A Hydrologic Study of the
Sand Creek Watershed

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Michigan's Nonpoint Source Program

Table of Contents

Summary 1
Project Goals 7
Watershed Description and Model Parameters 8
Model Results 18
Appendices A-1
  Appendix A: Sand Creek Hydrologic Model Parameters A-1
  Appendix B: Sand Creek Dam Failure A-4

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Michigan's Nonpoint Source Program

Summary

A hydrologic model of the Sand Creek watershed was developed by the Hydrologic Studies Unit (HSU) of the Michigan Department of Environmental Quality (MDEQ) using the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). The hydrologic model was developed to help determine the effect of land use changes in the watershed on Sand Creek's flow regime and to provide design flows for streambank stabilization Best Management Practices (BMPs). The Sand Creek Watershed Committee may combine this information with other determinants, such as open space preservation, to decide what locations are the most appropriate for wetland restoration, stormwater detention, in-stream BMPs, or upland BMPs. The communities within the watershed could also use the information to help develop stormwater ordinances.

The hydrologic model does not attempt to simulate the effect of the dam that was located below Leonard from approximately 1860 until May 21, 1989. A memo discussing the possible effects of the dam failure is included as Appendix B.

The hydrologic model has four scenarios corresponding to 1800, 1978, 1998, and build-out land use. The build-out scenario is based on zoning maps provided by the local units of government. Because the zoning maps do not show any wetland areas, this scenario is further subdivided to model the effect of retaining or eliminating the wetland storage. General land use changes are shown in Figure 1, which shows that urban land uses are projected to continue to increase, with a net loss of natural areas. More specific information is provided in Table 1.

Because of these land use trends, the model predicts increases in runoff volumes and peak flows from 1800 to 1978/1998 and from 1978/1998 to build-out for all three design storms analyzed, as shown in Figures 2 through 7. The model predicts nearly identical flows for the 1978 to 1998 land use scenarios. The 1978 scenario has therefore been omitted from Figures 2 through 7 for clarity. Flow details for the land use scenarios are listed in Tables 2 through 7.

The projected runoff volume and peak flow increases from the 10 and 4 percent chance (10-year and 25-year), 24-hour storms, Figures 4 through 7, would aggravate the flooding problems that are reported throughout the watershed, unless mitigated through the use of effective stormwater management techniques.

The projected increases from the 50 percent chance (2-year), 24-hour storm, Figures 2 and 3, will increase channel-forming flows. The channel-forming flow in a stable stream usually has a one- to two-year recurrence interval. These relatively modest storm flows, because of their higher frequency, have more effect on channel form than extreme flood flows. Hydrologic changes that increase this flow can cause the stream to become unstable. Stream instability is indicated by excessive erosion at many locations throughout a stream reach. The projected increase in volume and peak flow would therefore further increase streambank erosion that is already reported to be excessive in Sand Creek below Leonard Street. Stormwater management techniques used to mitigate flooding can also help mitigate projected channel-forming flow increases. However, channel-forming flow criteria should be specifically considered in the

stormwater management plan so that the selected BMPs will be most effective. For example, detention ponds designed to control runoff from the 4 percent chance, 24-hour storm often do little to control the runoff from the 50 percent chance, 24-hour storm unless the outlet is specifically designed to do so.

The Sand Creek watershed is in Kent and Ottawa Counties. The model stormwater ordinance adopted by Kent County is currently being considered by Ottawa County. The Kent County model stormwater ordinance calls for a maximum release rate of 0.05 cubic feet per second per acre (cfs/acre) for runoff from the 50 percent chance, 24-hour storm for Zone A areas, the most environmentally sensitive of the three zones. Currently, the average yield from this storm for the Sand creek watershed is 0.02 cfs per acre, well below the 0.05 standard, with no subbasins higher than 0.05 cfs/acre. The yield from five of the fifteen subbasins may exceed 0.05 cfs/acre with continued development. The ordinance also calls for a maximum release rate of 0.13 cfs/acre for runoff from the 4 percent chance, 24-hour storm for Zones A and B. Currently, the average yield from this storm for the Sand Creek watershed is 0.10 cfs per acre, with three subbasins higher than 0.13 cfs/acre. The yield from eleven of the fifteen subbasins may exceed 0.13 cfs/acre with continued development. Additional details are shown in Figures 8 and 9 and listed in Table 8. The developers of the Sand Creek watershed plan may want to consider whether the proposed standards will adequately protect Sand Creek and its tributaries.

