Rick Mystrom, Mayor

Anchorage Bowl OGS Performance Modeling

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MUNICIPALITY OF ANCHORAGE
WATERSHED MANAGEMENT PROGRAM

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WATERSHED
MANAGEMENT

Department of
Public Works

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ANCHORAGE BOWL OGS ASSESSMENT MODELING

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ANCHORAGE BOWL OGS ASSESSMENT MODELING

VOLUME I

SUMMARY REPORT

Municipality of Anchorage
Department of Public Works

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Volume I Summary Report

1.0 Introduction

Currently, the Municipality of Anchorage (MOA) employs oil and grit separators (OGS) as a conventional means of treating municipal storm water to remove sediment and floating oil originating primarily from city streets. Although past anecdotal evidence raised questions about the effectiveness of OGS in some locations, prior to this study there was no reliable data to guide where and to what size these devices should be built. To fill these data gaps, MOA Department of Public Works, Watershed Management Section (WMS) initiated this OGS study with the intention of not only assessing the applicability of OGS in Anchorage conditions, but also developing a method to estimate the costs associated with this treatment method.

This technical report contains the data and summary findings of the OGS Assessment Project. Results are normalized by approximate OGS life-cycle costs so that watershed managers can both evaluate a range of potential costs for each basin, and compare costs to other sediment mitigation practices (for example street sweeping).

Although OGS modeling was performed for all basins within the Anchorage "Bowl," the data are not intended to be used for design of these devices. Rather, the results are intended to indicate approximate OGS performance and cost within the range of Anchorage basin characteristics.

1.1 PROJECT SUMMARY

The OGS assessment was completed in two phases: field data collection and computer modeling. A field effort was first conducted to gather the data necessary to calibrate the model used to predict OGS efficiency. During the field effort, climate data, initial street sediment loads, sediment washoff loads, and runoff flow data were collected from both commercial and residential areas. This calibration data was collected from the fall of 1995 through the fall of 1996.

The second phase of the project focused on calibration of the model and subsequent assessment of OGS performance in each of Anchorage's drainage Basins. The model relied on algorithms from the EPA Storm Water Management Model (SWMM), street sediment load data from a related WMS project (Wheaton et. Al., 1997), and average Anchorage weather conditions to predict street sediment buildup, sediment washoff, street sweeping removal effects, and OGS treatment.

1.2 REPORT ORGANIZATION

This report is presented in four volumes:

- Volume I contains general project information, a description of the system studied, and a summary model description.
    - Section 1 contains the report introduction.
    - Section 2 presents a description of the street sediment buildup, redistribution, washoff, and treatment "system" that is represented by the computer model.
    - Section 3 contains a summary of the model used to represent OGS treatment of mobilized sediment in storm- and melt-water runoff.
    - Section 5 presents a summary of the basic themes noted in the modeling data.
    - Section 6 contains references cited in the report.
- Volume II contains results for each basin modeled.
- Volume III contains a detailed discussion of the model assumptions, formulation, and calibration strategy and results.
- Volume IV contains the base data used for modeling and associated metadata.

2.0 System Description - Sediment Buildup and Mobilization Dynamics, and OGS Treatment

The system studied has four components (sediment buildup, redistribution, washoff, and OGS treatment). Each of these system components must be understood for accurate modeling. The following text addresses each of the components and identifies which elements were selected for study. The modeling approach used to represent the natural system is presented in Section 3.0.

Sediment Buildup

In Anchorage, sediment impacts to area water bodies are primarily derived from road surfaces. Street sediment comes from a variety of sources including:

- Winter street sanding;
- Pavement wear and decomposition, primarily from tire studs;
- Vehicle related deposition (e.g., rust, oil);
- Dustfall;
- Litter;
- Mud and dirt trackout;
- Erosion from adjacent areas;
- Spills;
- Biological debris; and
- Tire and brake wear.

A recent study of street sediment loads by WMS suggests that winter traction sanding is the most significant source of street sediment, accounting for as much as 95% of the load remaining on the street at the end of the winter (Wheaton et. al, 1997). During the study, sediment loads were also measured before and after street sweeping events, allowing for calculation of both sediment buildup rates and street sweeping efficiency.

Conversations with MOA Street Maintenance and Alaska Department of Transportation and Public Facilities (DOT) indicate that sand-truck drivers apply sand to traffic lanes approaching controlled intersections based on the presence of snow or ice, traffic volume, and vehicle speed. Road types with large traffic volumes and high vehicle speeds (for example New Seward Highway) may be sanded up to 300 feet from the controlled intersection. Conversely, road types with low traffic volumes and vehicle speeds (for example residential streets) are only sanded to approximately 50 feet from a controlled intersection. Uncontrolled stretches of street and areas past controlled intersections are only incidentally sanded. Although sand is applied to streets with sharp turns or grades, the majority of Anchorage streets are straight and have little or no slope.

For the purposes of this study, road types are separated into four categories: local; collector; minor arterial; and major arterial. These categories are based on average daily traffic volumes of <2,000; 2,000 to 10,000; 10,000 to 20,000; and >20,000, respectively. Because these classifications are highly correlated to street sanding practices and are readily measurable, they are used as reasonably accurate predictors of street sediment loading.

Because most Anchorage parking lots are not owned or maintained by the MOA, sanding practices for these areas are not known, difficult to predict, and beyond the scope of this study.

Street Sediment Redistribution Forces

Once on the street, sediment is subject to a variety of forces that tend to redistribute the material to less-traveled areas, such as medians and gutters. In winter, redistribution forces include traffic, mid-winter thaws, street sweeping, and snow-removal activities. Current snow removal activities often transport sediment to pervious areas along the sides of streets and to snow dumps where it is not available for storm-water mobilization.

During the non-winter months, street sweeping, traffic energy, and storm-water mobilization primarily cause street sediment redistribution. Of these three factors, street sweeping and storm-water mobilization are believed to be the most significant and were included in the OGS Assessment. Because it is the primary mechanism for transporting sediment to receiving water bodies, storm-water mobilization (both rainfall and snowmelt) is discussed further in the next sub-section. Other forces, such as wind, also contribute to sediment redistribution, but were neglected because they are less significant.

Street Sweeping is used as a best management practice (BMP) to reduce air quality and receiving water impacts caused by street sediment. Currently, the MOA and DOT sweep streets three times each year, beginning with larger streets in late March. This initial sweeping event is typically followed by episodes in early and mid summer. A study by WMS suggests that sediment removal by this method varies by particle size and road type (Weaton et.al., 1997). In general, larger particles are almost completely removed from all streets; small particle (<100 micron) removal efficiencies vary from approximately 50% on larger streets to 0% on smaller streets.

Gutter loads tend to represent the majority of sediment on the street at any one time. As noted above, intersection and non-intersection areas tend to have different sand application rates, particularly at controlled intersections. Sediment loads may initially be redistributed to areas between traffic lanes (medians) but are invariably pushed to the gutters.

Stormwater Mobilization

Sediment is mobilized from streets by intense rainfall and by snowmelt during both spring breakup and mid-winter thaws. With sufficient kinetic energy from water or traffic agitation, particles are dislodged and carried with the stormwater. Sediment on the traffic surface is mobilized by sheet flow and traffic energy to the gutter. Sediment in the gutter is subject to a relatively vigorous channel flow where it is transported to the catch basins and inlets of piped transport systems.

Spring snowmelt and rainfall runoff are believed to account for a large majority of the sediment washed into receiving water bodies. Other runoff events, such as mid-winter thaws probably account for only a small fraction of the yearly sediment transport. Consequently, only spring snowmelt and rainfall runoff were considered for this study.

Storm-water transport networks consist of a series of catch basins, drainage pipes, and manholes, with treatment and flow bypass devices typically located at the end of these systems (e.g., OGS). Storm water enters the system at catch basins, travels along the pipe network, and is either treated before discharge or is discharged directly to the surface water. It is generally assumed that a long-term equilibrium exists between loads entering and loads mobilized in stormwater transport-systems. Some settling will occur when sediment loadings are high. Hydraulic loadings from infrequent, intense storms are likely to periodically flush sediment from the transport system.

The timing of pollutant load movement along the transport system is assumed to be dependent on the parameters listed below. However, the cumulative effect of these parameters, particularly on an event-by-event basis, are not well understood for Anchorage and are therefore difficult to model. As a result, the OGS assessment model neglects the piping system and assumes that mobilized sediment is transported instantaneously from the street to the OGS. Although this assumption may result in error when considering individual washoff events, modeled results for cumulative sediment loads over a relatively long period of time are believed to be reasonably accurate.

- Seasonal distribution of washoff loads;
- Pollutant particle sizes and densities;
- Storage capacity and geometry of catch basins;
- Flow rates and volumes;
- Pipe storage;
- Pipe geometry;
- Timing of loads carried by non-storm-water flows; and
- Distribution of washoff events.

Several drainage basin characteristics also directly affect the amount of mobilized sediment discharged from an individual outfall. In addition to the miles of each roadtype (described above), landuse within the basin (e.g., commercial, residential, etc.) is correlated with impervious area, which, in conjunction with basin size and shape, affects total, average, and peak storm water flows.

OGS Treatment

OGS treatment is a passive technology involving gravity separation of particulates in a relatively quiescent vessel prior to discharge to receiving water or drains. Stokes' Law, a function of particle and water density difference, particle diameter, and water viscosity, is used to estimate settling of discrete particulates in a water column. OGS in Anchorage are typically installed at the outfall from piped storm drain systems in urbanized areas. Urbanized areas are defined as having paved streets with curbs, gutters, and piped storm-water conveyance systems. These areas are located predominantly within the Anchorage lowlands commonly referred to as the "bowl" area.

OGS devices are suitable for the removal of coarser sediments and free-phase oily wastes transported in storm water. In the contiguous 48 states, these devices are typically applied to smaller basins (approximately 3 acres or less). In Anchorage, OGS are installed in much larger drainage basins as end-of-pipe treatment devices. OGS design criteria are typically set by selecting the smallest particle to be removed during some maximum flow through the device.

Once inside the OGS, smaller particles settle much more slowly than larger ones. The lower limit of particle size for consideration of OGS technology has been selected to match the 100-micron lower size limit recognized by the state water quality standard for sediment. Although particle sizes less than 100 micron are considered "untreatable loads," the total mass of this fraction is of interest to OGS assessment. Information about untreatable loads is important because effective assessment of OGS feasibility relative to other sediment management practices requires knowledge of not only what portion of the total load is treatable, but also knowledge of the total (total OGS treatable and untreatable) load in the storm-water runoff.

