Creating Polycyclic Aromatic Hydrocarbon Susceptibility Model in Kenai, Alaska

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Abstract

This project outlines procedures and resources used on the construction of polycyclic aromatic hydrocarbon (PAH) susceptibility model. The PAH susceptibility is due to PAH loading from impervious surface features in the watershed. The susceptibility model determines areas in the watershed which contribute to PAH loading. These hotspots represent areas that should be closely monitored, as they have the greatest potential to detrimentally impact the aquatic life in the No-Name Creek Watershed. The model also looks to find potential PAH sinks or other abnormalities within the watershed boundaries.

Introduction

Pollutant environmental loading is a question that faces multimedia researchers and modelers. They try to determine what sources are present in our immediate environment, where are they located, and how much pollution does each contribute. These are the answers that the polycyclic aromatic hydrocarbon (PAH) susceptibly model of a creek in the Kenai area will address. The susceptibility model will also address watershed delineation methods and their effects in determining PAH loading.

Kenai Peninsula's Ecological History

The Kenai Peninsula Borough is extremely valuable from an environmental research prospective because of its land ownership characteristics. Approximately 85% of the Kenai Peninsula Borough, KPB, is owned by federal and local government agencies. The KPB is compromised of the Kenai National Wildlife Refuge which consists of 1.92 million acres (U.S. Fish & Wildlife, 2004). The other 15% of the Borough is a collection of private landowners and homesteaders. The benefit of the land being owned by various government agencies is all land alterations must be approved thus creating a wealth of data about the land and its management practices.

The geologic structure of the Kenai Peninsula is young, since its entire land mass was covered by glacial ice as recently as 10,000 years ago (Hall et. al., 2001). Much of that frozen blanket still exists today in the 800-square mile Harding Ice Field, which is shared by Kenai Fjords National Park. Most of the streams and lakes on the Kenai Peninsula have glacial deposits including the Kenai River (Kyle et. al, 2001).

Human Impact

Kenai is one of the oldest Alaskan communities with evidence of prehistoric people dating back to approximately 8,000 B.C. The Athabaskan Indians were the first permanent inhabitants of the peninsula (KRPGA, 2004). In the 1700's, the Russian fur trade began to develop along the coast of Cook Inlet and the Gulf of Alaska. Kenai grew into headquarters of the Russian fur trading industry, later transitioning into the fishing industry capital.

Alaska's arctic environment is very fragile, easily showing the effects of human ingenuity. A climatic study showed a 3-degree rise in Arctic Ocean temperature depicts the impact of anthropogenic sources. The major concern with rising aquatic temperatures is decreased solubility of oxygen in the water and the increased biochemical activity caused by the warmer climate (Kyle et. al, 2001).

The health of the aquatic environment is a vital piece of the Alaskan economy. In 1997, the Cook Inlet Basin accounted for 50% of the state's sportfishing. The Kenai River is the most used water body in the state of Alaska. The Kenai River accounted for 12% of sportfishing in the Cook Inlet Basin (KRSA, 2004). The Kenai River Watershed is located in South-Central Alaska and consists of about 1.4 million acres. The river runs through a multitude of diverse landscapes containing: ice fields, lakes, mountains, flat tundra, and vast lowlands. The Kenai River begins at the outlet of Kenai Lake, and flows for 17 miles before it passes through Skilak Lake. From Skilak Lake the Kenai River flows another 50 miles until it empties into Cook Inlet near the city of Kenai. The total length of the Kenai River is about 82 miles (KRC, 2004).

Kenai Watershed Forum

The Kenai Watershed Forum has been monitoring the Kenai River and its tributaries for the last 10 years. In an effort to improve water management the Kenai Watershed Forum is cataloging the tributaries hydrologic features. The forum has collected data on polycyclic aromatic hydrocarbons levels in the Kenai watershed for the last 3 years. The data depicts both seasonal and yearly changes of the hydrocarbon content from the tributaries.

The Kenai Watershed Forum is developing an All Inclusive Environmental Simulation Model (ALCES). The ALCES model is comes from a predictive forest growth and recession model by using defined land management practices. The ALCES model integrates GIS derived layers to create these predictions. Some of the GIS layers include: elevation, slope, buildings, paved roads, dirt roads, and other impervious objects. The essence of the project will be to create impervious surface layers which will integrated into the ALCES model.

Gasoline

Gasoline is a complex liquid; it is categorized as a composition of a series of distillation temperature fractions. This liquid is specifically designed to meet a wide variety of engine designs and operating temperatures. Each blend of gasoline is unique to its environment, temperature, and altitude (Anonymous, 2002). Similarities between gasoline types are further complicated by differences in each company's refinery practices. This discrepancy in techniques and chemicals used in refining oil, within the same company, causes regional and local differences in the oil composition. Furthermore, oil batches differ in their organic composition from oil well to oil well as a result of the different compositions of decomposing animals and plants. No two batches of oil have the same characteristics or properties.

Refining Gasoline

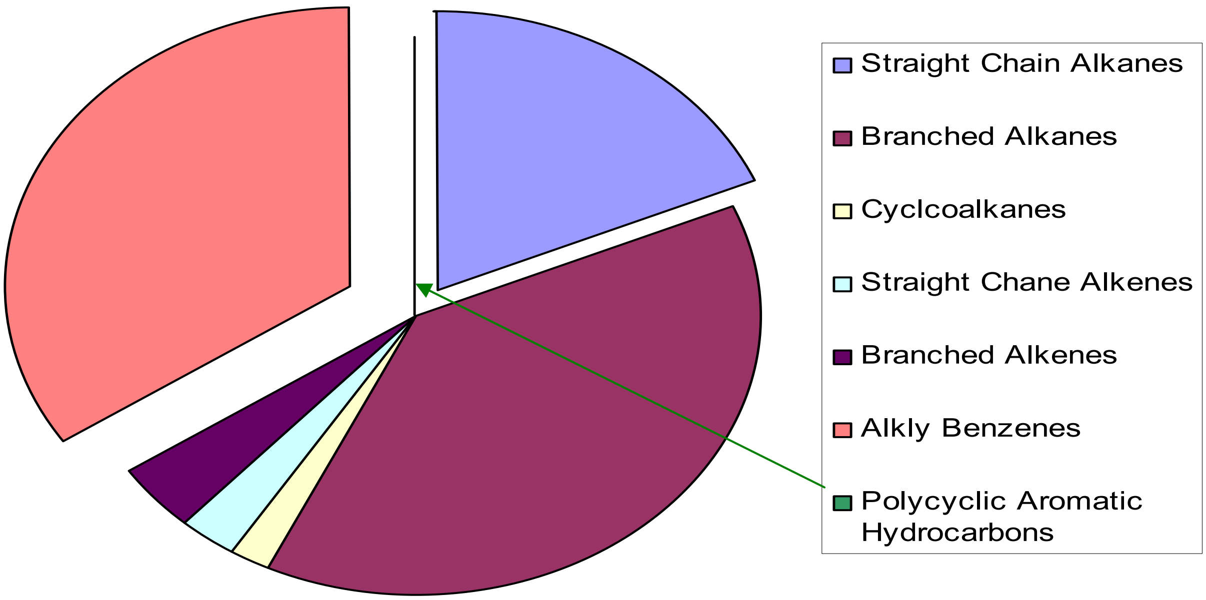

Figure 1. General composition of gasoline.

Gasoline is made in oil refineries all over the world. Of the daily 42 barrels of crude oil collected, over half are converted into gasoline. The collected crude oil is sent to the refinery where it is vaporized and collected in distillation towers based on the molecular density. The gasoline fraction contains hydrocarbons that have between 3 - 12 carbons and has a boiling range of 30°- 220°C. The jet fuel fraction contains hydrocarbons that have between 12 – 18 hydrocarbons (Logan, 1995).

Researcher's looking for an accurate structural composition of consumer purchased gasoline resort to analyzing gasoline with a gas chromatographic analysis. The percentage of PAH in gasoline is less than 1% however, during engine combustion, over 30% of the chemicals created are PAH's. Figure 1 illustrates the chemical composition of gasoline pre-combustion. Even though jet fuel contains a higher percentage of PAHs at onset, the jet engine is much more efficient and produces less PAHs (Logan, 1995).

Gasoline Toxics

Many of the toxins found in gasoline come from today's reformulated gasoline, which was caused by the 1979 ban of lead. Reformulated gasoline looks to increase efficiency by increasing oxygen levels. Ethyl and methyl bute ether (MTBE) are two known additive toxins. Many regulations are in place in an effort to limit the number of hazardous substances. Regulated substances include aromatics and olefins which are formed during the combustion. Other regulated additives include Benzene, Xylene, Toluene, and Ethyl Benzene.

