

# **Observations on Pennsylvania Flood Data**

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## **Introduction**

Pennsylvania's topography makes many areas in the state prone to flooding. While there are measures in place to deal with flood events, their implementation varies, and areas face damages with differing levels of severity when major weather events occur. The goal of this research is to answer the question, "How Do Severe Flood Events Affect Certain Infrastructure and Populations in Pennsylvania?" This is a broad question that is not necessarily qualifiable in all aspects. In order to answer this question specifically, a statistical analysis of Pennsylvania flood data will highlight key predictors that affect both bridges, critical pieces of Pennsylvania infrastructure, and populations within the state. An ideal answer to this question would highlight the association between certain variables and damages so that government officials can invest in safety measures in areas more prone to feel the damage of flooding. Given greater fluctuations in weather intensity due to climate change (include extra EDA here), identifying vulnerable infrastructure and populations is critical in order to prepare for catastrophic flooding events.

## **Data**

The data set for this research comes from the United States Geological Survey and FEMA's flood data release for Pennsylvania. The data can be found here: [Flood Data Collection in Pennsylvania](Flood Data Collection in Pennsylvania – Site Selection Data for the Development of a Rapid Deployment Network | U.S. Geological Survey (usgs.gov)

The following are key variables being used from the data set. Please note that variables having "Var" in the name have been normalized (by dividing the initial variable by its maximum value) in the data set already so that they are easier to work with:

## **Control Variables:**

**YEARCON:** The year in which a bridge was reconstructed (relabeled in this analysis as recon\_yr)

**DKSURFTYPE:** The surface type of the bridge deck (relabeled in this analysis as dk\_surf)

**COUNTY\_NAM:** the name of the county in which the data point was recorded (relabeled in this analysis as county)

**POPVar:** The mean population count within a 1 km radius of the location

**HURVar:** Hurricane track density in kilometers per square kilometers

**FLEVVar:** Distance to the nearest point in the historical flood event data collection site data set in meters

**DDVar:** Number of disaster declarations per 1000 square kilometers

**CLAVar:** Number of flood-related insurance claims per square kilometer

**INDAVar:** Number of flood-related individual assistance applications per square kilometer

**REPLVar:** Number of flood-related repetitive loss records per square kilometer

## **Response Variables**

**ScoCritVar:** Scour critical bridge indicator.

[SCBI Guide](Scour-Calculator-Manual.pdf (state.pa.us))

The Scour Critical Bridge Indicator (SCBI) Code and Scour Assessment Rating (SAR) calculator developed by the Pennsylvania Department of Transportation (PennDOT) and the U.S. Geological Survey to identify Pennsylvania bridges with excessive scour conditions or a high potential for scour.

Scour: *Bridge scour is the removal of sediment such as sand and gravel from around bridge abutments or piers. Hydrodynamic scour, caused by fast flowing water, can carve out scour holes, compromising the integrity of a structure. In the United States, bridge scour is one of the three main causes of bridge failure.* [Scour Definition](#)

Use of the calculator will enable PennDOT bridge personnel to quickly calculate these scour indices if site conditions change, new bridges are constructed, or new information needs to be included.

**SVIVar:** Social Vulnerability Index

## Methodology

Infrastructure Analysis

Population Analysis

Method Notes

## Quarto

Quarto enables you to weave together content and executable code into a finished document.  
To learn more about Quarto see <https://quarto.org>.

```
[1] 4
```

The `echo: false` option disables the printing of code (only output is displayed).

```
library(tidyverse)
```

```
-- Attaching core tidyverse packages ----- tidyverse 2.0.0 --
v dplyr     1.1.3     v readr     2.1.4
v forcats   1.0.0     v stringr   1.5.0
v ggplot2   3.4.3     v tibble    3.2.1
v lubridate  1.9.2     v tidyr    1.3.0
v purrr     1.0.2
-- Conflicts -----
x dplyr::filter() masks stats::filter()
x dplyr::lag()   masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to becom
```

```
library(yardstick)
```

```
Attaching package: 'yardstick'
```

```
The following object is masked from 'package:readr':
```

```
spec
```

```

library(broom)
library(pROC)

Type 'citation("pROC")' for a citation.

Attaching package: 'pROC'

The following objects are masked from 'package:stats':

cov, smooth, var

library(ggfortify)

fludd <- read.csv("paflooddata.csv")
view(fludd)