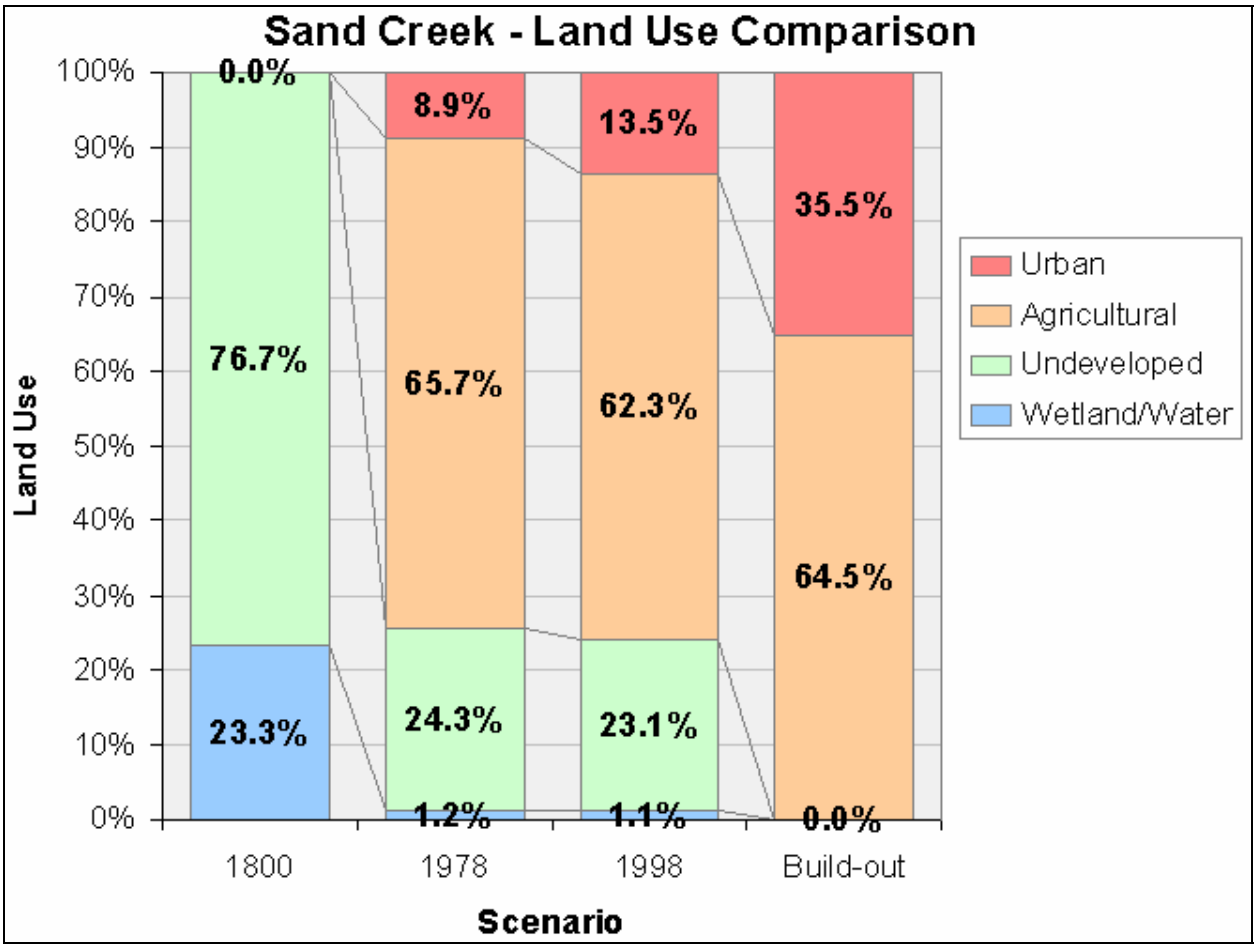

Figure 1: Land Use Comparison

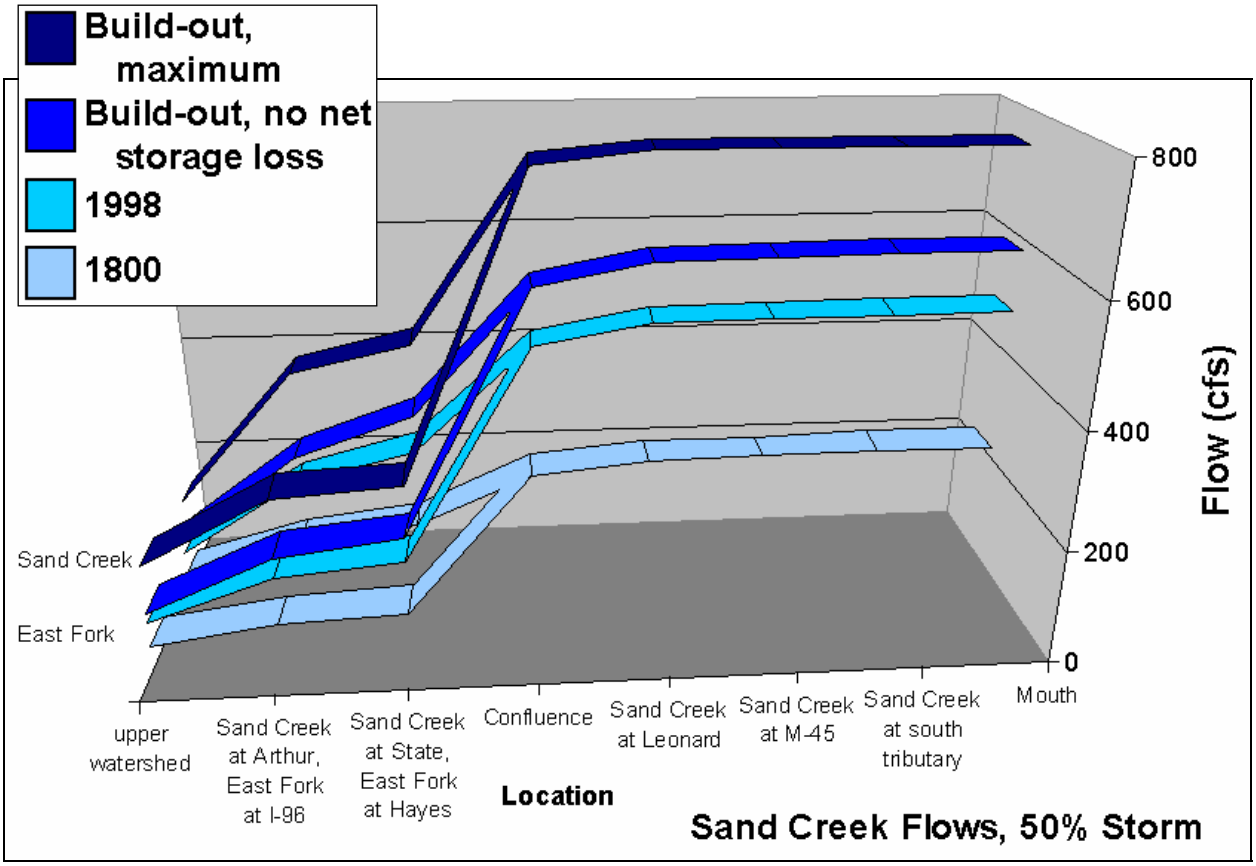

Figure 2: Predicted peak flows from 50 percent chance, 24-hour storm

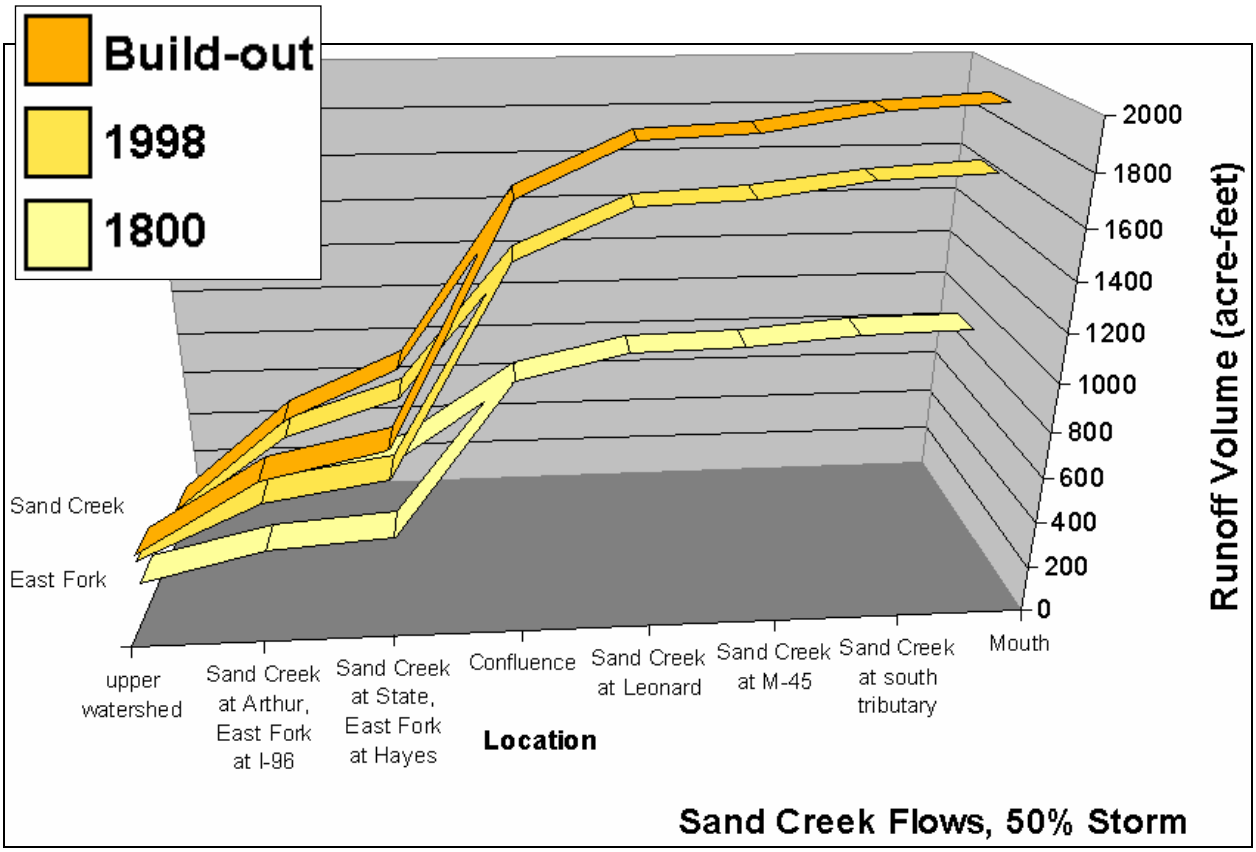

Figure 3: Predicted runoff volumes from 50 percent chance, 24-hour storm

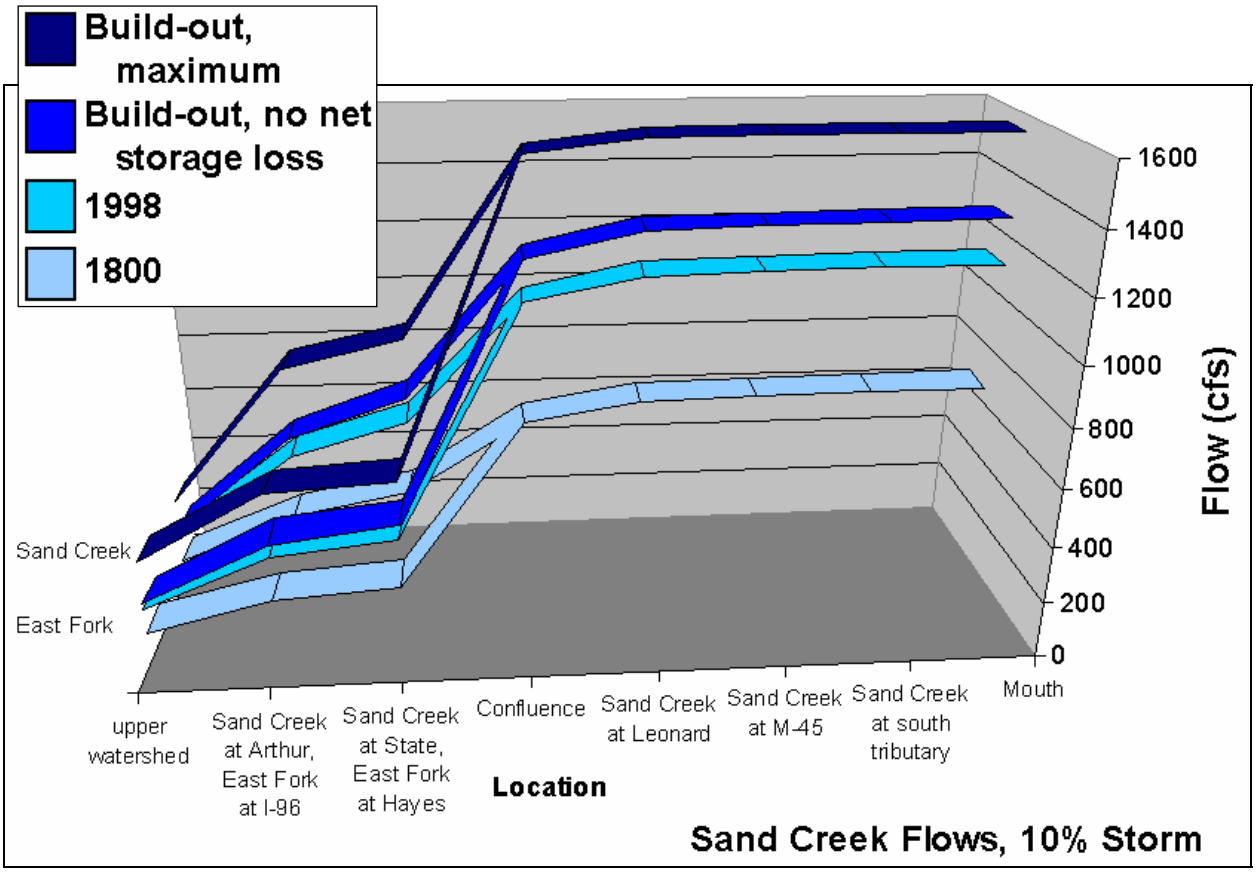

Figure 4: Predicted peak flows from 10 percent chance, 24-hour storm

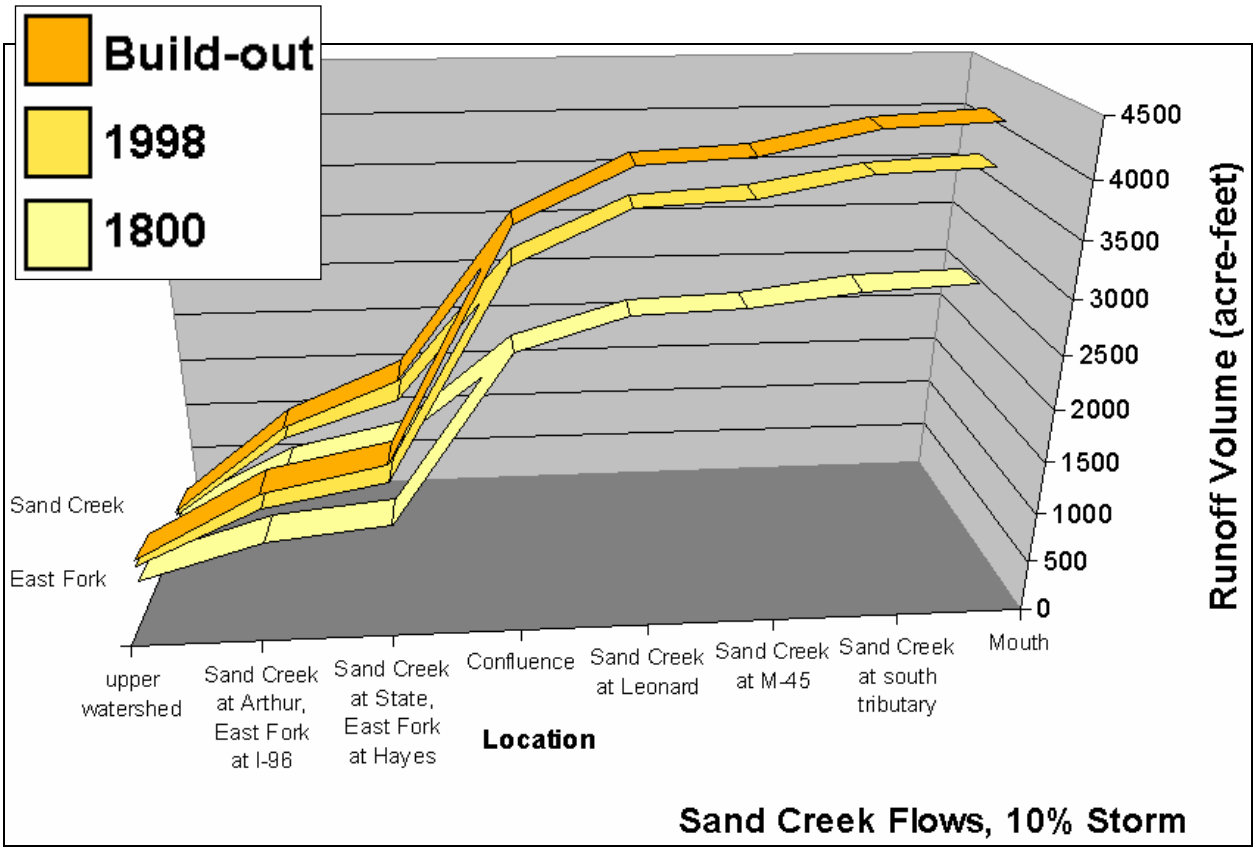

Figure 5: Predicted runoff volumes from 10 percent chance, 24-hour storm

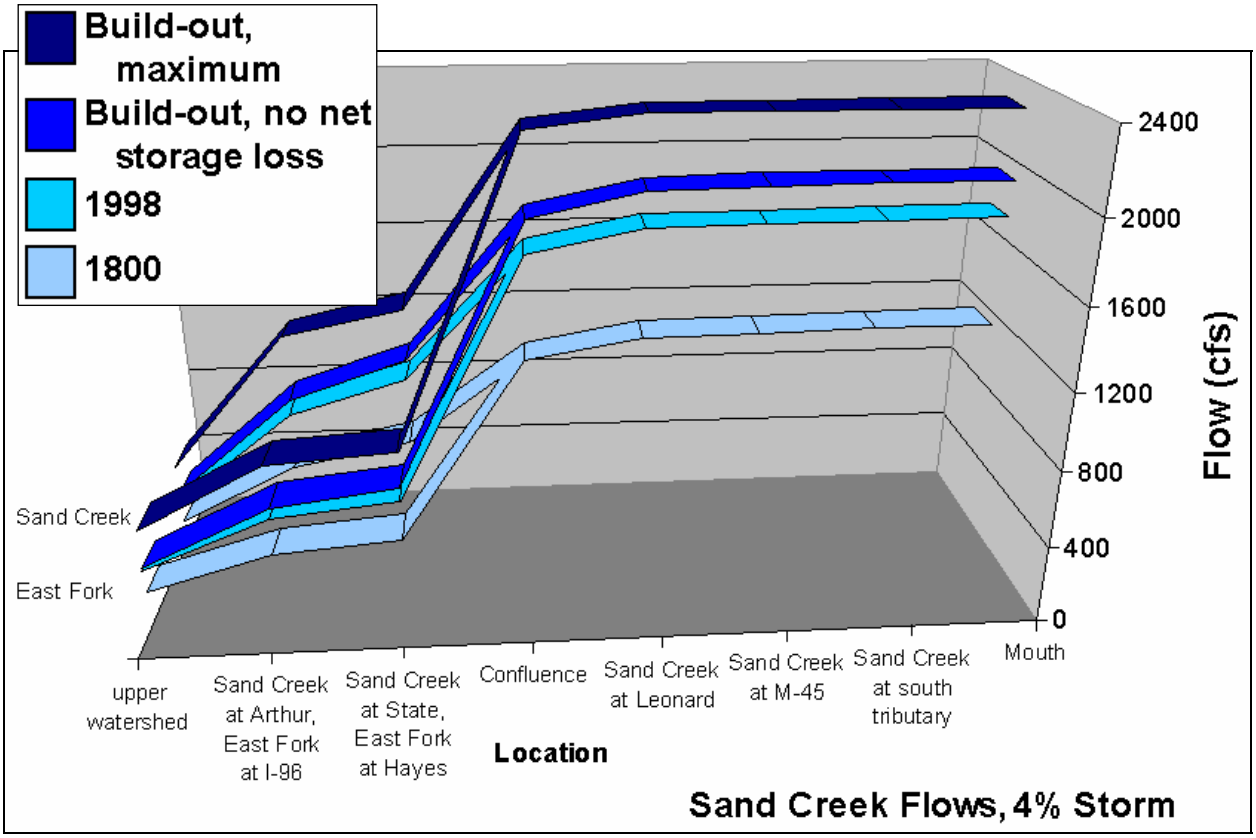

Figure 6: Predicted peak flows from 4 percent chance, 24-hour storm

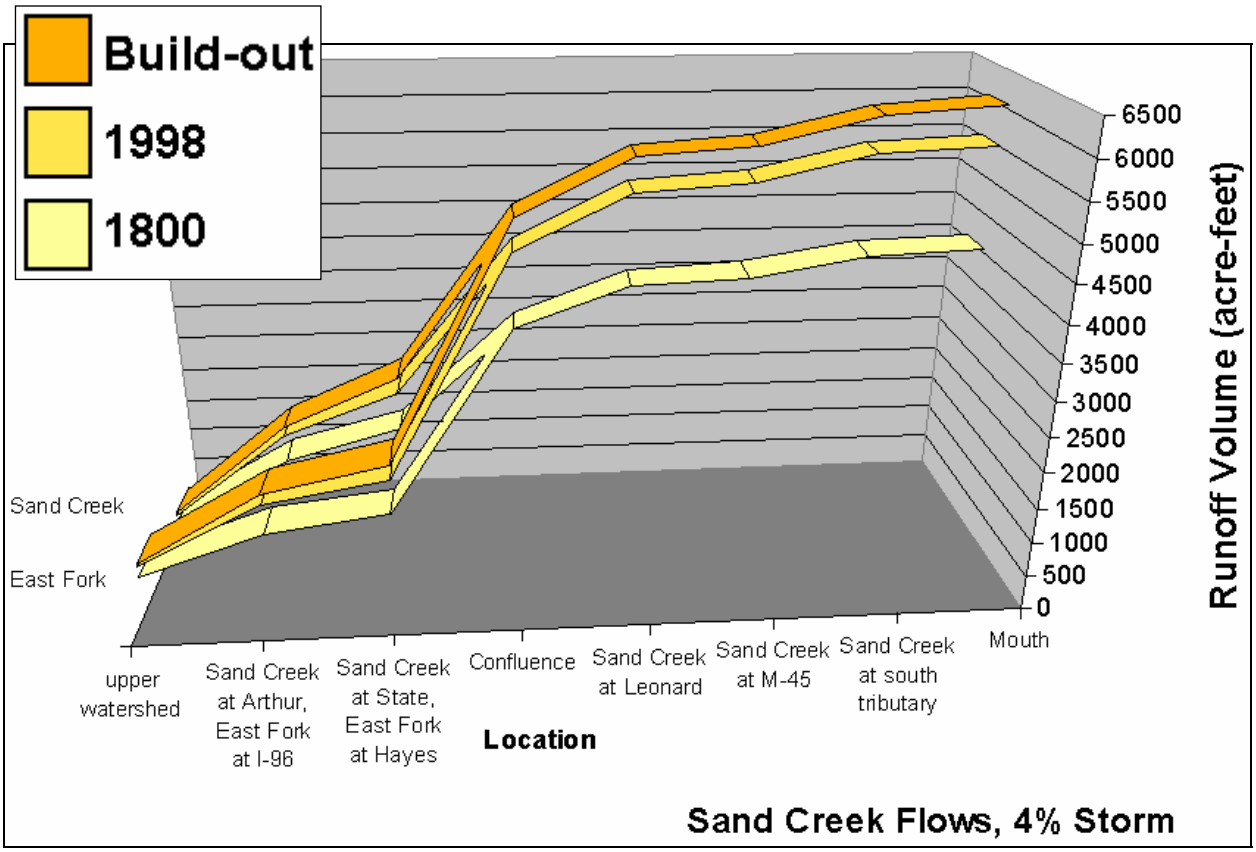

Figure 7: Predicted runoff volumes from 4 percent chance, 24-hour storm

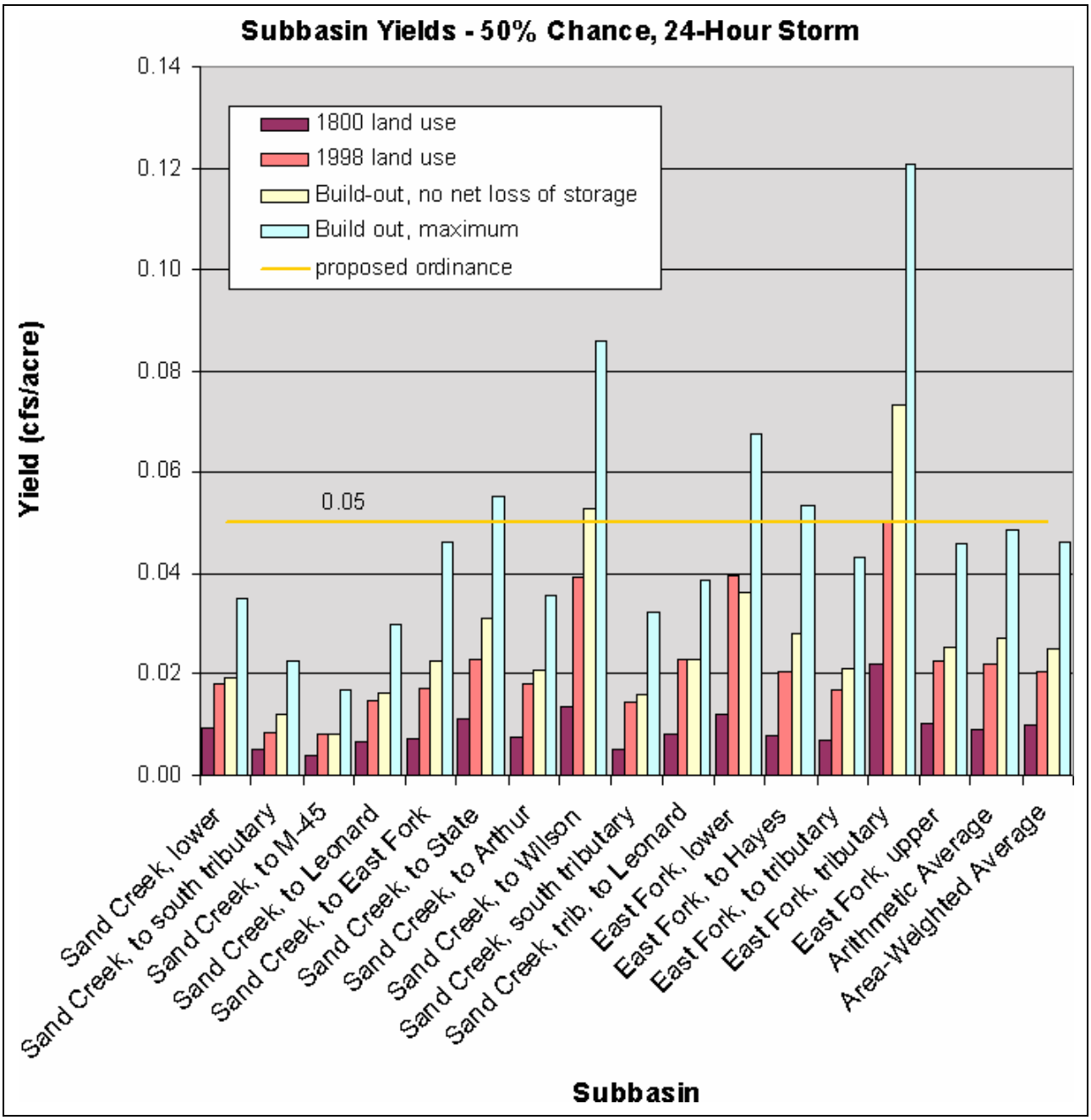

Figure 8: Subbasin Yields, 50 percent chance, 24-hour storm

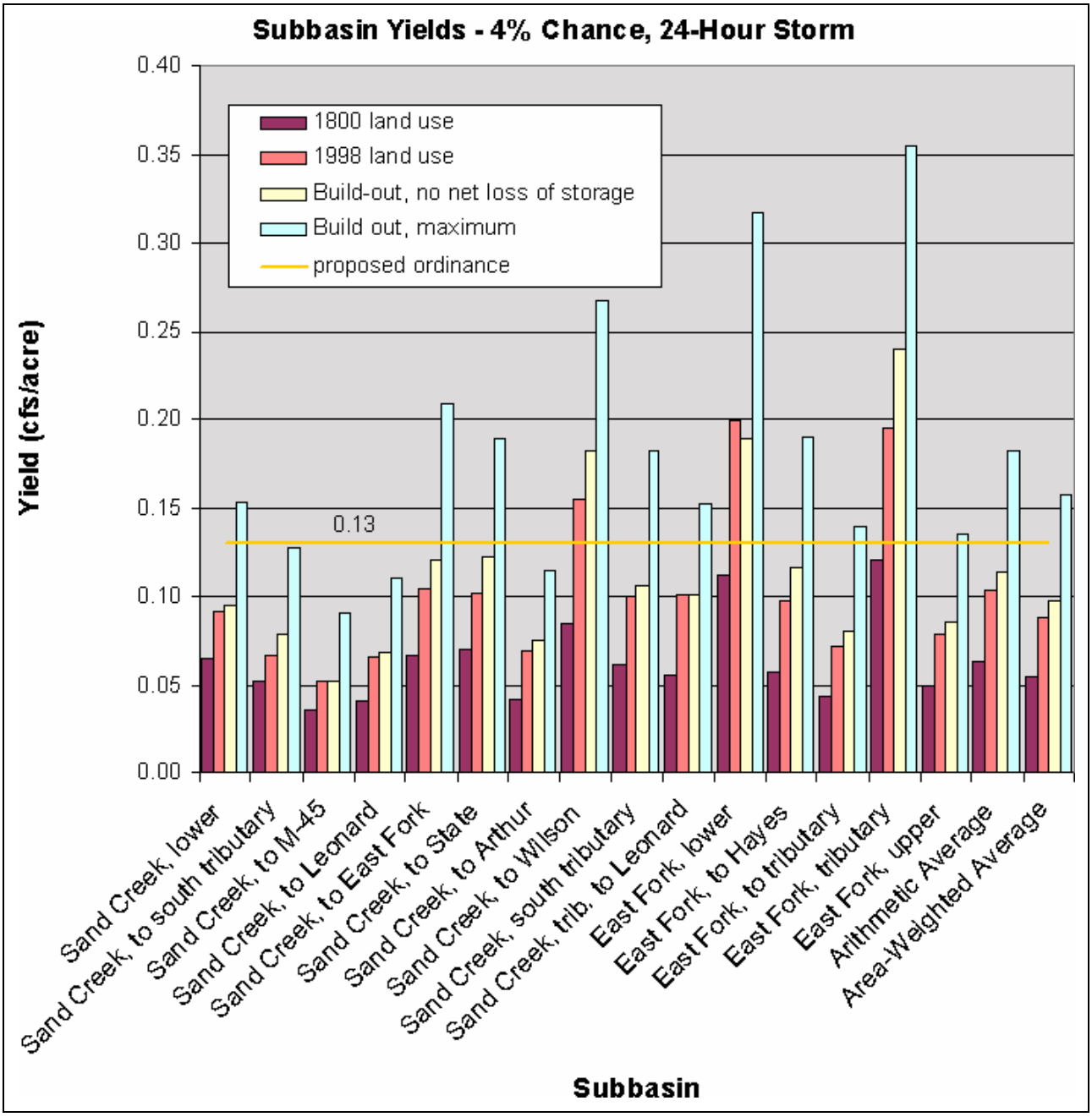

Figure 9: Subbasin Yields, 4 percent chance, 24-hour storm

Project Goals

The Sand Creek hydrologic study was initiated in support of a Lower Grand watershed project, which is funded in part by a United States Environmental Protection Agency (USEPA) Part 319 grant administered by the MDEQ. The goals of this study are:

- To better understand the watershed's hydrology and the impact of hydrologic changes, especially land use changes, in the Sand Creek watershed.
- To facilitate the selection and design of suitable BMPs.
- To provide information that can be used by local units of government to develop or improve stormwater ordinances.

Watershed Description and Model Parameters

The 54.8 square mile Sand Creek watershed, Figure 10, is located in Ottawa and Kent Counties. Sand Creek outlets to the Grand River in Ottawa County. The study divides the watershed into fifteen subbasins, as shown in Figure 11.

Our analysis of the watershed uses the curve number technique to calculate surface runoff volumes and peak flows. This technique, developed by the Natural Resources Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land use and soil data as a runoff curve number. The curve numbers for each subbasin, listed in Appendix A, were calculated from digital soil and land use data using Geographic Information Systems (GIS) technology.