MTBE has been added to gasoline since 1979, current human research on MTBE lists it as a moderately toxic compound due to its high water solubility and resistance to biodegradation. Research states that elevated levels of MTBE are linked with organ and neurological systems failure. The International Agency for Research on Cancer (IARC) says that there is insufficient evidence to classify MTBE as a human carcinogenic substance for humans, even though EPA drinking water standards have been placed on this chemical. MTBE is a known and classified as an animal carcinogen (Air Use Management, 1999). Other research of chronic MTBE depict MTBE can cause ineffective reproductive systems.

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemical compounds that are formed during incomplete combustion of organic substances (ATSDR, 1995). PAHs have both natural and human produced sources. There are 50 common PAHs that are the primary focus of research. The effects of PAHs are wide-ranging in both the particular organism affected and the type of effects it can cause. Research shows PAHs have negative effects on humans, mammals, birds, invertebrates, plants, amphibians, and fish. As of 2003, the EPA has registered 17 of the 100 PAHs with the Agency for Toxic Substances and Disease Registry (ATSDR) list. The EPA has determined that these 17 PAHs have sufficient evidence to be considered carcinogenic.

Polycyclic Aromatic Hydrocarbons have been linked with cancer since 1775, when chimney sweeps were seen to have a low life expectancy. In the 1800's, it was determined that the soot particles that chimney sweeps removed carried large amounts of polycyclic aromatic hydrocarbons, which contributed to lung and urinary cancer (Lefferts, 1989). PAHs have been found in almost half of the National Priority Sites identified by the EPA (ATSDR, 1995). PAHs are considered a pollutant because of their contribution and potential to become serious health risks.

PAH Characteristics

PAHs are organic compounds consisting of two or more fused benzene rings. The smallest PAH is Napthalene $C_{10}H_8$ consists of two fused Benzene rings. The largest PAH is hexabenzo[a,cd,f,j,lm,o]-perylene $C_{42}H_{22}$. PAHs exist naturally as mixtures of fossil fuels and can be found as typical components of: asphalts, fuels, oils, and greases (Anonymous, 1993). Low Molecular Weight (LMW) PAHs consist of two or three ring PAHs. They exhibit the following characteristics: high water solubility, low vaporization point, and are easily oxidized and reduced. High Molecular Weight (HMW) PAHs consist of four to seven ring PAHs, are solids at room temperatures, have high vaporization points, and exhibit a high organic solubility.

PAH Degradation

In the home, PAHs are present in tobacco smoke, smoke from wood fires, creosote-treated wood products, cereals, grains, flour, bread, vegetables, fruits, meat, processed or pickled foods, and contaminated cow's milk or human breast milk (Sinha, 2002). Table 1 describes various commercial uses of PAHs. Food grown in PAH contaminated soil or air may also contain PAHs. The level of PAHs in the typical U.S. diet is less than 2 ppb (ASTDR, 1995). PAHs entering the environment are broken down through two pathways metabolization and photo-oxidation. Bacteria and fungi are the only organisms known to continually metabolize PAHs without any side-effects in vitro. The fungus Cunninghamella *elegans* has been shown to inhibit mutations caused by PAHs (Wiley, 2001).

Organisms equipped with PAH metabolizing enzymes will not be as easily affected by PAHs. The human body possesses enzymes that allow it to metabolize PAHs, but it yields byproducts that are hazardous to the body (Qian, 2003). Bacteria and fungi byproducts are nontoxic. Cultured bacteria have been grown on PAH media such as naphthalene and phenanthrene. The bacteria were collected from various water bodies around the world. Studies like these seek to replicate the PAH degrading proteins in an effort to provide anaerobic PAH degradation (Wiley, 2001 & Lepo, 1999).

PAHs are absorbed through the ingestion, inhalation, and direct skin contact. Current studies state that PAHs metabolism is centralized in the liver, though no human studies have ever been constructed. Once PAHs enter the body they travel through the circulatory system until they reach the liver, where they are degraded and excreted in the bile and urine depending on polarity. Minor PAH metabolism is present in the adrenal glands, testes, lungs, thyroid, and the sebaceous glands of the skin (Brender et. al., 2003). Further research on PAH cellular interaction shows PAHs are converted into epoxides which are implicated in DNA adduction (Melendez-Colon et. al., 1999). Tissues that develop large amounts of DNA adduction are likely to develop into a carcinogenic tissue. The Center for Disease Control has developed a list of hazardous PAHs and their detectable metabolites.

PAH Hazardous Chemicals

PAHs have been designated a value of 1.3 on the health hazard spectrum and many countries have constructed work-safe standards to reduce exposure of PAHs (ASTDR, 1995). Since PAHs are group a wide ranging chemicals, standards are only set on individual PAHs and not the whole group of chemicals (NPI, 1990). PAHs can cause nausea and headaches. Some human studies show PAHs have caused damage to liver, kidneys, and red blood cells (ASTDR, 1995).

PAHs are highly potent carcinogens that can produce tumors in some organisms at even single doses. Several PAHs have caused tumors in laboratory animals by inhalation, oral ingestion, or by skin contact (Zahodiakin, 2002). Furthermore, an increase in mammary tumors in rats has been caused by both a single dose of benzo(a)pyrene (BaP) of 100mg/kg and from eight weekly doses of 12.5mg/kg (ATSDR, 1995). Experiments with BaP, show that aquatic organisms are most susceptible to exposure of BaP (Potter et al., 1994). Currently the EPA is focusing research on understanding the environmental effect of PAHs in the aquatic environment. Fish exposed to PAHs exhibit fin erosion, liver abnormalities, cataracts, and immune system impairments. The rate

Table 1. Commercial uses of PAHs in the United States (Table Source: Nagpal, 1993).

PAH	Use
Acenaphthene	Chemical intermediary in pharmaceutical & photographic industries; to a limited extent in the production of soaps, pigments and dyes, insecticides, fungicides,
Acridine	Laboratory chemical (as a dye) & to a limited extent in pharmaceuticals
Anthracene	As a dye or chemical intermediary for dyes, diluent for wood preservatives
Naphthalene	In the production of phthalic anhydride, carbaryl insecticide, beta-naphthol, tan-
Quinoline	In the preparation of hydroxyquinoline sulfate, niacin, some dyes; as a solvent for resins & terpines; decarboxylation agent

of PAHs bioaccumulation is much faster in aquatic then terrestrial environments (EPA-TP, 2003).

Watershed Delineation

Digital Elevation Models (DEM) are one of the most important pieces of data used to identify drainage features. DEMs allow researchers to identify things such as ridges, valley bottoms, channel networks, surface draining patterns, and sub-catchment areas. The accuracy of these features is dependant on the accuracy of the DEM. The accuracy of the DEM is controlled by two variables the resolution of the DEM and the extent of dataset. The resolution refers to the size of the cell. The more cells present in a defined area the greater the resolution, meaning the smaller the cell size the greater the resolution. Large cells sizes tend to leave out smaller features and over generalize the sub-basin. The dataset is generated by the extent of the study area. An accurate dataset will extend beyond the study area. Limited datasets will not be as accurate and may skew the identified features.

BASINS 3.0

The Environmental Protection Agency (EPA) is emphasizing watershed and water quality-based assessment of integrated analysis of point and non-point sources. This has led to the development of Better Assessment Science Integrating Point and Non-Point Sources (BASINS). BASINS was developed to meet the needs of such agencies by integrating a geographic information system (GIS) with national watershed data, meteorological data, assessment, and modeling tools into one convenient package. (EPA, 2000) The goal of the software was to addresses three objectives: facilitate examination of environmental information, provide an integrated watershed and modeling framework, and support analysis of point and non-point source management alternatives. BASINS supports the development of total maximum daily loads (TMDLs), which integrates both point and non-point sources. It can support the analysis of a variety of pollutants at multiple scales, using tools that range from simple to sophisticated.

The BASINS automatic delineation tools were deemed the most appropriate for the current research. The automatic delineation tool calculates possible hydrologic networks using a user-defined DEM. The EPA delineation tool uses some of the most current analytical methods for creating accurate watershed delineations. Another advantage of the auto-delineation tool is its repeatability.

Methods

BASINS 3.0 does not always install properly on computer systems. It is notorious for not installing all the necessary modeling components. The modeling extensions are not always properly placed into the C:\Esri\...\Ext32\ folder. To remediate this problem use Disc 1of the BASINS install CD's. Disc 1 contains the BASINS model folder, D:\Basins\Model folder, which contains another four folders. Each folder/directory has an executable which can be run to install the missing features.

Once BASINS 3.0 is properly installed, it will create a BASINS program menu. When running BASINS will modify the ArcView 3.x interface through dialog designer. It is possible to load a BASINS project in a regular ArcView setting, however the user will need to turn on a variety of extensions. The most important extension is the Dialog Designer which is necessary for the BASIN integration. Other necessary extensions are: Spatial Analyst, Image Analyst, and Geo Processing (EPA, 2000). It is easier to open up BASINS projects through the BASINS program menu and ArcView projects through the ArcView program menu. If BASINS begins to corrupt the ArcView operation, uninstall it completely. No data, delineations, or projects will be lost. The project can be accessed again by re-installing BASINS.