Also of interest to watershed managers are mobilized particles between 420 and 100 microns. A significant mass of particles in this size range can be mobilized in moderate stormwater flows, settle upon entering the receiving water. OGS can effectively treat this particle size range. To address the regulatory and biological issues associated with different particle sizes, three particle size ranges were modeled: greater than 420 microns (OGS large); 100 to 420 microns (OGS small); and less than 100 microns (OGS untreatable).

Periodically, accumulated sediment must be removed from OGS to maintain the efficiency of the unit and prevent scouring during high hydraulic loadings (e.g., large rainstorms). Small OGS can be quickly and cheaply maintained. However, with increasing size, OGS maintenance expands to a comparatively large effort requiring up to 20 hours of labor.

3.0 Summary of Modeling Approach

To model the system described above, the following critical system elements were identified for each of the system components.

1. **Street Sediment buildup** – Both initial (end of winter) sediment loads and sediment buildup rates by particle size and roadtype.
2. **Street Sediment Redistribution (excluding stormwater mobilization)** – Street sweeping removal efficiency by particle size and roadtype.
3. **Storm Water Mobilization of Sediment** – The volume of runoff for snowmelt and rain fall runoff events, and the associated mass of mobilized sediment (by particle size and basin characteristics).
4. **OGS Treatment** – mobilized sediment treatment efficiency by particle size; OGS costs for a range of device sizes.

The selected computer model, USEPA's Storm Water Management Model (SWMM), has several "blocks" that model different aspects of storm-water runoff and pollutant mobilization and transport. Included in these components is a runoff block that, when calibrated, can predict sediment mobilization from the street to catch basins. Other data for system components required by the model (i.e., initial sediment loads and buildup rates, street sweeping efficiency, OGS treatment efficiency and cost) were represented using results from existing studies and sources.

To model the four system components listed above, the modeling effort was performed in three phases. First, field data were collected to calibrate and verify the SWMM sediment mobilization portion of the model; secondly, the model was calibrated; finally the calibrated model was used to predict OGS treatment efficiency and cost for all of Anchorage's drainage basins. The following sections briefly describe these three phases and itemizes the assumptions and limitations inherent in each. A detailed description of the modeling effort is contained in Volumes III and IV.

3.1 Calibration Data Collection

Calibration data were collected during the Fall of 1995 and during the Spring and Summer of 1996 at two drainage basins representing commercial and residential landuse. The commercial site was located on Northern Lights Blvd. between Spenard Rd. and Arctic Blvd. The residential site was located on 21st and Blueberry Avenues off of Arctic Blvd. At both locations, the following data were collected to calibrate and validate the sediment mobilization portion of the OGS model. All calibration data sets are contained in Volume IV of this report.

Sediment Load Data - Street sediment were measured at both drainage basins several times during the study period as a part of a larger MOA street sediment loads assessment project. From these measurements, initial sediment loads at the end of winter, build up rates, and street sweeping efficiency were derived for the two drainage basins. A complete description of the sampling effort and resulting data is contained in *MOA Street Sediment Loading Assessment*

Data Report (Brown and Gropp 1997), WMS document number WMP APr97001. Following is a summary of the sediment loads project.

Based on MOA sanding practices, 33 sampling sites were selected at 18 controlled intersections in Anchorage to represent four major road types. The road types based on average daily traffic (ADT) volume: local, collector, minor arterial, and major arterial/freeway. These categories are based on ADTs of <2,000; 2,000 - 10,000; 10,000 - 20,000; and >20,000, respectively.

Sites located at controlled intersections were divided into “intersection” and “non-intersection” areas. Intersection areas include all street surfaces within 100 feet (30.5 meters) of the crossing street. Non-intersection areas include all surfaces from 100 to 200 feet (61 meters) of the crossing street. Each street area (intersection, non-intersection) was further divided into pavement strata representing “gutter” and “non-gutter” areas. Gutters were measured two feet into the street from the back of the raised curb, including the gutters created by raised medians. Non-gutter strata include all other street surfaces, excluding the tops of raised medians.

Three transects were established each intersection and non-intersection area. Transects were typically six inches wide (0.15 meters) and extended gutter-to-gutter across the street. A single gutter and non-gutter sample was composited from the three transects within each area during each sampling round. Samples for OGS assessment were collected from all sites using a wet/dry shop vacuum with a paper filter-bag. Samples were collected in the early spring before street sweeping, mid to late spring immediately after street sweeping, and mid-summer.

All samples were analyzed for particle size distribution (sieve analysis) using ASTM method C136 with a wet wash. Sediment loadings were calculated from transect area and sieve analysis data

Rainfall and SnowMelt Runoff Data - Continuous runoff data were collected via data loggers installed at all drop inlets where basin runoff entered the storm water conveyance system. Each drop inlet was equipped with a weir for accurate flow measurements. Additionally, the entire area contributing runoff was accurately mapped for impervious and total area. The combination of total contributing area and flow information allowed for calculation of total, average, and peak flows for a given snow melt or precipitation event over a basin of a particular size.

Local Climate Data - Local rainfall and temperature data were collected with a weather station installed on the roof of Stellar Alternative High School on Fireweed Lane. Snow depth data was obtained from National Weather Service measurements at Anchorage International Airport. To calculate snowmelt runoff, the model relied upon standard snow depletion curves, AIA snow fall records, and temperature data collected at Stellar Alternative High School.

Mobilized Street Sediment Data - At all drop inlets receiving runoff from the drainage basins, an insert was installed with 100-micron mesh screens. For each snowmelt and rainfall event, all mobilized sediment greater than 100 microns was retained on the screen. The retained sediment was then recovered and analyzed for mass and particle size distribution. To determine the mass of particles less than 100 micron, grab samples for Total Suspended Solids were collected at the drop inlets during selected runoff events.

3.2 Model Calibration

The following section presents model calibration methodology for critical system elements in each of the four components of the system studied. Each calibration ultimately relied on field data to determine the value of calibration parameters. Calibration values were determined by minimizing the cumulative error between modeled and observed results. A detailed discussion of the OGS Assessment model calibration is presented in Volume III.

1. **Street Sediment buildup –** The sediment buildup prediction model combines the results of the other calibrated parameters. Road area and basin area were assumed to be 20,000 sf and 50,000 sf respectively in all of the calibration basins. Sediment was uniformly distributed over the basins. Detailed spring and fall sediment load data were available for 20 road sites in Anchorage. Build up rates were calibrated by comparing the predicted Fall 1995 street sediment loads to the fall sediment loads predicted by the model based on 1996 initial sediment load, snow, thaw, and rain data. Since build up was not measured directly, the accuracy of the built up calibration is an aggregation of the accuracy of all other calibration parameters. The results of the calibration were generally well centered with little bias.

2. **Street Sediment Redistribution (Street Sweeping) –** Street-sweeping efficiency was calibrated using field data collected during the Street Sediment Loading Assessment. Data from sampling rounds 1 and 2 (early Spring before street sweeping and post-street sweeping, respectively) were compared. Efficiency values were calibrated for each road type and particle size range. The data and results were widely spread. The predicted results were equally likely to be larger or smaller than the observed results. There is a large right skew, meaning that the observed results could be significantly larger than the predicted sediment loading after sweeping. The 80% confidence interval for the calibration values was -55% to 102%.

3. **Storm Water Mobilization of Sediment** – Sediment is mobilized by both snow melt and rainfall runoff. The two types of runoff were calibrated similarly, except that spring snow melt requires calibration to predict the amount of runoff from a given snow pack, while rainfall runoff relies on rainfall amounts. For both types of runoff, the mass of mobilized sediment (by particle size) were produced by the model based on:

    - Measured initial Sediment Loads
    - Measured runoff from either a snowmelt or rainfall event
    - Basin size
    - Area of roads within each basin

The modeled mass was compared to field data for each event used for calibration. Calibration coefficients were then adjusted to minimize the error between the modeled and actual results. Additionally, snowmelt runoff was predicted using an area depletion curve that relies on several factors to predict runoff including the depth of snow and temperature. The snowmelt calibration coefficients were adjusted to match observed runoff during spring snowmelt. The sediment washoff calibration was good for all particle size ranges, and exceptionally good for particle sizes >100 micron (OGS small and OGS large).

4. **OGS Treatment –** OGS treatment is based on modeled flows, the minimum particle size desired for treatment (100 micron), and Stoke's law. The model used for this study predicted removal efficiency for a range of OGS sizes. Costs associated with each OGS size were then used to predict the cost per pound of sediment removed over the course of a year. Because OGS treatment relies on modeled flows from a calibrated flow model, and other, non-modeled input, the treatment component of the system was not "calibrated" like the other model elements. However because OGS settlement chambers are not perfectly quiescent but rather are subject to periodic and localized turbulence and scour, modeled results are expected to predict better removal efficiencies than are actually achieved.

3.3 Model Function and Operation

This section covers the model components created for the Anchorage OGS Assessment Model. Unless noted otherwise, the model uses the same methodology as SWMM. Where applicable, the algorithms forming the predictive model of each component are described in Appendix III.

In general, the model applied sediment buildup at the beginning of each day; swept sediment is removed at the beginning of each day that a sweep event occurs; and washed off sediment is removed at hourly increments. The load of each sediment class on each basin is stored in a database table in daily increments. Washoff quantities are calculated for each sediment class using the hourly runoff information from the runoff database table and the estimated sediment load on the basin. The washoff quantities are also stored in a database table at hourly intervals.

The following text describes additional model functionality for each of the system components assessed for the OGS study.

1. **Street Sediment buildup -** Initial sediment loads were estimated for each basin and sediment class. Sediment loads were applied to the entire basin surface based on the road area in each basin:

Initial Load (g ft-2)				
	Road Type			
Contaminant	1 *Local*	2 *Collector*	3 *Minor Arterial*	4 *Major Arterial*
Suspended Solids	3.8	3.3	7.6	7.4
OGS Small	6.4	7.3	16.7	29.1
OGS Large	18.0	26.1	19.2	39.1

2. **Street Sediment Redistribution (street sweeping)** – Street sweeping data gained from Brown and Gropp (1997) were used to determine sediment removal efficiency by particle size and roadtype.

3. **Storm Water Mobilization of Sediment** – The runoff and snowmelt component estimates runoff from each basin from rainfall and snow melt. Rainfall is based on hourly rain data from 1965 at Anchorage International Airport. 1965 was determined to be a close approximation of an average water year by the MOA NPDES Permit. Snowmelt is calculated from the initial measured and hourly temperatures interpolated from minimum and maximum recorded temperatures at the Anchorage International Airport. Runoff and snowmelt are both applied to the Laurenson flow algorithm (XP-SWMM Documentation 1997). The results are stored in a database table that lists runoff (ft^3s^{-1}) at hourly intervals for each basin.

