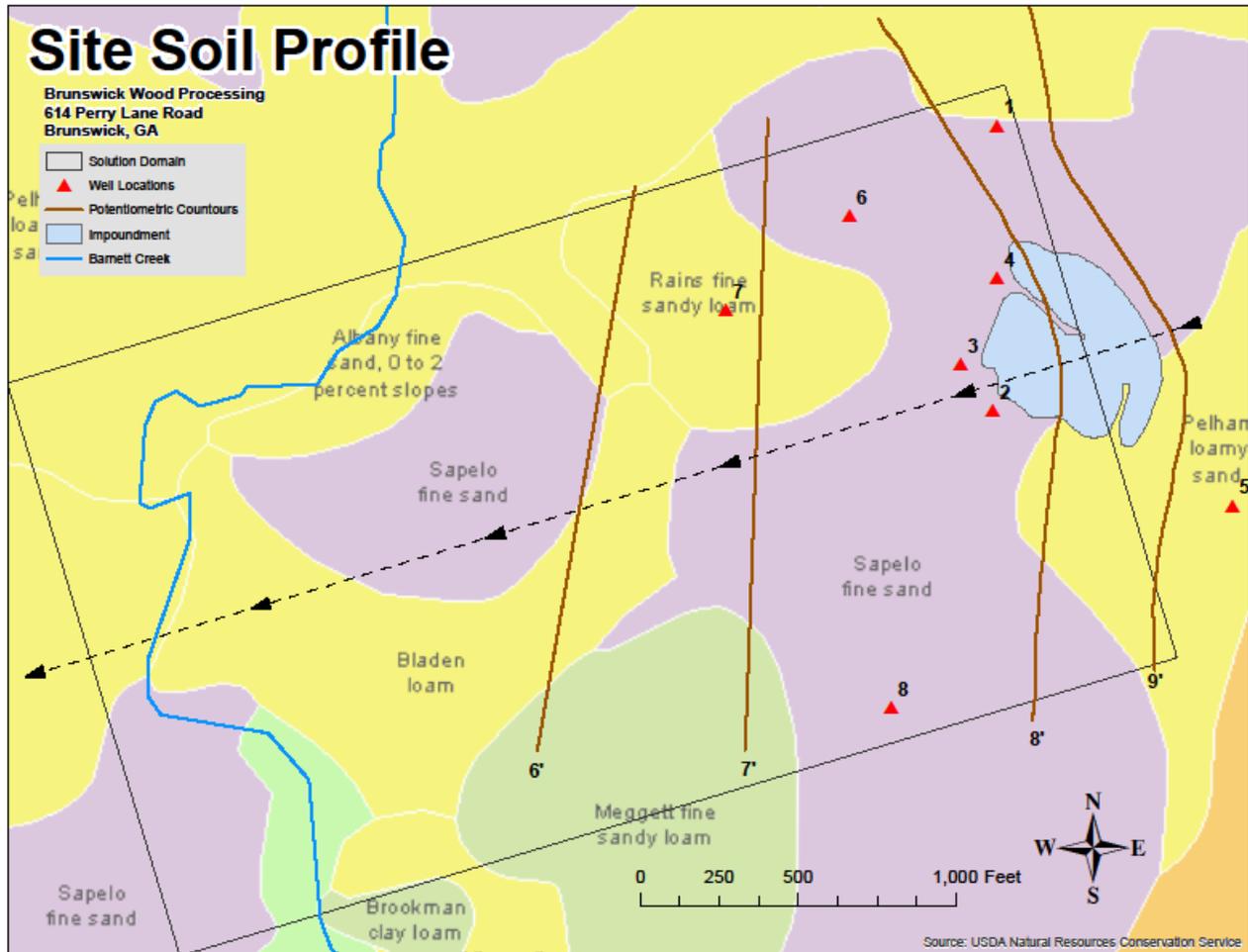


Figure 2: Soil profile consisting largely of fine sands and sandy loam, with the well locations, impoundment, flow direction, and domain drawn using the original ASTDR site map.

Mean reported values for the overall USCS group were compared to literature values pertaining to specifically observed values for the region to obtain an accurate range for the hydraulic conductivity and porosity of the soil underlying the domain. Using this range of permeability and reported transmissivity of the area, a Darcy velocity for the domain was calculated using the hydraulic gradient of the site determined from the potentiometric head lines and measured distances from the georeferenced ASTDR diagrams. Published values for the aquifer recharge rate and surficial aquifer thickness were obtained and used to further build the

model. Table 1 lists the parameters initially used to create the ACTS model; a two-dimensional saturated constant dispersion groundwater framework with a finite line source contamination was chosen as it best captures the nature of contaminant flow from the wide impoundment through the solution domain.

Table 1: Values used to inform the creation of the ACTS model

Parameter	Reported Value	Source
Porosity	0.378	Roman-Sierra, Munoz-Perez, and Navarro-Pons (2014)
Transmissivity	540-14,000 ft ² /day	Payne, Rumman, and Clarke (2005)
Recharge	49 in/year	Payne, Rumman, and Clarke (2005)
Hydraulic Conductivity	70 ft/day	Payne, Rumman, and Clarke (2005)
Aquifer Thickness	200-300 ft	Gill, Williams, and Bellino (2011)
Ethylbenzene Decay	0.3% per day	Suarez and Rifai (1999)

To calibrate the model for the best possible simulation of groundwater flow through the region, ethylbenzene was chosen to serve as the verification parameter as it was detected at the highest number of wells. These wells are spread across both sides of the centerline of the flow at varying distances, and provided three distinct points for which substantiation of model accuracy could be conducted. For tabulated locations of the wells and further information about the specifications of the solution domain, see the Appendix. Three different time domains were used to test the effects of extending the contamination period on known concentrations. The first used 1970 as the initial time period for contamination, although still well past the beginning of operations at the site, this year was mentioned in the literature as the time period when CCA was heavily in use and the facility was at full operation. A second, more recent time period (1980) was chosen to give further data points regarding possible contamination levels during operation, and a final initial time value of 1990 was chosen to see what initial concentrations would have been present during the final year of wood treatment at the study location. It was decided that using 1980 as the initial time value and selecting 1991 (the cessation of operation date) as the cutoff for contaminant input provided an adequate description of past pollution while maintaining the correct date for abeyance of contamination input. The specifications used in the model for the extent of the time range are also included in the Appendix.

Calibration proceeded in a pure analytical manner, with a process of iteration used to find an initial concentration that would provide the reported concentration in 1997. This value was then checked at the other two well locations to see if the initial concentration would provide a consistent plume dispersion when compared to the reported values at the second and third calibration locations. Once the model had been calibrated to correctly approximate the relative concentrations at each well location, back calculations were conducted to find the initial

concentration that would have been present in the surface impoundment during the years of operation. It was determined that for the levels of contamination seen at the monitoring wells in 1997, the concentration of ethyl benzene present in the surface impound would have exceeded 4 mg/l (4 ppm) – more than 5 times the maximum contaminant level (MCL) specified by the EPA. Table 2 displays the final deterministic values used in the ACTS model after calibration.

Table 2: Final deterministic values used in the calibration of the model for ethylbenzene.

Parameter	Value	Unit
Ground Water Darcy Velocity	0.10899	ft/day
Longitudinal Dispersion		
Coefficient	350	ft ² /day
Lateral Dispersion Coefficient	20	ft ² /day
Contaminant Half-Life	230	days
Aquifer Porosity	0.38	-
Net Recharge	0.01119	ft/day
Effective Aquifer Thickness	250	ft
Retardation Coefficient	4.7697	-

Groundwater flow parameters and aquifer characteristics remained constant throughout the running of the simulation, however the retardation coefficient and half-life are dependent on the chemical being modeled, and as such varied with each chemical simulation. The values used for these simulations of the full range of chemicals are found in the Appendix. The initial concentration of these chemicals was determined by using the calibrated model to determine the ratio of initial concentration to concentration present in 1997 – using the ASTDR reported concentrations allows for the back calculation of initial contaminant levels used in the modeling process.