Runoff curve numbers were calculated from the land use and soil data shown in Figures 12 through 16. Land use maps based on the MDEQ GIS data for 1800 and 1978 are shown in Figures 12 and 13, respectively. The 1800 land use information is provided at the request of the Sand Creek watershed committee. The MDEQ Nonpoint Source program does not expect or recommend that the flow regime calculated from 1800 land use be used as criteria for BMP design or as a goal for watershed managers. The 1998 land use map, Figure 14, is based on HSU's analysis of 1998 aerial photos and field verification. The build-out analysis, Figure 15, assumes land use is developed to the maximum allowed under zoning regulations. Zoning information was compiled by HSU from information provided by Ottawa County, the City of Walker, and Chester, Tallmadge, and Wright Townships. Because the zoning maps do not show any wetland areas, the Build-Out scenario is further subdivided to model the effect of retaining or eliminating the wetland storage. In the *Build-Out, No Net Loss of Storage* scenario, the 1998 storage coefficients were retained for the build-out condition. For the *Build-Out, Maximum* scenario, the storage coefficients were set equal to the times of concentration.

Land use information by subbasin is also detailed in Table 1. The Natural Resources Conservation Service (NRCS) soils data for the watershed is shown in Figure 16. Where the soil is given a dual classification, B/D for example, the soil type was selected based on land use. In these cases, the soil type is specified as D for natural land uses or the alternate classification (A, B, or C) for developed land uses. The runoff curve numbers calculated from the soil and land use data are listed in Appendix A.

The time of concentration for each subbasin, which is the time it takes for water to travel from the hydraulically most distant point in the watershed to the design point, was calculated from the United States Geological Survey (USGS) quadrangles. The storage coefficients, which represent storage in the subbasin, were iteratively adjusted to provide a peak flow reduction equal to the ponding adjustment factors described further in Appendix A. The two build-out scenarios differ only in their storage coefficients. In the *Build-Out, No Net Loss of Storage* scenario, the 1998 storage coefficients were used for the build-out condition to simulate the effect of retaining all of the wetlands. For the *Build-Out, Maximum* scenario, the storage coefficients were set equal to the corresponding time of concentration, which models the effect of eliminating all of the wetland storage. Lag for each reach, which is the travel time of water within each

section of the river, is also calculated from the USGS quadrangles. These values are listed in Appendix A.

