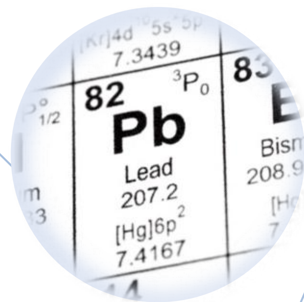
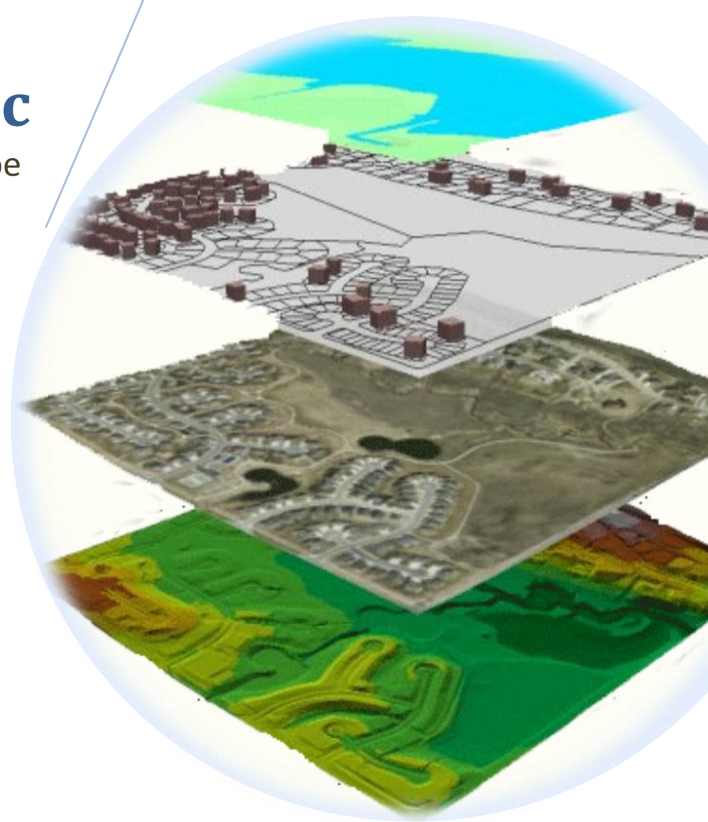


The Environmental Potential of PFC on Mopac

Visualizing contaminant reduction based on slope



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Introduction

As populations in US cities continue to grow, development and urbanization increases. Impervious surfaces, such as roads and freeways are necessary components of urban development. These roadways and the stormwater runoff that they produce can have a large impact on surrounding watersheds. When pollutants reach a waterbody, it is much more difficult and expensive to remove then if onsite treatment was available. Therefore, interest in stormwater treatment methods that prevents pollutants from contaminating receiving waters is increasing. Many low impact designs are being to reduce the impact of land development on the environment, as organizations such as the Environmental Protection Agency (EPA) and the Texas Commission on Environmental Quality (TCEQ) strengthen regulations. In Texas, wet ponds, vegetated filter strips, and sand filters are currently used to meet these requirements. However, cities like Austin, find that these methods have difficult land requirements in addition to being expensive to construct and maintain.

A permeable friction course or PFC as described by the Texas Department of Transportation (TxDOT) is a porous overlay approximately 2 inches thick that is placed on top of an existing asphalt or concrete highway. Rain that falls on the highway drains through the porous layer to the original impermeable surface, and then the rain drains within the PFC until arriving at the edge of the pavement. PFC is used by TxDOT to increase safety by reducing the amount of water on roadways. Current research by the University of Texas is exploring the ability of PFC to reduce the amount of contaminants in stormwater runoff using a test section along Mopac Freeway. As seen in Table 1, the study has shown a reduction of Total Suspended Solids (TSS) and of various heavy metals to be between 61% to 97% since 2010.

Table1: Reduction of Contaminates using PFC Overlay on Mopac

Constituent	Units	Conventional Pavement	PFC Overlay	reduction (%)
TSS	mg/L	259	45.6	82
P total	µg/L	0.52	0.204	61
Cu total	µg/L	52.8	20.8	61
Pb total	µg/L	153	3.99	97
Zn total	µg/L	294	65	78

These results suggest that in addition to the safety benefits, PFC could be implemented for EPA compliance without any extra land use for wet ponds or sand filters. However, PFC can only be implemented on roadways with slopes less that 5%, and are preferably only used on roadways with slopes of 2% or less. Further research is being conducted by the University of Texas to determine the effectiveness of underdrains in combination with PFC to make the larger slopes (2-5%) more acceptable. Underdrains still allow for the filtration of runoff through the pavement but also increase the capacity by providing more drainage in areas where ponding could occur.

Objective

The scope of this project is to determine the percentage of Mopac that meets the current slope requirements for PFC overlays, and how much more of Mopac could meet requirements if the under drain research is successful in alleviating ponding concerns Rainfall data is used in combination with the results of the UT study to calculate a volume of pollutants that would not be introduced into the environment if PFC was placed along all acceptable stretches of Mopac. In addition, the watersheds that could be affected by the potential reduction in pollutants are identified.

