GRAND RIVER INTER-COUNTY DRAINAGE BOARD

# Quantifying the Impact of Catch Basin and Street Sweeping on Storm Water Quality for a Great Lakes Tributary: A Pilot Study

TETRA TECH MPS

**in association with Pacific Water Resources, Inc.**

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# EXECUTIVE SUMMARY

In 1999, the Grand River Inter-County Drainage Board received an $81,000 grant from the Michigan Great Lakes Protection Fund to quantify the effect of street sweeping and catch basin cleaning practices on storm water quality. The project was supplemented by matching funds and in-kind services totaling approximately $39,000.

Current street sweeping practices include the use of broom and vacuum-style street sweepers. On average, a typical street is to be swept approximately four times per year. Catch basins are cleaned on an as-needed basis with the assumption that they are cleaned once every three to five years.

Five sampling sites were chosen within the City of Jackson, and one site was located north of the city in Blackman Township. Each of these sites was chosen to represent various land uses within the Jackson area. The land uses included single-family residential housing, industrial, highway, and the central business district. Street dirt and catch basin sediments were sampled at each of the sites from April, 2000, to September, 2000. The collected samples were sieved and divided into fine, medium, and course fractions. Chemical analysis was conducted on the fractions to determine the concentration of pollutants in the street sediments.

Sediment accumulation rates ranged from 136 to 474 pounds per curb mile per with an overall average of 255 lbs./curb-mile/month. Arsenic, barium, cadmium, chromium, copper, lead and zinc were all found present in the collected street dirt samples. The central business district was determined to have the lowest sediment accumulation rate, however, it exhibited the highest overall pollutant concentrations. Conversely, the highway site had the greatest sediment accumulation rate, but generally the lowest pollutant concentrations. Significant concentrations of pollutants including heavy metals were found in the fine, less than 63 microns, particle-size class.

The Simplified Particulate Transport Model (SIMPTM) was used to simulate the complicated interaction of sediment accumulation, washoff, and street sweeper pickup. The model was calibrated by simulating the predicted street dirt accumulation and then comparing it to actual

accumulation. The calibrated SIMPTM model was then used to simulate total suspended solids for an array of best management practices, including catch basin cleaning, mechanical sweeping, tandem sweeping, regenerative air sweeping, and high efficiency sweeping. Total and marginal cost curves were calculated to determine the most efficient, cost-effective management practice.

The simulations for the six land use areas suggest that existing frequency of sweeping practices reduce pollutant washoff only 4 to 17 percent, depending on the pollutant and the land use. It is estimated that sweeping every 14 days or 30 days with high-efficiency sweepers would reduce the annual washoff of total suspended solids (TSS), chemical oxygen demand (COD), total phosphorus, cadmium, chromium, lead, copper, and zinc by 66 to 87 percent annually, if the catch basin is clean and depending on the pollutant and the land use. Sweeping with regenerative air sweepers with a clean catch basin would reduce washoffs of these pollutants by 49 to 85 percent annually.

Results were examined using three separate removal targets. Examining the cost effectiveness, attributes, and cost of the various BMPs for the 75, 50, and 25 percent removal of total solids recommendations were developed. The high efficiency sweeper used at various frequencies is the most effective in achieving all three targets. Costs of high efficiency sweepers range from $216,000 to$269,000 and are not included in operation and maintenance estimates provided below.

To achieve 75 percent reduction of the total sediments, sweeping needs to occur bi-monthly frequency. The total cost to achieve this target is $2,325 per acre per year. To achieve the 50 percent target, a monthly sweeping program is needed. The total cost to achieve this target is $940 per acre per year. Finally, a frequency of approximately 4 times per year is needed to achieve 25 percent removal of total solids. The total cost to achieve this target is approximately $245 per acre per year.

Since the high efficiency sweeper has a relatively low travel speed, it is recommended that dumpsters should be staged in the sweeping areas. Once the sweeper has attained capacity, the sediments can be offloaded into the dumpsters which can be taken back to the disposal yard more efficiently.

Current street sweeping practices are achieving less than 18 percent reduction of the total sediments. Street sweeping and catch basin cleaning must be reviewed in the context of a complete Storm Water Pollution Prevention Initiative as defined by the USEPA Phase II Storm Water Rules. Because the City, County and neighboring townships are currently embarking on a coordinated and cooperative watershed planning approach to address Phase II Rules, it would be premature to recommend a specific target at this time. Our recommendation is that this analysis be used in the development of a suite of structural and nonstructural best management practices, including enhanced soil erosion and sedimentation control practices, to reduce nonpoint source loadings of sediment and associated contaminants in order to minimize loadings of sediment-based pollutants to the Grand River and to comply with Phase II Rules.

# INTRODUCTION

The Upper Grand River Watershed, headwaters to one of Michigan's largest river basins, is at once beautiful and troubled. Once studied for possible inclusion in the State's Natural Rivers system, and containing critical wetlands that provide refuge for thousands of migrating sandhill cranes (Grus canadensis) and other waterfowl, the River and its watershed provide a variety of recreational uses. Yet, much of the Watershed's value as a recreational asset is unrealized. Despite the Grand River Expedition 2000's findings that the River's water quality is vastly improved from a decade ago, portions of the river system still fail to meet water quality standards.

The Upper Grand River, from the City of Jackson downstream to Berry Road (8 miles), is listed on Michigan's 303(d) List for failure to attain designated stream uses. This stretch of the Upper Grand River exhibits poor aquatic habitat with correspondingly poor macroinvertebrate and fish communities, and violates Michigan water quality standards for pathogens and dissolved oxygen. Additionally, the entirety of the Grand River from the river's mouth at Lake Michigan upstream to the City of Jackson are listed due to PCB contamination; for violations of water quality standards for PCBs near the river's mouth and for fish contaminant advisories upstream. Sources of the PCBs are believed to be urban runoff and atmospheric deposition. In a biological and chemical survey conducted in 1991, the Michigan Department of Natural Resources staff (now MDEQ) also found elevated levels of nutrients, especially total phosphorus, and zinc, chromium, copper, lead arsenic, and cadmium downstream of the City of Jackson (MDEQ, 1992). Fish and invertebrate assemblages, and aquatic habitat exhibited degraded conditions extending beyond the 8 miles listed in the States 303(d) list.

In an effort to more fully realize the potential of the Grand River, the Grand River Inter-County Drainage Board (GRICDB) initiated two studies in 1997. Both studies were designed to evaluate the river relative to the drain channel and corridor characteristics including sedimentation, streambank erosion, hydraulic conditions, and potential nonpoint sources of pollution. One study focused on a section of the Grand River in Jackson and Ingham Counties. The other focused on a major tributary, the Portage River. Both studies identified sedimentation and other geomorphologic changes, which have resulted in log jams and channel restrictions (GRICDB, 1999 a, 1999 b).

In recognizing the importance of urban storm water quality to the Grand River, in 1999, the GRICDB applied for and received a grant from the Michigan Great Lakes Protection Fund to study the impact of catch basin cleaning and street sweeping on storm water quality. Because a number of Upper Grand River Watershed communities are listed on the U.S. Environmental Protection Agency's (USEPA) Phase II storm water regulations, it was further anticipated that this study would provide additional insight to communities which undertake the development of required Storm Water Pollution Prevention Initiatives.

Since numerous communities throughout Michigan will be required to comply with these new Phase II rules and their required components, it was further envisioned that the results of this study would benefit communities discharging to other Great Lakes tributaries.

# PURPOSE AND OBJECTIVES

In 1999, the Michigan Great Lakes Protection Fund provided a $81,000 grant to the GRICDB to conduct a pilot study assessing the impacts of street sweeping and catch basin cleaning on urban runoff in the Upper Grand River Watershed. An additional $39,000 in monetary and in-kind services was provided by the Jackson County Drain Commissioner, the City of Jackson, and the Jackson County Road Commission.

Street dirt is an inorganic material similar to silt and sand which has been found to be highly contaminated with urban runoff pollutants (USEPA, 1972). Street sweeping and catch basin cleaning are the primary best management practices used to minimize the transport of street dirt to downstream receiving waterbodies. The efficiency of street sweeping is a function of several parameters including frequency of sweeping, type of sweeper, speed of sweeper, particle size distribution, weather, interference (parked cars) and surface texture and condition. The primary methods of maintaining catch basin effectiveness is limiting debris and dirt available for transport through street sweeping and litter reduction campaigns including full leaf removal programs, and catch basin cleaning. The result of this pilot study will be used to demonstrate the costs and associated pollutant reduction of these types of programs for storm water management and control.

The purpose of the project was to determine the extent to which stormwater catch basin and street sweeping programs are an effective means of reducing pollution to the Grand River, as well as attempting to determine the optimal cost-effective mix of catch basin and street cleaning. The following were the study objectives:

- Document existing street sweeping and catch basin maintenance procedures and operations.
- Characterize street dirt accumulations and the associated pollutant loads.
- Develop a model to simulate street dirt accumulations.
- Develop an optimal cost-effective mix of catch basin and street cleaning.
- Prepare recommendations for street sweeping and catch basin cleaning practices.

The following list is a summary of the major tasks:

- Task 1: Characterize the study area.
- Task 2: Document existing street sweeping and catch basin maintenance procedures and operations.
- Task 3: Select pilot test areas and monitor accumulations of street dirt and catch basin sediments.
- Task 4: Calibrate the SIMPTM model to both the regional and study area specific data.
- Task 5: Develop a representative rainfall year.
- Task 6: Develop optimal cost-effective mix of catch basin street cleaning.
- Task 7: Develop a specific list of recommendations.
- Task 8: Document the results of the storm sewer maintenance program.

# METHODS

## STUDY AREA DESCRIPTION

The study area is located in and around the City of Jackson, Michigan. The City of Jackson is located in Jackson County in south central Michigan. The City of Jackson is approximately 11 square miles in size with a 2000 Census population of 36,316. The major land uses include single-family residential, commercial, industrial, parks vacant land, and public land. The percentage of land uses is listed in Table 1.

**Table 1 Percentages of Land Use for the City of Jackson**

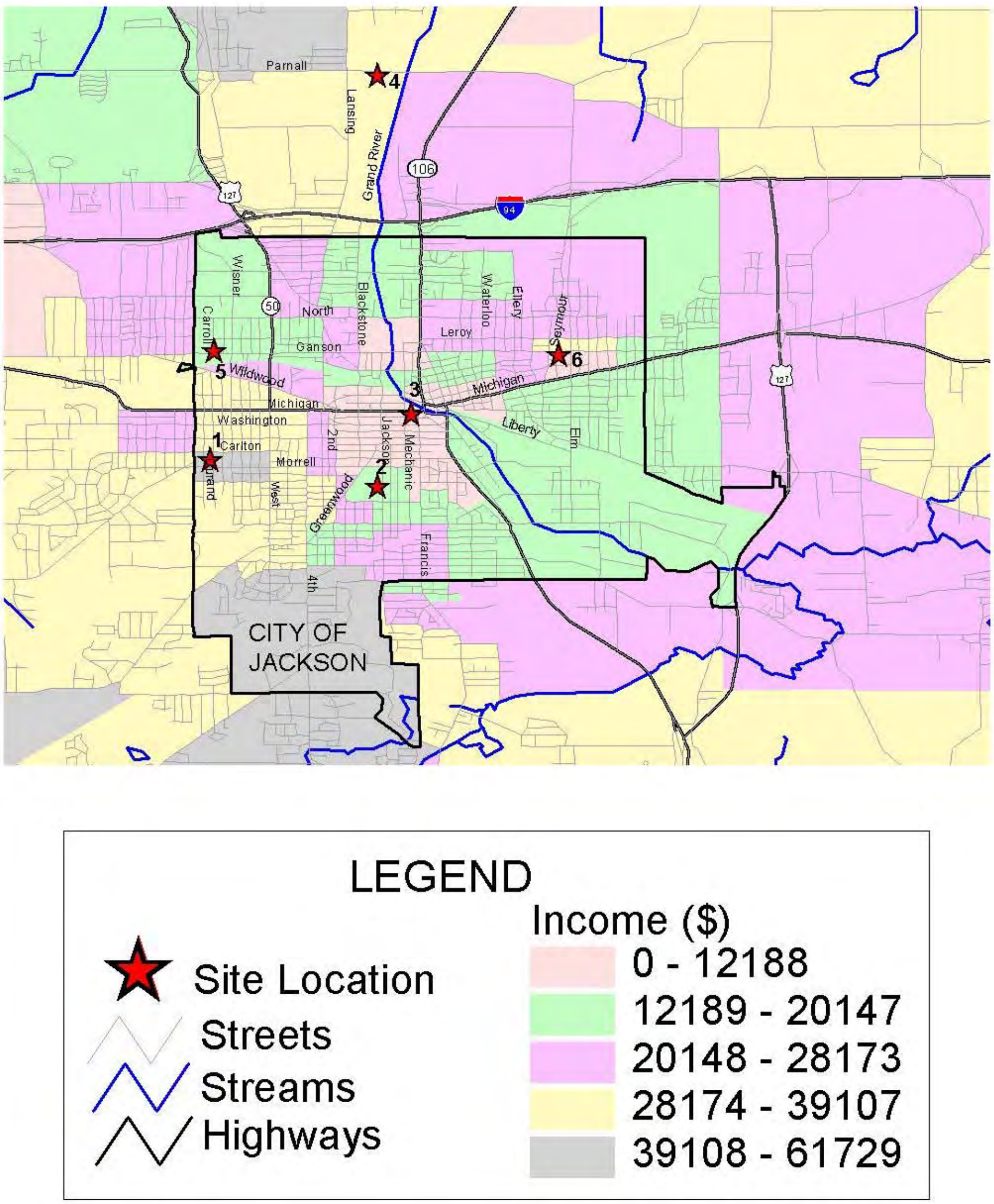
| Land Use | Acres | Percent of Developed Area |
|---|---|---|
| Single-Family Residential | 1,599 | 41 |
| Multiple-Family Residential | 199 | 6 |
| Commercial | 309 | 8 |
| Parks | 706 | 18 |
| Public Land | 440 | 11 |
| Transportation/Utilities | 102 | 3 |
| Industrial | 513 | 13 |
| Total | 3,868 | 100 |

Six sampling sites were selected within and around the City of Jackson. Figure 1 shows the location of these sites.

The sampling sites were chosen based on predominant urban land uses in the region, land use analysis and confirmed by a windshield survey. The targeted land uses included the central business district, a major highway, an industrial region, and residential areas. Each urban land use was represented by one sampling site with the exception of residential. Three of the six sampling sites represented the residential areas within the City of Jackson. Each of these residential sites was chosen to represent the various median household incomes found throughout Jackson, as shown in Figure 2.

**Figure 1 Study Area Map**

**Figure 2 Median Household Income**




Median income data compiled from the 1990 U.S. Census Information

The following is a description of each for the sampling sites.

***Durand Street (Site 1)***

Sampling Site 1 was located on the east side of Durand Street, north of West Morrell Street and Carlton Boulevard. Site 1, a residential street with household incomes between $39,000 and $62,000, includes 910 square feet of asphalt road with only concrete curbing and no gutter (see Figure 3). The monitored catch basin for this site was located at the north end. The asphalt surface was observed to be in fair condition with a substantial amount of cracks in the pavement.

**Figure 3 Durand Street (Site 1)**

***Jackson Street (Site 2)***

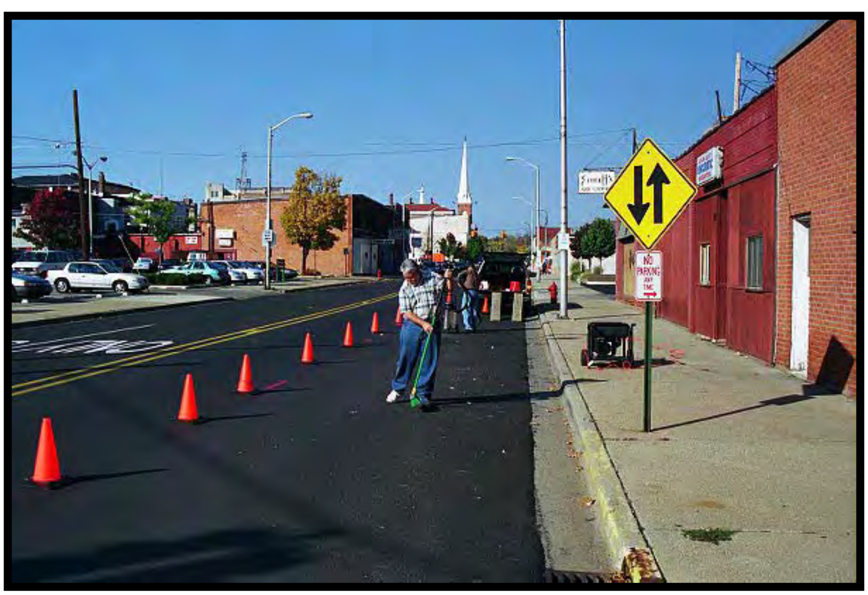
Sampling Site 2 was located on the east side of South Jackson Street between West Morrell Street and Rockwell Street (see Figure 4). The residential site consisted of 600 square feet of asphalt road with concrete curb and gutter. The driveways adjacent to the site have concrete aprons and are predominantly composed of gravel and dirt. The household income along this street range from approximately $12,000 to $20,000. The monitored catch basin is at the north end of the sampling site. The road surface is in good condition.

**Figure 4 Jackson Street (Site 2)**

***Courtland Street (Site 3)***

Sampling Site 3 was the central business district site and was located on East Cortland Street, between Francis and Mechanic Streets. Site 3 includes 840 square feet of asphalt road with concrete curb and gutter (see Figure 5). The monitored catch basin was located at the southern end of the sampling site. The site had been repaved two years prior to the sampling period, and was observed to be in good condition.

**Figure 5 Courtland Street (Site 3)**



*Highway - Parnell Road (Site 4)*

Sampling Site 4 was located approximately 300 feet west of the Grand River on the south side of Parnell Road in Blackman Township. Parnell Road, located in Blackman Township. Site 4 is a four lane, asphalt highway with concrete curb and gutter, characteristic of major highways of the region (see Figure 6). During the sampling period, construction occurred northwest of the site. The site was 360 square feet with the monitored catch basin located on the east side of the sampling site. The road surface was found to be in good condition, although it was characterized by some cracks in the asphalt.

**Figure 6 Parnell Road (Site 4)**

*Carroll Avenue (Site 5)*

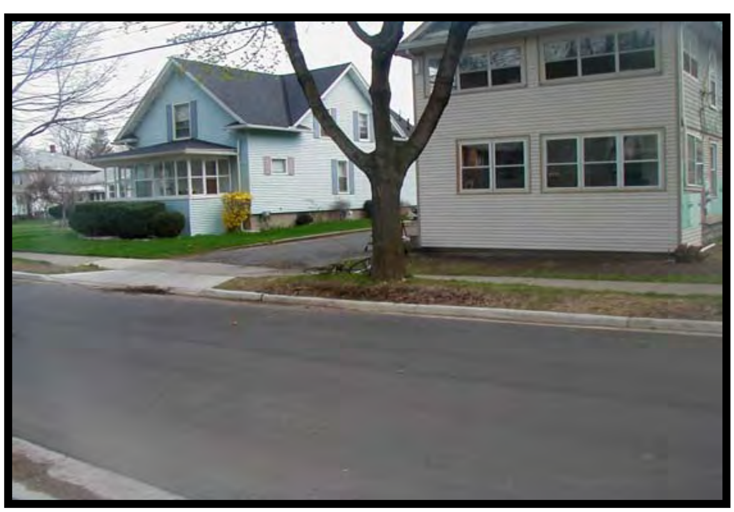
Sampling Site 5 was located on Carroll Avenue between West Ganson and West North Streets. The site, approximately 320 square feet of asphalt road and concrete curb and gutter, represented the industrial areas. The monitored catch basin was located at the north end of the site on the corner of Carroll and West Ganson Streets. Carroll Avenue had concrete curb and gutter with asphalt pavement. The pavement was found to be in good condition.

**Figure 7 Carroll Avenue (Site 5)**

***Seymour Street (Site 6)***

Sampling Site 6 was located on Seymour Street, between Leroy Street and East North Street. Sampling Site 6 was the third residential site, and had an approximate median household income of less than $12,000. The sampling site was approximately 600 square feet with the monitored catch basin at the north end of the site. This sampling site had been chip-sealed two years prior to this project, which made the road surface slightly rougher than the other sites. Since the sampling period, the road has been reconstructed with new concrete curb and gutter, and asphalt pavement.

**Figure 8 Seymour Street (Site 6)**



## EXISTING CLEANING PRACTICES

Existing catch basin cleaning and street sweeping maintenance procedures and operations were investigated and documented. Sites 1, 2, 3, 5, and 6 are in the City of Jackson and were the responsibility of the Jackson Department of Public Works. Site 4, Parnell Road, was under the jurisdiction of the Jackson County Road Commission. Surveys were conducted and meetings were held with Department of Public Works and County Road Commission personnel. The cleaning equipment and practices are summarized below with detailed information provided in Appendix A.

The City of Jackson owns two street sweepers, an Elgin Pelican and an Elgin Whirlwind. The Pelican is a three-year-old mechanical broom sweeper, and the Whirlwind is an eight-year-old vacuum sweeper. Both sweepers run full time from April to November. The City sweeps streets approximately 4-5 times per year. A two-year-old Vactor 2100 and a nine-year-old Vactor clean catch basins. Catch basins in the City of Jackson are cleaned only as required.

The County street sweeping begins in April and ends in December, using an 11-year-old Vac All E5-16BD vacuum sweeper. The County policy is that primary roads are swept first, followed by secondary roads. The County does not have a policy for cleaning during wet and inclement weather, but does not stop for inclement weather. Catch basin cleaning also starts in April and ends in December, beginning with primary roads and then secondary roads. The County uses a Vac All E5-16SPFB vacuum. Although the Jackson County Road Commission did not identify the number of times the streets were swept per year, it is assumed that the frequency is the same as the City of Jackson.

For this study, it was assumed that the City of Jackson's Department of Public Works and the Road Commission sweep curbed streets approximately four times per year, within their specified time frames. It was further assumed that catch basins are cleaned on an as-needed basis with a regular cleaning frequency that averages to once every three to five years.

## SEDIMENT SAMPLING

Street dirt and catch basin sediments were collected from each of the six sampling sites. The City of Jackson's Department of Public Works, County Road Commission, and Tetra Tech MPS (TTMPS) conducted the sampling with training provided by Pacific Water Resources (PWR). Samples were collected monthly at each site for a six-month period. Sample site forms were completed noting weather conditions, potential sources of sediment, the sampling team, and the road condition. See Appendix B for an example of the form.

### *Equipment*

The most significant piece of equipment utilized for sampling street dirt was a stainless steel vacuum. The vacuum used was a ten-gallon, stainless steel Shop-Vac, Model QL60B. The stainless steel canister reduced the risk of sample contamination. The vacuum was fitted with a dust filter to reduce the loss of extremely fine particles in the sample. Additional basic equipment included a broom, grade rod, paintbrush, chaining pin or screwdriver, and sample bags.

**Figure 9 Vacuum and Dust Filter**

***Sample Collection***

Street dirt sampling procedures were based on methods used by Pitt (1979). Sampling was conducted during the first week of each month from April, 2000 to September, 2000, unless otherwise noted on the form (see Appendix B). Catch basin sediments were collected at the same time for analytical analysis, but only during the months of April, July, and September. The catch basin samples were sieved prior to analytical analysis. All samples were collected during dry conditions. Routine street sweeping and catch basin cleaning were performed at the sample sites following the initial sampling. Routine street sweeping and catch basin cleaning of the sampling sites were suspended. The following procedure was used to collect the street dirt samples:

- Dirt was loosened from the concrete joints and cracks in the street using a chaining pin or screwdriver.
- The majority of the organic material, such as leaves and trash, was removed by hand and discarded. The organics were discarded because the study focused on the accumulation of street dirt sediments where the majority of contaminants are found, and the pollutants attached to those sediments. The model used in the analysis was also only designed to evaluate the washoff of street dirt sediments.
- A broom was used to sweep the sampling site, pushing the sediment toward the curb.
- The entire sampling area was vacuumed. Care was given specifically to the two feet nearest the curb.
- The contents of the vacuum were transferred to the sample bags. A paintbrush was used to collect the remaining fine sediments from the vacuum canister. The bags were numbered, dated, and labeled with the site number and street location.
- A sample site form was completed for each site visit.

To collect catch basin sediment samples, the following procedure was followed:

- After the initial cleaning of the catch basins, the distance from the catch basin frame to the bottom of the sump was measured.

- Using a grade rod, the distance from the top of the catch basin frame to the top of the accumulated material was measured at all four corners and noted on the sample site form.
- A representative sediment sample, containing as little of organic material as possible, was removed from the basin and placed in a labeled bag. The bag was typically filled to one-third full. If a sample or measurement could not be made, it was noted on the sample site form.

***Sieve Analysis***

Once the samples were collected, the sediment was sieved using stainless steel sieves. As with the vacuum, the stainless steel sieves reduce the potential for contaminating the sediment samples. The following sieves were used; 230, 120, 60, 30, 18, 10, ¼-inch, and >1/4-inch sieve. Three major purposes for sieving include:

1. Removing organic material from the sample.
2. Obtaining the dry weight of the sample for each sieve size.
3. Dividing the sediments into three major categories; coarse, medium, and fine.

***Chemical Analysis***

Chemical analysis was performed on both street and catch basin sediment collected during the months of April, July, and September. The chemical analysis included: total phosphorus, chemical oxygen demand, chloride, orthophosphate, and the ten total MDEQ metals - arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, copper, and zinc. A modified, Synthetic Precipitation Leaching Procedure (SPLP) was added to the September analysis for all of the metals, except mercury and selenium, because they were not present during the previous analyses. The modified SPLP simulates the sediment leaching process that is the result of rainfall and runoff conditions in this region. The SPLP involved weighing a sample and adding 20 times the samples' weight in an acidic fluid with a pH of 4.5, the average pH of rainfall in the region. The sample and fluid was then tumbled for 8 hours, which represented the average duration of rainfall in the region. The solution was then put through a digestion process, Method 3020, where nitric acid is added (USEPA, 1992). Table 2 lists the various chemical parameters tested, the test method used and the associated detection limits. RTI Laboratories conducted all chemical analysis. RTI Laboratories Quality Control documents are located in Appendix E.

**Table 2 Chemical Analysis Parameters and Test Methods (USEPA, 1992)**

| Parameter | Method | Detection Limit (ppm) | SPLP Detection Limit (ppm) |
|---|---|---|---|
| Total Phosphorus | 365.3 | 0.2 | - |
| COD | 410.1 | 1.0 | - |
| Chloride | 300 | 0.1 | - |
| Orthophosphate | 300 | 0.1 | 0.05 |
| Arsenic | 7060A | 1.0 | 0.05 |
| Barium | 6010 | 1.0 | 0.01 |
| Cadmium | 7131A | 0.05 | 0.02 |
| Chromium | 6010 | 2.5 | 0.05 |
| Lead | 6010 | 1.0 | - |
| Mercury | 7471A | 0.1 | - |
| Selenium | 7740 | 0.5 | - |
| Silver | 7761 | 0.5 | 0.02 |
| Copper | 6010 | 1.0 | 0.01 |
| Zinc | 6010 | 1.0 | 0.05 |

The purpose of conducting a chemical analysis of the sediments is to identify the concentration of pollutants in each of the three sediment fractions created during the sieve analysis. This data is then used to determine the pollutant loadings from street dirt, and which sediment fraction has the highest concentration of pollutants.

## MODELING

### *SIMPTM Overview*

This study used the Simplified Particulate Transport Model (SIMPTM) stormwater quality model (Sutherland and Jelen, 1998). The SIMPTM is a continuous stormwater quality model that accurately simulates the storm water pollutant loadings and expected load reductions from best management practices (BMPs), such as street sweeping and using and cleaning sediment trapping catch basins and manholes. SIMPTM is unique in its ability to simulate the accumulation, washoff and BMP removal of sediment and its associated pollutants (Sutherland and Jelen, 1996). Other applications of the model have demonstrated its ability to accurately simulate the observed pollutant loads and concentrations from gauged urban basins, such as those monitored for the City of Portland (Oregon) NPDES Storm Water Permit and the City of Bellevue (Washington) (Sutherland, 1991) Nationwide Urban Runoff Program (USEPA, 1983).

***Washoff and Accumulations***

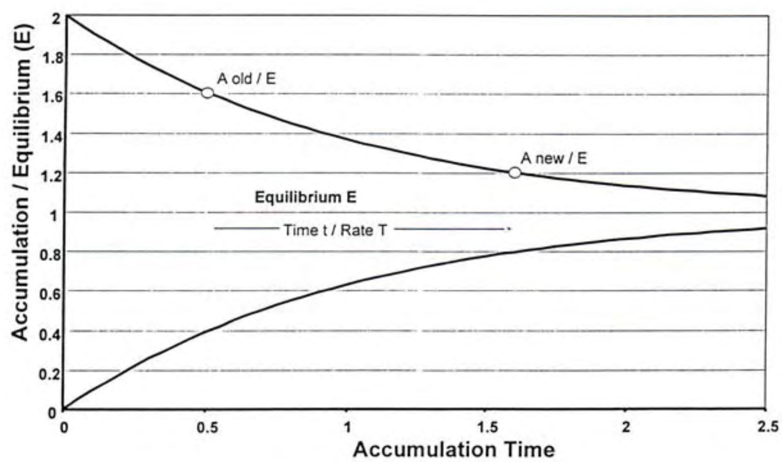
SIMPTM divides hourly precipitation records into rainfall events and provides monthly and annual statistics. For each event, it forms a runoff hydrographic, used to continually simulate sediment and bound pollutant transport using the Yalin-Einstein and Foster-Meyer equations, to simulate the capacity of the hydrograph to transport available accumulated sediment from paved areas.

The model also accounts for sediment deposition, armoring, and resuspension processes. Between events, SIMPTM calculates dry deposition and resuspension processes, and models scheduled cleaning of streets, parking lots, catch basins, or maintenance hatches. Overall removals from these practices are provided by SIMPTM, based upon measurable data, rather than input by the user, as most stormwater quality models require. Any excess erosion remains available for further simulation, so that actual accumulations may often exceed the equilibrium load previously assumed by many to be a maximum limit to accumulation.

Existing accumulation equations used by other models, such as USEPA's SWMM work contrary to the accumulation patterns observed during many urban runoff events. While accumulated loadings on paved surface have been observed to be greater during times of large rainfalls (i.e., wet season), it is almost always modeled as being much less, because the rainfall washes accumulated street sediment into the drainage system. Seldom is any provision made for washon, the increase that is often observed to result when washoff from adjoining unpaved areas (e.g., landscaped areas) actually increases the accumulation on paved surfaces following an event. A few models require seasonal parameters to model accumulation differently during wet and dry seasons, but the season is arbitrary and seldom correlates well with rainfall depth. Furthermore, even during the wet season, the model is using the dry weather accumulation algorithms, albeit with larger values.

Figure 10 illustrates the dry weather accumulation function, which exists within SIMPTM. It shows how the traditional maximum accumulation is better considered as an equilibrium accumulation. Accumulations both above and below the equilibrium, tend to lean towards it at the same rate as before. The underlying process of deposition balanced by removal from traffic and wind remains unchanged. Wet weather accumulations or washon from higher volume runoff events result in sediment accumulations that exceed the equilibrium accumulation level. When this occurs, the net result of dry weather that follows is a decrease in sediment accumulation.

**Figure 10 Dry Weather Accumulation Function**




$$A_{new} = (A - E)(e^{-t/T} - 1)$$

***Sediment Trapping Catch Basins***

Very little research has been conducted on the sediment retention effectiveness of sediment trapping inlets or catch basins. However, experiments by Lager, et al. (1977) concluded that sediment accumulation in catch basins is a function of the incoming sediment sizes, the catch basin volume available to trap sediment, and the runoff flow rate entering the catch basin. As expected, the larger particles had the highest retention percentage.

An initially clean catch basin can retain up to 45 percent of the incoming sediment (i.e., depending on its particle size distribution) until it becomes about half full. The efficiency then quickly drops to 0 as the trap fills to 60 percent. This critical point was defined as the breakthrough point. SIMPTM uses log-log regressions to relate the capture rate for each particle size group (Capfrac) to the retention rate (X) or flow over available trap storage:

$$Capfrac = 1/2(1 - A_{trap} \times B_{trap})$$

The two-parameter set, $A_{trap}$ and $B_{trap}$, are coded into the program. Each set of eight size-group values (i.e., $A_{trap}$ and $B_{trap}$) can be redefined. The default parameters for $A_{trap}$ and $B_{trap}$ used for this study were based on a calibration of the SIMPTM model to the extensive Bellevue (Washington) NURP data set (Sutherland, 1991).

***Sweeper Pickup Performance***

The ability of a street sweeper to reduce overall pollutant washoff loads depends on several factors. First is the sweeper's designed ability to remove accumulated sediment. Another is the environmental dynamics of sediment accumulation and resuspension and of sediment washoff during storm events, plus suspended sediment removal by downstream water quality controls.

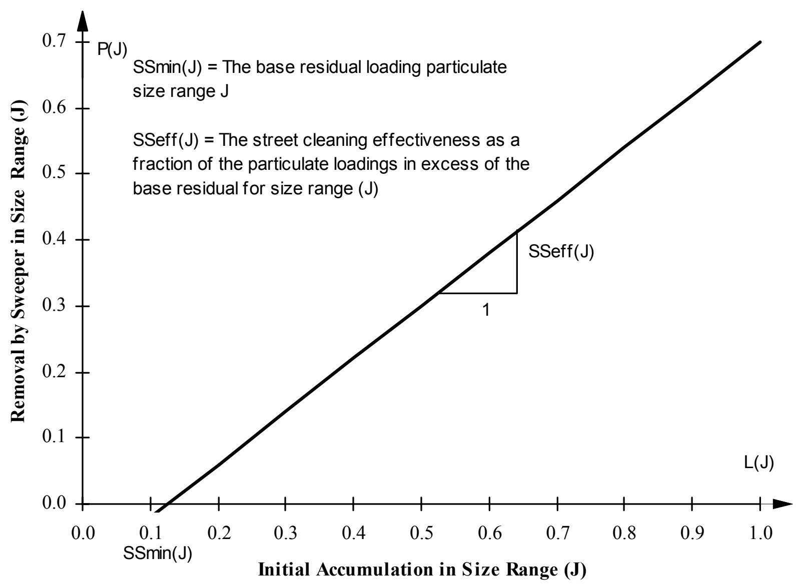
The SIMPTM program can accurately simulate this complicated interaction of accumulation, washoff, and street sweeper pickup that occurs over a period of time (Sutherland and Jelen, 1998). The street-sweeping component of the SIMPTM model was based on the results of Pitt's 1979 street sweeping study conducted in San Jose, California. This model was confirmed in additional studies conducted in Alameda County, California (Pitt and Shawley, 1982), and in Washoe County, Nevada (Pitt and Sutherland, 1982).

These studies found that sweeping removes little, if any, material below a certain base residual which was found to vary by particle size. Figure 11 illustrates the street cleaning component and equations used by SIMPTM. Above that base residual, the street sweeper's removal effectiveness was described as a straight-line percentage, which varied, by particle size.

For each of eight size groups (J), the amount removed (*P(J)*) is proportional to the initial accumulation (*L(J)*) in excess of a base residual (*SSmin*) by a sweeping efficiency (*SSeff*):

$$P(J) = SSeff * (L(J) - SSmin) \text{ for } L(J) > Ssmin$$

**Figure 11 Street Sweeping Model Component of SIMPTM**




Therefore, to describe a unique street sweeping operation one simply needs to know the operations SSmin and SSeff values for each of the eight particle size ranges simulated by SIMPTM. Note that SSeff is dimensionless, while that for SSmin must match that for accumulation, usually either pounds per curb mile, or pounds per paved acre.

**SIMPTM CALIBRATION**

The model calibration process involves the adjustments of parameter values to reproduce observed runoff volumes and pollutant loads. However, since no end-of-pipe stormwater flow and pollutant concentration data was obtained during the project, the calibration focused on reproducing the observed sediment accumulations on the street surfaces for each of the six land use test areas during the six-month sampling period of April through September, 2000.

### *Specific Characteristics of SIMPTM*

SIMPTM models rainfall losses using a single-parameter exponential curve that varies with rainfall depth. Once the maximum loss is specified, the exponential rate is automatically set so that the loss matches rainfall at the start of an event. For this study, the rainfall loss, which depends mainly on pavement texture or condition, was set to the value recently calibrated from Portland, Oregon runoff data at 0.05 inches.

Most SIMPTM parameters involving the hydraulics of washoff and sediment entertainment were related to measurable or fairly standard quantities, and were set as part of the land use test area characterization.

SIMPTM modeled accumulation as a constant deposition rate (mass per day) that became balanced over time by proportional resuspension rate due to wind and traffic (per day). As a result, accumulation approached an equilibrium limit determined by the deposition rate divided by the resuspension rate as shown in the previous section. Within each land use test area, each particle size group shared a constant rate, but apportioned the limit using a specified average particle size distribution that was determined by sieve analysis.

### *Rainfall During Sampling Period*

One problem the study encountered was obtaining hourly precipitation data recorded at Jackson during the six-month sampling period in a timely manner. At the scoping stage of the project, the consultant team checked into the location of hourly precipitation data being collected in Jackson. At that time, it was determined that data was being collected at the Jackson Airport and at a second location, some three miles north of the Airport. It was assumed that the data would be available four to six weeks after it was collected, which has typically been the case in other projects. As it turned out, it took the National Weather Service approximately five months to publish the hourly precipitation data collected at the Jackson 3N station located three miles north of the Airport. In addition, the Airport station only reported daily precipitation totals.

It was identified that the minimum-recorded value of precipitation at the Jackson 3N Station in 2000 was one-tenth of an inch, instead of one-hundredth of an inch. This created a problem for small storm hydrology because the basic thresholds for runoff are all less than one-tenth of an inch. As a result, another hourly precipitation recording station would have to be used for the model calibration.

Hourly precipitation data reported in hundredths was obtained for Ann Arbor, Battle Creek and Lansing, Michigan. Comparisons of the total precipitation depths recorded during the sampling period were made between each of these stations and the Jackson Airport Station. The Battle Creek Station, located approximately 40 miles to the west of Jackson, was selected since it provided the closest comparison of approximately a one inch difference in cumulative precipitation depth measured over the six-month sampling period.

Using the hourly rainfall data observed during the six-month sampling period at the Battle Creek (BC) Gauging Station located at the Battle Creek Airport, approximately 41 runoff producing rainfall events were identified with a total depth of 21.94 inches. The events spanned a total of 378 hours, which provided an average intensity of .058 inches per hour. Runoff producing rainfall events were those events that satisfied one of the three minimum depths versus time criteria:

1. 0.04 inches in one hour, or
2. 0.07 inches in three hours, or
3. 0.09 inches in six hours.

***Average Rainfall Year Development***

Rather than simulate many runs using many years of rainfall and summarize the extensive results, a long precipitation record was processed into many years of events, which were then evaluated. The twelve "best" months were combined to synthesize an average year that was used for the annual runs to evaluate different BMPs.

Continuous hourly precipitation data for 1948 through 1999 observed at the Jackson 3N Station was obtained from the National Climatological Data Center (NCDC) via a retrieval service called Hydrosphere that compiles and distributes the information on CD ROMs. The Jackson data was able to be used for the representative rainfall, because the level of detail was not as critical. This hourly precipitation data was processed into discrete runoff producing events using the thresholds of runoff presented earlier in the SIMPTM calibration section of the report. These events were then summarized by the following parameters for each month of each year:

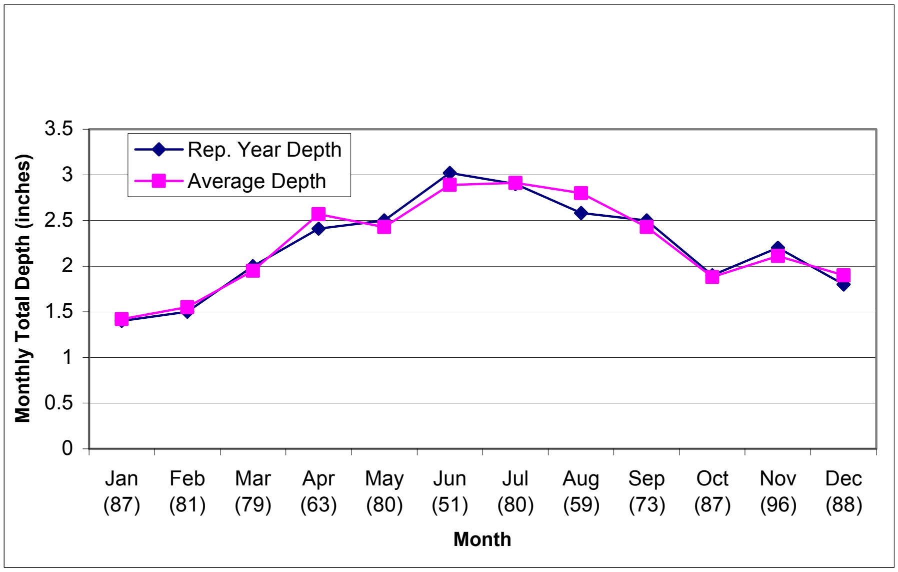
1. Number of events.
2. Total duration of events.
3. Total depth of events.
4. Maximum hourly precipitation.
5. Average intensity (*i.e.,* total depth/total duration).
6. Average dry time preceding events.