Uncertainty

As with any analytical model of a physical process, there is a degree of uncertainty and inherent error in the creation of the model. In this particular case, there are many factors that are unaccounted for or otherwise poorly simulated by the model created in ACTS. The largest discrepancy from the actual physical processes that occurred at the Brunswick Wood Preserving site is the simulation of a single point source in the model – the surface impoundment located at the Northeast edge of the site has been assumed to be the sole source of contamination in the region, however it is known that in fact wastewater was disposed of directly into Burnett Creek. In addition, there would have been a large amount of direct infiltration from the ground surface into the surficial aquifer that is not accounted for by the groundwater simulation. Chemicals that were leached directly from stock piles and spilled treatment solutions would have saturated a much greater surface area at the site than is represented by the retention pond in the model. It can be assumed that the extent of the contaminant plume is much greater than the model would illustrate.

The resolution and accuracy of the site maps used to inform the solution domain creation and location of the monitoring wells is also questionable. The accuracy available using modern computing techniques to spatially locate such features is undoubtedly greater than the techniques that were available at the time of creation for these original maps and documents describing the site. Relative locations of features at the facility are probably fairly accurate, however it was found when georeferencing the site map and well locations that a degree of distortion occurred while mapping the documents to the physical location. This distortion would have noticeable impact on the calibration of the model were it compared to a more accurate representation of the well locations at the site.

Also inadequately modeled in this application is the effect of remediation on the contaminant concentrations at the site and in the surrounding areas. The model assumes a complete cessation of chemical input at the date which the site ceased operations; reports indicate that a large amount of wastewater remained untreated at the site for a period before EPA driven cleaning efforts took place. In this case, the model would underreport the concentrations at dates after the closure date of the facility. Remediation efforts included the draining and removal of the sediments in the impoundment as well as treatment of the surface water and later the groundwater at the site (EPA Superfund 2015). None of these efforts are included in the model, and it is quite difficult to determine the quantitative effect these procedures had on the contamination at the site.

The volatility of many of the hydrocarbons analyzed in this report are quite substantial, especially at atmospheric conditions. Degradation rates for the compounds considered were researched for groundwater application, as the properties of the chemicals varies greatly depending on the mode of transport and ambient environment. Different isotopes of the compounds analyzed also have hugely varying half-lives, in this case the isotope with the longest half-life was used to provide a ‘worst case’ scenario for contamination. The proximity to a marine environment also would have a special effect on the transportation mixing and degradation of certain chemicals. As an example, was found that Arsenic, generally considered a conservative chemical, may display non-conservative properties when analyzed in an estuarine environment such as is present in this domain (Anninou and Cave 2009; Smedley and Kinniburgh 2002).

Private wells were also used to report contamination levels surrounding the site. The exact locations for these wells were not specified, although it was reported that some of them served as sources of potable water for the area. Had more data been available regarding well location, concentration levels, and measurement date, a more exact calibration of the model could have been conducted. As is, a non-conservative chemical and volatile chemical was used for calibration of the model. This is less than ideal, as degradation can vary widely depending on the characteristics of the medium through which the chemical is transported. Calibration of the model was conducted to the best extent that the available data would allow, however it is quite possible that due to unaccounted for features and circumstances of the environment the results coming from this simulation are conjecture at best.

Results

Three separate dates were analyzed using the model to provide a sketch of the contamination levels over time. To determine the possible exposure to wildlife and humans by consumption thereof, Burnett Creek was chosen as the intersection point for the plume. The first period evaluated was during full operation of the treatment facility and immediately before closure (1990) to determine the probable extent and intensity of contamination while the site was actively polluted. The model was then used to evaluate concentrations in 1997, the date for which the ASTDR reported on site monitoring well contamination levels. Lastly, the model was used to predict current concentrations of chemicals at the site – 2015. Probabilistic analysis was used to determine the plume concentrations reaching the creek, allowing for assessment of the likelihood of exceedance of modeled concentrations at this location. Tables 3, 4, and 5 report the values found at these dates.

Table 3: The evaluated compounds and the concentration values reaching Burnett Creek for which there is a 90% probability of exceedance in 1990.

Compound	Concentration (ppb)
Arsenic	0.142
Benzene	0.071
Beryllium	3.1
Chromium	-
Ethylbenzene	0.155
Lead	-

Table 4: The evaluated compounds and the concentration values reaching Burnett Creek for which there is a 90% probability of exceedance in 1997.

Compound	Concentration (ppb)
Arsenic	2.38
Benzene	0.114
Beryllium	7.92
Chromium	-
Ethylbenzene	0.65
Lead	-

Table 5: The evaluated compounds and the concentration values reaching Burnett Creek for which there is a 90% probability of exceedance in 2015.

Compound	Concentration (ppb)
Arsenic	3.25
Benzene	-
Beryllium	2.32
Chromium	-
Ethylbenzene	0.0397
Lead	-

The parameters for which Monte Carlo Analysis was performed for each chemical can be found in the Appendix, along with the range of statistical values used for modeling of the surficial aquifer. The complementary cumulative probability density functions used to determine 90% exceedance are also found in the Appendix.

Discussion

Most noticeably absent from the list of compounds reaching the nearby stream are Lead and Chromium – both metals were found on site by the monitoring wells in concentrations exceeding the EPA’s maximum concentration levels significantly, whereas many of the other chemicals detected at the site were not in exceedance of these health standards. This lack of contamination plume is due to the unusually high retardation coefficients found for the two metals, Chromium being listed as having a retardation rate between 2.5 and 329 (Stanin 2004) and lead having a reported retardation rate of an astounding 1100 (Hathhorn and Yonge 1995). Chromium, although not a conservative chemical, has a much longer half-life than the hydrocarbons and is much less volatile; one would expect it to be a lingering contaminant at the site and it may well be, however with this model the plume showed very little movement over the time extent evaluated. Lead was identified as a conservative chemical, although the retardation rate used would keep its contamination plume very close to the source. It is possible that high levels of the chemical persist in the subsurface environment at the site but have not been transported by advective forces over the years.

Of the compounds reaching the nearby stream, none are in exceedance of the maximum concentration levels established by the EPA. Table 6 has been provided for comparison between the published thresholds for safety of drinking water and the contaminant levels reaching the creek.

Table 6: EPA Maximum Concentration Level guidelines for the selected chemicals.

Contaminant	MCL (ppb)
Benzene	5
Ethylbenzene	700
Arsenic	50
Beryllium	4
Chromium	100
Lead	15

It can assuredly be said that the contamination of Burnett Creek due to the persisting contaminants in the groundwater directly stemming from infiltration from the original waste water impoundment at the site is currently well below the health and safety guidelines established by the EPA. However, since the retention pond was not the only source of pollution at the Brunswick Wood Processing site, a more holistic approach to the modeling of possible contamination transport would be necessary to declare the risk of exposure negligible.

Possible exposure pathways at this site are relegated to direct ingestion of the surface or groundwater without treatment and the consumption of fish and other aquatic wildlife that has

been exposed to the contamination present in the water system. Contaminants of particular concern at this site would be Beryllium and Arsenic. Beryllium has been found to have exceed the MCL threshold, while Arsenic has approached the limit but not surpassed it. It is possible that concentrations above the defined maximum have been reached due to bioaccumulation in the local ecosystem. Based on the concerns highlighted in the seafood consumption advisory, it would appear that these heavy metal traces are the remaining source of contamination at the site.