Methods

Digitation

A shapefile representing Mopac was crucial to the project so that geometric data could be collected about the area and length of sloped segments. In addition, layers containing important data such as precipitation would need to be clipped to the area of study. Many databases were found that contained either centerlines for mopac or shape files that were rough representations of the highway. Greater precision was needed and so a polygon was created in Arcmap, by visually tracing mopac using the imagery basemap. Figure 1 shows how vertexes were added on a need basis, with more being implemented on curves than on straight segments. A separate polygon was created for the northbound and southbound lanes and the medians were not included. A small portion of the freeway entrances and exits were incorporated into the overall shape.

Figure 1: Digitation Process

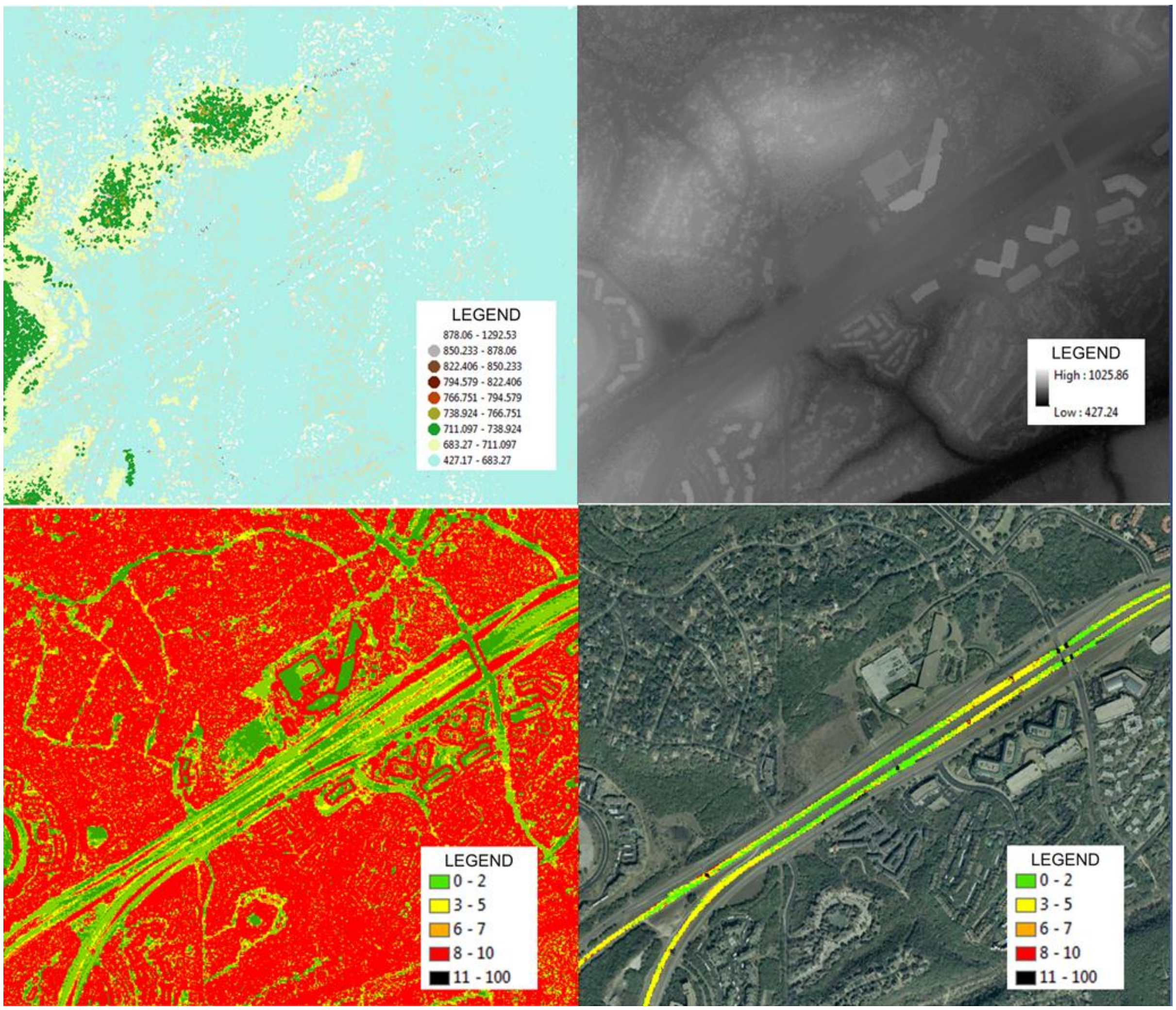
The polygon was used to calculate the total length and area of Mopac by adding geometric fields to the attribute tables. These values were used to compare with the known geometry of the mopac highway and were helpful in the analysis described later in this paper.