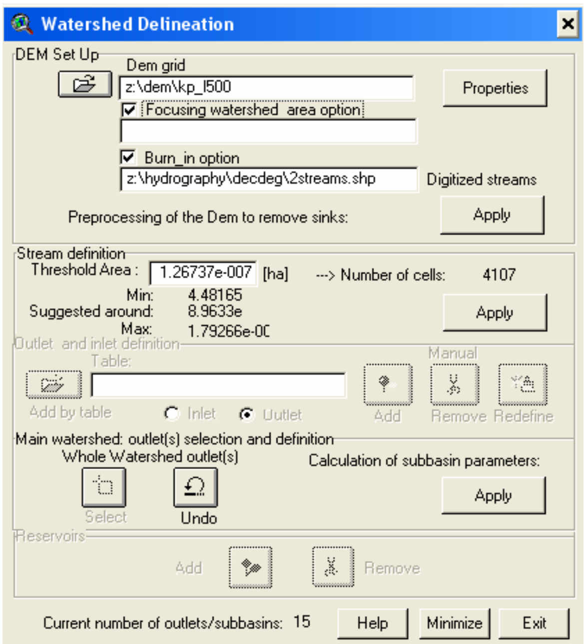

Figure 2. Watershed Delineation main menu.

The auto delineation tool is most easily accessed through the BASINS project. This requires loading the CD provided tutorial data. The auto delineation tool can be accessed through the BASINS file extension, located in the file menu. The BASINS extension has 5 menus of different extensions that can be loaded. The process for the automatic delineation is meticulous. Figure 2 shows the automatic delineation menu. The delineation tool can work with DEMs in both projected coordinate system as well as Decimal Degree formats. All user input data should be in the same coordinate system to ensure consistency. While going through the delineation process, the computer will automatically ask to load the data from the view or a disk. Select the disk option, unless the needed data is from the tutorial data set. The first step loads the DEM. The next two steps are optional, however more data added the faster the DEM processing will occur. If the project has a specific hydrologic feature that needs to be included, the "burn in" option should be selected. The "burn in" depicts every hydrologic feature present in the study area. If the resolution of the DEM is not accurate enough to detect the hydrologic feature automatically, the "burn in" option will load a line-shapefile containing those hydrologic features. The best hydrologic files are reach files which can be found for most USGS defined watersheds. Once the data is entered, the apply button will become active. The computer will prompt the user to select if the cells will flow from the outer to the inner cells. In this project, cells were not selected to flow from the inner cells to the outer cells.

The second step, stream definition, is the most important step. The computer automatically generates from the DEM what the stream definition threshold is. Once the threshold is set, the computer generates a hydrologic network from the input DEM. If the DEM and hydrologic network are not lying directly on top of each other, then the DEM needs to be reloaded and the process started over. The non-alignment suggests one of the files is in a different projection. If the hydrologic network does not include the wanted hydrologic features, the threshold must be adjusted. Increasing the number of cells will remove smaller hydrologic pieces. Lowering the number of cells will increase the number of present hydrologic features.

The last step involves selecting the

outlets or inlets. If the same outlets/inlets are going to be used in multiple watershed delineations the outlets can be loaded from a file. The selectable outlets will be represented by blue dots. Once selected, the computer will generate the watershed boundaries and all possible sub-basins within the study area. Accurate delineations are made by selecting outlets that are closest to the watershed of interest. By using specific outlets only hydrologic networks connected to that outlet will be delineated. The larger and more general outlets will create less specific delineation. Inlets are added if a point source is known to exist at a location. These can also be loaded through a table. The delineation process is completed once the watershed boundaries have been delineated. Additional features like reservoirs can be added if they are present in the study area. The delineation menu will allow the user to make adjustments to the data set on the fly.

Once the watershed delineation is created using the BASINS extension the shapefile "sub-basins" should be saved to a second directory. The sub-basins and all corresponding shapefiles will be in the same coordinate system. The "sub-basins" shapefile will be a multi-polygon file listing all of the corresponding sub-basins. The "watershed" shapefile will be the merged sub-basins and should be saved as well.

Heads Up Digitizing

All heads up digitizing was completed from the 2001 IKONOS 1-meter resolution color compressed image in figure 3. The image was compressed by ER Mapper. Heads up digitizing created the following layers: paved_impervous, gravel_impervious, buildings, lakes, and streams, see left image of figure 3. All layers were created in NAD 27 State Plane Alaska Zone 4. Knowledge of the area aided greatly in visual determination between objects. The high resolution photo did not contain an infrared layer so conducting a tassel cap analysis was not possible. The paved and gravel impervious surfaces were easily distinguishable from the satellite image due to their reflective properties. Creating accurate boundaries for many buildings in the residential area was extremely difficult due to the number of trees in each lot. The trees often cast shadows over sections of the house. The difficulty in digitizing buildings was increased by the non-uniformity of roofs. Materials used on roof top construction differed as well as the shape of the roof. A surprising number of roofs were

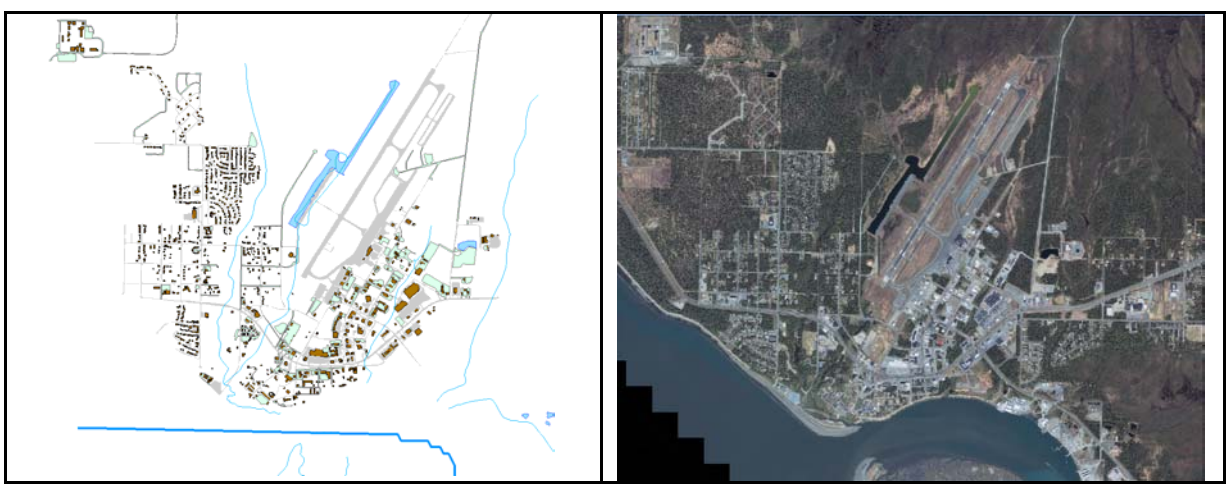

Figure 3. Comparison of digitized impervious surfaces and IKONOS satellite imagery.

present on the image due to the steep grade of roofs present in Alaska. Figure 4 shows various rooftops in the Kenai area. All digitized impervious surfaces are activated in figure 4.

Results

The automatic delineation tool of BASINS 3.0 generated more accurate watershed delineations when compared to the hand delineation. The hand delineations were created off a topologic map. (1986, C-4, 5m topological maps) This computer analysis between the watersheds determined that the accuracy of computer's delineation is not only based off the spatial resolution but also

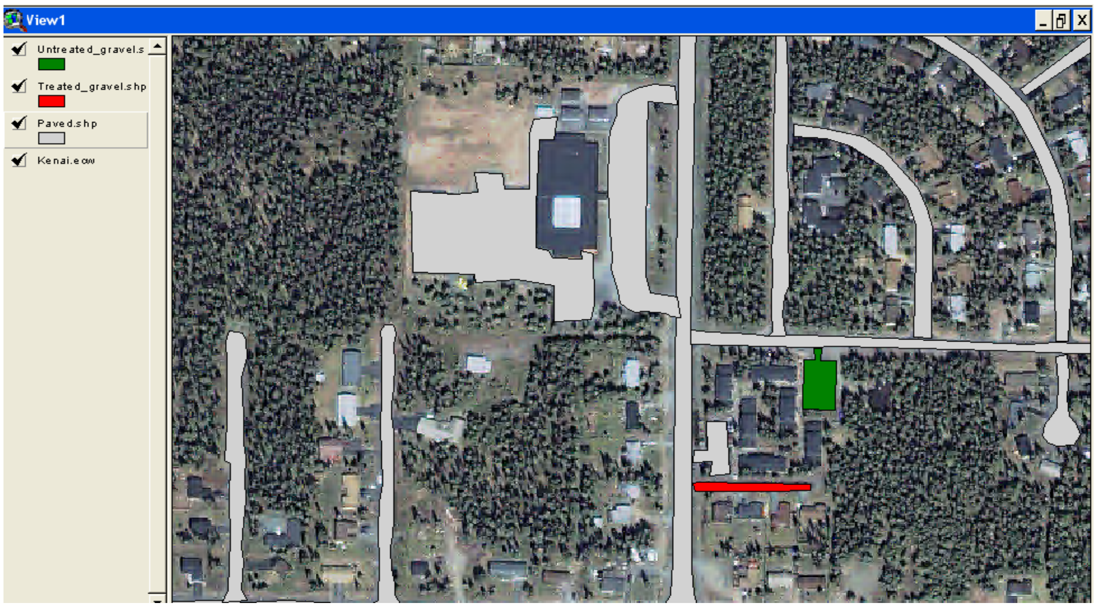

Figure 4. Sears Elementary and surrounding area digitized paved and gravel surfaces. This Figure depicts three different categorizations of impervious surfaces: paved, treated gravel, and untreated gravel.