4. **OGS Treatment** – The amount of sediment removed from the washoff stream is calculated at hourly increments. The total season treatment efficiencies for each sediment class and basin are stored in a database table. The treatment of sediment washing off from a basin is a function of the mass of sediment, the size of the sediment, and flow of water passing through the treatment device. The predictive model is based on Stokes Law. The settling velocity of each contaminant type was calculated by taking the average of the settling velocities of the smallest and largest particles within the contaminant size class. The relative cost of sediment removal is important to making decisions about applying OGS treatment. Both capital costs and maintenance costs were estimated. Capital costs were amortized using a 6% interest rate applied over 30 years. It is important to note that the OGS costs do not include real-estate costs. That is, predicted treatment costs are lower than actual treatment costs. Based on this cost analysis the costs of OGS units were estimated using a linear curve fit:

   OGS Unit Cost = $157 * [Effective OGS Area (sf)] + $1594

4.0 Summary of Results

The following summary is presented to provide a general overview of the major findings of the OGS assessment. The summary is focused on the amount and character of sediment mobilized by storm water flows, the relationship of basin characteristics to OGS performance, and the relative cost of OGS for selected basin characteristics.

<u>Mobilization of sediment by snow melt and rainfall runoff</u>

- 20 to 40% of the total annual street sediment load is washed off the streets with rainfall and snowmelt runoff. Rainfall runoff in summer and fall accounts for most of total annual washoff load (approximately 75% to 90%). Snowmelt runoff in spring accounts for about 10 to 25% of total annual washoff load.

- Of the sediment mobilized by stormwater, most (99% to 96%) is less than 100 micron (too fine to be practically treated by OGS). Based on these results, less than 10% of the total street sediment load is apparently treatable by OGS.

Sediment Mobilization and Basin Characteristics

- A large fraction of the total street sediment washoff load comes from off major streets (e.g., major arterials). Smaller streets (e.g., residential streets) contribute a smaller fraction of the washoff load.

- OGS may not be generally practicable for control of snowmelt wash off events. Snowmelt runoff is less energetic and the largest washoff fraction is fine particulate.

OGS Treatment Costs

- OGS efficiency is most strongly correlated to total street area as a percentage of the total basin area. This is because streets are the primary pollutant source in this model. Total basin area was not found to be strongly predictive of sediment load.

- OGS best marginal costs occur where major streets form a large percentage of street and basin area.

- OGS marginal costs grow logarithmically above a device size threshold. Similarly, OGS O&M costs increase rapidly above a certain size device

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ANCHORAGE BOWL OGS ASSESSMENT MODELING

VOLUME II
BASIN DETAIL REPORTS

Municipality of Anchorage
Department of Public Works
Montgomery Watson

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An individual basin report was generated for each basin with a predicted sediment load. Small basins without roads show up on the key maps, but have no basin report.

Each basin report is broken into four sections:

▪ Basin Information	Includes basin size, land use, and road area information, as well as a map of the basin showing the surrounding are and basin outfall.
▪ Sediment Fate	Shows the build up and ultimate fate of sediment on the basin: remains, swept, or washed off..
▪ Sediment Washoff	Shows the cumulative washoff and identifies the storm and melt events that cause washoff.
▪ OGS Treatment Efficiency	Shows the efficiency and cost effectiveness of different size OGS units on treating the annual washoff from a basin. Conceptual cost information is shown that includes construction and O&M. (Land costs are not included).

A key sheet is included that highlights the components of the basin detail reports.

You can navigate to individual basin reports by using the following index maps:

Anchorage Bowl Index Map			
Campbell Creek	Furrow Creek	Middle Fork Chester Creek	Rabbit Creek
Chester Creek	Little Campbell Creek	North Fork Campbell Creek	South Fork Campbell Creek
Craig Creek	Little Rabbit Creek	North Fork Chester Creek	South Fork Chester Creek
Fish Creek	Little Survival Creek	Potter Creek	Ship Creek

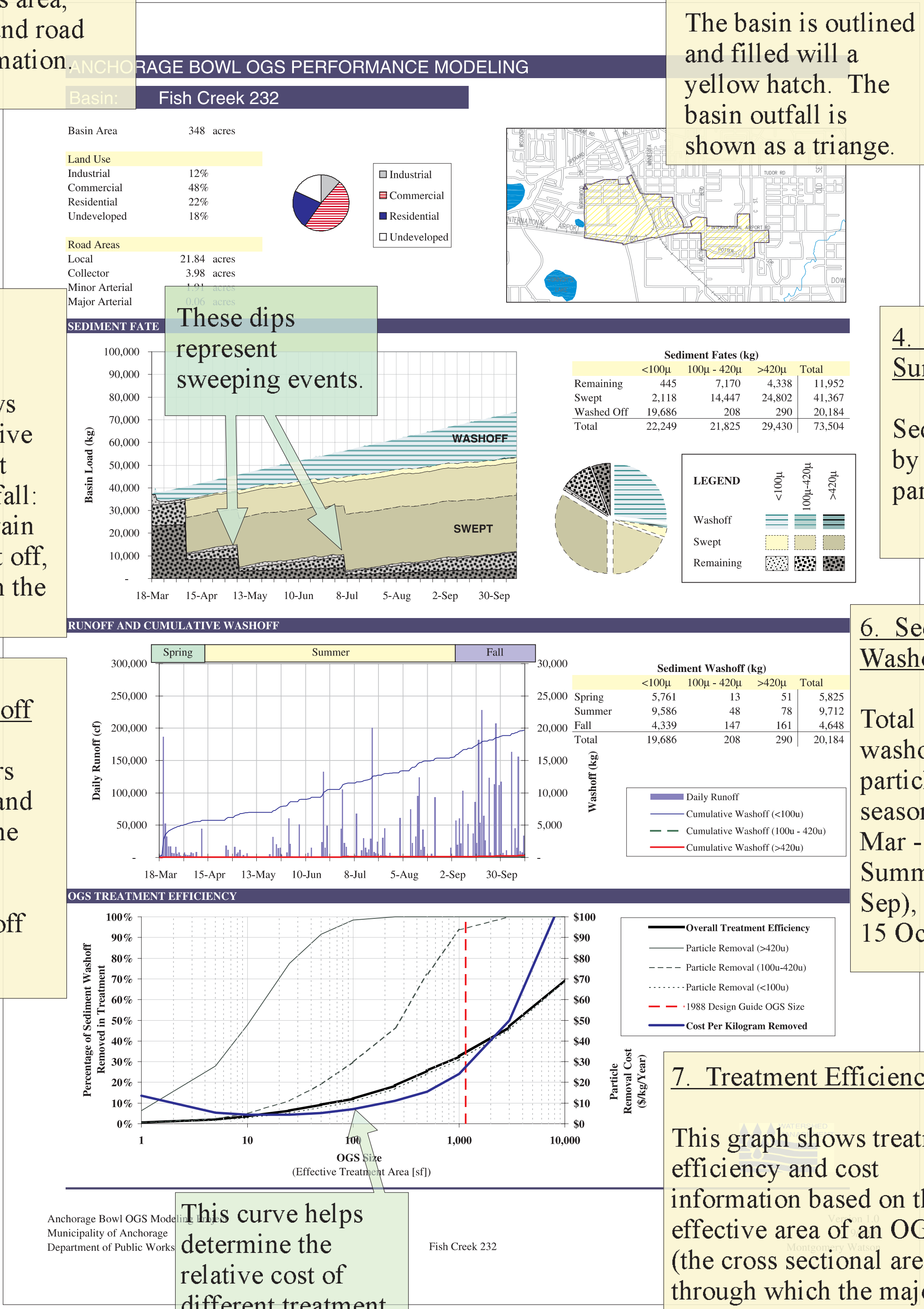
Basin Detail Reports
Key Sheet

1. Basin Statistics

This shows area, land use, and road area information.

2. Basin Map

The basin is outlined and filled will a yellow hatch. The basin outfall is shown as a triange.



ANCHORAGE BOWL OGS PERFORMANCE MODELING

Basin: Fish Creek 232

Basin Area 348 acres

Land Use	
Industrial	12%
Commercial	48%
Residential	22%
Undeveloped	18%

Road Areas		
Local	21.84	acres
Collector	3.98	acres
Minor Arterial	1.91	acres
Major Arterial	0.06	acres

SEDIMENT FATE

Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	445	7,170	4,338	11,952
Swept	2,118	14,447	24,802	41,367
Washed Off	19,686	208	290	20,184
Total	22,249	21,825	29,430	73,504

RUNOFF AND CUMULATIVE WASHOFF

Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	5,761	13	51	5,825
Summer	9,586	48	78	9,712
Fall	4,339	147	161	4,648
Total	19,686	208	290	20,184

OGS TREATMENT EFFICIENCY

Anchorage Bowl OGS Modeling Project
Municipality of Anchorage
Department of Public Works

Fish Creek 232

Version 1.0
Montgomery Watson

3. Cumulative sediment fates

This chart shows the the cumulative fate of sediment from spring to fall: washed off by rain and melt, swept off, or remaining on the

These dips represent sweeping events.

4. Sediment Fate Summary

Sediment masses by fate and particle size.

5. Cumulative Sediment Washoff

The vertical bars indicate storm and melt events. The lines show the cumulative sediment washoff by particle size.

6. Sediment Washoff Summary

Total sediment washoff mass by particle size and season: Spring (15 Mar - 15 Apr), Summer (15 Apr - 1 Sep), Fall (1 Sep - 15 Oct)

7. Treatment Efficiency

This graph shows treatment efficiency and cost information based on the effective area of an OGS (the cross sectional area through which the majority of flow will pass).

This curve helps determine the relative cost of different treatment methods.

ANCHORAGE BOWL OGS ASSESSMENT MODELING

VOLUME III
MODEL CALIBRATION & METHODOLOGY

Municipality of Anchorage
Department of Public Works
Montgomery Watson

WATERSHED
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Table of Contents

Introduction

The methodology of the model is closely tied to its calibration, as different parts of the model were tailored to the data available.

Section I describes the model calibration and the algorithms used in the predictive model, while Section II covers the actual mechanics of the model as it was implemented in this project. While SWMM and XP-SWMM formed the original model, the calibration requirements and the hundreds of individual model runs necessary in for this project required moving the model algorithms to a Visual Basic platform.

Calibration Documentation and Description

The calibration of each component (runoff, snowmelt, etc…) is described in six steps.