LIDAR Processing

Originally a digital elevation model (DEM) for travis county was downloaded and clipped to the Mopac polygon. However, DEM's represent the ground surface elevation and are not a good representation of manmade structures such as buildings or roadways. Therefore LIDAR data was obtained from the Texas Natural Resource Information System (TNRIS). The raw files obtained from TNRIS were LAS files. This data was placed into Arcmap by creating a new LAS dataset in the catalog and then adding the files along with correct accompanying projection files.

The output is a group of elevation points that can be seen in the top left corner of figure 2. This elevation data can be turned into a more useful format for GIS analysis by using the “LAS to raster” tool. Slopes were then calculated from the raster using the “slope” tool and the data was cut to the mopac polygon using the “extract to mask” tool.

Figure 2: Lidar Processing steps



Slope Analysis

Green was assigned to slopes that could sustain PFC (0-2%), yellow was used to represent slopes that one should be cautious about placing PFC on (2-5%), orange and red slopes should not have PFC (6-10%) and black slopes are slopes that should not appear on any highway. Visually the entire length of the extracted slope data was inspected and no areas bigger than a few pixels were orange, red or black. It was determined from this observation that all black pixels were caused by overpasses and all red/orange pixels were vehicles or vegetation. It was then assumed that the entire length of Mopac has slopes of less than 5%.

Raster Calculator was used to determine the percentage of Mopac with slopes of less than 2% compared with the percentage of Mopac with slopes between (2-5%). The areas that were not accounted for in this analysis because of overpasses, bridges and trees, were distributed evenly between the two subclasses based on percentage.

Rainfall and Contaminant Reduction

Precipitation data was downloaded from the Capital Area Council of Governments (CAPCOG). This data was cut by the Mopac polygon using the spatial analysis "clip" tool (Figure 3). Field calculator and attribute tables were then used to determine the average annual rainfall over the area of Mopac (Figure 4).

Figure 3: Rainfall Methods

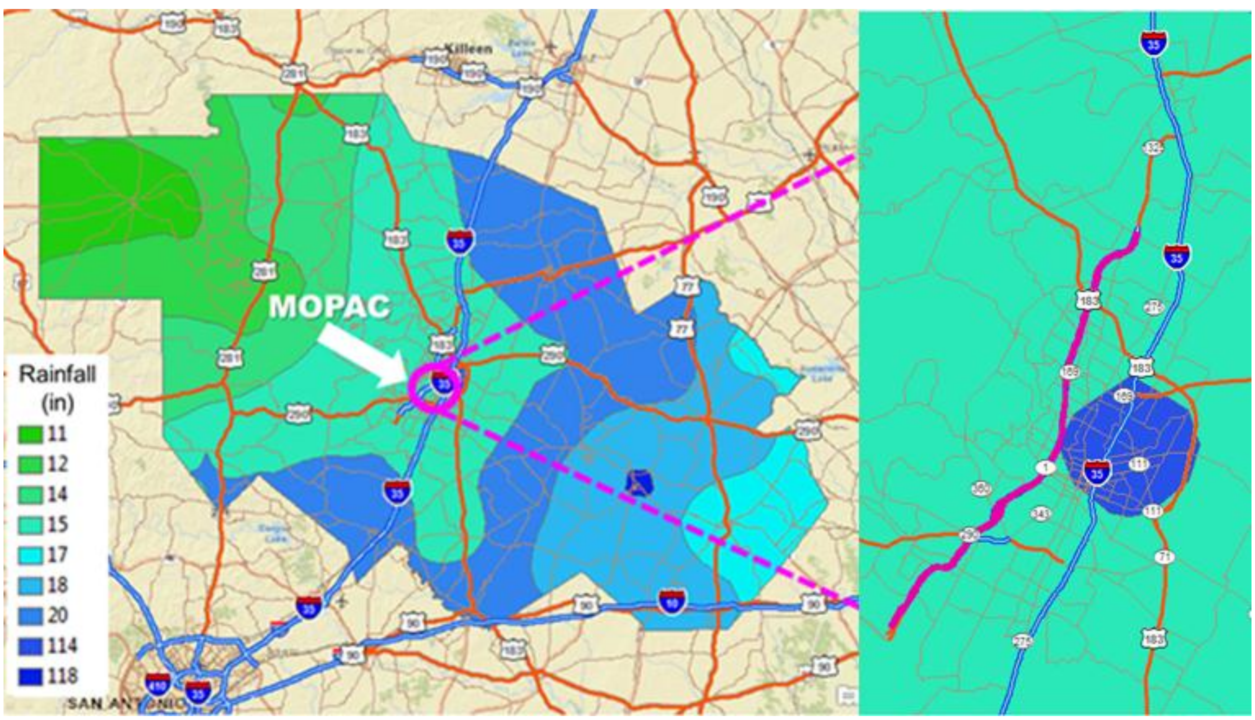
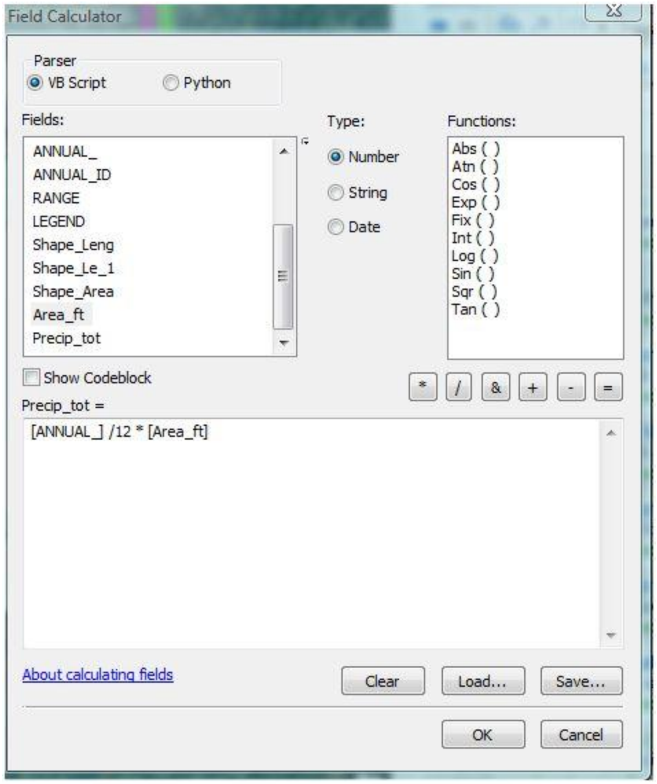
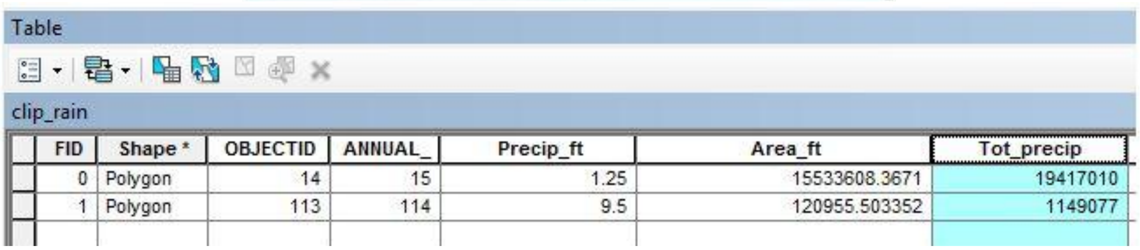