The selected precipitation events were the 50, 10, and 4 percent chance (2-, 10-, and 25-year), 24-hour storms. Design rainfall values for these events are tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129, and summarized for this site in Appendix A. These values have been multiplied by 0.946 to account for the size of the watershed.

These parameters were then incorporated into a HEC-HMS model to compute runoff volume and flow. Some refinements to the model are possible based on calibration data from flow monitors currently installed at four locations in the watershed.

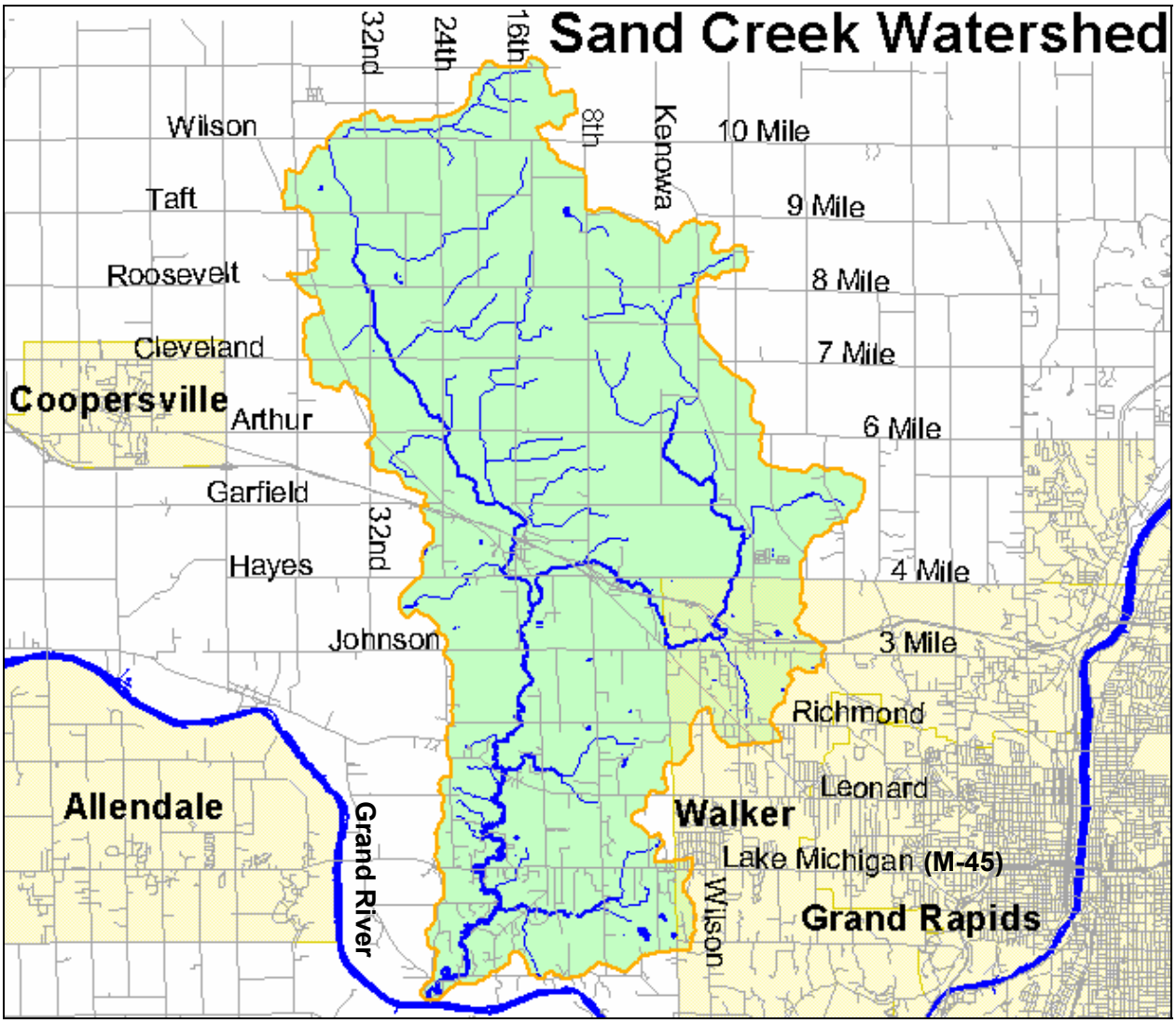

