# CITY OF SNOQUALMIE

# STORMWATER SYSTEM

# OPERATIONS AND MAINTENANCE MANUAL

**24 APRIL 2013**

TETRA TECH

nhc
northwest hydraulic consultants

# STORMWATER SYSTEM

# OPERATIONS AND MAINTENANCE MANUAL

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**City of Snoqualmie**

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# EXECUTIVE SUMMARY

This document presents a comprehensive summary of stormwater flow control and water quality facilities in the city of Snoqualmie. Maintenance requirements are identified for all types of facilities, and a methodology is presented for determining the cost of routine maintenance and minor repairs. Routine inspections and preventative maintenance, performed on a regular scheduled basis, can help avoid more costly major repairs.

As of 2013, the city was responsible for maintaining approximately 50 stormwater ponds providing water quality treatment and various levels of flow control, plus approximately 12 water quality bioswales and rain gardens. Counts are approximate because many of the ponds are multi-cell features which have been aggregated and counted as single facilities. Similar aggregation has been done for multi-segment rain gardens and bioswale segments, especially along the Snoqualmie Parkway. In addition to the main facilities, there is a conveyance system with nearly 70 miles of storm drain pipe and 4,500 catch basins. The conveyance system includes numerous flow splitters, flow controls, and pollution control devices. There are six stormwater outfalls to the Snoqualmie River, including an outfall from the North High Flow Bypass Line that crosses steep slope areas requiring periodic geotechnical assessment.

Requirements for routine maintenance and minor repairs are defined by the Department of Ecology 2005 Stormwater Management Manual for Western Washington and the King County 2009 Surface Water Design Manual. City of Snoqualmie municipal code Chapter 15.18 states that the intent of city stormwater management is to meet or exceed the thresholds, definitions, minimum requirements and exceptions/variance criteria in these documents.

The budget needed to maintain the city stormwater system to meet regulatory objectives is determined by five factors: (1) types of system components; (2) maintenance activities for each component; (3) the size or quantity of each component type; (4) frequency of occurrence of each maintenance activity; and (5) the unit cost of each maintenance activity. The only truly discretionary part of the cost equation is the frequency of maintenance activities.

Initial estimates of the frequency of maintenance activities and unit costs were developed in consultation with city public works staff and entered into a budget spreadsheet which was provided to public works as a separate work product. This was done to allow for ease of updating for changes to the city stormwater system inventory, GIS database, activity frequency, and unit costs, all of which will change over time. It also facilitates consideration of budget constraints on stormwater maintenance activity during a transition period while the program is ramped up to meet the requirements of the Western Washington Phase II Municipal Storm Water Permit.

## CREDITS AND ACKNOWLEDGEMENTS

This study was undertaken by Northwest Hydraulic Consultants (NHC) for the city of Snoqualmie under a prime agreement between the city and NHC. EBA Engineering Consultants Ltd., a Tetra Tech Company, provided services as a sub-consultant to NHC.

The project was managed for NHC by Malcolm Leytham, for Tetra Tech by W.A. (Bill) Rozeboom, and for the city of Snoqualmie by Mike Roy. Mr. Rozeboom was the principal investigator and principal author of the report. Derek Stuart of NHC assisted in review of facility location figures. Rick Schaefer of Tetra Tech (Seattle) provided advice and review on issues related to maintenance operation costs. The work was initiated while Mr. Rozeboom was with NHC and continued after he joined Tetra Tech.

The consultant team has a long history with the city of Snoqualmie. While with NHC, Mr. Rozeboom was the city's on-call drainage review engineer during the development and implementation of master drainage plans for Snoqualmie Ridge Phases 1 and 2, and has detailed knowledge of city drainage infrastructure constructed from 1994 through 2011. Dr. Leytham performed the pre-1994 city reviews for the original Snoqualmie Ridge Master Drainage Plan and has had ongoing, although discontinuous, involvement with city of Snoqualmie projects since that time. Mr. Schaefer was the developer's drainage consultant for both phases of Snoqualmie Ridge drainage planning and prepared the original 1997 estimates of stormwater system operation and maintenance costs for Snoqualmie Ridge.

The work was performed in close cooperation with city of Snoqualmie Public Works and GIS staff. Gary Stevens and Kevin Halbert identified gaps in the city's knowledge of the stormwater system which were then addressed during the course of this work. Brendon Ecker with the city GIS department performed an inventory analysis of the city's stormwater conveyance system and produced the GIS-derived location maps and facility location figures included in this report. Mike Roy reviewed the city's stormwater maintenance cost history and actively participated in determinations of unit costs and frequency of maintenance activities.

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# 1 INTRODUCTION

## 1.1 BACKGROUND AND STUDY APPROACH

The city of Snoqualmie has experienced rapid grown since 1992 through annexations of more than 2,000 acres of forested land for residential and mixed use developments at Snoqualmie Ridge. Stormwater infrastructure at Snoqualmie Ridge was constructed in compliance with evolving stormwater management regulations for conveyance capacity, water quality treatment, and peak flow control. The city's stormwater utility was created in 1998 to service the stormwater infrastructure at Snoqualmie Ridge.

The historic pre-annexation areas of the city are mostly located within the Snoqualmie River floodplain and are subject to periodic river flooding. As of 1992, the stormwater infrastructure in these areas was minimal by current standards, and consisted primarily of drainage conveyance systems. In 2003, the service area for the city stormwater utility was expanded to include the historic areas, and this raised expectations for drainage improvements in those areas.

Tetra Tech was retained by the city in 2007 to prepare a Stormwater Comprehensive Plan for the city which focussed on capital improvement needs for the historic areas of the city. The study goals were "*to address drainage and surface water flooding problems in the downtown area, assess the potential for reducing flood insurance rates with the adoption of the Plan, and plan for future growth. Additional goals are to evaluate the City's stormwater utility fee and recommend a capital improvement program (CIP) for stormwater projects.*" A draft report published in 2010 completed all objectives except for evaluation of the City's stormwater utility fee, which required information on stormwater system operations and maintenance costs. The report recommended that operations and maintenance costs should be addressed as a high priority, and that this information be used to update the comprehensive plan.

The objective for the present study was to develop a citywide stormwater operations and maintenance (O&M) manual which identifies required stormwater O&M activities for all areas of the city and which establishes the basis for estimating the cost of performing those activities. A major element of this work involved reviewing and updating the city's GIS inventory of stormwater facilities, particularly for Snoqualmie Ridge and other areas not included in the prior stormwater comprehensive plan for the downtown area. During this updating, previously archived documents that are relevant to stormwater system design and future operation were compiled in digital form and are attached as digital appendices to this report.

The primary focus of this report is to describe the inventory of city facilities, and then identify the operational and maintenance tasks which should periodically be done for each type of facility.

Information on the frequency of specific maintenance activities, unit costs, and total costs are presented in a companion spreadsheet which was developed as a concurrent but separate work product. This was done to accommodate future revisions of cost information to reflect city experience in implementing the O&M program and unit cost changes over time.

## 1.2 STORMWATER FACILITY NAMES AND NAMING CONVENTIONS

### 1.2.1 Master Drainage Plans

Nearly all of the city's existing major stormwater facilities were described in one of three Master Drainage Plan (MDP) documents: (1) the Snoqualmie Ridge 1995 MDP, (2) the Falls Crossing 1995 MDP, and (3) the Snoqualmie Ridge II 2004 MDP which was subsequently amended in 2008. The facility identifiers assigned in the MDP documents were used in subsequent engineering plans and Stormwater Management Plan and/or Technical Information Reports which provide details of the facility designs. Because the original names provide a link to the facility detailed design information, the original names need to be retained as part of the facility identification.

Different naming conventions were used for the three MDPs noted above. In the first Snoqualmie Ridge MDP, facilities identities usually corresponded to a drainage basin and facility sequence number. Figure 1.1 below is extracted from the original MDP and shows the drainage basin assignments which begin with "A" in the lower left of the figure. The preliminary alignment of the Snoqualmie Parkway runs through basin B (south-draining) and then basins D, E, P, and V which all drain towards the east. Basin C drains west to Lake Alice. Basins G, I, J, K, L, M, N, O, and Q all drain north through steep landslide hazard areas.

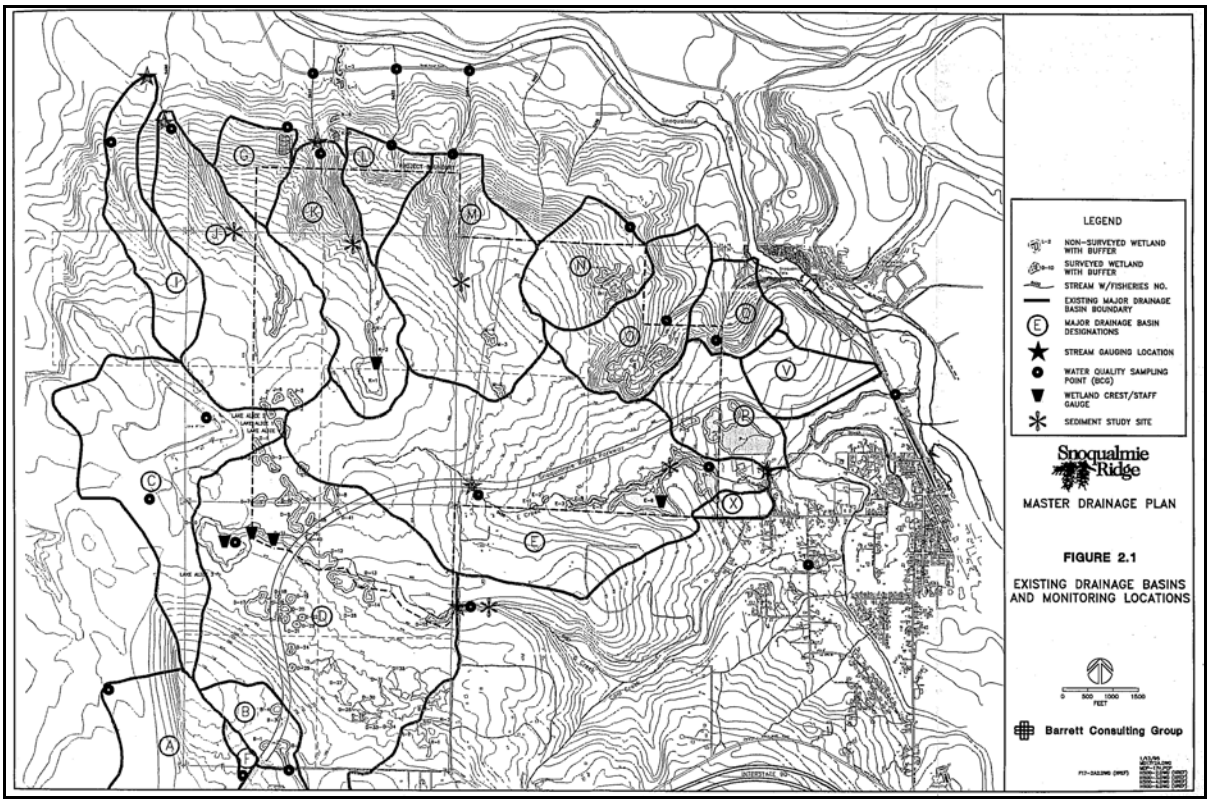


**Figure 1.1 - Snoqualmie Ridge 1995 MDP Basin Identifiers**

The basin identifiers assigned in the original Snoqualmie Ridge MDP also define the stream names for the MDPs and subsequent design reports. The major east-draining streams for the site are D-Creek and E-Creek, which drain Basins D and E respectively. In the north part of the site, the main streams which originate on site are I-Creek, J-Creek, K-Creek and M-Creek, each draining the basin with the corresponding identifier.

Stormwater ponds for the original Snoqualmie Ridge development were usually identified with the basin identifier, then a sequence number. For example, Ponds M1, M2, and M3 are all located in M-Basin, and the sequence number provides a unique identifier. In the K-Basin there is a single K1/K2 pond because what had once been proposed as two separate ponds were later merged to a single facility, while the original Pond K3 was retained. In the E-Creek basin, which has access to the Parkway high flow bypass line, some ponds have an "ED" identifier (i.e., ED3A, ED6) to signify a E-basin direct discharge pond for which peak flow control is accomplished by diversion to the bypass pipeline. This convention was generally followed except for ponds in the Snoqualmie Ridge Business Park (SRBP), located in Basin D, which are identified as SRBP2 and SRBP3, and in the Snoqualmie Ridge Neighbourhood Center (NC) which are identified as NC1 and NC2.

The Falls Crossing MDP was prepared at about the same time as the 1995 Snoqualmie Ridge MDP, and relied on the availability of the Parkway Storm Drain system to be constructed by others. The Falls Crossing project was located at the east end of the Snoqualmie Parkway. Over time, the project was reduced in scale to incorporate only two stormwater ponds identified in the Falls Crossing MDP as Ponds 1 and 2. When the project was further reduced and renamed as Kimball Creek Village, only a single pond – identified as Pond 2 – was eventually constructed.

MDP facility identifiers for the second phase of Snoqualmie Ridge development (SR II) during 2004 to 2012 were based on development parcel areas. Snoqualmie Ridge II occupied three distinct blocks of land: (1) a large multi-parcel southern block located south of D-Creek; (2) a large multi-parcel northern block straddling J-Creek in the northern part of the site; and a smaller single-parcel (N6) northern block. Facilities within these development areas were identified by North or South reference per the development area, and then a sequence identifier corresponding to the development parcel. Ponds in SR II are identified according to the parcel in which they were situated; i.e., N1, N2, N4, etc. in the north area, and S1A, S1B, S12, S15, etc. in the south area.

The project MDPs assigned unique names to flow control stormwater ponds. Names were not assigned to other facilities constructed solely to satisfy water quality treatment requirements. In particular, the MDPs did not provide a naming convention for water quality bioswales constructed along the east-draining portion of the Parkway and in many of the residential areas serviced by the project's North (NHFBL) and East (Parkway) high flow bypass lines.

### 1.2.2 Operations and Maintenance Manual, 2003

An operations and maintenance manual for the first phase of Snoqualmie Ridge development was prepared in 2003 by ESM. In that manual, facilities are organized by names which correspond to local signage; i.e., "Parkway," Business Park," and posted neighbourhood

names. Specific facilities within each development or neighbourhood area were described using the identifiers which had been assigned in the MDPs and design documents.

The ESM manual identifies several bioswales constructed within neighbourhoods, and generally named these based on the neighbourhood or local signage, i.e., "Crestview Park Biofiltration Swale." However, the manual does not identify or discuss other bioswales, including but not limited to those providing water quality treatment for Parkway runoff.

ESM's 2003 manual provides good facility information which is satisfactory for the present work. A copy of the ESM manual is included as Appendix A herein. With very few exceptions, this present report refers to ESM's 2003 report when applicable and does not expand on the prior descriptions or details given.

### 1.2.3 City GIS Naming Convention, Disclaimer, and Legend

Snoqualmie Ridge II development did not establish discrete named neighbourhoods as was done in the first phase of development, and it was therefore not possible to organize and index the new facilities based on neighbourhood signage as was done for the 2003 manual. Public works staff indicated that the MDP and design report identifiers would not be their preferred means of identification.

With this report a new naming convention is introduced based on street names that should be meaningful to city and contractor maintenance staff. In addition, a map grid established for other city activities has been incorporated to assist with finding locations. New, street-based, identifiers used in the present report were assigned in consultation with public works staff and have been incorporated into the city Geographic Information System (GIS) facility inventory.