Figure 4: Precipitation calculations





FID	Shape *	OBJECTID	ANNUAL_	Precip_ft	Area_ft	Tot_precip
0	Polygon	14	15	1.25	15533608.3671	19417010
1	Polygon	113	114	9.5	120955.503352	1149077

The 114 inches per year section of the capcog data seemed like a typo, therefore an alternate source of rainfall data was also used to compare with. Prism data from Oregon State University was overlayed with the mopac polygon and extrat by mask was used (Figure 5). The data was origionally in units of mm*100 and was converted to inches for comparison (Figure 6).

Figure 5: Prism data over mopac

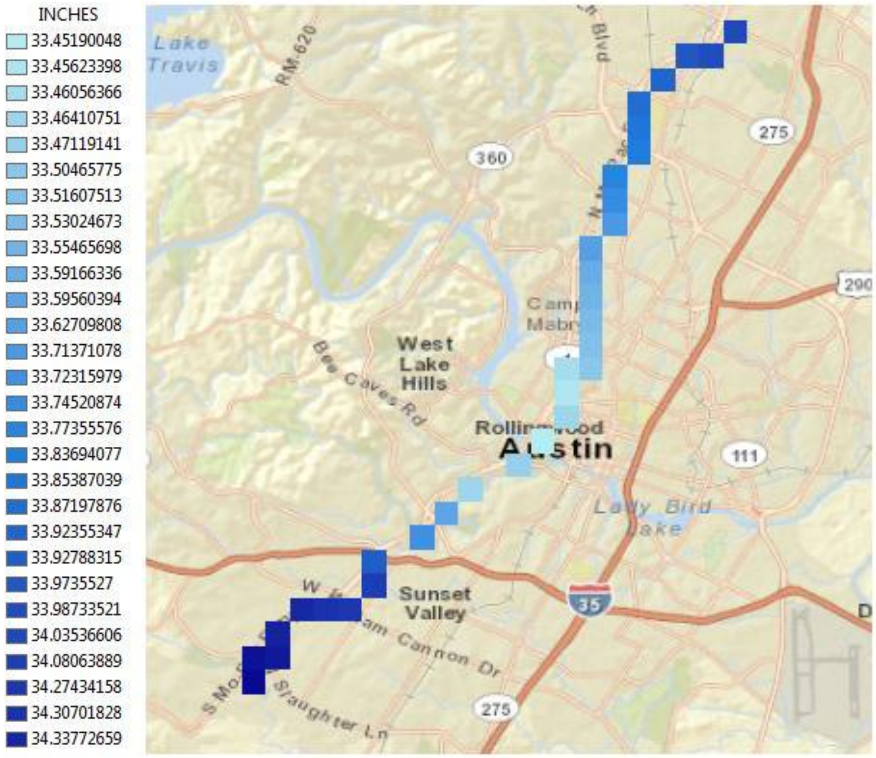
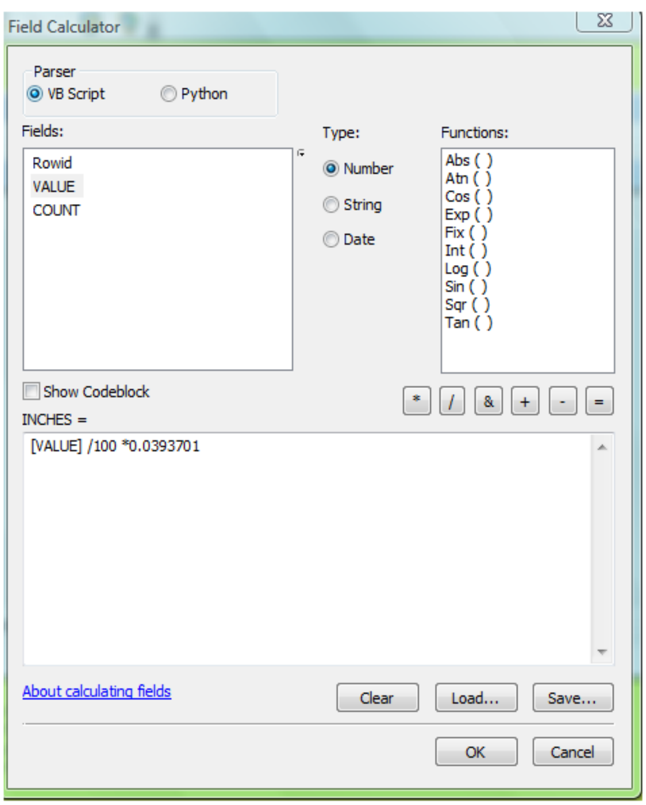