```

## Results

```

fludd <- fludd |>
  mutate(build_yr = as.factor(fludd$YEARBUILT),
         recon_yr = as.factor(fludd$YEARRECON),
         onbridge_service = as.factor(fludd$SERVTYPON),
         umbreon = as.factor(fludd$SERVTYPUND),
         dk_surf = as.factor(fludd$DKSURFTYPE),
         county = as.factor(fludd$COUNTY_NAM),
         watershed_id = as.factor(fludd$HUC8))

#cor(as.factor(fludd))

bridge_logit <- glm(ScoCritVar ~ recon_yr + dk_surf +
  POPVar + HURVar +
  FLEVVar + DDVar + (POPVar*DDVar),
  data = fludd,
  family = "binomial")
summary(bridge_logit)

```

```

Call:
glm(formula = ScoCritVar ~ recon_yr + dk_surf + POPVar + HURVar +
    FLEVVar + DDVar + (POPVar * DDVar), family = "binomial",
    data = fludd)

```

Coefficients:

	Estimate	Std. Error	z value	Pr(> z )
(Intercept)	-1.74768	0.12546	-13.930	< 2e-16 ***
recon_yr1875	18.90266	2399.54472	0.008	0.993715
recon_yr1882	17.83980	2399.54472	0.007	0.994068
recon_yr1902	-15.46037	2399.54472	-0.006	0.994859
recon_yr1907	19.44434	2399.54472	0.008	0.993535
recon_yr1909	-14.21186	2399.54472	-0.006	0.995274
recon_yr1914	17.74848	2399.54472	0.007	0.994098
recon_yr1915	18.23810	1669.60644	0.011	0.991284
recon_yr1918	1.29946	1.30349	0.997	0.318812
recon_yr1919	-15.44950	845.59314	-0.018	0.985423
recon_yr1920	0.42738	1.16120	0.368	0.712838
recon_yr1921	17.73123	2399.54472	0.007	0.994104
recon_yr1923	19.01369	2399.54472	0.008	0.993678
recon_yr1926	17.84914	2399.54472	0.007	0.994065
recon_yr1927	0.44036	1.18123	0.373	0.709300
recon_yr1928	-14.65179	1163.59142	-0.013	0.989953
recon_yr1929	2.74053	1.24316	2.204	0.027490 *
recon_yr1930	2.09890	0.75003	2.798	0.005135 **
recon_yr1931	-0.05924	1.08356	-0.055	0.956397
recon_yr1932	2.61724	1.30299	2.009	0.044576 *
recon_yr1933	1.12826	0.90355	1.249	0.211774
recon_yr1934	-0.58479	1.07121	-0.546	0.585127
recon_yr1935	0.71655	1.18709	0.604	0.546097
recon_yr1936	1.95332	0.60723	3.217	0.001296 **
recon_yr1937	0.91219	0.71227	1.281	0.200309
recon_yr1938	-0.09195	1.11654	-0.082	0.934367
recon_yr1939	0.00224	1.11085	0.002	0.998391
recon_yr1940	0.59095	0.48870	1.209	0.226581
recon_yr1941	1.07278	0.44159	2.429	0.015125 *
recon_yr1942	1.10271	0.52097	2.117	0.034289 *
recon_yr1943	2.53000	1.27324	1.987	0.046915 *
recon_yr1944	0.12517	1.12862	0.111	0.911694
recon_yr1945	0.63066	0.60393	1.044	0.296369
recon_yr1946	1.00655	0.44109	2.282	0.022491 *
recon_yr1947	0.59000	0.37617	1.568	0.116776
recon_yr1948	0.45183	0.32451	1.392	0.163815