1. **“Calibration Constants and Parameters”** lists the parameters that are being calibrated for the component.
2. **“Base Data”** briefly lists the sets of observed data that are used in calibration. This includes both measured and predefined input parameters for the predictive model and observed data values that are used to test the model output.
3. **“Prediction Model”** describes the algorithm used to generate predicted values. This also is a description of the algorithm used in the model.
4. **“Calibration Method**” discusses the method and values used to calibrate the calibration parameters.
5. **“Calibration Results”** lists the values chosen for the parameters based on the calibration.
6. **“Calibration Accuracy”** discusses the relative accuracy of the calibration. A plot of the relative error is shown for the each of the calibration methods. This plot is a histogram of the relative errors between the predicted and observed results of the calibration set.

I. Model Calibration

A. Street Sweeping Efficiency

1. Calibration Constants and Parameters

Parameter	Symbol	Unit
Percentage Removed	η	-
Base Load	β	$g\ m^{-3}$

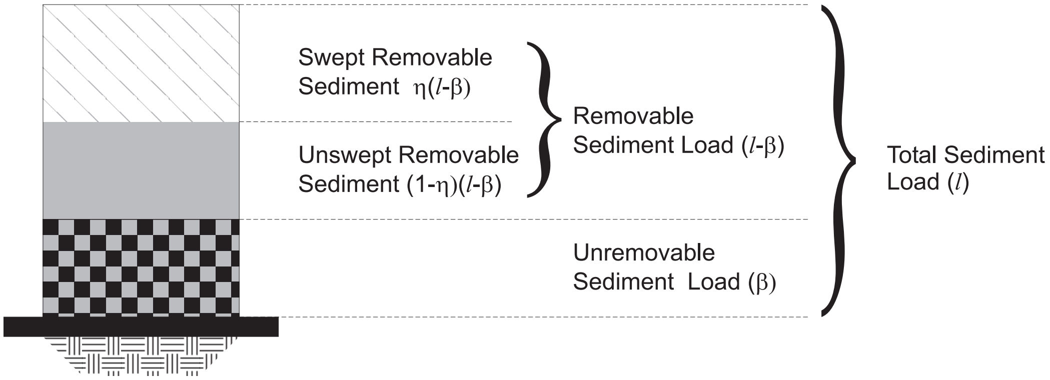
2. Base Data

The data used are based on the MOA Street Sediment Loading Assessment (Brown and Gropp, 1997). Round one data represents the initial street sediment load, whereas the second sampling round occurred promptly after an area was swept.

Parameter	Symbol	Unit
Round 1 Street Sediment Loading	l_{i1}	g
Round 2 Street Sediment Loading	l_{i2}	g

3. Prediction Model

The general sweep model removes a percentage of the removable street sediment load. The division of the sediment loads is shown below:



Following this logic, the sediment load remaining after a street is swept can be expressed as:

$$\hat{l}_{i2} = (1-\eta)(l_{i1}-\beta)+\beta \Rightarrow \hat{l}_{i2} = (1-\eta)l_{i1}+\eta\beta$$

4. Calibration Method

Linear Regression in the form:

$$\hat{l}_{i2} = (1-\eta)l_{i1} + \eta\beta$$

Where:

$$\beta \geq 0$$

$$0 \leq \eta \leq 1$$

Calibration of the sweeping model was performed by minimizing the error between the predicted and observed values of the round two loadings:

$$l_{i2} = \hat{l}_{i2} + \varepsilon$$

$$\bar{\varepsilon} \rightarrow 0$$

$$s(\varepsilon) \rightarrow 0$$

5. Calibration Results:

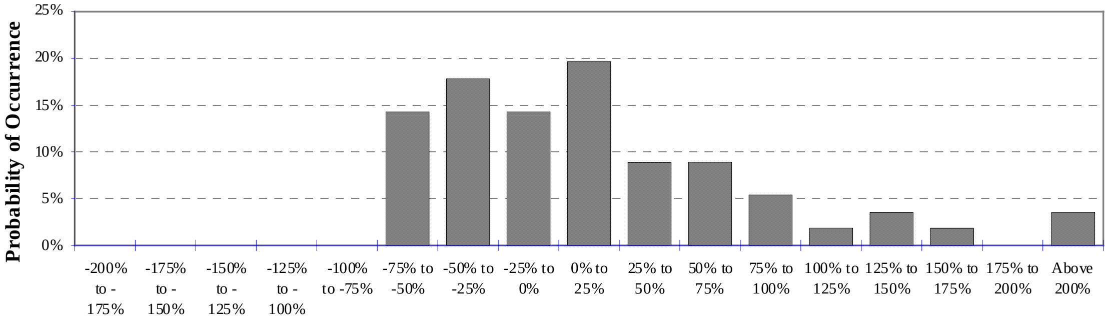
η		Susp. Solids	OGS Small	OGS Large
Road Type	1	0.46	0.67	0.89
	2	0.14	1.00	0.93
	3	0.92	1.00	1.00
	4	0.86	0.90	0.93

β		Susp. Solids	OGS Small	OGS Large
Road Type	1	24.7	29.1	0.0
	2	0.0	62.4	0.0
	3	10.6	38.8	12.7
	4	37.5	60.0	16.6

6. Calibration Accuracy:

The data and results were widely spread. The predicted results were equally likely to be larger or smaller than the observed results. There is a large right skew, meaning that the observed results could be significantly larger than the predicted sediment loading after sweeping.

Statistic	ε
Mean	21%
Median	1%
Standard Deviation	82%
Sample Size	57
80% Confidence Interval	-55% to 102%



Simplified Probability Plot of $\frac{\varepsilon}{\hat{l}_{i2}}$

B. Runoff

1. Calibration Constants and Parameters

Parameter	Symbol	Unit
Laurenson Power	n	-
Basin Slope	S	-

2. Base Data

Parameter	Symbol	Unit
Rainfall	$i_{(t)}$	$ft^3\ sec^{-1}$
Basin Area	A_{basin}	ft^2
Catchbasin runoff	q_t	$ft^3\ sec^{-1}$
Impervious Area	I	%
Runoff timestep	Δt	hour

3. Prediction Model

This runoff prediction model uses the Laurenson variant of the Muskingum flow routing method[1]:

$$\hat{q}_t = C_{t-2}\ i_t + C_{t-1}\ i_{t-1} + C_t\ q_{t-1}$$

Where:

$$C_0 = C_1 = \frac{\Delta t}{(2K_t + \Delta t)}$$

$$C_2 = \frac{2K_{t-1} - \Delta t}{2K_t + \Delta t}$$

$$K_t = Bq_t^n$$

A general method[2] was used for determining values for the factors *B* and *n*. The factors *B* and *n* can be calibrated for a specific basin. However, since a wide variety of basins will be modeled, a more general approach is more appropriate.

$$B = 0.285A^{0.52}(1+U)^{-1.97}S^{-0.50}$$

Where U (Urbanity Factor) is related to I (% of impervious land) by the relationship:

---

[1] detailed in the XP-SWMM documentation (June 1997, Page 156). Also, metric equivalents of the flow and area quantities are used (m^3s^{-1}, m^2).

[2] developed by Aitken (1975) and detailed in the XP-SWMM documentation (June 1997, Page 158)

$$I = \begin{bmatrix} 0.0 \\ 0.3 \\ 0.5 \\ 1.0 \end{bmatrix} \rightarrow U = \begin{bmatrix} 0.0 \\ 0.7 \\ 1.0 \\ 2.0 \end{bmatrix}$$

4. Calibration Method

A number of different characteristics of runoff flow are important for the functioning of a model. The model was calibrated using total flow, average flow, and maximum flow. In the following notation, *a* and *b* represent the start and end time respectively of an event.

Total Flow: $$\int_a^b q_{(t)}dt = \int_a^b \hat{q}_{(t)}dt + \varepsilon_1$$

Maximum Flow: $$\max_{t=a\rightarrow b} q_{(t)} = \max_{t=a\rightarrow b} \hat{q}_{(t)} + \varepsilon_2$$

Average Flow: $$\frac{\sum\left\{q \middle| q_{(t)} > 10^{-4}, a \le t \le b\right\}}{\left|\left\{q \middle| q_{(t)} > 10^{-4}, a \le t \le b\right\}\right|} = \frac{\sum\left\{\hat{q} \middle| \hat{q}_{(t)} > 10^{-4}, a \le t \le b\right\}}{\left|\left\{\hat{q} \middle| \hat{q}_{(t)} > 10^{-4}, a \le t \le b\right\}\right|} + \varepsilon_3$$

As shown above, flows less than 10^{-4} cfs (0.04 gpm) were not included in the calculation of the average flow.

5. Calibration Results

This calibration served as a test of a method and did not produce any specific parameters. A non-parameter based algorithm was chosen, because a wide variety of basins were modeled, whose characteristics varied greatly from that of the calibration basins.

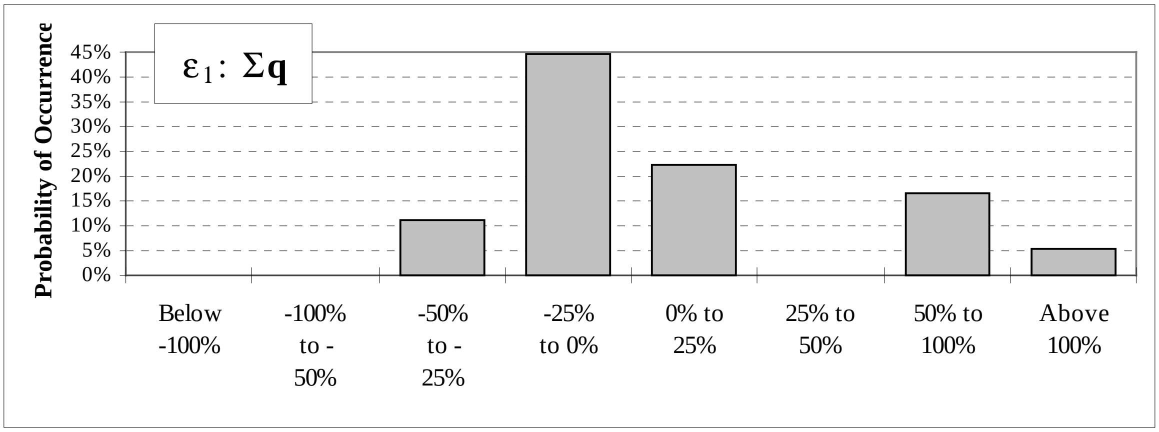
6. Calibration Accuracy

The error parameters had a large spread; the calibration was relatively close for estimating average flow but generally underestimated the maximum flow. The errors for the calibration of the August 30 rain event were especially high for all the test basins, and are not included in these statistics.