Figure 6: Field Calculator



The total precipitation was converted to liters so that it could be used with the University of Texas experimental contaminent values from the PFC test strip along mopac. The potential reduction of contaminants were calculate in kg/yr for the scenerio where only the slopes of 2% and less were paved with PFC and for the scenerio where PFC and underdrains were utilized to allow for the entire paving of Mopac. The following equation was used in this analysis.

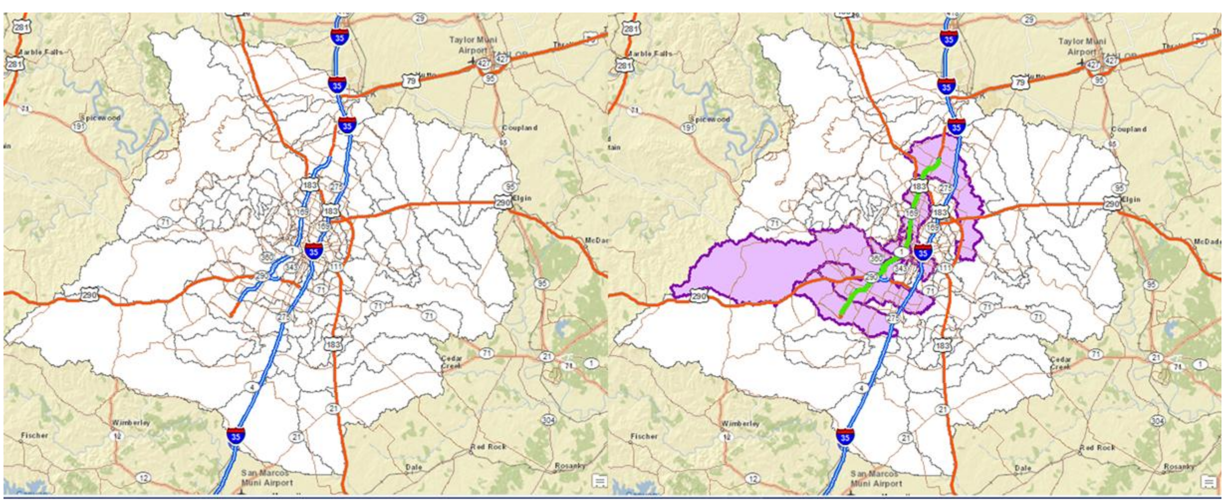
$$\frac{\boldsymbol{contaminent\ not\ introduced\ into\ environment}}{\boldsymbol{given\ pavement\ scenerio}}\left(\frac{\boldsymbol{kg}}{\boldsymbol{yr}}\right) = precip\left(\frac{L}{Yr}\right) * \frac{volume\ of\ contaminent}{1L\ of\ conventional\ pavement\ runoff}\left(\frac{kg}{L}\right) * \frac{\%\ reduction\ of\ contaminent}{when\ PFC\ is\ present} * \frac{\%\ of\ mopac\ paved\ with\ pfc}{given\ scenario}$$

Reduction was calculated for all 5 contaminents listed in the introduction under both pavement scenerios.