These events were then analyzed graphically in a spreadsheet month-by-month. Each statistic for each year was compared to its average for all years. The absolute "error" or "departure from mean" was graphed by year, with emphasis on the total monthly depth. Months that closely approximate the mean were found by looking for years where all data points (*i.e.,* "errors") neared "0".

In this manner, each of the twelve months was examined and the "best" month for each month was found. The hourly data for each were then combined to create a representative average year, which was analyzed by RAINEV to generate the events used by SIMPTM in its average annual runs. RAINEV is a rainfall analysis program included in the SIMPTM package.

Figure 12 represents the monthly precipitation depths contained within the representative year and compares them to the average depths from the entire 1948 through 1999 data set to those observed in 1955. The representative year is clearly more representative of the long-term average than a single year like 1955. In fact, the average monthly depths for the representative year are nearly indistinguishable from the averages for the entire record.

**Figure 12 Monthly Rainfall Depths Jackson, Michigan Station 3N. (1948-1998 Data)**




Figures similar to Figure 12 that document the characteristics of other parameters within the representative year and compare them to the long-term average are included in Appendix C. The figures in Appendix C address the other parameters presented above and used in the development of the representative year.

It is important that the representative year was a representative rainfall year, which means it must exclude the period of time when frozen conditions generally exist. Therefore, we obtained and examined the long-term temperature records for the Jackson Airport and concluded that the average long-term freeze up period was from December 21 to March 15. Any precipitation events that occurred during this period were ignored and not included in the final representative rainfall year.

The representative rainfall year contains 63 runoff-producing events, which occurred from March 16, 2000, through December 20, 2000. These events total 21.51 inches of rainfall over a total duration of 271 hours, which yields an average rainfall intensity of .079 inches/hour. The average event is 0.34 inches in depth and lasts for approximately 4.30 hours. The actual dates and characteristics of each of the 63 runoff-producing rainfall events that are contained within the representative rainfall year can be found in Table 13 located in Appendix C**.**

***Calibration Procedure***

The actual sampling event was simulated by the model to be a "perfect" sweeping event in which the minimum residuals (SSmin) are zero and the sweeper pickup efficiencies (SSeff) were all 100 percent. A "perfect" sweeping event was simulated by SIMPTM within a few days of each day in which an accumulation sample was obtained.

With all the washoff parameters set to reasonable values observed during other calibrations including one recently conducted on a Livonia, Michigan data set (Hubbell, Roth and Clark, 2001), the accumulation rate and equilibrium value were varied for each of the land use test areas until one set of numbers was found to provide the best overall match. The best overall match was determined by visually examining the model's simulated sediment accumulation values (lbs./acre) against the actual sample weight that was obtained.

**FINAL MODEL PARAMETERS**

Table 3 presents the final set of parameter values used by SIMPTM in the model calibration to each of the six land use test areas. In addition, Table 3 documents the parameter values used to simulate pollutant washoffs from the predominant land uses found in the urban areas of the City of Jackson and Blackman Township. However, in the BMP simulations, the initial street dirt accumulation values (Pint) are set equal to the equilibrium accumulation (Pequ) and the initial accumulation of sediments in the catch basins (Hint) are set to zero, if annual catch basin cleaning is assumed. If annual catch basin cleaning is not assumed, the (Hint) value is set equal to the maximum depth of available sediment storage (Hmax).

## Table 3 SIMPTM Final Parameter Values

| Land Use/Site Name | General | | | Hydraulics | | | | STCB Storage | | | Dry Weather Accumulation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slope | EIA | CurbDN | Flow | N | CBDN | Z | DIA | Hmax | Hint | Pint | Pequ | Rate |
| Central Business District | | | | | | | | | | | | | |
| Cortland (Site 3) | .010 | 100 | 460 | C&G | 0.08 | 2.0 | 48 | 4.0 | 0.5 | .13 | 200 | 220 | .020 |
| Highway | | | | | | | | | | | | | |
| Parnell (Site 4) | .006 | 95 | 1650 | C&G | 0.08 | 5.5 | 48 | 4.0 | 2.0 | .36 | 360 | 850 | .010 |
| Industrial | | | | | | | | | | | | | |
| Carroll (Site 5) | .005 | 70 | 200 | C&G | 0.08 | 0.6 | 48 | 1.0 | 2.0 | 2.0 | 615 | 1120 | .020 |
| Single-Family Residential | | | | | | | | | | | | | |
| Durand (Site 1) | .010 | 25 | 400 | C&G | 0.08 | 0.6 | 48 | 4.0 | 2.0 | 0 | 175 | 300 | .010 |
| Jackson (Site 2) | .015 | 35 | 350 | C&G | 0.08 | 0.8 | 48 | 4.0 | 2.0 | 2.0 | 285 | 600 | .017 |
| Seymour (Site 6) | .005 | 30 | 330 | C&G | 0.08 | 1.4 | 48 | 2.25 | 1.5 | 1.5 | 240 | 430 | .017 |

Key to Column Headings:

| | |
|---|---|
| Slope | Typical slope of paved flowpath ft/ft |
| EIA | Effective impervious area (%) |
| CurbDN | Curbed feet per acre |
| Flow | C&G – Curb & gutter |
| CBDN | Number of catch basins per acre |
| Z | (C&G) – Cross slope (run/rise) |
| STCB | Sediment trapping catch basin |
| DIA | Effective circular STCB diameter (ft) |
| Hmax | Available sediment storage depth in STCB's (ft) |
| Hint | Average starting depth of sediment in STCB's (ft) |
| Pequ & Pint | Equilibrium and initial sediment found on pavement (C&G) – lbs./curb mile |
| Rate | Exponential accumulation rate (per day) |

Other Parameters Held Constant:

Runoff Duration = 0.9 + 0.98 (rainfall duration)

| | |
|---|---|
| ImpInt = 0.04 | Initial loss for impervious areas (inches) |
| ImpMax = 0.05 | Maximum variable loss for impervious areas (inches) |
| ImpRate = 20.0 | Rate of approach to maximum loss for impervious area |
| PervInt = 0.2 | Initial loss for pervious areas (inches) |
| PervMax = 4.0 | Maximum variable loss for pervious areas (inches) |
| PervRate = 0.25 | Rate of approach to maximum loss for previous areas |
| SFMax = 0.15 | Maximum fraction of accumulation available for washoff |
| SFRun = 0.04 | The availability of accumulated street dirt quadratically increasing, reaching SFMAX with SFRun inches of runoff (inches) |

***BMP Production Functions***

Using the calibrated model parameters from each of the six land use areas and the representative rainfall year, SIMPTM was used to simulate average annual total solids loading or washoffs on a unit acre basis for a large array of BMPs. The practices that were evaluated included catch basin cleaning, mechanical street sweeping, tandem sweeping (*i.e.,* mechanical followed by vacuum-assisted), regenerative air sweeping, and high-efficiency sweeping.

High-efficiency street sweepers utilize strong vacuums and the mechanical action of uniquely designed main and gutter brooms, combined with an air filtration system that only returns clean air to the atmosphere (*i.e.,* filters particulates to 2.9 microns). These machines sweep dry and no water is used since they do not emit dust. Schwarze Industries, Inc.'s EV series, which includes the EV-1 and EV-2, are currently the only documented high-efficiency sweepers. High-efficiency sweepers were named for their unique ability to pick up and totally contain a very high portion of the fine, contaminated dirt that accumulates on streets and parking lots.

Regenerative air sweepers are closed-top systems that utilize high velocity jets of air to loosen street sediments. The sediments and sediment-laden air are sucked up into the hopper and allowed to settle. The finer particles are then filtered prior to the air being reused. Several manufacturers make these sweepers including Swartz, Tymco, and Elgin.

For the BMP simulations that were used, the frequency of the street sweeping was varied from bimonthly to bi-daily. The frequencies (i.e., days between sweepings) used were 61, 30, 14, 7, 4, and 2. Since the representative rainfall year was only nine months in length and sweeping was not assumed to begin until March 23, 2000, the date of first rainfall event, the actual number of sweepings that corresponded to the above frequencies were 4, 9, 20, 38, 67, and 135 times per year, respectively.

The BMP simulations also included the condition of no street sweeping and no catch basin cleaning occurring throughout the year. The simulations were also used to calculate how effective each of the BMPs were in removing total solids from the washoff (i.e., lbs./acre/year) that would have occurred. The relationship between effort and removal produces a curve called a production function.

***BMP Total Cost Curves***

The next step in establishing the optimal levels of the various BMPs, is to establish curves that show the relationships between total solids reduction and total cost. In order to establish these relationships, the cost of street sweeping and the cost of catch basin cleaning are needed. The production functions are then multiplied by these various costs.

The City of Jackson estimated the unit cost of street sweeping to be approximately $101 per curb mile swept, and the unit cost of catch basin cleaning to be $30 per catch basin cleaned. Jackson County estimated the unit cost of their street sweeping to be approximately $180 per curb mile swept and the unit cost of each catch basin cleaning to be $22.50 per catch basin cleaned. These costs include labor, overtime, equipment, and overhead associated with each activity.

For the purposes of the cost analysis conducted on this project, a unit cost of street sweeping of $140 per curb mile swept was assumed.

The potential differences in equipment capital costs and life cycle costs due to equipment type was not factored in to the analysis. The intent of the cost analysis was to keep it simple and see approximately how cost-effective various BMPs could be in reducing pollutants entering the Grand River and its tributaries. However, the unit cost of street sweeping was doubled for tandem sweeping, since two pieces of equipment is needed. The City of Jackson, and the Jackson County Road Commission both sweep the gutter and road surface immediately adjacent to the gutter.

***BMP Marginal Cost Curves***

In order for one to find the optimal level for any given practice, the relationship between solids removal and the change in cost of removing those solids. To understand this relationship, BMP marginal cost curves were developed. The graphs were used to determine the cost-effectiveness of different levels of removal, and ultimately to determine the optimal, most cost-effective, level of effort.

# RESULTS AND DISCUSSION

## SIEVE ANALYSIS

The sediments were sieved and divided into three fractions, coarse, medium, and fine. The basis by which the particles were divided into these three fractions is identified in Table 4. The various sediment fractions for each of the sites were then analyzed for pollutants.

**Table 4 Sediment Distribution**

| Sediment Size (Microns) | Particle Groups |
|---|---|
| <63 | Fine |
| 63 to 250 | Medium |
| 251 to 6,370 | Coarse |
| >6,370 | Discarded |

Table 5 is a summary of the average accumulation derived from the detailed sieve analysis data. The detailed sieve analysis data can be viewed in Appendix D. For comparison purposes, a similar study in the City of Livonia, Michigan (Hubbell, Roth and Clark, 2001), found on average the total sediment loading was 1.5 pounds per 1,000 square feet, which equates to 63% less accumulations when compared to this study. Likewise, a study in the City of Portland, Oregon, measured on average 133 pounds per curb mile, which equates to 48% less accumulation when compared to this study (HDR Engineering, 1993).

**Table 5 Summary of Sediment Accumulation**

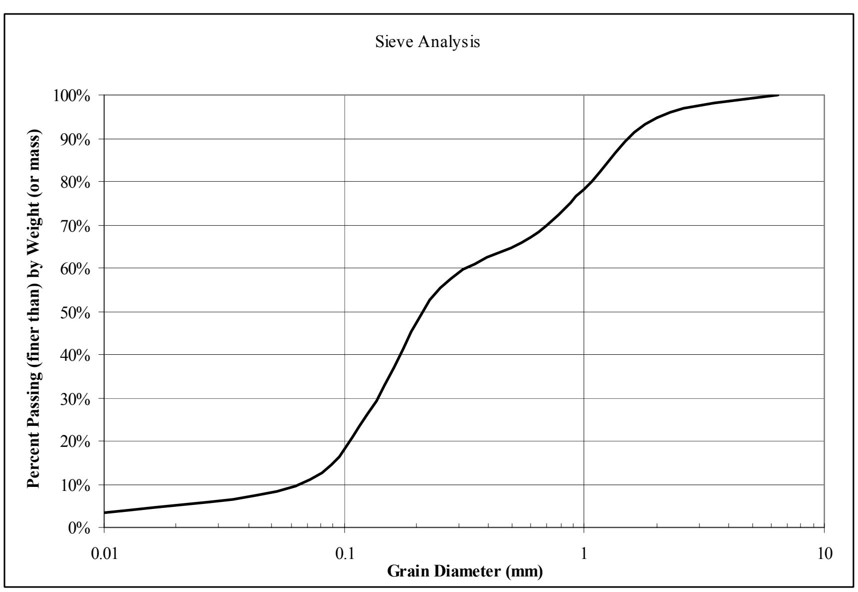
| | Average Monthly Solids Accumulation | | | | | |
|---|---|---|---|---|---|---|
| Site | Total (lbs./curb mile) | Fine (lbs./ 1,000 sf) | Medium (lbs./ 1,000 sf) | Course (lbs./ 1,000 sf) | Discarded (lbs./ 1,000 sf) | Total (lbs./ 1,000 sf) |
| Durand Street (Site 1) | 143 | 0.05 | 0.96 | 0.91 | 0.15 | 2.07 |
| Jackson Street (Site 2) | 232 | 0.21 | 2.45 | 0.94 | 0.09 | 3.69 |
| Courtland Street (Site 3) | 136 | 0.06 | 1.22 | 0.84 | 0.08 | 2.20 |
| Parnell Road (Site 4) | 387 | 0.16 | 2.80 | 2.88 | 0.36 | 6.20 |
| Carroll Avenue (Site 5) | 474 | 0.20 | 3.01 | 3.37 | 0.44 | 7.02 |
| Seymour Street (Site 6) | 158 | 0.10 | 1.73 | 1.10 | 0.15 | 3.08 |
| Average | 255 | 0.13 | 2.03 | 1.67 | 0.21 | 4.04 |
| | | (3%) | (50%) | (41%) | (5%) | (100%) |

Carroll Avenue and Parnell Road have the highest sediment accumulation of all sites sampled. Carroll Road is an industrial area with large amounts of truck traffic, which may account for the large sediment accumulations recorded at this site. The sediment accumulation found on Parnell Road may be attributed to the high traffic flow that the highway experiences. In addition, construction was occurring opposite of this site during the sampling period. The site did not appear to have a gravel access road, so sediment was most likely contributed as construction vehicles left the construction site.

The central business district average sediment accumulation was near the lowest accumulation rate in town at 2.20 lbs./1000 square feet. The only lower accumulation rate was from the upper income, single-family residential site (Site 1) at 2.02 lbs./1000 square feet. The accumulation rate was related to the traffic volume and, traditionally, a city's central business district has a high accumulation rate. Consequently, most cities concentrate their street-sweeping program on the central business district for this reason and for the improved appearance for business reasons. Assuming that no undisclosed street sweeping occurred in the central business district during the study period, this data would suggest that the central business district should not be the first priority, based solely on the sediment accumulation rates.

Figure 13 is a sediment distribution curve showing the percent passing each sieve by weight. The graph clearly shows that the majority of the sediments are in the medium to coarse range.

**Figure 13 Average Sediment Distribution Curve**



## CHEMICAL ANALYSIS

Table 6 provides the average results of the chemical analysis. The detailed results can be found in Appendix D. The results showed that there was a significantly higher concentration of orthophosphate than total phosphorus. RTI Laboratories stated that the values for orthophosphate were incorrect suggesting that an error had occurred in the analysis process. As a result, the orthophosphate values were removed from the test results.

**Table 6 Chemical Analysis Average Results**

| | Durand St. (Site 1) | Jackson St. (Site 2) | Courtland St. (Site 3) | Parnell Road (Site 4) | Carroll Ave. (Site 5) | Seymour St. (Site 6) | Average |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | 2.0 | 0.8 | 0.5 | 0.3 | 0.2 | 0.2 | 0.7 |
| COD | 76.9 | 45.9 | 49.0 | 18.5 | 34.9 | 1720.4 | 324.3 |
| Chloride | 65.7 | 22.4 | 161.6 | 158.8 | 39.0 | 24.0 | 78.6 |
| Arsenic | 3.5 | 1.6 | 2.8 | 6.0 | 2.9 | 2.4 | 3.2 |
| Arsenic (SPLP) | ND | ND | ND | ND | ND | NT | ND |
| Barium | 43.1 | 74.4 | 78.5 | 53.0 | 45.7 | 45.0 | 56.6 |
| Barium (SPLP) | ND | ND | ND | ND | ND | NT | ND |
| Cadmium | 0.2 | 0.3 | 0.5 | 0.2 | 0.4 | 0.3 | 0.3 |
| Cadmium (SPLP) | ND | ND | ND | ND | ND | NT | ND |
| Chromium | 65.9 | 23.2 | 67.0 | 23.1 | 33.4 | 39.6 | 42.0 |
| Chromium (SPLP) | ND | ND | ND | ND | ND | NT | ND |
| Copper | 22.6 | 25.6 | 98.8 | 31.1 | 40.5 | 29.4 | 41.3 |
| Copper (SPLP) | 0.45 | 0.07 | 0.01 | ND | ND | NT | 0.11 |
| Lead | 34.8 | 96.1 | 109.8 | 26.8 | 53.6 | 67.5 | 64.8 |
| Lead (SPLP) | ND | ND | ND | ND | ND | NT | ND |
| Mercury | ND | ND | ND | ND | ND | ND | ND |
| Selenium | ND | ND | ND | ND | ND | ND | ND |
| Silver | ND | ND | ND | ND | ND | ND | ND |
| Silver (SPLP) | ND | ND | ND | ND | ND | NT | ND |
| Zinc | 79.1 | 109.9 | 221.6 | 51.0 | 92.7 | 105.3 | 109.9 |
| Zinc (SPLP) | ND | 0.02 | 0.05 | ND | 0.01 | NT | 0.02 |

All results are in ppm.
ND = Not Detected

In eight out of the twelve chemicals that were detected, the central business district had the highest average concentration. Conversely, the highway site has among the lowest average concentrations except for chloride and arsenic, both of which were among the highest. Even though the central business district appears to have the highest pollutant concentrations and the highway has the least, it should be noted from Table 5 that the central business district had the lowest average sediment accumulation and the highway had the highest accumulation rate.

Table 7 provides comparison data with similar data from the City of Livonia, Michigan, and the City of Portland, Oregon. Based on the information collected, the sediment in Jackson has significantly less phosphorus and COD, but significantly more copper compared to Livonia. Compared to Portland, the Jackson sediment has substantially less COD and moderately less barium, lead and zinc.

**Table 7 Average Chemical Analysis Summary by Particle Group**

| Parameter | Jackson, MI | | | Livonia, MI | | | Portland, OR | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fine (ppm) | Med. (ppm) | Course (ppm) | Fine (ppm) | Med. (ppm) | Course (ppm) | Fine (ppm) | Med. (ppm) | Course (ppm) |
| Total Phosphorus | 0.9 | 0.8 | 0.7 | 22.3 | 31.5 | 26.6 | NT | NT | NT |
| COD | 140.7 | 49.4 | 549.9 | 5,735 | 7,501 | 6,312 | 144,444 | 153,909 | 345,833 |
| Chloride | 239.0 | 73.7 | 89.2 | NT | NT | NT | NT | NT | |
| Arsenic | 4.9 | 2.7 | 3.8 | 5.2 | 3.3 | 3.7 | 3 | 4 | 1 |
| Arsenic (SPLP) | ND | ND | ND | NT | NT | NT | NT | NT | NT |
| Barium | 124.4 | 60.7 | 45.3 | 67.0 | 98.0 | 62.4 | 330 | 362 | 322 |
| Barium (SPLP) | ND | ND | ND | NT | NT | NT | NT | NT | NT |
| Cadmium | 1.0 | 0.4 | 0.2 | 1.3 | 0.8 | 0.8 | 2 | 4 | 1 |
| Cadmium (SPLP) | ND | ND | ND | NT | NT | NT | NT | NT | NT |
| Chromium | 45.2 | 31.3 | 60.6 | 78.1 | 51.1 | 60.4 | 74 | 83 | 32 |
| Chromium (SPLP) | ND | ND | ND | NT | NT | NT | NT | NT | NT |
| Copper | 102.6 | 46.8 | 47.3 | 0.8 | ND | ND | 220 | 159 | 86 |
| Copper (SPLP) | 0.01 | 0.03 | 0.20 | NT | NT | NT | NT | NT | NT |
| Lead | 128.7 | 68.1 | 48.0 | 59.6 | 38.2 | 39.9 | 328 | 372 | 210 |
| Lead (SPLP) | ND | ND | ND | NT | NT | NT | NT | NT | NT |
| Zinc | 269.9 | 115.3 | 74.8 | 227.6 | 138.0 | 140.3 | 470 | 463 | 324 |
| Zinc (SPLP) | ND | 0.02 | 0.03 | NT | NT | NT | NT | NT | NT |

ND = Not Detected
NT = Not Tested

## MODEL CALIBRATION RESULTS

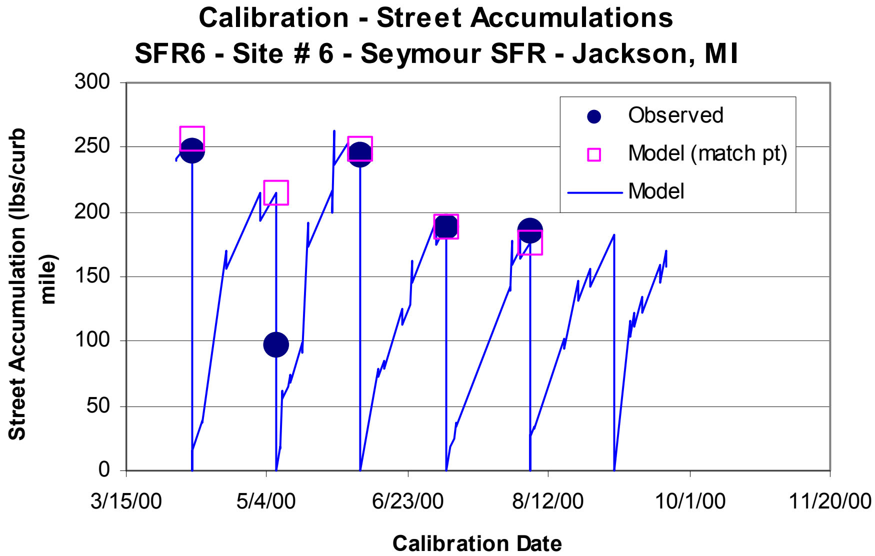
### *Street Dirt Accumulations*

The results of the street dirt accumulation for all six of the land use test areas are presented in Table 8 and in Appendix F. Figure 14 provides an example of the street dirt accumulation calibration. Table 8 and the figures in Appendix F clearly demonstrate the ability of SIMPTM to provide reasonable estimates of the magnitude of accumulated sediments found on the sample sites throughout the six-month sampling period. During this period, up to 41 runoff-producing rainfall events occurred, which also affected these observed accumulations.

**Table 8 Observed versus Simulated "Street Dirt" Accumulations**

| Land Use/ Site Name | Sampling Date | Observed Accumulation (lbs./curb mile) | Simulated Accumulation (lbs./curb mile) | Difference % (+/-) |
|---|---|---|---|---|
| | 4/6/00 | 180 | 182 | -1 |
| Durand Street (Site 1) | 5/4/00 | 140 | 132 | +6 |
| | 6/8/00 | 163 | 186 | -14 |
| | 7/11/00 | 132 | 118 | +11 |
| | 8/9/00 | 85 | 100 | -18 |
| | 9/6/00 | 152 | 103 | +32 |
| Average | | | | 3 |
| | 4/7/00 | 309 | 312 | -1 |
| Jackson Street (Site 2) | 5/4/00 | 209 | 264 | -26 |
| | 6/8/00 | 243 | 247 | -2 |
| | 7/11/00 | 157 | 228 | -45 |
| | 8/9/00 | 289 | 217 | +25 |
| | 9/6/00 | 243 | 227 | +7 |
| Average | | | | -7 |
| | 4/7/00 | 198 | 197 | <+1 |
| Courtland Street (Site 3) | 5/11/00 | 98 | 144 | -47 |
| | 6/8/00 | 135 | 160 | -19 |
| | 7/12/00 | 113 | 117 | -4 |
| | 8/10/00 | 180 | 103 | +43 |
| | 9/6/00 | 108 | 112 | -4 |
| Average | | | | -5 |
| | 4/6/00 | 385 | 386 | <-1 |
| Parnell Road (Site 4) | 5/4/00 | 359 | 272 | +24 |
| | 6/6/00 | 256 | 311 | -22 |
| | 7/17/00 | 186 | 242 | -30 |
| | 8/8/00 | 260 | 218 | +16 |
| | 9/13/100 | 180 | 235 | -31 |
| Average | | | | -7 |
| | 4/6/00 | 660 | 663 | <-1 |
| Carroll Avenue (Site 5) | 5/11/00 | 501 | 517 | -3 |
| | 6/9/00 | 587 | 484 | +18 |
| | 7/11/00 | 364 | 468 | -29 |
| | 8/9/00 | 449 | 435 | +3 |
| | 9/6/00 | 324 | 478 | -48 |
| Average | | | | -10 |
| | 4/6/00 | 247 | 257 | -4 |
| Seymour Street (Site 6) | 5/11/00 | 97 | 215 | -122 |
| | 6/8/00 | 244 | 249 | -2 |
| | 7/12/00 | 188 | 189 | <-1 |
| | 8/9/00 | 185 | 177 | +4 |
| Average | | | | -25 |

**Figure 14 Site 6 Seymour SFR Calibration**




The average percent difference in any observed versus simulated accumulation is approximately -8 percent. Sixteen of the thirty-five simulated accumulations were within 7 percent of the observed values. The greatest difference occurred on the May 11, 2000 sampling of the Seymour site, where the simulated value was 215 lbs./curb mile and the observed was 97 lbs./curb mile. This very large difference appears to be the results of a current model limitation.

The current version of SIMPTM cannot simulate the exact date of a sampling event (*i.e.,* perfect sweeping event) unless the frequency of sampling in days turned out to be exactly the same time frame between sample collections. Currently, the user must specify the first sampling event and the frequency of subsequent sample collection in days. The project was generally sampled on a monthly basis, starting on April 6, 2000. If one uses a start date of April 7, 2000, with a 30-day frequency, four day window of all of the actual sampling dates which would not create much modeling error provided the four-day period did not have any runoff events was achieved. This occurred in 23 of the 35 samplings with no significant runoff interference during periods of up to four days.

However, runoff interference did occur for the May 11 and September 13 sampling, as well as all of the samplings in July. In July, three storms totaling 0.58 inches were recorded between the modeled sampling date of July 6, and the actual July 11 and July 12 sampling dates. However, these storms were mild with average intensities of less than .02 inches per hour. As a result, their effect on accumulation was not very great.

The runoff interference in May and September was much more significant. On May 9, 2000, it rained 1.50 inches with an average intensity of 0.10 inches per hour. This runoff event occurred after the simulated sampling on May 4 and before the actual sampling on May 11, which could easily explain the large difference at Site No. 6 and the 47 percent difference on Site No. 3. Finally, on September 10, 2000, it rained 1.86 inches in 5 hours. This runoff event occurred after the simulated sampling on September 4 and before the actual sampling of September 13, which also explain the 31 percent difference at Site No. 4, shown in Table 8.

***Catch Basin Accumulations***

As presented in an earlier section, the accumulation of material within the catch basins located near the six-sample site was also monitored over the same six-month period. The initial monitoring that occurred on April 7 showed a wide range of catch basin accumulations from empty to 3.55 feet of depth. The City cleaned all of the catch basins on April 10. Accumulations within each of the catch basins were monitored whenever street dirt accumulation samples were collected.

As part of the SIMPTM calibration, catch basin cleaning was simulated on April 10 and the simulated accumulations in the catch basins were compared to those values observed near the end of the monitoring period at each of the sites. The results of this comparison are shown in Table 9. Graphs that show the observed versus modeled catch basin accumulations over time for all the sites are presented in Appendix F.

**Table 9 Observed versus Simulated Catch Basin Accumulations**

| No./Site Name | Monitoring Date | No. of Catch Basins | Observed Accumulation Avg. Depth of Material (ft) | Simulated Accumulation Avg. Depth of Sediment (ft) | Percent Difference |
|---|---|---|---|---|---|
| SFR – Durand Street (Site 1) | 9/6/00 | 1 | 0.14 | 0.04 | +71 |
| SFR – Jackson Street (Site 2) | 8/9/00 | 1 | 1.52 | 0.05 | +97 |
| CBD – Courtland Street (Site 3) | 9/6/00 | 1 | 0.08 | 0.02 | +75 |
| Highway – Parnell Road (Site 4) | 9/13/00 | 1 | 2.00 | 0.03 | +98 |
| Industrial – Carroll Avenue (Site 5) | 9/6/00 | 1 | 1.03 | 0.21 | +80 |
| SFR – Seymour Street (Site 6) | 8/9/00 | 1 | 0.06 | 0.03 | +50 |

Table 9 suggests that the model is significantly underestimating the amount of sediment accumulation in the catch basins over time. The significant difference between the observed and the simulated sediment accumulation may be linked to the fact that only one catch basin was monitored in each area and that the depth measurement may have included organic materials.

In a similar study in Livonia, Michigan, seven to fifteen catch basins were monitored within and given land use area (Hubble, Roth and Clark, 2001). Significant variations were found from one catch basin to the next within the same study area in that study. Monitoring additional catch basins may have produced a more accurate measurement of actual accumulated sediments.

In addition, field crews were instructed to measure the depth of material accumulation in the catch basin. This measurement included organic materials, which SIMPTM cannot simulate. Organic material occupies more volume than sediment and may have contributed to the discrepancy in accumulation.

The decision was made not to change the model's parameter values in an effort to achieve higher catch basin accumulations. It was also decided that there was not enough certainty in the models catch basin calibration to provide any significant insight or recommendations. As a result of this uncertainty, the catch basin cleaning was not part of the BMP analysis.

Although catch basin cleaning was not included as part of the BMP analysis in this study, this does not imply that catch basin cleaning is not an important practice. Catch basin sumps operate most efficiently up to 60 percent full, that is to say when the depth of solids is less than 60 percent of the depth from the invert of the lowest outlet pipe to the invert of the catch basin. When cleaning the catch basins sumps, traditional methods utilize a vacuum or clamshell. These methods are suitable for removing most of the solids accumulations, however, they do leave some debris behind. A recent study has found that this remaining disturbed debris can easily be suspended and washed down the storm drain during a storm event for the first several months after the catch basin was cleaned (TTMPS, 2000). Consequently, the ideal time to clean the catch basins is when capacity reaches the 60 percent full stage (TTMPS, 2000).

## MODEL RESULTS

### *Annual Pollutant Loads*

Sediment washoff was related to washoff of other pollutants by mass fractions, or potency factors assigned to each of the eight particle-size groups of accumulated sediment. These are generally set from observed fractions of accumulated sediment, or from observed sediment washed off during sampled events. Since no washoff data was obtained, the pollutant simulations were based on the chemical analyses of the collected samples.

As discussed earlier, chemical analyses of the street dirt samples were conducted for metals, COD, total phosphorus, and chloride. It was determined that in addition to total solids, the SIMPTM pollutant simulations would include COD, total phosphorus, cadmium, chromium, lead, copper, and zinc. The simulation of the particulate or suspended fraction of each pollutant was based on the mean potency factors found in the street dirt analyses presented in an earlier section. The annual pollutant loads for each site are identified in Table 10.

**Table 10 Annual Pollutant Load**
**(acre-ft/acre/year)**

| Site | TSS | COD | TP | Cd | Cr | Pb | Cu | Zn |
|---|---|---|---|---|---|---|---|---|
| Site No. 1 Durand | 44.8 | 0.024 | 3.03E-05 | 1.26E-03 | 2.34E-03 | 2.54E-03 | 2.13E-03 | 4.18E-03 |
| Site No. 2 Jackson | 103 | 0.047 | 7.83E-05 | 3.38E-05 | 5.06E-03 | 6.32E-03 | 5.12E-03 | 1.07E-02 |
| Site No. 3 Cortland | 68.2 | 0.037 | 5.04E-05 | 1.95E-05 | 3.56E-03 | 3.89E-03 | 3.27E-03 | 6.44E-03 |
| Site No. 4 Parnell | 329 | 0.158 | 2.47E-04 | 1.02E-04 | 1.63E-02 | 1.95E-02 | 1.60E-02 | 3.26E-02 |
| Site No. 5 Carroll | 80.3 | 0.038 | 6.02E-05 | 2.49E-05 | 3.98E-03 | 4.77E-03 | 3.90E-03 | 7.98E-03 |
| Site No. 6 Seymour | 54.4 | 0.026 | 4.07E-05 | 1.67E-05 | 2.70E-03 | 3.22E-03 | 2.63E-03 | 5.37E-03 |

***BMP Production Functions***

The relationship between effort and removal procedures, results in a curve called a production function. The figures in Appendix G represent various levels of sweeping operations simulated for the six predominate land use areas found throughout the urban areas in the City of Jackson and Jackson County. In each of the curves, the solids removal increases as the total costs increase. Early on, any given BMP will remove a substantial amount of solids for not much cost. As removals increase beyond this point, costs increase at a greater rate. Further along the curve, the cost increases bring smaller and smaller marginal increases in removal, until the cost becomes prohibitive and no additional removal can occur. Note in all six figures that high-efficiency sweeping is the most effective BMP followed closely by regenerative air sweeping.

***Annual Load Reductions for BMPs***

It is estimated that sweeping every 14 days or 30 days with high-efficiency sweepers and a clean catch basin that the annual washoff of total solids, COD, total phosphorus, cadmium, chromium, lead, copper, and zinc would be reduced by approximately 63 to 87 percent annually, depending on the pollutant and the land use (Appendix H). In comparison, sweeping with regenerative air sweepers and annual catch basin cleaning would reduce washoffs of these pollutants by approximately 49 to 85 percent annually, with a clean catch basin (Appendix H).

The simulations for the six land use areas suggest that existing levels of sweeping reduce pollutant washoffs only 4 to 17 percent, depending on the pollutant and the land use, respectively. No benefit is being projected for catch basin cleaning, which occurs once every three to five years on the average. This is not necessarily true, since some benefits would exist. However, it is impossible to simulate a cleaning frequency of approximately three years in a simulation of only one-year. It is estimated that cleaning the catch basins every three to five years may be providing an additional 2 percent reduction of these pollutants annually.

The BMP production functions are multiplied by the appropriate unit effort costs to create the BMP total cost curves. The figures in Appendix G, represent the BMP total cost curves for four different street sweeping operations without catch basin cleaning.

***BMP Marginal Cost Curves***

As with the total cost curves the marginal cost curves in Appendix I on page I-2, show a point where the cost exceeds the benefit of removal. The figures also show that the high efficiency and regenerative air sweepers remove more total solids than the mechanical or tandem sweeping methods, for a lower cost per pound. Examining both the marginal cost curves and the summary of BMP, it appears that the cost effectiveness of sweeping is reduced when the marginal cost is approximately $5.00. This occurs for both the high efficiency and the regenerative air sweeping methods. For mechanical and tandem sweeping methods it appears that breaking point is approximately $10.00. Table 11 displays the optimal BMP's determine by examining the marginal cost and the total solids removed.

**Table 11 Cost Effectiveness of Various BMPs**

| Site | BMP Description | Optimal Level of Effort | Marginal Costs $/lbs. Removed | Solids Removed (lbs./acre) | Solids Removed Percent Reduction |
|---|---|---|---|---|---|
| Durand Ave. Site 1 | High-efficiency sweeping | Every 30 days (9 times) | 5.10 | 23.6 | 53% |
| | Regenerative air sweeping | Every 30 days (9 times) | 8.69 | 13.7 | 31% |
| | Tandem sweeping | Every 61 days (4 times) | 20.69 | 4.1 | 9% |
| | Mechanical sweeping | Every 61 days (4 times) | 14.63 | 2.9 | 6% |

**Table 11 Cost Effectiveness of Various BMPs - Continued**

| Site | BMP Description | Optimal Level of Effort | Marginal Costs $/lbs. Removed | Solids Removed (lbs./acre) | Solids Removed Percent Reduction |
|---|---|---|---|---|---|
| South Jackson Street (Site 2) | High-efficiency sweeping | Every 30 days (9 times) | 3.96 | 45.9 | 45% |
| | Regenerative air sweeping | Every 14 days (20 times) | 5.08 | 56.4 | 55% |
| | Tandem sweeping | Every 30 days (9 times) | 7.48 | 23.9 | 23% |
| | Mechanical sweeping | Every 14 days (20 times) | 10.11 | 22.3 | 22% |
| Courtland Ave. (Site 3) | High-efficiency sweeping | Every 30 days (9 times) | 4.09 | 29.4 | 43% |
| | Regenerative air sweeping | Every 30 days (9 times) | 6.16 | 19 | 28% |
| | Tandem sweeping | Every 30 days (9 times) | 21.78 | 10.7 | 16 |
| | Mechanical sweeping | Every 30 days (9 times) | 14.52 | 7.7 | 11% |
| Parnell Rd. Site 4 | High-efficiency sweeping | Every 14 days (20 times) | 6.23 | 243.2 | 74% |
| | Regenerative air sweeping | Every 14 days (20 times) | 6.88 | 235 | 71% |
| | Tandem sweeping | Every 14 days (20 times) | 14.81 | 209 | 64% |
| | Mechanical sweeping | Every 14 days (20 times) | 8.30 | 154 | 47% |
| Carroll Rd. (Site 5) | High-efficiency sweeping | Every 14 days (20 times) | 2.80 | 55.1 | 69% |
| | Regenerative air sweeping | Every 14 days (20 times) | 3.69 | 41.9 | 55% |
| | Tandem sweeping | Every 14 days (20 times) | 10.70 | 27 | 34% |
| | Mechanical sweeping | Every 14 days (20 times) | 7.58 | 16.3 | 20% |
| Seymour Ave. (Site 6) | High-efficiency sweeping | Every 30 days (9 times) | 3.68 | 25.2 | 46% |
| | Regenerative air sweeping | Every 30 days (9 times) | 5.09 | 18.4 | 34% |
| | Tandem sweeping | Every 30 days (9 times) | 17.50 | 10.3 | 19% |
| | Mechanical sweeping | Every 30 days (9 times) | 14.11 | 6.2 | 11% |

Table 11 clearly shows that sweeping monthly with a high efficiency sweeper provides optimal total solids removal for the smallest marginal cost. This table also shows that using the regenerative air sweeper is the second best option. The optimal levels for using a regenerative sweeper would require a monthly sweeping frequency for residential areas with paved driveways and well-maintained yards and the central business district. For industrial areas, highways, and residential areas with unpaved driveways and poorly maintained yards, a bi-monthly frequency provides optimal levels for regenerative air sweeper.

## IDENTIFYING RECOMMENDED STREET SWEEPING MAINTENANCE BMPS

Table 12 is a summary of each site of total solids removed and associated cost for all technologies.