Figure 10: Delineated Sand Creek Watershed

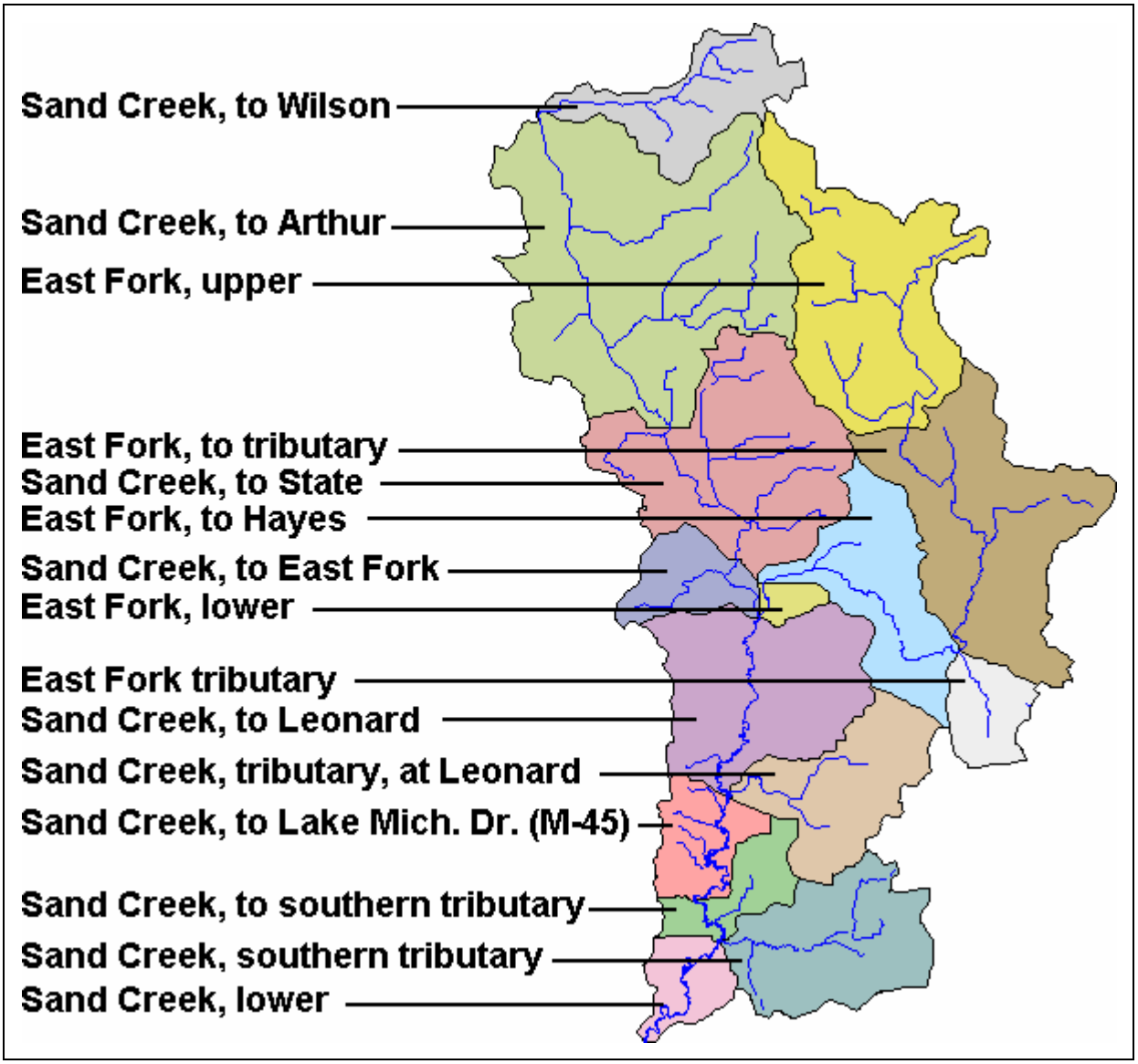

Figure 11: Subbasin Identification

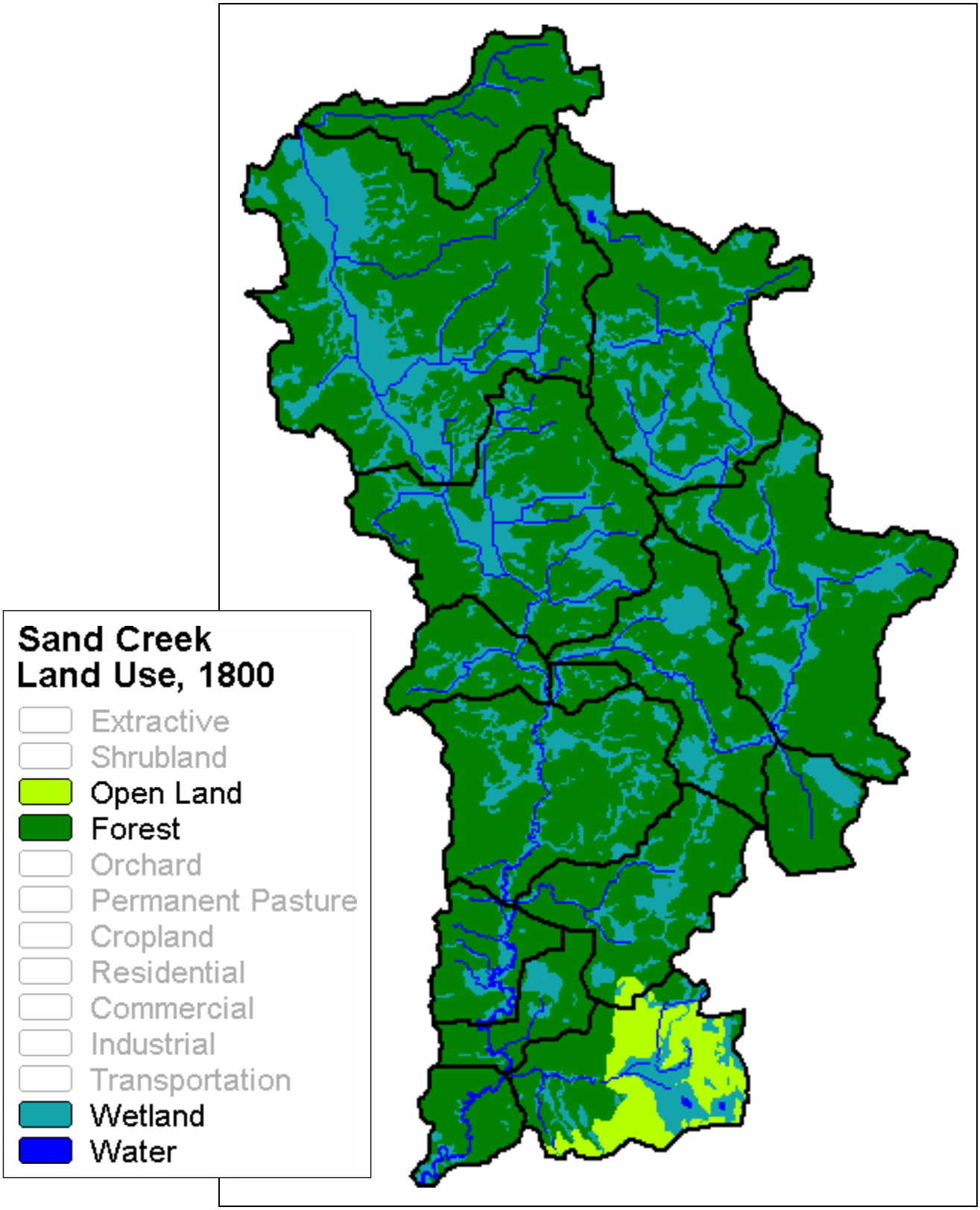

Figure 12: 1800 Land Use Data

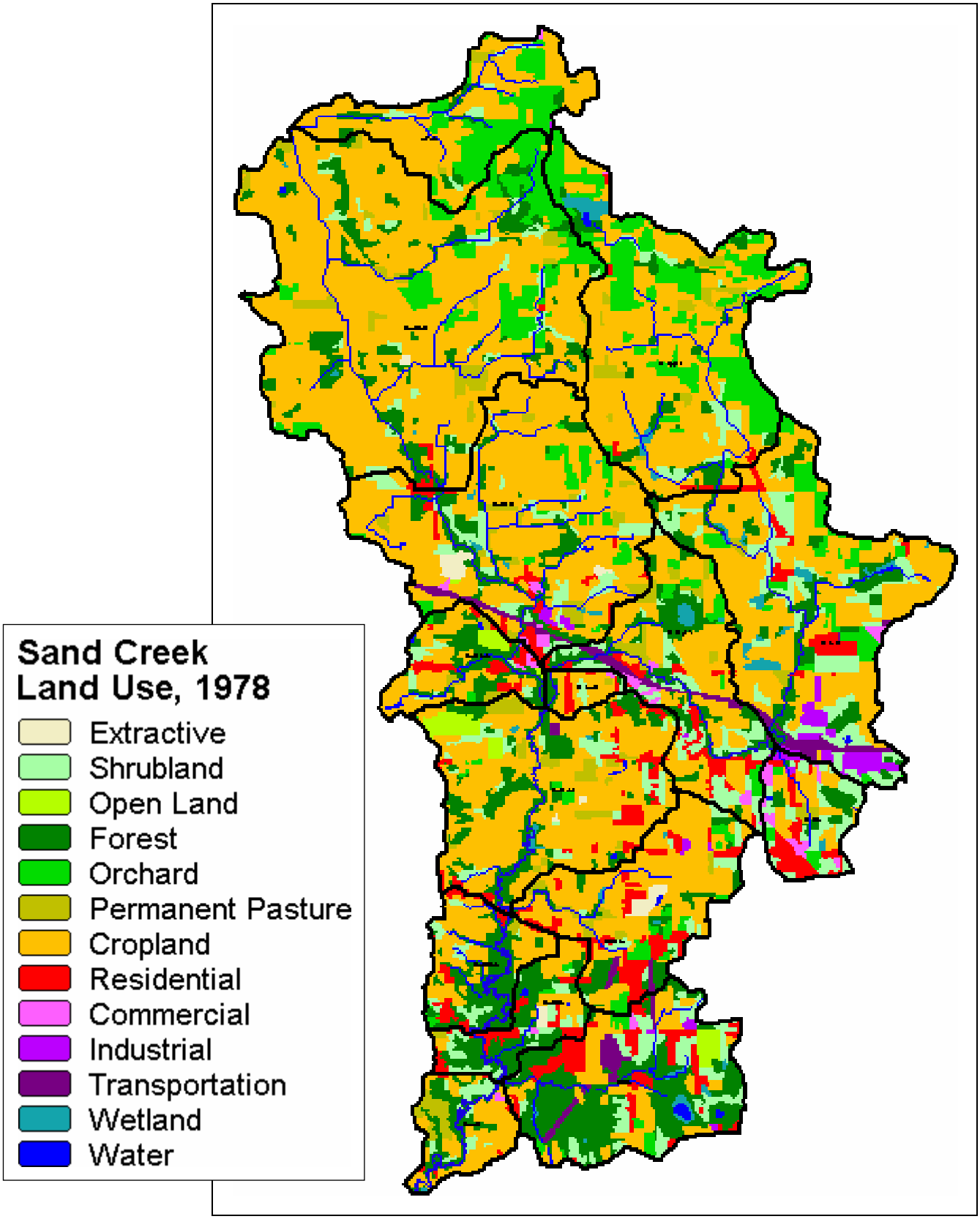

Figure 13: 1978 Land Use Data

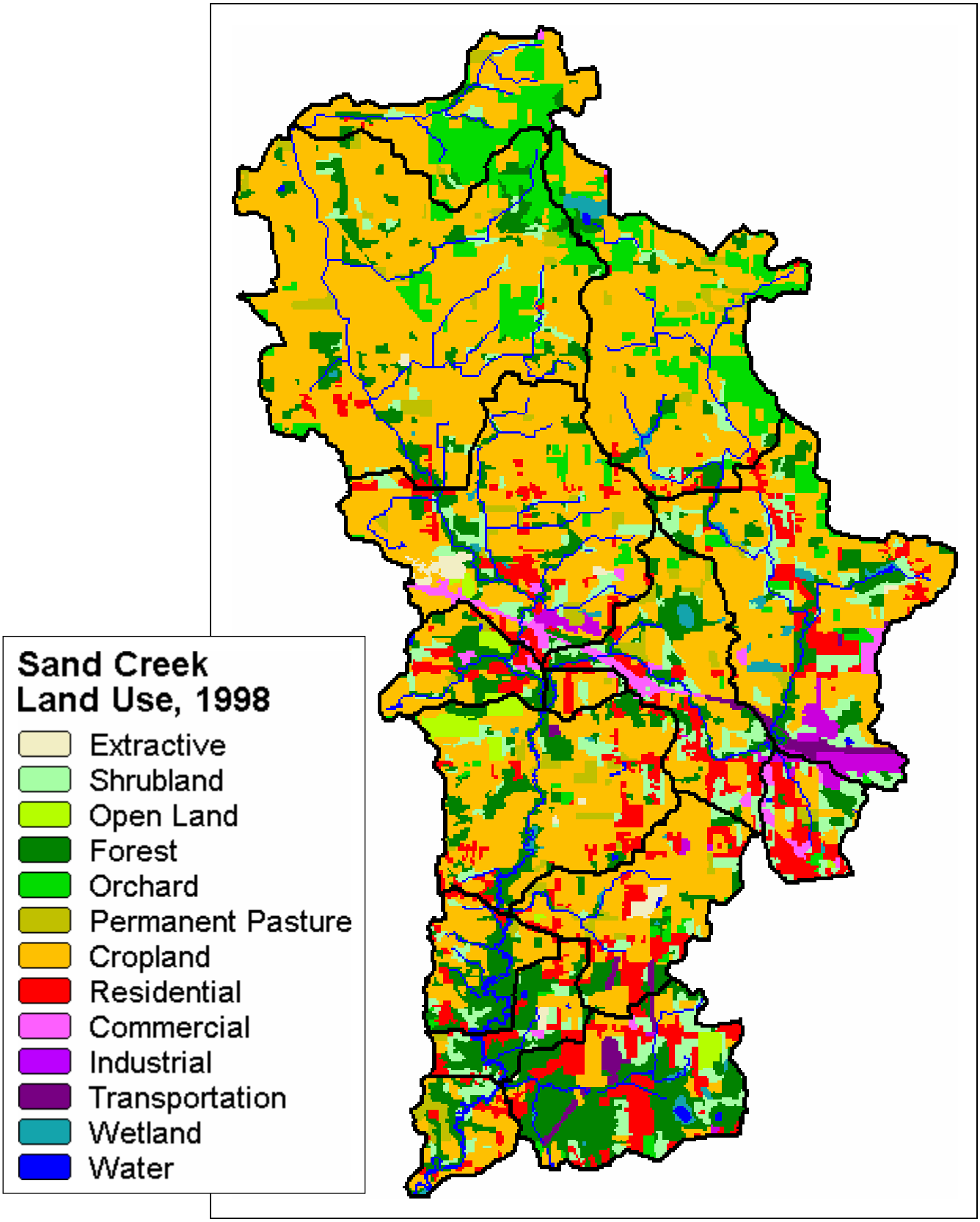

Figure 14: 1998 Land Use Data

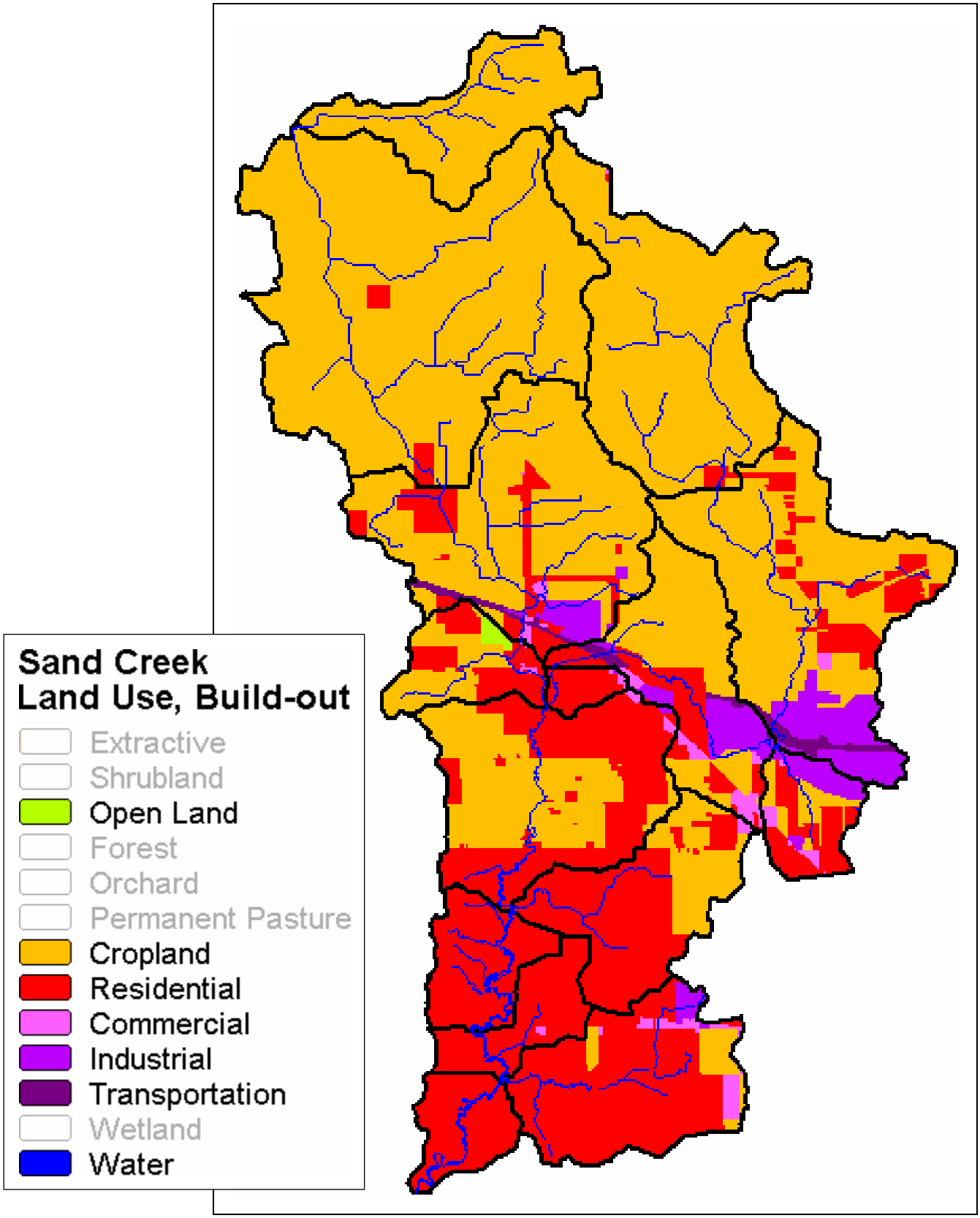

Figure 15: Zoned, or Build-Out, Land Use Data

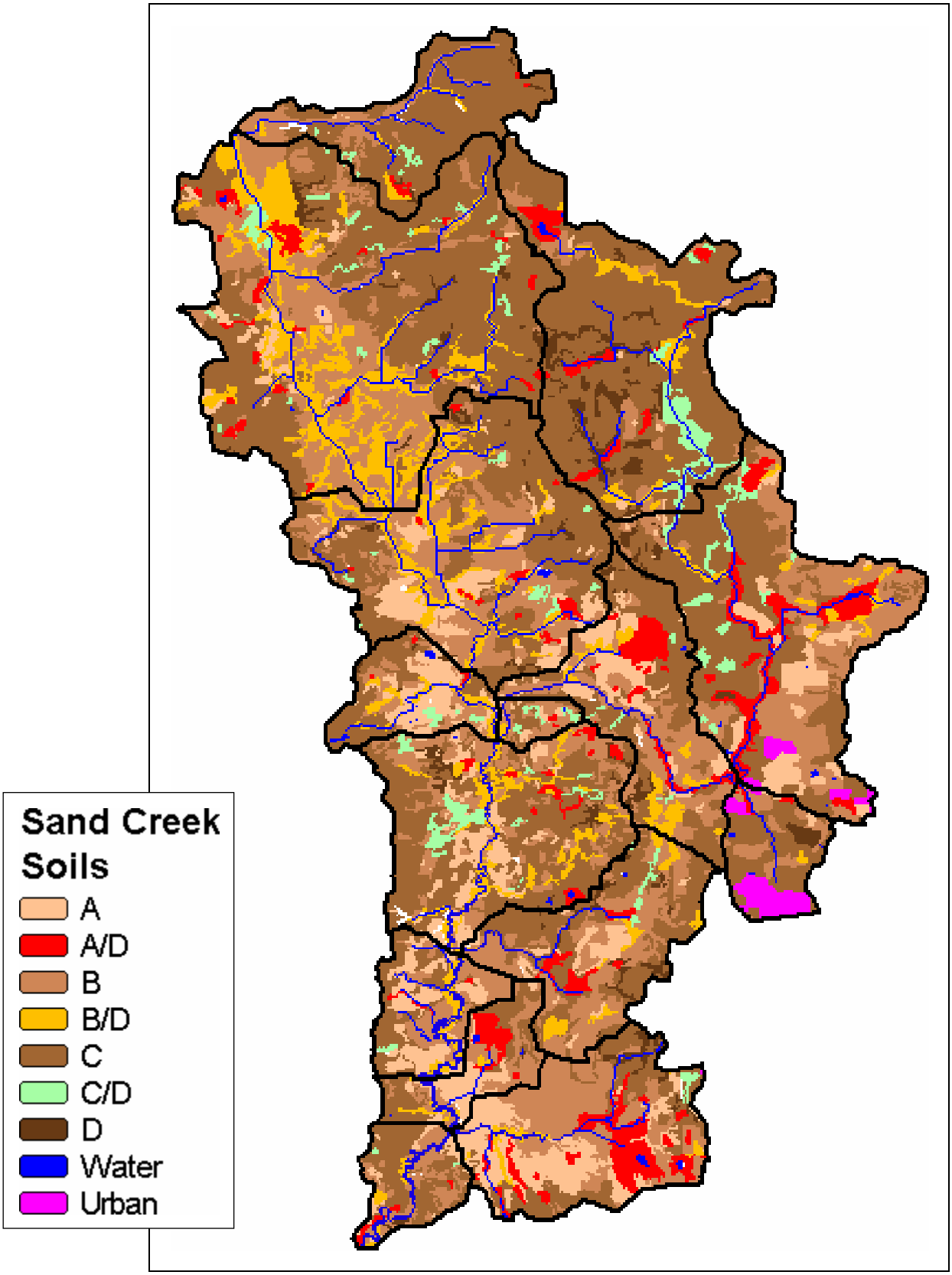

Figure 16: NRCS Soils Data

Table 1: Land Use by Subbasins (Land uses less than 0.5 percent are not listed because all percentages are rounded to the nearest percent)