Conclusion

Presently, the risk of exposure to the hazardous chemicals that were at one point found in significant concentrations at the site is quite low, and only certain elements at the site remain in concentrations high enough to be considered hazardous to human health. From the 2014 article “Health Consultation: Burnett Creek Fish Tissue,” it is noted that the lifetime cancer risk for adults exposed to arsenic from a two-meal per week consumption of fish caught in Burnett Creek is low: “approximately 7 excess cancers can be expected... in 100,000 people.” The article also concludes that there is a low likelihood of non-cancer health effects from the arsenic concentrations found in the samples fish tissue.

It can assumed that the risks to human health due to pollutant concentrations at this site are currently quite low, although more direct exposure likely occurred in the past and a cancer occurrence rate for individuals whom either worked at the site or were otherwise exposed through seafood consumption or contaminated potable water sources would be expected to be higher than average for this population.

The reliability of the results obtained from the ACTS model is of concern; the model can be said to be a fairly accurate representation of the surficial aquifer groundwater transport at the site in regards to the chemicals that entered the system at the main wastewater impoundment on site, however there are many variables for which the model does not account. The infiltration of hazardous chemicals from other sources at the site, as well as the direct disposal of treated waste water into Burnett Creek are likely to have created a contamination plume that is much further reaching than was exhibited by the simulation conducted for this report. The full extent of the contamination downstream and in the parent water bodies is unknown and not considered in the application of this model.

A further source of uncertainty in the model is the highly dependent nature of chemical transport on the retardation coefficient. The retardation coefficient is a function of the substrate bulk density and porosity, as well as the distribution coefficient for the material in question. This distribution coefficient can be highly variable when dependent on the total organic carbon content, which was not fully analyzed for this site. Monte Carlo analysis was used to provide an estimate for the most likely retardation coefficient for each compound, although the coefficient used for the heavy metals is debatable.

The environment which the model attempted to reproduce is of a great complexity. The unknowns were limited where possible and reported values for relevant situations used where appropriate, but many variables still remained in the chemical properties. The physical properties of the surficial aquifer were modeled with much greater certainty, leading to the conclusion that the largest sources of error were not in the modeling of plume transport through the aquifer, but in the behavior and geochemistry of the chemicals analyzed.

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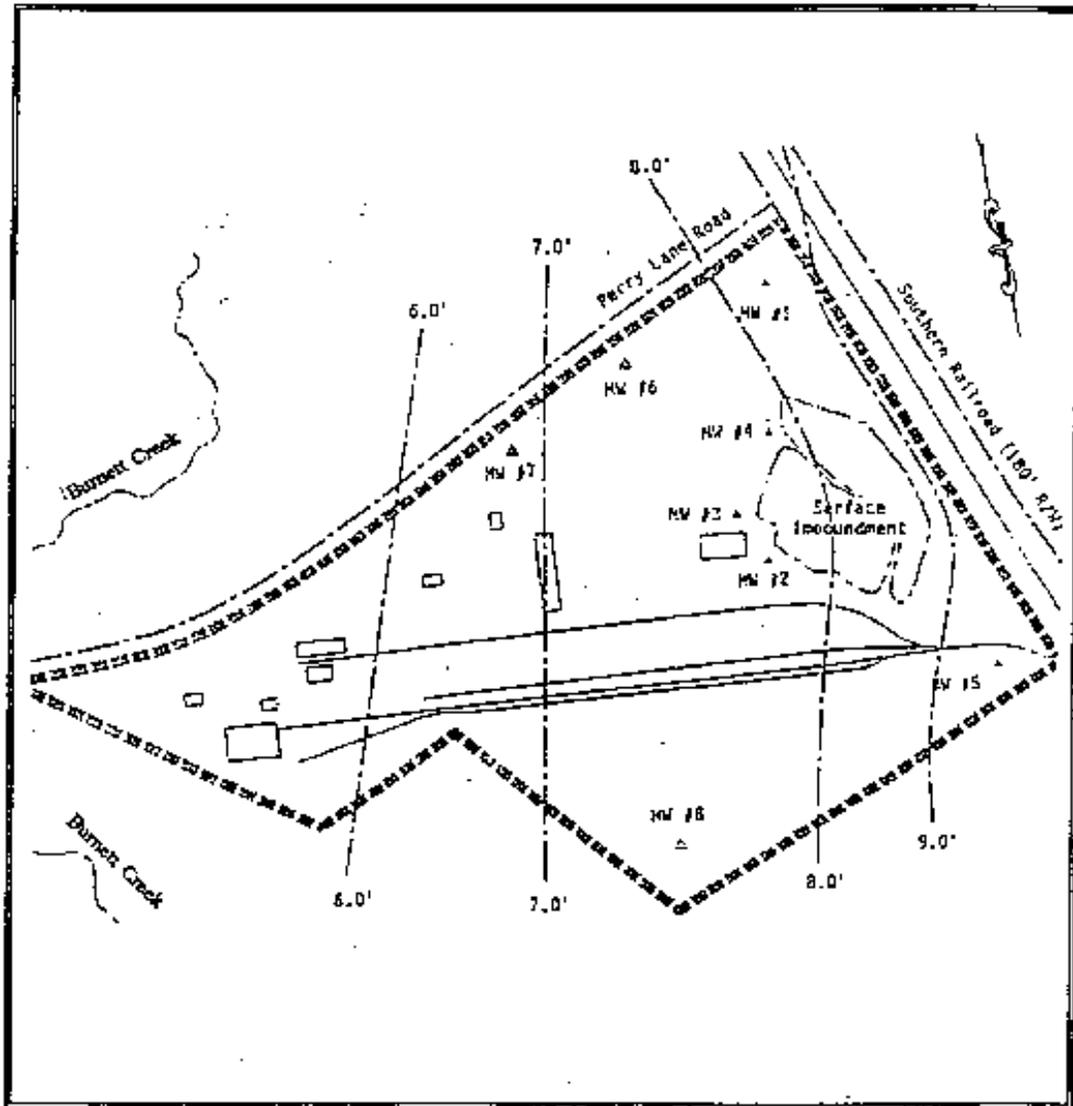
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Appendix



Original map of site showing potentiometric head contours and monitoring well locations, as well as the wastewater surface impoundment.

Contaminant	On-Site Monitoring Wells Maximum Contaminant Concentration (ppb)							MCL
	1	2	3	4	6	7	8	
Benzene	ND	ND	2.3	ND	ND	ND	ND	5
Ethylbenzene	ND	ND	51	3.6	0.9	ND	ND	700
Teretrahydrofuran	ND	ND	ND	ND	ND	6	ND	no value
Toluene	ND	ND	1.8	13	ND	ND	ND	1,000
Pentachlorophenol ⁽¹⁾	ND	ND	ND	ND	ND	ND	ND	1
Benzo(a)pyrene ⁽²⁾	ND	ND	ND	ND	ND	ND	ND	0.2
Arsenic	ND	ND	ND	40	ND	ND	ND	50
Beryllium	ND	ND	ND	6.6	ND	ND	ND	4
Chromium	ND	ND	ND	220	ND	ND	89	100
Lead	ND	ND	ND	45	ND	ND	89	15 (Action Level)

Table taken from the ASTDR documents profiling the contamination on site observed at the monitoring wells.

Solution domain attributes, including monitoring well locations used for calibration.

Attribute	X (feet)	Y (feet)
Solution Domain	3500	2000
Plume line Source*	0	1000
Well 3	388	1091
Well 4	197	1320
Well 6	592	1646
*Width of Source: 400 feet		

The literature values that informed the modeling of each chemical.

Compound	Half Life	Source	Retardation	
			Coefficient	Source
Arsenic	Conservative*	Anninou and Cave (2009)	2 to 10	Harvey et. al. (2006)
Benzene	231 Days	Suarez and Rifai (1999)	3.36	Lovanh, Zhang, Heathcote, and Alvarx (2000)
Beryllium	Conservative*	Kaste, Nortion, and Hess (2002)	-	-
Chromium	2.5 Years	Henderson (2005)	2.5-329	Stanin 2004
Ethylbenzene	231 Days	Suarez and Rifai (1999)	4.76	Lovanh, Zhang, Heathcote, and Alvarx (2000)
Lead	Conservative*	Kubare, Mutsvangwa, and Masuku (2010)	1100	Hathhorn and Yonge (1995)
Toluene**	1.73 Days	Suarez and Rifai (1999)	-	-

* Compounds identified as conservative were modeled with deterministic decay rates of 1.0e10 days.