## Table 12  Summary of BMP Analysis

| LAND USE AND SWEEPING FREQUENCY | | Total Solids Washoff (lbs/acre/year) | Total Solids Removal (lbs/acre/year) | Solids Removed Percent Reduction | Annual Cost ($/acre/year) | Marginal Cost (d-$/d-Lbs Removal) |
|---|---|---|---|---|---|---|
| **SITE #1 DURAND, JACKSON, MICHIGAN** | | | | | | |
| *High Eff. (EVI) Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 44.8 | | 0 | $ - | $ - |
| 61 | 4 | 31.6 | 13.2 | 29 | $ 42 | $ 3.21 |
| 30 | 9 | 21.2 | 23.6 | 53 | $ 95 | $ 5.10 |
| 14 | 20 | 11.7 | 33.1 | 74 | $ 212 | $ 12.28 |
| 7 | 38 | 8.65 | 36.15 | 80 | $ 403 | $ 62.59 |
| 4 | 67 | 6.6 | 38.2 | 85 | $ 711 | $ 150.04 |
| 2 | 135 | 4.88 | 39.92 | 89 | $ 1,432 | $ 419.31 |
| *Existing (Newer Mech.) Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 44.8 | | 0 | $ - | $ - |
| 61 | 4 | 41.9 | 2.9 | 6 | $ 42 | $ 14.63 |
| 30 | 9 | 39.2 | 5.6 | 13 | $ 95 | $ 19.64 |
| 14 | 20 | 35.6 | 9.2 | 21 | $ 212 | $ 32.41 |
| 7 | 38 | 33.6 | 11.2 | 25 | $ 403 | $ 95.45 |
| 4 | 67 | 32.5 | 12.3 | 27 | $ 711 | $ 279.61 |
| 2 | 135 | 31.6 | 13.2 | 29 | $ 1,432 | $ 801.35 |
| *Regenerative Air Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 44.8 | | | $ - | $ - |
| 61 | 4 | 37.2 | 7.6 | 17 | $ 42 | $ 5.58 |
| 30 | 9 | 31.1 | 13.7 | 31 | $ 95 | $ 8.69 |
| 14 | 20 | 25.6 | 19.2 | 42 | $ 212 | $ 21.21 |
| 7 | 38 | 23.9 | 20.9 | 47 | $ 403 | $ 112.30 |
| 4 | 67 | 23 | 21.8 | 49 | $ 711 | $ 341.75 |
| 2 | 135 | 22.2 | 22.6 | 50 | $ 1,432 | $ 901.52 |
| *Tandem Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 44.8 | | | $ - | $ - |
| 61 | 4 | 40.7 | 4.1 | 9 | $ 85 | $ 20.69 |
| 30 | 9 | 37.4 | 7.4 | 17 | $ 191 | $ 32.14 |
| 14 | 20 | 34.2 | 10.6 | 24 | $ 424 | $ 72.92 |
| 7 | 38 | 33.1 | 11.7 | 26 | $ 806 | $ 347.11 |
| 4 | 67 | 32.6 | 12.2 | 27 | $ 1,421 | $ 1,230.30 |
| 2 | 135 | 32.2 | 12.6 | 28 | $ 2,864 | $ 3,606.06 |

## TABLE 12 SUMMARY OF BMP ANALYSIS-CONTINUED

| LAND USE AND SWEEPING FREQUENCY | | Total Solids Washoff (lbs/acre/year) | Total Solids Removal (lbs/acre/year) | Solids Removed Percent Reduction | Annual Cost ($/acre/year) | Marginal Cost (d-$/d-Lbs Removal) |
|---|---|---|---|---|---|---|
| **SITE #2 JACKSON, JACKSON, MICHIGAN** | | | | | | |
| *High Eff. (EVI) Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 103 | | 0 | $ - | $ 1.61 |
| 61 | 4 | 79.9 | 23.1 | 22 | $ 37 | $ 2.04 |
| 30 | 9 | 57.1 | 45.9 | 45 | $ 84 | $ 3.96 |
| 14 | 20 | 31.3 | 71.7 | 70 | $ 186 | $ 16.06 |
| 7 | 38 | 20.9 | 82.1 | 80 | $ 353 | $ 44.12 |
| 4 | 67 | 14.8 | 88.2 | 86 | $ 622 | $ 115.37 |
| 2 | 135 | 9.33 | 93.67 | 91 | $ 1,253 | $ |
| *Existing (Newer Mech.) Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 103 | | 0 | $ - | $ |
| 61 | 4 | 97.6 | 5.4 | 5 | $ 37 | $ 6.87 |
| 30 | 9 | 90.8 | 12.2 | 12 | $ 84 | $ 6.82 |
| 14 | 20 | 80.7 | 22.3 | 22 | $ 186 | $ 10.11 |
| 7 | 38 | 74.7 | 28.3 | 27 | $ 353 | $ 27.84 |
| 4 | 67 | 71.2 | 31.8 | 31 | $ 622 | $ 76.89 |
| 2 | 135 | 67.6 | 35.4 | 34 | $ 1,253 | $ 175.29 |
| *Regenerative Air Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 103 | | 0 | $ - | $ - |
| 61 | 4 | 84.9 | 18.1 | 18 | $ 37 | $ 2.05 |
| 30 | 9 | 66.7 | 36.3 | 35 | $ 84 | $ 2.55 |
| 14 | 20 | 46.6 | 56.4 | 55 | $ 186 | $ 5.08 |
| 7 | 38 | 38.4 | 64.6 | 63 | $ 353 | $ 20.37 |
| 4 | 67 | 33.9 | 69.1 | 67 | $ 622 | $ 59.81 |
| 2 | 135 | 29.6 | 73.4 | 71 | $ 1,253 | $ 146.76 |
| *Tandem Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 103 | | 0 | $ - | $ - |
| 61 | 4 | 91.5 | 11.5 | 12 | $ 74 | $ 6.46 |
| 30 | 9 | 79.1 | 23.9 | 23 | $ 167 | $ 7.48 |
| 14 | 20 | 64.7 | 38.3 | 38 | $ 371 | $ 14.18 |
| 7 | 38 | 58.6 | 44.4 | 43 | $ 705 | $ 54.77 |
| 4 | 67 | 56 | 47 | 46 | $ 1,244 | $ 207.02 |
| 2 | 135 | 53.4 | 49.6 | 48 | $ 2,506 | $ 485.43 |

**TABLE 12 SUMMARY OF BMP ANALYSIS-CONTINUED**

| LAND USE AND SWEEPING FREQUENCY | | Total Solids Washoff (lbs/acre/year) | Total Solids Removal (lbs/acre/year) | Solids Removed Percent Reduction | Annual Cost ($/acre/year) | Marginal Cost (d-$/d-Lbs Removal) |
|---|---|---|---|---|---|---|
| **SITE #3 CORTLAND, JACKSON, MICHIGAN** | | | | | | |
| *High Eff. (EVI) Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 68.2 | | 0 | $ - | $ - |
| 61 | 4 | 53.7 | 14.5 | 21 | $ 49 | $ 3.36 |
| 30 | 9 | 38.8 | 29.4 | 43 | $ 110 | $ 4.09 |
| 14 | 20 | 23.3 | 44.9 | 66 | $ 244 | $ 8.66 |
| 7 | 38 | 15.9 | 52.3 | | $ 463 | $ 29.67 |
| 4 | 67 | 11.6 | 56.6 | 83 | $ 817 | $ 82.26 |
| 2 | 135 | 7.97 | 60.23 | 88 | $ 1,647 | $ 228.48 |
| *Existing (Newer Mech.) Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 68.2 | | 0 | $ - | $ - |
| 61 | 4 | 64.7 | 3.5 | 5 | $ 49 | $ 13.94 |
| 30 | 9 | 60.5 | 7.7 | 11 | $ 110 | $ 14.52 |
| 14 | 20 | 54.8 | 13.4 | 70 | $ 244 | $ 23.54 |
| 7 | 38 | 50.7 | 17.5 | 26 | $ 463 | $ 53.55 |
| 4 | 67 | 48.4 | 19.8 | 30 | $ 817 | $ 153.79 |
| 2 | 135 | 46.3 | 21.9 | 32 | $ 1,647 | $ 394.95 |
| *Regenerative Air Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 68.2 | | 0 | $ - | $ - |
| 61 | 4 | 59.1 | 9.1 | 13 | $ 49 | $ 5.36 |
| 30 | 9 | 49.2 | 19 | 28 | $ 110 | $ 6.16 |
| 14 | 20 | 39.4 | 28.8 | 42 | $ 244 | $ 13.69 |
| 7 | 38 | 34.8 | 33.4 | 49 | $ 463 | $ 47.73 |
| 4 | 67 | 32.6 | 35.6 | 52 | $ 817 | $ 160.78 |
| 2 | 135 | 30.5 | 37.7 | 55 | $ 1,647 | $ 394.95 |
| *Tandem Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 68.2 | | 0 | $ - | $ - |
| 61 | 4 | 63.1 | 5.1 | 7 | $ 98 | $ 19.13 |
| 30 | 9 | 57.5 | 10.7 | 16 | $ 220 | $ 21.78 |
| 14 | 20 | 51.4 | 16.8 | 25 | $ 488 | $ 43.99 |
| 7 | 38 | 48.4 | 19.8 | 31 | $ 927 | $ 146.36 |
| 4 | 67 | 47.2 | 21 | 33 | $ 1,634 | $ 589.52 |
| 2 | 135 | 46 | 22.2 | | $ 3,293 | $ 1,382.32 |

## TABLE 12 SUMMARY OF BMP ANALYSIS-CONTINUED

| LAND USE AND SWEEPING FREQUENCY | | Total Solids Washoff (lbs/acre/year) | Total Solids Removal (lbs/acre/year) | Solids Removed Percent Reduction | Annual Cost ($/acre/year) | Marginal Cost (d-$/d-Lbs Removal) |
|---|---|---|---|---|---|---|
| **SITE #4 PARNELL, JACKSON, MICHIGAN** | | | | | | |
| *High Eff. (EVI) Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 329 | | 0 | $ - | $ - |
| 61 | 4 | 238 | 91 | 28 | $ 175 | $ 1.92 |
| 30 | 9 | 163 | 166 | 50 | $ 394 | $ 2.92 |
| 14 | 20 | 85.8 | 243.2 | 74 | $ 875 | $ 6.23 |
| 7 | 38 | 56.4 | 272.6 | 83 | $ 1,663 | $ 26.79 |
| 4 | 67 | 39.7 | 289.3 | 88 | $ 2,931 | $ 75.97 |
| 2 | 135 | 25.5 | 303.5 | 92 | $ 5,906 | $ 209.51 |
| *Existing (Newer Mech.) Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 329 | | 0 | $ - | $ - |
| 61 | 4 | 280 | 49 | 15 | $ 175 | $ 3.57 |
| 30 | 9 | 233 | 96 | 29 | $ 394 | $ 4.65 |
| 14 | 20 | 175 | 154 | 47 | $ 875 | $ 8.30 |
| 7 | 38 | 146 | 183 | 56 | $ 1,663 | $ 27.16 |
| 4 | 67 | 129 | 200 | 61 | $ 2,931 | $ 74.63 |
| 2 | 135 | 114 | 215 | 65 | $ 5,906 | $ 198.33 |
| *Regenerative Air Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 329 | | 0 | $ - | $ - |
| 61 | 4 | 237 | 92 | 28 | $ 175 | $ 1.90 |
| 30 | 9 | 164 | 165 | 50 | $ 394 | $ 3.00 |
| 14 | 20 | 94 | 235 | 71 | $ 875 | $ 6.88 |
| 7 | 38 | 68.8 | 260.2 | 79 | $ 1,663 | $ 31.25 |
| 4 | 67 | 54.1 | 274.9 | 84 | $ 2,931 | $ 86.31 |
| 2 | 135 | 41.2 | 287.8 | 87 | $ 5,906 | $ 230.62 |
| *Tandem Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 329 | | 0 | $ - | $ - |
| 61 | 4 | 250 | 79 | 24 | $ 350 | $ 4.43 |
| 30 | 9 | 185 | 144 | 44 | $ 788 | $ 6.73 |
| 14 | 20 | 120 | 209 | 64 | $ 1,750 | $ 14.81 |
| 7 | 38 | 96.3 | 232.7 | 71 | $ 3,325 | $ 66.46 |
| 4 | 67 | 84.1 | 244.9 | 74 | $ 5,863 | $ 207.99 |
| 2 | 135 | 73.2 | 255.8 | 78 | $ 11,813 | $ 545.87 |

## TABLE 12 SUMMARY OF BMP ANALYSIS-CONTINUED

| LAND USE AND SWEEPING FREQUENCY | | Total Solids Washoff (lbs/acre/year) | Total Solids Removal (lbs/acre/year) | Solids Removed Percent Reduction | Annual Cost ($/acre/year) | Marginal Cost (d-$/d-Lbs Removal) |
|---|---|---|---|---|---|---|
| **SITE #5 CARROLL, JACKSON, MICHIGAN** | | | | | | |
| *High Eff. (EVI) Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 80.3 | | 0 | $ - | $ - |
| 61 | 4 | 62.8 | 17.5 | 22 | $ 21 | $ 1.21 |
| 30 | 9 | 46 | 34.3 | 43 | $ 48 | $ 1.58 |
| 14 | 20 | 25.2 | 55.1 | 69 | $ 106 | $ 2.80 |
| 7 | 38 | 16.2 | 64.1 | 80 | $ 202 | $ 10.61 |
| 4 | 67 | 11 | 69.3 | 86 | $ 355 | $ 29.57 |
| 2 | 135 | 6.46 | 73.84 | 92 | $ 716 | $ 79.43 |
| *Existing (Newer Mech.) Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 80.3 | | 0 | $ - | $ - |
| 61 | 4 | 76.2 | 4.1 | 5 | $ 21 | $ 5.17 |
| 30 | 9 | 71.7 | 8.6 | 11 | $ 48 | $ 5.89 |
| 14 | 20 | 64 | 16.3 | 20 | $ 106 | $ 7.58 |
| 7 | 38 | 59.2 | 21.1 | 26 | $ 202 | $ 19.89 |
| 4 | 67 | 56.2 | 24.1 | 30 | $ 355 | $ 51.26 |
| 2 | 135 | 53.4 | 26.9 | 33 | $ 716 | $ 128.79 |
| *Regenerative Air Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 80.3 | | 0 | $ - | $ - |
| 61 | 4 | 67 | 13.3 | 17 | $ 21 | $ 1.59 |
| 30 | 9 | 54.2 | 26.1 | 33 | $ 48 | $ 2.07 |
| 14 | 20 | 38.4 | 41.9 | 55 | $ 106 | $ 3.69 |
| 7 | 38 | 31.7 | 48.6 | 61 | $ 202 | $ 14.25 |
| 4 | 67 | 28.3 | 52 | 65 | $ 355 | $ 45.23 |
| 2 | 135 | 25.1 | 55.2 | 69 | $ 716 | $ 112.69 |
| *Tandem Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 80.3 | | 0 | $ - | $ - |
| 61 | 4 | 72.3 | 8 | 10 | $ 42 | $ 5.30 |
| 30 | 9 | 64.2 | 16.1 | 20 | $ 95 | $ 6.55 |
| 14 | 20 | 53.3 | 27 | 34 | $ 212 | $ 10.70 |
| 7 | 38 | 48.5 | 31.8 | 40 | $ 403 | $ 39.77 |
| 4 | 67 | 46.5 | 33.8 | 42 | $ 711 | $ 153.79 |
| 2 | 135 | 44.4 | 35.9 | 45 | $ 1,432 | $ 343.43 |

## TABLE 12 SUMMARY OF BMP ANALYSIS-CONTINUED

| LAND USE AND SWEEPING FREQUENCY | | Total Solids Washoff (lbs/acre/year) | Total Solids Removal (lbs/acre/year) | Solids Removed Percent Reduction | Annual Cost ($/acre/year) | Marginal Cost (d-$/d-Lbs Removal) |
|---|---|---|---|---|---|---|
| **SITE #6 SEYMOUR, JACKSON, MICHIGAN** | | | | | | |
| *High Eff. (EVI) Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 54.4 | | 0 | $ - | $ - |
| 61 | 4 | 41.1 | 13.3 | 24 | $ 35 | $ 2.63 |
| 30 | 9 | 29.2 | 25.2 | 46 | $ 79 | $ 3.68 |
| 14 | 20 | 16.4 | 38 | 70 | $ 175 | $ 7.52 |
| 7 | 38 | 11.4 | 43 | 79 | $ 333 | $ 31.50 |
| 4 | 67 | 8.26 | 46.14 | 85 | $ 586 | $ 80.81 |
| 2 | 135 | 5.54 | 48.86 | 90 | $ 1,181 | $ 218.75 |
| *Existing (Newer Mech.) Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 54.4 | | 0 | $ - | $ - |
| 61 | 4 | 51.3 | 3.1 | 6 | $ 35 | $ 11.29 |
| 30 | 9 | 48.2 | 6.2 | 11 | $ 79 | $ 14.11 |
| 14 | 20 | 43.5 | 10.9 | 20 | $ 175 | $ 20.48 |
| 7 | 38 | 40.9 | 13.5 | 25 | $ 333 | $ 60.58 |
| 4 | 67 | 39.3 | 15.1 | 28 | $ 586 | $ 158.59 |
| 2 | 135 | 37.8 | 16.6 | 31 | $ 1,181 | $ 396.67 |
| *Regenerative Air Sweeping* | | | | | | |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 54.4 | | 0 | $ - | $ - |
| 61 | 4 | 44.6 | 9.8 | 18 | $ 35 | $ 3.57 |
| 30 | 9 | 36 | 18.4 | 34 | $ 79 | $ 5.09 |
| 14 | 20 | 26.9 | 27.5 | 51 | $ 175 | $ 10.58 |
| 7 | 38 | 23.4 | 31 | 57 | $ 333 | $ 45.00 |
| 4 | 67 | 21.4 | 33 | 61 | $ 586 | $ 126.88 |
| 2 | 135 | 19.6 | 34.8 | 64 | $ 1,181 | $ 330.56 |
| *Tandem Sweeping* | | | | | $ | $ |
| Days/Swept | Sweeps/Yr | Inlets Uncleaned | Inlets Uncleaned | | Inlets Uncleaned | Inlets Uncleaned |
| None | 0 | 54.4 | | 0 | $ - | $ - |
| 61 | 4 | 49.1 | 5.3 | 10 | $ 70 | $ 13.21 |
| 30 | 9 | 44.1 | 10.3 | 19 | $ 158 | $ 17.50 |
| 14 | 20 | 38.6 | 15.8 | 29 | $ 350 | $ 35.00 |
| 7 | 38 | 36.3 | 18.1 | 33 | $ 665 | $ 136.96 |
| 4 | 67 | 35.3 | 19.1 | 35 | $ 1,173 | $ 507.50 |
| 2 | 135 | 34.3 | 20.1 | 37 | $ 2,363 | $ 1,190.00 |

To provide additional guidance for the selection of technologies when developing a Storm Water Pollution Prevention Initiative, three sediment removal rates, 75%, 50%, 25% were identified. Utilizing the production functions and cost curves, the frequency, total costs, and marginal costs were identified for each of the target removal rates. The results are shown in Table 12 .

In Table 12 , N/A was entered in place of data that was not represented on the production functions and cost curves. As a result the N/A placeholder represents that BMPs inability to reach the target removal rates or an extremely cost ineffective method. The data presented in Table 12 shows that using a high-efficiency sweeper approximately every two weeks is the only BMP that will remove approximately 75% of the total solids. The combined marginal cost for removing 75% of the total solids is approximately $92.30 per pound removed.

The high efficiency sweepers are capable of removing 50% of the total solids on every site if the streets are swept approximately monthly. The marginal cost would be approximately $23.00. The regenerative air sweeper is also capable of removing 50% of the total solids from every site except Site 1. To achieve 50% removal at Site 1, the streets would have to be swept bimonthly. The data from the central business district for this BMP appears to be an anomaly and was excluded from this analysis. Disregarding Site 1 and Site 3 the marginal cost is approximately $52.00.

Finally, Table 12 suggests that all of the BMPs are capable of removing at least 25% of the total solids, but that only the high-efficiency and regenerative air sweepers are cost effective. The high-efficiency sweeper used at a frequency of 6 sweeps per year will have a marginal cost of $13.00 per pound removed from the entire site. Sweeping approximately 9 times per year, the regenerative air sweeper will have a marginal cost of approximately $23.00 per pound of sediment removed.

**Table 13 Results of Target Removal Rates**

| Site | BMP | Percent Removal of Total Solids | Total Solids Removed (lbs./acre/year) | Number of Sweeps per Year | Approximate Total Cost ($) | Approximate Marginal Cost ($) |
|---|---|---|---|---|---|---|
| Site 1 | High Efficiency | 75 | 33.6 | 20 | 210 | 21 |
| | | 50 | 22.4 | 9 | 180 | 5 |
| | | 25 | 11.2 | 3 | 60 | 3 |
| | Regenerative Air | 75 | 33.6 | N/A | N/A | N/A |
| | | 50 | 22.4 | N/A | 1440 | N/A |
| | | 25 | 11.2 | 7 | 230 | 7.00 |
| | Mechanical Sweeping | 75 | 33.6 | N/A | N/A | N/A |
| | | 50 | 22.4 | N/A | N/A | N/A |
| | | 25 | 11.2 | 41 | 375 | 100 |
| | Tandem Sweeping | 75 | 33.6 | N/A | N/A | N/A |
| | | 50 | 22.4 | N/A | N/A | N/A |
| | | 25 | 11.2 | 30 | 600 | 70 |
| Site 2 | High Efficiency | 75 | 77.3 | 30 | 250 | 10 |
| | | 50 | 51.5 | 11 | 80 | 4 |
| | | 25 | 25.8 | 5 | 30 | 3 |
| | Regenerative Air | 75 | 77.3 | N/A | N/A | N/A |
| | | 50 | 51.5 | 17 | 130 | 5 |
| | | 25 | 25.8 | 6 | 40 | 3.50 |
| | Mechanical Sweeping | 75 | 77.3 | N/A | N/A | N/A |
| | | 50 | 51.5 | N/A | N/A | N/A |
| | | 25 | 25.8 | 23 | 250 | 17.00 |
| | Tandem Sweeping | 75 | 77.3 | N/A | N/A | N/A |
| | | 50 | 51.5 | N/A | N/A | N/A |
| | | 25 | 25.8 | 10 | 135 | 8.00 |
| Site 3 | High Efficiency | 75 | 51.2 | 35 | 450 | 128.00 |
| | | 50 | 34.1 | 10 | 180 | 5.00 |
| | | 25 | 17.1 | 5 | 80 | 3.50 |
| | Regenerative Air | 75 | 51.2 | N/A | N/A | N/A |
| | | 50 | 34.1 | 40 | 450 | 25.00 |
| | | 25 | 17.1 | 8 | 110 | 6.50 |
| | Mechanical Sweeping | 75 | 51.2 | N/A | N/A | N/A |
| | | 50 | 34.1 | N/A | N/A | N/A |
| | | 25 | 17.1 | 33 | 450 | 50.00 |
| | Tandem Sweeping | 75 | 51.2 | N/A | N/A | N/A |
| | | 50 | 34.1 | N/A | N/A | N/A |
| | | 25 | 17.1 | 21 | 520 | 45.00 |
| Site 4 | High Efficiency | 75 | 246.8 | 20 | 1000 | 6.30 |
| | | 50 | 164.5 | 9 | 400 | 3.00 |
| | | 25 | 20.1 | N/A | N/A | N/A |
| | Regenerative Air | 75 | 246.8 | 26 | 1100 | 17.00 |
| | | 50 | 164.5 | 9 | 400 | 3.00 |
| | | 25 | 20.1 | N/A | N/A | N/A |
| | Mechanical Sweeping | 75 | 246.8 | N/A | N/A | N/A |
| | | 50 | 164.5 | 27 | 1000 | 18.00 |
| | | 25 | 20.1 | N/A | N/A | N/A |
| | Tandem Sweeping | 75 | 246.8 | 68 | N/A | 200.00 |
| | | 50 | 164.5 | 12 | 1000 | 10.00 |
| | | 25 | 20.1 | N/A | N/A | N/A |

| Table 13 Results of Target Removal Rates – Continued | | | | | | |
|---|---|---|---|---|---|---|
| Site | BMP | Percent Removal of Total Solids | Total Solids Removed (lbs./acre/year) | Number of Sweeps per Year | Approximate Total Cost ($) | Approximate Marginal Cost ($) |
| Site 5 | High Efficiency | 75 | 60.2 | 32 | 160 | 7.00 |
| | | 50 | 40.2 | 12 | 70 | 2.00 |
| | | 25 | 20.1 | 12 | 25 | 1.00 |
| | Regenerative Air | 75 | 60.2 | N/A | N/A | N/A |
| | | 50 | 40.2 | 17 | 95 | 3.00 |
| | | 25 | 20.1 | 17 | 35 | 2.00 |
| | Mechanical Sweeping | 75 | 60.2 | N/A | N/A | N/A |
| | | 50 | 40.2 | N/A | N/A | N/A |
| | | 25 | 20.1 | 33 | 180 | 17.00 |
| | Tandem Sweeping | 75 | 60.2 | N/A | N/A | N/A |
| | | 50 | 40.2 | N/A | N/A | N/A |
| | | 25 | 20.1 | 31 | 135 | 8.00 |
| Site 6 | High Efficiency | 75 | 40.8 | 30 | 255 | 20.00 |
| | | 50 | 27.2 | 10 | 100 | 4.00 |
| | | 25 | 13.6 | 3 | 50 | 2.00 |
| | Regenerative Air | 75 | 40.8 | N/A | N/A | N/A |
| | | 50 | 27.2 | 20 | 200 | 10.50 |
| | | 25 | 13.6 | 5 | 60 | 4.00 |
| | Mechanical Sweeping | 75 | 40.8 | N/A | N/A | N/A |
| | | 50 | 27.2 | N/A | N/A | N/A |
| | | 25 | 13.6 | 30 | 350 | 55.00 |
| | Tandem Sweeping | 75 | 40.8 | N/A | N/A | N/A |
| | | 50 | 27.2 | N/A | N/A | N/A |
| | | 25 | 13.6 | 10 | 275 | 27.00 |

Table 14 provides out information and costs for various sweepers including a mechanical sweeper, several models of regenerative air, and two models of high efficiency sweeper.

**Table 14 Sweeper Information**

| Make | Model | Type of Sweeper | Cost | Life Span | Sweeping Speed (MPH) | Travel Speed (MPH) | Capacity(cu yds) | Days to Delivery |
|---|---|---|---|---|---|---|---|---|
| Elgin | Pelican | Mechanical | $110,000 | 8-10 | 5-7 | 20 | 3 | 56-70 |
| Elgin | Crosswind | Regenerative Air | $140,000 | 8-10 | 5-7 | 55-60 | 8 | 70-84 |
| Tymco | 210 | Regenerative Air | $59,000 | unavailable | unavailable | unavailable | 2.4 | 30-90 |
| Tymco | 435 | Regenerative Air | $84,388 | unavailable | unavailable | unavailable | 4 | unavailable |
| Tymco | 600 | Regenerative Air | $125,000 | unavailable | unavailable | unavailable | 6 | unavailable |
| Tymco | FHD | Regenerative Air | $128,000 | unavailable | unavailable | unavailable | 4.5 | unavailable |
| Schwarze | EV1 | High Efficiency | $257,500 | 4000-7000 hours | 3 | 25 | 7 | 120 |
| Schwarze | EV2 | High Efficiency | $216,000 | 4000-7000 hours | 3 | 25 | 4.5 | 120 |

***75 Percent Removal Target***

The high efficiency sweeper option is the only BMP that is capable of attaining 75 percent removal of total solids. To attain 75 percent removal, the highways and residential areas in the upper income bracket with paved driveways and well-maintained yards should be swept every two weeks. The remainder of the residential areas, the central business district and the industrial areas could be swept on a week to week, or one and one-half week intervals. The total cost of removal is $2325 per acre/per year.

***50 Percent Removal Target***

There are two sweeper options that are capable of attaining 50 percent removal of total solids. The high efficiency sweeper would require sweeping to occur on a monthly basis, where utilizing a regenerative air sweeper would require almost a two-week frequency of sweeping. The total cost per year of removing 50 percent of the sediments using a high efficiency sweeper is approximately $940 per acre per year. In the same situation, the regenerative air sweeper removes 50 percent of the total solids at a cost of $1,275 per acre per year.

***25 Percent Removal Target***

All of the street sweeping BMPs were able to remove 25 percent of the total solids from the street. The mechanical sweeper, sweeping weekly, has a total cost of $1,605 per acre per year of sediment removal. Tandem sweeping would require sweeping every two weeks at a total cost of $1,665 per acre, per year of sediment removal. The high efficiency sweeper requires sweeping to occur every 61 days with a total cost of $245 dollars per acre/per year. The regenerative air sweeper would need to be used at a frequency of once-per-month to obtain the 25 percent removal. The total cost would be $475 per acre per year.

# CONCLUSIONS AND RECOMMENDATIONS

Under the Michigan Voluntary Storm Water Permit a Watershed Management Plan is required. One of the implementation documents developed out of the planning process is a Storm Water Pollution Prevention Initiative (SWPPI). This SWPPI details the actions that each permitted community will undertake in a fixed timeframe in an effort to meet the goals of the Watershed Management Plan.

If the traditional permitting approach is undertaken in lieu of the Voluntary Permit, the following six minimum measures are required:

1. Public Education and Outreach on Storm Water Impacts
2. Public Involvement/Participation
3. Illicit Discharge Detection and Elimination
4. Construction Site Storm Water Runoff Control
5. Post-Construction Storm Water Management in New Development and Redevelopment
6. Pollution Prevention/Good Housekeeping for Municipal Operations.

Minimum measure number 6 shares the same elements of the SWPPI. Whether the Voluntary Permit or the traditional permit is applied for, the same elements will need to be addressed.

MDEQ has identified the following components of the SWPPI (MDEQ, 2001):

- Actions proposed in the Watershed Management Plan
- Implementation timeline for proposed actions.
- Evaluation of pollution prevention and good housekeeping activities including:
    - Maintenance activities, schedules, and inspection procedures for storm water structural controls
    - Control of street, road, highway and parking lot pollutant discharges
    - Procedure for the disposal of maintenance waste (dredgings, sediments, etc.)
    - Procedure to ensure that new flood control projects assess impacts on water quality

  - Implement controls to reduce discharge of pesticides, herbicides, and fertilizers
- The actions proposed by each community should be as specific as possible and should include:
  - The Advisory Groups goals addressed by each action
  - A method for implementation
  - Short-term and long-term actions, as appropriate
  - A timetable or schedule
  - Responsible parties for evaluating progress
  - A method for measuring progress (simple reporting, instream monitoring, sediment removed, etc.)

This study looked specifically at one component of a potential SWPPI or Pollution Prevention minimum measure – street dirt removal. A critical component of street dirt management is prevention. A review of county and local soil erosion and sedimentation control practices was outside the scope of this study. However, in developing a Watershed Management Plan and SWPPI, such a review is critical. The cost of preventing street dirt is less than removing from the street or catch basin, and many times less than removing it from the stream.

We conclude from this study that current street sweeping practices are achieving less than 18 percent reduction of the total solids. This study provides guidance to achieve the removal from local streets of total solids of 75 percent, 50 percent, and 25 percent. Once additional loadings of solids are identified and strategies of prevention are been evaluated, appropriate street sweeping and catch basin technologies can be selected. In this light, the following recommendations are made:

- If high-efficiency sweeping is pursued, it is recommended that a disposal plan be developed to allow a full sweeper to offload its hopper in strategic areas onto a roll-off dumpster or dump truck, instead of traveling to a disposal yard. This will reduce the down time the sweeper experience traveling to a central disposal yard.

- Although catch basin cleaning was removed from this study, it is still important to maintain catch basins. TTMPS (2000) concluded that catch basin cleaning might decrease the effectiveness of catch basins for up to six months. After this period, the performance of cleaned catch basins appeared to improve. Catch basins should be cleaned when they reach 60 percent capacity. A regular program of catch basin inspection and cleaning should be developed as part of developing a SWPPI.

- All local and county soil erosion and sedimentation control programs should be evaluated concerning their effectiveness. This too should be undertaken as part of the Watershed Management Plan and SWPPI processes.

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**APPENDIX A**

**Existing Cleaning Practices**

| Street Sweeping Equipment | City of Jackson | | | Jackson County Road Commission |
|---|---|---|---|---|
| A. Type | Elgin #410 | Elgin #292 | | Vacume |
| B. Model | Pelican | Whirlwind LE | | Vac A11 E5-16BD |
| C. Age | 1998 | 1993 | | 1990 |
| D. Down Time | This equipment runs full time from April 1 to November 1, provided there is not heavy rain. Maintenance is minimal (change brushes and service). #410 was down for service 11.2 hours, 57 days total down time<br># 292 was down for service 82.6 hours, 57 days total down time. | | | 75 hours |
| E. Equipment Life | 10 years each | | | 10-15 years |
| F. Frequency and Routes | 4-5 rounds per year covering all city streets | | | Sweeping begins in April (weather permitting) and ends in December (weather permitting). Primary roads are swept first followed by secondary roads. |

| Catchbasin Cleaning Equipment | | | | |
|---|---|---|---|---|
| A. Type | Vactor #290 | #291 | #281 | Vacuum |
| B. Model | Vactor 2100 | Vactor | International, CB claw and hoist rig | Vac A11 E5-16SPFB |
| C. Age | 1999 | 1992 | 1982 | 1985 |
| D. Down Time | # 290 was down between 01-01-99 to 01-01-00, 10 hours for service # 291 was down between 01-01-99 to 01-01-00, 31 hours for service. Does not clean CB's full time.<br># 281 no longer used. Sold June 1999. | | | 75 hours |
| E. Equipment Life | 10 years each | | | 10-15 years |
| F. Frequency and Routes | None. Only as required to eliminate flooding calls. | | | Catchbasin Cleaning begins in April and ends in December (weather permitting). Primary roads are swept first followed by secondary roads. |

| Cost of Cleaning | See Attached | |
|---|---|---|
| A. Labor Costs | $70,897.82 | $21.970 (including fringe rates) |
| B. Equipment Costs | $114,355.61 | $34.00 per hour |
| C. Capital Costs | | $139,940.00--street sweeper/ $100,016.00--catch basin cleaner |
| D. Equipment Maintenance Costs | Included in item B | $ 37,000.00 average cost per year |
| E. Appropriate Overhead Costs | Overhead $37,135.99<br>Fringes $27,891.32 | 8.50% |
| F. Contracted Costs | | **County** $200.00 per mi-pri<br>$170.00 per mi--loc<br>**State Trunkline** $368.00 per curb mi.<br>$95.00 per bridge deck $368.00--wall<br>per mile |

| Cleaning Policies | | |
|---|---|---|
| A. Policies for Cleaning During Wet and Inclement Weather | March-April--Spring cleaning<br>April-November--Routine sweeping November--<br>December--Fall cleanup | There are not any policies in place as inclement weather does not stop operations. |
| B. Policies/Methods for Cleaning Public Streets | Temperatures must be above 40 degrees Fahrenheit. Cleaning is also dependent on the weather. The Vactor truck is used after heavy rains to clean some catch basins. | |
| C Policies for Cleaning Private Streets, Parking Lots, and Uncurbed Public Streets and Parking Lots. | Parking lots are swept as needed. The downtonw section is swept monthly or as neeeded for special events. | Generally services are not contracted out. |

| General | | |
|---|---|---|
| A. Typical Characteristics of Street Cleaning Operation such as Forward Speed and Parked Car Interference. | Forward Speed is 4-5 mph while sweeping. Sweeping is done as close to the curb and parked cars as possible. The sweeper goes around parked cars and proceeds with each section. | Characteristics of the job are nomally up to the discretion of the operator |
| B. Disposal of Collected Materials Including Incurred Costs. | Once per year materials collected through sweeping are tested by Hugo Environmental and hauled to a Class III dump facility for disposal. Cost for hauling sweepings: $62,710.43 | The solid waste generated shall be disposed of at a Type II landfill. Solid is defined as having no releasable liquids. The landfill may require testing before accepting the waste. Costs are based on a per ton cost. Lab costs are based on material being tested. |
| C. Special Issues Such as Safety, Operator Training and Street Parking Controls. | Seminars are availiable annually for sweeper operation and Vactor operation. | Operators are trained in house regarding saftey and operation. |
| D. Leaf Collection and Disposal Programs. | November 1 starts the leaf program. A rotation is done through pre-established sections where leaves are pused into a pile with a tractor and a 1-ton truck with a plow. Two loaders with claw buckets are used to load 8+ trucks wich haul the leaved to a recovery location. A temporary site was established to reduce the bulk which in turn reduces haul times. Two complete rounds are done, weather permitting. | |
| E. Snow and Ice Control | Snow and ice control is dictated by the weather, with a priority on trunklines and emergency snow routes. Second priority is major streets and local hills. Third priority is normal local streets. Priorities 1 and 2 are completed as needed and priority 3 is done on straight time during the normal work week. Parking lots are done with two 1-ton trucks and a loader, if needed. Priority is #3 for budget reasons (straight time wages). | **County Roads**<br>4-land roadways Cost $327.00/lane mile including truck, labor, material, overhead, maintenance.<br>**State Trunkline**<br>24 hours on call when slippery conditions warrent approximately 500# /lane mile |
| F. Spring Cleanup Following Snow Melt. | Consists mainly of sweeping and picking up yard junk and debris. | No special cleaning, just routine operations. |

# APPENDIX B

## Forms

**SAMPLE SITE FORM**
*"GRAND RIVER STUDY"*

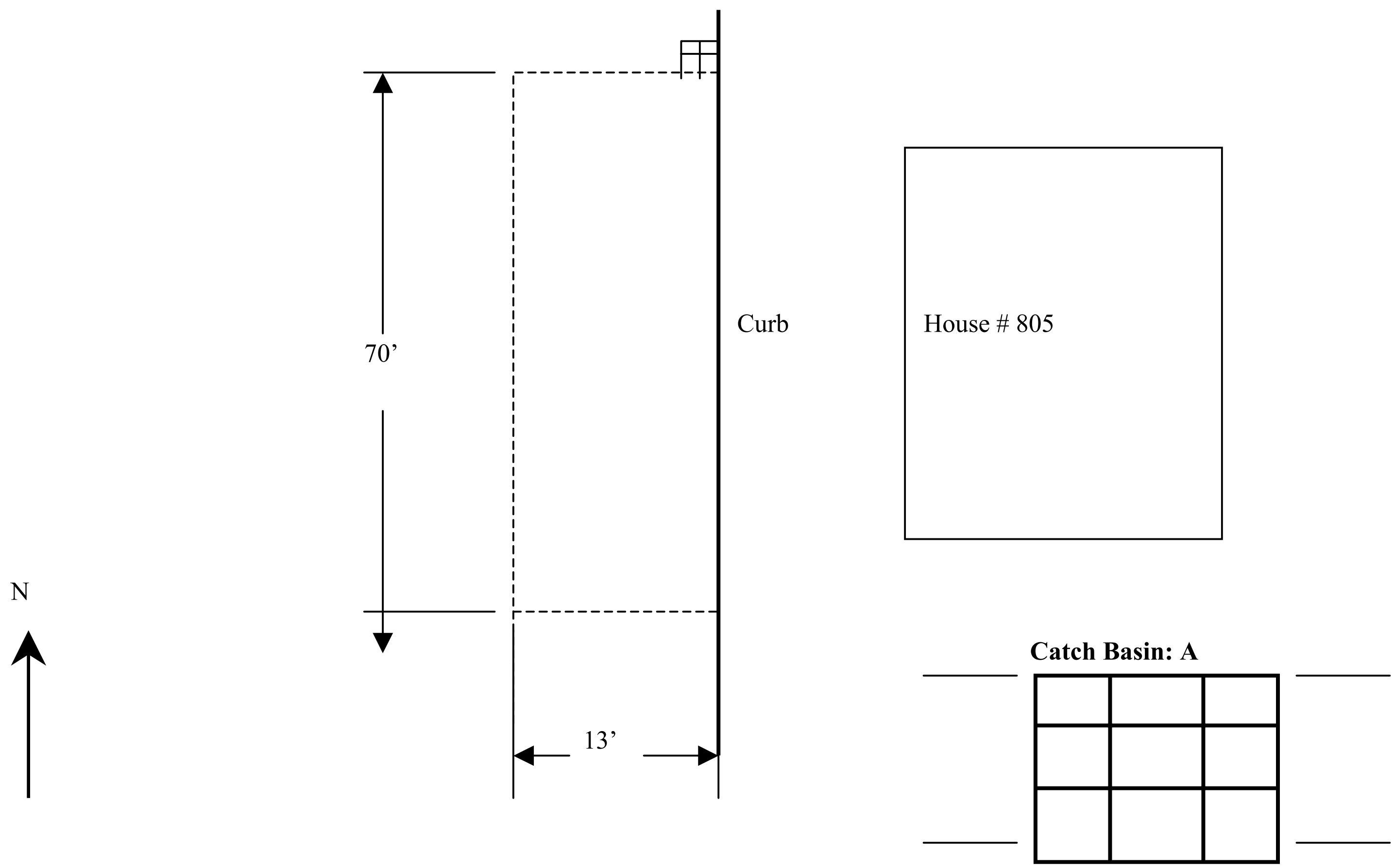
| **Sampling Site:** 1<br><br>Location: Durand Street, North of Morrell | **Sampling Team:** | **Date:**<br><br>**Weather:** |
|---|---|---|

Condition of Road:

Potential Sources of Sediment (ex: nearby construction site):

Sketch

Make any notes about the study site on this form. Also, label elevations of sediment in catch basin.



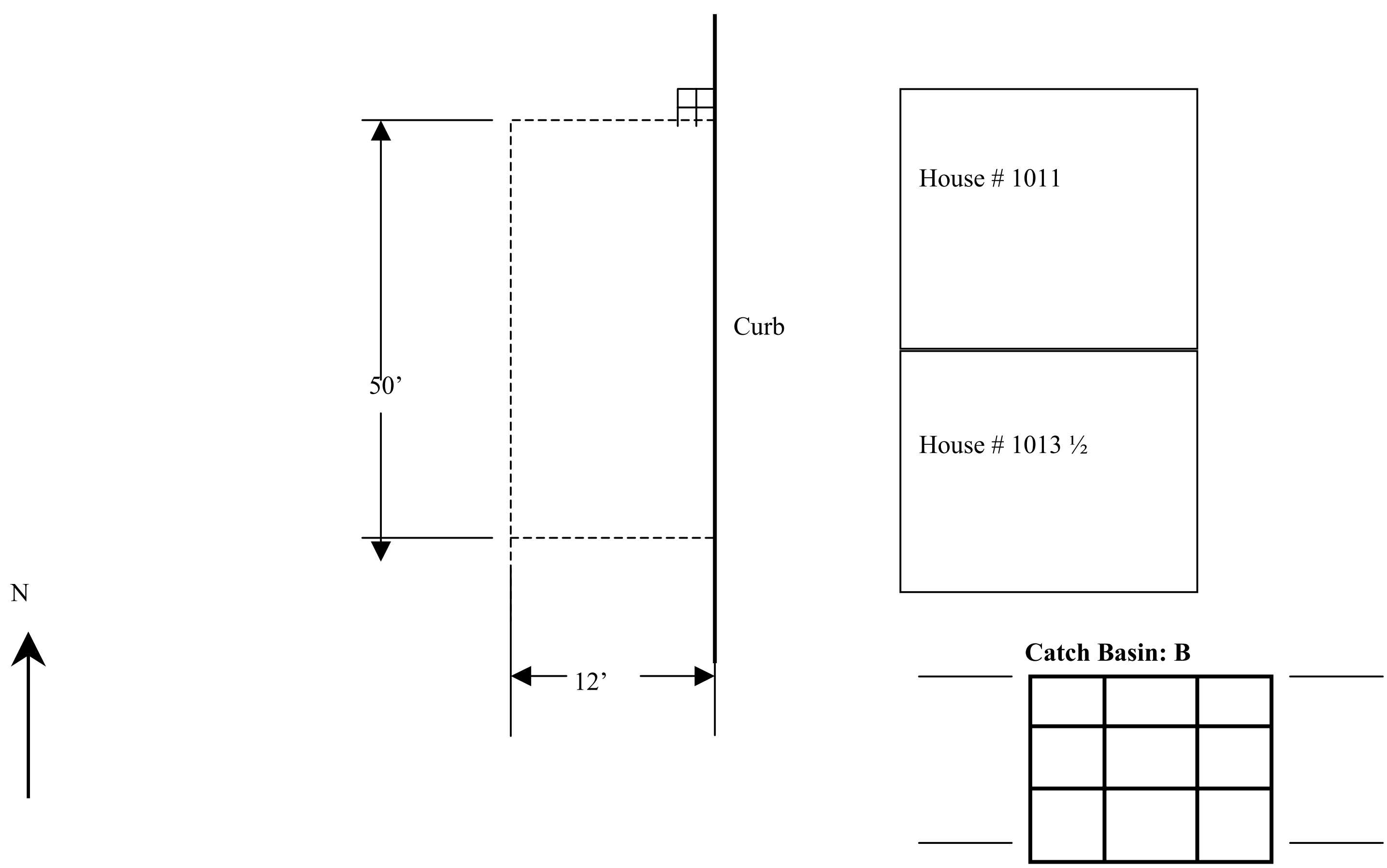
**SAMPLE SITE FORM**
*"GRAND RIVER STUDY"*

| | | |
|---|---|---|
| **Sampling Site:** 2<br><br>Location: South Jackson Street | **Sampling Team:** | **Date:**<br><br>**Weather:** |

Condition of Road:

Potential Sources of Sediment (ex: nearby construction site):

Sketch
Make any notes about the study site on this form. Also, label elevations of sediment in catch basin.