Description	Scenario	Residential	Commercial	Industrial	Road	Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
Sand Creek, lower	1800											88%		12%
	1978	3%	1%					47%		11%	10%	28%		
	1998	12%						39%		10%	11%	28%		
	Build-out	100%												
Sand Creek, to south tributary	1800											84%		16%
	1978	16%				2%		21%	1%	1%	15%	42%	1%	
	1998	20%	1%			2%		18%	1%	1%	14%	43%	1%	
	Build-out	99%	1%											
Sand Creek, to M-45	1800											78%		22%
	1978	9%						41%	2%	1%	8%	40%		
	1998	10%						40%	2%	1%	7%	40%		
	Build-out	100%												
Sand Creek, to Leonard	1800											80%		20%
	1978	6%					4%	58%	1%	6%	6%	18%		1%
	1998	10%					5%	55%	1%	4%	6%	17%		1%
	Build-out	52%	1%					47%						
Sand Creek, to East Fork	1800											80%		20%
	1978	11%	2%				5%	39%	2%	4%	6%	30%	1%	
	1998	15%	3%				6%	35%		3%	6%	31%	1%	
	Build-out	44%	1%				5%	49%						
Sand Creek, to State	1800											73%		27%
	1978	3%	1%	1%	2%	2%		65%	5%	4%	7%	10%		1%
	1998	8%	3%	2%		2%	1%	61%	3%	3%	7%	10%		1%
	Build-out	14%	1%	4%	2%			78%						
Sand Creek, to Arthur	1800											69%		31%
	1978							71%	11%	4%	3%	11%		
	1998	1%						73%	9%	3%	3%	11%		
	Build-out	2%						98%						
Sand Creek, to Wilson	1800											95%		5%
	1978							59%	28%	2%	3%	7%		
	1998							55%	33%	2%	3%	7%		
	Build-out							100%						
Sand Creek, south tributary	1800										43%	33%		24%
	1978	13%		1%	4%		3%	19%	2%		15%	40%	1%	2%
	1998	22%			4%		3%	13%	1%		13%	40%	1%	2%
	Build-out	83%	5%	3%				9%						

Description	Scenario	Residential	Commercial	Industrial	Road	Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
Sand Creek, tributary to Leonard	1800										2%	79%		19%
	1978	14%		1%	2%	2%		55%	6%	4%	5%	10%		1%
	1998	17%		1%	2%	2%		57%	2%	4%	5%	10%		1%
	Build-out	70%	1%					29%						
East Fork, lower	1800											79%		21%
	1978	19%	2%					50%		2%	11%	15%		
	1998	19%	2%					50%		2%	11%	15%		
	Build-out	94%	5%	1%										
East Fork, to Hayes	1800											76%		24%
	1978	8%	2%		4%			41%	5%	5%	16%	19%		1%
	1998	13%	5%		1%			41%	1%	5%	13%	19%		1%
	Build-out	22%	6%	13%	3%			56%						
East Fork, to tributary	1800											79%		21%
	1978	4%		4%	3%			50%	8%	1%	15%	13%		2%
	1998	9%	2%	6%	3%			48%	5%	1%	12%	13%		2%
	Build-out	14%		14%	3%			69%						
East Fork, tributary	1800											82%		18%
	1978	20%	7%	4%				22%	4%	3%	27%	11%		1%
	1998	33%	8%	8%			1%	15%	2%	3%	21%	9%		
	Build-out	49%	6%	23%				23%						
East Fork, upper	1800											74%		26%
	1978	1%						55%	27%	4%	4%	7%		2%
	1998	2%						63%	21%	3%	3%	7%		2%
	Build-out	1%						99%						
Totals	1800										3%	74%		23%
	1978	5%	1%	1%	1%		1%	53%	9%	3%	8%	16%		1%
	1998	9%	1%	1%	1%	1%	1%	53%	7%	3%	7%	16%		1%
	Build-out	30%	1%	4%	1%			65%						

Model Results

The modeled results for the 50, 10, and 4 percent chance, 24-hour storms and the 1800, 1978, 1998, and build-out land use scenarios are illustrated in Figures 2 through 7 and detailed in Tables 2 through 7. Because the runoff volumes computed for the *Build-Out, No Net Loss of Storage* and the *Build-Out, Maximum* scenarios are identical, these values are only shown once and labeled *Build-Out*. Table 2 lists the predicted peak flows from each subbasin. These values represent the peak flow contribution from the subbasins, not the flow in the creek. Table 3 lists the predicted peak flows at locations in the creek. Table 4 compares peak flow changes from 1800 to 1998 and from 1998 to build-out conditions. Table 5 lists the predicted runoff volumes from each subbasin. Table 6 lists the predicted runoff volumes at locations in the creek. Table 7 compares runoff volume changes from 1800 to 1998 and from 1998 to build-out conditions.

The model does not predict significant flow changes from 1978 to 1998. The projected increases in stormwater runoff volume and peak flows from 1998 to build-out conditions are of primary interest to Sand Creek watershed's stormwater managers. Model predictions based on this land use change show significant increases in runoff volumes and peak flows for all three design storms. Peak flows and runoff volumes from the 50 percent chance, 24-hour storm are predicted to increase more, on a percentage basis, than flows from the 10 percent chance, 24-hour storm or the 4 percent chance, 24-hour storm. The projected increases in runoff volumes and peak flows from the 50 percent chance storm would increase the channel forming flow, which will increase streambank erosion that is already reported to be excessive in Sand Creek below Leonard Street. The projected increases in runoff volumes and peak flows from the 10 and 4 percent chance storms will aggravate flooding problems, which are reported throughout the watershed. These projected increases can be moderated through the use of effective stormwater management techniques.

The Sand Creek watershed is within Kent and Ottawa Counties. The model stormwater ordinance adopted by Kent County is currently being considered by Ottawa County. The Kent County model stormwater ordinance calls for a maximum release rate of 0.05 cfs/acre for runoff from the 50 percent chance, 24-hour storm for Zone A areas, the most environmentally sensitive of the three zones. Currently, the average yield from this storm is 0.02 cfs per acre, with no subbasins higher than 0.05 cfs/acre, as shown in Figure 15. The yield from five of the fifteen subbasins may exceed 0.05 cfs/acre with continued development. The ordinance also calls for a maximum release rate of 0.13 cfs/acre for runoff from the 4 percent chance, 24-hour storm for Zones A and B. Currently, the average yield from this storm is 0.10 cfs per acre, with three subbasins higher than 0.13 cfs/acre, as shown in Figure 16. The yield from eleven of the fourteen subbasins may exceed 0.13 cfs/acre with continued development. Additional details are listed in Table 8.

Table 2: Peak flows per subbasin

Subbasin	Peak Flow (cfs) from 50% chance, 24-hour storm					Peak Flow (cfs) from 10% chance, 24-hour storm					Peak Flow (cfs) from 4% chance, 24-hour storm				
	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.
Sand Creek, lower	7	14	13	14	25	24	40	37	40	68	47	69	66	69	111
Sand Creek, to south tributary	4	7	7	10	18	20	28	28	35	60	42	54	54	64	105
Sand Creek, to M-45	4	8	8	8	17	17	27	27	27	52	35	51	51	51	89
Sand Creek, to Leonard	21	52	48	52	95	69	129	123	129	225	129	217	208	217	350
Sand Creek, to East Fork	7	16	16	21	43	30	52	52	63	118	62	97	97	113	195
Sand Creek, to State	44	100	93	125	221	153	256	242	300	501	281	428	409	487	758
Sand Creek, to Arthur	55	129	129	148	256	164	304	304	334	551	295	492	492	532	819
Sand Creek, to Wilson	23	72	67	90	146	77	173	164	202	308	144	274	263	311	455
Sand Creek, south tributary	12	35	35	39	77	66	127	127	136	248	146	240	240	254	437
Sand Creek, tributary to Leonard	17	47	47	47	78	58	122	122	122	196	113	205	205	205	311
East Fork, lower	3	9	9	8	15	12	26	26	25	44	26	46	46	44	73
East Fork, to Hayes	17	41	44	61	116	64	116	123	153	269	126	200	210	251	412
East Fork, to tributary	28	65	70	86	175	94	164	172	200	380	176	278	290	327	566
East Fork, tributary	18	38	41	59	98	54	93	98	126	196	98	150	157	193	286
East Fork, upper	40	82	88	100	179	110	185	194	213	362	192	295	307	331	526

Table 3: Peak flows in Sand Creek

Location	Peak Flow (cfs) from 50% chance, 24-hour storm					Peak Flow (cfs) from 10% chance, 24-hour storm					Peak Flow (cfs) from 4% chance, 24-hour storm				
	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.
East Fork at 6 mile	40	82	88	100	179	110	185	194	213	362	192	295	307	331	526
East Fork at I-96	72	148	159	188	286	210	344	361	405	580	369	547	568	624	842
East Fork at Hayes	83	167	179	215	299	245	388	407	462	608	426	614	638	706	884
Sand Creek at Wilson	23	72	67	90	146	77	173	164	202	308	144	274	263	311	455
Sand Creek at Arthur	77	200	195	237	376	240	471	462	529	788	436	749	737	822	1160
Sand Creek at State	105	257	248	306	421	321	596	582	672	880	569	933	915	1027	1293
Sand Creek at confluence with East Fork	192	426	429	526	719	574	993	997	1146	1487	1009	1560	1566	1750	2177
Sand Creek at Leonard	213	465	466	565	738	638	1078	1080	1232	1531	1110	1684	1687	1875	2243
Sand Creek at M-45	215	469	469	568	739	644	1087	1088	1240	1533	1121	1696	1699	1887	2246
Sand Creek at south tributary	219	472	473	572	739	651	1091	1093	1246	1533	1129	1701	1703	1891	2245
Sand Creek at mouth	220	473	474	573	739	653	1093	1094	1247	1533	1131	1703	1705	1894	2245

Table 4: Predicted peak flow changes

Location	1800 to 1998			1998 to build-out, no net storage loss			1998 to build-out, maximum		
	50% Chance Storm	10% Chance Storm	4% Chance Storm	50% Chance Storm	10% Chance Storm	4% Chance Storm	50% Chance Storm	10% Chance Storm	4% Chance Storm
Flow Changes in Creek									
Sand Creek at M-45	118%	69%	52%	21%	14%	11%	57%	41%	32%
Sand Creek/East Fork	124%	74%	55%	23%	15%	12%	67%	49%	39%
Sand Creek at State	137%	81%	61%	24%	16%	12%	70%	51%	41%
East Fork at Hayes	115%	66%	50%	20%	13%	11%	67%	49%	39%
Flow Changes from Subbasins									
Sand Creek, lower	41%	54%	95%	5%	6%	9%	70%	83%	95%
Sand Creek, to south tributary	29%	39%	64%	19%	23%	36%	93%	115%	155%
Sand Creek, to M-45	44%	56%	102%	0%	0%	0%	75%	91%	105%
Sand Creek, to Leonard	61%	77%	130%	4%	5%	8%	68%	83%	97%
Sand Creek, to East Fork	55%	72%	131%	17%	21%	31%	101%	129%	168%
Sand Creek, to State	45%	58%	108%	19%	24%	36%	85%	107%	139%
Sand Creek, to Arthur	67%	85%	134%	8%	10%	15%	67%	81%	98%
Sand Creek, to Wilson	83%	112%	191%	18%	23%	35%	73%	88%	119%
Sand Creek, south tributary	64%	93%	180%	6%	7%	10%	82%	96%	120%
Sand Creek, tributary to Leonard	82%	108%	176%	0%	0%	0%	51%	61%	68%
East Fork, lower	78%	112%	225%	-5%	-6%	-8%	59%	67%	70%
East Fork, to Hayes	67%	93%	155%	20%	25%	36%	96%	119%	160%
East Fork, to tributary	64%	84%	152%	13%	16%	23%	96%	121%	152%
East Fork, tributary	61%	79%	128%	23%	29%	45%	82%	101%	140%
East Fork, upper	60%	77%	117%	8%	10%	14%	71%	86%	104%