Statistic	ε_1	ε_2	ε_3
	Σq	q_{max}	q_{avg}
Mean	12%	49%	-1%
Median	-4%	21%	-7%
n	18	18	18
Standard Deviation	45%	71%	38%
10th Percentile	-23%	-23%	-33%
90th Percentile	60%	129%	53%
Within 50%	78%	56%	83%

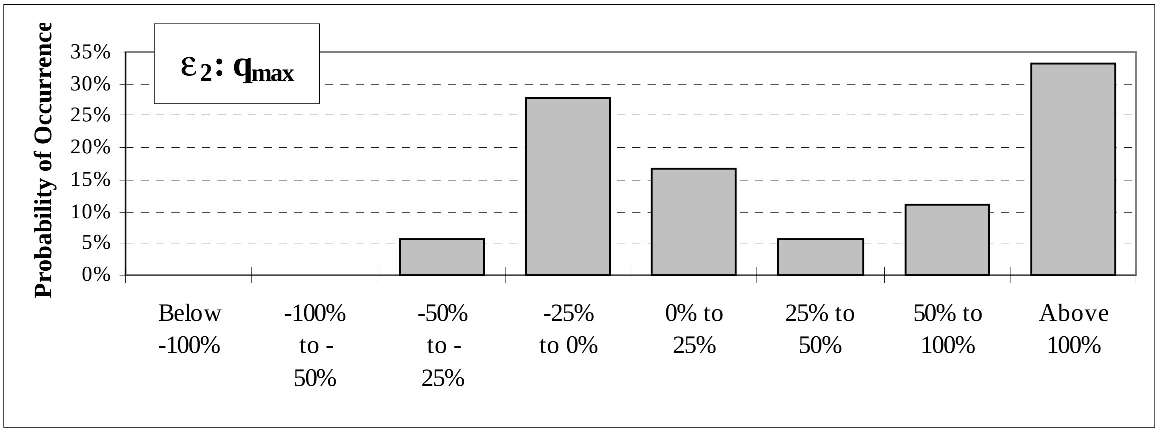
Total Flow

Total flow estimation was relatively good, with a some of outliers, where the total flow was underpredicted. Over 65% of the observed values were within 25% of the predicted value. Total flow is largely independant of many of the calibration factors in the test basins, and much of the error can be attributed to spatial differences in the rain event and measurement errors.



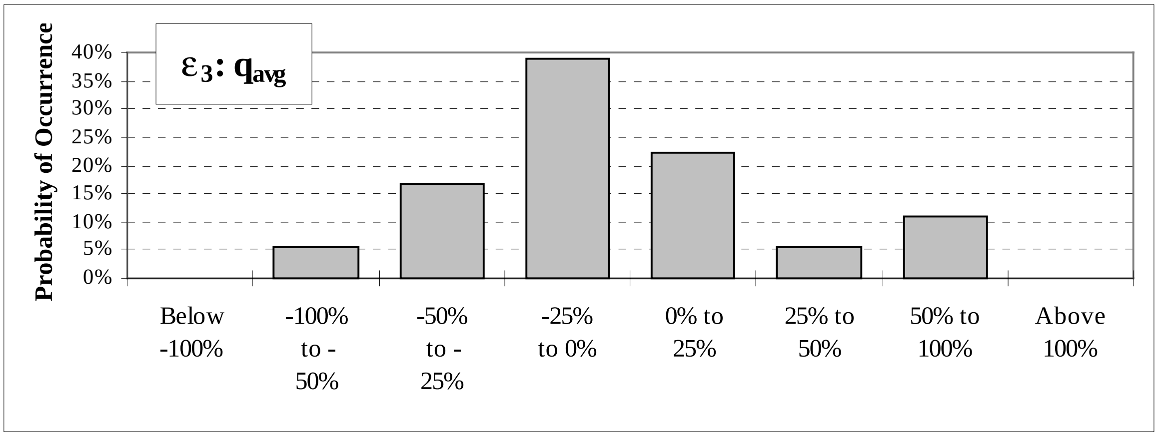
Maximum Flow

Maximum flow was often underestimated, largely because the runoff and rain measurement intervals are 6 minutes and 30 minutes respectively. Consequently, peaks in the rainfall intensity that are on the order of 10 minutes long are not reflected in the predicted runoff, since rainfall data represents an average intensity over 30 minutes.



Average Flow

The calibration of average flow was relatively successful, with over 60% of the predicted values falling within 25% of the observed values. Predicted values were well balanced around the observed values with a few outliers where the value was underestimated.


ε_3: q_{avg}
Probability of Occurrence
40%
35%
30%
25%
20%
15%
10%
5%
0%
Below -100%
-100% to -50%
-50% to -25%
-25% to 0%
0% to 25%
25% to 50%
50% to 100%
Above 100%

C. Sediment Washoff

1. Calibration Constants and Parameters

Parameter	Symbol	Unit
Runoff Coefficient	R	-
Washoff Power	p	-

2. Base Data

Parameter	Symbol	Unit
Initial Sediment Loads	l_0	g
Runoff	$q_{(t)}$	in hr^{-1}
Basin size	A_{basin}	ft^2
Area of Roads	A_{roads}	ft^2
Cumulative Event Washoff	$W_{(a-b)}$	g
Instantaneous washoff	$w_{(t)}$	g hr^{-1}

3. Prediction Model

Instantaneous washoff is predicted using the following formula[3]:

$$\hat{w}_{(t)} = L_{(t)}\left[1 - e^{-R\left(\frac{q_{(t)}}{A_{\text{Basin}}}\right)^p}\right]\frac{1}{\Delta t}$$

Cumulative washoff can be calculated as follows:

$$\hat{W}_{a\to b} = \int_a^b \hat{w}_{(t)}\,dt$$

The street load $L_{(t)}$ decreases as sediment washes off. The cumulative washoff, accounting for the decreased street sediment load, can be approximated by:

$$\hat{W}_{a\to b} \approx L_a\left[1 - \prod_{t=a}^{b}\left(1 - e^{\left[-\frac{1}{2}R\cdot\Delta t\left(\left[\frac{q_{(t)}}{A_{\text{Basin}}}\right]^p + \left[\frac{q_{(t-\Delta t)}}{A_{\text{Basin}}}\right]^p\right)\right]}\right)\right]$$

4. Calibration Method

OGS Large and OGS Small:

Total Washoff: $\hat{W}_{a\to b} = W_{a\to b} + \varepsilon_1$

Suspended Solids:

Instantaneous Washoff: $\hat{w}_{(t)} = w_{(t)} + \varepsilon_2$

---

[3] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Page 156, Formula (4-32)

5. Calibration Results

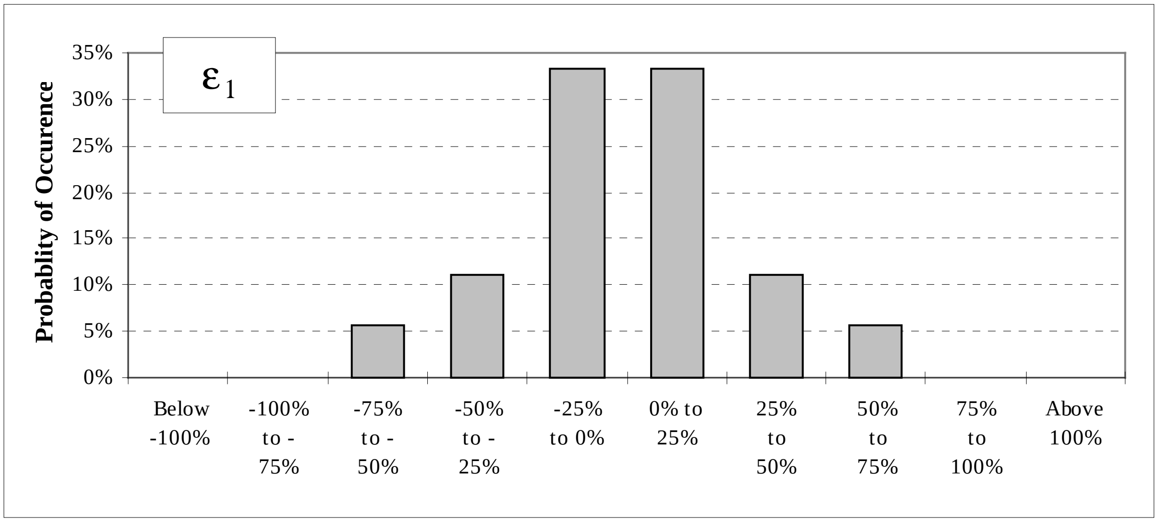
The difference in the washoff parameters for OGS Small and OGS Large are actually more similar than they appear

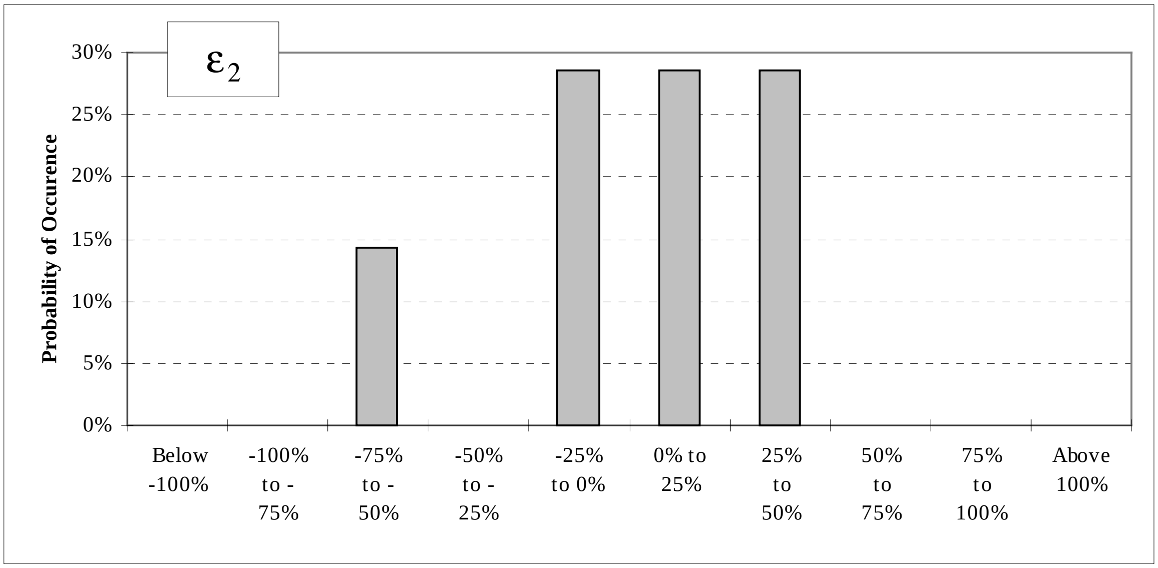
Parameter	OGS Large	OGS Small	Suspended Solids Residential	Suspended Solids Commercial
R	4.297	0.993	1.284	0.446
p	3.159	2.488	1.410	0.574

6. Calibration Accuracy

Calibration was good for all particle sizes, and exceptionally good for particle sizes >100m.