**SAMPLE SITE FORM**
*"GRAND RIVER STUDY"*

| **Sampling Site:** 3<br><br>Location: Cortland Street At intersection with Francis Street | **Sampling Team:** | **Date:**<br><br>**Weather:** |
|---|---|---|

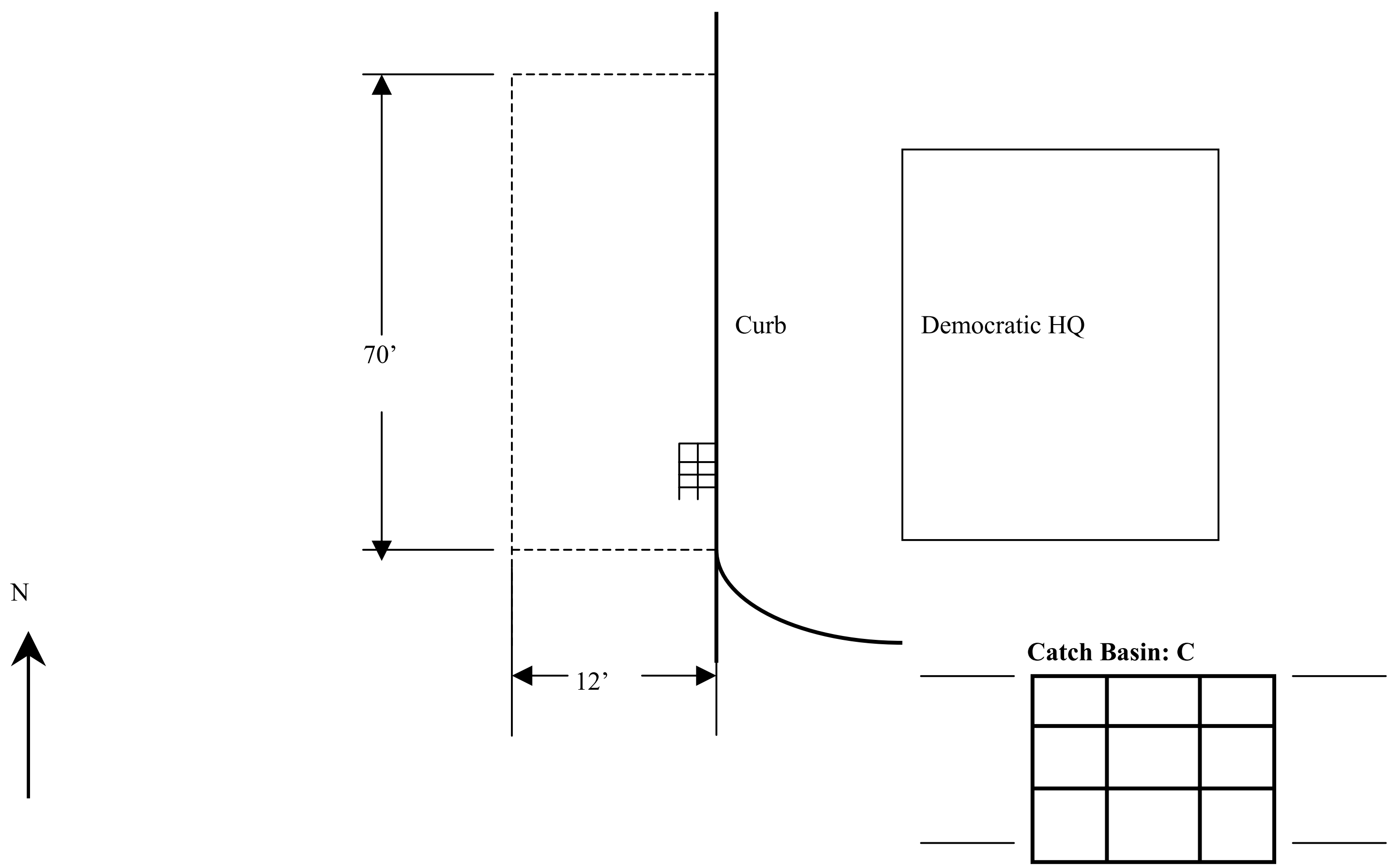
Condition of Road:

______________________________________________

Potential Sources of Sediment (ex: nearby construction site):

______________________________________________

Sketch
Make any notes about the study site on this form. Also, label elevations of sediment in catch basin.



**SAMPLE SITE FORM**
*"GRAND RIVER STUDY"*

| **Sampling Site:** 4<br><br>Location: Parnell Road Sample site just west of the Grand River. | **Sampling Team:** | **Date:**<br><br>**Weather:** |
|---|---|---|

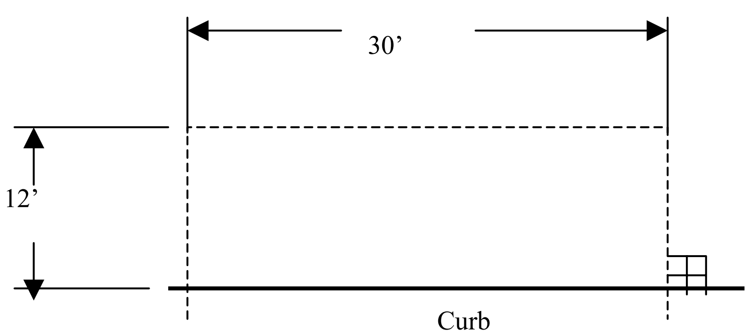
Condition of Road:

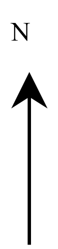
___

Potential Sources of Sediment (ex: nearby construction site):

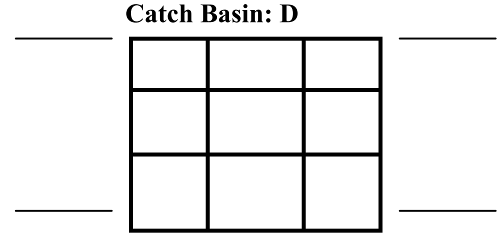
___

Sketch
Make any notes about the study site on this form. Also, label elevations of sediment in catch basin.




**Catch Basin: D**



**SAMPLE SITE FORM**
*"GRAND RIVER STUDY"*

| | | |
|---|---|---|
| **Sampling Site:** 5<br><br>Location: Carroll Street at the intersection of Carroll and Ganson Streets. | **Sampling Team:** | **Date:**<br><br>**Weather:** |

Condition of Road:

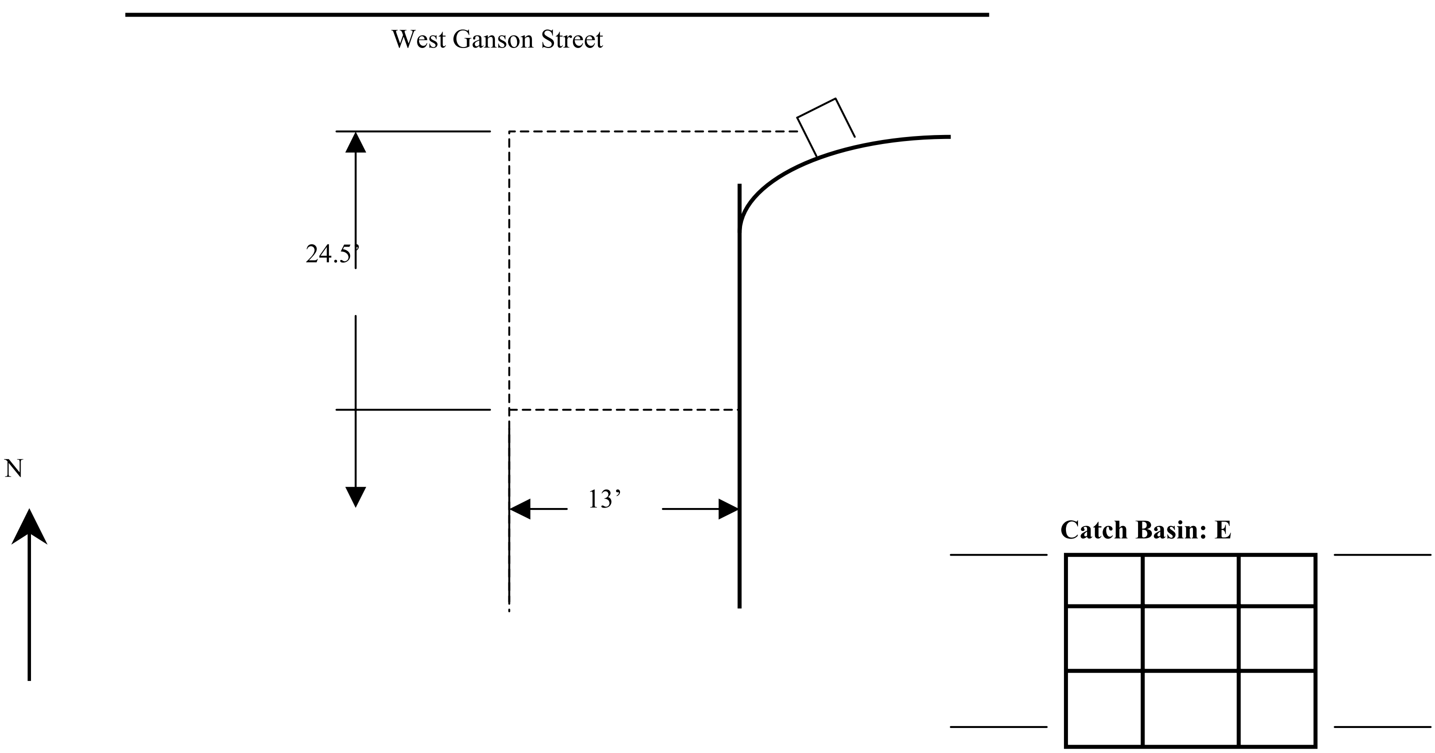
_______________________________________________

Potential Sources of Sediment (ex: nearby construction site):

_______________________________________________

Sketch

Make any notes about the study site on this form. Also, label elevations of sediment in catch basin.



**SAMPLE SITE FORM**
*"GRAND RIVER STUDY"*

| **Sampling Site:** 6<br><br>Location: Seymour Street Half way between Leroy and North Streets. | **Sampling Team:** | **Date:**<br><br>**Weather:** |
|---|---|---|

Condition of Road:

______________________________________________________________________

______________________________________________________________________

__________________________________

Potential Sources of Sediment (ex: nearby construction site):

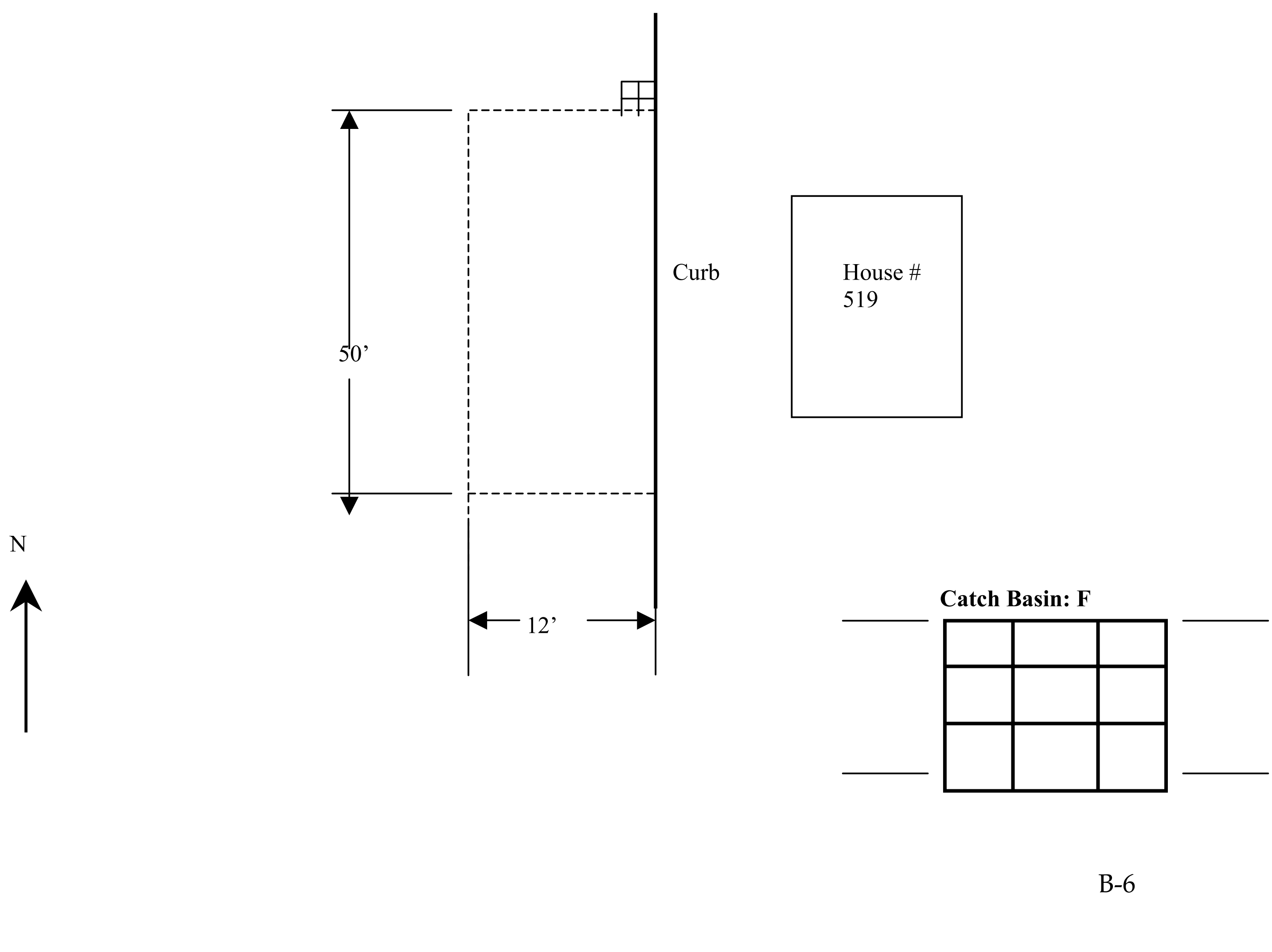
______________________________________________________________________

______________________________________________________________________

__________________________________

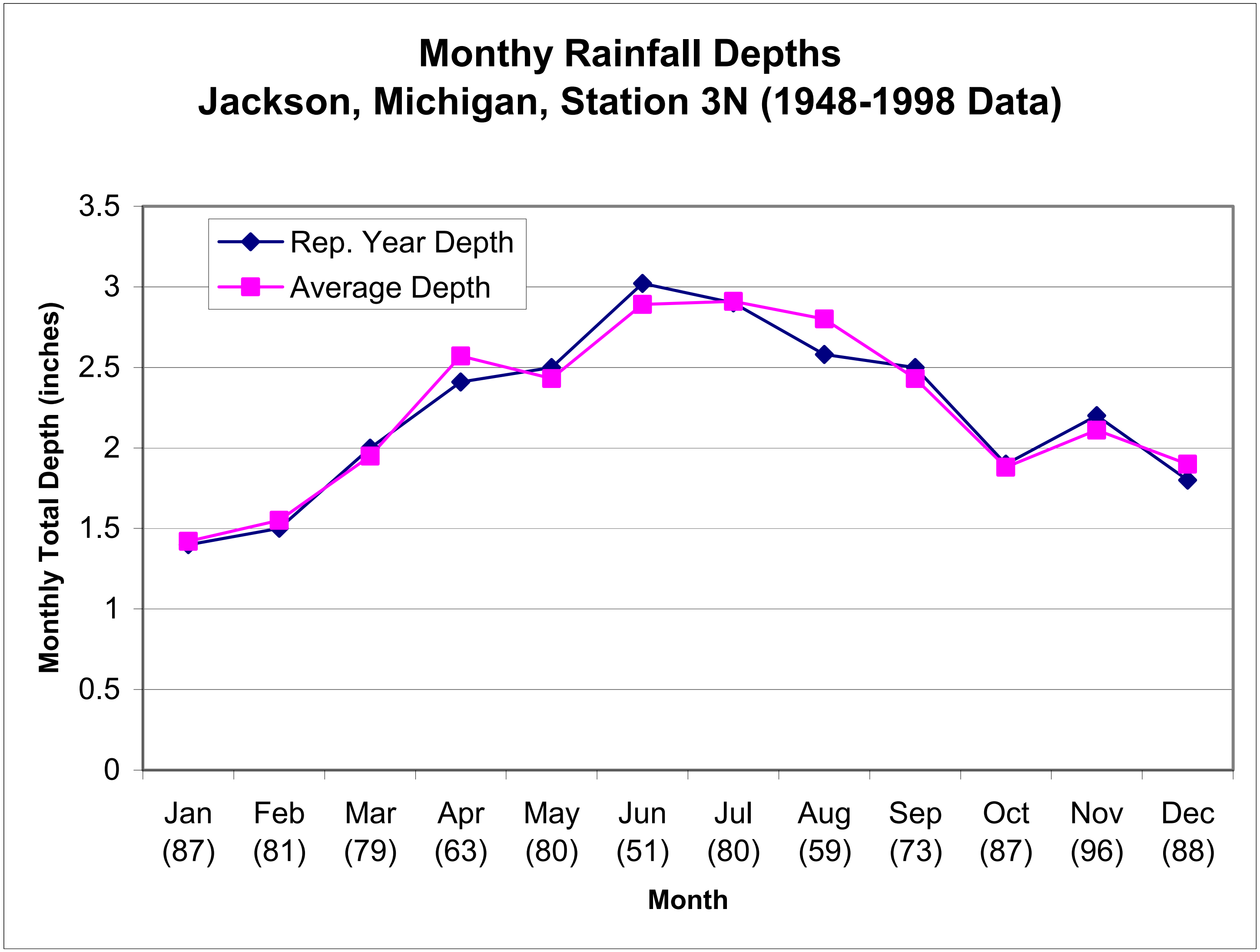
Sketch

Make any notes about the study site on this form. Also, label elevations of sediment in catch basin.

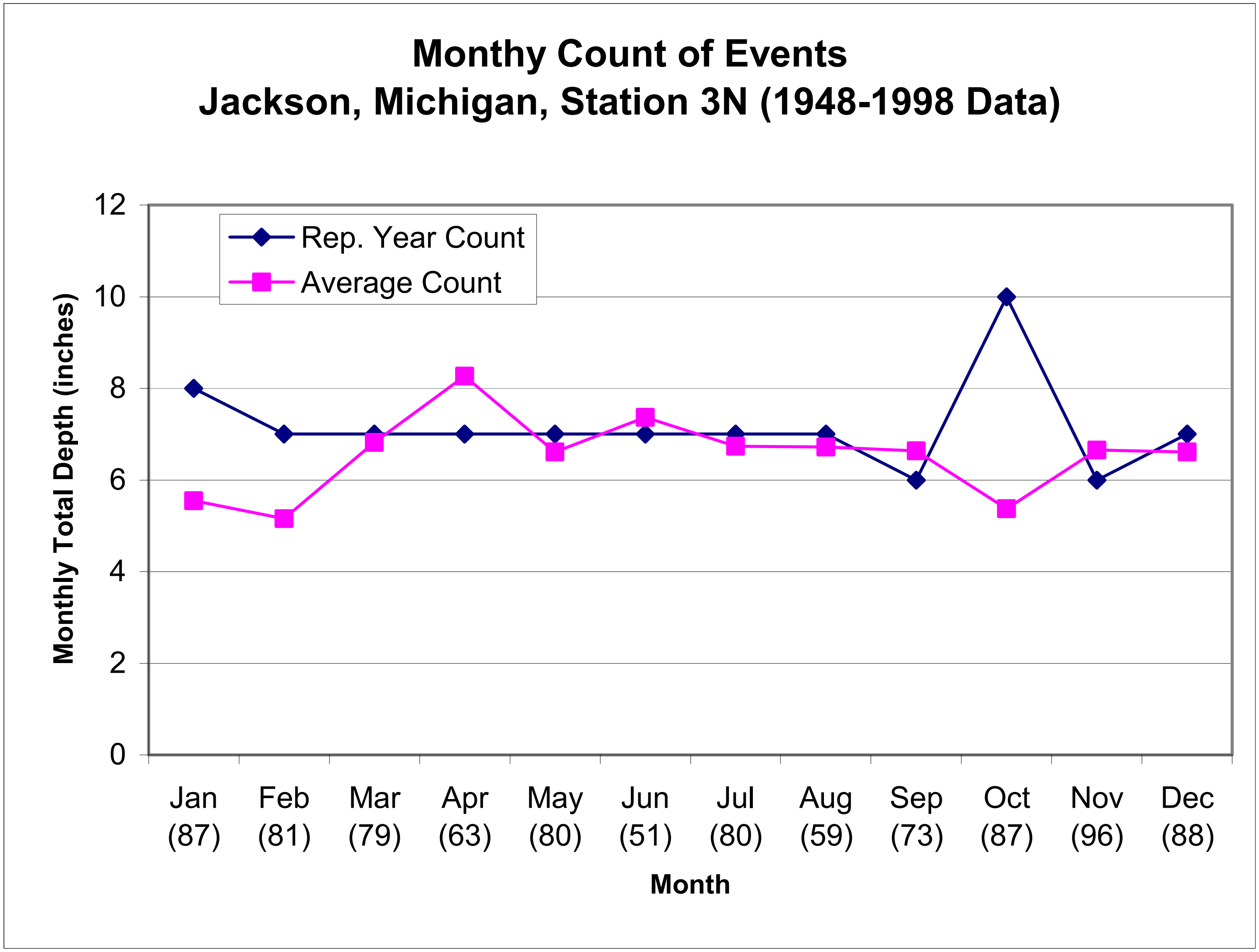


# APPENDIX C

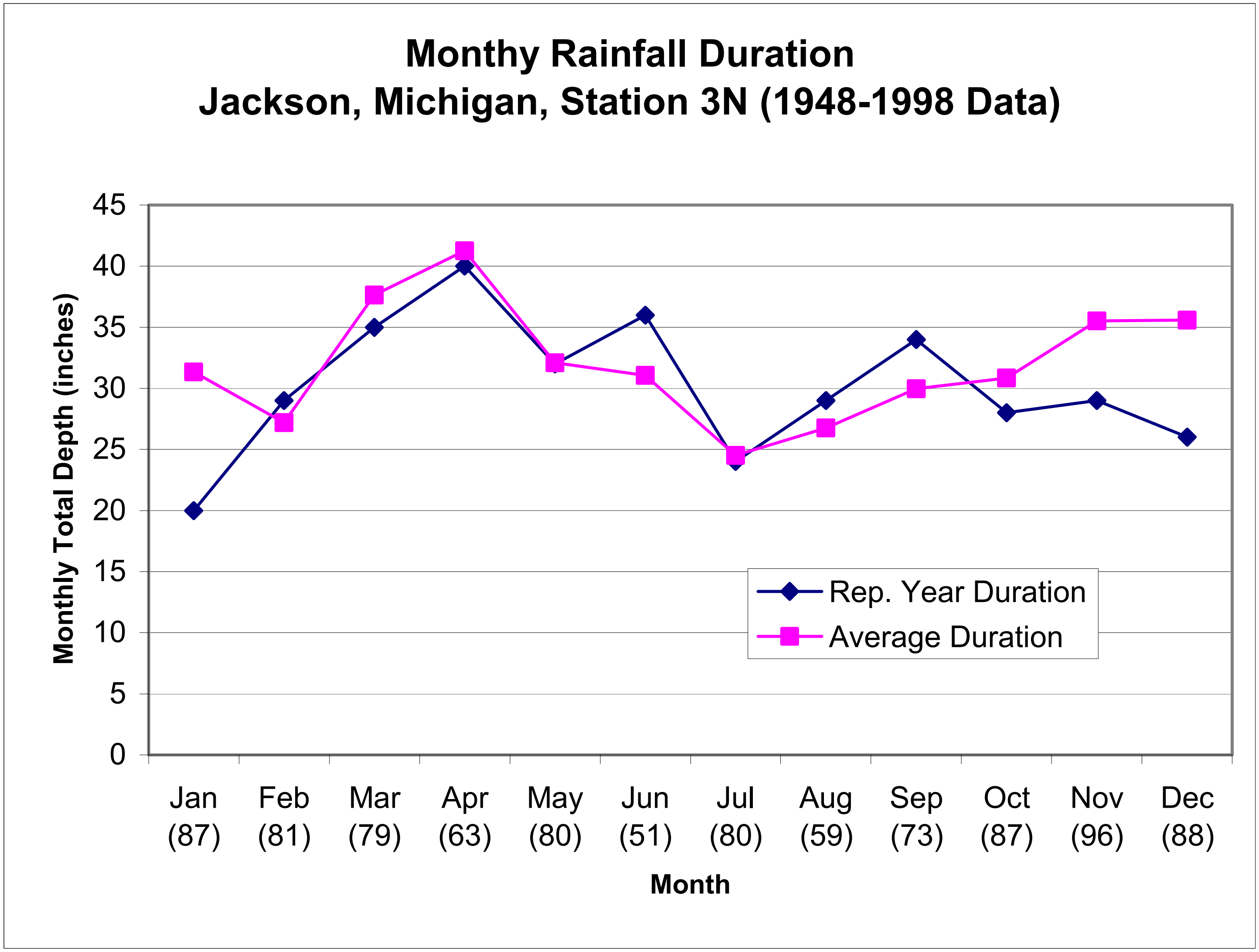
## Representative Rainfall Data



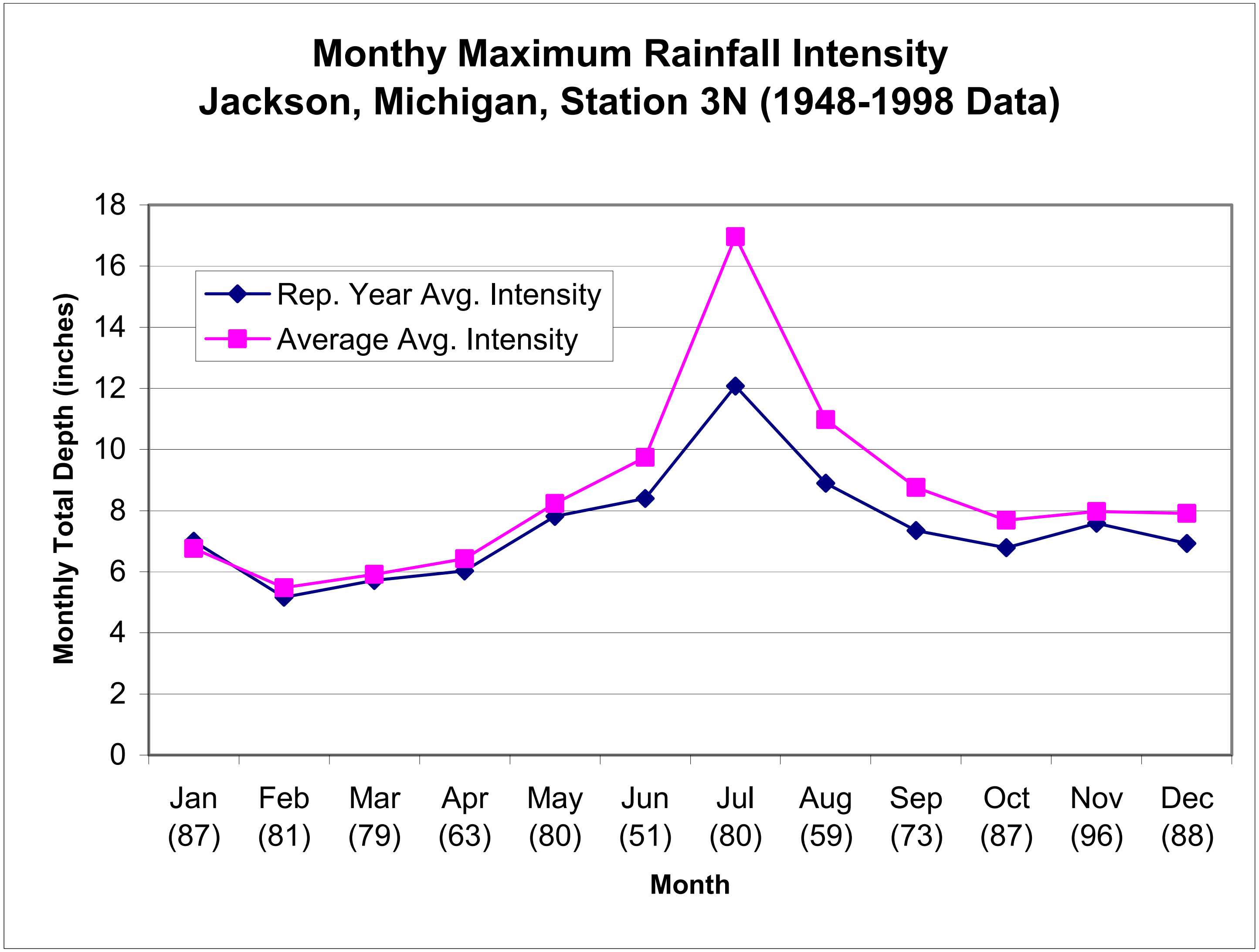
Monthy Rainfall Depths
Jackson, Michigan, Station 3N (1948-1998 Data)
Rep. Year Depth
Average Depth
Monthly Total Depth (inches)
3.5
3
2.5
2
1.5
1
0.5
0
Jan (87)
Feb (81)
Mar (79)
Apr (63)
May (80)
Jun (51)
Jul (80)
Aug (59)
Sep (73)
Oct (87)
Nov (96)
Dec (88)
Month

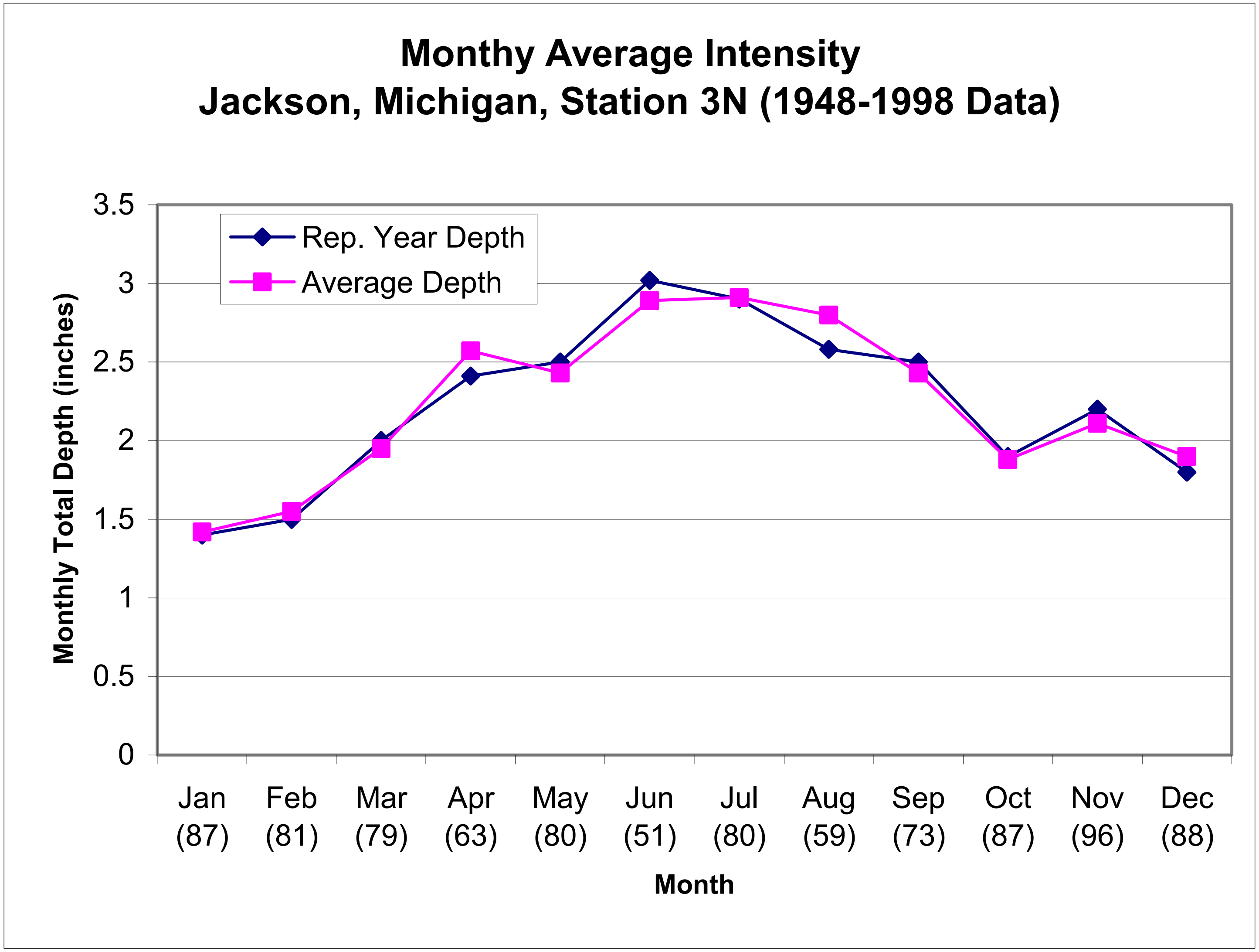


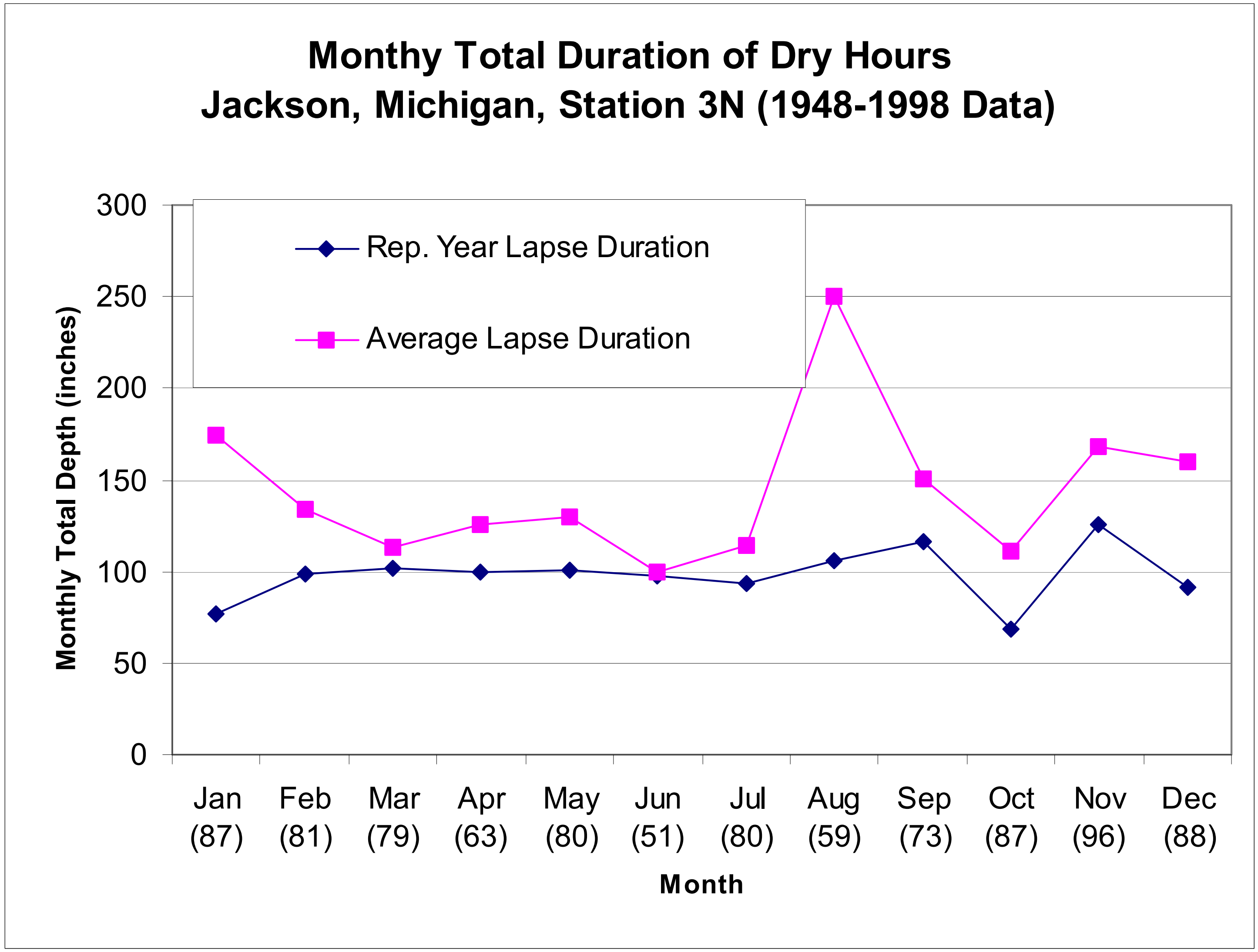
Monthy Count of Events
Jackson, Michigan, Station 3N (1948-1998 Data)
Rep. Year Count
Average Count
Monthly Total Depth (inches)
12
10
8
6
4
2
0
Jan (87)
Feb (81)
Mar (79)
Apr (63)
May (80)
Jun (51)
Jul (80)
Aug (59)
Sep (73)
Oct (87)
Nov (96)
Dec (88)
Month



Monthy Rainfall Duration
Jackson, Michigan, Station 3N (1948-1998 Data)
Monthly Total Depth (inches)
45
40
35
30
25
20
15
10
5
0
Jan (87)
Feb (81)
Mar (79)
Apr (63)
May (80)
Jun (51)
Jul (80)
Aug (59)
Sep (73)
Oct (87)
Nov (96)
Dec (88)
Month
Rep. Year Duration
Average Duration


Monthy Maximum Rainfall Intensity
Jackson, Michigan, Station 3N (1948-1998 Data)
Monthly Total Depth (inches)
18
16
14
12
10
8
6
4
2
0
Rep. Year Avg. Intensity
Average Avg. Intensity
Jan (87)
Feb (81)
Mar (79)
Apr (63)
May (80)
Jun (51)
Jul (80)
Aug (59)
Sep (73)
Oct (87)
Nov (96)
Dec (88)
Month


Monthy Average Intensity
Jackson, Michigan, Station 3N (1948-1998 Data)
Rep. Year Depth
Average Depth
Monthly Total Depth (inches)
3.5
3
2.5
2
1.5
1
0.5
0
Jan (87)
Feb (81)
Mar (79)
Apr (63)
May (80)
Jun (51)
Jul (80)
Aug (59)
Sep (73)
Oct (87)
Nov (96)
Dec (88)
Month



Monthy Total Duration of Dry Hours
Jackson, Michigan, Station 3N (1948-1998 Data)
Rep. Year Lapse Duration
Average Lapse Duration
Monthly Total Depth (inches)
300
250
200
150
100
50
0
Jan (87)
Feb (81)
Mar (79)
Apr (63)
May (80)
Jun (51)
Jul (80)
Aug (59)
Sep (73)
Oct (87)
Nov (96)
Dec (88)
Month