Watershed Analysis

Watersheds for travis county were downloaded from the City of Austin Website. The watersheds affected by Mopac's stormwater runoff were determined by selecting those watersheds that were bisected by the Mopac Shapefile. The affected watersheds were extracted into their own feature class to visually show the local areas that contain receiving bodies for the contaminated highway runoff (Figure 7).

Figure 7: Watershed Identification



Results

Digitation

The digitation process resulted in two separate polygons that represent the lanes of Mopac in each direction (figure 8). The geometric statistics found from the attribute table matched known information about Mopac. The length and area were calculated to be 23.5 miles and 15,654,563.8 ft^2 respectively (Table 2).

Figure 8 : Digitation results

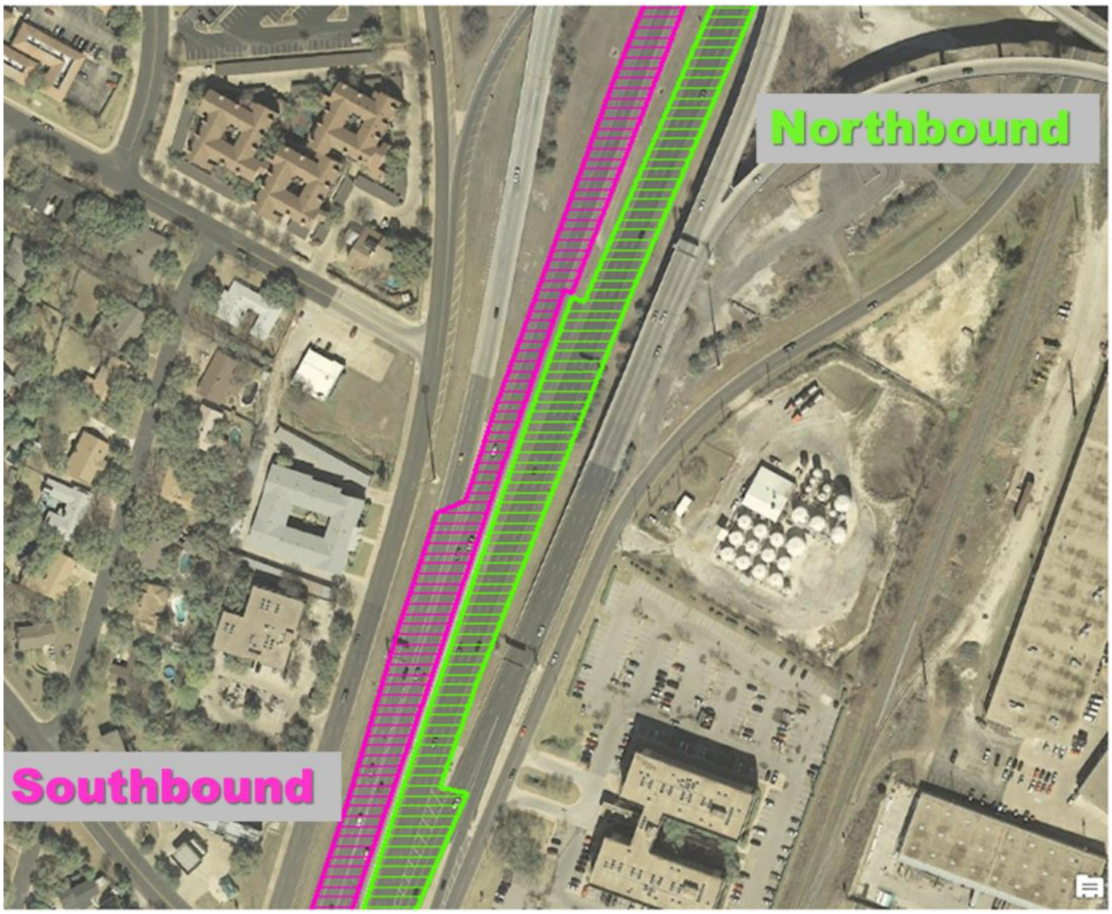


Table 2: Geometric Statistics of Mopac

Direction	Length(miles)	Area(ft^2)	square miles
North Bound	23.5	7820725.88	0.281
South Bound	23.6	7833837.92	0.281
Total:	**47.1**	**15654563.8**	**0.6**

Lidar/ Slope Analysis

The LiDAR Processing was successful in determining the distribution of slopes along the length of Mopac. Visible stretches of the highway were clearly designed at slopes within the two ranges. The smallest stretches of consistent slope were about ¼ of a mile which seems reasonable for typical highway design (Figure 9). It was determined from the raster calculator analysis that 56% of Mopac has slopes less that 2% and the remaining 44% is sloped less than 5%. Therefore over half of Mopac could easily support PFC based on slope requirements and all of Mopac could be paved with PFC if underdrains were utilized. These results and the calculations involved are in Table 3.