The map figures presented in this report were all produced by city GIS staff based on a database which was under development at the time. The orthophotos used in the map figures show conditions on April 19, 2012. The maps are provided with the following disclaimer: *All users of the data shall be advised that the map features are approximate and are intended only to provide an indication of said feature. Additional areas that have not been mapped may be present. THIS IS NOT A SURVEY. The City of Snoqualmie assumes no liability for variations ascertained by an actual survey. ALL DATA IS EXPRESSLY PROVIDED ´AS IS´ AND ´WITH ALL FAULTS´. The City makes no warranty of fitness for a particular purpose.*

Figure 1.2 provides a legend for the GIS symbols and line types used in the subsequent figures in this report.

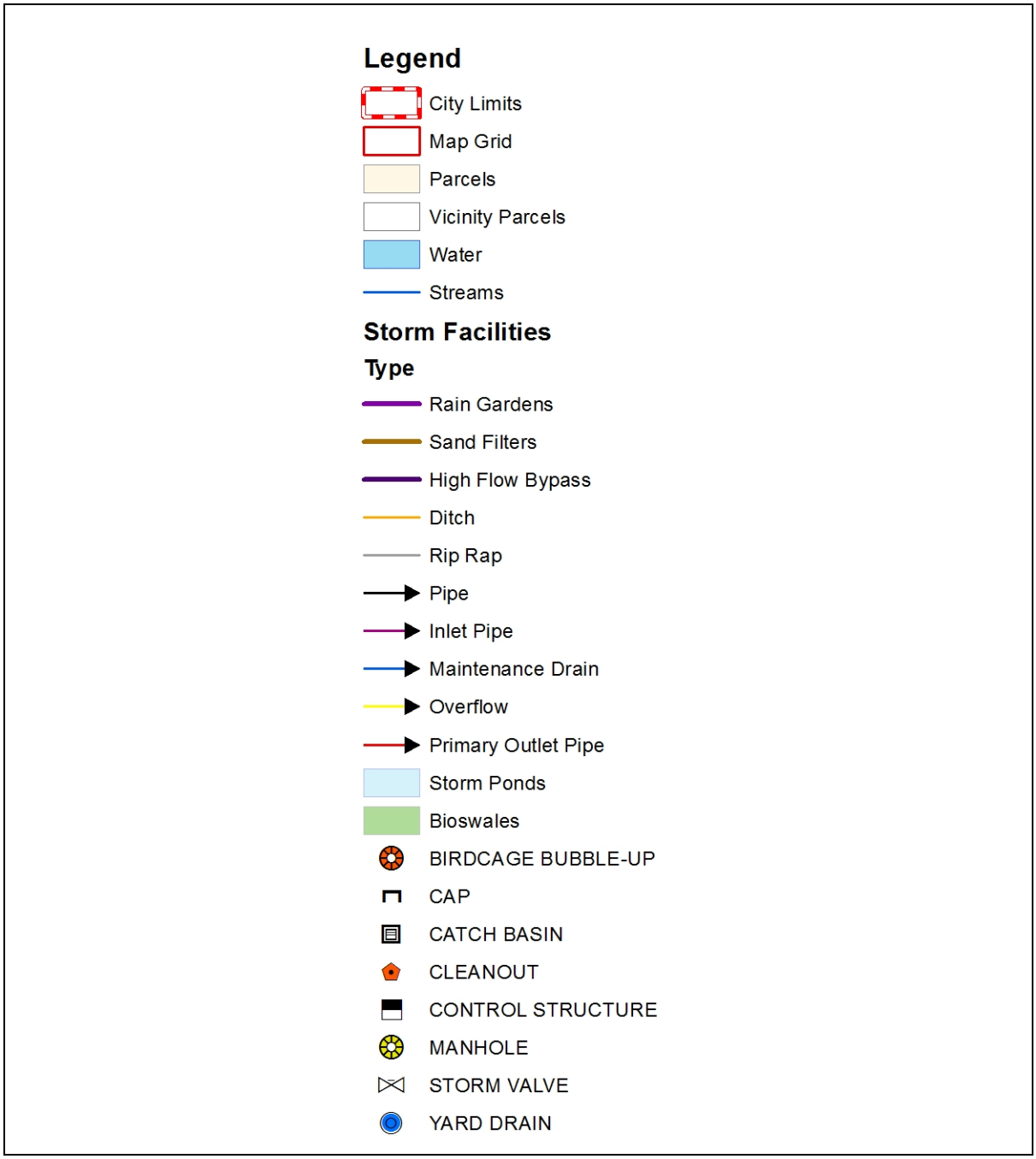


**Figure 1.2 - GIS Map Legend for Stormwater Facility Figures**

# 2 CITY FACILITIES INVENTORY

## 2.1 CONTENTS AND ORGANIZATION OF INVENTORY

In 2012, when this report was being prepared, there were approximately 70 city facilities providing water quality treatment and/or peak flow control. The ESM 2003 *Snoqualmie Ridge Operations and Maintenance Manual* (Appendix A) provided drawings and text descriptions for 21 of approximately 30 facilities which had been designed as of 2003. Primary omissions from the 2003 report were stormwater ponds which had been designed by firms other than ESM, and several water quality facilities without a flow control function.

Table 2.1 provides a summary list of known city stormwater facilities, excluding conventional conveyance system elements (catch basins, manholes, storm drain pipes, and outfalls). A location map showing facility locations is provided by Figure 2.1 as a folded full size exhibit in a sleeve at the back of this report, and at a reduced scale on the following page.

City stormwater facilities are generally located on city-owned lands, easements, or rights of way. However the inventory also includes the privately owned golf course stormwater ponds at Snoqualmie Ridge which receive runoff from city residential areas and which the city helps to maintain in cooperation with the golf course staff.

The types of facilities in the inventory include:

(1) flow control facilities including retention/detention ponds, infiltration ponds, and rain gardens;

(2) water quality facilities including wetponds, sand filters, bioswales, and filter cartridges; and

(3) the North High Flow Bypass Line which is listed as a specific facility because of its unique physical characteristics and specialized maintenance needs relative to the conventional parts of the city stormwater conveyance systems.

The inventory is organized chronologically, with some grouping by development phase. This organization method was selected over other options such as alphabetically, geographically, or by facility type because a chronological approach can most easily be updated to add future facilities. Chronology also helps to group facilities of similar vintage and may be helpful in understanding how facility designs have changed over time to comply with evolving stormwater regulations.

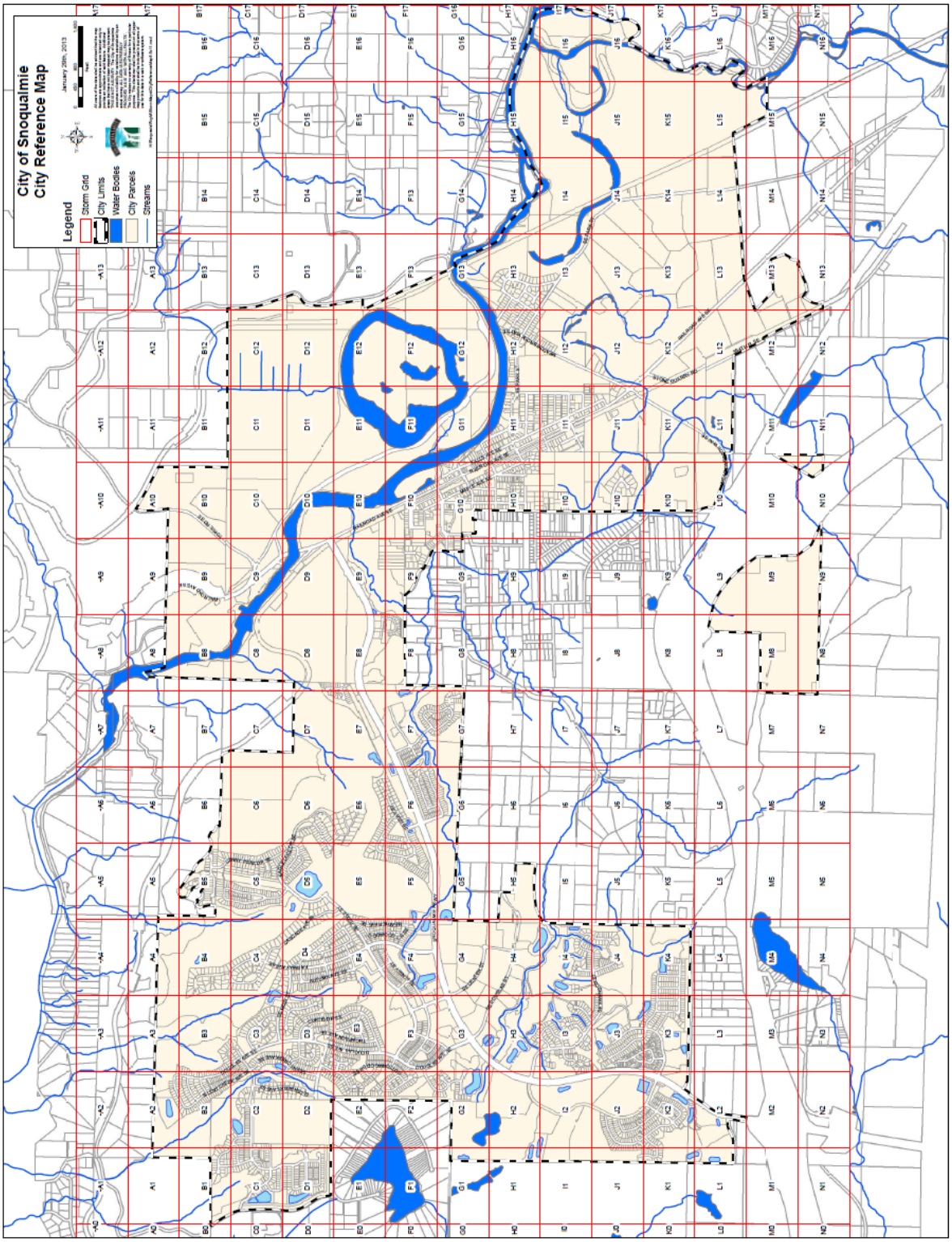


**Figure 2.1 – Facilities Location Map (reduced). Folded full size map is at end of report.**

## Table 2.1: Stormwater Water Quality and Flow Control Facility Inventory

| Year Approved | Facility GIS Name (and Design Name): | Development Phase | Water Quality | Flow Control |
|---|---|---|---|---|
| 1996 | Douglas1 (Pond DP2) | Parkway | wetpond | Level 1 |
| 1996 | Parkway_Swale (bioswales) | Parkway | bioswale | direct discharge |
| 1996? | North_Bypass (NHFBL) | Golf Course & P Plat 1 | pre-treated | direct discharge |
| 1996 | Eagle_Lake (Pond M1) | Golf Course & P Plat 1 | wetpond | direct discharge |
| 1997 | Crestview (Pond M2) | Golf Course & P Plat 1 | wetpond | direct discharge |
| 1997 | FairwayPl (Pond M3) | Golf Course & P Plat 1 | wetpond | direct discharge |
| 1997 | Isley1 (Pond ED4) | Golf Course & P Plat 1 | wetpond | direct discharge |
| 1997? | Hole6_Shunt (from SandFilter6) | Golf Course & P Plat 1 | sand filter | direct discharge |
| 1997 | Autumn (Pond K1/K2) | P Plat 1, Parcels I, O | wetpond | direct discharge |
| 1997 | Muir (Pond K3) | P Plat 1, Parcels J, M, K | wetpond | direct discharge |
| 1997 | Heather (Pond ED3A) | P Plat 2 | wetpond | direct discharge |
| 1998 | Douglas2 (Pond SRBP3) | Business Park | wetpond | Level 1 |
| 1998 | BPA_South (Pond SRBP2) | Business Park | wetpond | Level 1 |
| 1998 | Osprey (Pond D1) | P Plats 3-6 | wetpond | Level 1 |
| 2000 | Kinsey (Pond NC1) | P Plats 3-6 | wetpond | direct discharge |
| 2000 | Fairway (Pond NC2) | P Plats 3-6 | wetpond | direct discharge |
| 2000 | Gravenstein (Pond Y1) | Basin E4 | wetpond | direct discharge |
| 2001 | SilentCreek (Pond J1) | P Plat 7, Basin J | wetpond | direct discharge |
| 2001 | Carmichael3 (J4 bioswale) | P Plat 7, Basin J | wetpond | direct discharge |
| 2004 | Burke (Pond J3) | P Plat 7, Basin J | wetpond | direct discharge |
| 2001 | Carmichael2 (Pond J2) | P Plat 7, Basin J | bioswale | direct discharge |
| 2002 | WoodyCreek1 (Woody Ck bioswale) | Parcel W-1, Woody Creek | bioswale | direct discharge |
| 2002 | Crestview1 (Parcel E North Swale) | P Plat 11, Parcel E | bioswale | infiltration |
| 2002 | Crestview2 (Parcel E South Swale) | P Plat 11, Parcel E | bioswale | direct discharge |
| 2002 | Fury (Kimball Creek Village Pond 2) | Kimball Ck Village | wetpond | direct discharge |
| 2003 | Isley2 (Pond ED4A) | P Plat 8, Parcel W | wetpond | direct discharge |
| 2003 | Fisher1&2 (Pond ED6: two cells) | P Plat 8, Parcel W | wetpond | direct discharge |
| 2003 | Isley3 (ED6B swale) | P Plat 8, Parcel W | bioswale | direct discharge |
| 2002 | Orchard (Parcel Z stormfilters) | P Plat 13, Parcel Z | cartridge filter | direct discharge |
| 2003 | Melrose (Parcel Z north bioswale) | P Plat 13, Parcel Z | bioswale | direct discharge |
| 2003 | Gala (Parcel Z south bioswale) | P Plat 13, Parcel Z | bioswale | direct discharge |
| 2003 | Denny (Parcel D north swale) | P Plat 14, Parcel D | bioswale | infiltration |
| 2004 | Allman (Parcel Y2 bioswale) | Parcel Y-2 | bioswale | direct discharge |
| 2005 | Strouf (Infiltration Pond N1) | P Plat 19 | wetpond | infiltration |
| 2005 | Sorenson (Infiltration Pond N2) | P Plat 19 | wetpond | infiltration |
| 2005 | Carmichael1 (Pond N4) | P Plat 19 | wetpond | direct discharge |
| 2005 | Swenson_E1 (Pond S11 West) | P Plat 20 | wetpond | Level 2 |
| 2005 | Swenson_E2 (Pond S11 East) | P Plat 20 (Replaces DP1) | wetpond | Level 1 |
| 2005 | Swenson_E3 (Pond S10) | P Plat 20 | wetpond | Level 2 |
| 2005 | Swenson_E4 (Pond S8) | P Plat 20 | wetpond | Level 2 |