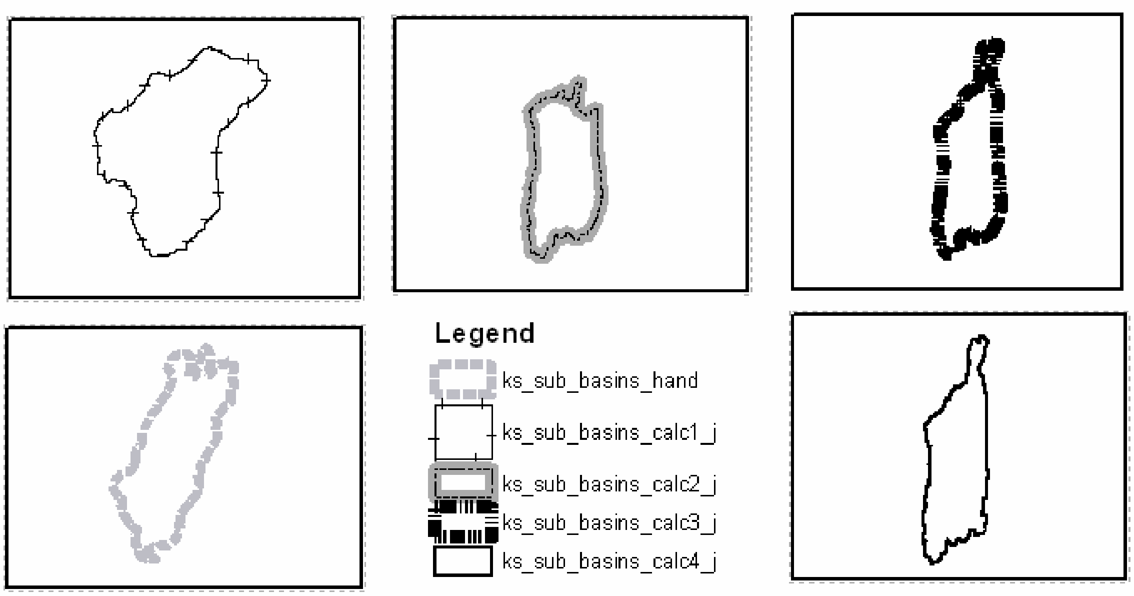

Figure 5. Progression of No-name Creek Watershed delineations.

the size of the DEM. There were a few factors that affected the watershed delineation tool. The first was the accuracy of the DEM, which directly correlates with the accuracy of the delineation. A DEM with the cell size of 100 meters will cause the tool to create large interpolations. This is largest limiting factor of the delineation tool. The second factor concerning the DEM was its geographic extent. A truncated DEM can influence the DEM to create a smaller boundary. The result of DEM influence can be found in figures 5 and 6, which represented all basin delineations. Subbasin calculation 2 (ks_sub_basins_calc2) and subbasin calculation 3 (ks_sub_basins_calc3) are delineation coming from similar parameters, but with differing DEM extents. The truncation of the watershed delineation, subbasin calculation 2, occurred because of the processing requirements of the computer. A smaller grid was extracted from the original kp_grid. This grid contained all the values of the original data set, but did not extend as far north. This resulted in a much smaller grid, north and south, but with similar dimensions east and west. Thus changing the accuracy of the DEM extent affected the size of the calculated watershed. The resulting watersheds can be seen in Figures 5 and 6. The subbasin calculation 3 is the result of using the full DEM.

The last factor that affected the delineation was stream definitions. The original stream shapefile was not accurately defined. Coupled with the lack of DEM resolution this caused the tool to ignore smaller stream segments. This problem was solved by digitizing missing stream segments. A lack of stream definition may not cause a problem with a large data set, but when analyzing a small hydrologic network the more detail the better.
Table 2 depicts the accuracy available for delineation in research study area. The smallest sub-watershed possible to define was 2,000 cells. Decreasing the number of cells needed increased the accuracy of the watershed. Decreasing the allowable threshold to 2,500 cells allowed the computer to delineate all of the watersheds in the Kenai area. The maximum threshold for No-name watershed was 4,420 cells. However when compared to the 2,500 cell delineation it is very inaccurate. The 2,000 cell watershed delineation of No-name watershed provided no further information or accuracy.

The nomenclature used in the file naming process is listed in table 3. It explains what areas were delineated, the type of delineation, and what version. The subbasin hand delineation is named (ks_sub_basins_me) representing the hand delineation of the Kenai area, whereas Subbasin calculation 4 is named

Table 2. Computable Watershed Delineation Threshold Area.

Threshold Area	*# of Cells*	*Minimum Watershed Area(m)^2*	*Minimum Watershed Area (ft)^2*	*Minimum Watershed Area (Miles)^2*
0.01267 e-007	4420	877,039.03	9,440,678.44	0.339
0.1147 e-007	4000	793,700.48	8,543,600.40	0.306
0.10029 e-0007	3498	694,091.07	7,471,378.55	0.268
0.10035 e-007	3000	595,275.36	6,407,700.30	0.230
0.717 e-008	2500	496,062.80	5,339,750.25	0.191
0.573 e-008	2000	396,850.24	4,271,800.20	0.153

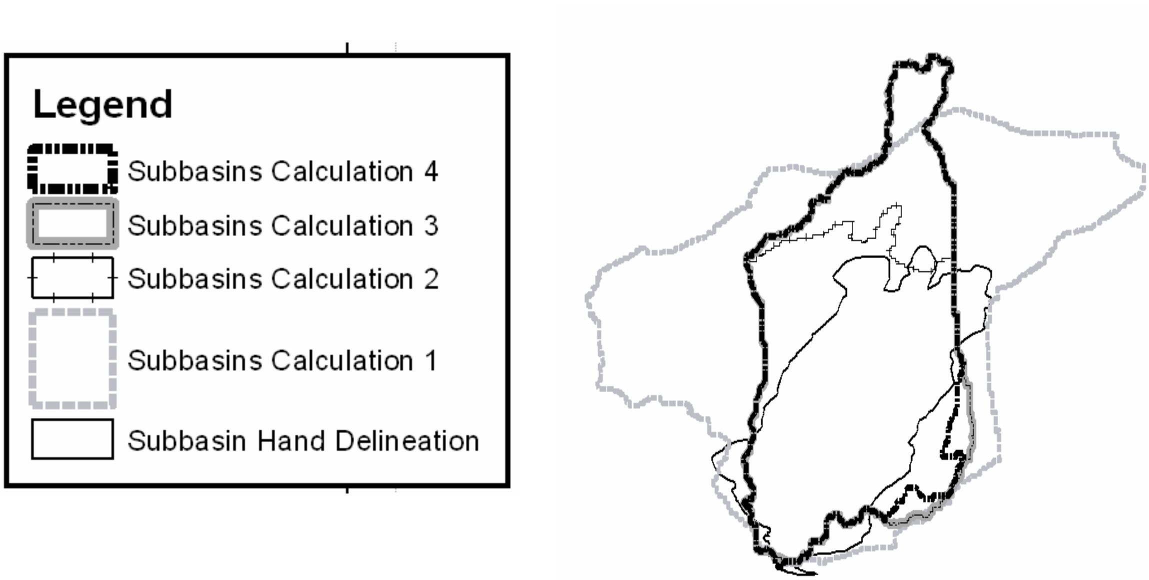

Figure 6. No-Name Creek Watershed delineations superimposed.

(ks_sub_basins_calc4_j) depicting the fourth version of computer generated delineation of the Kenai area. The “j” references that this file is a joined file based on the current basin. All corresponding subbasins were merged into thier large basin or watershed, No-name creek watershed. The subbasins calculation 4 shapefile is the common name given to the ks_sub_basins_calc4_j.

The result of using different DEM’s in the delineation process created a progression in watershed accuracy. The end product is the green watershed in figure 6. This delineation process displayed the sensitivity of the watershed delineation tool.