Figure 9: Segment of Mopac slopes

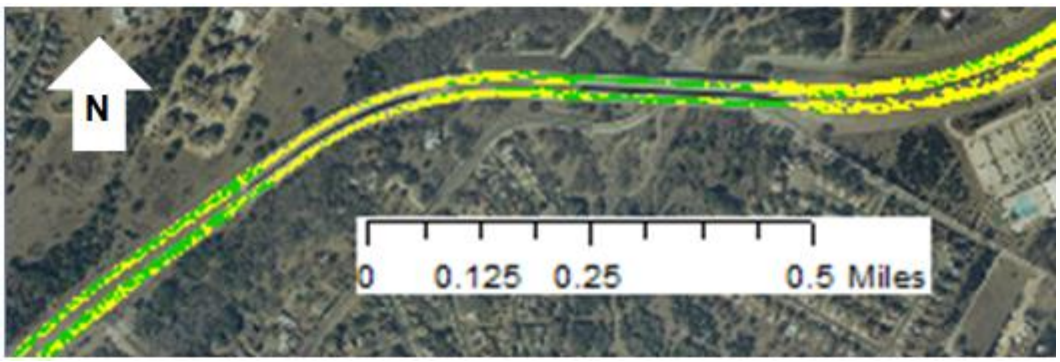


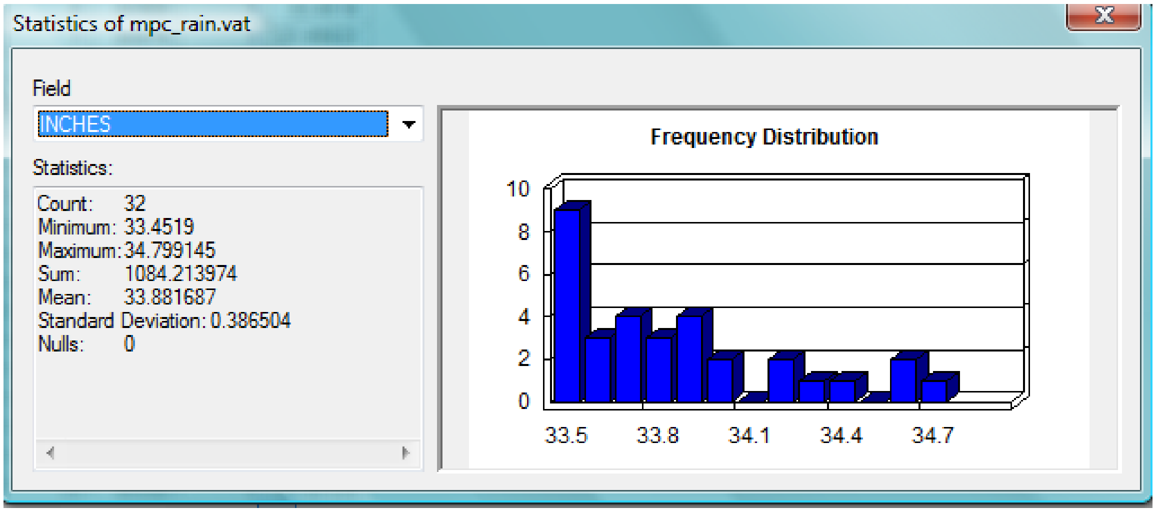
Table 3: Slope results

slope	Raster calculator	raster cells	Fraction	Area(sq. ft)
0-5	"mopac_slope"< = 5	96031	1	15,654,564
0-2	"mopac_slope"< = 2	53969	0.56	8,797,796
2-5	"0-5" - "0-2"	42062	0.44	6,856,768

Rainfall

The PRISM rainfall data suggested that the average rainfall over mopac was 33.88 inches per year (figure 10). This suggests that different years worth of data was used in the Prism analysis and the CAPCOG analysis. The CAPCOG data was used in the rest of this project with the accompanying assumption that the 114 inch value was supposed to be 14 inches.

Figure 10: Prism Rainfall statistics



Most of Mopac (99.2%) fell within the teal 15 in/yr precipitation polygon. However, A small portion of the lanes in each direction near Windsor Rd (0.77%) lies inside the Blue 14 in/yr polygon (Figure 11). The total average rainfall per year along mopac is 553,886,099 L/yr (Table 4). The quality of this large volume of runoff could be improved If the entire length of Mopac were paved with PFC, however, 310,176,215 L/yr could still be affected if only the sections of roadway that are sloped less than 2% were paved (Table 5).

Figure 11: Rainfall Polygon

Table 4: Rainfall results

Rainfall (in)	Rainfall (ft)	Area (ft^3)	Total Precip(ft^3)	Total Precip(L/yr)
15	1.25	15533608	19417010	549889723
14	1.17	120956	141115	3996376
Total:				553,886,099

Table 5: Rainfall Distribution

Implementation	slope	rainfall effected (L/yr)
PFC Only	0-2%	310,176,215
PFC+Underdrain	0-5%	549889723