| | | | | |
|---|---|---|---|---|
| 2005 | Swenson_E5 (Pond S7) | P Plat 20 | wetpond | Level 2 |
| 2005 | Swenson_E6 (Pond S6A) | P Plat 20 | wetpond | Level 2 |
| 2005 | Swenson_E7 (Pond S6B) | P Plat 20 | wetpond | Level 2 |
| 2005 | Swenson_E8 (Pond S6C) | P Plat 20 | wetpond | Level 2 |
| 1997&2005 | Jacobia_E1 (Pond at 1040 Reservoir) | 1040 Reservoir | wetpond | Level 1 |
| 2006 | South_Parkway (Interim Pond S21B) | Parkway | wetpond | ditch capacity |
| 2006 | Hancock1 (Pond S1) | Parcel S1a BSIP | wetpond | Level 2 |
| 2006 | Kendall1 (Raingarden N6A) | P Plat 23 | raingarden | infiltration |
| 2006 | Kendall2 (Raingarden N6B) | P Plat 23 | raingarden | infiltration |
| 2006 | Kendall3 (Raingarden N6C) | P Plat 23 | raingarden | infiltration |
| 2006 | Kendall4 (Raingarden N6E) | P Plat 23 | raingarden | infiltration |
| 2006 | Whitacre1 (Raingarden N6D) | P Plat 23 | raingarden | infiltration |
| 2006 | Whitacre2 (Raingarden N6F) | P Plat 23 | raingarden | infiltration |
| 2006 | Jacobia_E2 (Pond S2B) | P Plat 24 | wetpond | Level 2 |
| 2007 | Merritt (Pond S2C) | P Plat 24 | wetpond | Level 2 |
| 2007 | Swing (Pond S3) | P Plat 24 | wetpond | Level 2 |
| 2007 | Raines (Pond S4) | P Plat 24 | wetpond | Level 2 |
| 2008 | Frontier1 (Pond S20) | P Plat 25 | wetpond | Level 2 |
| 2008 | Frontier2 (Pond S16B) | P Plat 25 | wetpond | Level 2 |
| 2008 | Frontier3 (Pond S16A) | P Plat 25; replaces BP1 | wetpond | Level 2 |
| 2008 | Jacobia_W2 (S16A bioswale) | P Plat 25 | bioswale | direct discharge |
| 2011 | Swenson_W1 (Pond S12A) | P Plat 25 | wetpond | Level 2 |
| 2011 | Swenson_W2&W3 (Pond S14 & filter) | P Plat 25 | wetpond plus sand filter | Level 2 |
| 2011 | Swenson_W4 (Pond S13) | P Plat 25 | wetpond | Level 2 |
| 2011 | Hospital (Pond S21A) | Parcel S21 Hospital | wetpond | Level 2 |
| 2012 | Jacobia_W1 (Pond S15) | Community Park | wetpond | Level 2 |
| future | to be determined (Final Pond S21B) | Future - per SR II MDP | wetpond | Level 2 |
| future | to be determined (Pond N3) | Future - per SR II MDP | wetpond | direct discharge |
| future | to be determined (Pond N3A or N7) | Future - per SR II MDP | wetpond | Level 2 |
| future | to be determined (Pond S1C) | Future - per SR II MDP | wetpond | Level 2 |
| | **SNOQUALMIE RIDGE GOLF COURSE PRIVATE FACILITIES** | | | |
| 1998 | Golf_SF1 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1997 | Golf_SF4 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1997 | Golf_SF5 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1997 | Golf_SF6 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1998 | Golf_SF8B (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1998 | Golf_SF12 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1997 | Golf_SF16 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1997 | Golf_SFPA1 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 1997 | Golf_SFPA2 (SR golf course sand filter) | Golf Course | sand filter | direct discharge |
| 2001 | Golf_Mntce_Swale (SR golf course swale) | Golf Course | bioswale | direct discharge |
| 1997? | Golf_BPA_Rd_Swale (SR golf course swale) | Golf Course | bioswale | direct discharge |
| 1998? | Golf_Hole2Swales (SR golf course swale) | Golf Course | bioswales | direct discharge |
| 2007 | Golf_Mntce_Wastwtr (SR golf course filter) | Golf Course | filter strip | direct discharge |

| | OTHER PRIVATE FACILITES | | | |
|---|---|---|---|---|
| 1996 | KC_Swale+Pond (privately maintained) | Kimball Ck Drive | bioswale | Level 1 (assumed) |
| 1997 | Peggys_Pl_Swale (privately maintained) | Peggys Place | bioswale | direct discharge |
| unknown | Bus_Gar_swale (privately maintained) | School Bus Barns | swale | direct discharge |
| 2006 | Winery (city-maintained WSDNR facility) | Rattlesnake Mtn Trailhead | raingarden | infiltration |

## 2.2 SNOQUALMIE PARKWAY (1995 - 1996)

The Snoqualmie Parkway was the first development project to break ground at Snoqualmie Ridge, and its construction began while the Snoqualmie Ridge Master Drainage Plan was still in preparation. Stormwater design standards for the Parkway were defined by the 1990 King County Surface Water Design Manual (KCSWDM).

The Parkway is an eastward extension of SR 18 from Interstate 90 west of Snoqualmie Ridge to SR 202 in the Snoqualmie River valley. It has small stream crossings at E-Creek and D-Creek within the development site, the latter of which is bridged with a large span box culvert intended to minimize impacts to wetlands at the crossing. Elsewhere, cross-drainage is provided by corrugated metal culverts, and by interflow blankets to allow for subsurface passage of seepage flow in wetland areas. Level spreaders were installed at the outlets of culverts which drained to wetlands immediately downslope from the parkway. The performance of the level spreaders was found to be generally poor in that water would re-concentrate a short distance below the spreader. From this experience, most outfalls to wetlands for subsequent phases of development were constructed with simple splash blocks for energy dissipation.

The eastern portion of the Parkway corridor contains the East High Flow Bypass Line (EHFBL) which was constructed concurrent with the Parkway. The EHFBL, also known as the Parkway HFBL is a large-diameter conventional concrete storm drain line that discharges directly to the Snoqualmie River without peak flow control, as was (and is) allowed under city of Snoqualmie and King County stormwater regulations. It was sized to convey treated undetained 100-year (or 25-year plus 30%) stormwater peak flows from all areas of planned Snoqualmie Ridge development that could be connected to this line. Water quality treatment of roadway runoff from the eastern portion of the Parkway is provided by grassed bioswales adjacent to the roadway.

The south and west portions of the Parkway corridor do not have access to the EHFBL, and the stormwater regulations required Level 1 peak flow control in addition to water quality treatment. Level 1 flow control limits post-development 2-year and 10-year peak flows to the corresponding pre-development peaks. Stormwater peak flow and water quality requirements were met by three stormwater ponds: BP1, DP1, and DP2, located in Basins B and D respectively. Each of these ponds was constructed with three cells separated by rock berms as required by the 1990 KCSWDM. These ponds, plus the one at Kimball Creek Village at the lower end of the Parkway, are the only ponds in the city to have been constructed with this design configuration. Two of the ponds (BP1 and DP1) were subsequently replaced with newer facilities.

### 2.2.1 Stormwater Ponds BP1 and DP1

Stormwater Ponds BP1 and DP1 are the first two facilities identified in the 2003 O&M Manual (Appendix A). Neither of these facilities still exist as both were graded out and replaced during the development of Snoqualmie Ridge Phase II. Pond BP1, located near the original southern boundary of Snoqualmie Ridge, was replaced by Pond Frontier3 (S16A) which is described in Section 2.4.22. Pond DP1, one of two Parkway Ponds adjacent to D-Creek, was replaced by Pond Swenson_E2 (S11 East) which is described in Section 2.4.5.

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### 2.2.2 Douglas1 (DP2) Stormwater Pond

Stormwater Pond "Douglas1" is identified in the original design drawings and in the 2003 O&M Manual as Parkway Pond DP2. It is located behind the police station immediately north of D-Creek. It provides water quality treatment and Level 1 flow control. Additional information is provided in Appendix A (the 2003 O&M Manual).

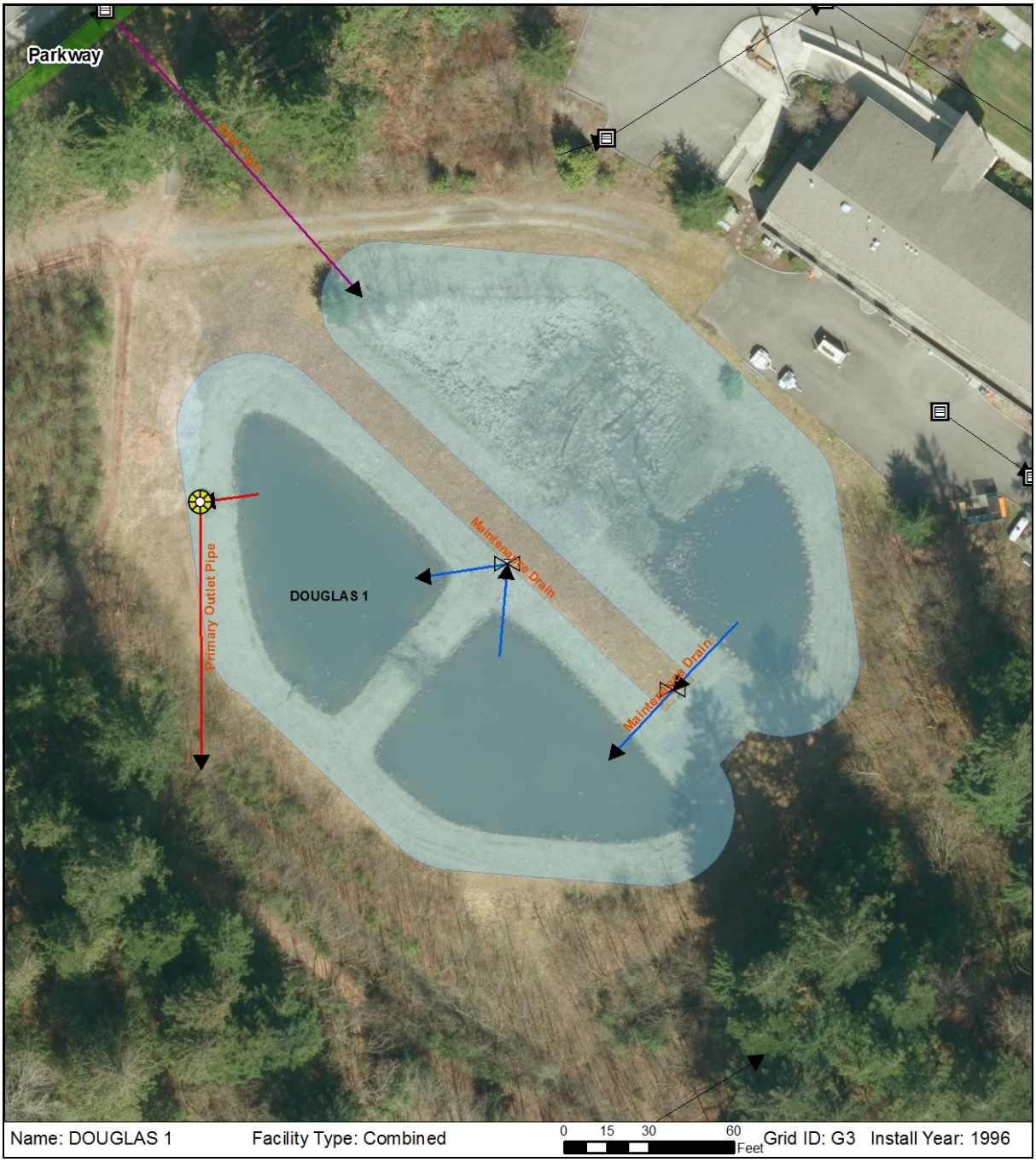


**Figure 2.2 –Douglas1 (DP2) Stormwater Pond**

### 2.2.3 Parkway Bioswales

The parkway bioswales provide water quality treatment for road runoff which drains to the East High Flow Bypass Line located in the median of the Parkway. The swales were designed with an eight-foot wide bottom and 3:1 (H:V) sideslopes. Maintenance requirements include regular mowing with removal of grass clippings, and periodic removal of the sediment and turf buildup at the pavement edge which causes water to flow down the edge of pavement instead of along the swale bottom where filtration occurs.


**Figure 2.3 – Parkway Bioswales**

### 2.2.4 Parkway Runoff South of SE 96th Street

Prior to development of Snoqualmie Ridge, the southernmost segment of what is now the Parkway from the I-90 interchange to SE 96th Street was an existing road named Echo Glen Road.

When Echo Glen Road was first widened in 1996 to accommodate Parkway traffic, a detention pipe with an orifice restrictor providing Level 1 flow control was installed near the entrance to the Leisure Time Resorts RV Park. In 2006 this segment of road was again widened, and the detention pipe was removed. Stormwater management for the cumulative widening of the former Echo Glen Road is provided in Interim Pond S21/S21B described in Section 2.4.13. The Snoqualmie Ridge II MDP anticipates that Permanent Pond S21B will eventually be constructed to treat and detain runoff from future development of Parcel S21 in addition to the parkway runoff.

## 2.3 SNOQUALMIE RIDGE & KIMBALL CREEK VILLAGE (1996 – 2003)

In the early 1990s, environmental assessments and Master Drainage Plans (MDPs) were prepared for two major proposed developments both relying on the Snoqualmie Parkway for access: (1) Snoqualmie Ridge and (2) Falls Crossing. Snoqualmie Ridge was a planned mixed use development with residential and business areas, schools, parks, and a TPC golf course. Falls Crossing was a smaller project at the downhill northern end of the Parkway and located partially within the Snoqualmie River floodplain. The Falls Crossing project was greatly scaled back from its original concept after much of the site was acquired by the city to be conserved as a natural area. What remained of the project became Kimball Creek Village, with a single stormwater pond that drains to the Parkway East High Flow Bypass Line.

Stormwater facilities for Snoqualmie Ridge were designed in compliance with the 1990 King County Surface Water Design Manual (KCSWDM) and additional water quality measures which, at the time, were expected to be incorporated in an updated version of the manual. When the MDP was approved by the city in 1995, the design standards defined in the MDP document were grandfathered for the duration of project buildout which continued until about 2003. The stormwater pond for Kimball Creek Village was designed in compliance with the 1990 KCSWDM without any updated water quality measures. Because of this, the configuration of the pond for Kimball Creek Village is most similar to the configuration of ponds for the Parkway, rather than the other Snoqualmie Ridge ponds.

The KCSWDM identifies the Snoqualmie River as a direct discharge receiving water, meaning that development which can discharge directly to the river is exempt from having to provide peak flow control. To take advantage of this exemption, Snoqualmie Ridge was developed with two large high flow bypass lines which drain the north and east areas of the site. The East High Flow Bypass Line is a large diameter but otherwise conventional concrete storm drain pipe constructed in the median of the Snoqualmie Parkway. The North High Flow Bypass Line is a buried large-diameter HDPE pipe on steep grades through a landslide hazard area with difficult access.

In development areas served by the high flow bypass lines, most water quality ponds have an outlet flow splitter to provide controlled return flow to the site's wetlands and streams. Flow splitter designs varied over the course of the project due to design engineer creativity combined with an absence of design guidance in either the KCSWDM or the MDP. In some areas, dedicated conveyance systems were constructed for roof runoff which is presumed to be clean and does not require water quality treatment before release to the natural environment. Some roof runoff systems discharge directly to wetlands or streams while others were used solely to bypass, and to minimize the size of, water quality facilities.

Initial pond designs prepared in 1996 and 1997, prior to publication of the updated 1998 KCSWDM, were developed by Hugh G. Goldsmith Associates for residential areas (Ponds K1/K2, K3, and ED3A) and by Earth Tech for Golf Course facilities. Ponds constructed since 1998 were mostly designed by ESM, and incorporate detailed water quality pond specifications from the 1998 manual, such as for inverted outlet pipes. Most ponds constructed after 1999 also have a spill control oil water separator installed in the first catch basin upstream from the pond inlet.

Details for some permanent drainage infrastructure were specified on Grading and Temporary Erosion and Sediment Control (TESC) plan sheets and are unavailable from other sources. This occurred for steep slope bypass shunt lines and outfalls for facilities draining to the NHFBL, and also some wetland outfalls and pond emergency overflow spillways.

The following inventory of stormwater facilities is intended to capture all facilities that were engineered to provide either a flow control or a water quality treatment function. In particular, the inventory does not include roof drain bypasses which provide wetland recharge. Most such bypasses involve collection from one or two rooftops with water discharged to a simple outfall at the edge of a wetland buffer. The most complex roof drain system for wetland recharge in Snoqualmie Ridge Phase 1 was for Wetland D8 located behind the Echo Ridge development and involved two long level spreaders. The inventory of stormwater facilities also does not include storm drain inlets and related infrastructure which provide drainage from wetlands that are located within, or upstream from, development areas.