** Omitted from analyses due to the extremely short duration of persistence in the environment

The statistical values used for the Monte Carlo analysis of the aquifer's physical parameters

Variable	Mean	Minimum	Maximum	Variance	# Terms	Distribution
Darcy Velocity	0.10899	0.01	1	0.001	1000	normal
Dx	350	100	1000	1	1000	normal
Dy	20	5	70	1	1000	normal
Porosity	0.38	0.15	0.5	0.001	1000	normal
Net Recharge	0.01119	1.00E-07	0.1	1.00E-04	1000	normal
Thickness	250	100	350	1	1000	normal
Width	400	200	600	1	1000	normal

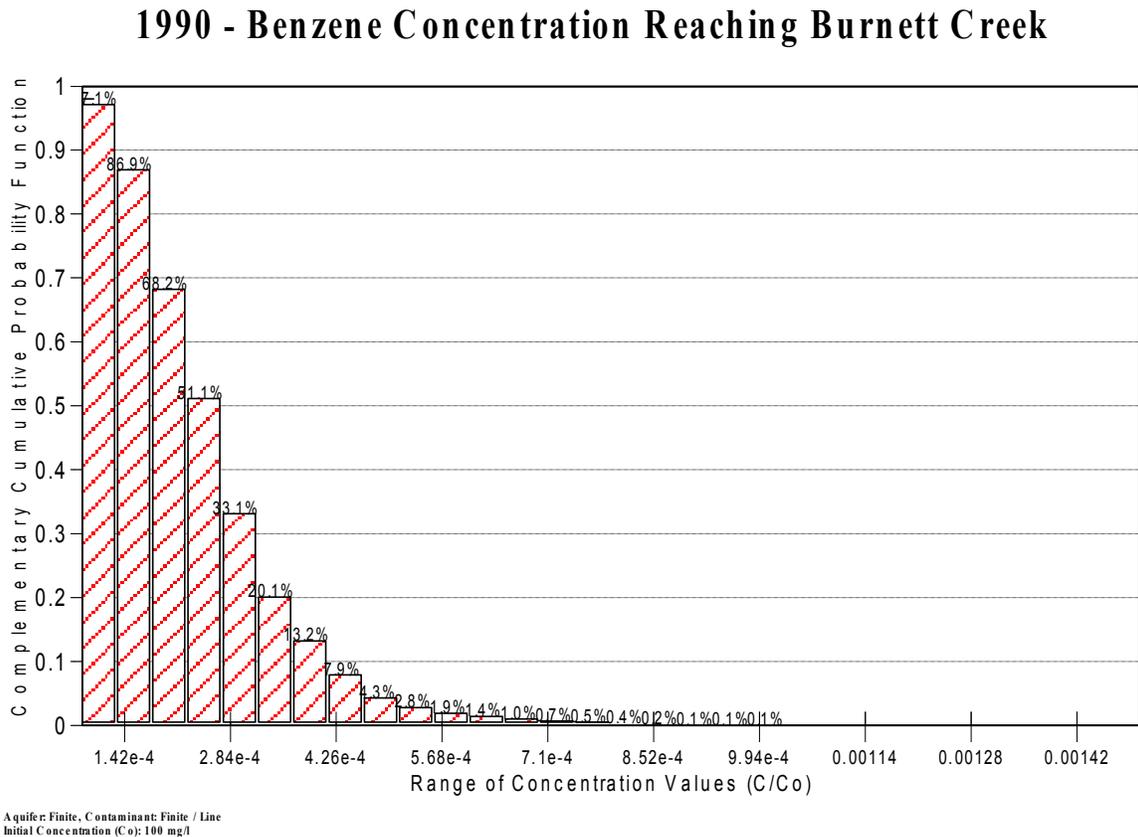
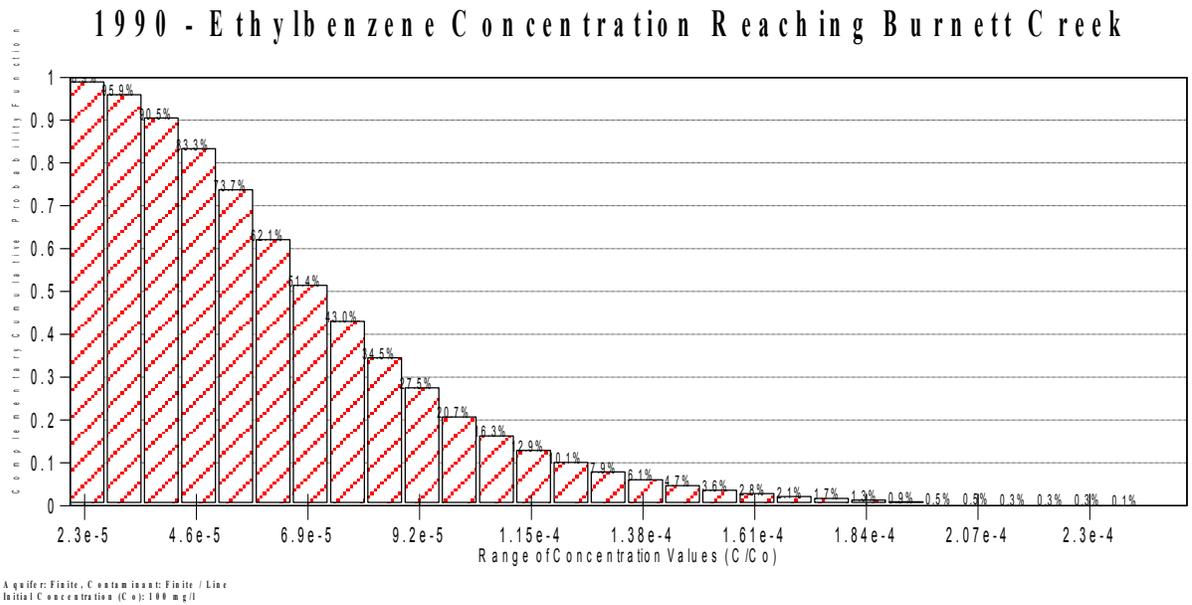
Initial Concentrations determined from back calculation using ASTDR reported concentration in 1997 and the calibrated models ratio of C/Co.

Compound	Initial Concentration (mg/l)
Arsenic	2.5
Benzene	0.5
Beryllium	0.4
Chromium	100
Ethylbenzene	4.5
Lead	150