REPRESENTATIVE YEAR RAINFALL STATISTICS
JACKSON, MICHIGAN, STATION 3N

| EVENT | | DATE | TIME | DURATION (Hours) | VOLUME (Inches) | TDRY (hours) | AVG. INT. (Inches/Hour) | PMAX |
|---|---|---|---|---|---|---|---|---|
| 1 | (*) | Jan 02 | 2:00 PM | 1 | 0.1 | 38 | 0.1 | 0.1 |
| 2 | (*) | Jan 08 | 11:00 PM | 7 | 0.3 | 152 | 0.043 | 0.1 |
| 3 | (*) | Jan 09 | 6:00 PM | 1 | 0.1 | 12 | 0.1 | 0.1 |
| 4 | (*) | Jan 13 | 7:00 PM | 1 | 0.1 | 96 | 0.1 | 0.1 |
| 5 | (*) | Jan 17 | 12:00 AM | 4 | 0.2 | 76 | 0.05 | 0.1 |
| 6 | (*) | Jan 17 | 3:00 PM | 1 | 0.1 | 11 | 0.1 | 0.1 |
| 7 | (*) | Jan 18 | 1:00 PM | 4 | 0.4 | 21 | 0.1 | 0.2 |
| 8 | (*) | Jan 28 | 10:00 PM | 1 | 0.1 | 245 | 0.1 | 0.1 |
| 9 | (*) | Feb 01 | 6:00 AM | 11 | 0.4 | 79 | 0.036 | 0.1 |
| 10 | (*) | Feb 09 | 2:00 PM | 1 | 0.1 | 189 | 0.1 | 0.1 |
| 11 | (*) | Feb 10 | 10:00 AM | 13 | 0.6 | 19 | 0.046 | 0.1 |
| 12 | (*) | Feb 16 | 11:00 AM | 1 | 0.1 | 132 | 0.1 | 0.1 |
| 13 | (*) | Feb 22 | 8:00 PM | 1 | 0.1 | 152 | 0.1 | 0.1 |
| 14 | (*) | Feb 24 | 12:00 AM | 1 | 0.1 | 27 | 0.1 | 0.1 |
| 15 | (*) | Feb 27 | 9:00 PM | 1 | 0.1 | 92 | 0.1 | 0.1 |
| 16 | (*) | Mar 01 | 7:00 AM | 1 | 0.1 | 33 | 0.1 | 0.1 |
| 17 | (*) | Mar 03 | 7:00 PM | 12 | 0.4 | 59 | 0.033 | 0.1 |
| 18 | (*) | Mar 09 | 4:00 PM | 5 | 0.2 | 129 | 0.04 | 0.1 |
| 19 | | Mar 23 | 12:00 PM | 1 | 0.1 | 327 | 0.1 | 0.1 |
| 20 | | Mar 25 | 8:00 PM | 1 | 0.1 | 55 | 0.1 | 0.1 |
| 21 | | Mar 29 | 2:00 PM | 10 | 0.7 | 89 | 0.07 | 0.2 |
| 22 | | Mar 30 | 9:00 PM | 5 | 0.4 | 21 | 0.08 | 0.2 |
| 23 | | Apr 01 | 11:00 AM | 2 | 0.37 | 33 | 0.185 | 0.35 |
| 24 | | Apr 17 | 7:00 AM | 2 | 0.25 | 378 | 0.125 | 0.22 |
| 25 | | Apr 19 | 12:00 AM | 3 | 0.41 | 39 | 0.137 | 0.37 |
| 26 | | Apr 19 | 1:00 PM | 8 | 0.44 | 10 | 0.055 | 0.21 |
| 27 | | Apr 22 | 6:00 PM | 14 | 0.49 | 69 | 0.035 | 0.11 |
| 28 | | Apr 29 | 1:00 PM | 4 | 0.25 | 149 | 0.063 | 0.15 |
| 29 | | Apr 30 | 9:00 AM | 7 | 0.2 | 16 | 0.029 | 0.11 |
| 30 | | May 10 | 11:00 PM | 3 | 0.3 | 247 | 0.1 | 0.1 |
| 31 | | May 12 | 11:00 PM | 10 | 0.3 | 45 | 0.03 | 0.1 |
| 32 | | May 17 | 1:00 PM | 14 | 1 | 100 | 0.071 | 0.2 |
| 33 | | May 29 | 8:00 AM | 1 | 0.1 | 269 | 0.1 | 0.1 |
| 34 | | May 30 | 5:00 PM | 1 | 0.1 | 32 | 0.1 | 0.1 |
| 35 | | May 31 | 12:00 AM | 2 | 0.6 | 6 | 0.3 | 0.5 |
| 36 | | May 31 | 8:00 AM | 1 | 0.1 | 6 | 0.1 | 0.1 |
| 37 | | Jun 01 | 9:00 PM | 5 | 0.6 | 36 | 0.12 | 0.41 |
| 38 | | Jun 03 | 3:00 PM | 5 | 0.08 | 37 | 0.016 | 0.04 |
| 39 | | Jun 13 | 6:00 PM | 2 | 0.3 | 238 | 0.15 | 0.15 |
| 40 | | Jun 19 | 5:00 PM | 5 | 0.39 | 141 | 0.078 | 0.21 |
| 41 | | Jun 22 | 1:00 AM | 11 | 1.35 | 51 | 0.123 | 0.71 |
| 42 | | Jun 27 | 5:00 PM | 2 | 0.2 | 125 | 0.1 | 0.11 |
| 43 | | Jun 30 | 1:00 AM | 6 | 0.1 | 54 | 0.017 | 0.05 |
| 44 | | Jul 05 | 7:00 AM | 5 | 0.5 | 120 | 0.1 | 0.2 |
| 45 | | Jul 08 | 5:00 AM | 1 | 0.1 | 65 | 0.1 | 0.1 |
| 46 | | Jul 09 | 9:00 AM | 5 | 0.5 | 27 | 0.1 | 0.2 |
| 47 | | Jul 14 | 10:00 AM | 1 | 0.1 | 116 | 0.1 | 0.1 |
| 48 | | Jul 16 | 8:00 AM | 1 | 1 | 45 | 1 | 1 |
| 49 | | Jul 19 | 4:00 PM | 1 | 0.1 | 79 | 0.1 | 0.1 |

**REPRESENTATIVE YEAR RAINFALL STATISTICS**
**JACKSON, MICHIGAN, STATION 3N**

| EVENT | | DATE | TIME | DURATION (Hours) | VOLUME (Inches) | TDRY (hours) | AVG. INT. (Inches/Hour) | PMAX |
|---|---|---|---|---|---|---|---|---|
| 50 | | Jul 28 | 4:00 AM | 10 | 0.6 | 203 | 0.06 | 0.1 |
| 51 | | Aug 03 | 9:00 PM | 7 | 0.35 | 151 | 0.05 | 0.18 |
| 52 | | Aug 07 | 12:00 PM | 6 | 0.73 | 80 | 0.122 | 0.28 |
| 53 | | Aug 15 | 2:00 PM | 2 | 0.2 | 188 | 0.1 | 0.19 |
| 54 | | Aug 16 | 12:00 PM | 6 | 0.08 | 20 | 0.013 | 0.04 |
| 55 | | Aug 17 | 6:00 PM | 2 | 0.37 | 24 | 0.185 | 0.35 |
| 56 | | Aug 26 | 9:00 PM | 5 | 0.62 | 217 | 0.124 | 0.32 |
| 57 | | Aug 29 | 2:00 PM | 1 | 0.23 | 60 | 0.23 | 0.23 |
| 58 | | Sep 05 | 3:00 PM | 1 | 0.1 | 168 | 0.1 | 0.1 |
| 59 | | Sep 17 | 10:00 AM | 8 | 0.7 | 282 | 0.088 | 0.2 |
| 60 | | Sep 22 | 12:00 AM | 6 | 0.2 | 102 | 0.033 | 0.1 |
| 61 | | Sep 25 | 8:00 PM | 6 | 0.3 | 86 | 0.05 | 0.2 |
| 62 | | Sep 27 | 7:00 PM | 12 | 0.9 | 41 | 0.075 | 0.3 |
| 63 | | Sep 29 | 4:00 AM | 1 | 0.3 | 21 | 0.3 | 0.3 |
| 64 | | Oct 02 | 7:00 PM | 1 | 0.1 | 86 | 0.1 | 0.1 |
| 65 | | Oct 06 | 2:00 PM | 1 | 0.1 | 90 | 0.1 | 0.1 |
| 66 | | Oct 10 | 7:00 PM | 1 | 0.1 | 100 | 0.1 | 0.1 |
| 67 | | Oct 11 | 10:00 AM | 1 | 0.1 | 14 | 0.1 | 0.1 |
| 68 | | Oct 20 | 4:00 AM | 3 | 0.2 | 209 | 0.067 | 0.1 |
| 69 | | Oct 21 | 12:00 AM | 1 | 0.1 | 17 | 0.1 | 0.1 |
| 70 | | Oct 22 | 1:00 PM | 5 | 0.2 | 36 | 0.04 | 0.1 |
| 71 | | Oct 24 | 7:00 AM | 8 | 0.4 | 37 | 0.05 | 0.1 |
| 72 | | Oct 26 | 11:00 PM | 6 | 0.5 | 56 | 0.083 | 0.1 |
| 73 | | Oct 28 | 6:00 PM | 1 | 0.1 | 37 | 0.1 | 0.1 |
| 74 | | Nov 07 | 5:00 AM | 20 | 1.6 | 226 | 0.08 | 0.3 |
| 75 | | Nov 13 | 5:00 PM | 1 | 0.1 | 136 | 0.1 | 0.1 |
| 76 | | Nov 18 | 5:00 PM | 1 | 0.1 | 119 | 0.1 | 0.1 |
| 77 | | Nov 28 | 12:00 AM | 1 | 0.1 | 222 | 0.1 | 0.1 |
| 78 | | Nov 29 | 2:00 PM | 1 | 0.1 | 37 | 0.1 | 0.1 |
| 79 | | Nov 30 | 2:00 AM | 5 | 0.2 | 11 | 0.04 | 0.1 |
| 80 | | Dec 02 | 12:00 AM | 1 | 0.1 | 41 | 0.1 | 0.1 |
| 81 | | Dec 11 | 12:00 PM | 1 | 0.1 | 227 | 0.1 | 0.1 |
| 82 | (*) | Dec 22 | 1:00 PM | 1 | 0.1 | 264 | 0.1 | 0.1 |
| 83 | (*) | Dec 22 | 11:00 PM | 5 | 0.5 | 9 | 0.1 | 0.2 |
| 84 | (*) | Dec 25 | 3:00 PM | 1 | 0.1 | 59 | 0.1 | 0.1 |
| 85 | (*) | Dec 27 | 12:00 AM | 1 | 0.1 | 32 | 0.1 | 0.1 |
| 86 | (*) | Dec 27 | 8:00 AM | 16 | 0.8 | 7 | 0.05 | 0.3 |

*NOTES:* *The following parameters were used to for this rep. year:*

*6 Minimum Hours TDRY Dry Lapse Time*
*2 Trace (minimum hourly rainfall included)*
*4 Threshold - 1 hour*
*7 Threshold - 3 hours*
*9 Threshold - 6 hours*

*TDRY - Antecedent Dry Time (hours)*
*PMAX - Maximum Hourly Intensity (Inches / Hour)*
*(*) Representative year excludes these events during frons from mid-December to mid-March*

*Rainfall from Jackson 3N2 gauge*

# APPENDIX D

## Sieve Analysis Results and Catch Basin Sampling

## Quantifying the Impact of Catch Basin and Street Sweeping on Storm Water Quality for a Great Lakes Tributary: A Pilot Study
### Chemical Analysis of Street and Catch Basin Accumulations

| | | Pollutant Potency (ppm) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Other Pollutants | | | Total Metals | | | | | | | | | | SPLP Metals | | | | | | | | | |
| Sample ID | Date | CL | COD | TP | OrthoP | As | Ba | Cd | Cr | Pb | Hg | Se | Ag | Cu | Zn | As | Ba | Cd | Cr | Pb | Hg | Se | Ag | Cu | Zn |
| | | | | | | | **STREETS** | | | | | | | | | | | | | | | | | | |
| **FINE** | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-F | 4/6/2000 | 120.0 | 469 | 3.4 | 0.0 | 7.28 | 68.99 | 1.10 | 35.20 | 82.83 | 0.00 | 0.00 | 0.00 | 48.10 | 194.05 | | | | | | | | | | |
| 1-F | 7/11/2000 | 432.0 | 49 | 0.5 | 32.0 | 0.00 | 161.28 | 0.00 | 30.20 | 72.50 | 0.00 | 0.00 | 0.00 | 93.10 | 140.40 | | | | | | | | | | |
| 1-F | 9/6/2000 | nt | nt | nt | nt | 0.00 | 106.00 | 0.98 | 20.00 | 74.80 | nt | nt | 0.00 | 74.80 | 148.00 | | | | | | | | | | |
| Average 1F | | 276.0 | 259.0 | 2.0 | 16.0 | 2.4 | 112.1 | 0.7 | 28.5 | 76.7 | 0.0 | 0.0 | 0.0 | 72.0 | 160.8 | | | | | | | | | | |
| 2-F | 4/6/2000 | 148.0 | 167 | 0.4 | 0.0 | 8.29 | 162.27 | 0.94 | 43.85 | 198.20 | 0.00 | 0.00 | 0.00 | 55.99 | 274.98 | | | | | | | | | | |
| 2-F | 7/11/2000 | 41.0 | 16 | 2.9 | 22.0 | 0.00 | 129.27 | 0.00 | 27.16 | 204.29 | 0.00 | 0.00 | 0.00 | 73.10 | 221.04 | | | | | | | | | | |
| 2-F | 9/6/2000 | 6.4 | 77 | 0.4 | 0.7 | 13.00 | 128.00 | 0.95 | 18.50 | 261.00 | nt | 0.00 | 0.00 | 57.00 | 221.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| Average 2F | | 65.1 | 87 | 1.2 | 7.6 | 7.10 | 139.85 | 0.63 | 29.84 | 221.16 | 0.00 | 0.00 | 0.00 | 62.03 | 239.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| 3-F | 4/6/2000 | 1250.0 | 331 | 0.3 | 0.0 | 11.37 | 145.70 | 1.98 | 79.39 | 194.31 | 0.00 | 0.00 | 0.00 | 126.51 | 582.20 | | | | | | | | | | |
| 3-F | 7/11/2000 | 145.0 | 68 | 0.4 | 14.0 | 0.00 | 183.00 | 0.00 | 110.70 | 163.42 | 0.00 | 0.00 | 0.00 | 210.61 | 409.20 | | | | | | | | | | |
| 3-F | 9/2/2000 | NT | nt | nt | nt | 8.60 | 147.00 | 1.84 | 67.70 | 174.00 | NT | nt | 0.00 | 234.00 | 515.00 | | | | | | | | | | |
| Average 3F | | 697.5 | 200 | 0.4 | 7.0 | 6.66 | 158.57 | 1.27 | 85.93 | 177.24 | 0.00 | 0.00 | 0.00 | 190.37 | 502.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4-F | 4/6/2000 | 140.0 | 22 | 0.0 | 0.0 | 13.49 | 102.79 | 1.43 | 42.17 | 65.87 | 0.00 | 0.00 | 0.00 | 64.87 | 184.13 | | | | | | | | | | |
| 4-F | 7/11/2000 | 278.0 | 28 | 0.0 | 0.0 | 0.00 | 103.89 | 0.00 | 39.80 | 56.60 | 0.00 | 0.00 | 0.00 | 134.42 | 177.48 | | | | | | | | | | |
| 4-F | 9/6/2000 | NT | Nt | nt | nt | 0.00 | 102.00 | 1.74 | 31.10 | 65.50 | nt | nt | 0.00 | 93.80 | 153.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average 4F | | 209.0 | 25 | | 0.0 | 4.50 | 102.89 | 1.06 | 37.69 | 62.66 | 0.00 | 0.00 | 0.00 | 97.70 | 171.54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-F | 4/6/2000 | 244.0 | 151 | 0.0 | 0.0 | 9.37 | 138.78 | 2.62 | 41.18 | 121.14 | 0.00 | 0.00 | 0.00 | 72.73 | 321.00 | | | | | | | | | | |
| 5-F | 7/11/2000 | 146.0 | 76 | 0.9 | 0.0 | 0.00 | 133.08 | 0.00 | 62.37 | 112.70 | 0.00 | 0.00 | 0.00 | 120.81 | 309.40 | | | | | | | | | | |
| 5-F | 9/6/2000 | NT | NT | NT | NT | 6.10 | 121.00 | 1.57 | 39.00 | 131.00 | NT | NT | 0.00 | 158.00 | 301.00 | | | | | | | | | | |
| Average 5F | | 195.0 | 114 | 0.5 | 0.0 | 5.16 | 130.95 | 1.40 | 47.52 | 121.61 | 0.00 | 0.00 | 0.00 | 117.18 | 310.47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-F | 4/6/2000 | 111.0 | 348 | 1.5 | 0.0 | 5.79 | 85.49 | 1.51 | 38.08 | 101.56 | 0.00 | 0.00 | 0.00 | 48.45 | 241.20 | | | | | | | | | | |
| 6-F | 7/11/2000 | 45.0 | 27 | 0.5 | 87.0 | 0.00 | 96.94 | 0.00 | 41.72 | 108.08 | 0.00 | 0.00 | 0.00 | 77.27 | 195.77 | | | | | | | | | | |
| 6-F | 9/6/2000 | na | na | na | na | na | na | na | na | na | na | na | na | na | na | | | | | | | | | | |
| Average 6F | | 78.0 | 188 | 1.0 | 43.5 | 2.90 | 91.22 | 0.76 | 39.90 | 104.82 | 0.00 | 0.00 | 0.00 | 62.86 | 218.49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg All Sites | | 253.4 | 145.2 | 1.0 | 12.3 | 4.8 | 122.6 | 1.0 | 44.9 | 127.4 | 0.0 | 0.0 | 0.0 | 100.4 | 267.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **MEDIUM** | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-M | 4/6/2000 | 62 | 161 | 0 | 0 | 6.82 | 47.21 | 0.4 | 28.17 | 45.12 | 0 | 0 | 0 | 33.39 | 103.03 | | | | | | | | | | |
| 1-M | 7/11/2000 | 114 | 11 | 5.9 | 14 | 0 | 45.25 | 0 | 21.18 | 33.51 | 0 | 0 | 0 | 29.35 | 49.65 | | | | | | | | | | |
| 1-M | 9/6/2000 | 3 | 50 | 0.9 | 2.9 | 0 | 46 | 0.28 | 11.3 | 42.5 | 0 | 0 | 0 | 13.7 | 86.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | 0 |
| Average 1m | Average 1F | 59.66667 | 74 | 2.26667 | 5.6333 | 2.2733 | 46.1533 | 0.22667 | 20.217 | 40.37667 | 0 | 0 | 0 | 25.48 | 79.69333 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | 0 |
| 2-M | 4/6/2000 | 50 | 85 | 0 | 0 | 3.93 | 110.74 | 0.42 | 32.64 | 97.08 | 0 | 0 | 0 | 35.99 | 131.95 | | | | | | | | | | |
| 2-M | 7/11/2000 | 10 | 8 | 1.6 | 0 | 0 | 57.49 | 0 | 15.75 | 85.75 | 0 | 0 | 0 | 27.32 | 95.97 | | | | | | | | | | |
| 2-M | 9/6/2000 | 3.1 | 49 | 0.5 | 0.8 | 0 | 51.6 | 0.48 | 9.4 | 108 | 0 | 0 | 0 | 16.9 | 97.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 | 0 |
| Average 2M | Average 2F | 21.03333 | 47.33333 | 0.7 | 0.2667 | 1.31 | 73.2767 | 0.3 | 19.263 | 96.94333 | 0 | 0 | 0 | 26.737 | 108.5733 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 | 0 |
| 3-M | 4/6/2000 | 703 | 82 | 0 | 0 | 6.11 | 84.69 | 0.47 | 77.04 | 118.84 | 0 | 0 | 0 | 102.72 | 226.2 | | | | | | | | | | |
| 3-M | 7/11/2000 | 41 | 14 | 1.9 | 0 | 0 | 101.84 | 0 | 100.7 | 101.17 | 0 | 0 | 0 | 86.6 | 205.22 | | | | | | | | | | |
| 3-M | 9/6/2000 | 3.8 | 78 | 0 | 0 | 0 | 74.7 | 0.98 | 46 | 117 | nt | nt | 0 | 104 | 250 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.07 |

## Quantifying the Impact of Catch Basin and Street Sweeping on Storm Water Quality for a Great Lakes Tributary: A Pilot Study
## Chemical Analysis of Street and Catch Basin Accumulations

| | | | Other Pollutants | | | Total Metals | | | | | | | | | | SPLP Metals | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample ID | Date | CL | COD | TP | OrthoP | As | Ba | Cd | Cr | Pb | Hg | Se | Ag | Cu | Zn | As | Ba | Cd | Cr | Pb | Hg | Se | Ag | Cu | Zn |
| Average 3M | Average 3F | 249.2667 | 58 | 0.63333 | 0 | 2.0367 | 87.0767 | 0.48333 | 74.58 | 112.3367 | 0 | 0 | 0 | 97.773 | 227.14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.07 |
| 4-M | 4/6/2000 | 140 | 22 | 0 | 0 | 6.16 | 64.89 | 0.54 | 23.81 | 39.21 | 0 | 0 | 0 | 31.28 | 80.52 | | | | | | | | | | |
| 4-M | 22 | 52 | 12 | 0.8 | 0 | 0 | 54.54 | 0 | 19.6 | 25.64 | 0 | 0 | 0 | 61.58 | 65.6 | | | | | | | | | | |
| 4-M | 9/6/2000 | 2.5 | 33 | 0.3 | 0 | 8.1 | 43.4 | 0.35 | 14.9 | 26.9 | nt | nt | 0 | 23.1 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average 4M | Average 4F | 64.83333 | 22.33333 | 0.36667 | 0 | 4.7533 | 54.2767 | 0.29667 | 19.437 | 30.58333 | 0 | 0 | 0 | 38.653 | 65.37333 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-M | 4/6/2000 | 74 | 44 | 0 | 0 | 5.9 | 63.32 | 0.41 | 29.24 | 74.55 | 0 | 0 | 0 | 39.16 | 119.52 | | | | | | | | | | |
| 5-M | 7/11/2000 | 27 | 10 | 0.6 | 0 | 0 | 54.16 | 0 | 33.49 | 51.07 | 0 | 0 | 0 | 66.51 | 106.65 | | | | | | | | | | |
| 5-M | 9/6/2000 | 1.9 | 43 | 0.3 | 0 | 4.9 | 45.9 | 1.73 | 17.8 | 55.8 | 0 | 0 | 0 | 60.6 | 101 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 |
| Average 5M | Average 5F | 34.3 | 32.33333 | 0.3 | 0 | 3.6 | 54.46 | 0.71333 | 26.843 | 60.47333 | 0 | 0 | 0 | 55.423 | 109.0567 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 |
| 6-M | 4/6/2000 | 27 | 135 | 0.6 | 0 | 4.38 | 50.55 | 0.59 | 29.98 | 88.66 | 0 | 0 | 0 | 35.57 | 110 | | | | | | | | | | |
| 6-M | 7/11/2000 | 11 | 2 | 0 | 37 | 0 | 35.55 | 0 | 21.52 | 46.93 | 0 | 0 | 0 | 27.49 | 79.87 | | | | | | | | | | |
| 6-M | 9/6/2000 | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 | NA | NA | | | | | | | | | | |
| Average 6M | Average 6F | 19 | 68.5 | 0.3 | 18.5 | 2.19 | 43.05 | 0.295 | 25.75 | 67.795 | 0 | 0 | 0 | 31.53 | 94.935 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **COARSE** | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-C | 4/6/2000 | 49 | 166 | 1.3 | 0 | 3.25 | 26.22 | 0.21 | 428.47 | 25.23 | 0 | 0 | 0 | 13.36 | 63.44 | | | | | | | | | | |
| 1-C | 7/11/2000 | 136 | 6 | 3.4 | 0 | 0 | 42.3 | 0 | 11.33 | 18.72 | 0 | 0 | 0 | 26.13 | 37.29 | | | | | | | | | | |
| 1-C | 9/6/2000 | 2 | 32 | 0.6 | 1.2 | 9.3 | 35.9 | 0.26 | 10.6 | 32 | nt | nt | 0 | 8 | 106 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 |
| Average 1m | Average 1m | 62.33333 | 68 | 1.76667 | 0.4 | 4.1833 | 34.8067 | 0.15667 | 150.13 | 25.31667 | 0 | 0 | 0 | 15.83 | 68.91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 |
| 2-C | 4/6/2000 | 22 | 44 | 0 | 0 | 3.18 | 79.1 | 0.2 | 55.22 | 45.77 | 0 | 0 | 0 | 15.99 | 86.56 | | | | | | | | | | |
| 2-C | 7/11/2000 | 18 | 0 | 2.2 | 0 | 0 | 69.89 | 0 | 19.76 | 76.29 | 0 | 0 | 0 | 17.7 | 81.3 | | | | | | | | | | |
| 2-C | 9/6/2000 | 3.9 | 52 | 0.6 | 0.7 | 0 | 34.5 | 0.23 | 21.2 | 65.8 | nt | nt | nf | 9.4 | 78.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.16 | 0.09 |
| Average 2M | Average 2M | 14.63333 | 32 | 0.93333 | 0.2333 | 1.06 | 61.1633 | 0.14333 | 32.06 | 62.62 | 0 | 0 | 0 | 14.363 | 82.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.16 | 0.09 |
| 3-C | 4/6/2000 | 74 | 37 | 0 | 0 | 3.66 | 27.72 | 0.19 | 36.88 | 49.09 | 0 | 0 | 0 | 23.96 | 103.82 | | | | | | | | | | |
| 3-C | 7/11/2000 | 137 | 37 | 0.9 | 31 | 0 | 43.68 | 0 | 79.3 | 115.9 | 0 | 0 | 0 | 46.85 | 71.74 | | | | | | | | | | |
| 3-C | 9/6/2000 | 6 | 105 | 1.1 | 1.8 | 11.2 | 75.2 | 0.62 | 38.7 | 72.3 | nt | 0 | 0 | 445 | 125 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0.06 |
| Average 3M | Average 3M | 72.33333 | 59.66667 | 0.66667 | 10.933 | 4.9533 | 48.8667 | 0.27 | 51.627 | 79.09667 | 0 | 0 | 0 | 171.94 | 100.1867 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0.06 |
| 4-C | 4/6/2000 | 895 | 25 | 0.3 | 0 | 6.52 | 70.67 | 0.22 | 18.69 | 22.88 | 0 | 0 | 0 | 26.25 | 32.31 | | | | | | | | | | |
| 4-C | 7/11/2000 | 22 | 0 | 0.7 | 0 | 0 | 51.11 | 0 | 20.07 | 22.01 | 0 | 0 | 0 | 33.48 | 46.04 | | | | | | | | | | |
| 4-C | 9/2/2000 | 1.2 | 24 | 0 | 0.1 | 14.4 | 29.8 | 0.11 | 34.5 | 17.6 | nt | nt | 0 | 8.4 | 12.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average 4M | Average 4M | 306.0667 | 16.33333 | 0.33333 | 0.0333 | 6.9733 | 50.5267 | 0.11 | 24.42 | 20.83 | 0 | 0 | 0 | 22.71 | 30.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-C | 4/6/2000 | 34 | 31 | 0 | 0 | 8.4 | 34.5 | 0.2 | 41.67 | 37.69 | 0 | 0 | 0 | 23.81 | 74.31 | | | | | | | | | | |
| 5-C | 7/11/2000 | 65 | 17 | 0.7 | 27 | 0 | 39.46 | 0 | 36.19 | 52.75 | 0 | 0 | 0 | 47.23 | 101.61 | | | | | | | | | | |
| 5-C | 9/6/2000 | 1.1 | 45 | 0 | 0.2 | 0 | 25.9 | 0.18 | 33 | 41.6 | NT | NT | 0 | 13.5 | 34.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average 5M | Average 5M | 33.36667 | 31 | 0.23333 | 9.0667 | 2.8 | 33.2867 | 0.12667 | 36.953 | 44.01333 | 0 | 0 | 0 | 28.18 | 70.04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-C | 4/6/2000 | 23 | 8700 | 0 | 0 | 5.01 | 50.11 | 0.2 | 44.01 | 94.38 | 0 | 0 | 0 | 18.4 | 115.06 | | | | | | | | | | |
| 6-C | 7/11/2000 | 28 | 27 | 0 | 41 | 0 | 34.03 | 0 | 100.26 | 26.22 | 0 | 0 | 0 | 26.91 | 101.87 | | | | | | | | | | |
| 6-C | 9/6/2000 | nt | nt | nt | nt | nt | nt | nt | nt | nt | nt | nt | nt | nt | nt | | | | | | | | | | |
| Average 6M | Average 6M | 25.5 | 4363.5 | 0 | 20.5 | 2.505 | 42.07 | 0.1 | 72.135 | 60.3 | 0 | 0 | 0 | 22.655 | 108.465 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | **CATCHBASINS** | | | | | | | | | | | | | | | | | | | |
| **FINE** | | | | | | | | | | | | | | | | | | | | | | | | | |
| CB #3-4-5 F | 4/6/2000 | 1439.0 | 122.0 | 0.0 | 0.0 | 20.83 | 175.35 | 5.63 | 84.48 | 208.20 | 0.00 | 0.00 | 0.58 | 167.25 | 614.37 | | | | | | | | | | |

## Quantifying the Impact of Catch Basin and Street Sweeping on Storm Water Quality for a Great Lakes Tributary: A Pilot Study
### Chemical Analysis of Street and Catch Basin Accumulations

| | | | Other Pollutants | | | Total Metals | | | | | | | | | | SPLP Metals | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample ID** | **Date** | **CL** | **COD** | **TP** | **OrthoP** | **As** | **Ba** | **Cd** | **Cr** | **Pb** | **Hg** | **Se** | **Ag** | **Cu** | **Zn** | **As** | **Ba** | **Cd** | **Cr** | **Pb** | **Hg** | **Se** | **Ag** | **Cu** | **Zn** |
| CB #3-4-5 F | 7/11/2000 | 122.0 | 73.0 | 0.0 | 0.0 | 0.00 | 167.37 | 0.00 | 78.46 | 178.81 | 0.00 | 0.00 | 0.00 | 265.44 | 619.84 | | | | | | | | | | |
| CB #3-4-5 F | 9/6/2000 | 0.5 | 27 | 0.3 | 0 | 8.8 | 34.7 | 0.36 | 25.2 | 79.6 | NT | Nt | 0 | 13.9 | 89.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 |
| Average 3-4-5 F | | 520.5 | 74.0 | 0.1 | 0.0 | 9.88 | 125.81 | 2.00 | 62.71 | 155.54 | 0.00 | 0.00 | 0.19 | 148.86 | 441.17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 |
| **MEDIUM** | | | | | | | | | | | | | | | | | | | | | | | | | |
| CB #3-4-5 M | 4/6/2000 | 493.0 | 54.0 | 0.0 | 0.0 | 6.76 | 104.47 | 0.85 | 63.46 | 116.56 | 0.00 | 0.00 | 0.00 | 66.48 | 249.52 | | | | | | | | | | |
| CB #3-4-5 M | 7/11/2000 | 26.0 | 10.0 | 0.0 | 0.0 | 0.00 | 65.83 | 0.00 | 41.22 | 64.95 | 0.00 | 0.00 | 0.00 | 93.41 | 132.56 | | | | | | | | | | |
| CB #3-4-5 M | | | | | | | | | | | | | | | | | | | | | | | | | |
| Average 3-4-5 M | | 259.5 | 32.0 | 0.0 | 0.0 | 3.38 | 85.15 | 0.43 | 52.34 | 90.76 | 0.00 | 0.00 | 0.00 | 79.95 | 191.04 | | | | | | | | | | |
| **COARSE** | | | | | | | | | | | | | | | | | | | | | | | | | |
| CB #3-4-5 C | 4/6/2000 | 396.0 | 81.0 | 0.0 | 0.0 | 6.28 | 134.23 | 1.01 | 82.71 | 112.08 | 0.00 | 0.00 | 0.00 | 30.05 | 162.25 | | | | | | | | | | |
| CB #3-4-5 C | 7/11/2000 | 17.0 | 3.0 | 0.0 | 0.0 | 0.00 | 43.50 | 0.00 | 37.24 | 36.35 | 0.00 | 0.00 | 0.00 | 48.86 | 73.89 | | | | | | | | | | |
| CB #3-4-5 C | | | | | | | | | | | | | | | | | | | | | | | | | |
| Average 3-4-5 C | | 206.5 | 42.0 | 0.0 | 0.0 | 3.14 | 88.87 | 0.51 | 59.98 | 74.22 | 0.00 | 0.00 | 0.00 | 39.46 | 118.07 | | | | | | | | | | |

## Quantifying the Impact of Catch Basin and Street Sweeping on Storm Water Quality for a Great Lakes Tributary: A Pilot Study

## Sieve Analysis Results

Sieve Data in Columns E-M

| | | | | Sieve Analysis | | | | | | | | | Wt. Fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Small Fraction | Medium Fraction | | | Coarse Fraction | | | | | Small Fraction | Medium Fraction | | | Coarse Fraction | | | | |
| | | | | PS1 | PS2 | PS3 | PS4 | PS5 | PS6 | PS7 | PS8 | Total | PS1 | PS2 | PS3 | PS4 | PS5 | PS6 | PS7 | PS8 | |
| **Date** | **Site** | **Sample** | **Surface** | <63 mm | 63-125 | 125-250 | 250-600 | 600-1000 | 1000-2000 | 2000-6370 | >6370 | Sieve | <63 mm | 63-125 | 125-250 | 250-600 | 600-1000 | 1000-2000 | 2000-6370 | >6370 | Totals |
| 4/6/2000 | 1 | Durand | street | 60.8 | 94.5 | 188 | 315.7 | 103.9 | 89.3 | 168.7 | 60.8 | 1081.70 | 0.056 | 0.087 | 0.174 | 0.292 | 0.096 | 0.083 | 0.156 | 0.056 | 1.0000 |
| 5/4/2000 | 1 | Durand | street | 23.20 | 58.00 | 161.60 | 314.50 | 91.80 | 59.90 | 88.80 | 46.10 | 843.90 | 0.027 | 0.069 | 0.191 | 0.373 | 0.109 | 0.071 | 0.105 | 0.055 | 1.0000 |
| 6/8/2000 | 1 | Durand | street | 5.40 | 28.70 | 110.30 | 191.90 | 275.40 | 92.50 | 191.50 | 88.20 | 983.90 | 0.005 | 0.029 | 0.112 | 0.195 | 0.280 | 0.094 | 0.195 | 0.090 | 1.0000 |
| 7/11/2000 | 1 | Durand | street | 19.20 | 40.40 | 102.00 | 184.40 | 73.10 | 98.40 | 201.60 | 77.70 | 796.80 | 0.024 | 0.051 | 0.128 | 0.231 | 0.092 | 0.123 | 0.253 | 0.098 | 1.0000 |
| 8/9/2000 | 1 | Durand | street | 3.10 | 9.70 | 45.70 | 138.80 | 80.80 | 93.10 | 97.90 | 45.70 | 514.80 | 0.006 | 0.019 | 0.089 | 0.270 | 0.157 | 0.181 | 0.190 | 0.089 | 1.0000 |
| 9/6/2000 | 1 | Durand | street | 8.60 | 31.50 | 128.50 | 241.60 | 93.90 | 119.00 | 238.30 | 55.10 | 916.50 | 0.009 | 0.034 | 0.140 | 0.264 | 0.102 | 0.130 | 0.260 | 0.060 | 1.0000 |
| Totals | 1 | Durand | street | 120.30 | 262.80 | 736.10 | 1386.90 | 718.90 | 552.20 | 986.80 | 373.60 | 5137.60 | 0.023 | 0.051 | 0.143 | 0.270 | 0.140 | 0.107 | 0.192 | 0.073 | 1.0000 |
| | | | | | | | | | | | | | | | | | | | | | |
| 4/7/2000 | 2 | Jackson Street | street | 100.8 | 135.4 | 304.2 | 404.3 | 107.9 | 83.7 | 160.5 | 32 | 1328.80 | 0.076 | 0.102 | 0.229 | 0.304 | 0.081 | 0.063 | 0.121 | 0.024 | 1.0000 |
| 5/4/2000 | 2 | Jackson Street | street | 90.90 | 139.40 | 148.60 | 341.20 | 80.70 | 48.70 | 22.20 | 26.80 | 898.50 | 0.101 | 0.155 | 0.165 | 0.380 | 0.090 | 0.054 | 0.025 | 0.030 | 1.0000 |
| 6/8/2000 | 2 | Jackson Street | street | 3.30 | 40.80 | 162.80 | 483.80 | 106.30 | 77.90 | 113.10 | 59.70 | 1047.70 | 0.003 | 0.039 | 0.155 | 0.462 | 0.101 | 0.074 | 0.108 | 0.057 | 1.0000 |
| 7/11/2000 | 2 | Jackson Street | street | 31.90 | 66.50 | 160.10 | 218.70 | 54.20 | 58.60 | 76.50 | 7.70 | 674.20 | 0.047 | 0.099 | 0.237 | 0.324 | 0.080 | 0.087 | 0.113 | 0.011 | 1.0000 |
| 8/9/2000 | 2 | Jackson Street | street | 54.50 | 93.50 | 223.60 | 318.40 | 96.20 | 96.70 | 130.80 | 13.30 | 1027.00 | 0.053 | 0.091 | 0.218 | 0.310 | 0.094 | 0.094 | 0.127 | 0.013 | 1.0000 |
| 9/6/2000 | 2 | Jackson Street | street | 63.60 | 158.20 | 311.90 | 282.60 | 74.80 | 66.90 | 76.90 | 12.10 | 1047.00 | 0.061 | 0.151 | 0.298 | 0.270 | 0.071 | 0.064 | 0.073 | 0.012 | 1.0000 |
| totals | 2 | Jackson Street | street | 345.00 | 633.80 | 1311.20 | 2049.00 | 520.10 | 432.50 | 580.00 | 151.60 | 6023.20 | 0.057 | 0.105 | 0.218 | 0.340 | 0.086 | 0.072 | 0.096 | 0.025 | 1.0000 |
| | | | | | | | | | | | | | | | | | | | | | |
| 4/7/2000 | 3 | Cortland | street | 47.30 | 56.30 | 135.60 | 302.70 | 182.30 | 181.60 | 231.00 | 54.60 | 1191.40 | 0.040 | 0.047 | 0.114 | 0.254 | 0.153 | 0.152 | 0.194 | 0.046 | 1.0000 |
| 5/11/2000 | 3 | Cortland | street | 22.7 | 46.8 | 105.4 | 186.7 | 77.7 | 58.1 | 67 | 23.5 | 587.90 | 0.039 | 0.080 | 0.179 | 0.318 | 0.132 | 0.099 | 0.114 | 0.040 | 1.0000 |
| 6/8/2000 | 3 | Cortland | street | 6.70 | 33.70 | 114.70 | 425.80 | 104.20 | 58.10 | 50.20 | 18.70 | 812.10 | 0.008 | 0.041 | 0.141 | 0.524 | 0.128 | 0.072 | 0.062 | 0.023 | 1.0000 |
| 7/12/2000 | 3 | Cortland | street | 18.00 | 41.90 | 105.50 | 203.40 | 83.10 | 89.60 | 111.50 | 30.20 | 683.20 | 0.026 | 0.061 | 0.154 | 0.298 | 0.122 | 0.131 | 0.163 | 0.044 | 1.0000 |
| 8/10/2000 | 3 | Cortland | street | 32.30 | 75.20 | 187.20 | 356.00 | 134.20 | 108.10 | 145.90 | 46.90 | 1085.80 | 0.030 | 0.069 | 0.172 | 0.328 | 0.124 | 0.100 | 0.134 | 0.043 | 1.0000 |
| 9/6/2000 | 3 | Cortland | street | 24.30 | 60.50 | 122.10 | 211.90 | 91.40 | 67.00 | 56.20 | 17.80 | 651.20 | 0.037 | 0.093 | 0.188 | 0.325 | 0.140 | 0.103 | 0.086 | 0.027 | 1.0000 |
| Totals | 3 | Cortland | street | 151.30 | 314.40 | 770.50 | 1686.50 | 672.90 | 562.50 | 661.80 | 191.70 | 5011.60 | 0.030 | 0.063 | 0.154 | 0.337 | 0.134 | 0.112 | 0.132 | 0.038 | 1.0000 |
| | | | | | | | | | | | | | | | | | | | | | |
| 4/6/2000 | 4 | Parnell | street | 63 | 90.6 | 267.9 | 421.5 | 134.1 | 167 | 244.4 | 57.1 | 1445.60 | 0.044 | 0.063 | 0.185 | 0.292 | 0.093 | 0.116 | 0.169 | 0.039 | 1.0000 |
| 5/4/2000 | 4 | Parnell | street | 53.60 | 81.00 | 283.10 | 473.40 | 124.30 | 107.40 | 163.20 | 63.60 | 1349.60 | 0.040 | 0.060 | 0.210 | 0.351 | 0.092 | 0.080 | 0.121 | 0.047 | 1.0000 |
| 6/6/2000 | 4 | Parnell | street | 1.5 | 8.6 | 54.1 | 280.1 | 116.9 | 198 | 230.8 | 72.4 | 962.40 | 0.002 | 0.009 | 0.056 | 0.291 | 0.121 | 0.206 | 0.240 | 0.075 | 1.0000 |
| 7/17/2000 | 4 | Parnell | street | 11.10 | 24.90 | 77.90 | 156.40 | 87.50 | 141.80 | 162.70 | 34.90 | 697.20 | 0.016 | 0.036 | 0.112 | 0.224 | 0.126 | 0.203 | 0.233 | 0.050 | 1.0000 |
| 8/8/2000 | 4 | Parnell | street | 12.60 | 26.90 | 80.00 | 181.10 | 92.30 | 136.20 | 358.70 | 90.00 | 977.80 | 0.013 | 0.028 | 0.082 | 0.185 | 0.094 | 0.139 | 0.367 | 0.092 | 1.0000 |
| 9/13/2000 | 4 | Parnell | street | 12.60 | 31.90 | 87.30 | 145.80 | 75.30 | 114.10 | 173.20 | 36.30 | 676.50 | 0.019 | 0.047 | 0.129 | 0.216 | 0.111 | 0.169 | 0.256 | 0.054 | 1.0000 |
| Totals | 4 | Parnell | street | 154.40 | 263.90 | 850.30 | 1658.30 | 630.40 | 864.50 | 1333.00 | 354.30 | 6109.10 | 0.025 | 0.043 | 0.139 | 0.271 | 0.103 | 0.142 | 0.218 | 0.058 | 1.0000 |
| | | | | | | | | | | | | | | | | | | | | | |
| 4/6/2000 | 5 | Ganson Carroll | street | 83.20 | 101.30 | 235.50 | 289.80 | 100.70 | 133.70 | 374.90 | 73.20 | 1392.30 | 0.060 | 0.073 | 0.169 | 0.208 | 0.072 | 0.096 | 0.269 | 0.053 | 1.0000 |
| 5/11/2000 | 5 | Ganson Carroll | street | 19.70 | 47.90 | 300.70 | 130.50 | 143.20 | 132.00 | 195.60 | 87.60 | 1057.20 | 0.019 | 0.045 | 0.284 | 0.123 | 0.135 | 0.125 | 0.185 | 0.083 | 1.0000 |
| 6/9/2000 | 5 | Ganson Carroll | street | 10.70 | 37.10 | 114.40 | 289.00 | 251.50 | 186.60 | 275.50 | 73.00 | 1237.80 | 0.009 | 0.030 | 0.092 | 0.233 | 0.203 | 0.151 | 0.223 | 0.059 | 1.0000 |
| 7/11/2000 | 5 | Ganson Carroll | street | 27.80 | 46.70 | 118.60 | 192.80 | 86.90 | 123.90 | 137.90 | 33.60 | 768.20 | 0.036 | 0.061 | 0.154 | 0.251 | 0.113 | 0.161 | 0.180 | 0.044 | 1.0000 |
| 8/9/2000 | 5 | Ganson Carroll | street | 32.60 | 64.80 | 174.40 | 290.80 | 128.50 | 132.10 | 96.70 | 26.80 | 946.70 | 0.034 | 0.068 | 0.184 | 0.307 | 0.136 | 0.140 | 0.102 | 0.028 | 1.0000 |
| 9/6/2000 | 5 | Ganson Carroll | street | 3.50 | 8.10 | 42.40 | 121.40 | 71.30 | 108.40 | 245.10 | 83.00 | 683.20 | 0.005 | 0.012 | 0.062 | 0.178 | 0.104 | 0.159 | 0.359 | 0.121 | 1.0000 |
| Totals | 5 | Ganson Carroll | street | 177.50 | 305.90 | 986.00 | 1314.30 | 782.10 | 816.70 | 1325.70 | 377.20 | 6085.40 | 0.029 | 0.050 | 0.162 | 0.216 | 0.129 | 0.134 | 0.218 | 0.062 | 1.0000 |
| | | | | | | | | | | | | | | | | | | | | | |
| 4/6/2000 | 6 | Seymour | street | 71.00 | 88.40 | 183.70 | 286.30 | 105.70 | 104.50 | 180.70 | 42.90 | 1063.20 | 0.067 | 0.083 | 0.173 | 0.269 | 0.099 | 0.098 | 0.170 | 0.040 | 1.0000 |
| 5/11/2000 | 6 | Seymour | street | 2.40 | 10.30 | 59.20 | 123.20 | 48.40 | 34.90 | 86.60 | 50.50 | 415.50 | 0.006 | 0.025 | 0.142 | 0.297 | 0.116 | 0.084 | 0.208 | 0.122 | 1.0000 |
| 6/8/2000 | 6 | Seymour | street | 4.00 | 24.00 | 86.40 | 420.90 | 257.80 | 91.90 | 105.30 | 61.70 | 1052.00 | 0.004 | 0.023 | 0.082 | 0.400 | 0.245 | 0.087 | 0.100 | 0.059 | 1.0000 |
| 7/12/2000 | 6 | Seymour | street | 25.50 | 67.10 | 201.60 | 282.70 | 68.40 | 65.10 | 78.50 | 19.10 | 808.00 | 0.032 | 0.083 | 0.250 | 0.350 | 0.085 | 0.081 | 0.097 | 0.024 | 1.0000 |
| 8/9/2000 | 6 | Seymour | street | 26.80 | 54.90 | 176.40 | 284.80 | 88.00 | 75.00 | 55.80 | 34.70 | 796.40 | 0.034 | 0.069 | 0.221 | 0.358 | 0.110 | 0.094 | 0.070 | 0.044 | 1.0000 |
| 9/6/2000 | 6 | Seymour | street | | | | | | | | | | | | | | | | | | |
| Totals | 6 | Seymour | street | 129.70 | 244.70 | 707.30 | 1397.90 | 568.30 | 371.40 | 506.90 | 208.90 | 4135.10 | 0.031 | 0.059 | 0.171 | 0.338 | 0.137 | 0.090 | 0.123 | 0.051 | 1.0000 |
| | | | | | | | | | | | | | | | | | | | | | |
| **Average for Site Sieve Fractions** | | | | | | | | | | | | | PS1 | PS2 | PS3 | PS4 | PS5 | PS6 | PS7 | PS8 | |
| **Averages** | **Site** | **Type** | | | | | | | | | | | <63 mm | 63-125 | 125-250 | 250-600 | 600-1000 | 1000-2000 | 2000-6370 | >6370 | Total |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | 1 | street | | | | | | | | | | | 0.023 | 0.051 | 0.143 | 0.270 | 0.140 | 0.107 | 0.192 | 0.073 | 1.000 |
| Site | 2 | street | | | | | | | | | | | 0.057 | 0.105 | 0.218 | 0.340 | 0.086 | 0.072 | 0.096 | 0.025 | 1.000 |
| Site | 3 | street | | | | | | | | | | | 0.030 | 0.063 | 0.154 | 0.337 | 0.134 | 0.112 | 0.132 | 0.038 | 1.000 |
| Site | 4 | street | | | | | | | | | | | 0.025 | 0.043 | 0.139 | 0.271 | 0.103 | 0.142 | 0.218 | 0.058 | 1.000 |
| Site | 5 | street | | | | | | | | | | | 0.029 | 0.050 | 0.162 | 0.216 | 0.129 | 0.134 | 0.218 | 0.062 | |
| Site | 6 | street | | | | | | | | | | | 0.031 | 0.059 | 0.171 | 0.338 | 0.137 | 0.090 | 0.123 | 0.051 | |
| | | | | | | | | | | | | | | | | | | | | | |
| Total Average | | | | | | | | | | | | | 0.033 | 0.062 | 0.164 | 0.295 | 0.122 | 0.110 | 0.163 | 0.051 | 1.000 |