### 2.3.1 North High Flow Bypass Line

The North High Flow Bypass Line (NHFBL) is included as a distinct "facility" to call attention to its unique characteristics and maintenance needs. Appendix B01 contains information extracted from design reports. Appendix C contains the NHFBL isolation procedures manual which would be followed if the line needs to be shut down for either planned maintenance or emergency repair. Appendix D contains a bypass maintenance checklist extracted from the Golf Course Facilities Maintenance Plan.

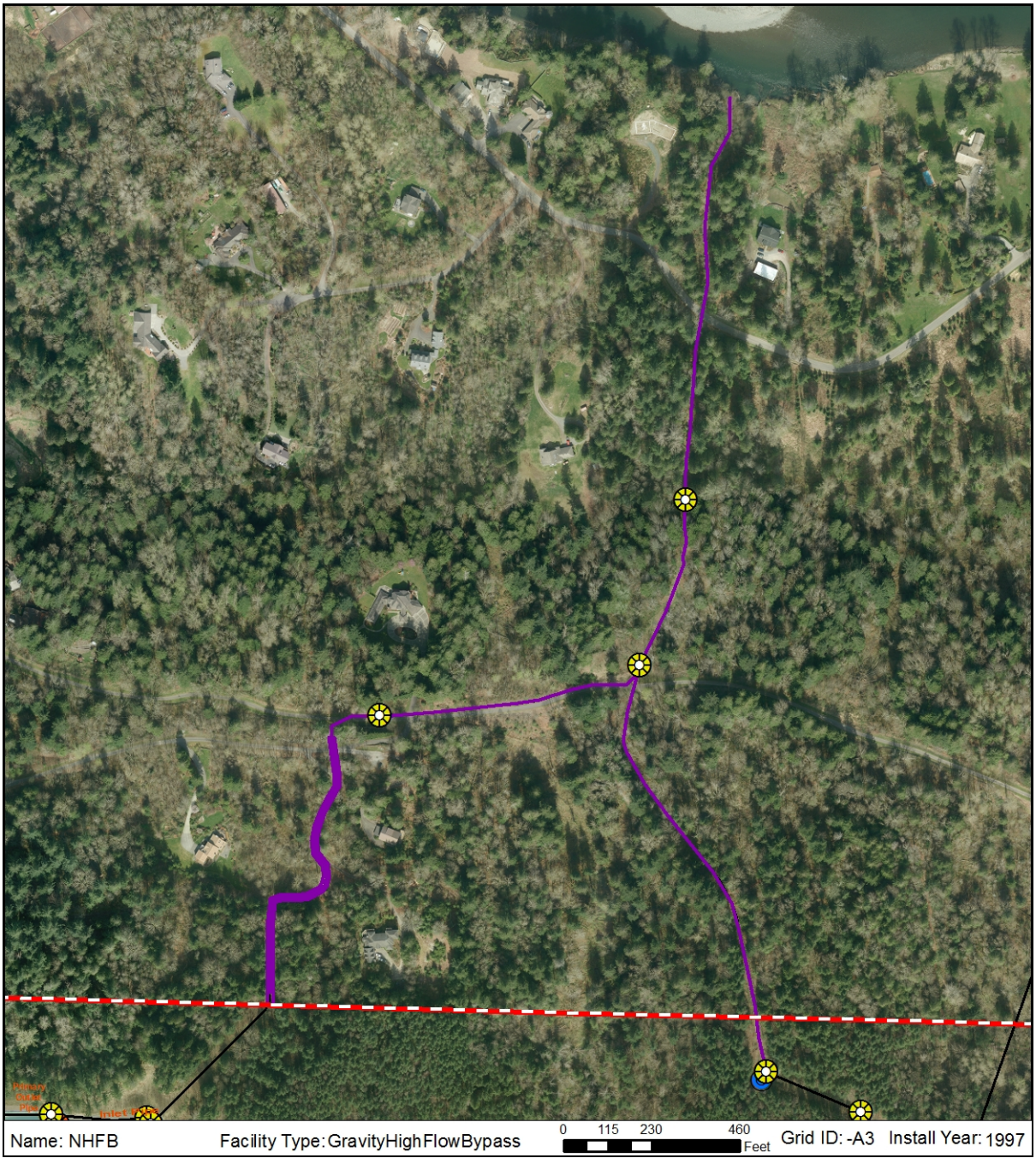


**Figure 2.4 – North High Flow Bypass Line**

### 2.3.2 Eagle Lake (M1) Stormwater Pond and Reservoir

"Eagle Lake" is identified in MDP and golf course design documents as direct discharge Pond M1 which drains to the NHFBL and, seasonally, with split flow to M-Creek. The pond is owned by the golf course but receives city runoff and the city has assumed responsibility for maintenance of the pond outlet controls. The pond is the reclaimed wastewater irrigation water supply reservoir for Snoqualmie Ridge, used by both the city and the golf course, and is a regulated dam under state rules. Excerpts from facility design calculations and engineering plans are in Appendix B02.


**Figure 2.5 –Eagle Lake (M1) Stormwater Pond**

### 2.3.3 Crestview (M2) Stormwater Pond

Stormwater Pond "Crestview" is identified in MDP and golf course design documents as direct discharge Pond M2 with outflow that is split between M-Creek and the NHFBL. The pond is owned by the golf course but receives city runoff and the city has assumed responsibility for maintenance of the pond outlet controls. Excerpts from facility stormwater design calculations and engineering plans are in Appendix B02.


**Figure 2.6 –Crestview (M2) Stormwater Pond**

### 2.3.4 FairwayPl (M3) Stormwater Pond

Stormwater Pond "FairwayPl" is identified in the MDP and golf course design documents as direct discharge Pond M3 with outflow that is split between M-Creek and the NHFBL. The pond is owned by the golf course but receives city runoff and the city has assumed responsibility for maintenance of the pond outlet controls. The pond has a 10" outside diameter steep slope outlet pipe over city-owned land to an outfall adjacent to M-Creek. Excerpts from facility stormwater design calculations and engineering plans are in Appendix B02. Appendix C includes information on operation of the pond outlet valves.


**Figure 2.7 –FairwayPl (M3) Stormwater Pond**

### 2.3.5 Isley1 (ED4) Stormwater Pond

Stormwater Pond "Isley1" is identified in MDP and golf course design documents as direct discharge Pond ED4 which drains to the Parkway HFBL. The pond is owned by the golf course but receives city runoff and the city has assumed responsibility for inspection and maintenance of the pond outlet controls. Excerpts from facility stormwater design calculations and engineering plans are in Appendix B02.


**Figure 2.8 –Isley2 (ED4) Stormwater Pond**

### 2.3.6 Hole6_Shunt (SF6) Steep Slope Shunt Line

At the lower end of the Snoqualmie Ridge Golf Course Hole 6 fairway, there is a 12" outside diameter steep slope shunt line over city-owned lands to a gabion outfall in King County adjacent to L-Creek. If required, this line would be used to bypass golf course runoff which would normally flow to NHFBL from golf course Sand Filter 6. Shunt line design details (from erosion control plans approved March 1997) are included at the end of Appendix B02. Appendix C includes information on operation of the shunt line.


**Figure 2.9 –Hole 6 Steep Slope Shunt Line**

### 2.3.7 Autumn (K1/K2) Stormwater Pond

Stormwater Pond "Autumn" is identified in Preliminary Plat 1 design documents as direct discharge Pond K1/K2 which delivers treated water to the adjacent Class 1 Wetland K1 via infiltration recharge systems on both sides of the wetland and discharges excess water to the NHFBL via a flow splitter below Pond K3. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual). Additional information on the wetland recharge system is provided in Appendix B03.


**Figure 2.10 – Autumn (K1/K2) Stormwater Pond**

### 2.3.8 Muir (K3) Stormwater Pond

Stormwater Pond "Muir" is identified in Preliminary Plat 1 design documents as Pond K3 with direct discharge outflow that is split between K-Creek and the NHFBL. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.11 – Muir (K3) Stormwater Pond**

### 2.3.9 Heather (ED3A) Stormwater Pond

Stormwater Pond "Heather" is identified in Preliminary Plat 1 design documents as Pond ED3A with direct discharge outflow that is split between K-Creek and the Parkway HFBL. This pond is not included in Appendix A. Excerpts from facility stormwater design calculations and plans are in Appendix B04.


**Figure 2.12 – Heather (ED3A) Stormwater Pond**

### 2.3.10 Douglas2 (SRBP2) Stormwater Pond

Stormwater Pond "Douglas2" is identified in Business Park design documents as Business Park Pond SRBP2, providing Level 1 flow control and discharging to D-Creek. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.13 – Douglas 2 (SRBP2) Stormwater Pond**

### 2.3.11 BPA_South (SRBP3) Stormwater Pond

Stormwater Pond "BPA_South" is identified in Business Park design documents as direct discharge Business Park Pond SRBP3, providing water quality treatment and discharging entirely to the Parkway HFBL. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).

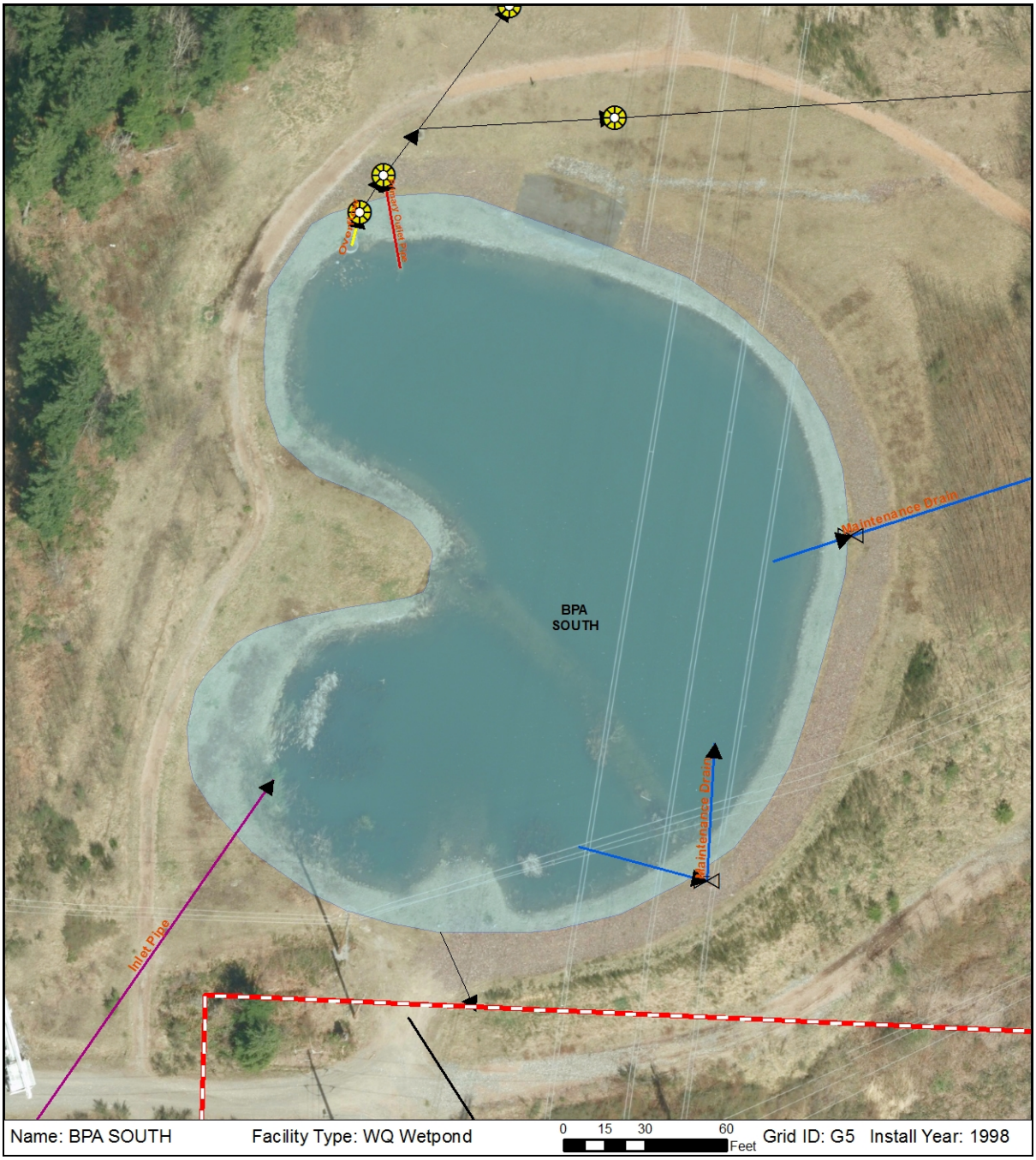


**Figure 2.14 – BPA_South (SRBP3) Stormwater Pond**

### 2.3.12 Osprey (D1) Stormwater Pond

Stormwater Pond "Osprey" is identified in Preliminary Plats 3-6 design documents as Pond D1, providing Level 1 flow control and discharging entirely to D-Creek. This pond is classified as a dam and is subject to state dam safety regulations. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.15 – Osprey (D1) Stormwater Pond**

### 2.3.13 Kinsey (NC1) Stormwater Pond

Stormwater Pond "Kinsey" is identified in Neighborhood Center design documents as Neighborhood Center Pond NC1, with direct discharge outflow that is split between E-Creek and the Parkway HFBL. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.16 – Kinsey (NC1) Stormwater Pond**

### 2.3.14 Fairway (NC2) Stormwater Pond

Stormwater Pond "Fairway" is identified in Neighborhood Center design documents as Neighborhood Center Pond NC2, with direct discharge outflow that is split between E-Creek and the Parkway HFBL. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).