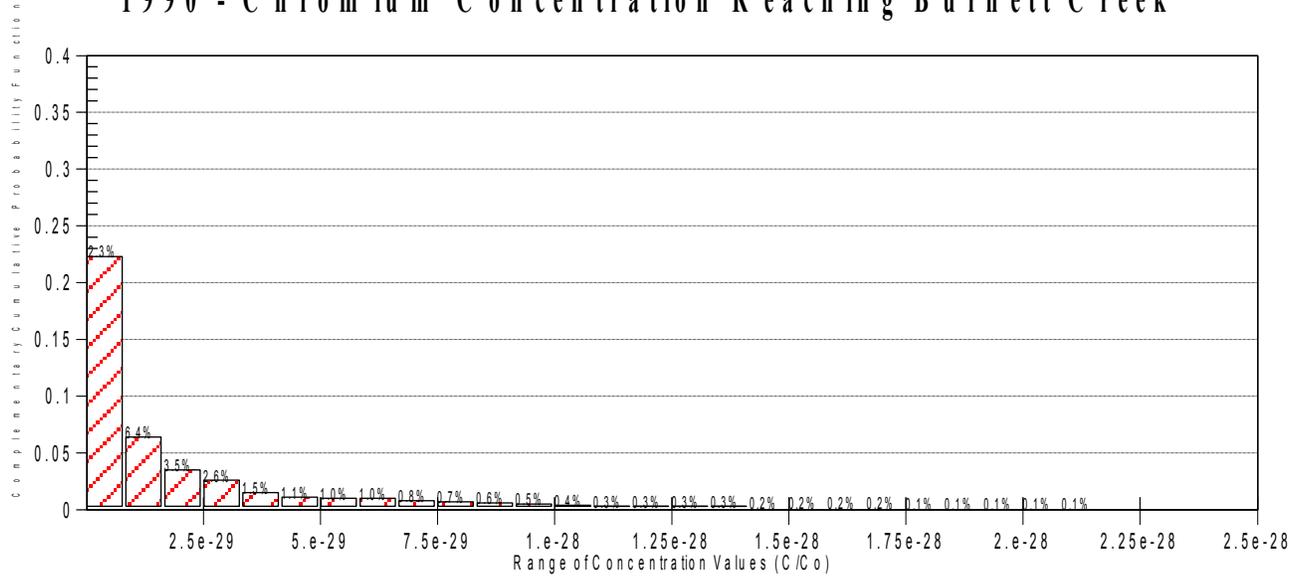
Monte Carlo terms for chemical modeling. All compounds used 1000 terms and a normal distribution

Compound	Attribute	Mean	Minimum	Maximum	Variance
Arsenic	Half Life	Conservative	-	-	-
	Retardation	6	2	10	0.01
Benzene	Half Life	230 days	3	350	1
	Retardation	3.36	1	7	0.01
Beryllium	Half Life	Conservative	-	-	-
	Retardation	2.5	1	10	0.01
Chromium	Half Life	912 days	720	1100	10
	Retardation	50	2.5	329	1
Ethylbenzene	Half Life	230 days	3	350	1
	Retardation	4.7697	1	10	0.01
Lead	Half Life	Conservative	-	-	-
	Retardation	500	100	1100	10

1990 Complementary Cumulative Probability Density Functions for all Contaminants

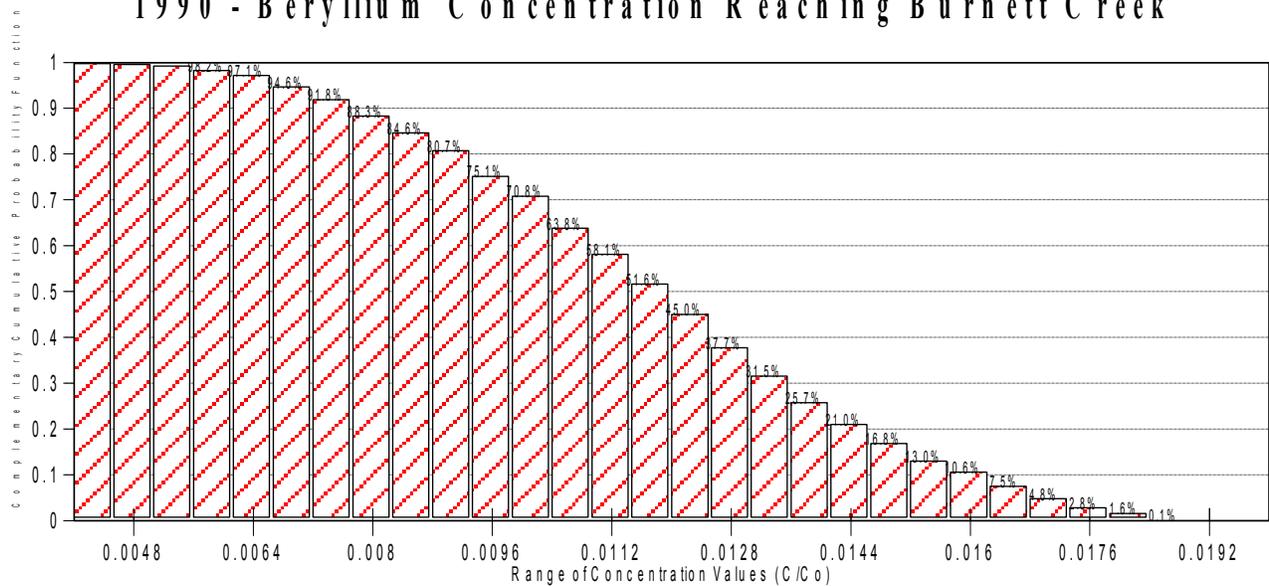


1990 - Chromium Concentration Reaching Burnett Creek



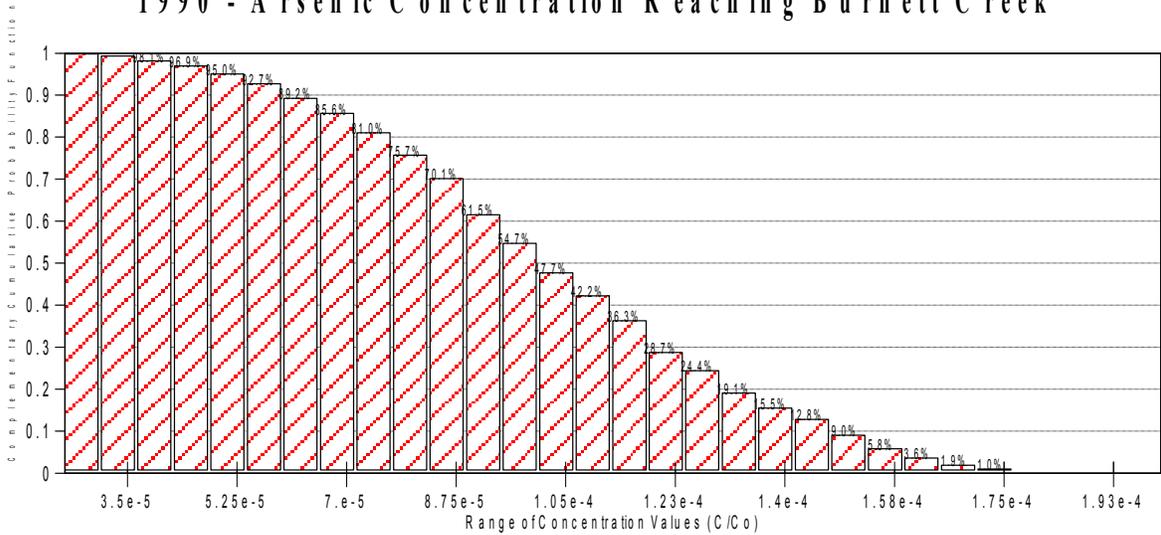
Aquifer: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l