The first watershed was generated with a low resolution DEM that had a cell size of 143.2ft. The resulting watershed comprised half of the coastal bluff in the Kenai Area and was much too big. This DEM was obtained from Chris Clough of the Kenai Peninsula Borough. The Spruce DEM lacked the accuracy needed for accurate watershed delineation. The Spruce DEM created the ks_sub_basins_calc1_j.

The next DEM was obtained from the Geospatial Services of Saint Mary’s University. This DEM had a greater resolution due to its dataset. The subsequent sub basin calculations were created using kp_proj2 and kp_proj. The subbasin

Table 3. No-name Watershed delineations & nomenclature.

Common Name	**Delineation Shapefile Name**	**Description of file**
Subbasin hand delineation	Ks_sub_Basins_me	Created from topographic paper map
Subbasin Calculation 1	Ks_sub_Basins_calc1_j	Computer generated delineation from DEM (Spruce_l300)
Subbasin Calculation 2	Ks_sub_Basins_calc2_j	Computer generated delineation from DEM (kp_proj2). The truncated DEM made with study_bnd
Subbasin Calculation 3	Ks_sub_Basins_calc3_j	Computer generated delineation from DEM (kp_proj)
Subbasin Calculation 4	Ks_sub_Basins_calc4_j *(KP_Basins)*	Final computer generated delineation from DEM (kp_proj) with edited stream shapefile

calculation 2 watershed was truncated and outlined by the a solid line with hash markings in figure 6. The truncation is due to the modified grid kp_clip1 used in the delineation process. Subbasin calculation 3 is depicted in figure 6, by a gray shaded line with dashes in the center, it is similar to calculation 2 in all aspects except in its vertical length. Once again this is because the third calculation was formed by using the full DEM dataset kp_proj.

The third delineation was originally thought to be the final product; this neglected to take into account complimentary streams. Meaning that each watershed should be adjacent to a corresponding watershed if another stream is present. By selecting adjacent hydrologic networks in the area a fourth and final delineation was created, subbasin calculation 4 (KP_sub_basins_calc_4_j). The addition of the adjacent watersheds cropped off portions of lower section of the watershed.

Figures 7 and 8 depicts histogram views of No-Name creek's elevation. Elevation and slope are the most important factors in watershed delineations. In the case of no-name creek there was not much of an elevation change due to the Kenai Peninsula being formed by glacial scraping. This scraping has given the peninsula a flat appearance throughout much of the no-name watershed boundary. The Kenai area sits on a 100-200 ft shelf over looking the Kenai River. This also reduces the amount of slope present in the watershed. The left segment of no-name creek, Woodland

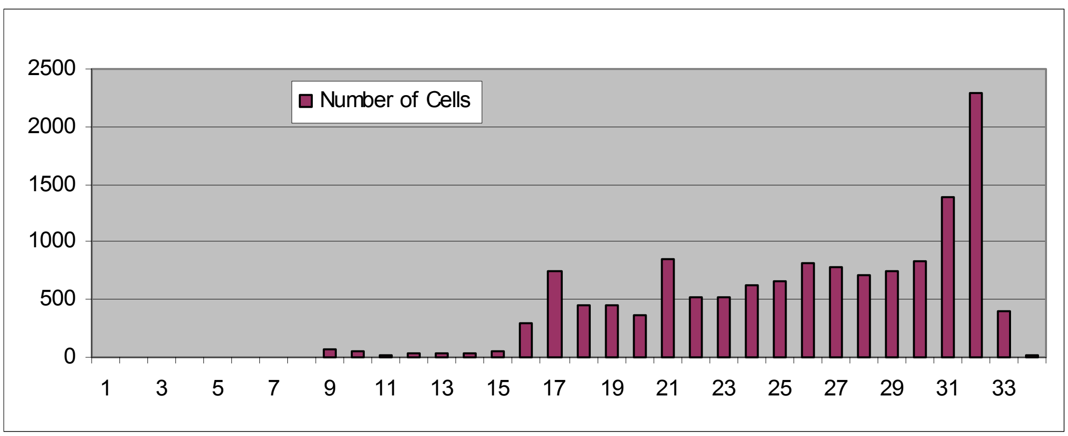

Figure 7. No-Name Watershed Elevation (Meters).

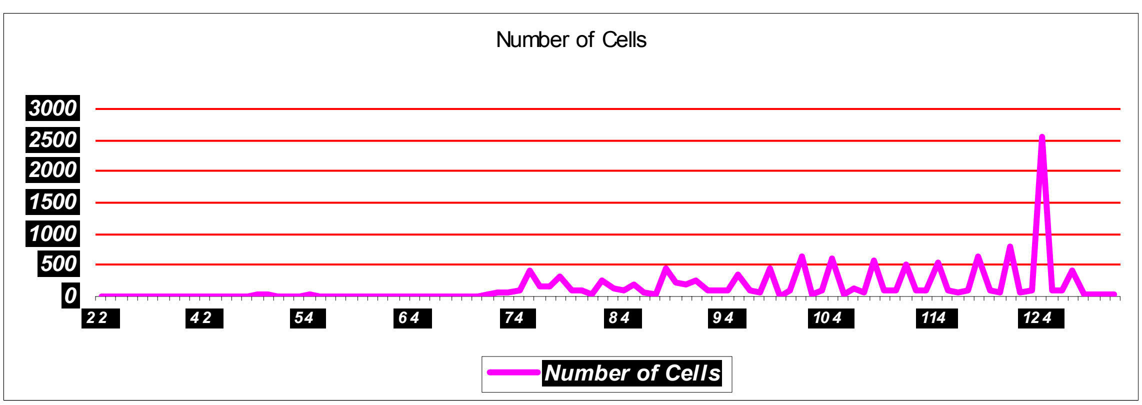

Figure 8. Elevation of No_Name Creek Watershed (Feet).

Figure 9. Finalized Kenai/Soldotna area hydrologic network (KP_Basins). All computer delineations are based off the hydraulic adjacency model. Delineations left to right :No-Name Creek Basin, Kenai Creek Basin, Beaver Creek Basin, Soldotna Creek Basin.

Creek, has cut through much of the Kenai landscape. The elevation change between Woodland Creek and the rest of the Kenai shelf ranges from 50-75 ft. The right segment of no-name creek, Airport Creek, shows similar but less drastic characteristics. The elevation range present in Airport Creek is much smaller 25-40 ft.

Heads Up Digitizing

The on screen digitizing process was vital for the models implementation. All impervious surfaces were digitized from a 2001 IKONOS satellite image obtained from Chris Clough of the Kenai Peninsula Borough GIS department.

Figure 10 depicts the entire digitized Kenai area. All digitized surfaces were checked against the Kenai Parcel database to ensure accuracy. The impervious surfaces were not the only files that needed to be altered. The hydrology files needed to be updated. The result is Figure 9, which consists of about 150 lakes and streams. Updating the hydrologic network improved the accuracy of the no-name creek watershed and adjacent watersheds.

PAH Susceptibility Model

The PAH model is an arithmetic overlay model that uses distance to and from impervious surfaces as the main variable.