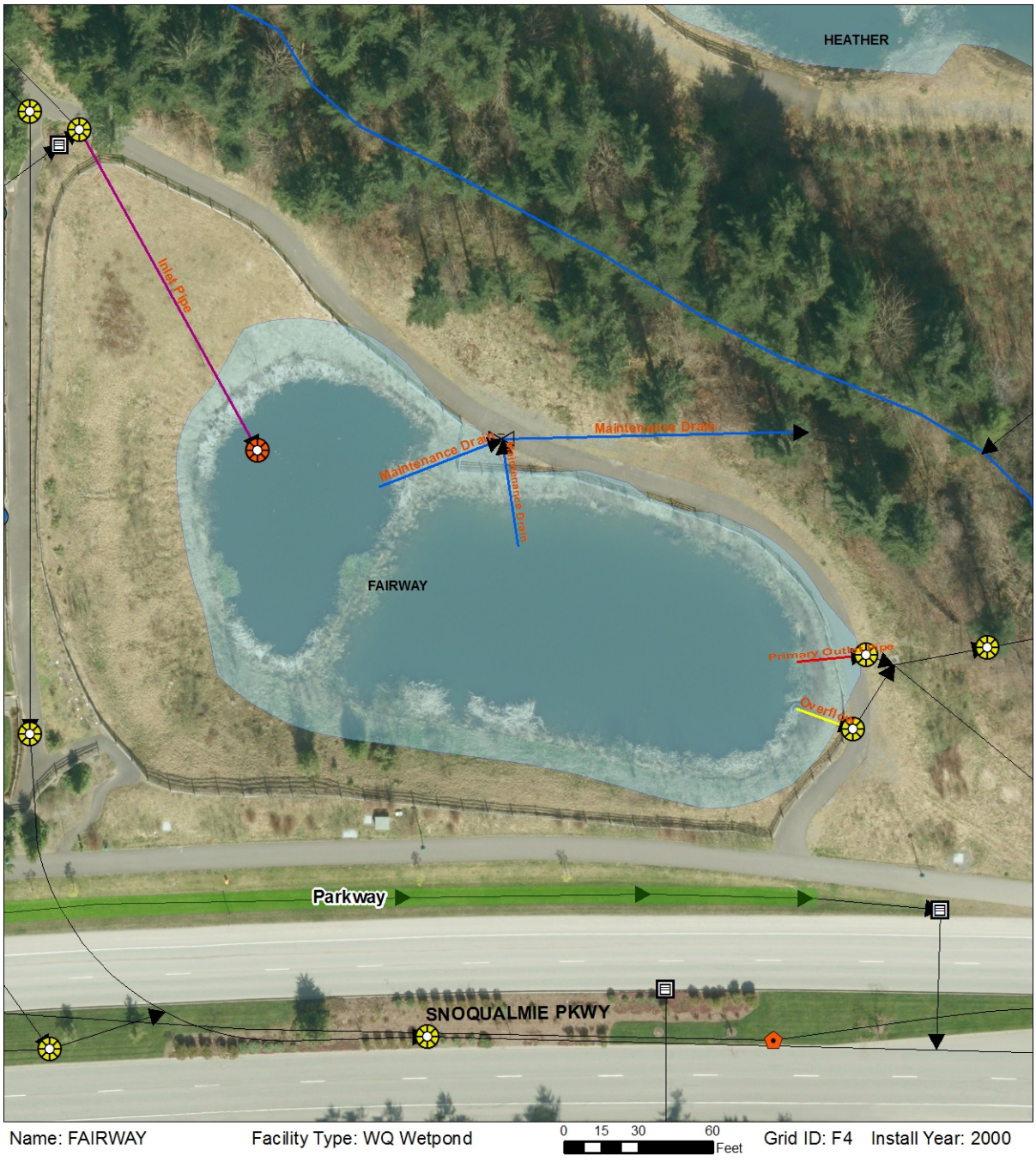


**Figure 2.17 – Fairway (NC2) Stormwater Pond**

### 2.3.15 Gravenstein (Y1) Stormwater Pond

Stormwater Pond "Gravenstein" is identified in the Basin E4 design documents as Pond Y1, which provides water quality treatment and discharges entirely to E-Creek without explicit peak flow control. Direct discharge to the creek was made possible by over-control of flows from other E-Basin ponds that discharge to the Parkway HFBL. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).

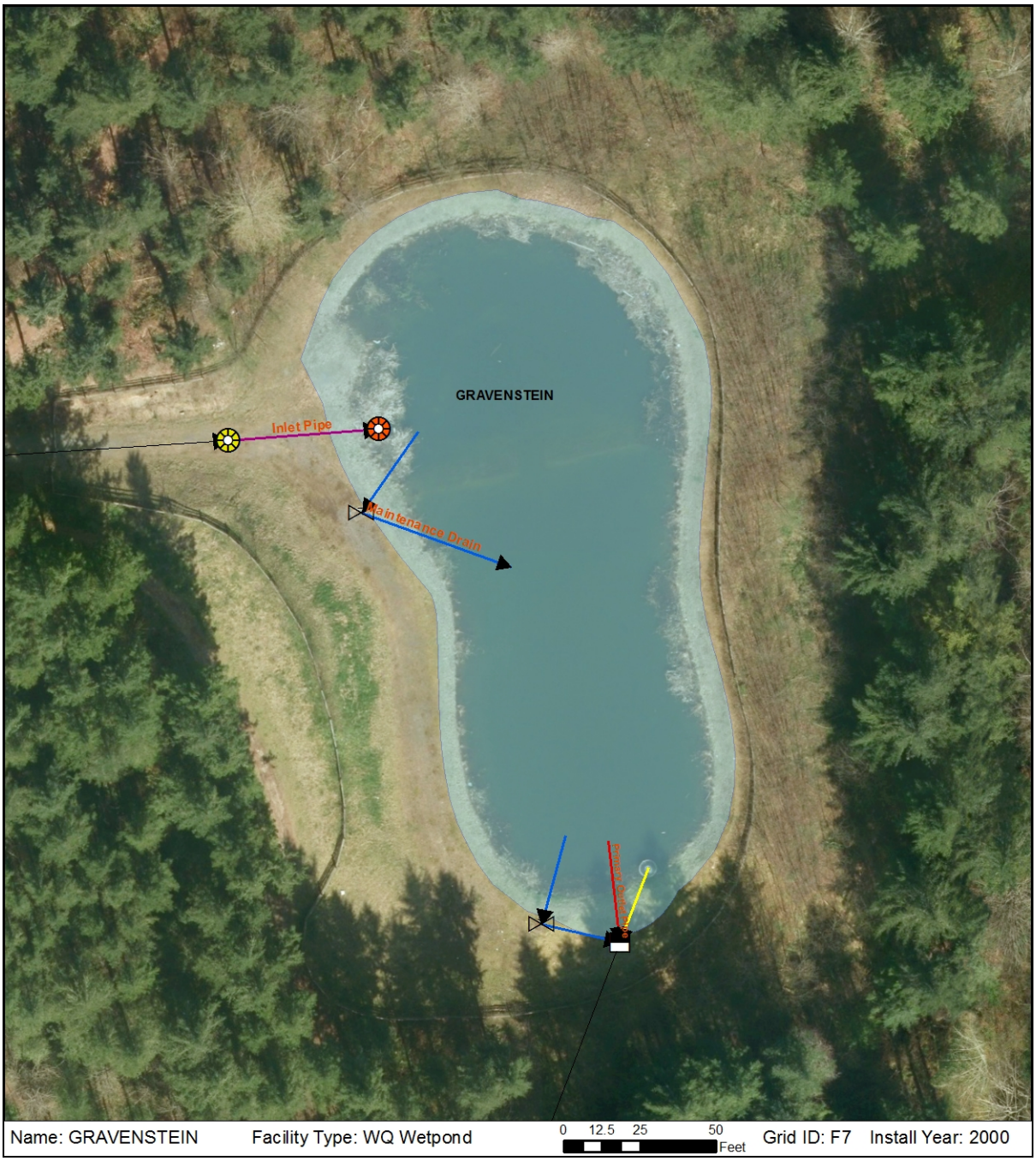


**Figure 2.18 – Gravenstein (Y1) Stormwater Pond**

### 2.3.16 SilentCreek (J1) Stormwater Pond

Stormwater Pond "SilentCreek" is identified in Preliminary Plat 7 (Basin J) design documents as direct discharge Pond J1, with flow releases which are split between the NHFBL and J-Creek. This pond has a history of not holding water at its design water quality pool elevation; the city decided in July 2009 to accept the leaky pond performance because there were no obvious adverse environmental consequences of the leakage. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.19 – SilentCreek (J1) Stormwater Pond**

### 2.3.17 Carmichael2 (J2) Stormwater Pond

Stormwater Pond "Carmichael3" is identified in Preliminary Plat 7 (Basin J) design documents as direct discharge Pond J2, with flow releases which are split between the NHFBL and J-Creek. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.20 – Carmichael2 (J2) Stormwater Pond**

### 2.3.18 Burke (J3) Stormwater Pond

Stormwater Pond "Burke" is identified in Preliminary Plat 7 (Basin J) design documents as direct discharge Pond J3, which discharges entirely to the NHFBL. The pond is located adjacent to steep slope areas. The design includes a 12" outside diameter HDPE shunt line down the steep slopes with a perforated pipe energy dissipater adjacent to J-Creek. The shunt line is intended for use during isolation of the NHFBL. Additional information for this pond is provided in Appendix B05. Appendix C includes information on operation of the shunt line.


**Figure 2.21 – Burke (J3) Stormwater Pond**

### 2.3.19 Carmichael3 (J4) Bioswale

Bioswale "Carmichael3" is identified in Preliminary Plat 7 (Basin J) design documents as facility J4. The swale is adjacent to Pond J2, and collects water from a drain at the sag point of Carmichael Road at the J-Creek Crossing. It has never performed satisfactorily and requires major rehabilitation which should include the removal of dense trees which prevent sunlight from reaching the swale bottom. Facility performance may have also been adversely affected by creek backwater. Design information is provided in Appendix B05.

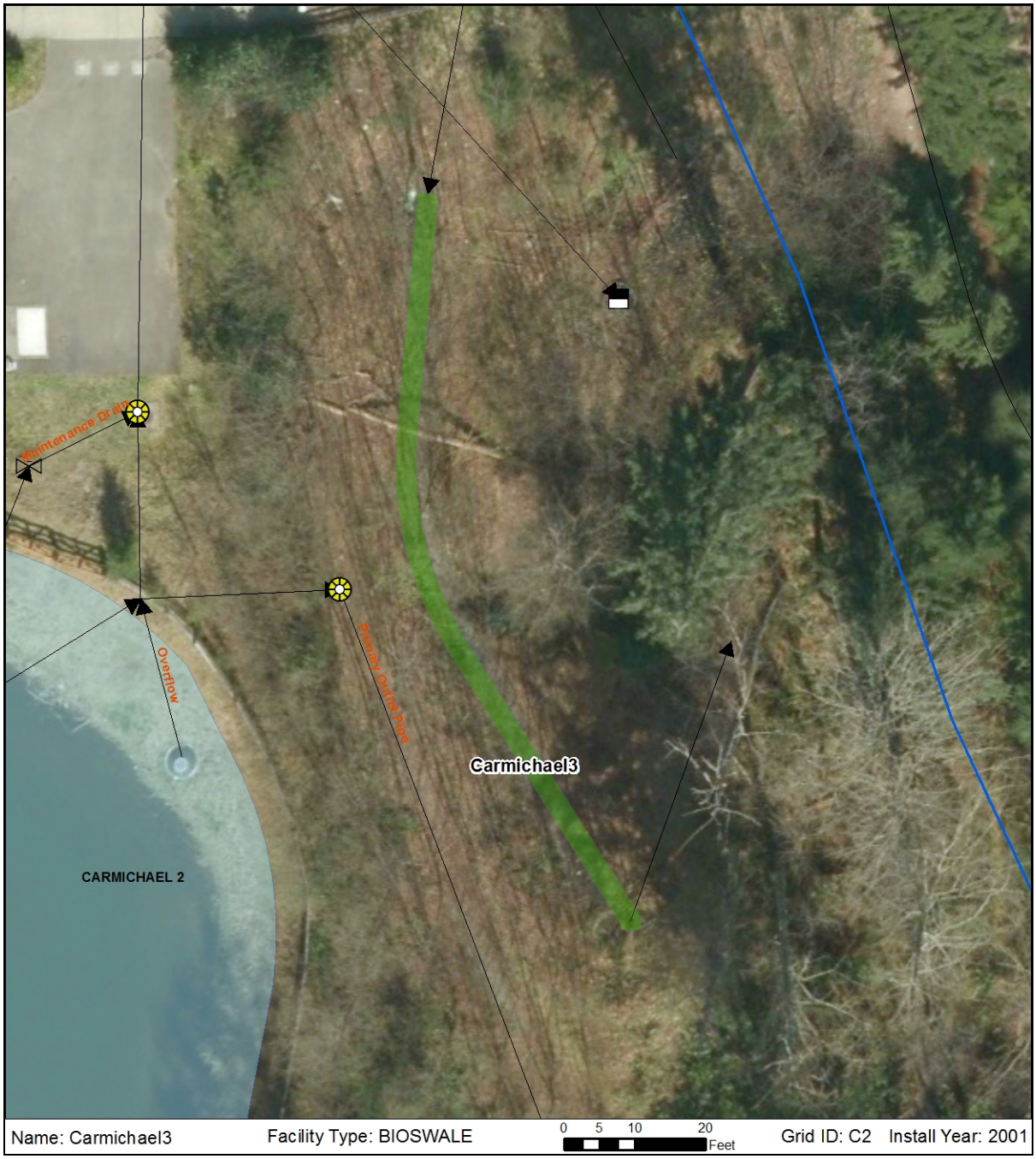


**Figure 2.22 – Carmichael3 (J4) Bioswale**

### 2.3.20 WoodyCreek1 (Woody Creek) Bioswale

The WoodyCreek1 bioswale is identified in Parcel W-1 (Woody Creek) design documents as the bioswale providing water quality treatment from the northern part of the Woody Creek development. Future maintenance may require management of trees adjacent to the facility which produce shade and are a source of undesirable woody debris during windstorms. Direct discharge runoff is released to an unnamed tributary to E-Creek. Additional information for this bioswale is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.23 – WoodyCreek1 (Woody Creek) Bioswale**

### 2.3.21 WoodyCreek2 (W1) Stormwater Pond

Stormwater Pond "WoodyCreek2" is identified in Parcel W-1 (Woody Creek) design documents as direct discharge Pond W1 which drains to E-Creek via a small unnamed tributary channel. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual). There had been concerns over the effect of increased flows on the stability of the unnamed tributary channel, but periodic visual inspection made over the first three years of operation did not find any obvious signs of accelerated erosion.


**Figure 2.24 – WoodyCreek2 (W1) Stormwater Pond**

### 2.3.22 Crestview1 (M2 North) Bioswale

The "Crestview1" bioswale is identified in Preliminary Plat 11 (Parcel E) design documents as the M2 North Swale. The swale is located above a former gravel pit which was reconstructed as a below-ground infiltration gallery. Swale outflow infiltrates to groundwater. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.25 – Crestview1 (M2 North) Bioswale**

### 2.3.23 Crestview2 (M2 South) Bioswale

The "Crestview2" bioswale is identified in Preliminary Plat 11 (Parcel E) design documents as the M2 South Swale. The swale discharges to the North High Flow Bypass Line, with split flow release to the upper end of M-Creek. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual).