recon_yr1949	0.69921	0.24835	2.815	0.004872	**
recon_yr1950	0.90358	0.24180	3.737	0.000186	***
recon_yr1951	-0.04181	0.42005	-0.100	0.920712	
recon_yr1952	0.41540	0.36612	1.135	0.256534	
recon_yr1953	0.13121	0.37227	0.352	0.724498	
recon_yr1954	-0.02816	0.39507	-0.071	0.943182	
recon_yr1955	0.93635	0.40396	2.318	0.020453	*
recon_yr1956	0.44741	0.38870	1.151	0.249724	
recon_yr1957	-0.24448	0.54457	-0.449	0.653478	
recon_yr1958	1.22311	0.46481	2.631	0.008503	**
recon_yr1959	-0.28104	0.48755	-0.576	0.564328	
recon_yr1960	0.41594	0.30464	1.365	0.172140	
recon_yr1961	1.00970	0.34789	2.902	0.003704	**
recon_yr1962	0.17150	0.32993	0.520	0.603202	
recon_yr1963	0.38742	0.36638	1.057	0.290315	
recon_yr1964	0.65435	0.31652	2.067	0.038702	*
recon_yr1965	0.83691	0.37959	2.205	0.027468	*
recon_yr1966	0.18765	0.45995	0.408	0.683284	
recon_yr1967	0.76474	0.43451	1.760	0.078408	.
recon_yr1968	0.53783	0.43683	1.231	0.218243	
recon_yr1969	0.12659	0.55758	0.227	0.820402	
recon_yr1970	1.21281	0.31078	3.902	9.52e-05	***
recon_yr1971	1.14703	0.47171	2.432	0.015031	*
recon_yr1972	0.51319	0.41163	1.247	0.212491	
recon_yr1973	0.92762	0.35110	2.642	0.008241	**
recon_yr1974	0.74866	0.37050	2.021	0.043313	*
recon_yr1975	0.21464	0.38594	0.556	0.578105	
recon_yr1976	0.24426	0.40351	0.605	0.544954	
recon_yr1977	0.44662	0.35997	1.241	0.214709	
recon_yr1978	1.16396	0.26903	4.327	1.51e-05	***
recon_yr1979	0.80404	0.30205	2.662	0.007768	**
recon_yr1980	0.81341	0.27453	2.963	0.003047	**
recon_yr1981	-0.28612	0.36428	-0.785	0.432197	
recon_yr1982	0.80749	0.22081	3.657	0.000255	***
recon_yr1983	1.01988	0.23159	4.404	1.06e-05	***
recon_yr1984	0.70632	0.24685	2.861	0.004219	**
recon_yr1985	0.57298	0.22299	2.570	0.010184	*
recon_yr1986	0.94266	0.21348	4.416	1.01e-05	***
recon_yr1987	0.54386	0.25070	2.169	0.030057	*
recon_yr1988	-0.02023	0.29632	-0.068	0.945562	
recon_yr1989	0.33663	0.32720	1.029	0.303563	
recon_yr1990	0.15008	0.28873	0.520	0.603211	
recon_yr1991	0.71292	0.24099	2.958	0.003093	**