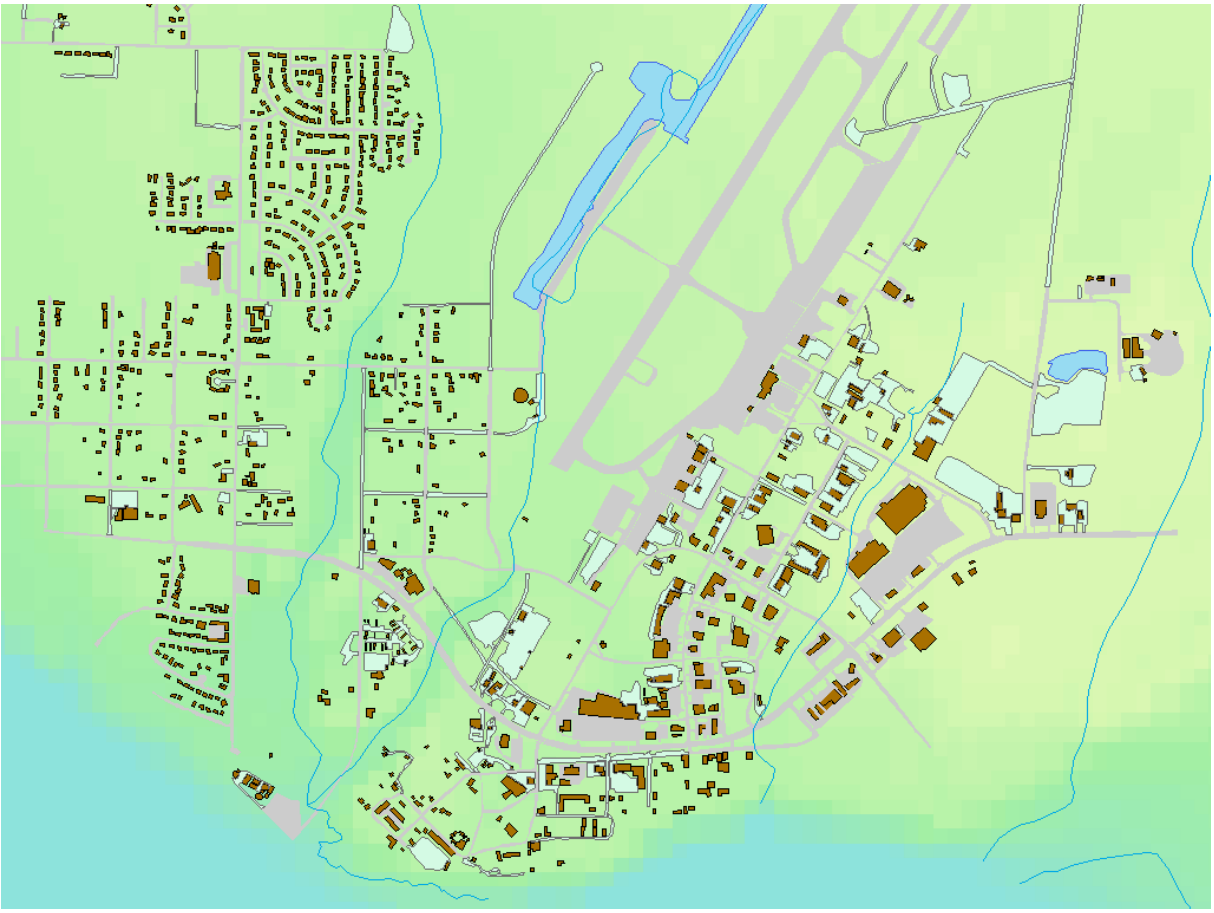

Figure 10. Digitized Impervious Surfaces of the Kenai area. Completed digitizing of the are included the following surfaces: residential, paved, treated gravel, untreated gravel, lakes, and streams.

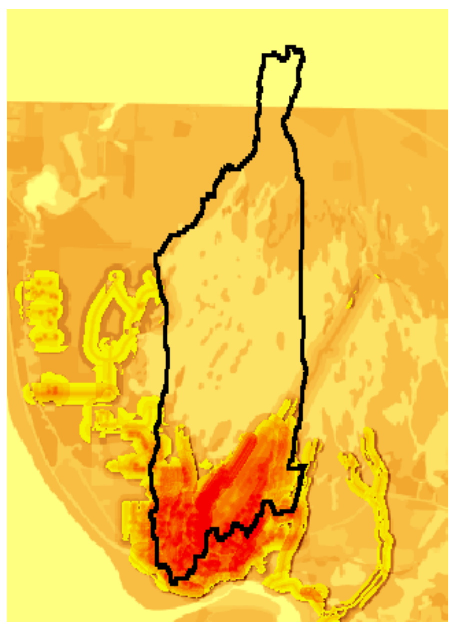

Figure 11. PAH Susceptibility Grid generated from PAH Susceptibility Model.

Reflecting the potential for various layers to affect the PAH environmental loading levels. The susceptibility model uses three groups of layers to determine which areas in the No-Name watershed contribute to PAH environmental loading, which are represented as red or darker shaded areas in Figure 11. The first group consists of geographic layers such as slope and vegetation. These layers are stationary and relatively non-changing. They will affect the areas in their immediate vicinity. The second group consists of the impervious surface layers which look to keep PAHs suspended in a variety of substances. The effect of these layers have on the PAH model will be seen in the distance weighted modeling. The last group consists of specialty features. These specialized impervious surfaces are designated as significantly important PAH contributors in the watershed.

The PAH model takes into account three different sources of information: geographic, digitized impervious surfaces, and specialized anthropogenic surfaces. The ArcView 3.x model was chosen because of its uniform and non-partisan modeling capabilities. When converting the shapefiles into raster formats there are a number of different ways the conversion process can take place. Using the model builder ensures that all of the conversions are done the same way and have the same cell size. Cell size was important because many of the digitized surfaces contained small areas, less than 20 ft. The model builder utility allowed all created grids to have their cell size be set at 15 ft.

To ensure consistency throughout the model a set of model rules were developed. All model layers would have values in 0-8 range. Values >4 were considered to be susceptible. Values <4 were considered to be non-susceptible, thus removing PAHs from the environment. A value of 4 was given to neutral sources.

Geographic Surfaces

The geographic sources include: digital elevation model, streams, lakes, wetlands, and vegetation. The Digital Elevation Model was analyzed and then classified based on the degree of slope. See Appendix IV for values. The stream and lake shapefiles were converted from vector to raster format then buffered. The streams and lakes were buffered up to 500 ft every 50 ft for 10 intervals. The buffers were then given values, based on their distance from the hydrologic feature. Cells within the 0-50 ft area were given the value of 8, 50-100 ft area were given the value of 7, 100-250 ft area were given the value of 6, and 250-500 ft area were given the value of 5.

The vegetation and wetland were converted from vector to raster format. However they were not buffered because distance to a type of vegetation or wetland was unimportant. The type of vegetation or wetland was far more important then the distance. The vegetation shapefile was modified from its traditional eight categories into a five category file. All areas classified as water were removed from the wetland shapefile. The wetland class Aquatic Beds were given a value of six because of their direct link with hydrologic networks and their physical characteristics will allow them to mobilize the PAHs. The Beach Bar class was given a value of 5 because of its relationship with hydrologic networks. The sand present on the Beach Bar will adsorb the PAHs and protect it from degradation. The emergent vegetation class was given the value of 4 because of it hydrologic properties as well. The value is lower depicting the availability and potential presence of bacteria. The flat and upland classes were merged and given a value of 3. The classes were given the value of three because they are typically populated by grass species. These grasses can act an environmental sink for PAHs. The forest and shrub categories were also merged. This last class was given the value of 1 because of its ability to hold soil and promote bacteria life. This class represents the largest sink present in the model.

The vegetation shapefile was modified from its original dataset. The vegetation dataset could be classified by two different groups: Species1 and Type. Species1 listed the most predominate plant species present in that area, however it also included the species water and ocean. The type class only listed the vegetation by categories. To alleviate this problem, the water and ocean categories were removed and the resulting shapefile was converted into raster based on the Type category. The Needle Leaf class was given the value of 4 because of it neutral characteristics. Coniferous trees are beneficial because they stop erosion by holding onto the soil, however they also emit some PAHs. The Broadleaf and Harvest Area categories were merged and given a value of 3. Short grasses and trees will stop erosion and enhance bacteria growth. The mixed category was given a value of 2. The mixed category represents areas populated by many different species, like a home landscape. The Non-Forest, Herbaceous, and Shrub categories were all merged together and give the value of 1. The value of 1 is due their ability to promote bacteria life.

Impervious Surfaces

The impervious surfaces used in the model were paved surfaces, gravel untreated surfaces, gravel treated surfaces, and buildings. The building layer was divided into high density residential and low density residential. All impervious surfaces were digitized, converted into raster format, and then buffered.

The paved surfaces were buffered up to 800 ft, at 8 x 100 ft intervals. Cells within the area of 1-100 ft were given the value of 6. This range represents areas that would be most affected by traffic pollution. 30% of the products created from internal combustion are PAHs. Cells within the area of 100-200 ft were given the value of 5, depicting they would be the second most affected. Cells within the area of 200-300 ft were given the value of 4. Cells within the area of 300-500 ft were given the value of 3, and cell within the area of 500-800 ft were given the value of 2. The last two classifications are designed to show that an overall impact still exists.

The gravel untreated surfaces were buffered up 975 ft at 13 x 75 ft intervals. The highest value 5, are cells within the 0-75 ft range. This area represents ditches and their drainages. The second group contains cells within the 75-150 ft range. The next two groups once again depict the chronic widespread affect of the internal combustion engine. Cells within the area of 150-525 ft were given the value of 3, and cells within the range of 525-975 ft were given the value of 2.

The treated gravel surfaces were buffered up to 500 ft at 10 x 50 ft intervals. The gravel is treated with a chemical called CS1, which is an anti-dusting agent. CS1 is a petroleum product, which could contribute to PAH mobility. The 50-100 ft ranges represents the most susceptible areas ditches and driveways, and were given the value of 8. The next classification contains cells within the area of 50-150 ft and was given the value of 7. The chronic widespread effect will not be as far spread in the treated surfaces, because that is the purpose of the treatment. The next two groups contain the ranges of 150-250 ft and 250-500 ft and were given the values 6 and 5 respectively.

It is debatable which gravel surface is more susceptible. The treated surfaces, though small in number, are liquid source of hydrocarbons. Whereas the untreated gravel will allow the PAHs to adsorb to it and allow it travel much further un-metabolized. In this model, the treated gravel surfaces were viewed as much larger contributors then the untreated.