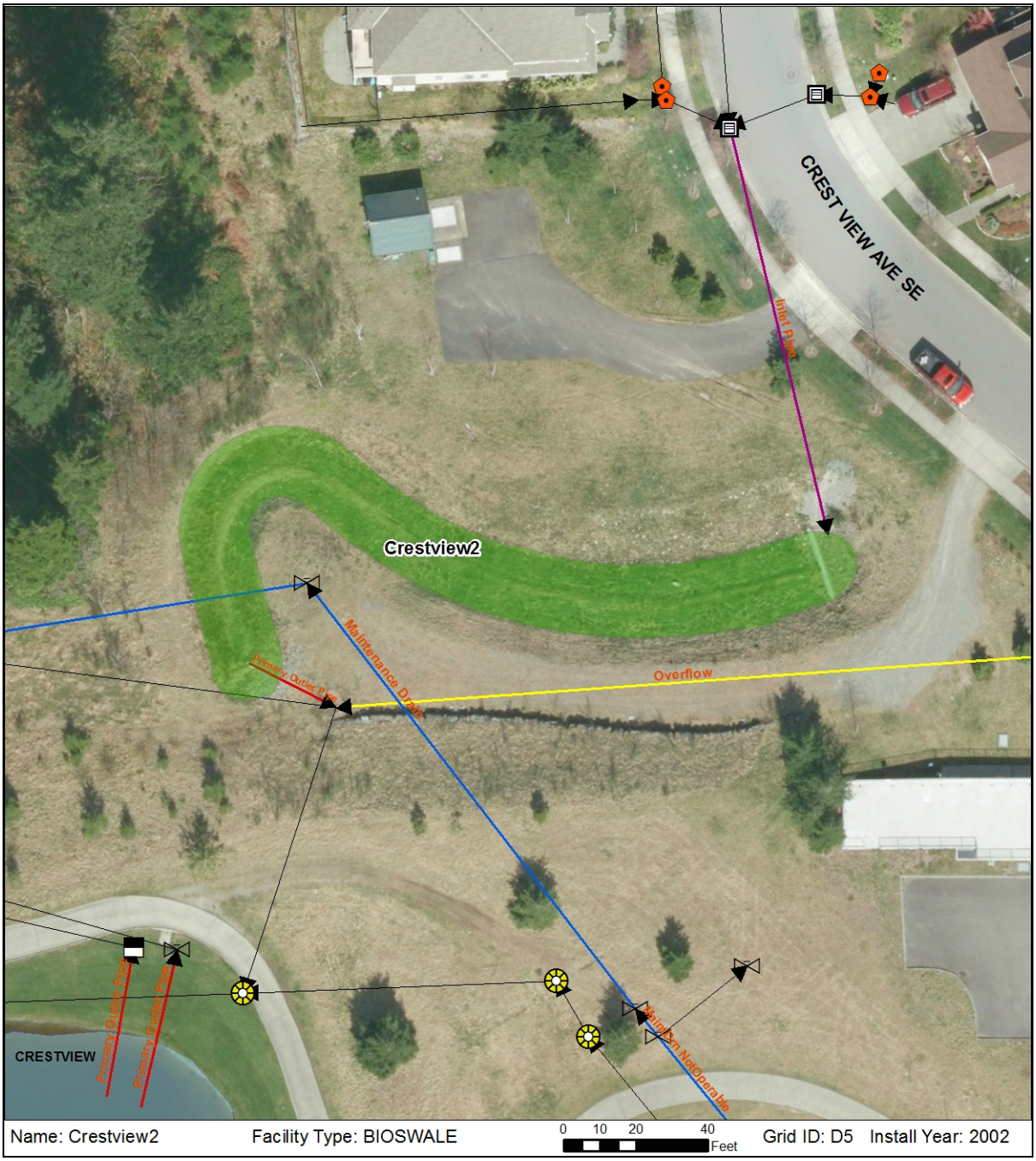


**Figure 2.26 – Crestview2 (M2 South) Bioswale**

### 2.3.24 Fury (Kimball Creek Village) Stormwater Pond

Stormwater Pond "Fury" is identified in Falls Crossing and subsequent Kimball Creek Village design documents as Pond 2, which provides water quality treatment and drains to the Parkway EHFBL. This is the only facility to be constructed for this development (Pond 1 was never build). Additional information for the pond is provided in Appendix B6.


**Figure 2.27 – Fury (Kimball Creek Village) Stormwater Pond**

### 2.3.25 Isley2 (ED4A) Stormwater Pond

Stormwater Pond "Isley2" is identified in Preliminary Plat 8 (Parcel W) design documents as Pond ED4A, with direct discharge outflow that is split between E-Creek and the Parkway EHFBL. Flows directed to E-Creek are equally split to two tributary channels located east and west of the WoodyCreek1 bioswale. Additional information for this pond (ED4A) and also the outlets to two E-Creek tributary channels (shown on the exhibit for the Woody Creek facility) is provided in Appendix A (the 2003 O&M Manual) and in Appendix B7.

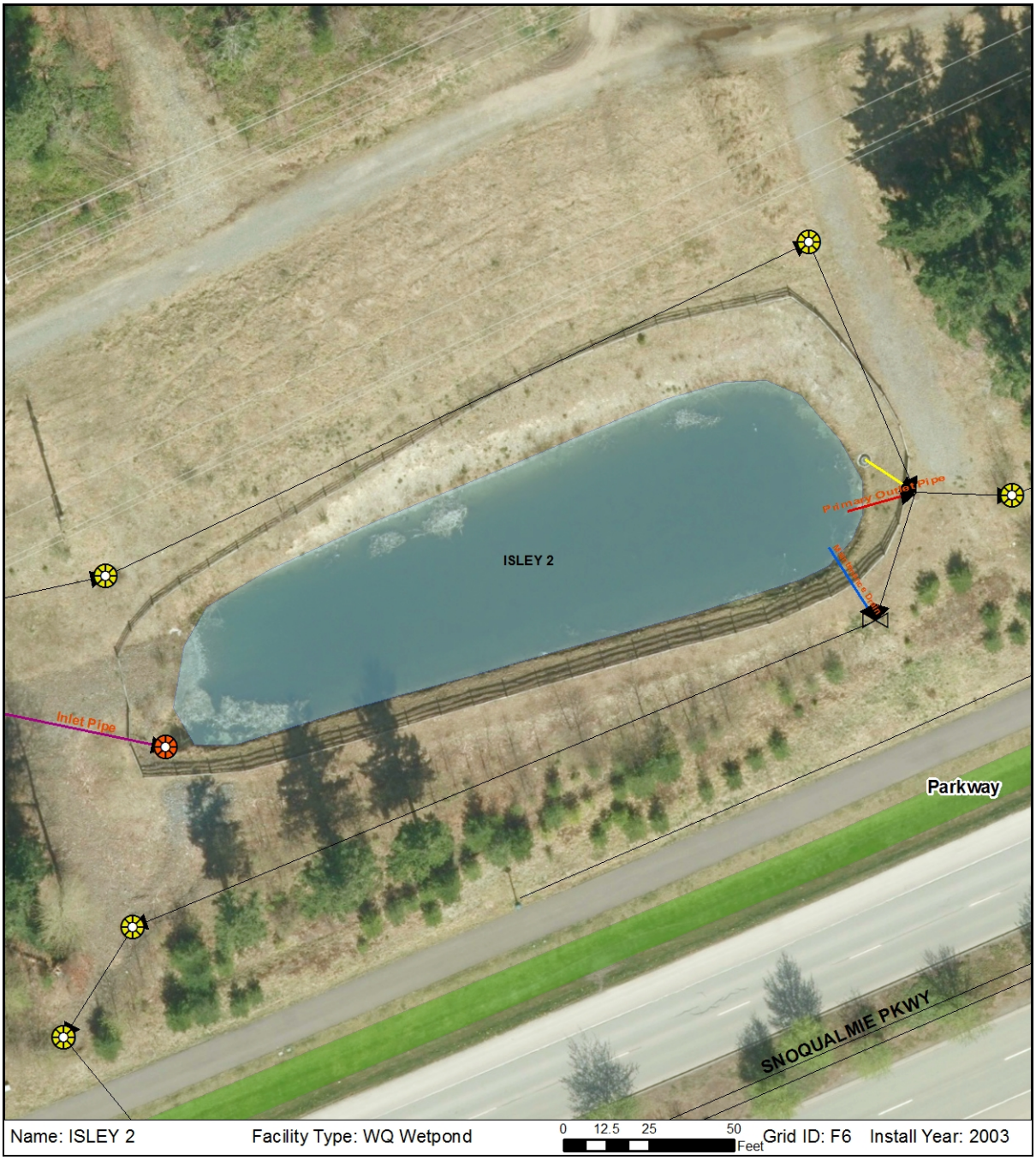


**Figure 2.28 – Isley2 (ED4A) Stormwater Pond**

### 2.3.26 Fisher1&2 (ED6) Stormwater Pond

Stormwater Pond "Fisher1&2" is identified in Preliminary Plat 8 (Parcel W) design documents as Pond ED6, with direct discharge outflow that is split between E-Creek and the Parkway EHFBL. The facility has the appearance of being two separate ponds, but it is designed to function as a single two-cell pond with a connecting pipe. Additional information for this pond is provided in Appendix A (the 2003 O&M Manual) and in Appendix B7.


**Figure 2.29 – Fisher1&2 (ED6) Stormwater Pond**

### 2.3.27 Isley3 (ED6B) Bioswale

The Isley3 bioswale is identified in Preliminary Plat 8 (Parcel W) design documents as providing water quality treatment for sub-basin ED6B. Water (from author recollection) drains to a flow splitter below one of the two Parcel W ponds, and is combined with pond outflow prior to being split between releases to E-Creek and the Parkway EHFBL. Additional information for this bioswale is provided in Appendix B7.


**Figure 2.30 – Isley3 (ED6B) Bioswale**

### 2.3.28 Orchard (E-Ck Bridge) Stormfilter Cartridges

The "Orchard" stormwater facility consists of two catch basin stormfilter systems that were described in the design documents for Preliminary Plat 13, Parcel Z. Treated runoff drains to E-Creek. Additional information for these cartridge filters is provided in Appendix B8. Maintenance recommendations are included in Appendix A (the 2003 O&M Manual).


**Figure 2.31 – Orchard (E-Ck Bridge) Stormfilter Cartridges**

### 2.3.29 Melrose (Braeburn North) Bioswale

The "Melrose" bioswale is identified in Preliminary Plat 13 (Parcel Z) design documents as the Braeburn North Swale, which discharges to wetlands in the E-Creek Basin. Additional information for this bioswale is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.32 – Melrose (Braeburn North) Bioswale**

### 2.3.30 Gala (Braeburn South) Bioswale

The "Gala" bioswale is identified in Preliminary Plat 13 (Parcel Z) design documents as the Braeburn South Swale, which discharges to wetlands in the E-Creek Basin. Additional information for this bioswale is provided in Appendix A (the 2003 O&M Manual).


**Figure 2.33 – Gala (Braeburn South) Bioswale**

### 2.3.31 Denny (M2G North) Swale and Infiltration Trench

The "Denny" facility is identified in Preliminary Plat 14 (Parcel D) design documents as a swale and infiltration trench for runoff from sub-basin M2G. Biofiltration water quality treatment occurs in the swale and then the water is infiltrated to groundwater. Additional information for this facility is provided in Appendix B9.


**Figure 2.34 – Denny (M2G) Swale and Infiltration Trench**

### 2.3.32 Allman (Parcel Y2) Bioswale

The "Allman" bioswale is identified in Parcel Y-2 design documents as the water quality facility for this development. The facility drains to the Parkway EHFBL. Additional information is provided in Appendix B10.


**Figure 2.35 – Allman (Parcel Y-2) Bioswsale**

## 2.4 SNOQUALMIE RIDGE II (2004 – 2012)

A second phase of Snoqualmie Ridge development (SR II) occurred under the May 2004 Snoqualmie Ridge II Master Drainage Plan (MDP). The Phase II development involved lands that were annexed adjacent to the south boundary and northern part of the west boundary of the original Snoqualmie Ridge development. The MDP and subsequent design documents refer to the Phase II development in terms of a South area and a North area.

SR II drainage facilities were planned and designed to meet the regulatory requirements of the 1998 King County Surface Water Design Manual. The main difference in regulations between the 1998 manual and the manual in effect for the original development was the need to provide Level II flow control. Level II flow control limits the duration of erosive discharges -- instead of only controlling the magnitude of peak flows -- and results in detention ponds with live storage volumes that are significantly larger than would have been required under the prior peak flow control regulations.

SR II south area water management is provided with combined water quality and detention ponds that are sized to provide Level II flow control. Development of this part of the site was complicated by the need to minimize impacts to the hydrology of numerous wetlands located within and adjacent to the site. Impacts were minimized by the frequent use of flow splitters to direct pond outflows to the various affected wetlands, and by construction of dedicated roof drain collection and drainage systems to accomplish the same objective.

SR II north area water management is provided mostly by a combination of large infiltration ponds which drain to groundwater above the Lake Alice aquifer, small scale rain garden infiltration facilities where feasible, and direct discharge to the NHFBL subject to its remaining capacity after assumed full buildout of the original development.

### 2.4.1 Strouf (N1) Water Quality and Infiltration Ponds

Infiltration Pond "Strouf" is identified in Preliminary Plat 19 design documents as Pond N1. The facility consists of: (1) a water quality wetpond and (2) an infiltration cell. The N1 water quality cell has not held water at its design water level, resulting in repairs in 2011which may have not been successful. Additional information on the pond design is provided in Appendix B11. Maintenance recommendations are presented in Appendix E and post-construction hydrology monitoring of pond performance is included in Appendix F.

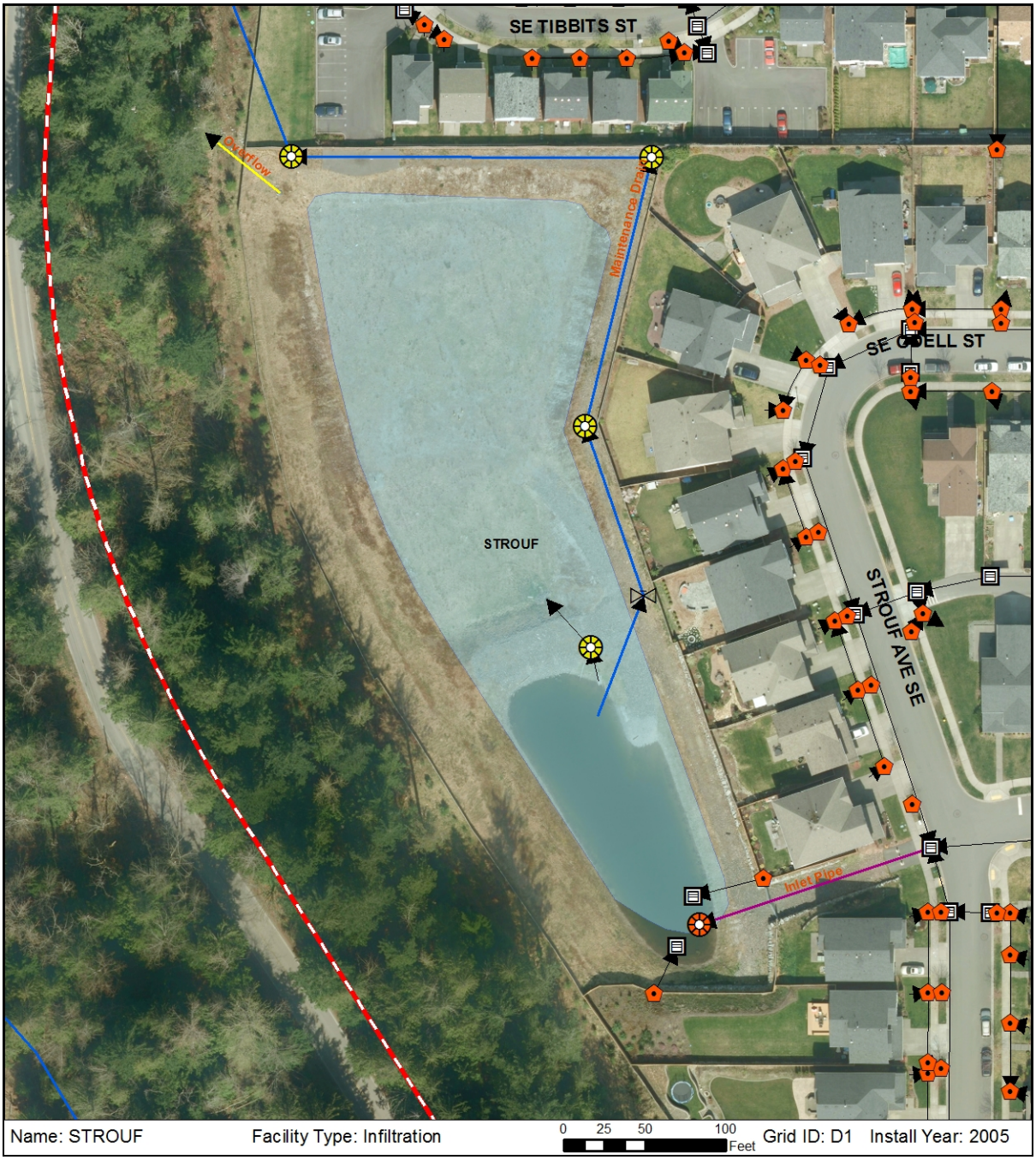


**Figure 2.36 – Strouf (N1) Water Quality and Infiltration Ponds**

### 2.4.2 Sorenson (N2) Water Quality and Infiltration Ponds

Infiltration Pond "Sorenson" is identified in Preliminary Plat 19 design documents as Pond N2. The facility consists of: (1) a water quality wetpond and (2) an infiltration cell. Additional information on the pond design is provided in Appendix B11. Maintenance recommendations are presented in Appendix E and post-construction hydrology monitoring of pond performance is included in Appendix F.