Statistic	OGS Small & Large	Suspended Solids
	ε_1	ε_2
Mean	-2%	1%
Median	-3%	0%
Standard Deviation	31%	37%
n	18	7
10th Percentile	-34%	-34%
90th Percentile	31%	36%
Within 50%	89%	86%




ε_2
Probability of Occurence
30%
25%
20%
15%
10%
5%
0%
Below -100%
-100% to -75%
-75% to -50%
-50% to -25%
-25% to 0%
0% to 25%
25% to 50%
50% to 75%
75% to 100%
Above 100%

D. Spring Thaw Snowmelt

1. Calibration Constants and Parameters

Parameter	Symbol	Unit
Base melting temperature	T_{base}	°F
Observed snow depth to Water equivalent depth factor	D_S/D_0	-
Minimum annual melt coefficient	M_{min}	in $°F^{-1}$ day^{-1}
Maximum annual melt coefficient	M_{max}	in $°F^{-1}$ day^{-1}
Snow Area Depletion Curve Parameters	S_0	-
Depth (D) and Snow Cover (S)	D_1	in
	S_1	-
	D_2	in
	S_2	-
Snowpack free water holding capacity	F_W	-

2. Base Data

Parameter	Symbol	Unit
Basin area	A_{basin}	ft^2
Basin runoff	q	ft^2s^{-1}
Air temperature	T	°F
Rain intensity	r	ft^2s^{-1}
Observed snow depth	D_S	in

3. Prediction Model

The snowmelt prediction model applies meltwater to the basin in the same way that rain water is applied. The amount of melt water $\hat{i}_{(t)}$ flowing onto the basin at time *t* is expressed in cfs.

$$\hat{i}_{(t)} = A_{\text{basin}} \sigma_{(D(t))} M_{(t)} \tau_{(t)} F_{(t)}$$ [4]

$\sigma_{(D)}$ represents the areal depletion curve for the snow cover. This curve represents the area in a basin that is covered by snow for a given water equivalent snow depth. The curves that are used in this model are only suitable for thaw simulation and not for modeling the life cycle of the snow pack.

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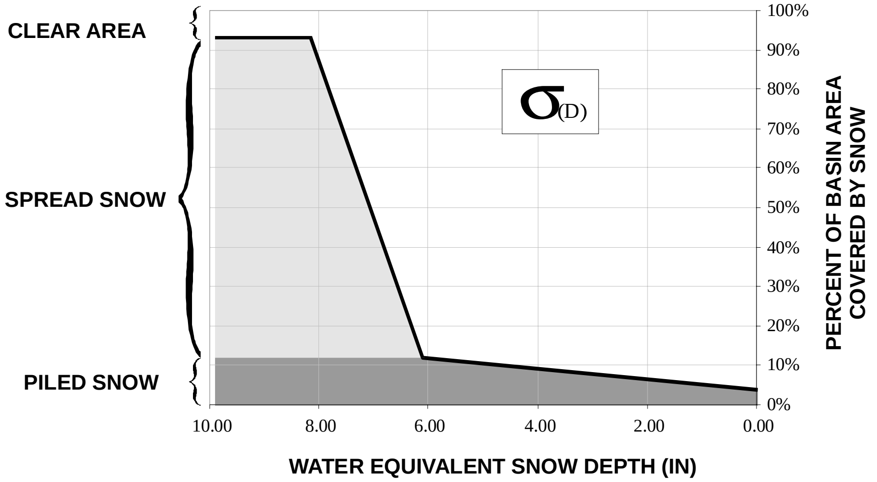
[4] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Appendix II, Page 412



$M_{(t)}$ is the melt factor expressed in (inches °F^{-1} $days^{-1}$). The melt factor for a particular day is calculated from a sinusoidal interpolation of the minimum and maximum annual melt factors.

$$M_{(t)} = \frac{\left(M_{\max} + M_{\min}\right)}{2} + \frac{\left(M_{\max} - M_{\min}\right)}{2}\sin\left[\frac{\pi}{182}\left(t_{days} - 81\right)\right]$$

$\tau_{(t)}$ is the number of degrees Fahrenheit above the temperature at which melting begins, T_{base}.

$$\tau_{(t)} = \begin{cases} T_{(t)} - T_{base} \text{ if } & T_{(t)} > T_{base} \\ 0 \text{ if } & T_{(t)} \le T_{base} \end{cases}$$

$F_{(t)}$ represents the water holding capacity of the snowpack. In the model, no melted water drains from the snowpack until the total amount melted exceeds the free water holding capacity of the snowpack, expressed as a percentage of the depth of the snowpack, F_w. The starting point *a* of the interval $\left(a \rightarrow t\right)$ is the last time the snowpack was frozen. In this model that is assumed to be when the temperature dropped below freezing.

$$F_{(t)} = \begin{cases} 0 \text{ if } \int_a^t \tau_{(t)} M_{(t)} dt <= F_w D_{(t)} \\ 1 \text{ if } \int_a^t \tau_{(t)} M_{(t)} dt > F_w D_{(t)} \end{cases}$$

4. Calibration Method

Many characteristics of snow melt are important for the functioning of a model. The model was calibrated using total flow and maximum flow. In the following notation, *a* and *b* represent the start and end time of a day modeled for snow melt.

Total Flow: $$\int_a^b q_{(t)} dt = \int_a^b \left(\hat{i}_{(t)} - r_{(t)}\right) dt + \varepsilon_1$$

Maximum Flow: $$\max_{t=a\to b} q_{(t)} = \max_{t=a\to b}\left(\hat{i}_{(t)} - r_{(t)}\right) + \varepsilon_2$$

Calibration Notes:

The reasonable range for T_{base} is (25 to 32 °F)[5] T_{base} of 32°F was used because it agreed well with the periods that flow data occurred, and for a thaw event, the ground underneath the snow is likely to be colder than the ambient air.

$M_{(t)}$ and D_0 are mutually dependant:

$$D_0 = \int M_{(t)} \tau_{(t)} F_{(t)} dt$$

Neither $M_{(t)}$ and D_0 were directly measured, so reasonable values[6] were chosen for both. F(t) was assumed to be 1 for the entire thaw period. Once F(t) was calibrated $M_{(t)}$ and D_0 were adjusted.

An estimate of the snow area depletion curve can be determined[7] from the measured runoff data using:

$$\sigma_{(a\to b)} = \frac{\int_a^b q_{(t)} dt}{A_{\text{basin}} M_{(a\to b)} \int_a^b \tau_{(t)} F_{(t)} dt}$$

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[5] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Page 429

[6] Reasonable values for M(t) are based on SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Page 429. The values for D_0 were based on the results of the calibration of $\sigma_{(t)}$ and familiarity with the calibration basins.

[7] This estimate requires the following assumptions:

- The basin is relatively small and impervious, so that $i_{(t)} \approx q_{(t)}$.
- $M_{(t)} \approx M_{(a\to b)}$ over the interval $a \to b$.
- $\sigma_{(t)} \approx \sigma_{(a\to b)}$ over the interval $a \to b$.

Using these assumptions the estimate for σ can be derived from the melt function:
Substituting q for i:

$$q_{(t)} = A_{\text{basin}} \sigma_{(D(t))} M_{(t)} \tau_{(t)} F_{(t)}$$

Integrating both sides over the interval $a \to b$:

$$\int_a^b q_{(t)} dt = \int_a^b A_{\text{basin}} \sigma_{(D(t))} M_{(t)} \tau_{(t)} F_{(t)} dt$$

Placing the assumed constants outside of the integral:

$$\int_a^b q_{(t)} dt = A_{\text{basin}} M_{(a\to b)} \sigma_{(a\to b)} \int_a^b \tau_{(t)} F_{(t)} dt$$

$\sigma_{(a\to b)}$ is then isolated algebraically.

T_{base}, $M_{(t)}$, D_0, and $\sigma_{(D)}$ are calibrated to the measured total daily runoff. The maximum daily runoff is generally underestimated when F_w=0. Increasing F_w allows higher values of $M_{(t)}$ to be used, thus increasing the peak runoff, while maintaining the cumulative runoff during the day.

5. Calibration Results

U/R represents parameter values for undeveloped and residential areas, and C/I represents commercial and industrial areas.

Function	Parameter	Unit	U/R	C/I
$\tau_{(t)}$	T_{base}	°F	32	32
D_0	D_S/D_0		1.25	0.55
$M_{(t)}$	M_{min}	in $°F^{-1}$ day^{-1}	0.05	0.187
	M_{max}	in $°F^{-1}$ day^{-1}	0.102	0.187
$\sigma_{(D)}$	S_0		3%	5%
	D_1	in	3.02	7.28
	S_1		7%	10%
	D_2	in	3.27	9.86
	S_2		80%	100%
F(t)	F_W		10%	2%

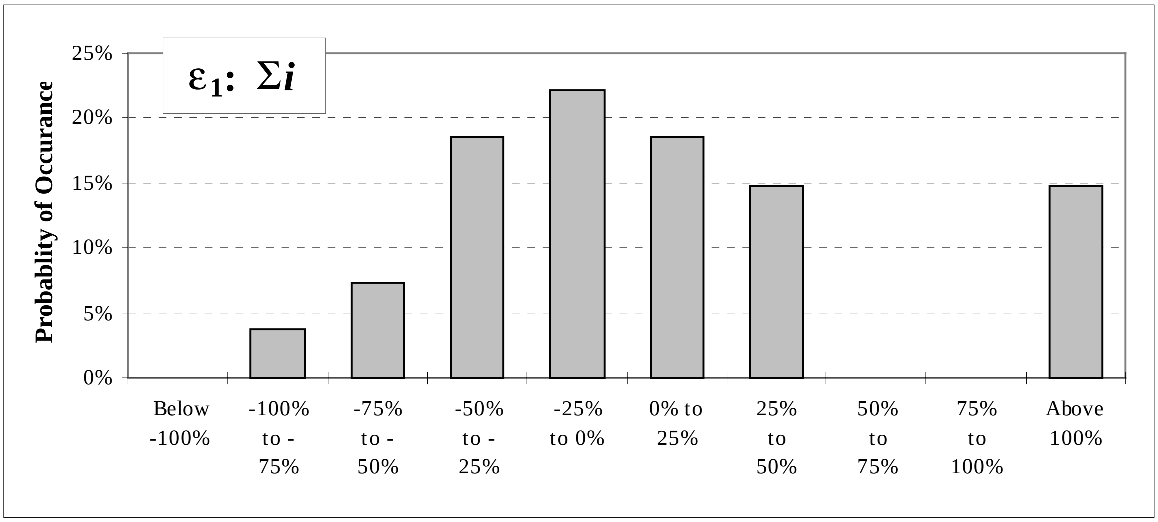
6. Calibration Accuracy

Snow melt calibration in terms of total melt on a day by day basis was good. Predicting maximum flows from snowmelt was difficult, probably because of environmental effects not accounted for in the model parameters (wind, solar radiation, etc.). The model parameters were chosen to provide accurate prediction of Σi and i_{max} during the high flow melt events at the beginning of spring thaw. Much of the error shown in the following distributions occur later in the thaw during significantly smaller thaw events. In general the error in the residential snow melt calibration is smaller than the error in the commercial calibration