1990 - Beryllium Concentration Reaching Burnett Creek



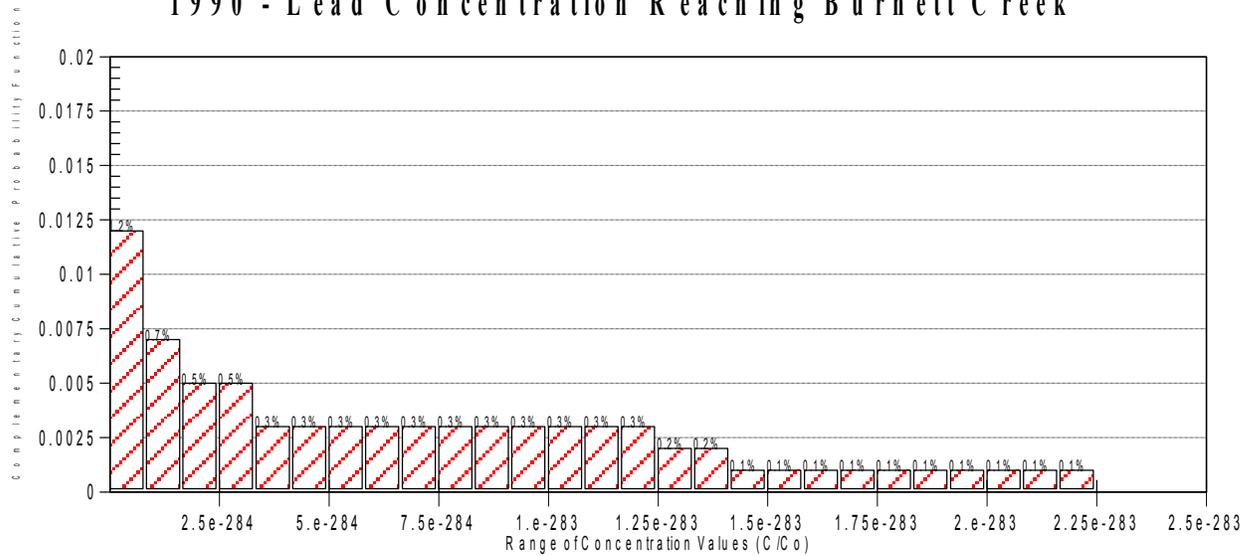
Aquifer: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l

1990 - Arsenic Concentration Reaching Burnett Creek



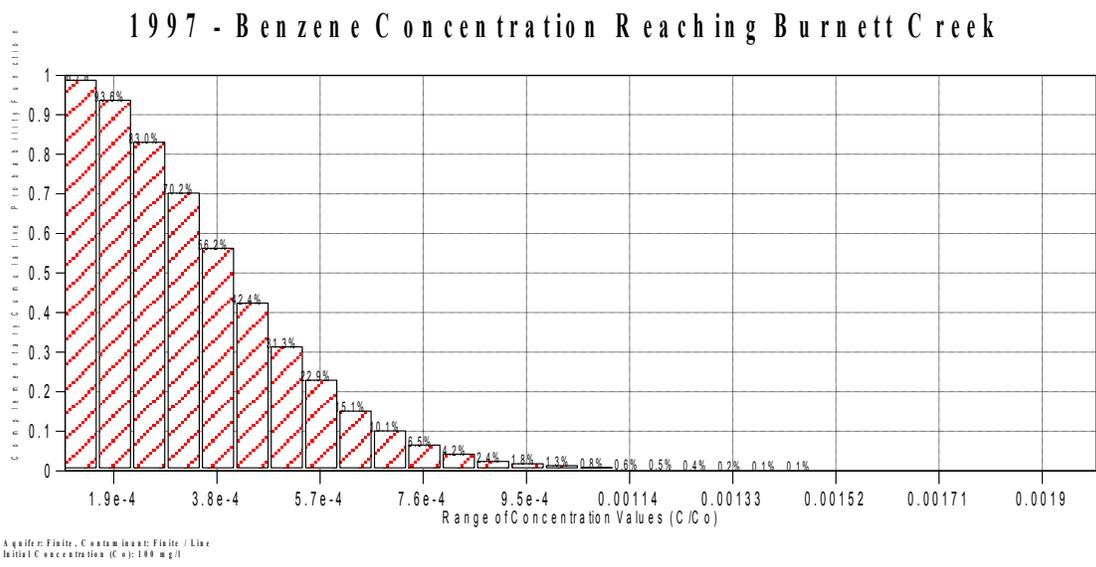
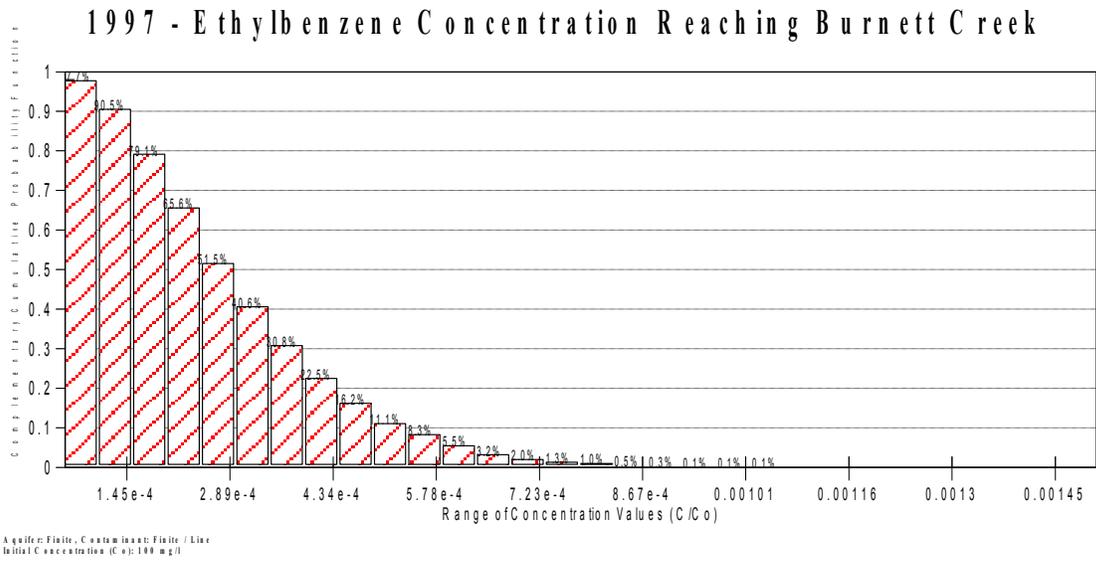
Aggr: Fuite, C onstant: Fuite / Lix
Initial C oncentration (C₀): 100 mg/l