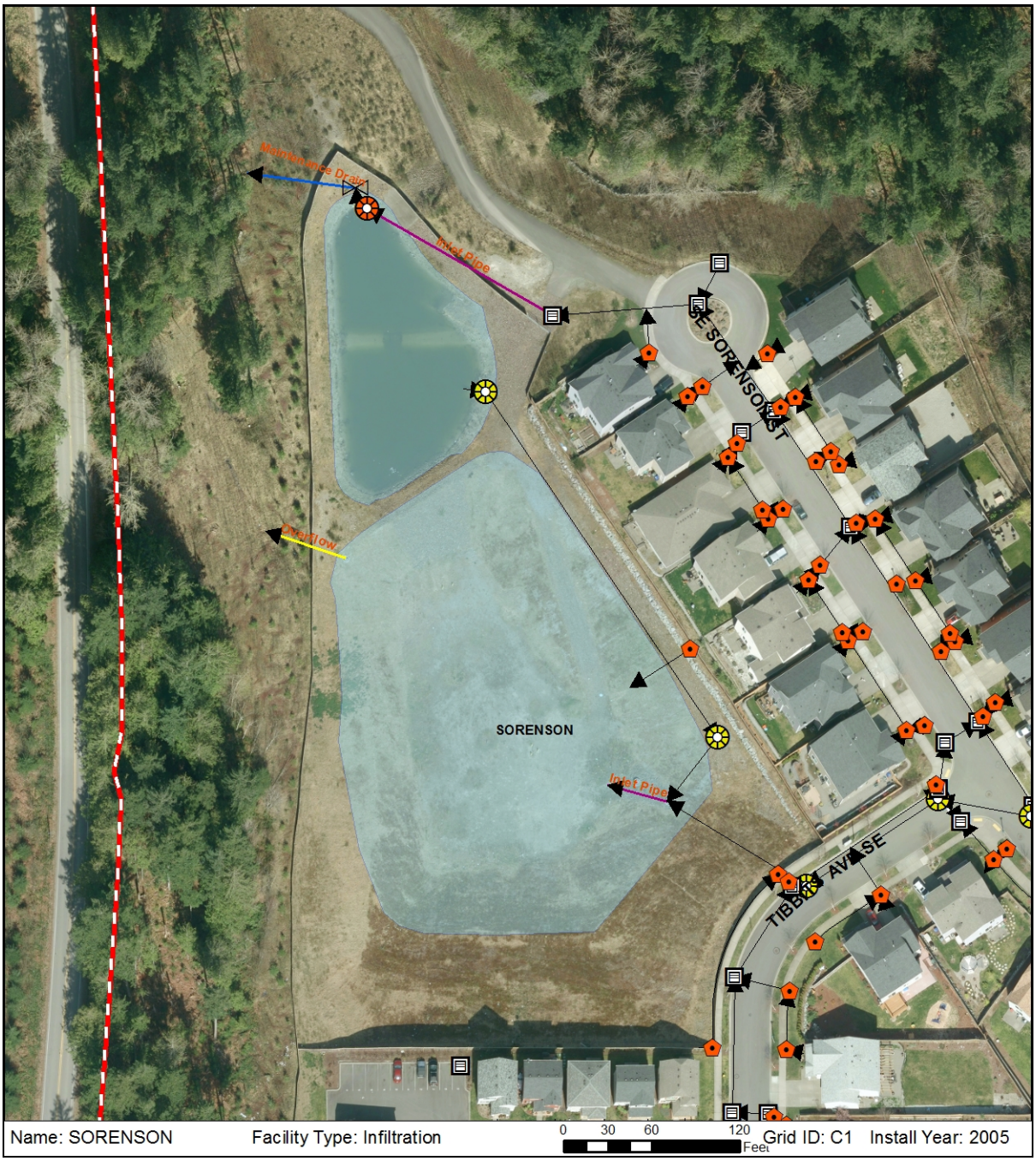


**Figure 2.37 – Sorenson (N2) Water Quality and Infiltration Ponds**

### 2.4.3 Carmichael1 (N4) Stormwater Pond

Stormwater Pond "Carmichael1" is identified in Preliminary Plat 19 design documents as direct discharge Pond N4 which drains to the NHFBL. Additional information on the pond design is provided in Appendix B11.


**Figure 2.38 – Carmichael1 (N4) Stormwater Pond**

### 2.4.4 Swenson_E1 (S11 West) Stormwater Pond

Stormwater Pond "Swenson_E1" is identified in Preliminary Plat 20 design documents as Pond S11 West, which provides Level 2 flow control and discharges to D-Creek via Wetland D13. The pond footprint occupies the location where Parkway Pond DP1 was originally constructed. Some existing storm drain pipes near and beneath Pond Swenson_E1 were constructed with Pond DP1, the details of which are included on construction drawings for the Parkway. Design information for Pond Swenson_E1 is provided in Appendix B12.


**Figure 2.39 – Swenson_E1 (S11 West) Stormwater Pond**

### 2.4.5 Swenson_E2 (S11 East) Stormwater Pond

Stormwater Pond "Swenson_E2" is identified in Preliminary Plat 20 design documents as Pond S11 East, which provides Level 1 flow control and discharges to D-Creek via Wetland D13. This pond replaced Parkway Pond DP1 which provided Level 1 flow control. The SR II MDP had anticipated that there would be single S11 pond providing hybrid flow control but during detailed design it was decided to construct separate East and West ponds. Additional information on the pond design is provided in Appendix B12.


**Figure 2.40 – Swenson_E2 (S11 East) Stormwater Pond**

### 2.4.6 Swenson_E3 (S10) Stormwater Pond

Stormwater Pond "Swenson_E3" is identified in Preliminary Plat 20 design documents as Pond S10, which provides Level 2 flow control and discharges to D-Creek via Wetland D13. Additional information on the pond design is provided in Appendix B12. Monitoring results of pond hydrologic performance for years 2007 through 2011 are included in Appendix E.


**Figure 2.41 – Swenson_E3 (S10) Stormwater Pond**

### 2.4.7 Swenson_E4 (S8) Stormwater Pond

Stormwater Pond "Swenson_E4" is identified in Preliminary Plat 20 design documents as Pond S8, which provides Level 2 flow control and discharges to D-Creek via split flow releases to Wetland D15 and MDP Creek 4. The facility has two distinct cells, with the uppermost cell providing water quality treatment. Additional information on the pond design is provided in Appendix B12. Monitoring results of pond hydrologic performance for years 2007 through 2011 are included in Appendix E.


**Figure 2.42 – Swenson_E4 (S8) Stormwater Pond**

### 2.4.8 Swenson_E5 (S7) Stormwater Pond

Stormwater Pond "Swenson_E5" is identified in Preliminary Plat 20 design documents as Pond S7, which provides Level 2 flow control and discharges to D-Creek via Wetland D15. Additional information on the pond design is provided in Appendix B12. Monitoring results of pond hydrologic performance for years 2007 through 2011 are included in Appendix E.


**Figure 2.43 – Swenson_E5 (S7) Stormwater Pond**

### 2.4.9 Swenson_E6 (S6A) Stormwater Pond

Stormwater Pond "Swenson_E6" is identified in Preliminary Plat 20 design documents as Pond S6A, which provides Level 2 flow control and discharges to D-Creek via MDP Creek 5. Additional information on the pond design is provided in Appendix B12. Monitoring results of pond hydrologic performance for years 2007 through 2011 are included in Appendix E.


**Figure 2.44 – Swenson_E6 (S6A) Stormwater Pond**

### 2.4.10 Swenson_E7 (S6B) Stormwater Pond

Stormwater Pond "Swenson_E7" is identified in design documents as Pond S6B, which provides Level 2 flow control and discharges to D-Creek via MDP Creek 7. Additional information on the pond design is provided in Appendix B12. Monitoring results of pond hydrologic performance for years 2007 through 2011 are included in Appendix E.

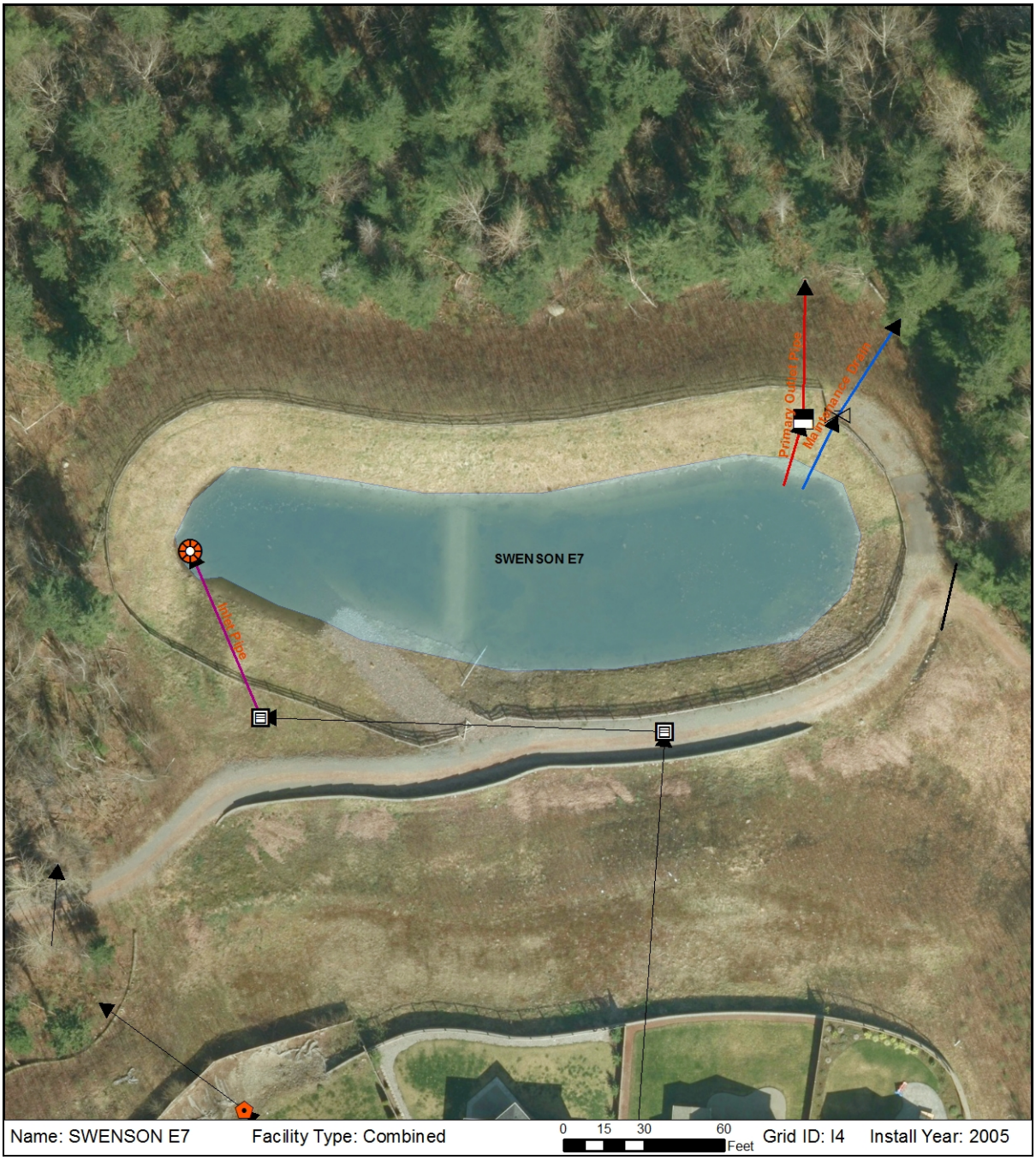


**Figure 2.45 – Swenson_E7 (S6B) Stormwater Pond**

### 2.4.11 Swenson_E8 (S6C) Stormwater Pond

Stormwater Pond "Swenson_E8" is identified in Preliminary Plat 20 design documents as Pond S6C which provides Level 2 flow control and discharges to D-Creek via MDP Creek 7. Additional information on the pond design is provided in Appendix B12. Monitoring results of pond hydrologic performance for years 2007 through 2011 are included in Appendix E. The monitoring identified a severe leakage problem at Pond S6C which requires repair.

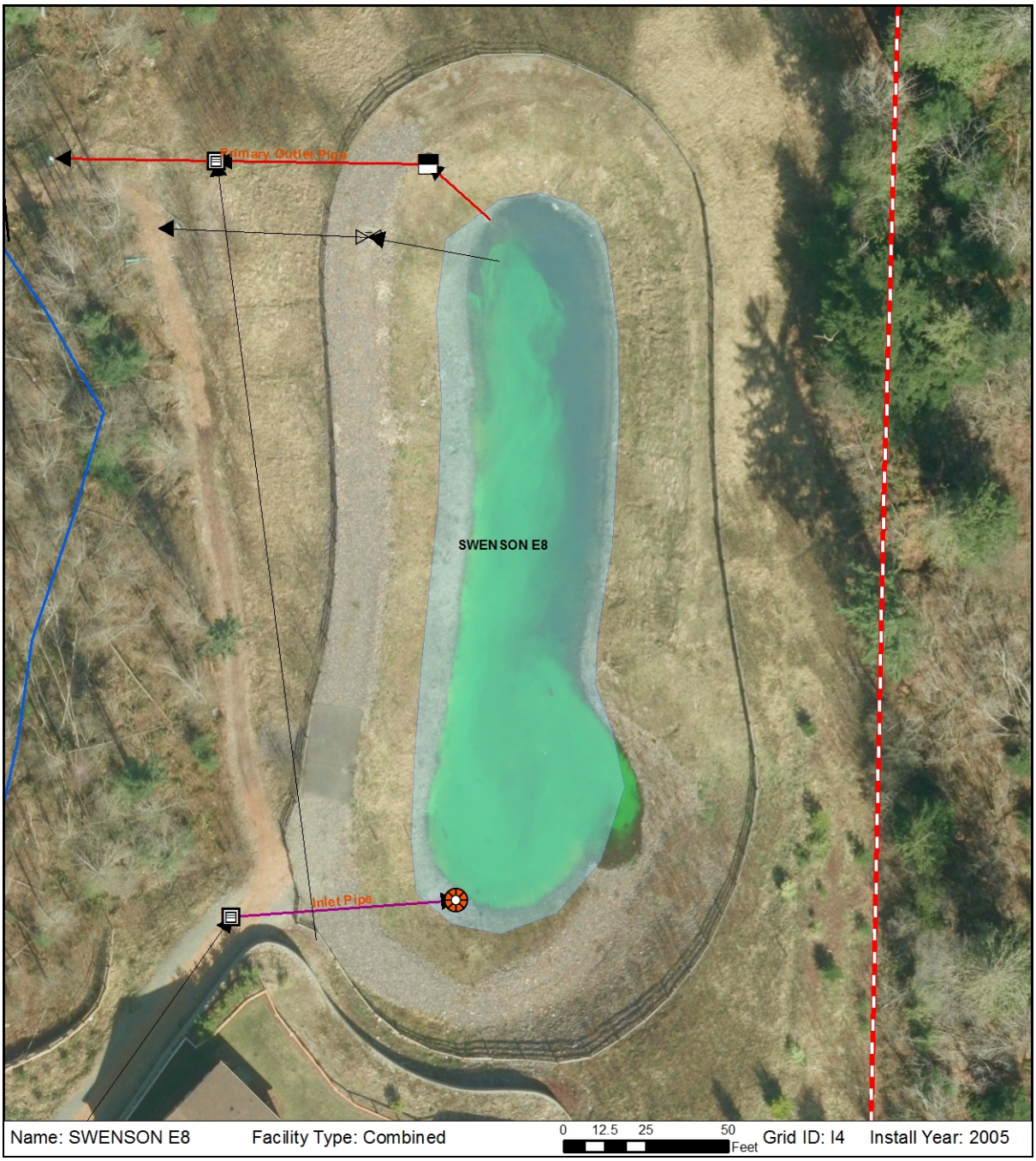


**Figure 2.46 – Swenson_E8 (S6C) Stormwater Pond**

### 2.4.12 Jacobia_E1 (1040 Reservoir) Stormwater Pond

Stormwater Pond "Jacobia_E1" is a stormwater pond constructed in about 1996 for the city's 1040 reservoir site. The pond configuration and stormwater controls were reviewed in 2005/06 when the second reservoir tank was added. The pond drains to the adjacent Wetland B5/B6; the drain line that connects to the parkway is a water tank drain line, not the pond outlet. Design information was not readily available; Appendix B13 is reserved as a placeholder for design information to be added if located in the future.