# APPENDIX E

## Laboratory Quality Control Documentation

# RTI Laboratories, Inc.

## Quality Assurance Plan

## 1-QAO-001-G

Effective Date: 1/9/01

Previous Date: 11/6/00

The pages herein contain the quality policies and procedures utilized within the laboratory and are recognized and communicated by our top management (owners), are carried out by all personnel, and are updated and enforced by the below listed personnel.

Jerry Singh, General Manager and Technical Director

Lloyd Kaufman, Quality Assurance Manager

ACCREDITED IN ACCORDANCE WITH nelac

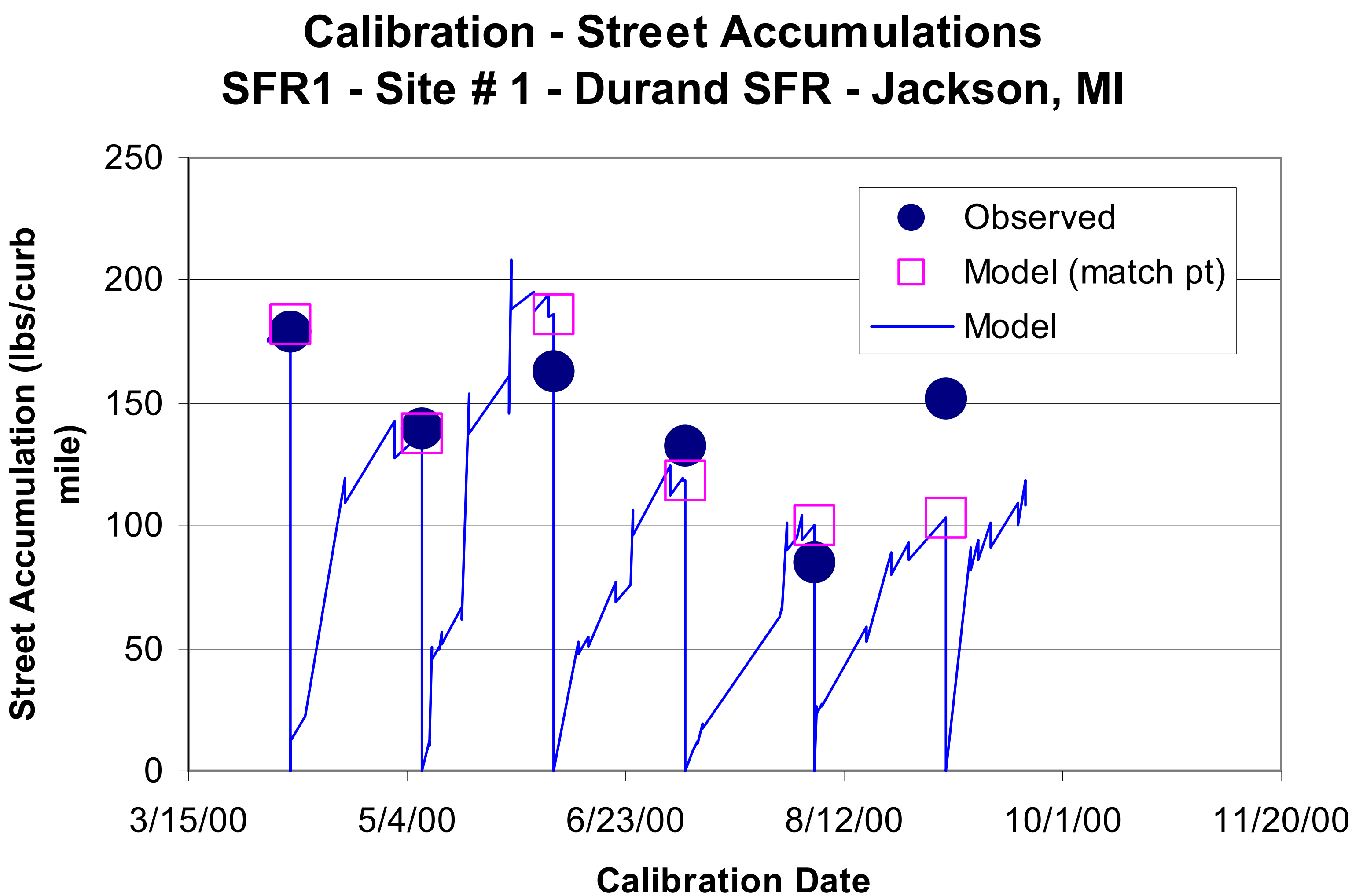
NELAP ACCREDITED
#100428

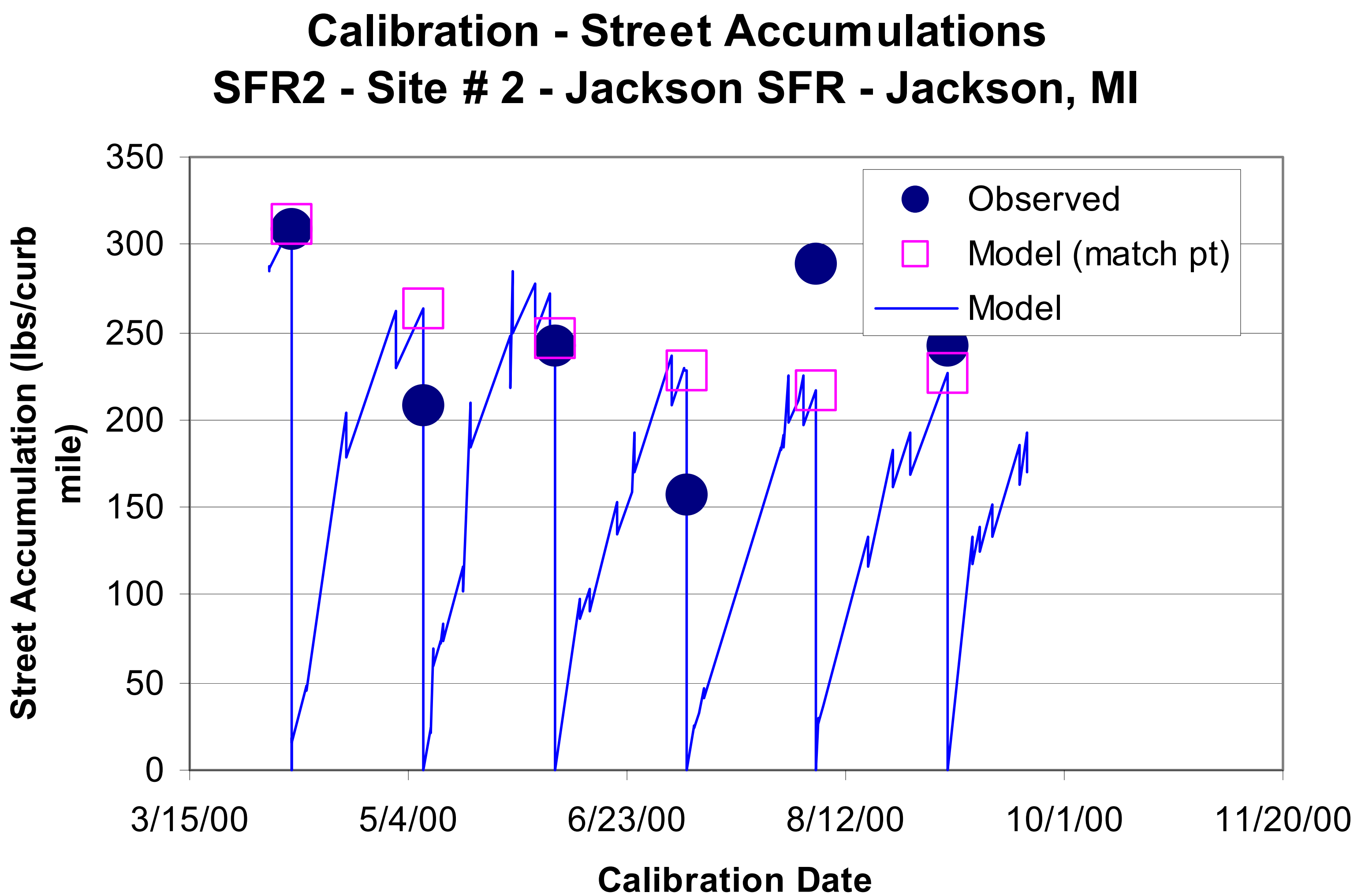
ACCREDITED
Accredited by The American Association for Laboratory Accreditation

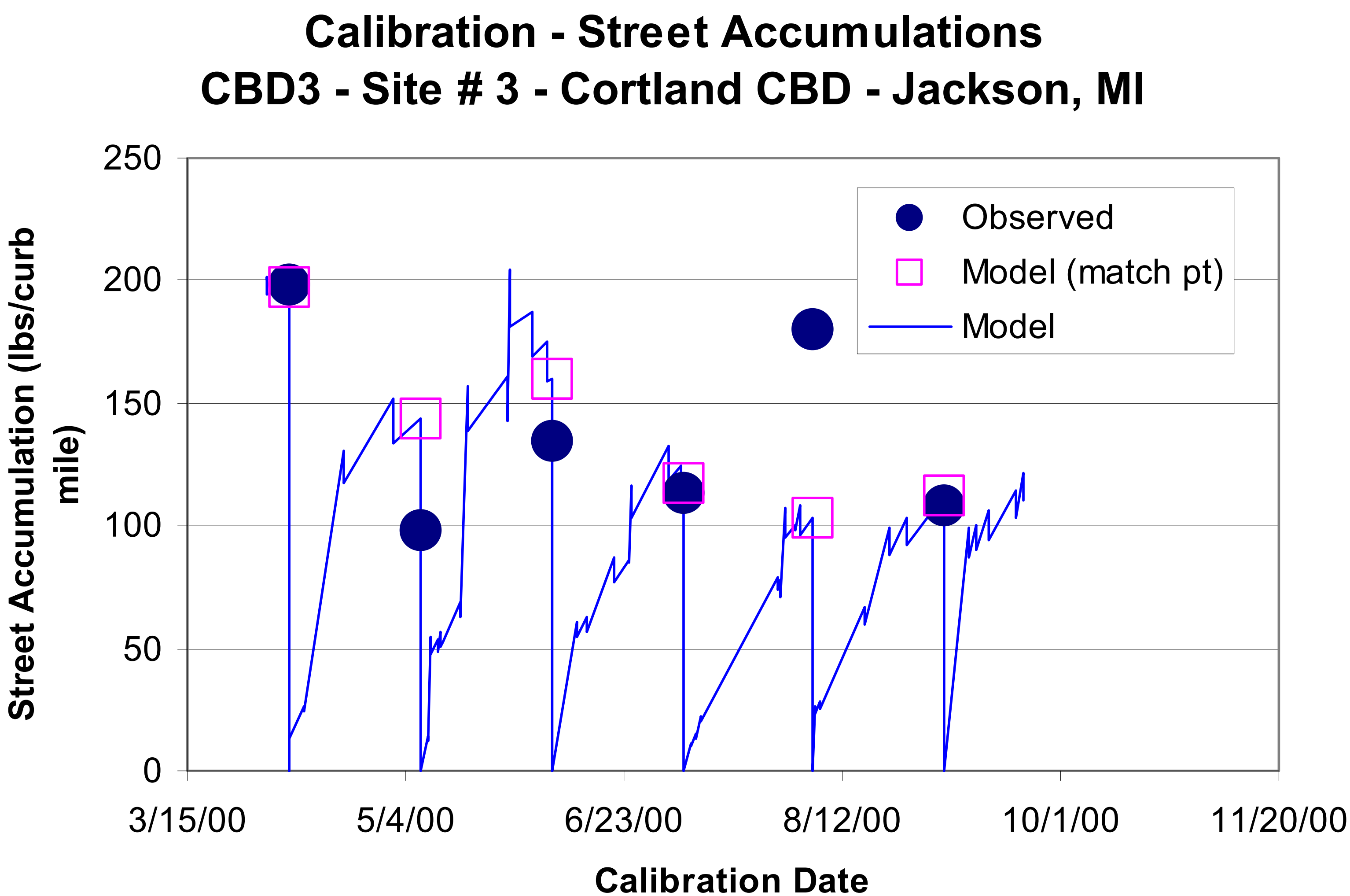
*RTI Laboratories, Inc. Quality Assurance Plan may be acquired by contacting RTI Laboratories.*

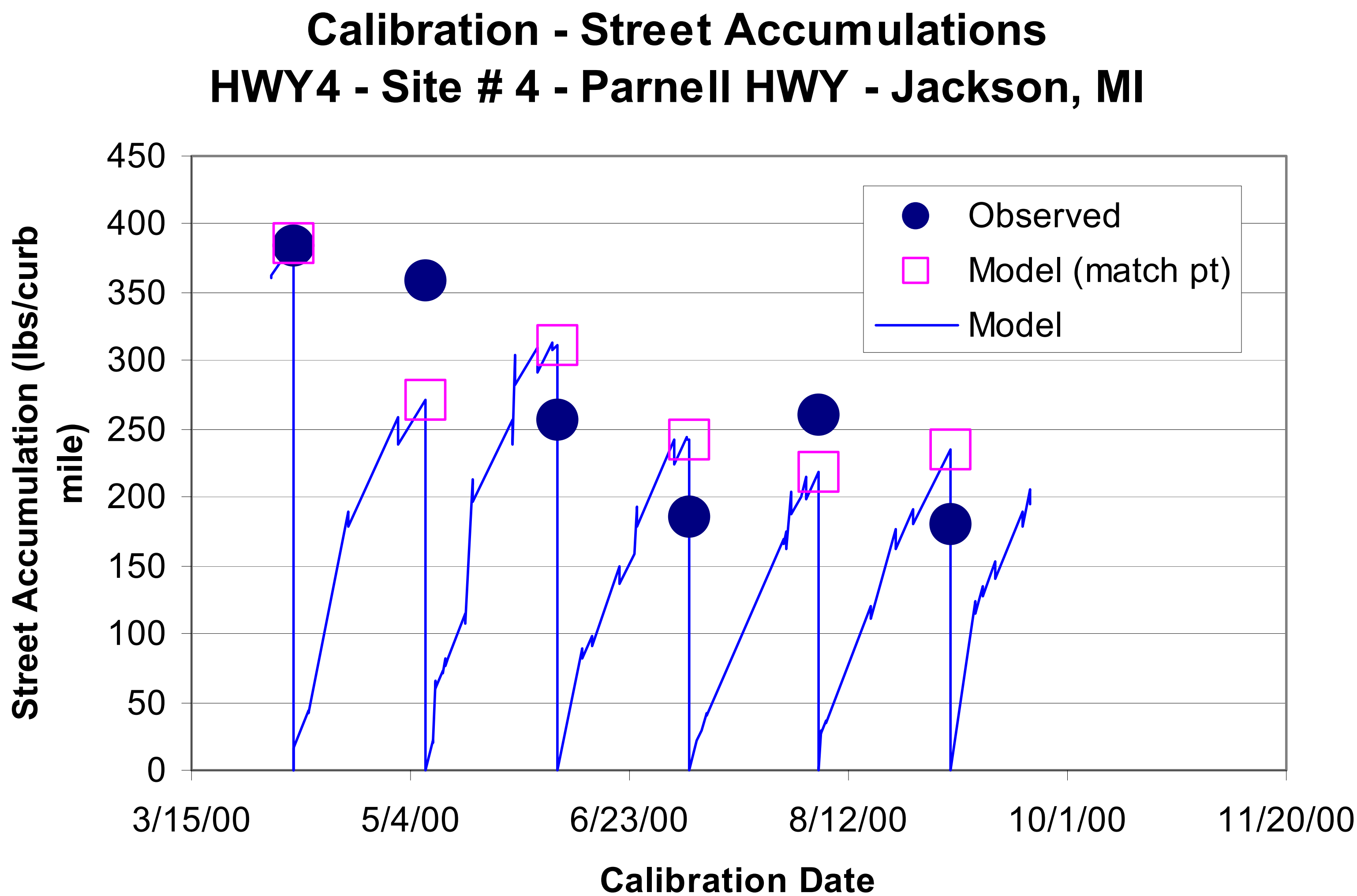
# APPENDIX F

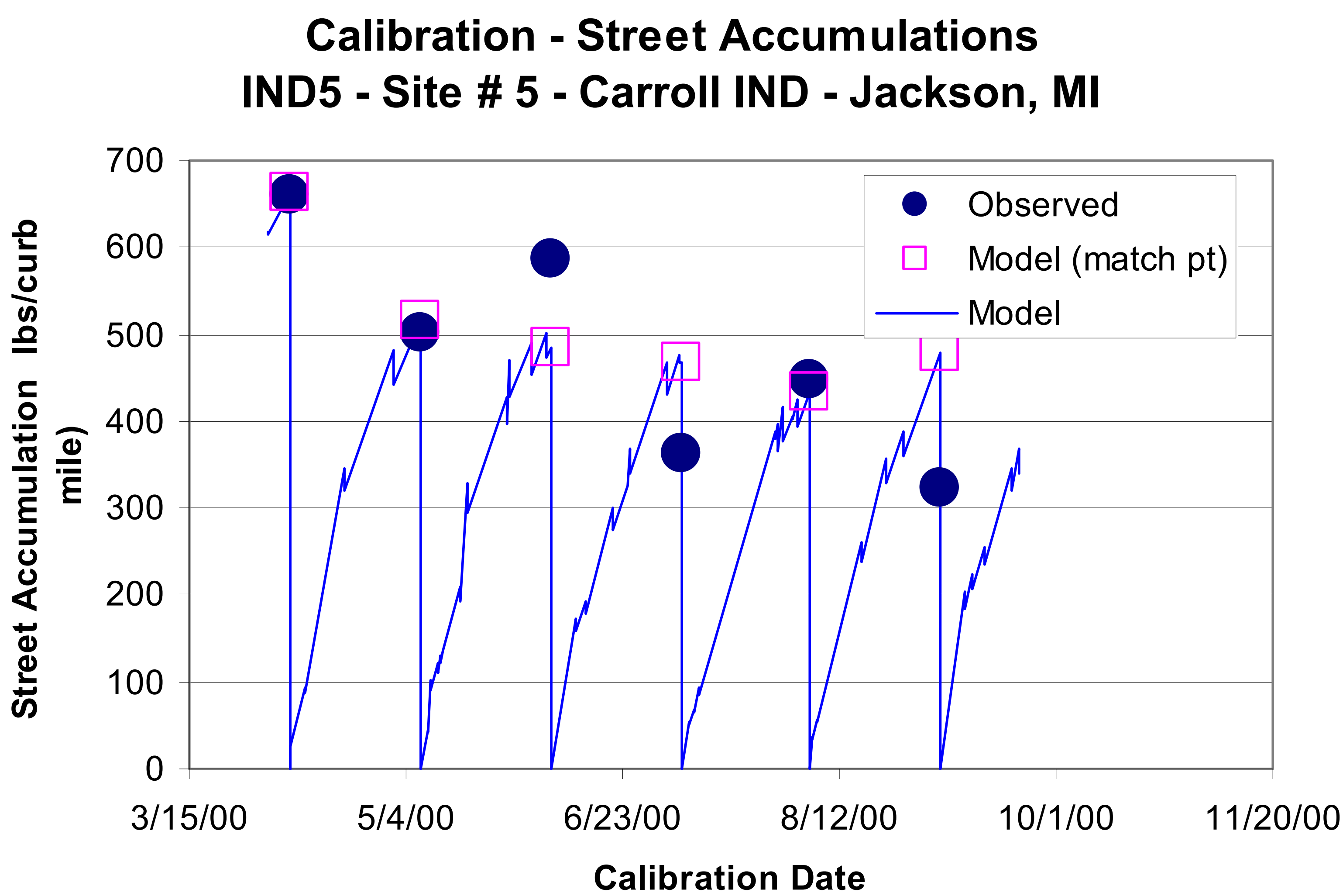
## Street Dirt: Catch Basin Calibration Graphs


Calibration - Street Accumulations
SFR1 - Site # 1 - Durand SFR - Jackson, MI
Street Accumulation (lbs/curb mile)
250
200
150
100
50
0
Observed
Model (match pt)
Model
3/15/00
5/4/00
6/23/00
8/12/00
10/1/00
11/20/00
Calibration Date

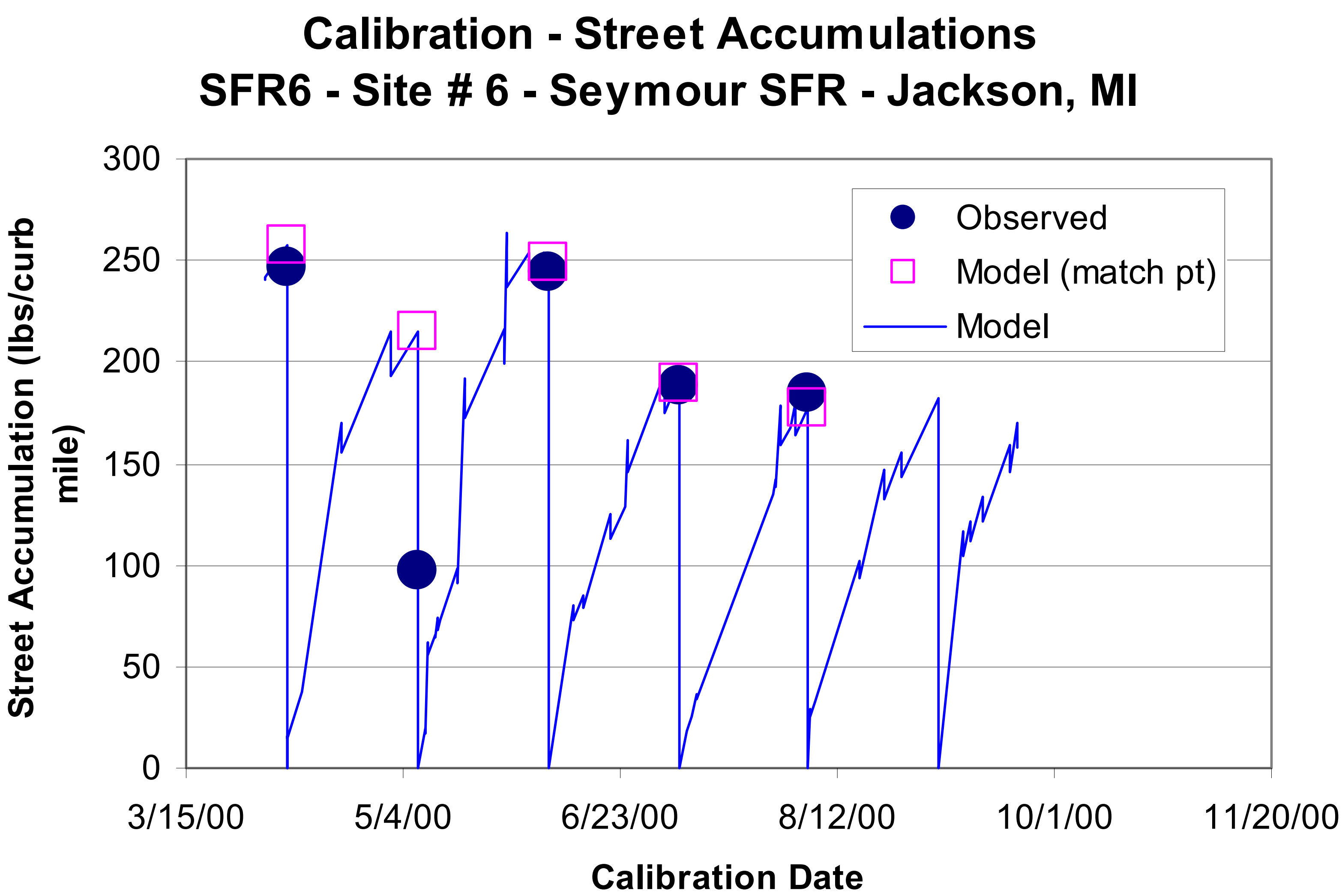

Calibration - Street Accumulations
SFR2 - Site # 2 - Jackson SFR - Jackson, MI
Street Accumulation (lbs/curb mile)
350
300
250
200
150
100
50
0
3/15/00
5/4/00
6/23/00
8/12/00
10/1/00
11/20/00
Calibration Date
Observed
Model (match pt)
Model

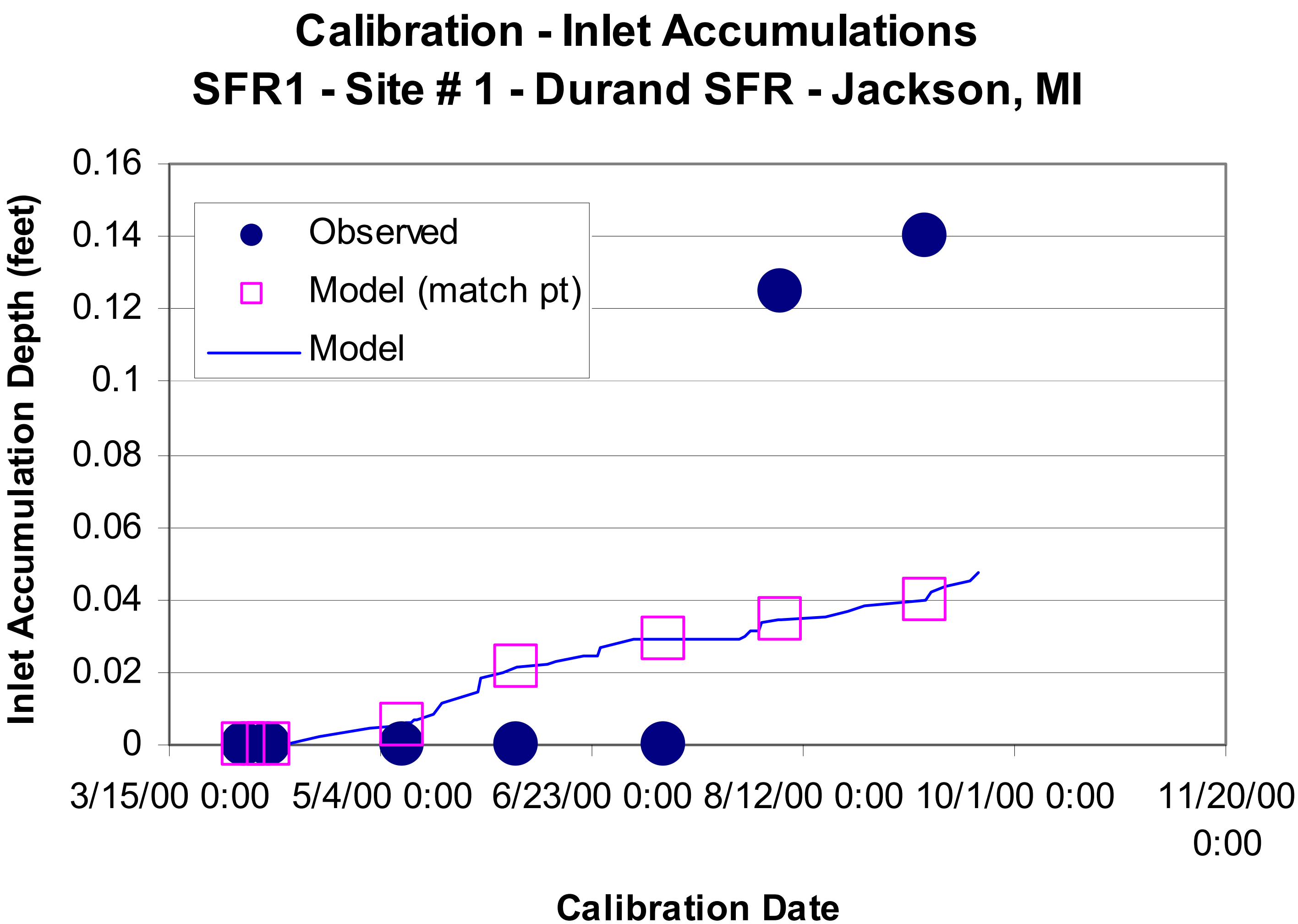

Calibration - Street Accumulations
CBD3 - Site # 3 - Cortland CBD - Jackson, MI
Street Accumulation (lbs/curb mile)
250
200
150
100
50
0
3/15/00
5/4/00
6/23/00
8/12/00
10/1/00
11/20/00
Calibration Date
Observed
Model (match pt)
Model

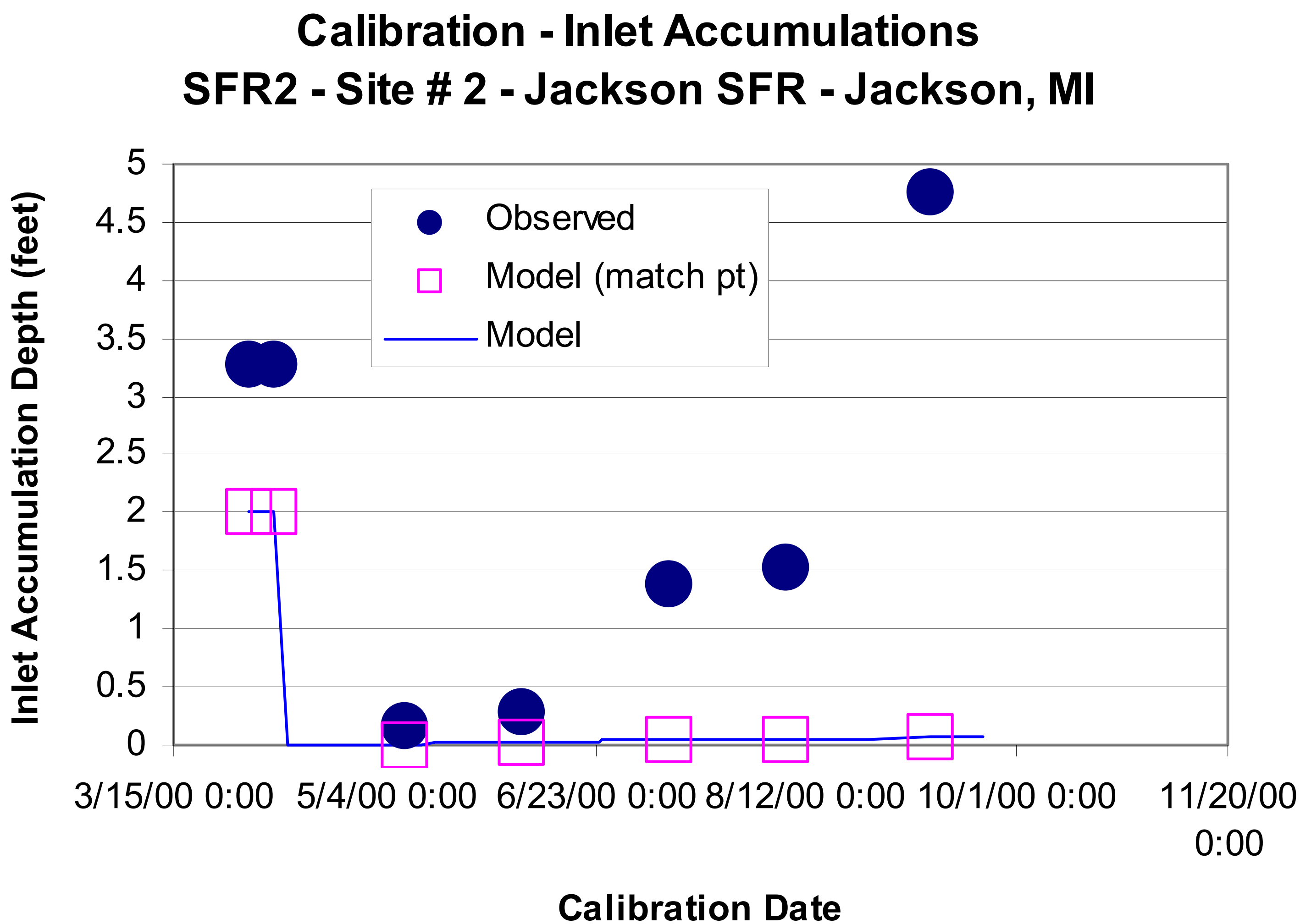

Calibration - Street Accumulations
HWY4 - Site # 4 - Parnell HWY - Jackson, MI
Street Accumulation (lbs/curb mile)
450
400
350
300
250
200
150
100
50
0
3/15/00
5/4/00
6/23/00
8/12/00
10/1/00
11/20/00
Calibration Date
Observed
Model (match pt)
Model



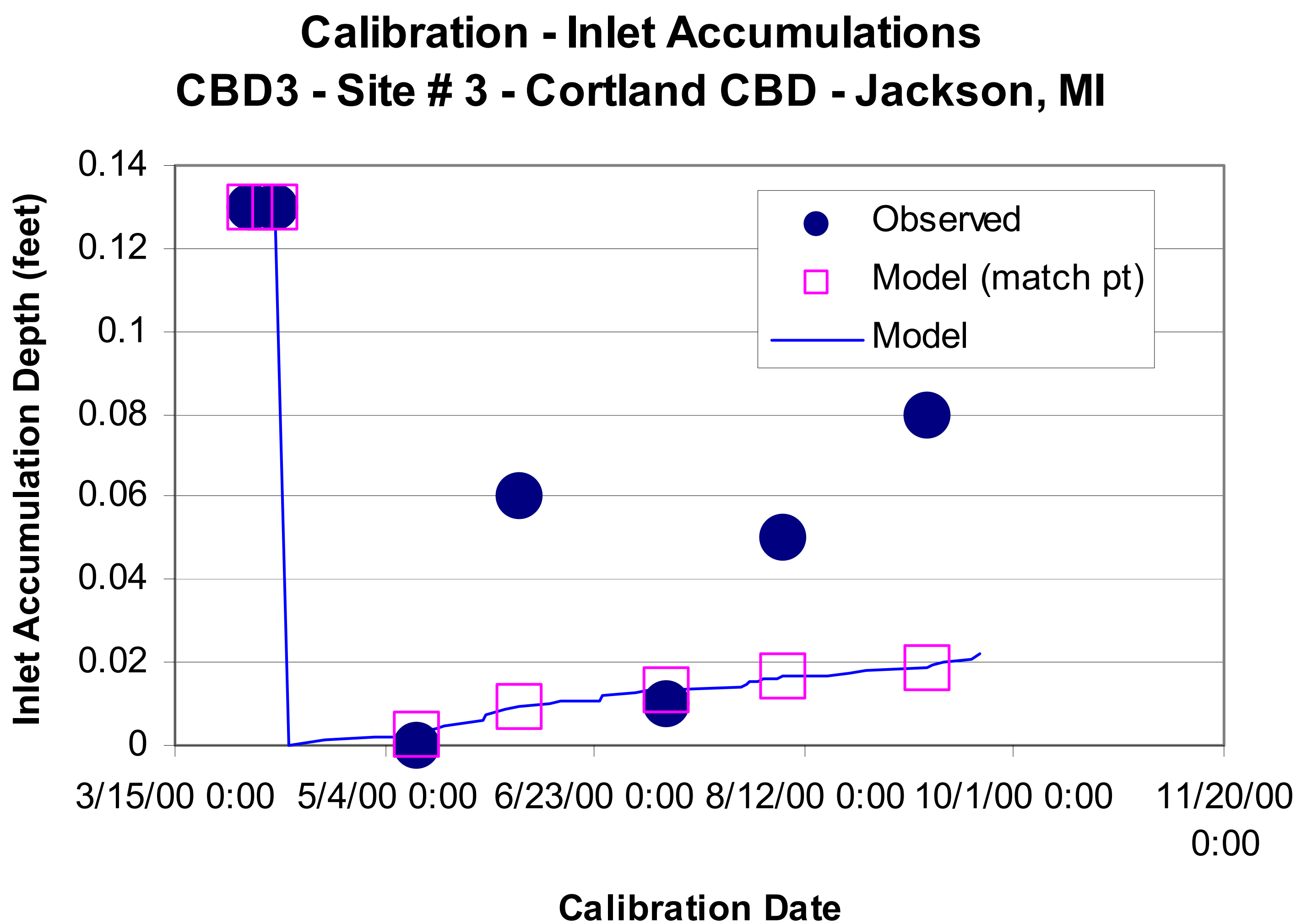
Calibration - Street Accumulations
IND5 - Site # 5 - Carroll IND - Jackson, MI
Street Accumulation lbs/curb mile)
700
600
500
400
300
200
100
0
3/15/00
5/4/00
6/23/00
8/12/00
10/1/00
11/20/00
Calibration Date
Observed
Model (match pt)
Model