1990 - Lead Concentration Reaching Burnett Creek

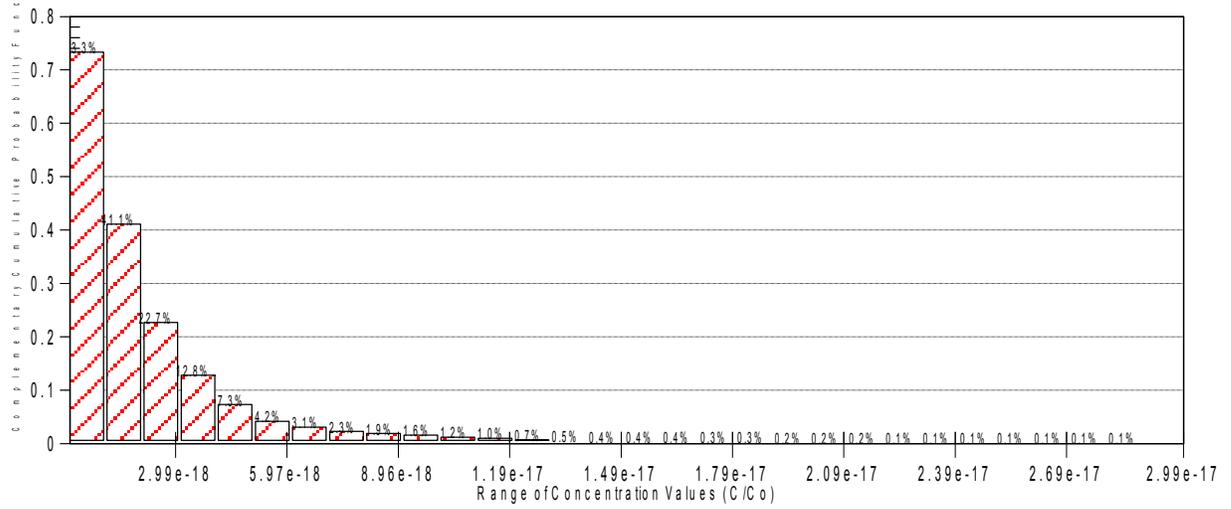


Aggr: Fuite, C onstant: Fuite / Lix
Initial C oncentration (C₀): 100 mg/l

1997 Complementary Cumulative Probability Density Functions for all Contaminants

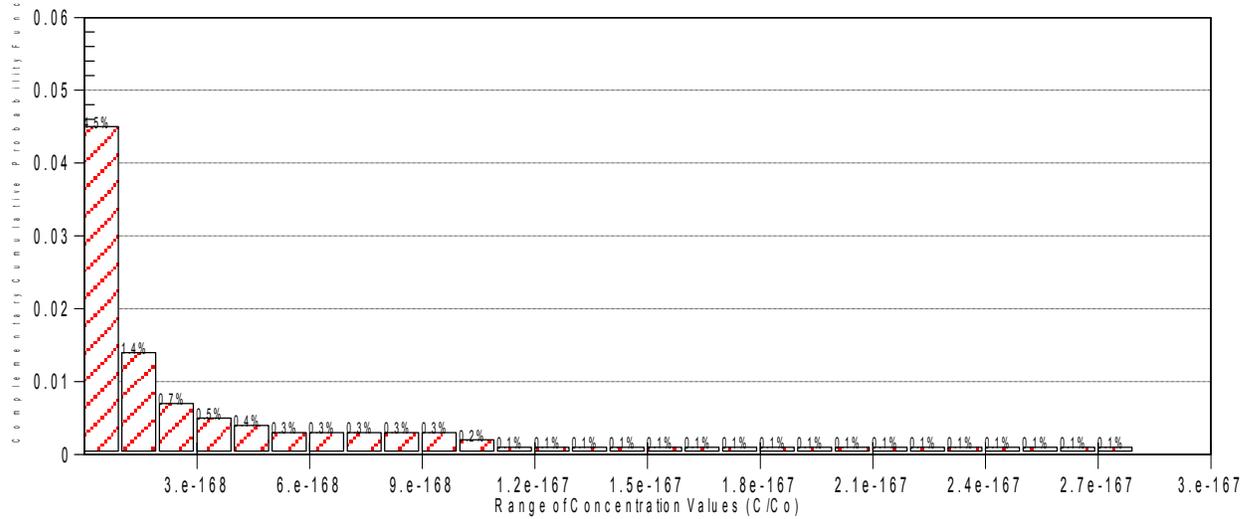


1997 - Chromium Concentration Reaching Burnett Creek



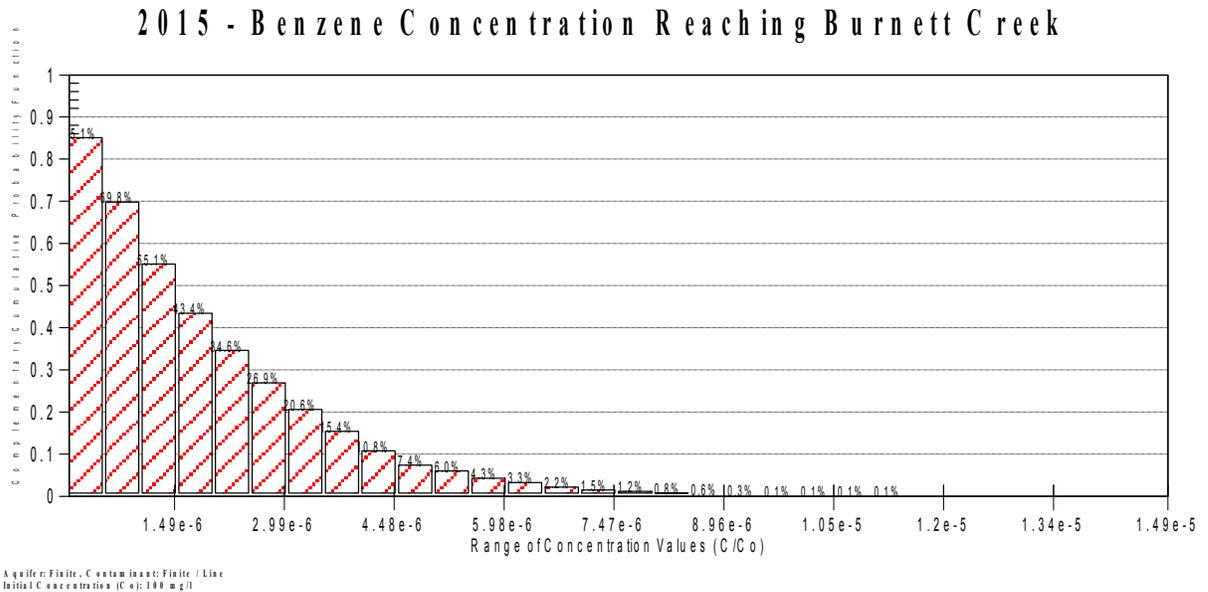
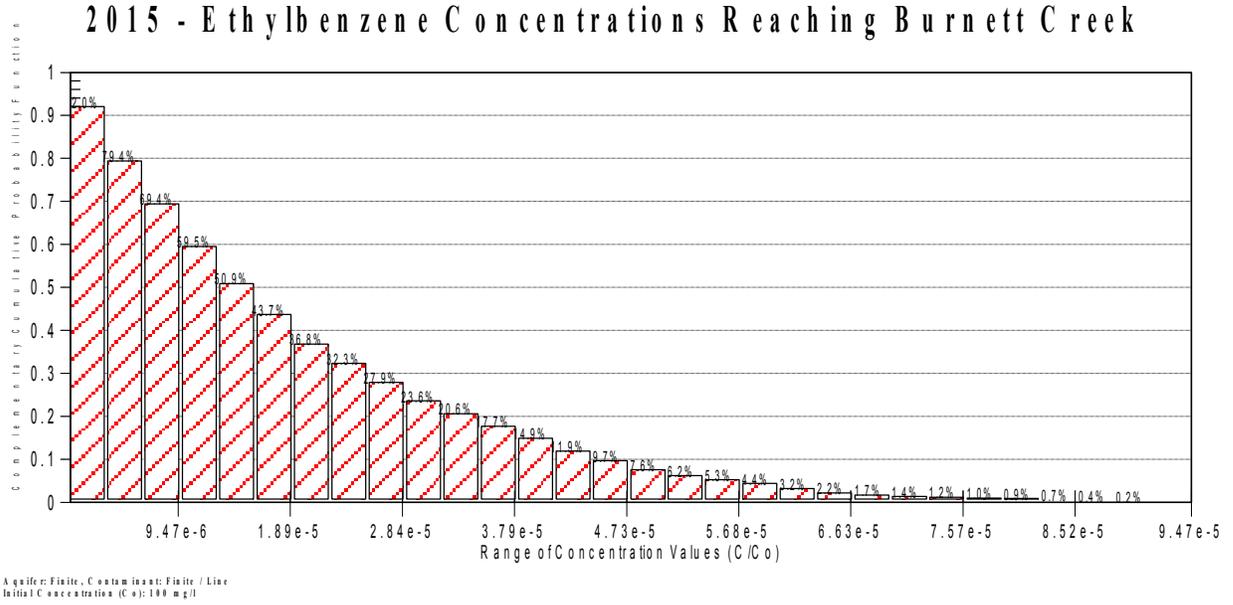
Aquifer: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l