Table 5: Runoff volumes per subbasin

Subbasin	Runoff Volume (acre-feet) from 50% chance 24-hour storm				Runoff Volume (acre-feet) from 10% chance 24-hour storm				Runoff Volume (acre-feet) from 4% chance 24-hour storm			
	1800 land use	1978 land use	1998 land use	Build -out	1800 land use	1978 land use	1998 land use	Build -out	1800 land use	1978 land use	1998 land use	Build -out
Sand Creek, lower	15	26	24	26	46	64	61	64	77	101	97	101
Sand Creek, to south tributary	11	14	14	19	40	45	45	55	71	79	79	91
Sand Creek, to M-45	13	23	23	23	48	66	66	66	85	110	110	110
Sand Creek, to Leonard	74	144	134	144	214	330	314	330	356	505	485	505
Sand Creek, to East Fork	16	26	26	34	52	70	70	83	90	115	115	131
Sand Creek, to State	94	182	169	224	269	416	396	480	448	636	611	714
Sand Creek, to Arthur	216	370	370	423	566	812	812	891	913	1219	1219	1315
Sand Creek, to Wilson	48	95	89	115	128	204	194	233	209	303	292	338
Sand Creek, south tributary	29	56	56	62	107	160	160	170	195	267	267	280
Sand Creek, trib. to Leonard	48	86	86	86	136	201	201	201	227	310	310	310
East Fork, lower	4	9	9	8	14	22	22	20	23	34	34	32
East Fork, to Hayes	46	78	85	113	137	193	203	248	231	304	317	372
East Fork, to tributary	95	184	197	241	272	420	441	508	453	643	669	749
East Fork, tributary	29	42	45	62	72	92	96	120	113	138	143	172
East Fork, upper	151	233	248	281	366	490	512	559	571	722	749	805

Table 6: Runoff volumes in Sand Creek

Location	Runoff Volume (acre-feet) from 50% chance 24-hour storm				Runoff Volume (acre-feet) from 10% chance 24-hour storm				Runoff Volume (acre-feet) from 4% chance 24-hour storm			
	1800 land use	1978 land use	1998 land use	Build -out	1800 land use	1978 land use	1998 land use	Build -out	1800 land use	1978 land use	1998 land use	Build -out
East Fork at 6 mile	151	233	248	281	366	490	512	559	571	722	749	805
East Fork at I-96	275	458	490	585	709	1002	1050	1188	1137	1503	1561	1726
East Fork at Hayes	320	536	575	698	845	1195	1253	1435	1368	1807	1878	2098
Sand Creek at Wilson	48	95	89	115	128	204	194	233	209	303	292	338
Sand Creek at Arthur	263	465	459	539	695	1016	1006	1124	1122	1522	1511	1653
Sand Creek at State	357	647	628	762	963	1432	1402	1604	1570	2158	2121	2367
Sand Creek at confluence with East Fork	697	1219	1238	1502	1873	2719	2747	3143	3050	4113	4148	4627
Sand Creek at Leonard	816	1448	1457	1731	2220	3249	3262	3674	3631	4927	4942	5442
Sand Creek at M-45	827	1471	1480	1755	2264	3315	3328	3740	3713	5037	5052	5552
Sand Creek at south tributary	866	1541	1550	1835	2409	3521	3534	3965	3978	5383	5398	5924
Sand Creek at mouth	879	1566	1573	1861	2451	3585	3594	4030	4051	5485	5495	6025

Table 7: Predicted runoff volume changes

Location	1800 to 1998			1998 to build-out		
	50% Chance Storm	10% Chance Storm	4% Chance Storm	50% Chance Storm	10% Chance Storm	4% Chance Storm
Runoff Volume Changes in Creek						
Sand Creek at M-45	79%	47%	36%	19%	12%	10%
Sand Creek/East Fork	78%	47%	36%	21%	14%	12%
Sand Creek at State	76%	46%	35%	21%	14%	12%
East Fork at Hayes	80%	48%	37%	21%	15%	12%
East Fork, upper	64%	40%	31%	13%	9%	7%
Runoff Volume Changes from Subbasins						
Sand Creek, lower	57%	34%	26%	8%	5%	4%
Sand Creek, to south tributary	26%	15%	11%	36%	21%	16%
Sand Creek, to M-45	72%	39%	30%	0%	0%	0%
Sand Creek, to Leonard	80%	47%	36%	8%	5%	4%
Sand Creek, to East Fork	63%	36%	28%	28%	18%	14%
Sand Creek, to State	80%	47%	36%	32%	21%	17%
Sand Creek, to Arthur	72%	43%	34%	14%	10%	8%
Sand Creek, to Wilson	85%	51%	40%	30%	20%	16%
Sand Creek, south tributary	95%	50%	37%	10%	6%	5%
Sand Creek, tributary to Leonard	80%	47%	36%	0%	0%	0%
East Fork, lower	103%	58%	44%	-7%	-5%	-4%
East Fork, to Hayes	84%	49%	37%	33%	22%	17%
East Fork, to tributary	108%	62%	48%	23%	15%	12%
East Fork, tributary	54%	35%	27%	37%	25%	20%
East Fork, upper	64%	40%	31%	13%	9%	7%

Table 8: Subbasin yields

Subbasin	Yield (cfs/acre) from 50% chance 24-hour storm					Yield (cfs/acre) from 4% chance 24-hour storm				
	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.	1800 land use	1978 land use	1998 land use	Build-out, no net loss of storage	Build-out, max.
Sand Creek, lower	0.01	0.02	0.02	0.02	0.04	0.06	0.10	0.09	0.10	0.15
Sand Creek, to south tributary	0.01	0.01	0.01	0.01	0.02	0.05	0.07	0.07	0.08	0.13
Sand Creek, to M-45	0.00	0.01	0.01	0.01	0.02	0.04	0.05	0.05	0.05	0.09
Sand Creek, to Leonard	0.01	0.02	0.02	0.02	0.03	0.04	0.07	0.07	0.07	0.11
Sand Creek, to East Fork	0.01	0.02	0.02	0.02	0.05	0.07	0.10	0.10	0.12	0.21
Sand Creek, to State	0.01	0.02	0.02	0.03	0.06	0.07	0.11	0.10	0.12	0.19
Sand Creek, to Arthur	0.01	0.02	0.02	0.02	0.04	0.04	0.07	0.07	0.07	0.12
Sand Creek, to Wilson	0.01	0.04	0.04	0.05	0.09	0.08	0.16	0.15	0.18	0.27
Sand Creek, south tributary	0.01	0.01	0.01	0.02	0.03	0.06	0.10	0.10	0.11	0.18
Sand Creek, tributary to Leonard	0.01	0.02	0.02	0.02	0.04	0.06	0.10	0.10	0.10	0.15
East Fork, lower	0.01	0.04	0.04	0.04	0.07	0.11	0.20	0.20	0.19	0.32
East Fork, to Hayes	0.01	0.02	0.02	0.03	0.05	0.06	0.09	0.10	0.12	0.19
East Fork, to tributary	0.01	0.02	0.02	0.02	0.04	0.04	0.07	0.07	0.08	0.14
East Fork, tributary	0.02	0.05	0.05	0.07	0.12	0.12	0.19	0.19	0.24	0.35
East Fork, upper	0.01	0.02	0.02	0.03	0.05	0.05	0.08	0.08	0.08	0.13
Arithmetic Average	0.01	0.02	0.02	0.03	0.05	0.06	0.10	0.10	0.11	0.18
Area-Weighted Average	0.01	0.02	0.02	0.03	0.05	0.05	0.09	0.09	0.10	0.16

Appendices

Appendix A: Sand Creek Hydrologic Model Parameters

This appendix is provided so that the model may be recreated by an engineering consultant, or others, if desired. Table A1 provides the design rainfall values specific to the region of the state where Sand Creek is located. Figure A1 summarizes the hydrologic elements in the HEC-HMS model. Tables A2 and A3 provide the parameters that were specified for each of these hydrologic elements. The initial loss field in HEC-HMS is left blank so that the default equation based on the curve number is used. Table A4 provides the reach parameters for the routing method. The control specified in HEC-HMS was for a seven day duration using a five-minute time interval.

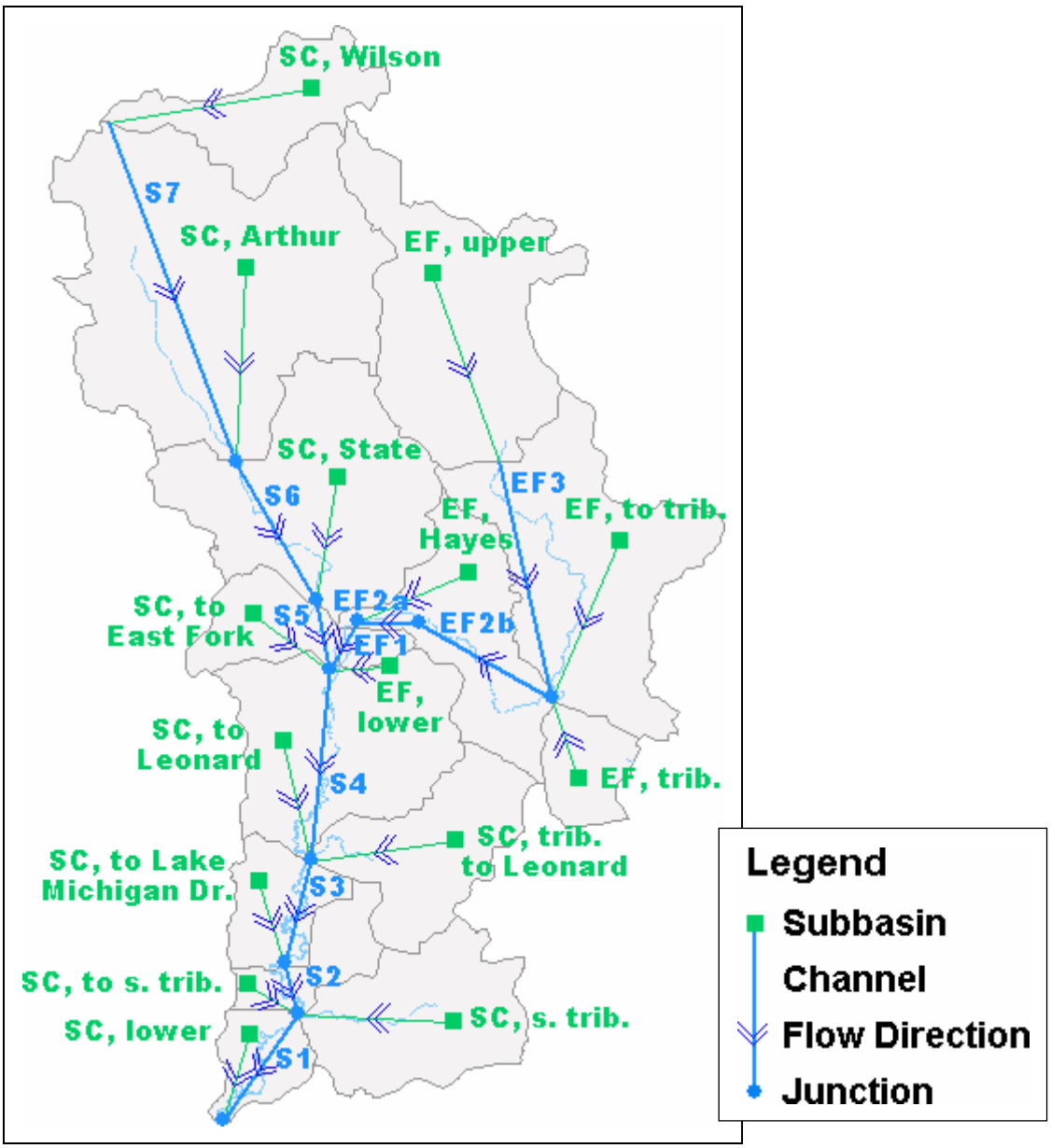

Figure A1: Hydrologic Elements defined for HEC-HMS model

Table A1: Design Rainfall Values for Kent and Ottawa County (Region 8)

Precipitation Event	Precipitation*
50% chance (2-year), 24-hour storm	2.24”
10% chance (10-year), 24-hour storm	3.33”
4% chance (25-year), 24-hour storm	4.21

*standard values were multiplied by 0.946 to account for the watershed size

Table A2: Subbasin Parameters – Area, Curve Number, Time of Concentration

Subbasin	Area (sq. mi.)	Initial Loss	Curve Number				Time of Concentration (hours)
			1800	1978	1998	Build-out	
Sand Creek, lower	1.1	Default	67	73	72	73	5.00
Sand Creek, to south tributary	1.3	Default	63	65	65	68	4.53
Sand Creek, to M-45	1.5	Default	63	68	68	68	7.16
Sand Creek, to Leonard	5.0	Default	68	76	75	76	9.16
Sand Creek, to East Fork	1.5	Default	65	70	70	73	3.38
Sand Creek, to State	6.3	Default	68	76	75	79	5.42
Sand Creek, to Arthur	11.1	Default	71	78	78	80	10.61
Sand Creek, to Wilson	2.7	Default	70	79	78	82	4.08
Sand Creek, south tributary	3.7	Default	62	68	68	69	3.06
Sand Creek, trib. to Leonard	3.2	Default	68	75	75	75	5.69
East Fork, lower	0.4	Default	66	74	74	73	1.98
East Fork, to Hayes	3.4	Default	67	73	74	78	5.10
East Fork, to tributary	6.3	Default	68	76	77	80	8.34
East Fork, tributary	1.3	Default	73	78	79	84	3.15
East Fork, upper	6.1	Default	74	80	81	83	10.07
Total	**54.8**						