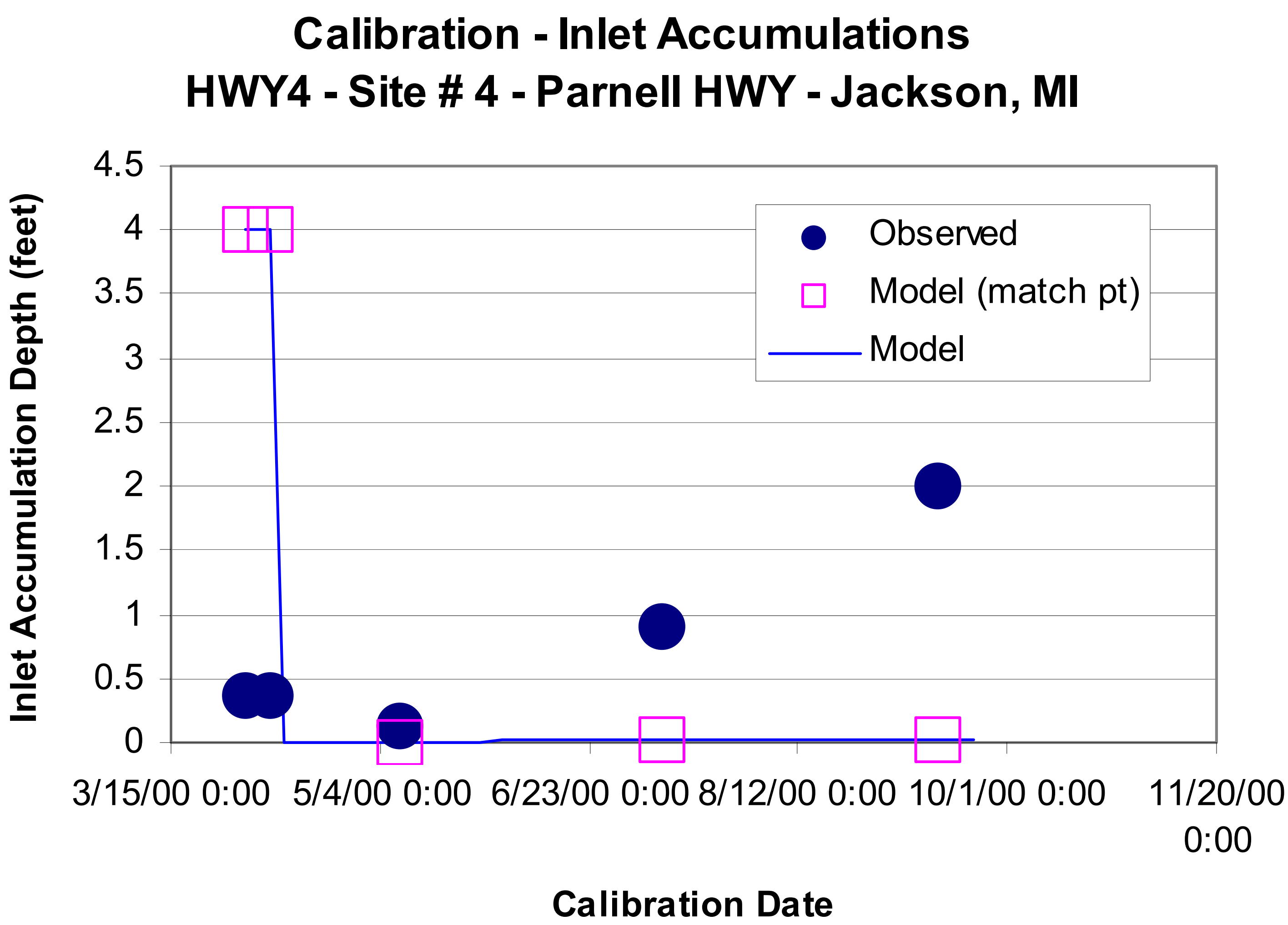

Calibration - Street Accumulations
SFR6 - Site # 6 - Seymour SFR - Jackson, MI
Street Accumulation (lbs/curb mile)
300
250
200
150
100
50
0
3/15/00
5/4/00
6/23/00
8/12/00
10/1/00
11/20/00
Calibration Date
Observed
Model (match pt)
Model


Calibration - Inlet Accumulations
SFR1 - Site # 1 - Durand SFR - Jackson, MI
Inlet Accumulation Depth (feet)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Observed
Model (match pt)
Model
3/15/00 0:00
5/4/00 0:00
6/23/00 0:00
8/12/00 0:00
10/1/00 0:00
11/20/00 0:00
Calibration Date

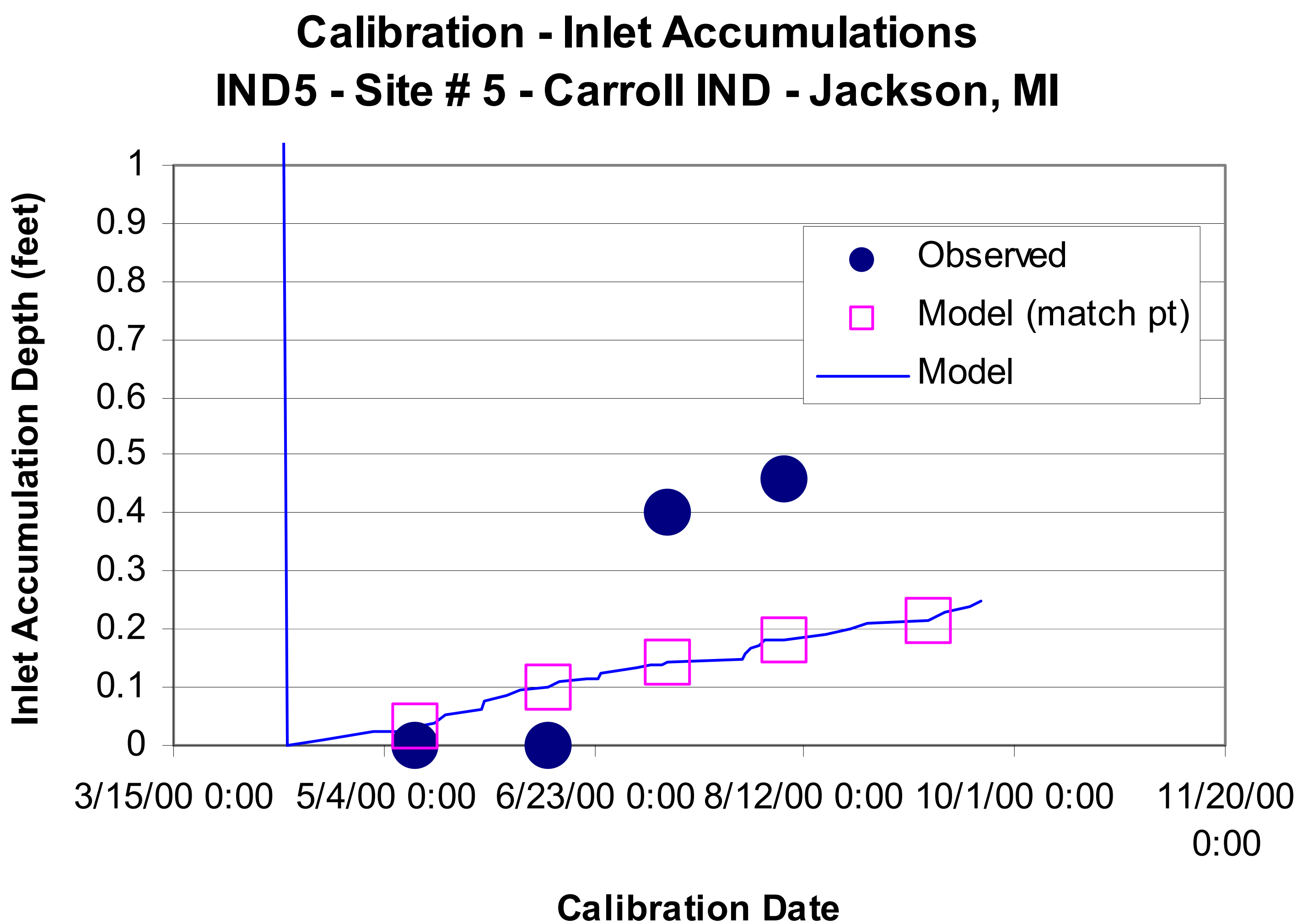


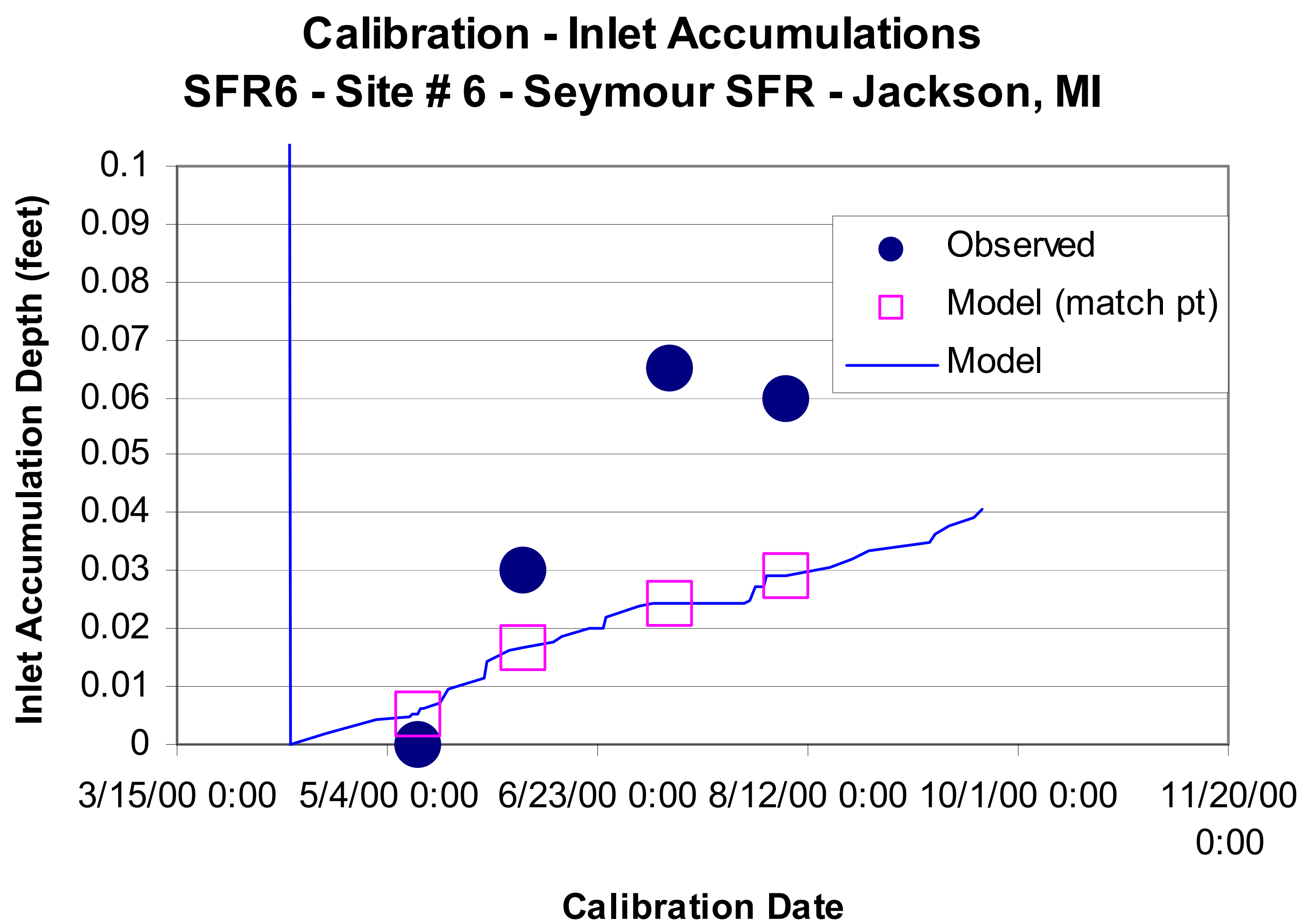
Calibration - Inlet Accumulations
SFR2 - Site # 2 - Jackson SFR - Jackson, MI
Inlet Accumulation Depth (feet)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Observed
Model (match pt)
Model
3/15/00 0:00
5/4/00 0:00
6/23/00 0:00
8/12/00 0:00
10/1/00 0:00
11/20/00 0:00
Calibration Date


Calibration - Inlet Accumulations
CBD3 - Site # 3 - Cortland CBD - Jackson, MI
Observed
Model (match pt)
Model
Inlet Accumulation Depth (feet)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
3/15/00 0:00
5/4/00 0:00
6/23/00 0:00
8/12/00 0:00
10/1/00 0:00
11/20/00 0:00
Calibration Date



Calibration - Inlet Accumulations
HWY4 - Site # 4 - Parnell HWY - Jackson, MI
Inlet Accumulation Depth (feet)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
3/15/00 0:00
5/4/00 0:00
6/23/00 0:00
8/12/00 0:00
10/1/00 0:00
11/20/00 0:00
Calibration Date
Observed
Model (match pt)
Model

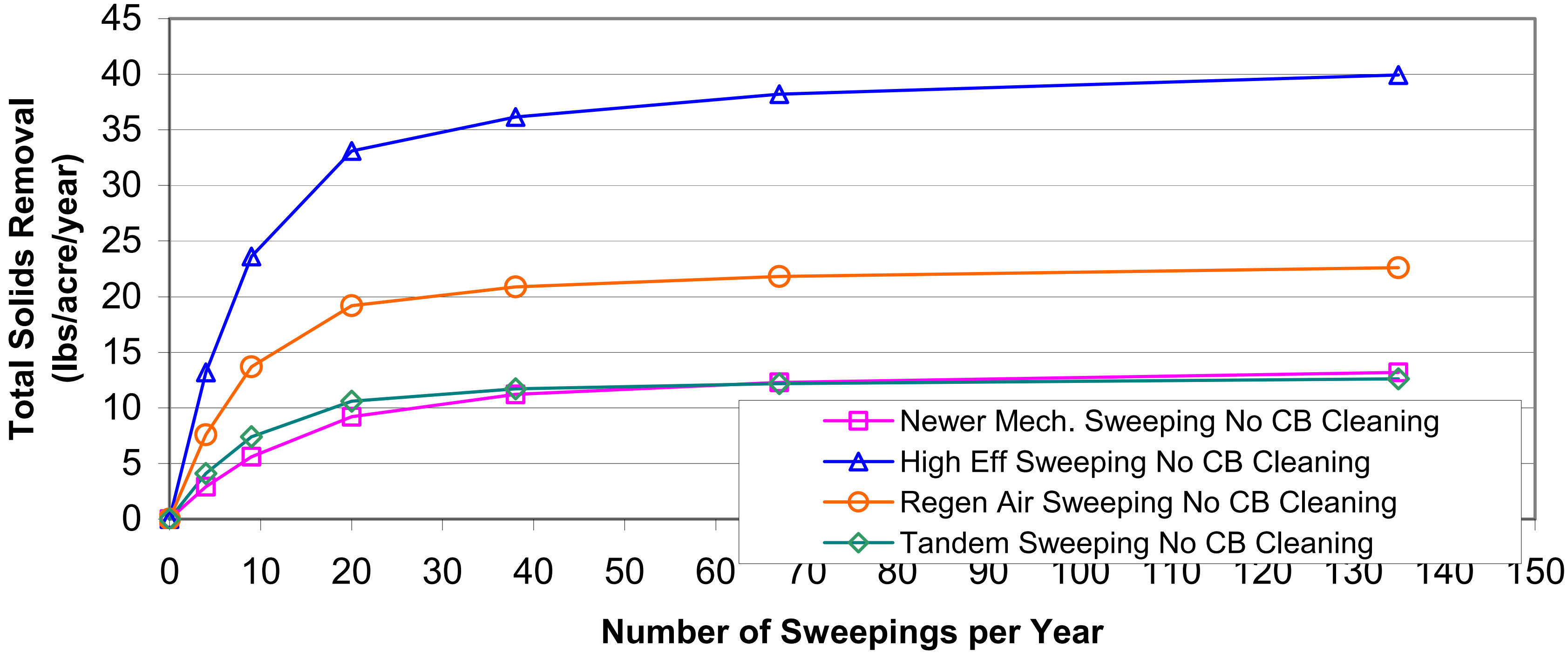

Calibration - Inlet Accumulations
IND5 - Site # 5 - Carroll IND - Jackson, MI
Inlet Accumulation Depth (feet)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Observed
Model (match pt)
Model
3/15/00 0:00
5/4/00 0:00
6/23/00 0:00
8/12/00 0:00
10/1/00 0:00
11/20/00 0:00
Calibration Date

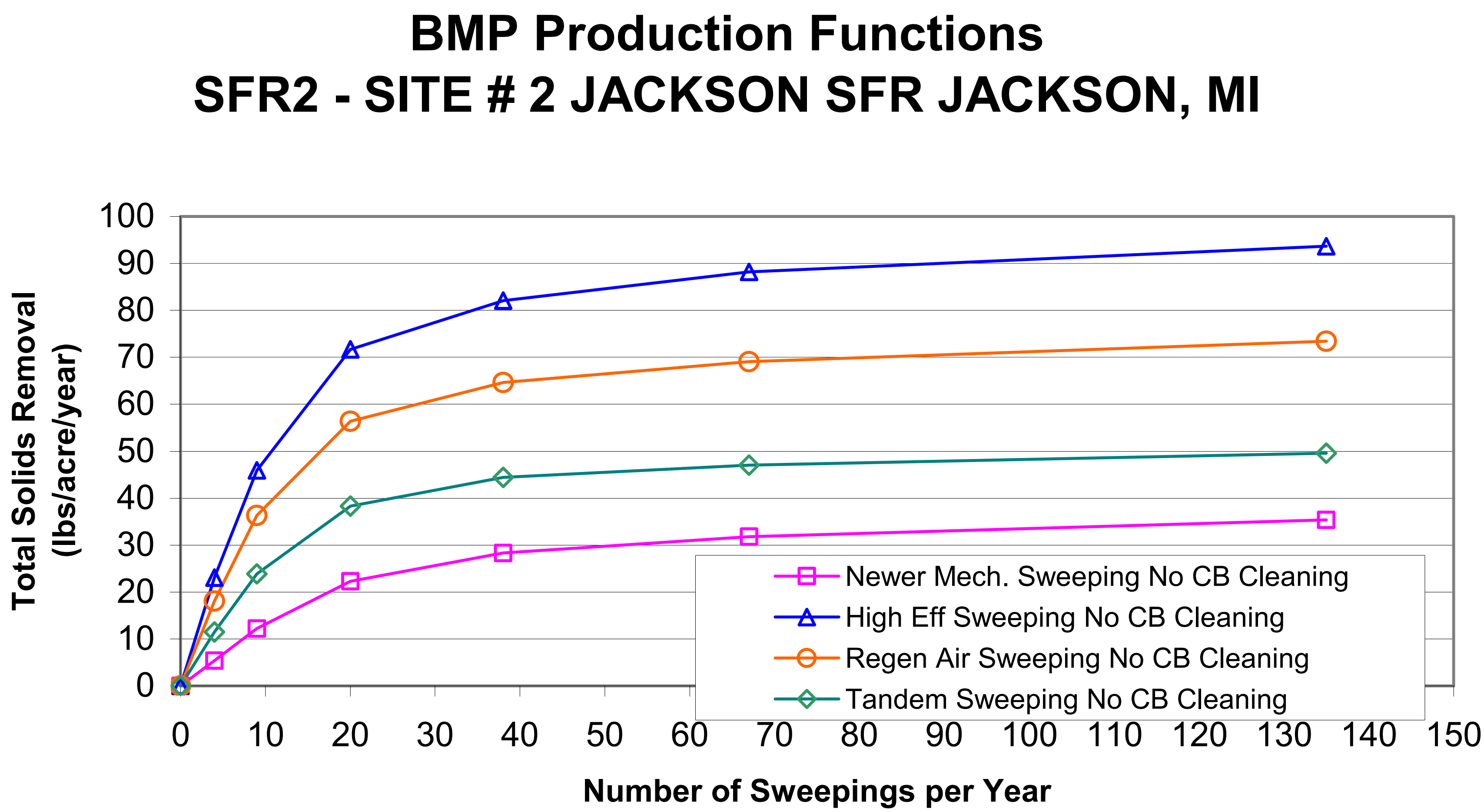

Calibration - Inlet Accumulations
SFR6 - Site # 6 - Seymour SFR - Jackson, MI
Inlet Accumulation Depth (feet)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Observed
Model (match pt)
Model
3/15/00 0:00
5/4/00 0:00
6/23/00 0:00
8/12/00 0:00
10/1/00 0:00
11/20/00 0:00
Calibration Date

# APPENDIX G

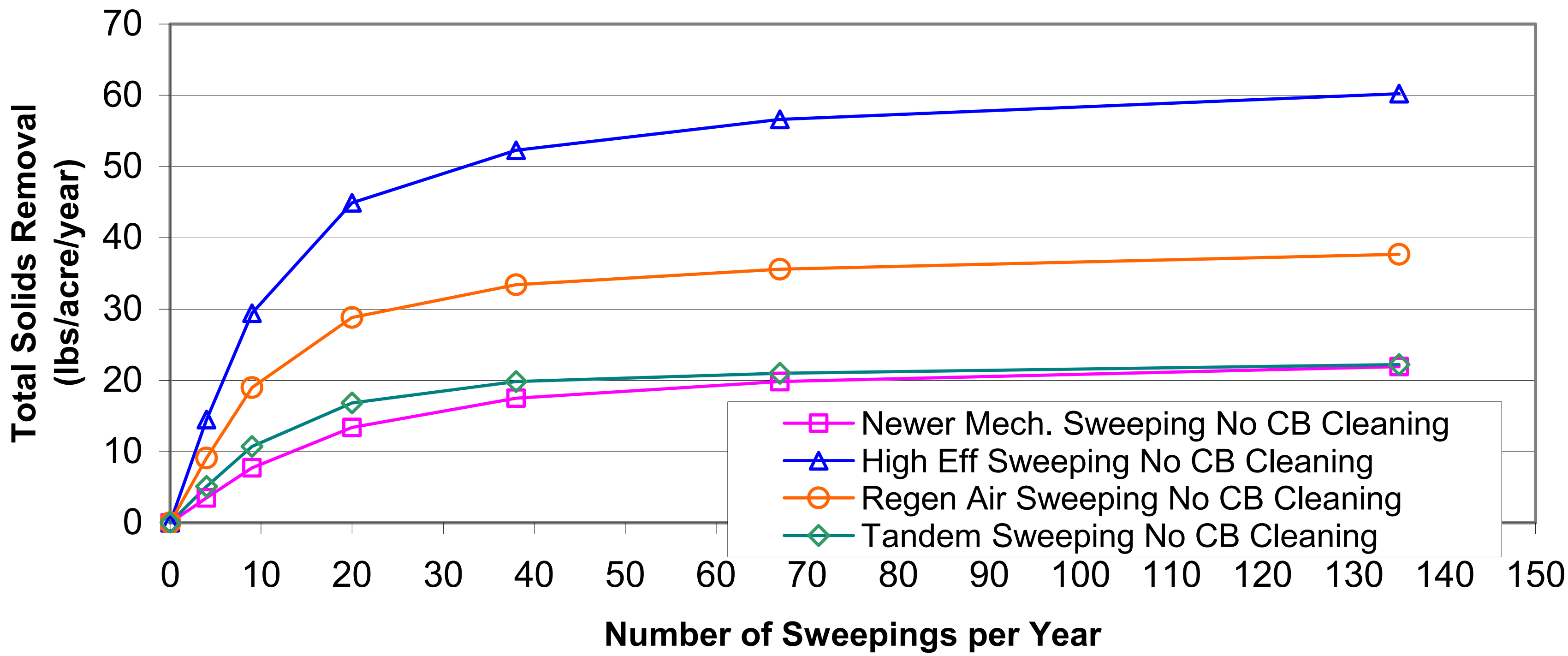
## Production Functions

# BMP Production Functions
# SFR1 - SITE # 1 DURAND SFR JACKSON, MI

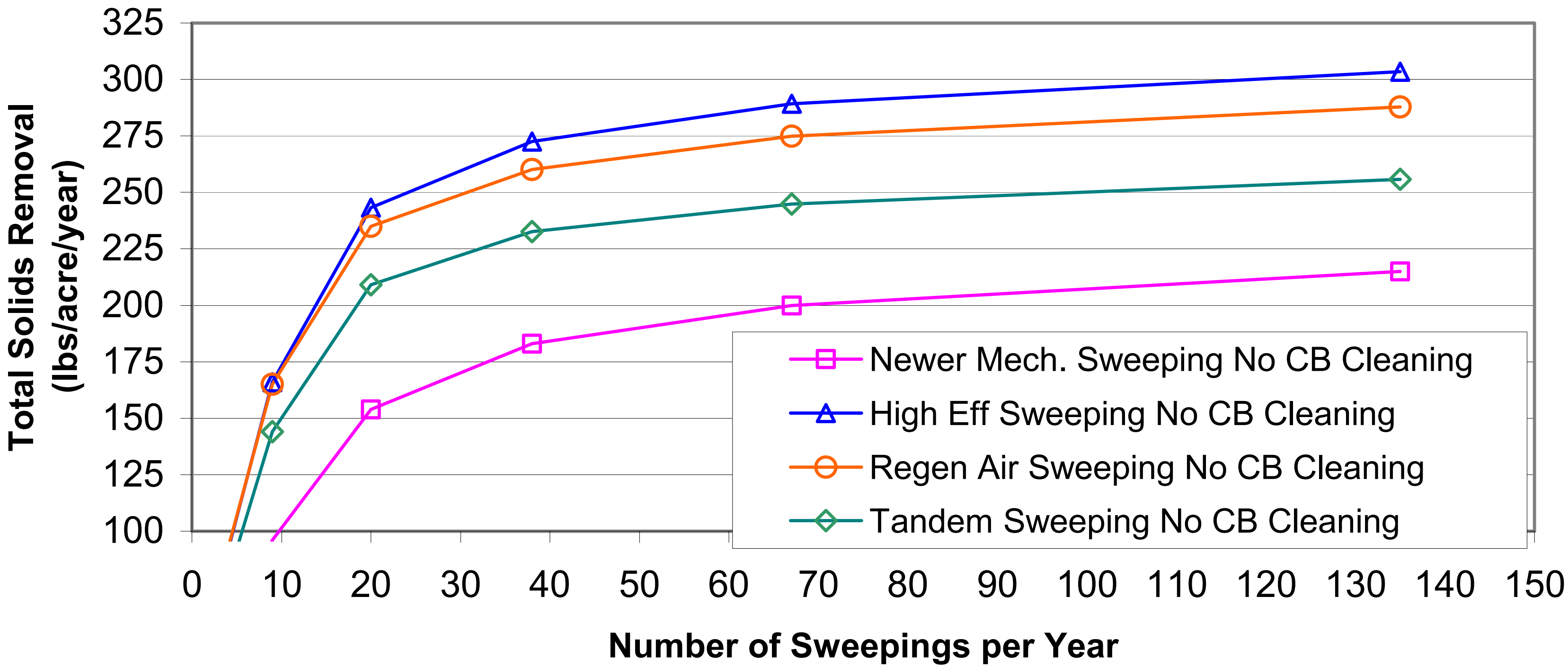



BMP Production Functions
SFR2 - SITE # 2 JACKSON SFR JACKSON, MI
Total Solids Removal (lbs/acre/year)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Number of Sweepings per Year
Newer Mech. Sweeping No CB Cleaning
High Eff Sweeping No CB Cleaning
Regen Air Sweeping No CB Cleaning
Tandem Sweeping No CB Cleaning

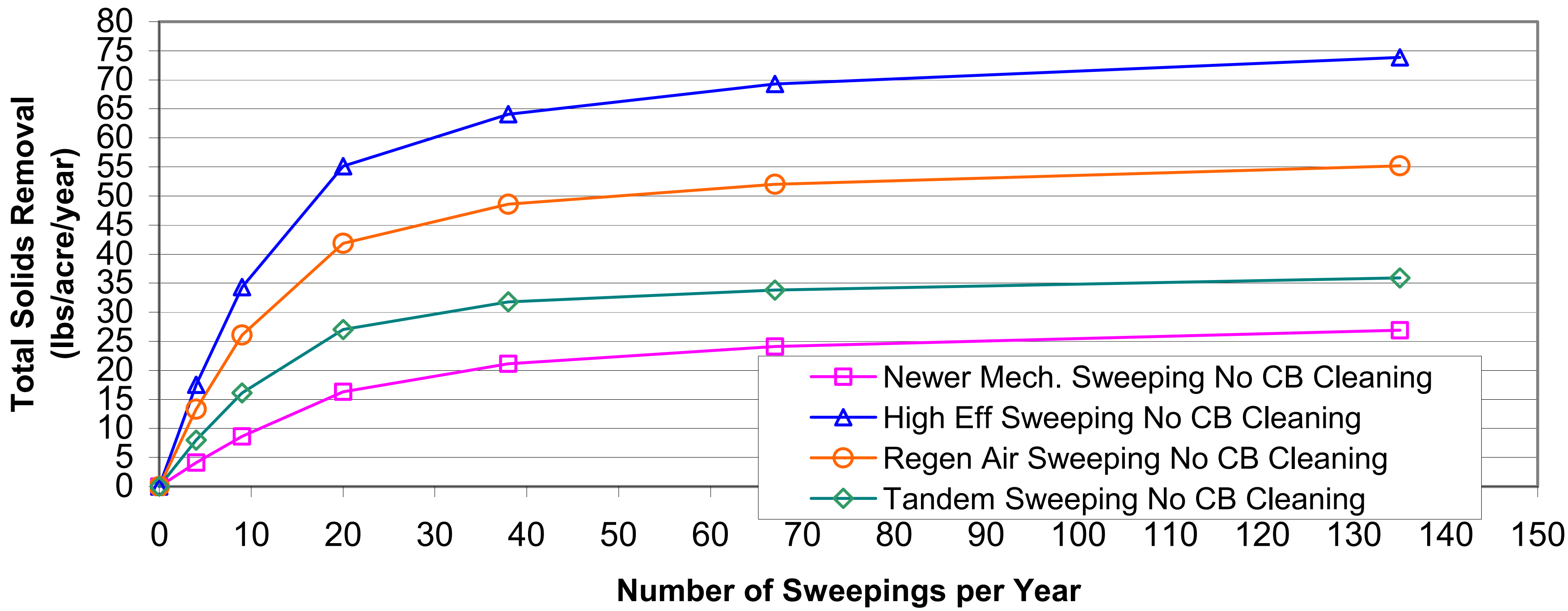
# BMP Production Functions
# CBD3 - SITE # 3 CORTLAND CBD JACKSON, MI



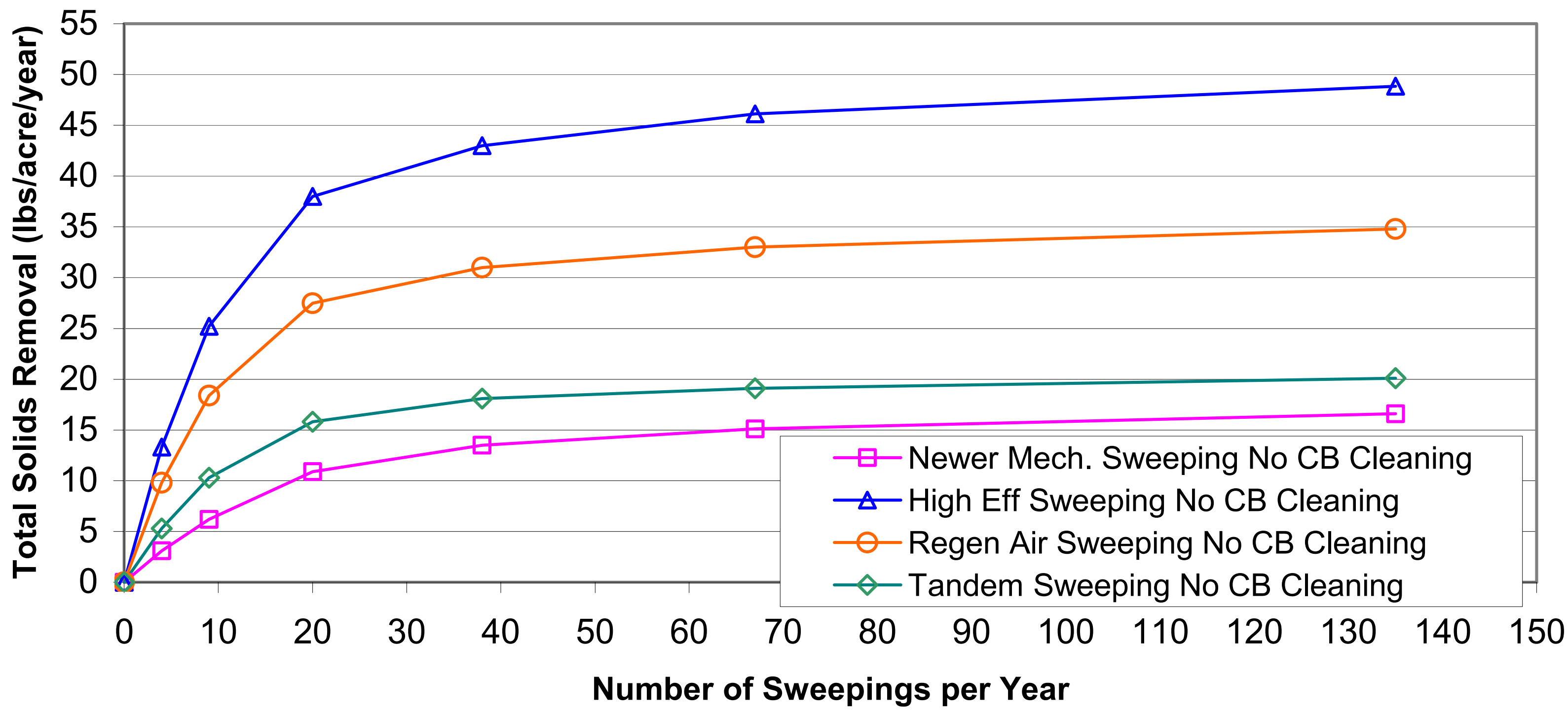
# BMP Production Functions
# HWY4 - SITE # 4 PARNELL HWY JACKSON, MI



# BMP Production Functions
# IND5 - SITE # 5 CARROLL IND JACKSON, MI



# BMP Production Functions
# SFR6 - SITE # 6 SEYMOUR SFR JACKSON, MI



# APPENDIX H

## Annual Load Reductions

**Quantifying the Impact of Catch Basin and Street Sweeping on Strom Water Quality for a Great Lakes Tributary: A Pilot Study**

**SUMMARY OF AVERAGE ALTERNATIVE UNIT POLLUTANT WASHOFFS**

Percent Reduction of Washoff Compared to Existing

| LAND USE AND BMP DESCRIPTION | | TSS | COD | TP | Cd | Cr | Pb | Cu | Zn |
|---|---|---|---|---|---|---|---|---|---|
| **SFR1 - SITE # 1 DURAND SFR JACKSON, MICHIGAN** | | | | | | | | | |
| Optimal | High Eff. (EV1) Sweeping (30 day interval; 9 per year) with Annual Inlet Cleaning | 73% | 74% | 72% | 71% | 73% | 72% | 72% | 71% |
| Alternatve | Regenerative Air Sweeping (61 day interval; 4 per year) with Annual Inlet Cleaning | 52% | 54% | 52% | 50% | 53% | 51% | 52% | 51% |
| **SFR2 - SITE # 2 JACKSON SFR JACKSON, MICHIGAN** | | | | | | | | | |
| Optimal | High Eff. (EV1) Sweeping (14 day interval; 20 per year) with Annual Inlet Cleaning | 82% | 84% | 82% | 81% | 83% | 81% | 82% | 81% |
| Alternatve | Regenerative Air Sweeping (14 day interval; 20 per year) with Annual Inlet Cleaning | 74% | 74% | 73% | 72% | 73% | 73% | 72% | 72% |
| **CBD3 - SITE # 3 CORTLAND CBD JACKSON, MICHIGAN** | | | | | | | | | |
| Optimal | High Eff. (EV1) Sweeping (30 day interval; 9 per year) with Annual Inlet Cleaning | 66% | 69% | 66% | 63% | 67% | 65% | 65% | 64% |
| Alternatve | Regenerative Air Sweeping (61 day interval; 4 per year) with Annual Inlet Cleaning | 49% | 52% | 48% | 45% | 50% | 47% | 48% | 46% |
| **HWY4 - SITE # 4 PARNELL HWY JACKSON, MICHIGAN** | | | | | | | | | |
| Optimal | High Eff. (EV1) Sweeping (14 day interval; 20 per year) with Annual Inlet Cleaning | 84% | 85% | 83% | 82% | 84% | 83% | 83% | 83% |
| Alternatve | Regenerative Air Sweeping (14 day interval; 20 per year) with Annual Inlet Cleaning | 82% | 84% | 81% | 79% | 83% | 80% | 81% | 80% |
| **IND5 - SITE # 5 CARROLL IND JACKSON, MICHIGAN** | | | | | | | | | |

**Quantifying the Impact of Catch Basin and Street Sweeping on Strom Water Quality for a Great Lakes Tributary: A Pilot Study**

**SUMMARY OF AVERAGE ALTERNATIVE UNIT POLLUTANT WASHOFFS**

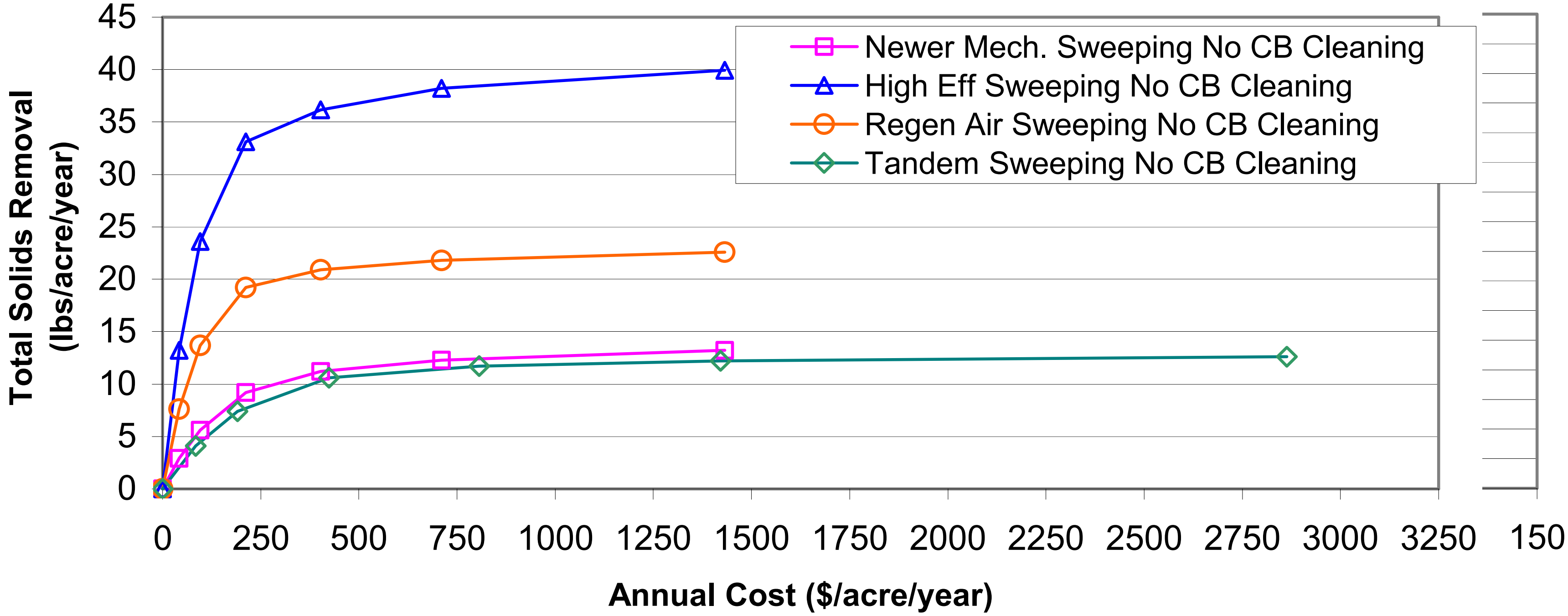
Percent Reduction of Washoff Compared to Existing