1997 - Lead Concentration Reaching Burnett Creek

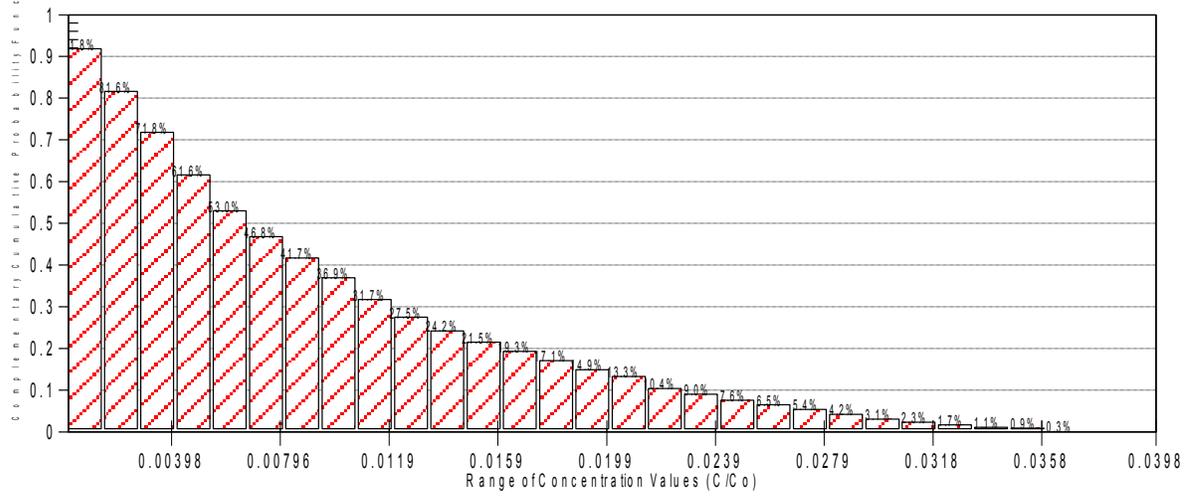


Aquifer: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l

2015 Complementary Cumulative Probability Density Functions for all Contaminants

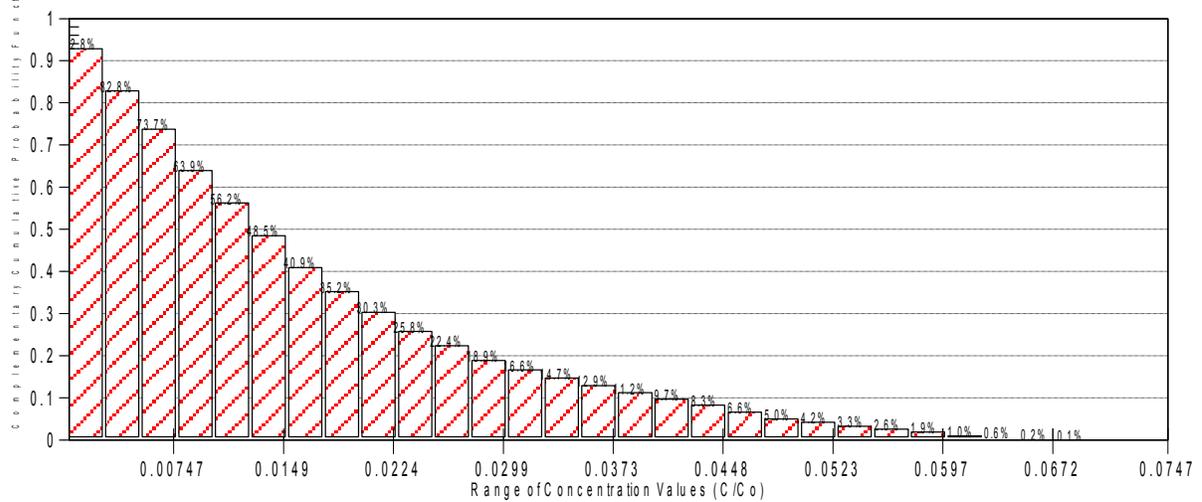


2015 - Arsenic Concentration Reaching Burnett Creek



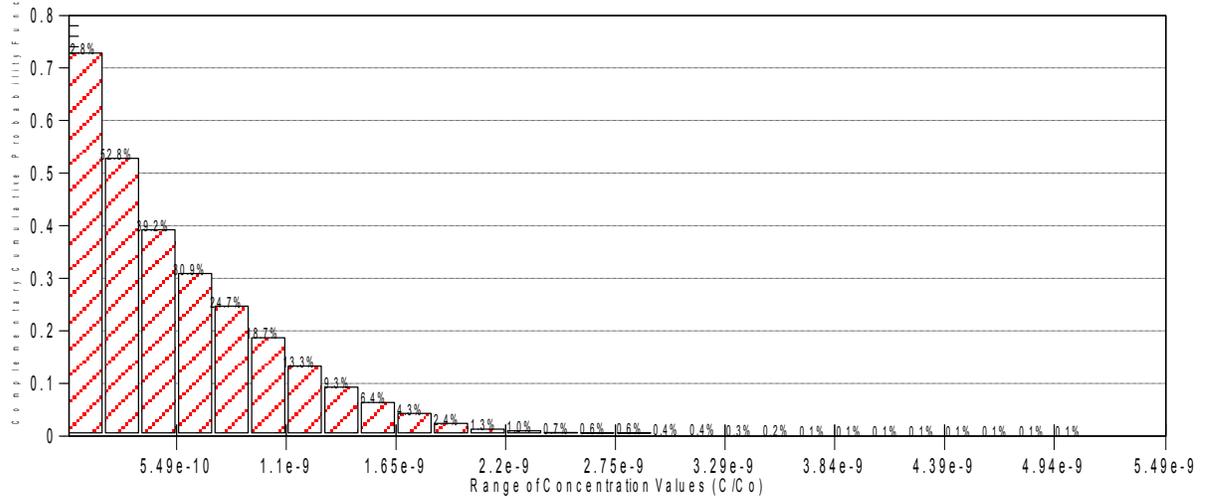
Aquifer: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l

2015 - Beryllium Concentration Reaching Burnett Creek



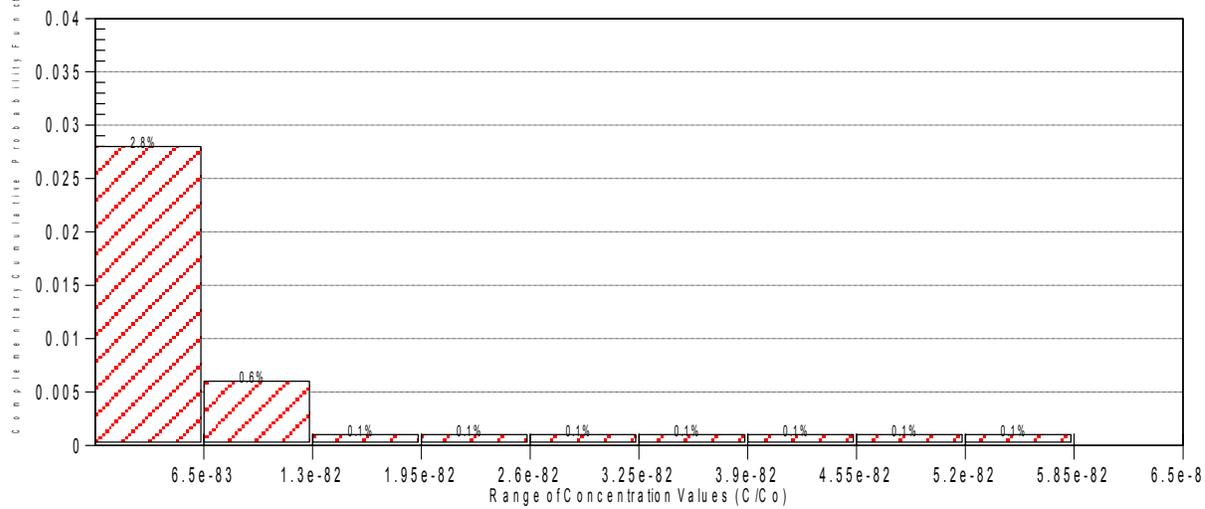
Aquifer: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l

2015 - Chromium Concentration Reaching Burnett Creek



Aggr: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l

2015 - Lead Concentration Reaching Burnett Creek



Aggr: Finite, Contaminant: Finite / Line
Initial Concentration (C₀): 100 mg/l