recon_yr1992	0.67356	0.24488	2.751	0.005950	**
recon_yr1993	0.41392	0.29611	1.398	0.162152	
recon_yr1994	-0.50801	0.35569	-1.428	0.153220	
recon_yr1995	0.24615	0.27683	0.889	0.373921	
recon_yr1996	0.74140	0.27317	2.714	0.006646	**
recon_yr1997	0.23986	0.30872	0.777	0.437185	
recon_yr1998	0.90183	0.24516	3.679	0.000235	***
recon_yr1999	0.58560	0.26920	2.175	0.029603	*
recon_yr2000	0.14524	0.33357	0.435	0.663274	
recon_yr2001	0.45760	0.25517	1.793	0.072927	.
recon_yr2002	0.13175	0.31180	0.423	0.672628	
recon_yr2003	-0.08135	0.35078	-0.232	0.816617	
recon_yr2004	-0.10888	0.39003	-0.279	0.780127	
recon_yr2005	0.60137	0.29332	2.050	0.040344	*
recon_yr2006	0.43962	0.28390	1.549	0.121500	
recon_yr2007	-0.25560	0.32614	-0.784	0.433207	
recon_yr2008	0.52727	0.22617	2.331	0.019737	*
recon_yr2009	0.42721	0.20174	2.118	0.034203	*
recon_yr2010	0.30610	0.19399	1.578	0.114576	
recon_yr2011	0.27931	0.21362	1.308	0.191041	
recon_yr2012	0.10096	0.24734	0.408	0.683153	
recon_yr2013	0.44682	0.23815	1.876	0.060632	.
recon_yr2014	0.10017	0.26663	0.376	0.707150	
recon_yr2015	0.24798	0.27760	0.893	0.371687	
recon_yr2016	-0.57616	0.37339	-1.543	0.122820	
recon_yr2017	-0.74301	0.39543	-1.879	0.060244	.
recon_yr2018	-0.32910	0.33896	-0.971	0.331597	
recon_yr2019	-0.39971	0.32273	-1.239	0.215524	
recon_yr2020	0.09662	0.32997	0.293	0.769671	
recon_yr2021	-0.04953	0.40842	-0.121	0.903469	
recon_yr2022	-15.11049	2399.54473	-0.006	0.994976	
dk_surf1	-1.55377	0.09635	-16.127	< 2e-16	***
dk_surf2	-0.19502	0.28138	-0.693	0.488263	
dk_surf3	-2.10413	0.22078	-9.531	< 2e-16	***
dk_surf4	-0.86998	1.13183	-0.769	0.442105	
dk_surf5	-2.09859	0.18963	-11.067	< 2e-16	***
dk_surf6	-0.23677	0.08733	-2.711	0.006705	**
dk_surf7	-0.13895	0.17340	-0.801	0.422939	
dk_surf8	0.18876	0.30008	0.629	0.529322	
dk_surf9	-0.65242	0.42793	-1.525	0.127358	
dk_surfN	-1.38577	0.09372	-14.787	< 2e-16	***
dk_surfP	-15.41523	125.07627	-0.123	0.901912	
POPVar	-0.27744	0.67172	-0.413	0.679591	

```

HURVar      -0.40927   0.11591  -3.531 0.000414 ***
FLEVVar     0.44775   0.10578   4.233 2.31e-05 ***
DDVar       2.32495   0.18555  12.530 < 2e-16 ***
POPVar:DDVar -4.79305  1.27261  -3.766 0.000166 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

(Dispersion parameter for binomial family taken to be 1)

```

Null deviance: 21893  on 27428  degrees of freedom
Residual deviance: 19954  on 27303  degrees of freedom
AIC: 20206

```

Number of Fisher Scoring iterations: 15

```

vul_lm <- lm(SVIVar ~ county + HURVar + POPVar +
               FLEVVar +
               CLAVar + INDavar + REPLVar,
               data = fludd)

summary(vul_lm)

```

Call:

```

lm(formula = SVIVar ~ county + HURVar + POPVar + FLEVVar + CLAVar +
    INDavar + REPLVar, data = fludd)

```

Residuals:

Min	1Q	Median	3Q	Max
-0.89020	-0.09782	-0.00751	0.09479	0.63397

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	0.400623	0.008856	45.238	< 2e-16 ***
countyALLEGHENY	-0.115296	0.009914	-11.629	< 2e-16 ***
countyARMSTRONG	0.148413	0.011545	12.855	< 2e-16 ***
countyBEAVER	-0.025948	0.011685	-2.221	0.026392 *
countyBEDFORD	0.148984	0.010051	14.824	< 2e-16 ***
countyBERKS	-0.063602	0.009838	-6.465	1.03e-10 ***
countyBLAIR	0.094747	0.011028	8.592	< 2e-16 ***
countyBRADFORD	0.127304	0.009538	13.347	< 2e-16 ***

countyBUCKS	-0.187243	0.010073	-18.588	< 2e-16	***
countyBUTLER	-0.017001	0.011103	-1.531	0.125724	
countyCAMBRIA	0.150554	0.011446	13.153	< 2e-16	***
countyCAMERON	0.027164	0.017557	1.547	0.121829	
countyCARBON	0.086706	0.014066	6.164	7.19e-10	***
countyCENTRE	-0.135664	0.010422	-13.017	< 2e-16	***
countyCHESTER	-0.112494	0.009822	-11.454	< 2e-16	***
countyCLARION	0.249235	0.013063	19.080	< 2e-16	***
countyCLEARFIELD	0.210403	0.010346	20.336	< 2e-16	***
countyCLINTON	0.179951	0.012198	14.752	< 2e-16	***
countyCOLUMBIA	0.009925	0.011405	0.870	0.384177	
countyCRAWFORD	0.169671	0.010537	16.102	< 2e-16	***
countyCUMBERLAND	-0.037049	0.010700	-3.462	0.000536	***
countyDAUPHIN	-0.009312	0.011063	-0.842	0.399934	
countyDELAWARE	-0.077081	0.012189	-6.324	2.59e-10	***
countyELK	-0.061823	0.014532	-4.254	2.10e-05	***
countyERIE	0.000368	0.010248	0.036	0.971354	
countyFAYETTE	0.207101	0.010990	18.845	< 2e-16	***
countyFOREST	0.199183	0.017473	11.399	< 2e-16	***
countyFRANKLIN	0.025369	0.010411	2.437	0.014825	*
countyFULTON	0.065634	0.012847	5.109	3.26e-07	***
countyGREENE	0.168184	0.010690	15.732	< 2e-16	***
countyHUNTINGDON	0.092977	0.010825	8.589	< 2e-16	***
countyINDIANA	0.183778	0.011040	16.646	< 2e-16	***
countyJEFFERSON	0.133492	0.012465	10.709	< 2e-16	***
countyJUNIATA	0.265484	0.011382	23.325	< 2e-16	***
countyLACKAWANNA	-0.029199	0.011237	-2.599	0.009368	**
countyLANCASTER	0.051095	0.009182	5.565	2.65e-08	***
countyLAWRENCE	0.081257	0.012027	6.756	1.44e-11	***