The building surfaces were divided into high density residential and low density residential. The high density residential consisted of Woodland and Beachfront subdivisions. The low density residential contained all other buildings not represented in high density or the special surfaces. Both surfaces were buffered with similar ranges, 0-200 ft at 25 ft intervals. The high density classification had four categories with values 6:3. Low density classification had four categories with values 5:2. One of the major possibilities of residential contribution was oil run off from oil changing, of small engines, boats, and vehicles. The second contributing factor was the amount of gasoline consumed in those small engines and vehicles.

Special Surfaces

Two special surfaces were included in the susceptibility model. The surfaces consisted of multiple layers including: building, paved, untreated gravel, and treated gravel. The two special surfaces were airport and high density commercial. The airport was chosen because of its use of jet fuel for airplanes. This fuel contains a higher percentage of PAHs then gasoline. The airport was buffered up to 1500 ft at 3 x 500 ft intervals. Cells within the range of 0-500 ft were given a value of 8. Cells within the range of 500-1000 ft were given a value of 6, and cells within the range of 1000-1500 ft were given a value of 4. The jet fuel depicts an interesting problem in the model. Jets will affect a larger area because they are airborne. However their emitted PAHs will degrade faster because they do not have many surfaces to adsorb to. This will cause them photo-oxidized at an extremely high rate.

The next surface analyzed was high density commercial. The high density commercial represents two of the more frequented business areas. These areas often have large parking lots and the subsequent traffic allows for them to be large places for PAH contribution. These areas also have gas stations which are potential contributors to PAHs. The commercial area was buffered from 0-200 ft at 25 ft intervals. The area most affected by this potential PAH contribution lies within the 0-25ft range and was given the value of 6. Cells within the range of 25-75ft range were given the value of 5. The last two categories show the chronic widespread affect and have a range of 75-150ft and 150-200ft. These ranges were given values of 4 and 3 respectively.

Figure 12 depicts the completed PAH Susceptibility model. The left image of Figure 12 shows an unique value classification scheme, whereas the image on the right of figure 12 depicts a stretched value analysis. The unique classification allows the user to define a range of values that will all have a particular color. In figure 12, the left image has 9 different categories. Cells are assigned colors depending on their value and its designated color. The stretch analysis uses a color gradient, which means a set of colors (green, white, and red) are chosen and ranked by value in figure 12. Cells are assigned colors depending on their value. Cells with lower values are assigned green, medium values are white, and high values are red. Cells that are in between are assigned a mixture of the colors. The stretched value analysis shows the contribution of vegetation and wetland shapefiles. This image portrays the effects of not having a complete dataset. The vegetation and wetland shapefiles start 400ft after the tip of the watershed and can be seen by the darker green color changing to a white-ish green color. The image on left in figure 12, is a better visual representation of the susceptibility model. There is merely a cosmetic difference between the right and left images of figure 12. The areas most susceptible are those closest to hydrologic features, colored red. The image on the right in figure 12, allows the user to see the

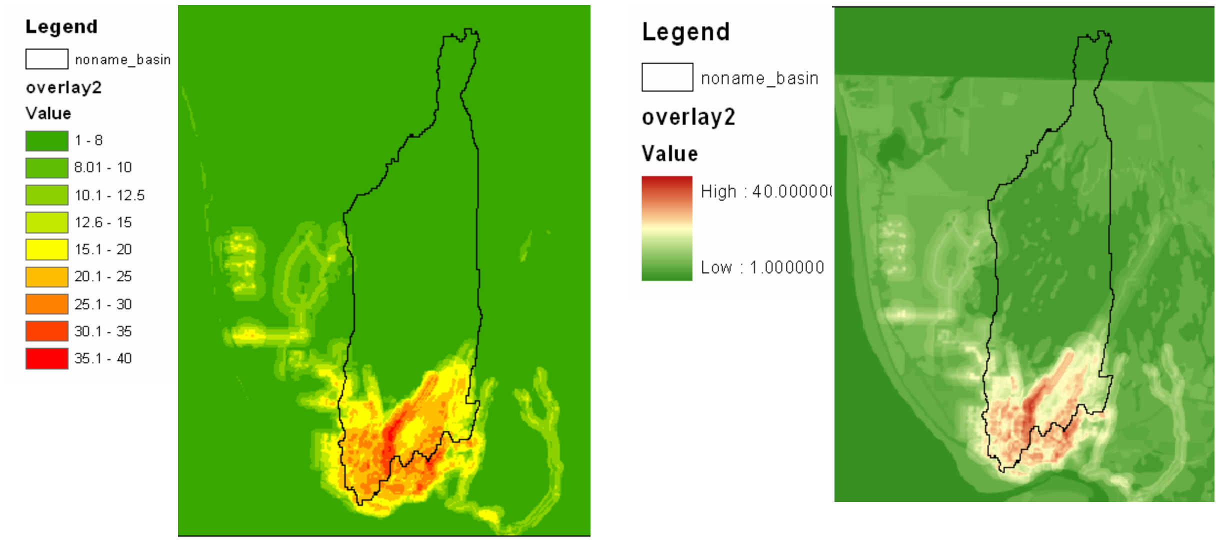

Figure 12. PAH Susceptibility model original classification (left) and PAH Susceptibility model stretched classification (right).

effects of arithmetic model and the shortened dataset. Cells that are colored red, in the right image of figure 12, represents more susceptible areas.

The arithmetic model has a maximum value of 40 and minimum value of 1. Cells that have a value less than 15 represent areas that are not susceptible to PAH loading. Cells with values above 25 represent areas very susceptible to PAH loading. Cells with values between 15:25 are moderately susceptible to PAH loading. Cells that are likely to contribute to PAH loading have a range of value from 25:40

The most susceptible areas were located around the hydrologic features. These were sections of the streams that were close to roads: paved or gravel. Neither paved nor gravel were more susceptible, instead the most susceptible features were the treated gravel surfaces.

The most susceptible feature is the

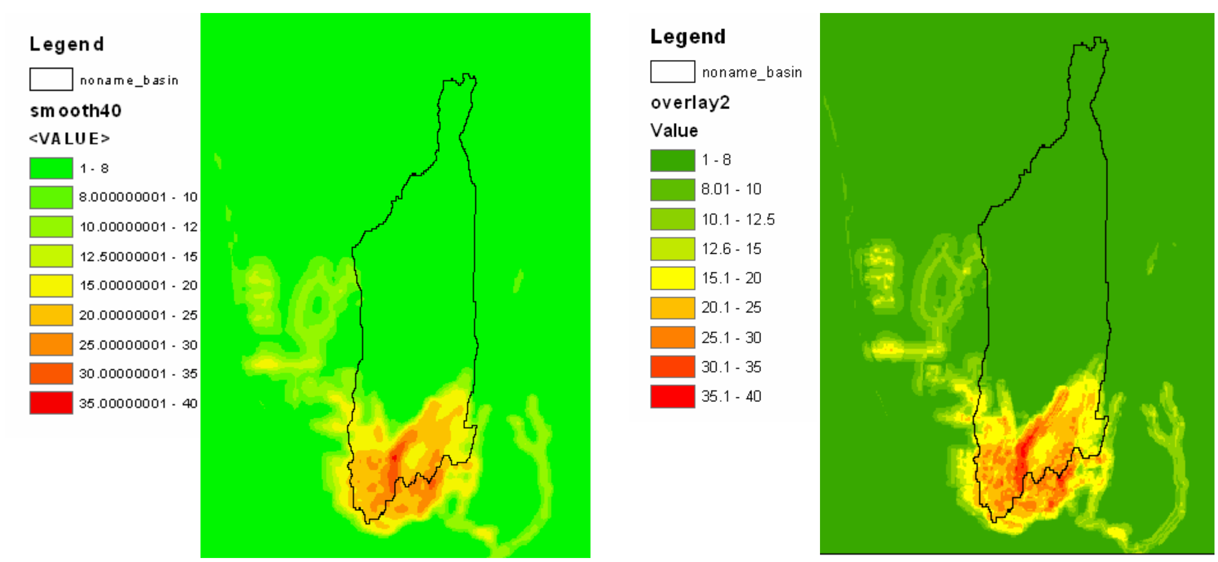

Figure 13. PAH Susceptibility Model Neighborhood analysis with original classification (left) and PAH susceptibility model with original classification (right).

lagoon in Airport Creek. The lagoon is particularly susceptible due to the Airport feature. In addition the paved surfaces around the airport add and give the areas around the lagoon an average value of 30. The commercial area also proved to be a highly susceptible area. The average value of the commercial area was much smaller then the average value of the lagoon. A few other minor spots are present in the model. This is due to location of treated gravel surfaces. Three treated gravel roads are located between the two creeks. These treated surfaces have the potential to greatly impact the amount of PAH loading done.