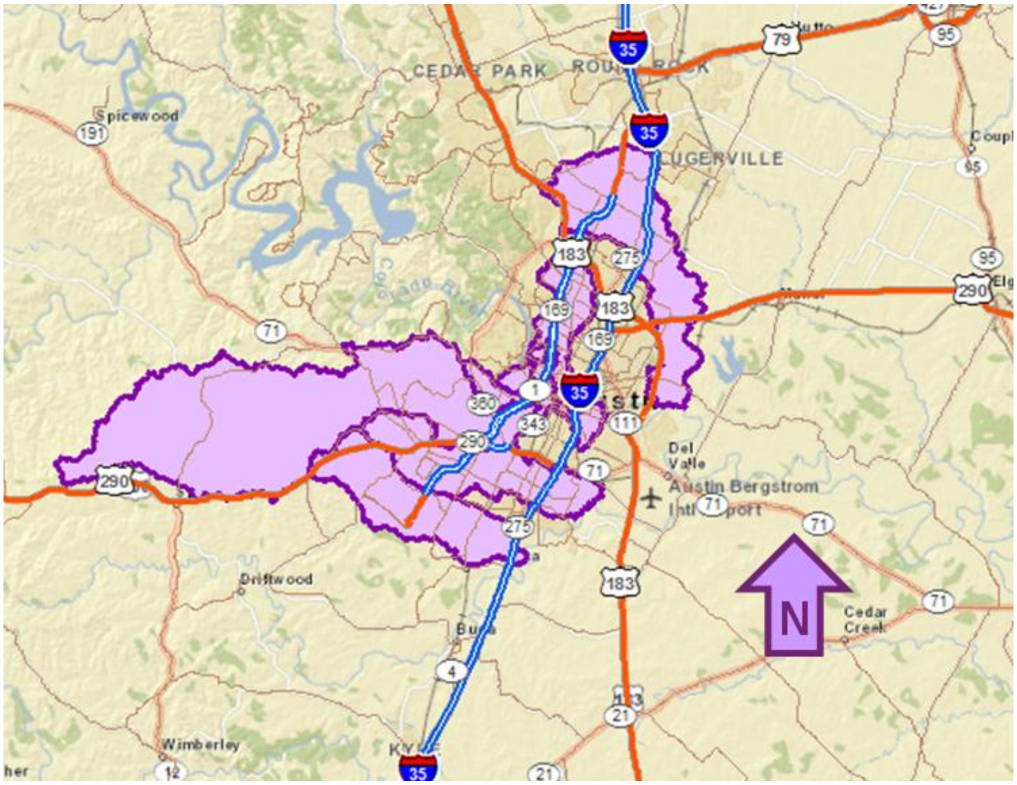
Contaminants

This Project assumes that the contaminant load found in the rainfall collected near Camp Mabry is a representative sample of contaminant loads along all of Mopac. These contaminant load results were combined with the effected rainfall values from table five to calculate pollutant mass for both pavement scenerios previously described. The mass of pollutants that would still be introduced into the environment vs. those that would be reduced from the runoff can be found in Table six. The results suggest that if PFC were to be installed along all of Mopac, up to 124,315 kg/yr of suspended solids and about 240 kg/yr of studied metals could be kept from entering the environment. The Watersheds that currently receive highway runoff from Mopac can be seen in Figure 12. These are the areas that could benefit from the reduction of pollutants such as heavy metals and suspended solids described below.

Table 6: Contaminant reduction results

	Contaminant Load still Present (kg/yr)			Contaminant Load Reduced (kg/yr)	
	No PFC Installed	**PFC on 0-2% slopes**	**PFC on 0-5% slopes**	**PFC on 0-2% slopes**	**PFC on 0-5% slopes**
TSS	150,850	81,233	26,534	69,617	124,315
Ptotal	0.30	0.20	0.12	0.10	0.18
Cutotal	31	20	12	10	19
Pbtotal	89	41	2	49	87
Zntotal	171	96	38	75	134

Figure 12: Watersheds Affected by Mopac Runoff



Conclusions

While the water quality information above in table 6 was calculated using real data, the actual reduction of pollutants from paving all or some of Mopac with PFC can not be decisively determined from this process. This exercise does show, however, that there is a potential for watershed improvement from PFC overlays on highways although the exact effect is not quantified. The maps produced in an analysis like this could also aid in the decision making process for city planners. GIS has the capability to show Department of Trasportations which watersheds they could improve by focusing on certain roadways.

GIS has also proved to be a useful tool in determining the slopes of current highways. While slope records are kept in most city offices after a roadway is constructed, the plans for older systems and cities are not always accurate or easily accessible. As LiDAR Data becomes more comprehensive, accurate and easily accessible, it could be used to determine the slopes of any digitized area. In addition, an accurate estimation of the average rainfall over any paved surface is necessary to the design process. The approach used in arcmap is a quick and easy method for any region where precipitation maps are currently available.

While the slope and rainfall analysis was successful in determining the possibility of PFC installation in some respects, there are other issues to consider in practice. While not problematic in Austin Texas, PFC is not preferred in locations with prolonged freeze-thaw, high water tables, or where salt treatment for snow control is utilized. Some transportation engineers are still concerned about the relative strength of PFC to traditional pavement and choose not to use it on roads with heavy vehicle usage. The approach used in this project is just one possible method for city planners to aid in the decision making process. In addition, the visualizations produced in similar analysis could be helpful in conveying technical information more efficiently.

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