Statistic	**Σi**	**i_{max}**
	ε_1	ε_2
Median	0%	29%
Mean	18%	130%
Standard Deviation	80%	240%
n	27	27
10th Percentile	-51%	-41%
90th Percentile	147%	382%
Within 50%	74%	41%

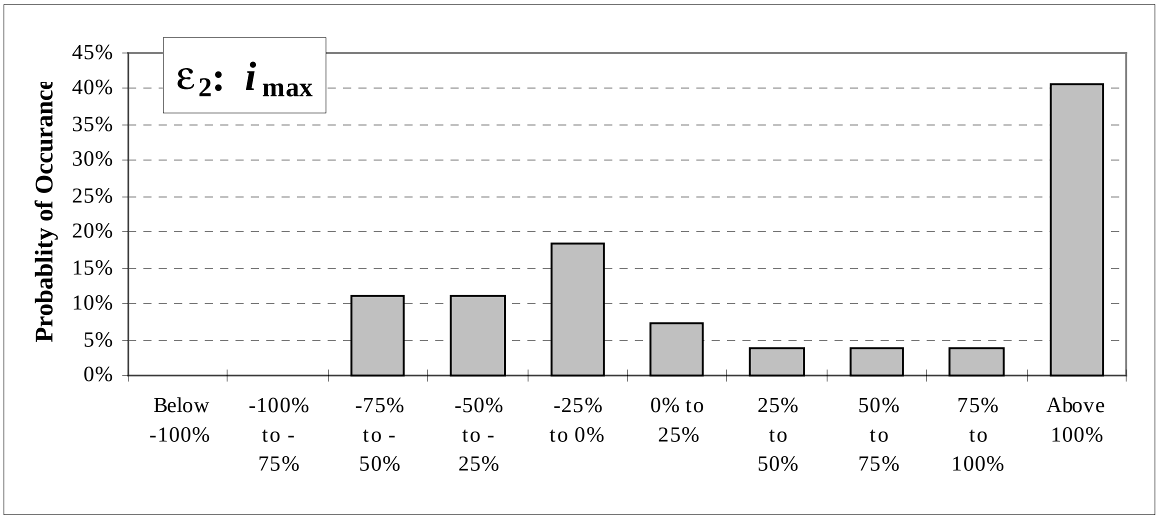
Total Flow

Total flow estimation was generally good for both residential and commercial, with a small number of instances where the measured value was 125% to 225% higher than the predicted value. These occured at various times during the thaw.



Maximum Flow

Maximum flow prediction was fair for early thaw events. In both the undeveloped/residential and commercial/industrial calibration, maximum flow was consistently underpredicted. This may have resulted in a change in F_w as the spread snow melted and piled snow remained or weather events. It was assumed that the initial melt events during spring thaw were more important to model accurately, since that is a period of significant sediment washoff.



E. Sediment Build-up

1. Calibration Constants and Parameters

Parameter	Symbol	Unit
Build up rate	b	g m^2 day^{-1}

2. Base Data

Parameter	Symbol	Unit
Round 1 Load	l_1	g
Round 3 Load	l_3	g
Sweeping Efficiency	$S_{(t)}$	%
Sediment Washoff	$w_{(t)}$	g
Basin road area	A_{basin}	m^2

3. Prediction Model

The prediction model combines the results of the previous calibrations. Road area and basin area were assumed to be 20,000 sf and 50,000 sf respectively in all of the calibration basins. Sediment was uniformly distributed over the basins.

$$\hat{l}_3 = l_1 - \sum_{s=1}^{\#SweepEvents} S\ l_{(s)} + \int_{t_{R1}}^{t_{R3}} \left(-w_{(t)} + bA_{RoadArea}\right)dt$$

4. Calibration Method

Detailed spring and fall sediment load data were available for 20 road sites in Anchorage. Build up rates were calibrated by comparing the predicted fall sediment loads to the fall sediment loads predicted by the model based on 1996 initial sediment load, snow, thaw, and rain data.

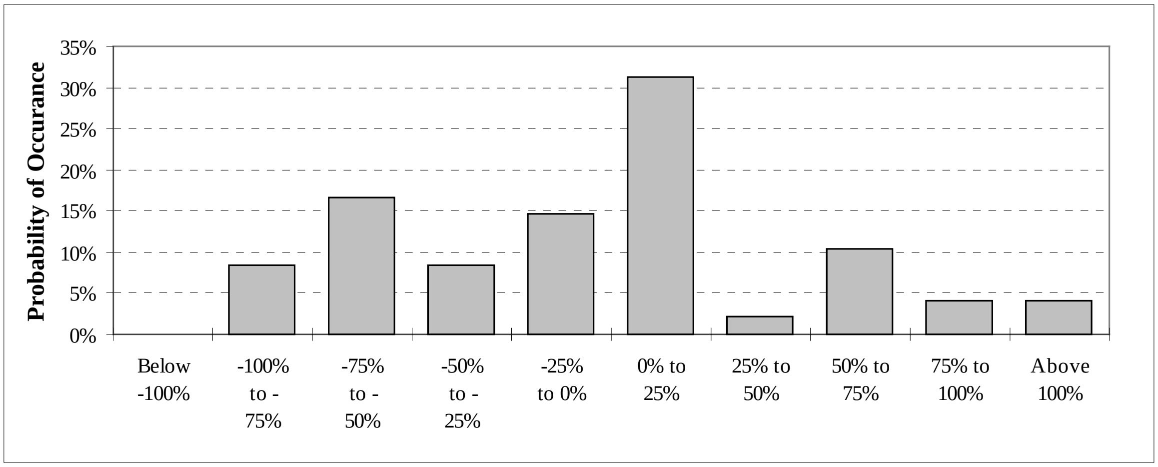
5. Calibration Results

	Build Up (g m^2 day^{-1})		
Road Type	**Susp. Solids**	**OGS Small**	**OGS Large**
1	0.373	0.598	0.241
2	0.639	0.159	0.054
3	2.144	0.770	0.810
4	9.482	2.089	2.750

6. Calibration Accuracy

Since build up was not measured directly, the accuracy of the built up calibration is an aggregation of the accuracy of all other calibration parameters. The results of the calibration were generally well centered with little bias. Particle sizes >100µ generally calibrated better than sizes <100µ. Road type 2 (collector streets) calibrated poorly compared to other road types.

Statistic	**l_3**
	ε
Median	2%
Mean	-1%
Standard Deviation	76%
n	60
10th Percentile	-73%
90th Percentile	56%
w/in 50%	57%


Probability of Occurance
35%
30%
25%
20%
15%
10%
5%
0%
Below -100%
-100% to -75%
-75% to -50%
-50% to -25%
-25% to 0%
0% to 25%
25% to 50%
50% to 75%
75% to 100%
Above 100%

II. Model Operation and Function

This section covers the components of the model created for the Anchorage OGS Assessment Model. Unless noted otherwise, the model uses the same methodology as SWMM. When applicable, the algorithms forming the predictive model of each component are described in the calibration section.

The model tracks the fates of three size classifications of sediment: suspendable solids (<100μ), OGS small (100μ – 420μ), and OGS large (>420μ).

Initial Loads

Initial sediment loads were estimated for each basin and sediment class. Sediment loads were applied to the entire basin surface based on the road area in each basin:

Initial Load (g ft^{-2})				
	Road Type			
Contaminant	1	2	3	4
Suspended Solids	3.8	3.3	7.6	7.4
OGS Small	6.4	7.3	16.7	29.1
OGS Big	18.0	26.1	19.2	39.1

Runoff and Snowmelt Component

The runoff and snowmelt component estimates runoff from each basin from rainfall and snow melt. Rainfall is based on hourly rain data from 1965 at Anchorage International Airport. Snowmelt is calculated from the initial measured snowpack at the beginning of that and hourly temperatures interpolated from minimum and maximum recorded temperatures at the Anchorage International Airport.

Runoff and snowmelt are both applied to the Laurenson flow algorithm. The results are stored in a database table that lists runoff (ft^{3}s^{-1}) at hourly intervals for each basin.

Build Up, Sweeping, and Washoff Component

The model tracks the load of three size classifications of sediment on the basins: suspendable solids (<100μ), OGS small (100μ – 420μ), and OGS large (>420μ). Build up is applied at the beginning of each day; swept sediment is removed at the beginning of each day where a sweep event occurs; and sediment washed off is removed at hourly increments. The load of each sediment class on each basin is stored in a database table in daily increments. Washoff quantities are calculated for each sediment class using the hourly runoff information from the runoff database table and the estimated sediment load on the basin. The washoff quantities are also stored in a database table at hourly intervals.

Treatment Component

The amount of sediment removed from the washoff stream is calculated at hourly increments. The total season treatment efficiencies for each sediment class and basin are stored in a database table.

The treatment of sediment washing off from a basin is a function of the mass of sediment, the size of the sediment, and flow of water passing through the treatment device. The predictive model is based on stokes law and is calculated using the following equation[8]:

$$E = E_Q + \frac{\ln \alpha}{4.605}\left(E_Q - E_T\right)$$

Where:

E_Q = Treatment efficiency during quiescent flow.
E_T = Treatment efficiency during turbulent flow.
α = Turbulence factor.

Quiescent flow treatment efficiency is calculated using the equation[9]:

$$E_Q = \min\begin{cases} 1 \\ v_s / v_u \end{cases}$$

Where:

v_s = Terminal or settling velocity
v_u = Overflow velocity

Turbulent flow treatment efficiency is calculated using the equation using the same values as the quiescent flow equation[10]:

$$E_T = e^{\left(-v_s / v_u\right)}$$

The relative contribution of the quiescent and turbulent flow equations is determined by the turbulence factor[11]:

$$\alpha = \frac{v_s y^{1/6}}{v_t n \sqrt{g}}$$

Where:

v_s = Terminal or settling velocity
v_t = Flow through velocity
y = Depth of water in OGS treatment unit
n = Manning's roughness coefficient
g = Gravitational constant

The settling velocity of each contaminant type was calculated by taking the average of the settling velocities of the smallest and largest particles within the contaminant type. The terminal velocity of a particle size is calculated using[12]:

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[8] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Equation IV-34, Page 469.