Table A3: Subbasin Parameters – Storage Coefficients

Subbasin	50% chance, 24-hour storm			10% chance, 24-hour storm			4% chance, 24-hour storm		
	1800	1978, 1998	Build-out	1800	1978, 1998	Build-out	1800	1978, 1998	Build-out
Sand Creek, lower	17.3	12.4	5.0	12.9	11.0	5.0	11.2	10.00	5.0
Sand Creek, to south tributary	20.8	13.2	4.5	13.5	10.3	4.5	11.2	9.20	4.5
Sand Creek, to M-45	18.3	23.3	7.2	10.2	18.9	7.2	8.0	6.70	7.2
Sand Creek, to Leonard	29.7	22.7	9.2	22.3	20.4	9.2	18.5	16.20	9.2
Sand Creek, to East Fork	32.0	10.1	3.4	26.0	8.5	3.4	22.5	18.20	3.4
Sand Creek, to State	23.5	12.4	5.4	17.8	11.3	5.4	14.8	10.40	5.4
Sand Creek, to Arthur	17.8	23.5	10.6	11.3	21.7	10.6	9.2	7.40	10.6
Sand Creek, to Wilson	15.0	8.2	4.1	11.8	7.6	4.1	10.7	10.30	4.1
Sand Creek, south tributary	36.0	9.6	3.1	30.4	7.5	3.1	26.3	19.80	3.1
Sand Creek, trib. to Leonard	14.8	12.5	5.7	11.2	11.4	5.7	9.7	7.20	5.7
East Fork, lower	9.2	5.1	2.0	6.0	4.6	2.0	5.0	4.20	2.0
East Fork, to Hayes	21.5	13.1	5.1	15.7	11.4	5.1	13.0	10.40	5.1
East Fork, to tributary	30.5	23.3	8.3	24.0	20.6	8.3	20.5	18.20	8.3
East Fork, tributary	10.4	6.5	3.2	8.4	6.1	3.2	7.4	5.70	3.2
East Fork, upper	34.0	23.3	10.1	29.0	21.5	10.1	25.0	19.60	10.1

Table A4: Channel Reach Parameters

Reach	Lag (hours)
Sand Creek 1: mouth to southern tributary	5.90
Sand Creek 2: southern tributary to M-45	1.95
Sand Creek 3: M-45 to Leonard	6.88
Sand Creek 4: Leonard to confluence with East Fork	8.71
Sand Creek 5: confluence with East Fork to State	2.15
Sand Creek 6: State to Arthur	5.39
Sand Creek 7: Arthur to Wilson	10.50
East Fork 1: Confluence with Sand Creek to Hayes	1.04
East Fork 2: Hayes to near I-96	5.23
East Fork 3: near I-96 to 6 mile	8.35

Appendix B: Sand Creek Dam Failure

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

May 21, 2002

TO: Janice Tompkins, Surface Water Quality Division
Grand Rapids District Office

FROM: Dave Fongers, Hydrologic Studies Unit
Land and Water Management Division

SUBJECT: Sand Creek, Ottawa and Kent Counties

At your request on behalf of a recently-formed Sand Creek watershed group, the Hydrologic Studies Unit (HSU) of the Land and Water Management Division (LWMD) began a watershed monitoring study on April 11, 2002. The locations of the flow monitors and rain gages within the watershed are shown in Figure 1.

This study was requested because increased magnitude and frequency of flood (out of bank) flows and streambank erosion have been identified as problems throughout the watershed. The stream reach that appears to be experiencing the most extensive streambank erosion is located from approximately Leonard Street to Lake Michigan Drive. Increases in the flow regime and the associated streambank erosion would be reduced below Lake Michigan Drive because the Grand River is a hydraulic control that attenuates peak flows near its confluence with Sand Creek.

Changes in the flow regime of Sand Creek as a result of changes in the hydrologic characteristics of the watershed are thought to be a contributing cause of the increased erosion and flood flows, particularly because portions of the watershed are under development pressure from the expanding Grand Rapids metropolitan area. A better understanding of these problems and their causes is necessary to identify and design appropriate Best Management Practices (BMPs) to rehabilitate the stream. This assessment would be required for the installation of BMPs funded through a Clean Michigan Initiative (CMI) grant.

As part of these watershed monitoring studies, we routinely measure discharge at each monitoring location to develop a stage-discharge relationship, termed a rating curve. While doing this at the Leonard Street site, we discovered the remains of a failed dam, shown in Figures 2 and 3. We have researched this dam with the assistance of Jim Hayes with the LWMD's Dam Safety Program. A dam has been at this site since approximately 1860. In a January 1980 report, the hydraulic height, normal pool storage capacity, and maximum pool storage capacity of the dam were listed as 9.8 feet, 80 acre-feet, and 200 acre-feet, respectively. The design of the dam is shown in Figure 4.

The dam foundation failed on May 21, 1989. Photos of the site on May 22, 1989 are shown in Figures 5, 6, and 7. As a result of the failure, the sediment that had accumulated behind the dam was released downstream. The hydraulic gradient, or slope, of the stream increased significantly, increasing the water velocity and erosive stress on the banks. The movement of

the sediment and changes in the flow regime could easily have altered the form, or morphology, of the channel. The sediment released by the dam failure may now be relatively stationary, deposited in the Grand River, near the mouth of Sand Creek, or on the Sand Creek floodplain. We would not, however, expect the channel morphology to have fully adapted to the altered flow regime in thirteen years. Other researchers have indicated that streams can take 60 years or more to adapt to an altered flow regime. Excessive and extensive streambank erosion is a typical symptom of unstable channel morphology.

The HSU recommends that current land use in the watershed be compared to 1978 land use. If land use has not changed significantly, hydrologic modeling to help identify the cause of the streambank erosion would not be needed. Modeling may still be needed to provide data for the selection and design of appropriate BMPs. Modeling solely to address flooding questions would not be appropriate under the Section 319 grant that is funding this watershed study. Because the monitors require no maintenance, we recommend that the monitoring program be continued until all parties involved decide whether hydrologic modeling is needed.

cc: Ralph Reznick, SWQD
Ric Sorrell, LWMD
Gerald Fulcher, LWMD
Jim Hayes, LWMD

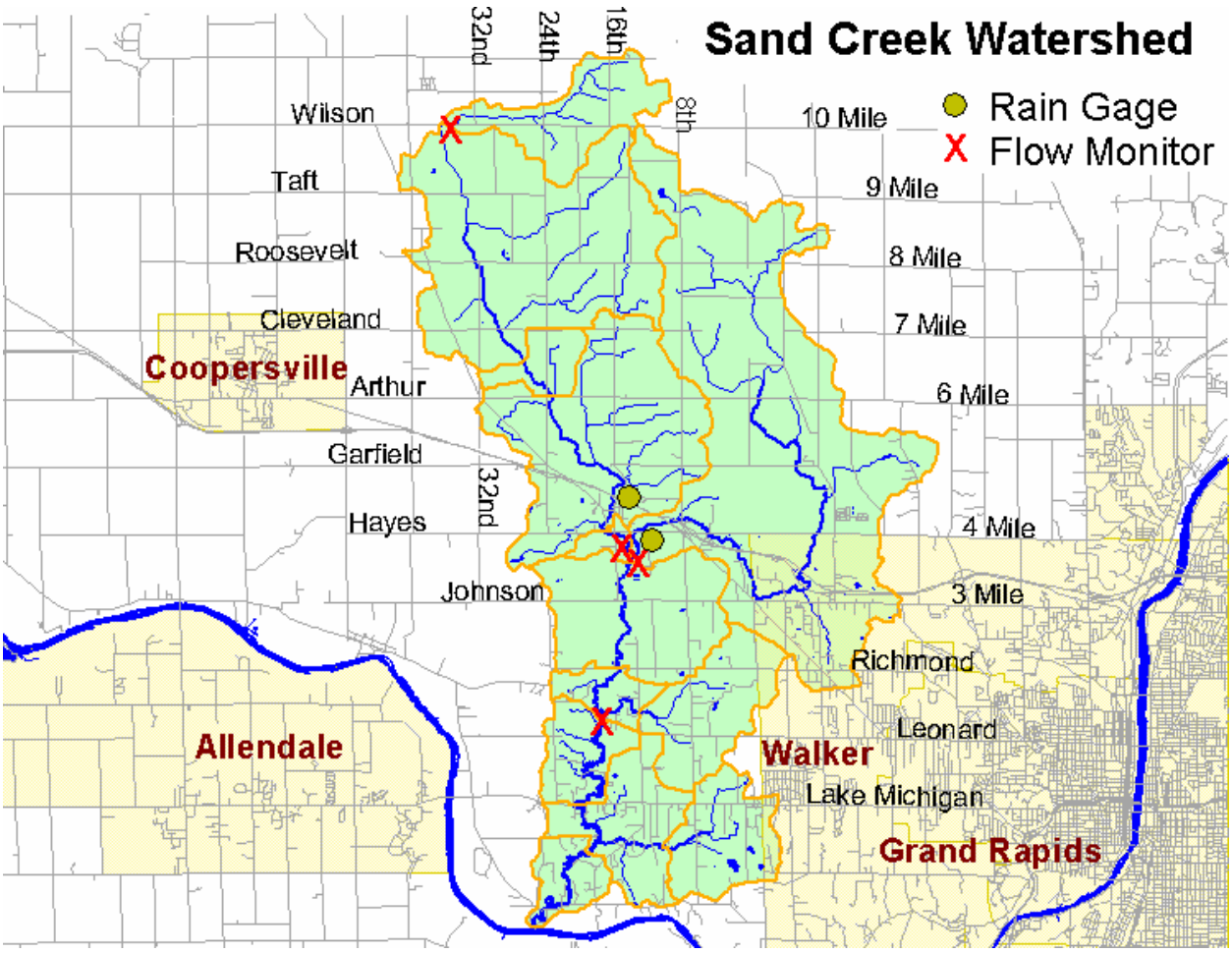

Figure 1: Watershed Study Monitoring Locations

Figure 2: Failed dam below Leonard Street, May 2002

Figure 3: Failed dam below Leonard Street, May 2002

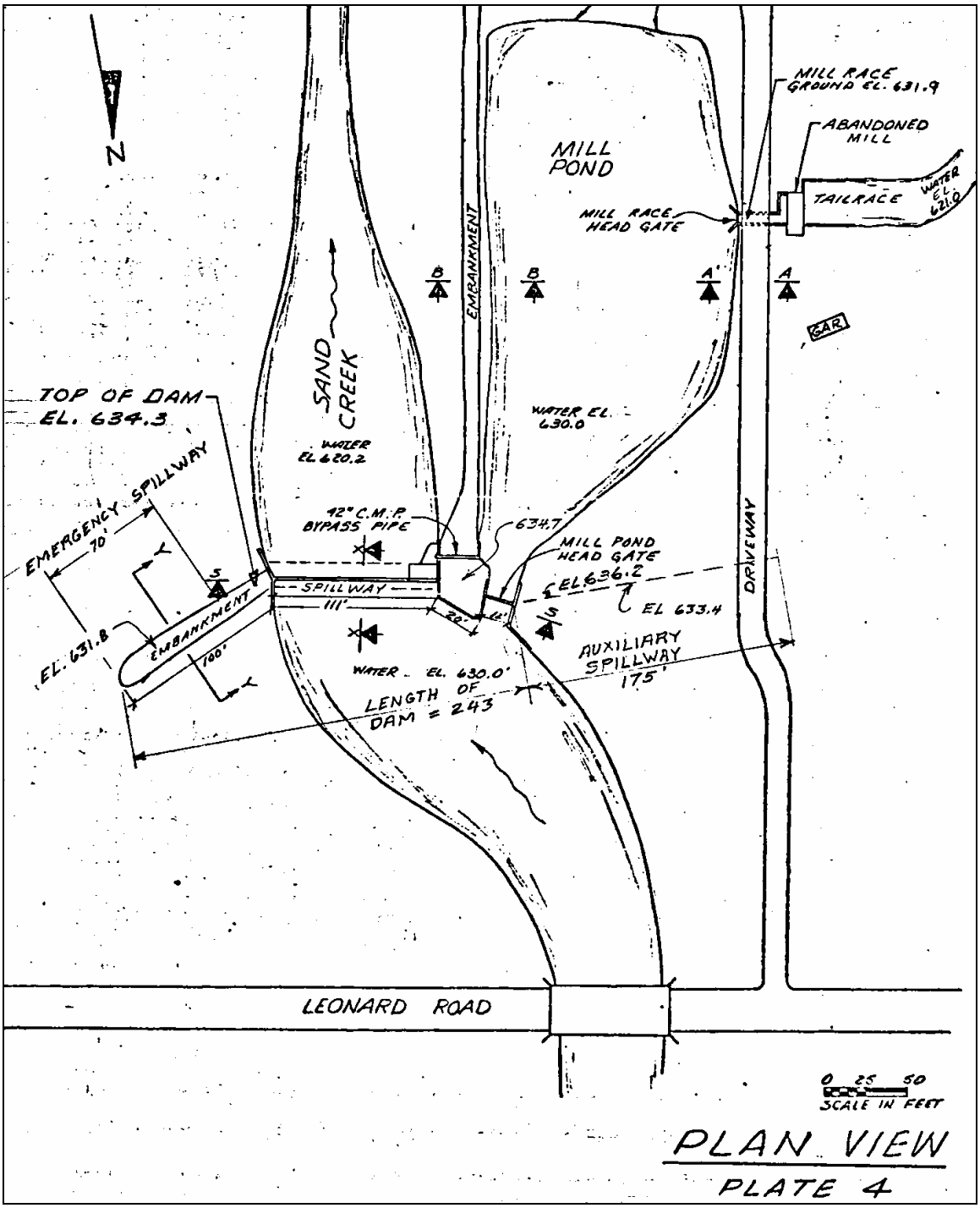

Figure 4: Plan View of Root Dam

Figure 5: Root Dam on 5/22/1989, one day after failure

Figure 6: Root Dam on 5/22/1989, one day after failure

Figure 7: Impoundment of Root Dam on 5/22/1989, one day after failure