A neighborhood analysis was conducted on the completed arithmetic overlay, Figure 13 (Left). The analysis averaged cell values looking to eliminate extreme values. The neighborhood parameters were a circular analysis of 40cells. This analysis provides a better product because it looks to highlight and identify trends, while removing the extremes. The number of hotspots is present in the watershed are reduced from 15 to 8. This is a better reflection of a natural occurring phenomenon. There would be a gradual descend from one hotspot to the next.

Conclusion

There were two goals in mind for this project. The first was to create a standard operating procedure for watershed delineations. The BASINS program provided an effective and accurate watershed that was repeatable. The BASINS software was flexible enough to address and deal with the give dataset.

The second goal was to create a PAH susceptibility model of the No-Name Creek watershed. The neighborhood analysis model proved to most accurate of the three datasets. It normalized the dataset and depicted the gradual rise and decline between susceptible and unsusceptible areas. The total area of highly susceptible area was 11,635 meters^2. This consists of cells with a value between 25 and 38. Only 2,268 meters^2 of the highest susceptible value of 38 were present in No-Name Watershed. This susceptible area centers around the lagoon. The lagoon behind the airport represents the largest hotspot in the watershed. Another highly susceptible area included the treated gravel road spruce. The gravel road was a hotspot because of its proximity to hydrologic features. The road is located between airport and woodland creek. It also near other treated gravel surfaces.

Discussion

The project was successful in both creating an accurate standard operating procedure for watershed delineation and creating the PAH susceptibility model. The model prove to be useful tool in future PAH determination project. The project provided many new challenges with data collection, data organization, and model implementation, but the result of the project was far better then expected. The model will prove to be a useful to in assessing other watersheds in the area.

No-Name Creek

The hand delineation that was created for the Kenai Watershed Forum was much better then expected. The accuracy of the hand delineation is much easier seen in an on-screen comparison to that of number basis. The hand delineation lacked the accuracy needed for delineation, because of its 5 meter contour interval limit of the paper topology map. The computer generated watershed delineation seems to be more accurate, however not having another watershed delineation tool to compare against or another accurate DEM to use makes it difficult to determine. The repeatability of the computer generated delineation suggest that it is an accurate delineation.

Susceptibility Model

The vegetation and wetland shapefiles had a much larger visual then numerical impact on the susceptibility model. This is due to the fact that the shapefile did not encompass the entire watershed. The northern portion of the watershed has very low values because there are no other layers present.

The slope performed even less a role then predicted. Most of the landscape was given a value of 1 for slope. The higher values came about in the drastic elevation change of the coastal shelf and the inlet. As the accuracy of the DEM increases slope may begin to be a larger factor. In this model, slope should be ignored as a contributing factor to PAH loading in the model.

It was particularly surprising that the High Density Residential layer had almost no role in the model calculation. Overall there was almost no impact on the susceptibility levels of the surrounding areas. Both subdivisions come very close to the streams beds, but the largest buffer range was 200ft and had a value of 3. It is difficult to know whether or not this is an accurate representation of the affects of High Density Residential on PAH loading. Research on PAH levels in much larger cities, Seoul, Korea or Beijing, China, depicts a direct relationship which reflects the accuracy of the PAH Susceptibility Model (Kang, et. al, 2002). The model suggests that smaller communities like Kenai, AK will have a minimal impact on PAH loading.

Future Work

The Kenai Watershed Forum is currently trying to map the PAH levels present in the Woodland and Airport Creeks. By taking the collected PAH samples they can create accurate fingerprints the selected creeks. The model suggests locations where the samples should be taken. The lagoon in airport creek is the largest hotspot present in the watershed. Therefore, samples should be taken before the lagoon and after. This will ensure that measurement is detecting the amount of PAH input from the airport jet fuel.

Another location to collect samples would be along Woodland Creek, specifically the length of Spruce Rd. This stream section is surrounded by six different sections of treated gravel. The first collection should be on Woodland creek before the Spruce Rd begins and the second collection should be after the termination of the road. This ensures that the collection points are maximizing their chances of collection PAHs due to the CS1 gravel road treatment. One item that can help increase the accuracy of the model is updating the DEM. The slope and distance from hydrology are the two largest factors that impact the model. Two secondary factors that can impact the model are precipitation and wind.

By updating the wetland and vegetation files to complete datasets, they would eliminate the truncation problem present in the first model. The updated files would also have a more accurate dataset, which accurately reflects the land today. The last improvement would be designing better buffers. They should be created on the specific vegetation type and not the overall dataset. Thus creating a more reflective model.

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Appendix I Polycyclic Aromatic Hydrocarbons

List of U.S. Government Department and their PAH Categorization

Department of Health and Human Services	
Animal Carcinogens	Benz[a]anthracene, benzo[b]fluoranthene, benzo [j]fluoranthene, benzo[k]fluoranthene, benzo[a]
International Agency for Research on Cancer *(IARC)*	
Probable Carcinogenic to Humans	benz[a]anthracene and benzo[a]pyrene
Possible Human Carcinogens	benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene,
Non-Classifiable	anthracene, benzo[g,h,i]perylene, benzo[e] pyrene, chrysene, fluoranthene, fluorene, phe-
Environmental Protection Agency	
Probable Human Carcinogens	benz[a]anthracene, benzo[a]pyrene, benzo[b] fluoranthene, benzo[k]fluoranthene, chrysene,
Non-Classifiable	acenaphthylene, anthracene, benzo[g,h,i] perylene, fluoranthene, fluorene, phenanthrene,

List of PAH Hazardous Metabolites by the CDC (Table Source: NPI, 1990)

Benz[a]anthracene	1-hydroxybenz[a]anthracene, 3-hydroxybenz[a]anthracene
Benzo[c]phenanthrene	1-hydroxybenzo[c]phenanthrene, 2-hydroxybenzo[c]phenanthrene, 3-hydroxybenzo[c]phenanthrene
Chrysene	3-hydroxychrysene, 6-hydroxychrysene
Fluoranthene	3-hydroxyfluoranthene
Fluorene	2-hydroxyfluorene, 3-hydroxyfluorene
Phenanthrene	1-hydroxyphenanthrene, 2-hydroxyphenanthrene, 3-hydroxyphenanthrene
Pyrene	1-hydroxypyrene

Appendix II Digital Data Sources

Digitized Elevation Maps Name: Kenai (C-4) SE, Alaska Source: Kenai Peninsula Borough Format: Mr. SID Universal Transverse Mercator Year: 1986
IKONOS Imagery Name: Kenai.ews Source: Kenai Peninsula Borough Format: ER Mapper Compression Year: 2001
Digital Ortho-Quarter Quadrangle (DOQQ) Name: 1996_DOQQ (Folder) Source: Kenai Peninsula Borough Format: Mr. SID Year: 1996
GSS Grid Delineation Parameters Name: L300 Source: GeoSpatial Services of St. Mary's University Format: GRS Mercator Year: 2002 Cell Size: 30 F
KP Grid Delineation Parameters Name: KP Grid Source: Kenai Peninsula Borough Format: NAD 27 State Plane, Zone 4 Year: 1990 Cell Size: 46.2158FT Range: 0-148
KP Grid Spruce Bark Delineation Parameters Name: KenaiSold Source: Spruce Bark Beetle Format: NAD 27 State Plane, Zone 4 Year: 2000 Cell Size: 45M Range: 0-3000

Appendix III PAH Susceptibility Model

Appendix IV Model Calculation Values

Stream Buffer Values

1	50	8
50	100	7
100	250	6
250	500	5

Lake Buffer Values

1	50	8
50	100	7
100	250	6
250	500	5

Wetlands Reclassification (-Open Water)

Aquatic Bend	6
Beach Bar	5
Emergent	4
Flat & Upland	3
Forest & Shrub	3

Vegetation Reclassification –(Water & Ocean)

Needle Leaf (Evergreen)	4
Broadleaf & Harvest Area	3
Mixed	2
Non-Forest	1

Slope (Slope map is made in a discrete configuration. Each cell has a defined value, integer.)

0	5	1
5	10	2
10	15	3
15	20	4
20	25	5
25	30	6
30	35	7
35	40	8
40	45	9
45	90	10

High Density Residential Buffer Values

0	25	6
25	75	5
75	150	4
150	200	3

Low Density Residential Buffer Values

0	25	5
25	75	4
75	125	3
125	200	2

Paved Surfaces Buffer Values

0	100	6
100	200	5
200	300	4
300	500	3
500	800	2

Treated Gravel Surfaces Buffer Values

0	50	8
50	150	7
150	250	6
250	500	5

Untreated Gravel Surfaces Buffer Values

0	75	5
75	150	4
150	525	3
525	975	2

Airport Buffer Values

0	500	8
500	1000	6
1000	1500	4

High Density Commercial Buffer Values

0	25	6
25	75	5
75	150	4
150	200	3