[9] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Equation IV-25, Page 466
[10] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Equation IV-32, Page 469
[11] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Equation IV-31, Page 467
[12] SWMM, Version 4: User's Manual, EPA/600/3-88/001a, Equation IV-19, Page 465

$$v_s = \sqrt{\frac{4}{3}\frac{gd}{C_D}\left(S_P - 1\right)}$$

Where

g = Gravitational constant
d = Diameter of particle
C_D = Drag coefficient
S_p = Specific gravity of particle

The following settling velocities were used to characterize the modeled contaminants:

Contaminant	Settling Velocity (feet/second)
SS	$1.25 \cdot 10^{-3}$
OGS Small	$8.62 \cdot 10^{-2}$
OGS Large	$4.69 \cdot 10^{-1}$

OGS Cost

The relative cost of sediment removal is important to making decisions about applying OGS treatment. Both capital costs and maintenance costs were estimated. Capital costs were amortized using a 6% interest rate applied over 30 years. The following table summarizes the OGS cost analysis:

Physical Parameters								
Type			Manhole With Tee	Baffled Chamber	Baffled Chamber	Baffled Chamber	Baffled Chamber	Baffled Chamber
Length (Diameter)	ft		6	6	10	12	20	30
Width	ft			6	6	8	10	12
Depth	ft		10	6	8	8	10	10
Actual Area	sf		28.3	36	60	96	200	360
Effective Flow Area	sf		2.8	12	20	32	66.7	120.0
Costs								
Item	Unit	Unit Cost	Quantity					
Capital Costs								
Type I Manholes	each	$5,000	0	3	3	3	0	0
Type II Manholes	each	$8,000	1	0	0	0	3	0
Type III Manholes	each	$12,000	0	0	0	0	0	4
18" Sewer Pipe	lf	$55	20	56.8	62.4	65.3	0	0
24" Sewer Pipe	lf	$75	0	0.0	0.0	0.0	76.6	0
36" Sewer Pipe	lf	$110	0	0.0	0.0	0.0	0.0	78.0
Bedding	cy	$34	0.5	2.8	3.4	4.2	8.0	12.4
Excavation	cy	$15	18	111.1	130.8	151.2	177.1	274.4
Reinforced Concrete Walls	sf	$25	0	216.0	376.0	512.0	1000.0	1560.0
Thaw Protection	each	$8,000	0	0.0	0.0	1.0	1.0	1.0
Surface restoration	sf	$25	96.5	185.5	244.9	322.5	553.1	876.0
Subtotal			$11,802	$29,921	$36,033	$49,863	$79,498	$130,020
Other Items	%	30%	$3,540	$8,976	$10,810	$14,959	$23,849	$39,006
Subtotal			$15,342	$38,897	$46,843	$64,822	$103,347	$169,026
Management / Engineering	%	15%	$2,301	$5,835	$7,026	$9,723	$15,502	$25,354
Total Capital Cost			**$17,643**	**$44,731**	**$53,870**	**$74,545**	**$118,849**	**$194,380**
Amortized Cost (30yr @ 6%)			**$1,282**	**$3,250**	**$3,914**	**$5,416**	**$8,634**	**$14,121**
Operation & Maintenance								
Labor	hr	$65	2	4	5	8	30	40
Vac Truck	hr	$120	2	2	2.5	4	15	20
Trash pump	hr	$20					15	20
Safety Equipment	hr	$10					30	40
Total O&M Cost			**$370**	**$500**	**$625**	**$1,000**	**$4,350**	**$5,800**
Total Annual Cost			**$1,652**	**$3,750**	**$4,539**	**$6,416**	**$12,984**	**$19,921**

It is important to note that the OGS costs do not include real-estate costs. Based on this cost analysis the costs of OGS units were estimated using a linear curve fit:

OGS Unit Cost = $157 * [Effective OGS Area (sf)] + $1594

ANCHORAGE BOWL OGS ASSESSMENT MODELING

VOLUME IV

DATA SET DESCRIPTIONS

Municipality of Anchorage
Department of Public Works
Montgomery Watson

WATERSHED
MANAGEMENT

Table of Contents

Introduction

The following data sets were used for calibrating and running the Anchorage Bowl OGS Assessment model. The data sets are in dBase IV and Arcview shape file format and are located in the “data sets” folder on this CD ROM.

Climate Data

Rain Data

The data set incudes 1996 rain data from Montgomery Watson’s rain guage at Stellar High School and 1965 historical hourly rain data from the National Climactic Data Center for the Anchorage International Airport.

Filename: \DataSets\Databases\Rainfall.dbf

Structure:

Field Name	Field Type	Description
Date	Date	Date of measurement
Time	Text (8)	Time of measurement
Inches	Number	Inches of rainfall during the time interval

First Order Summary of the Day (FSOD)

This data set was used as a source of daily minimum and maximum temperature and initial snow depths. The data summarizes daily readings at the Anchorage International Airport and was obtained from the National Climactic Data Center.

Filename: \DataSets\Databases\Fsod.dbf

Structure:

Field Name	Field Type	Description
Date	Date	Date of measurement
PRCP	Number	Total precipitation (inches), rain and snow
SNOW	Number	Snowfall (inches)
SNWD	Number	Current snow depth (inches)
TMIN	Number	Minimum temperature (°F)
TMAX	Number	Maximum temperature (°F)

Physical Data

Catch Basin Runoff

This data set was used to calibrate basin runoff. The data set includes the readings of pressure transponders that were installed in weir structures placed in four catch basins. The weir constants are needed for each catch basin. Additionally, the depth of water below the bottom of the weir must be determined from the data prior to each runoff event. Temperature data were also collected, but were not used.

Filename: \DataSets\Databases\CatchBasinRunoff.dbf

Structure:

Field Name	Field Type	Description
CatchBasin	Text (3)	Name of catchbasin
SampleDate	Date	Date of measurement
SampleTime	Text(8)	Time of Measurement
Depth	Number	Depth of water above pressure transponder (feet)
Temperatur	Number	Temperature (°C)

Catch Basin Sediment Traps

This data set describes the washed off sediment that was captured in sediment traps installed in four catch basins.

Filename: \DataSets\Databases\BasinTrap.dbf

Structure:

Field Name	Field Type	Description
SampleSite	Text (3)	Name of catchbasin
SampleDate	Date	Date sample was collected
R38_10mm	Number	Percent passing the 38.10mm sieve
R19_00mm	Number	Percent passing the 19.00mm sieve
R9_50mm	Number	Percent passing the 9.50mm sieve
R4_76mm	Number	Percent passing the 4.76mm sieve
R2_00mm	Number	Percent passing the 2.00mm sieve
R0_84mm	Number	Percent passing the 0.84mm sieve
R0_42mm	Number	Percent passing the 0.42mm sieve
R0_149mm	Number	Percent passing the 0.149mm sieve
R0_074mm	Number	Percent passing the 0.074mm sieve
DryWeight	Number	Dry weight of material collected in trap (g)

TSS Washoff

This data set describes the concentration of total suspended solids in the grab samples taken at four catch basin inlets.

Filename: \DataSets\Databases\TSSWashoff.dbf

Structure:

Field Name	Field Type	Description
SampleSite	Text (3)	Name of catchbasin
SampleDate	Date	Date sample was collected
Time	Text(8)	Time sample was collected
SampleID	Text(12)	Lab Sample ID
TSS	Number	Total Suspended Solids Concentration (mg/l)
Sheen	Number	Percent sheen visible in runoff into catchbasin

Street Sediment

This data set lists the results of the street sediment load sampling.

Filename: \DataSets\Databases\StreetSediment.dbf

Structure:

Field Name	Field Type	Description
Round	Number	Sampling Round (1-3)
Site_ID	Text(5)	Sampling Location Code
TO	Text(1)	Track-Out Area (T,F)
Strata	Text(5)	Sample strata ([Intersection, Non-Intersection] [Gutter, Non-Gutter])
SampleDate	Date	Date sample was collected
TransWidth	Number	Width of sample transect (m)
TransLength	Number	Length of sample transect (m)
TransArea	Number	Area of sample transect (m^2)
TotDryWt	Number	Total Dry Weight of Sample (g)
R38_10mm	Number	Percent passing the 38.10mm sieve
R19_00mm	Number	Percent passing the 19.00mm sieve
R9_50mm	Number	Percent passing the 9.50mm sieve
R4_76mm	Number	Percent passing the 4.76mm sieve
R2_00mm	Number	Percent passing the 2.00mm sieve
R0_84mm	Number	Percent passing the 0.84mm sieve
R0_42mm	Number	Percent passing the 0.42mm sieve
R0_149mm	Number	Percent passing the 0.149mm sieve
R0_074mm	Number	Percent passing the 0.074mm sieve
BagWt	Number	Weight of emptied sampling vacuum bag

		after sampling (g)
BagTare	Number	Weight of sampling vacuum bag before sampling (g)
Retained	Number	Weight of material retained in bag and not analyzed (g)
Notes	Text(25)	Sampling notes

Geographic Data

Road Data

This data set describes the total road length by road type in each basin.

Filename: \DataSets\Databases\RoadTypes.dbf

Structure:

Field Name	Field Type	Description
UniqueID	Text (32)	Unique ID of Catchbasin (includes basinname)
Road1Lengt	Number	Length of type one roads in basin (ft)
Road2Lengt	Number	Length of type two roads in basin (ft)
Road3Lengt	Number	Length of type three roads in basin (ft)
Road4Lengt	Number	Length of type four roads in basin (ft)

Land use

This data set from the NPDES permit application describes the land use characteristics of each outfall and basin.

Filename: \DataSets\Databases\NPDESAnc.dbf

Structure:

Field Name	Field Type	Description
Map	Text (4)	Map name on which outfall appears
Watershed	Text (25)	Watershed Name
Outfall	Number	NPDES Outfall Number
AreaAC	Number	Area of drainage basin (acres)
Class	Text (1)	Outfall class
ResAreaPer	Number	Residential area as percentage of total basin area
ComAreaPer	Number	Commercial area as percentage of total basin area
IndAreaPer	Number	Industrial area as percentage of total basin

		area
AgrAreaPer	Number	Agricultural area as percentage of total basin area
UndAreaPer	Number	Undeveloped area as percentage of total basin area
Shortname	Text (3)	Short name for watershed

Drainage Basins

This gis coverage shows the location of each drainage basin. It is a newer version of what was used in the model, and includes some additional basins.

Filename: \DataSets\gis\ofbasin.shp

Basin Outfalls

This gis coverage shows the location and type of each outfall.

Filename: \DataSets\gis\outfals.shp