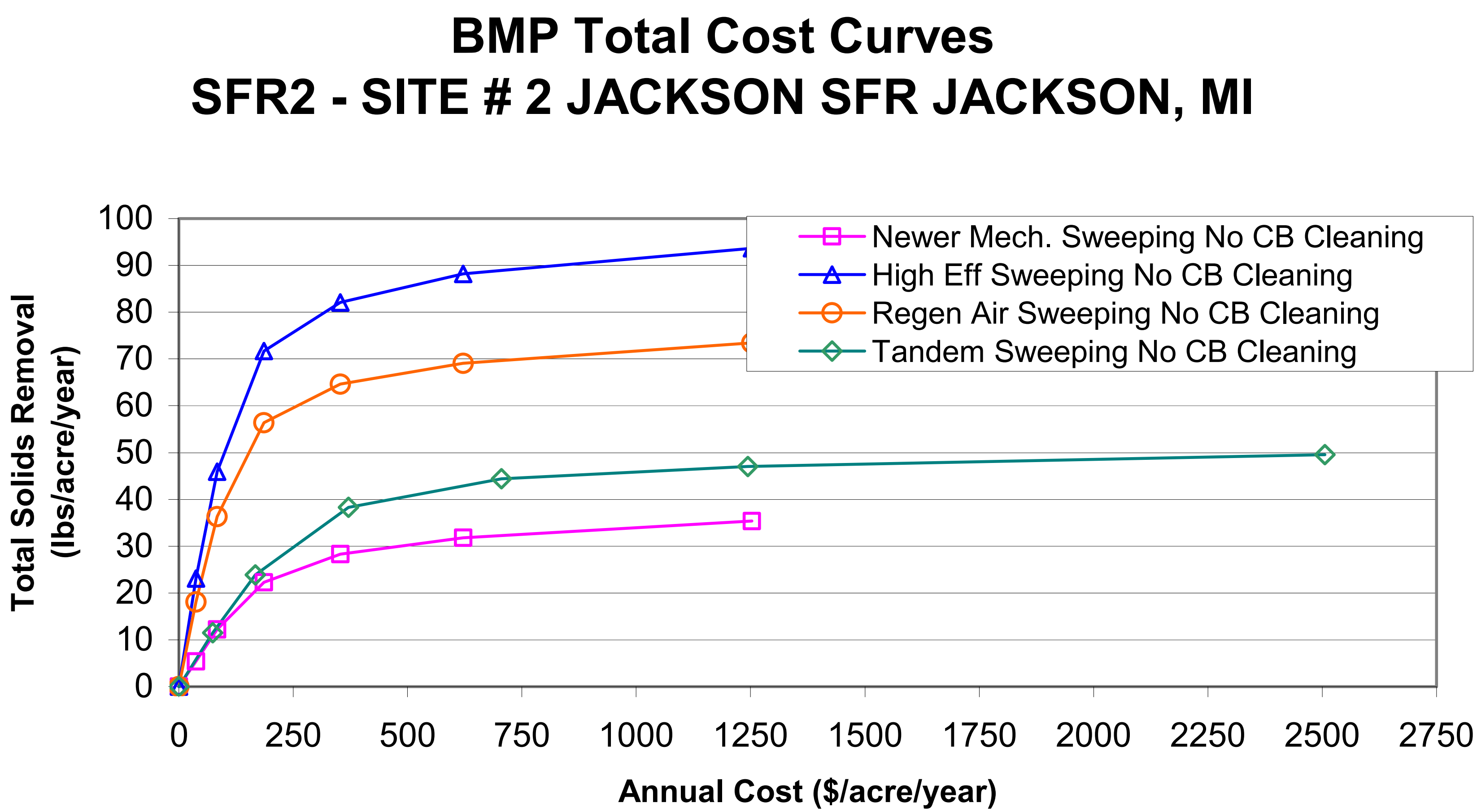
| LAND USE AND BMP DESCRIPTION | | TSS | COD | TP | Cd | Cr | Pb | Cu | Zn |
|---|---|---|---|---|---|---|---|---|---|
| Optimal | High Eff. (EV1) Sweeping (14 day interval; 20 per year) with Annual Inlet Cleaning | 79% | 82% | 79% | 77% | 80% | 78% | 78% | 77% |
| Alternatve | Regenerative Air Sweeping (14 day interval; 20 per year) with Annual Inlet Cleaning | 69% | 71% | 68% | 65% | 69% | 67% | 67% | 66% |
| **SFR6 - SITE # 6 SEYMOUR SFR JACKSON, MICHIGAN** | | | | | | | | | |
| Optimal | High Eff. (EV1) Sweeping (30 day interval; 9 per year) with Annual Inlet Cleaning | 69% | 71% | 68% | 66% | 69% | 67% | 68% | 67% |
| Alternatve | Regenerative Air Sweeping (30 day interval; 9 per year) with Annual Inlet Cleaning | 61% | 63% | 61% | 59% | 62% | 60% | 60% | 59% |
| **AVERAGE WASHOFF REMOVAL** | | | | | | | | | |
| Optimal | High Efficiency Sweeping | 75% | 78% | 75% | 73% | 76% | 74% | 75% | 74% |
| Optimal | Regenerative Air Sweeping | 65% | 66% | 64% | 62% | 65% | 63% | 63% | 62% |

# APPENDIX I

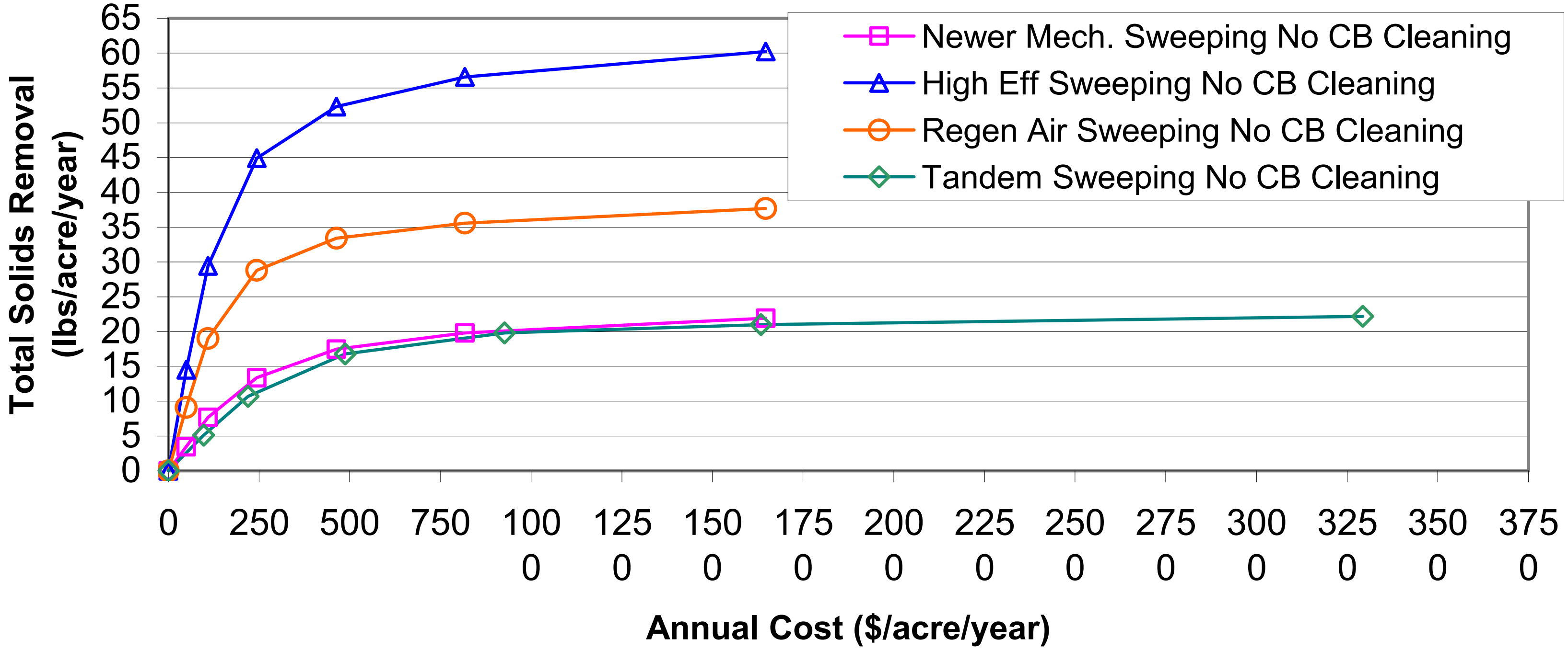
## Cost Curves

# BMP Total Cost Curves
# SFR1 - SITE # 1 DURAND SFR JACKSON, MI

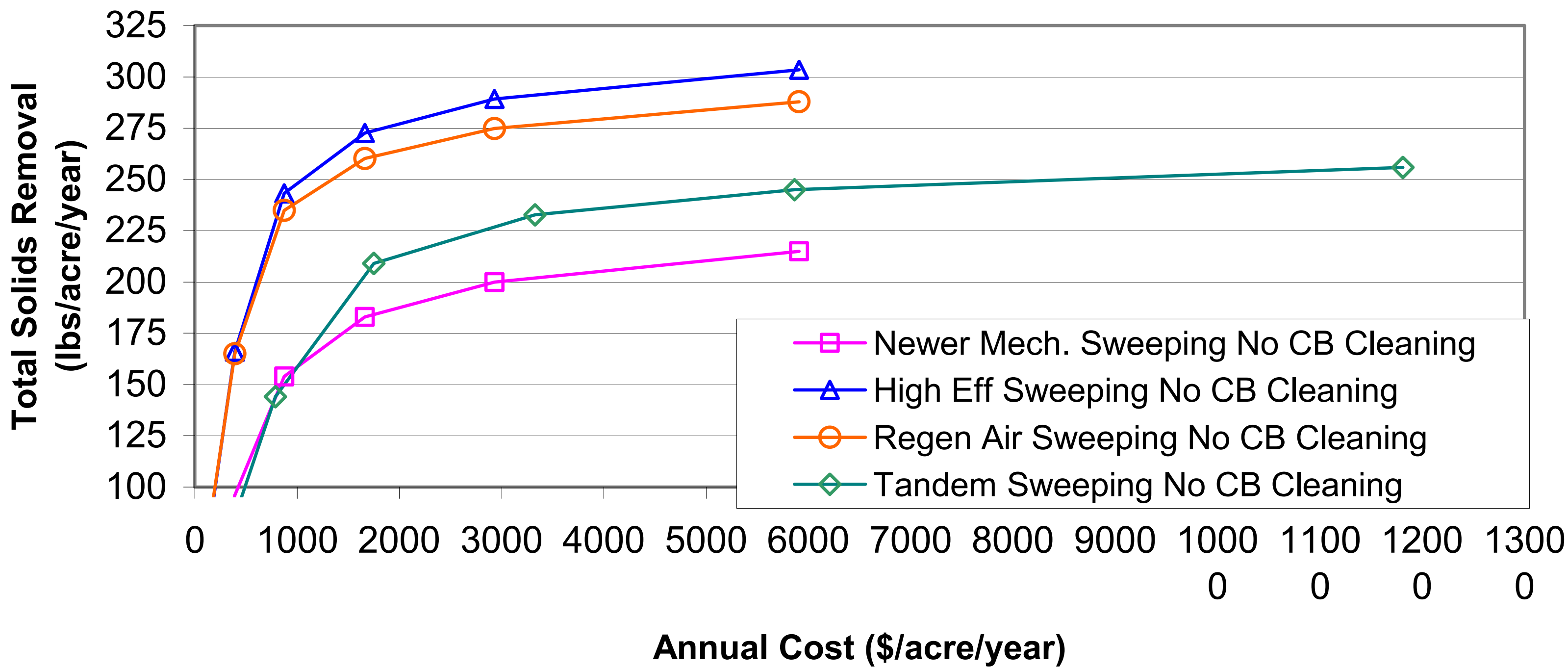


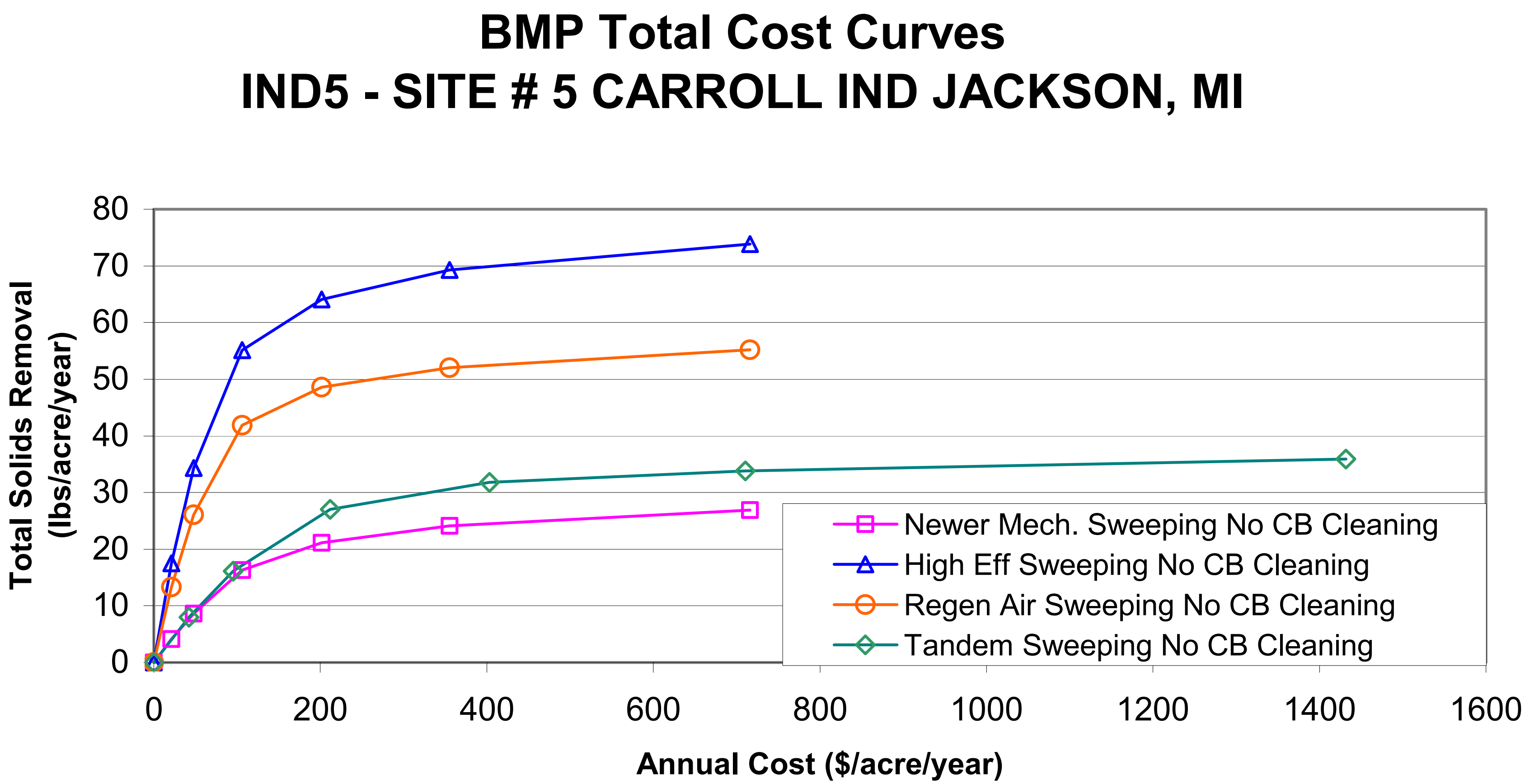

BMP Total Cost Curves
SFR2 - SITE # 2 JACKSON SFR JACKSON, MI
Newer Mech. Sweeping No CB Cleaning
High Eff Sweeping No CB Cleaning
Regen Air Sweeping No CB Cleaning
Tandem Sweeping No CB Cleaning
Total Solids Removal (lbs/acre/year)
100
90
80
70
60
50
40
30
20
10
0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
Annual Cost ($/acre/year)

## BMP Total Cost Curves
## CBD3 - SITE # 3 CORTLAND CBD JACKSON, MI

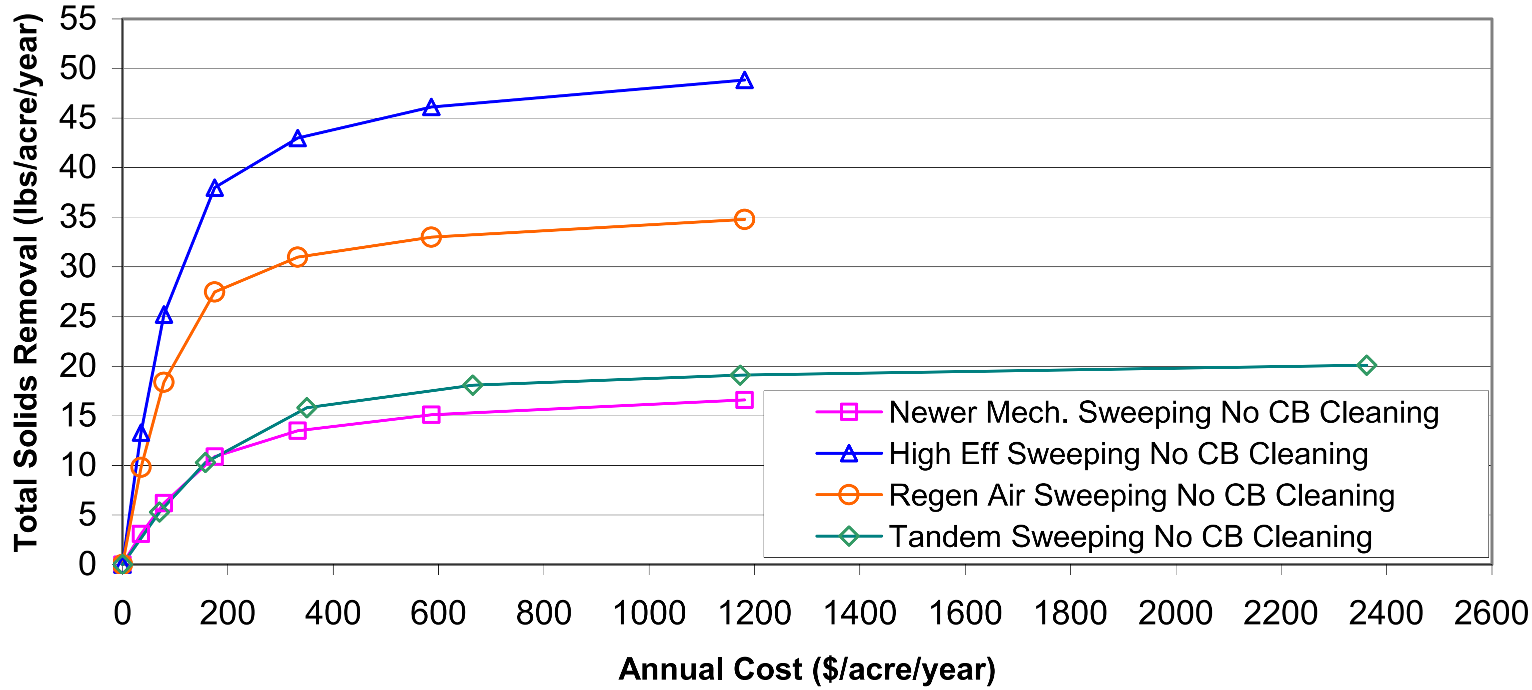


# BMP Total Cost Curves
# HWY4 - SITE # 4 PARNELL HWY JACKSON, MI

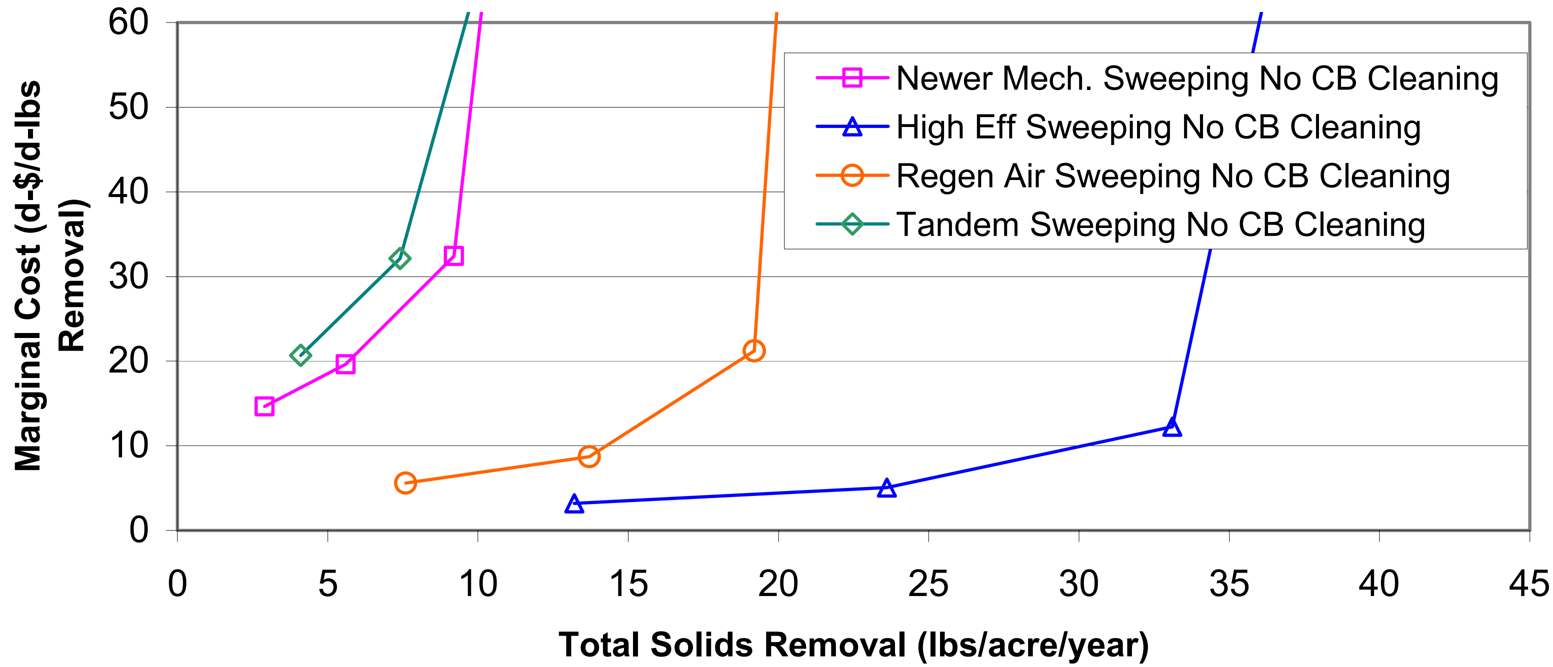



BMP Total Cost Curves
IND5 - SITE # 5 CARROLL IND JACKSON, MI
Total Solids Removal (lbs/acre/year)
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
Annual Cost ($/acre/year)
Newer Mech. Sweeping No CB Cleaning
High Eff Sweeping No CB Cleaning
Regen Air Sweeping No CB Cleaning
Tandem Sweeping No CB Cleaning

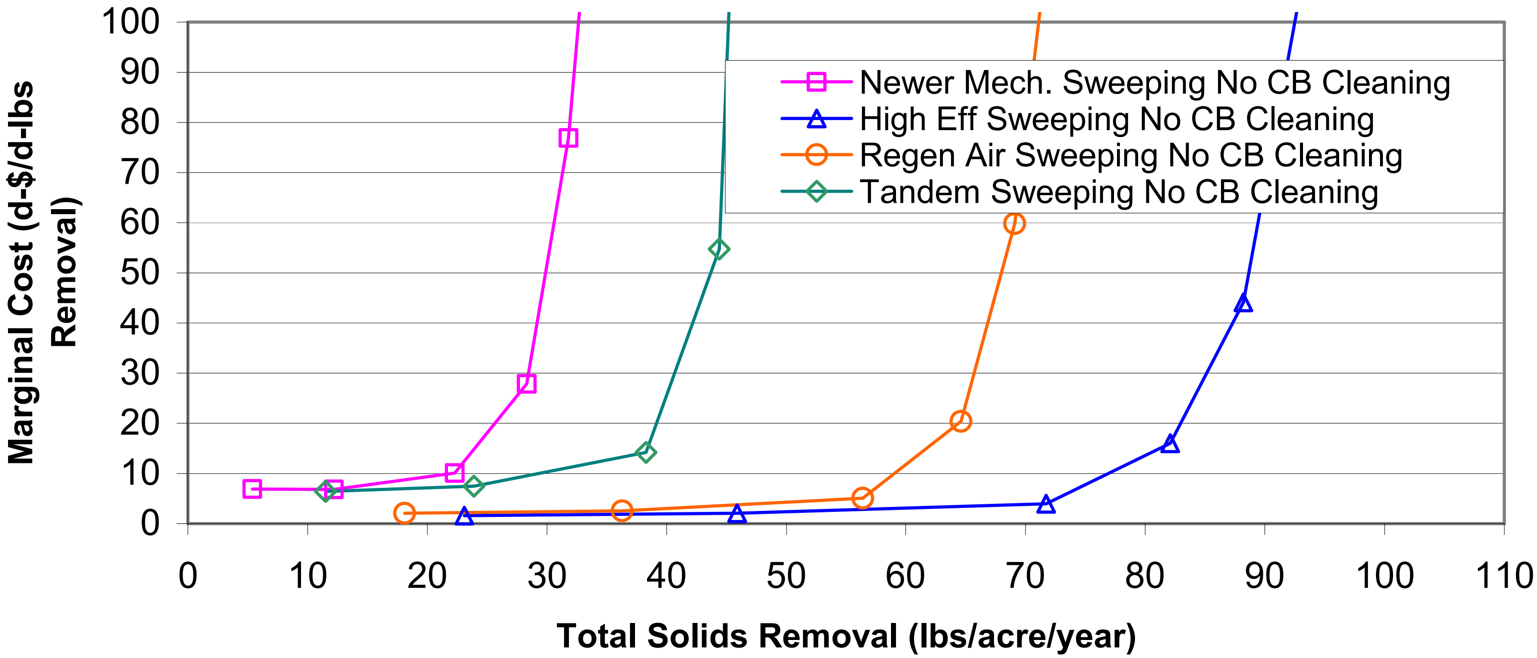
# BMP Total Cost Curves
# SFR6 - SITE # 6 SEYMOUR SFR JACKSON, MI



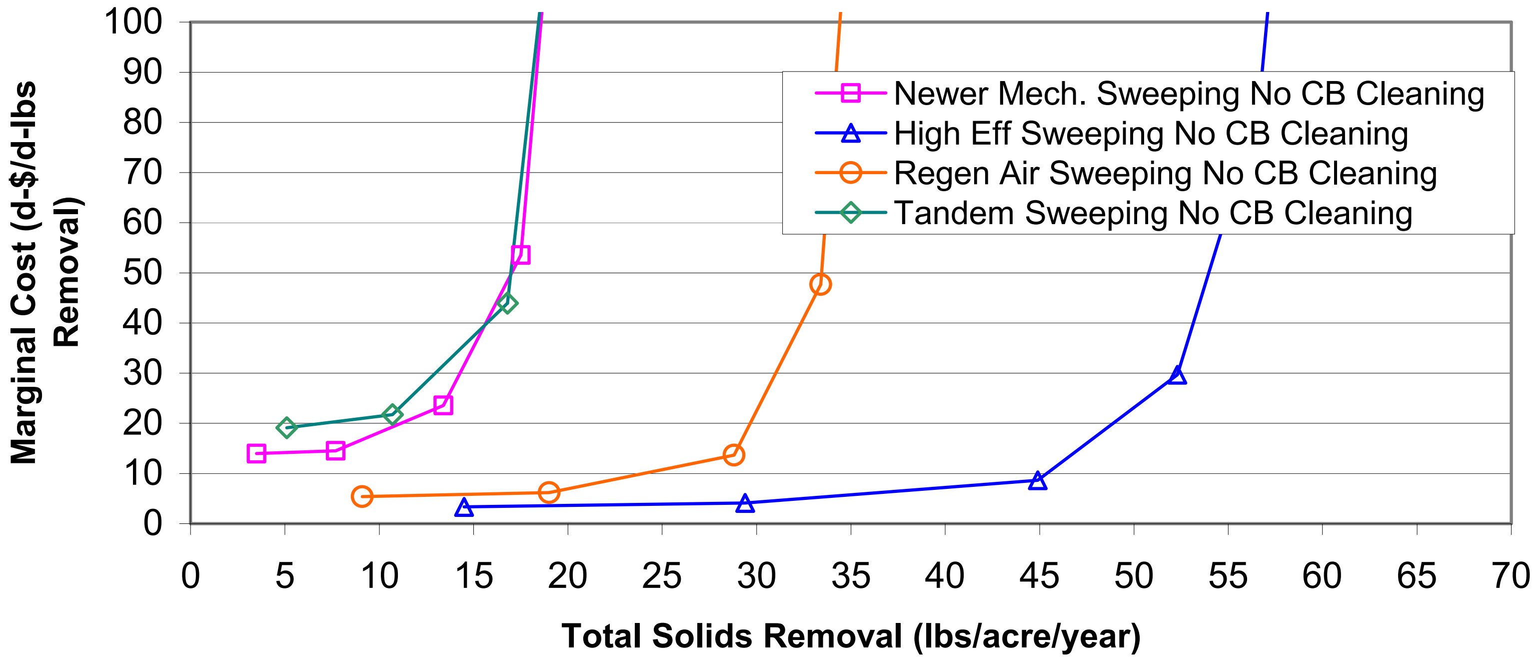
## BMP Marginal Cost Curves
## SFR1 - SITE # 1 DURAND SFR JACKSON, MI



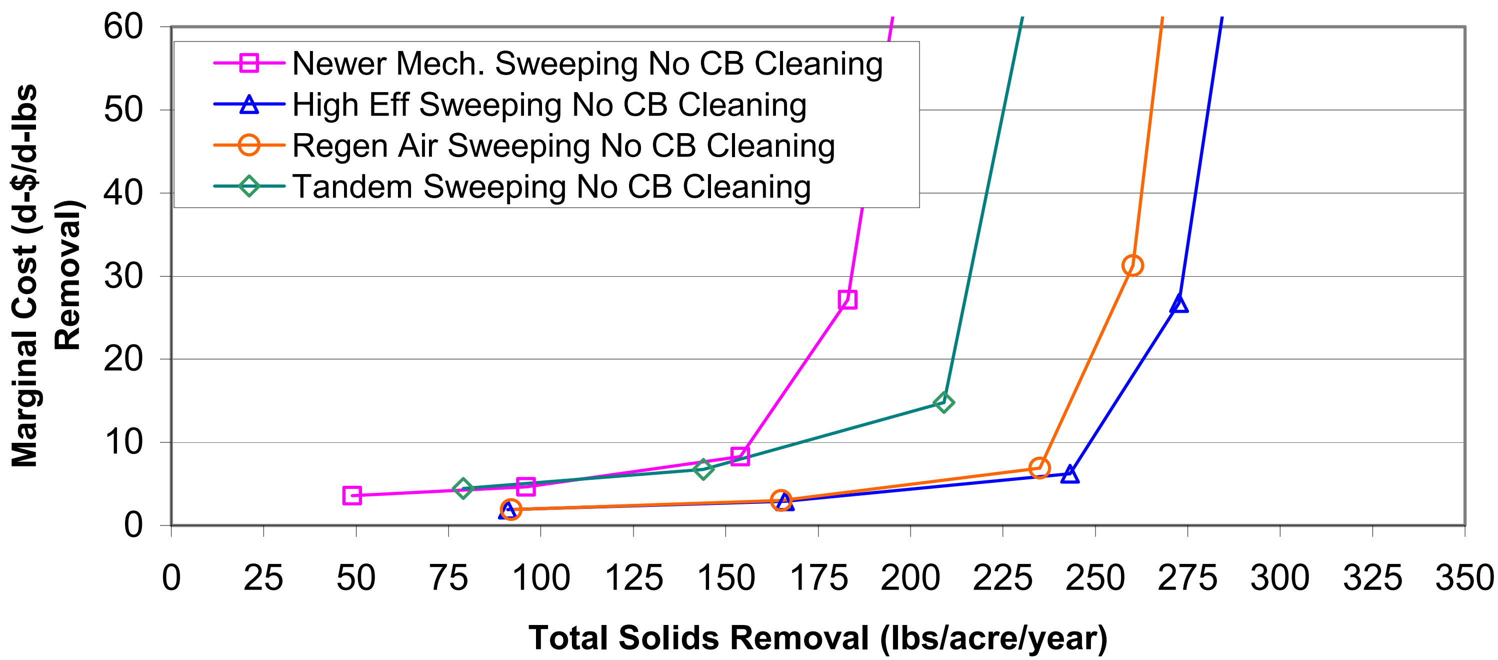
# BMP Marginal Cost Curves
# SFR2 - SITE # 2 JACKSON SFR JACKSON, MI



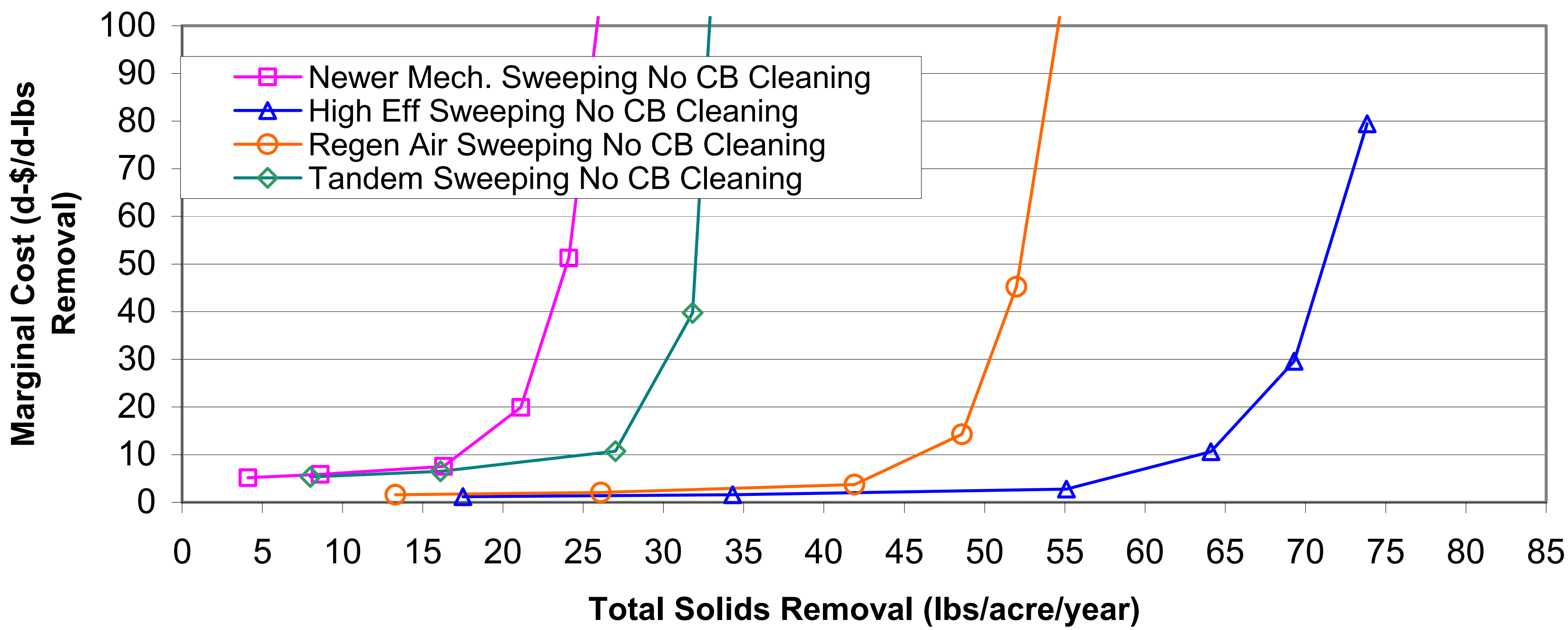
# BMP Marginal Cost Curves
# CBD3 - SITE # 3 CORTLAND CBD JACKSON, MI

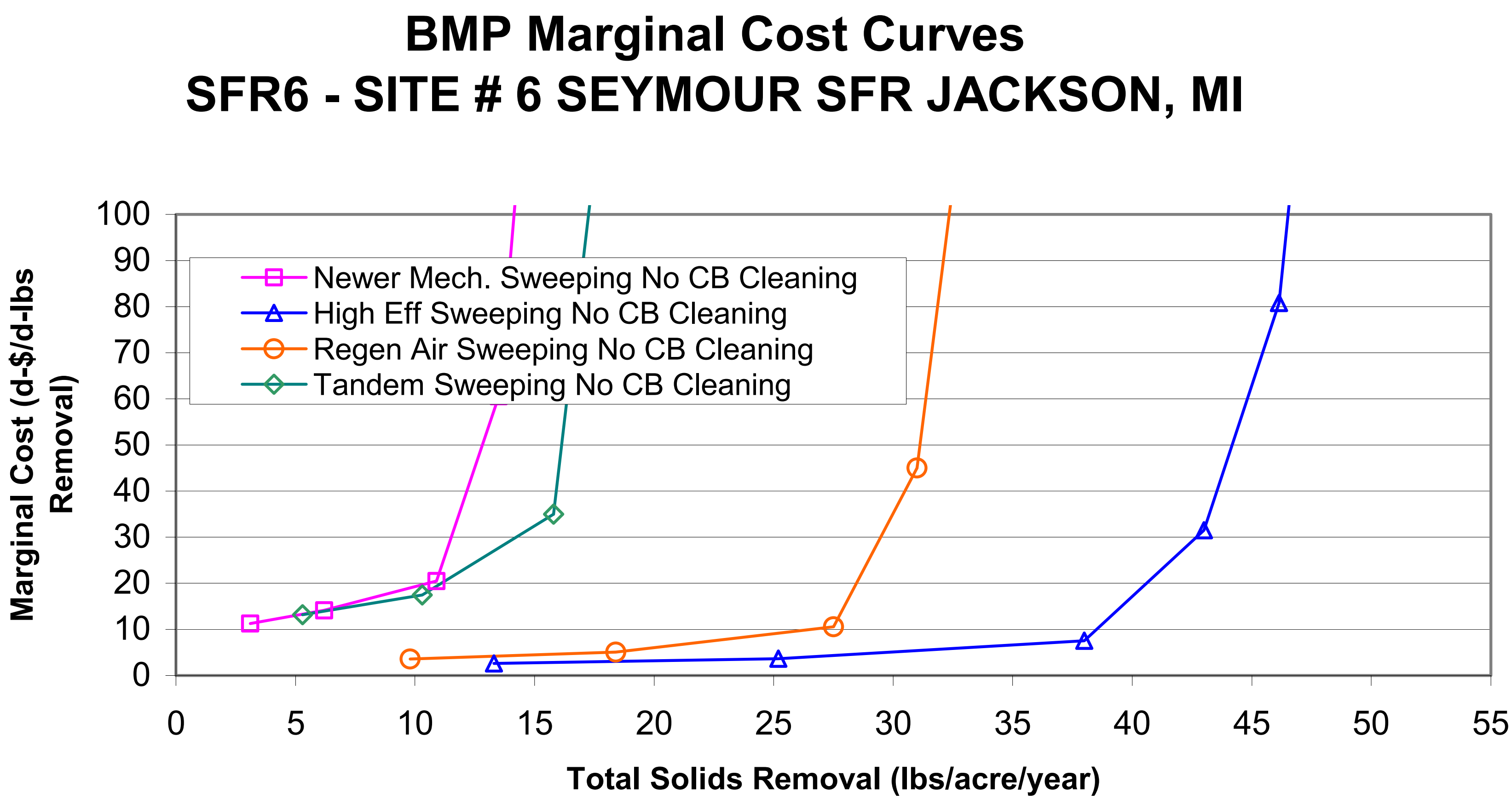


## BMP Marginal Cost Curves
## HWY4 - SITE # 4 PARNELL HWY JACKSON, MI



# BMP Marginal Cost Curves
# IND5 - SITE # 5 CARROLL IND JACKSON, MI




BMP Marginal Cost Curves
SFR6 - SITE # 6 SEYMOUR SFR JACKSON, MI
Marginal Cost (d-$/d-lbs Removal)
Total Solids Removal (lbs/acre/year)
Newer Mech. Sweeping No CB Cleaning
High Eff Sweeping No CB Cleaning
Regen Air Sweeping No CB Cleaning
Tandem Sweeping No CB Cleaning
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45
50
55