countyLEBANON	0.065037	0.012153	5.351	8.80e-08	***
countyLEHIGH	-0.139323	0.010939	-12.736	< 2e-16	***
countyLUZERNE	-0.019275	0.010366	-1.859	0.062984	.
countyLYCOMING	0.031464	0.010025	3.139	0.001699	**
countyMCKEAN	0.165203	0.011974	13.797	< 2e-16	***
countyMERCER	0.169993	0.010667	15.936	< 2e-16	***
countyMIFFLIN	0.097118	0.012548	7.740	1.03e-14	***
countyMONROE	0.092431	0.011106	8.323	< 2e-16	***
countyMONTGOMERY	-0.133826	0.010165	-13.166	< 2e-16	***
countyMONTOUR	0.024355	0.014547	1.674	0.094090	.
countyNORTHAMPTON	-0.111308	0.010965	-10.151	< 2e-16	***
countyNORTHUMBERLAND	0.007753	0.010776	0.719	0.471845	
countyPERRY	0.100410	0.011205	8.961	< 2e-16	***
countyPHILADELPHIA	-0.195791	0.017789	-11.006	< 2e-16	***

countyPIKE	0.062014	0.013655	4.542	5.61e-06	***
countyPOTTER	0.273556	0.011840	23.105	< 2e-16	***
countySCHUYLKILL	0.034526	0.010712	3.223	0.001270	**
countySNYDER	0.075215	0.011474	6.555	5.64e-11	***
countySOMERSET	0.184265	0.010947	16.833	< 2e-16	***
countySULLIVAN	0.178125	0.013154	13.542	< 2e-16	***
countySUSQUEHANNA	0.063841	0.010098	6.322	2.61e-10	***
countyTIOGA	0.142225	0.009399	15.133	< 2e-16	***
countyUNION	0.181137	0.012447	14.553	< 2e-16	***
countyVENANGO	0.155240	0.012726	12.199	< 2e-16	***
countyWARREN	0.118193	0.011813	10.005	< 2e-16	***
countyWASHINGTON	-0.022962	0.009829	-2.336	0.019487	*
countyWAYNE	0.026198	0.010656	2.459	0.013955	*
countyWESTMORELAND	-0.031018	0.010158	-3.054	0.002263	**
countyWYOMING	0.049509	0.012192	4.061	4.90e-05	***
countyYORK	-0.070750	0.009225	-7.669	1.78e-14	***
HURVar	0.007419	0.006927	1.071	0.284230	
POPVar	1.444860	0.023181	62.328	< 2e-16	***
FLEVVar	-0.124188	0.009597	-12.941	< 2e-16	***
CLAVar	-0.223889	0.037905	-5.907	3.53e-09	***
INDAVar	-0.259271	0.022491	-11.528	< 2e-16	***
REPLVar	0.170122	0.041972	4.053	5.07e-05	***

---

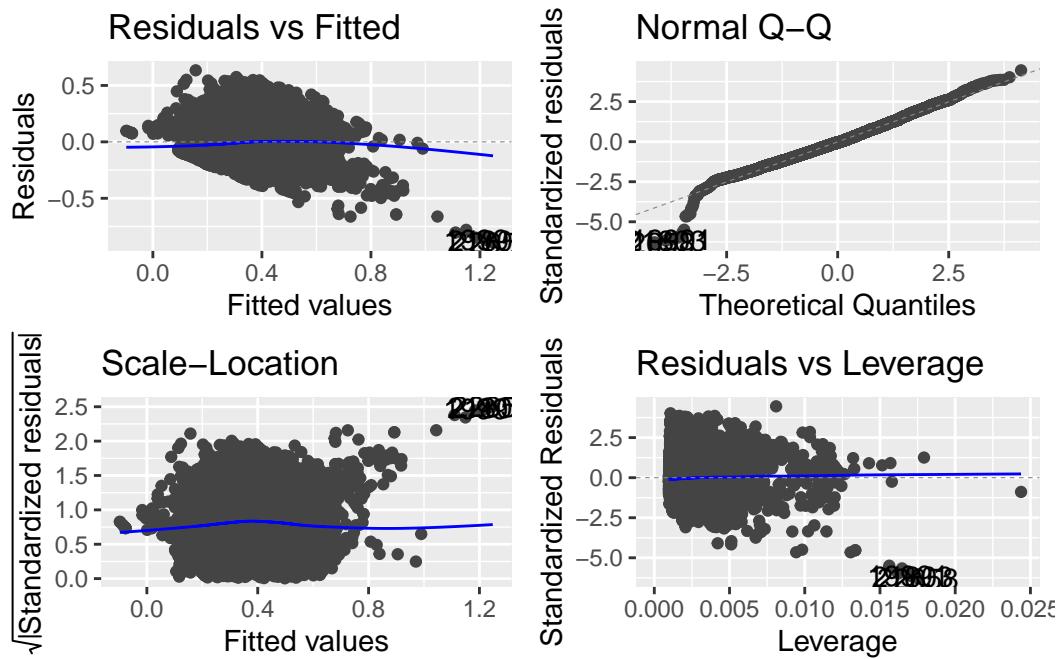
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.143 on 27356 degrees of freedom

Multiple R-squared: 0.4017, Adjusted R-squared: 0.4001

F-statistic: 255.1 on 72 and 27356 DF, p-value: < 2.2e-16

```
 autoplot(vul_lm)
```



## Discussion