**Figure 2.47 – Jacobia_E1 (1040 Reservoir) Stormwater Pond**

### 2.4.13 South_Parkway (S21) Interim Stormwater Pond

Stormwater Pond "South_Parkway" is identified in Parkway Widening design documents as interim Pond S21, at the location reserved in the MDP for future Pond S21B. The interim pond provides water quality treatment and Level 1 flow control for Parkway runoff and drains to the state highway drainage system. Design documents anticipate that the final pond at this location will provide Level 2 flow control for the runoff from the Parkway plus SR II Parcel S21B. Additional information on the pond design is provided in Appendix B14.


**Figure 2.48 – South_Parkway (S21) Interim Stormwater Pond**

### 2.4.14 Hancock1 (S1) Stormwater Pond

Stormwater Pond "Hancock1" is identified in Parcel S1A design documents as Pond S1 which provides Level 2 flow control and discharges to Wetland B5 in the upper D-Creek basin. Additional information on the pond design is provided in Appendix B15. Monitoring results of pond hydrologic performance for years 2007 through 2011 are included in Appendix E.


**Figure 2.49 – Hancock1 (S1) Stormwater Pond**

### 2.4.15 Kendall1-4 & Whitacre1-2 (N6) Rain Gardens

Stormwater management for Preliminary Plat 23 (Parcel N6) is provided with six distributed Low Impact Development bioretention rain gardens which infiltrate to groundwater. Stormwater facilities Kendall1, Kendall2, Kendall3, and Kendall4 are identified in Parcel N6 design documents as rain gardens N6A, N6B, N6C, and N6E respectively. Facilities Whitacre1 and Whitacre2 are identified in the same documents as rain gardens N6D and N6F. Additional information on the rain garden designs is provided in Appendix B16.

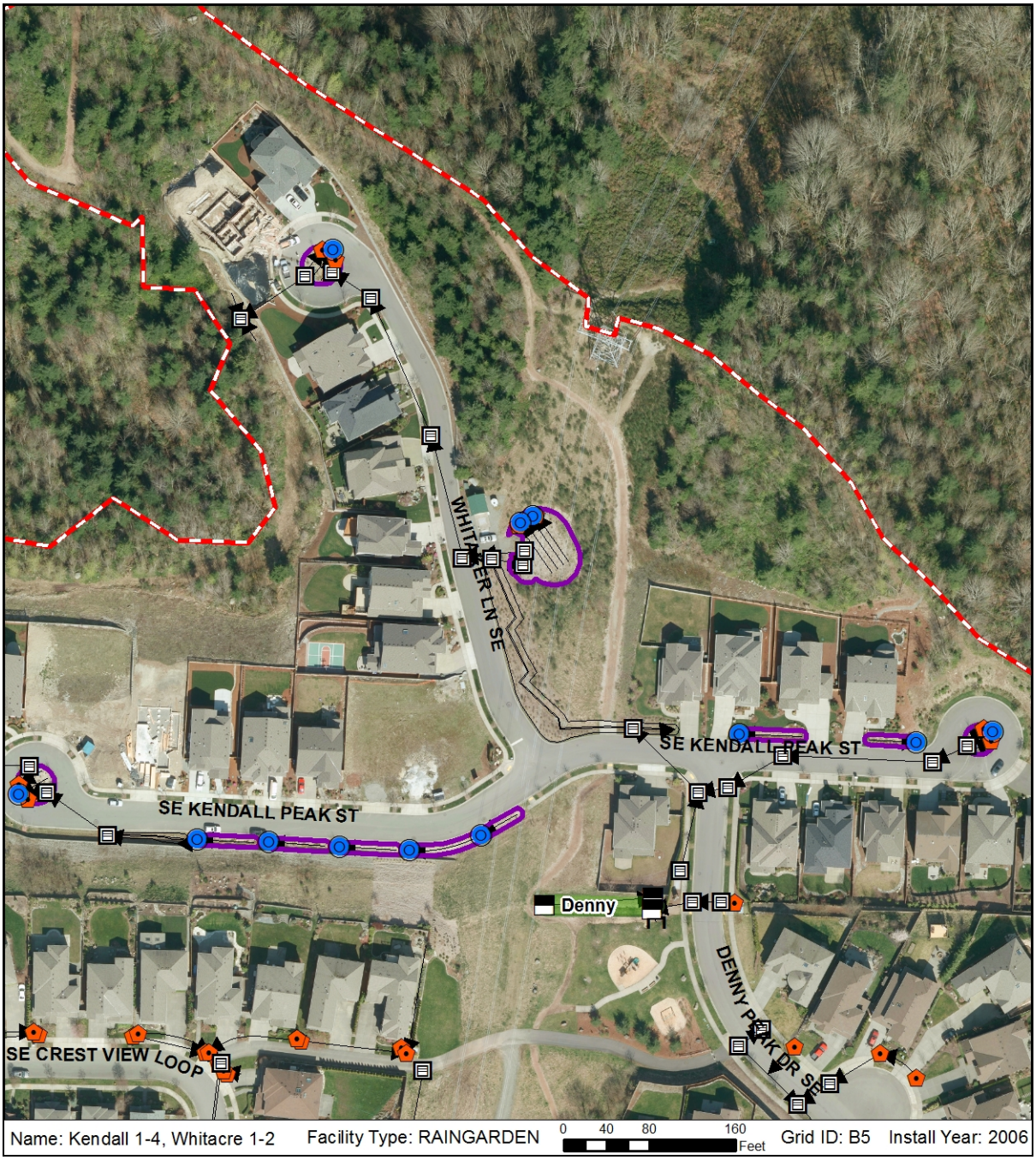


**Figure 2.50 – Kendall1-4 & Whitacre1-2 (N6) Rain Gardens**

### 2.4.16 Jacobia_E2 (S2B) Stormwater Pond

Stormwater Pond "Jacobia_E2" is identified in Collector Road "C" and Preliminary Plat 24 design documents as Pond S2B which provides Level 2 flow control with split outflow to two (east and central) locations above Wetland D27 in the upper D-Creek basin. Additional information on the pond and flow splitter designs is provided in Appendix B17. The original design calculations and drawings for Pond S2B are described in the Collector Road "C" excerpts located at the end of Appendix B17, after the Preliminary Plat 24 plans.


**Figure 2.51 – Jacobia_E2 (S2B) Stormwater Pond**

### 2.4.17 Merritt (S2C) Stormwater Pond

Stormwater Pond "Merritt" is identified in Preliminary Plat 24 design documents as Pond S2C which provides Level 2 flow control with split outflow to two (west and central) locations above Wetland D27 in the upper D-Creek basin. Additional information on the pond and flow splitter designs is provided in Appendix B17.


**Figure 2.52 – Merritt (S2C) Stormwater Pond**

### 2.4.18 Swing (S3) Stormwater Pond

Stormwater Pond "Raines" is identified in Preliminary Plat 24 design documents as Pond S4 which provides Level 2 flow control with three outlet flow splitters in series to deliver water to four wetlands: R2, D/T1, D50 and D33. Additional information on the pond and flow splitter designs is provided in Appendix B17.


**Figure 2.53 – Swing (S3) Stormwater Pond**

### 2.4.19 Raines (S4) Stormwater Pond

Stormwater Pond "Raines" is identified in Preliminary Plat 24 design documents as Pond S4 which provides Level 2 flow control with split outflow to the Wetland D28 and the east section of Wetland D27 in the upper D-Creek basin. Additional information on the pond and flow splitter designs is provided in Appendix B17.

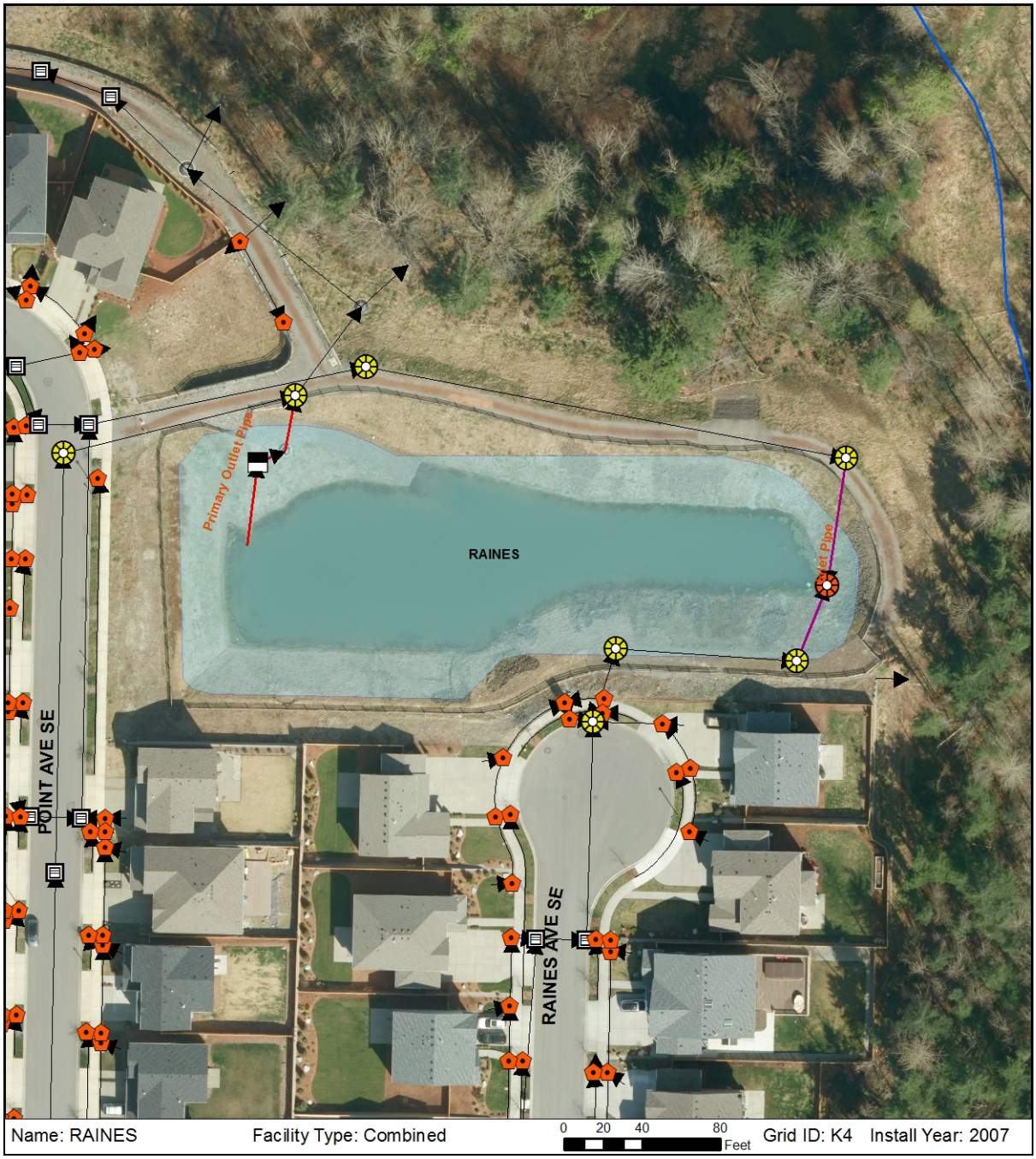


**Figure 2.54 – Raines (S4) Stormwater Pond**

### 2.4.20 Frontier1 (S20) Stormwater Pond

Stormwater Pond "Frontier1" is identified in Preliminary Plat 25 Phase 1 design documents as Pond S20 which provides Level 2 flow control with split outflow to Wetland SW4 and a poorly defined drainage course at the site west boundary. Additional information on the pond and flow splitter designs is provided in Appendix B18.


**Figure 2.55 – Frontier1 (S20) Stormwater Pond**

### 2.4.21 Frontier2 (S16B) Stormwater Pond

Stormwater Pond "Frontier2" is identified in design documents as Pond S16B which provides Level 2 flow control and discharges to Wetland B10, which drains southward to Lake Creek. Additional information on the pond design is provided in Appendix B18.


**Figure 2.56 – Frontier2 (S16B) Stormwater Pond**

### 2.4.22 Frontier3 (S16A) Stormwater Pond

Stormwater Pond "Frontier3" is identified in design documents as Pond S16A, which provides Level 2 flow control and discharges to Wetland B1, which flows to Wetland B2 and eventually drains to Lake Creek. This pond receives runoff from SRII development areas in addition to the parkway basin which originally drained to Parkway Pond BP1. Pond BP1 was eliminated and replaced by S16A. Additional information on the pond design is provided in Appendix B18.


**Figure 2.57 – Frontier3 (S16A) Stormwater Pond**

### 2.4.23 Jacobia_W2 (S16A Bypass) Bioswale

The "Jacobia_W2" bioswale is identified in Preliminary Plat 25 Phase 1 design documents as the basin S16A bypass bioswale with direct discharge to Wetland B1. Additional information on the bioswale design is provided in Appendix B18.


**Figure 2.58 – Jacobia_W2 (S16A Bypass) Bioswale**

### 2.4.24 Swenson_W1 (S12A) Stormwater Pond

Stormwater Pond "Swenson_W1" is identified in Preliminary Plat 25 overall grading plan design documents as Pond S12A, which provides Level 2 flow control and discharges to Wetland D10 which is the main headwater wetland for D-Creek. Additional information on the pond design is provided in Appendix B19.


**Figure 2.59 – Swenson_W1 (S12A) Stormwater Pond**

### 2.4.25 Swenson_W2&W3 (S14) Pond and Sand Filter

Stormwater Pond "Swenson_W2" and Sand Filter "Swenson_W3" operate in series to provide enhanced stormwater treatment prior to release to distributed outlets to Wetland LA3 which is a high value wetland. These facilities are described in Preliminary Plat 25 Swenson Avenue design documents as a combined S14 facility. Additional information on the pond and sand filter designs is provided in Appendix B20.


**Figure 2.60 – Swenson_W2&W3 (S14) Pond and Sand Filter**

### 2.4.26 Swenson_W4 (S13) Stormwater Pond

Stormwater Pond "Swenson_W4" is identified in Preliminary Plat 25 overall grading plan design documents as Pond S13, which provides Level 2 flow control with three-way split outflow to Wetlands D17, D21, and LA3. Additional information on the pond and flow splitter designs is provided in Appendix B19.


**Figure 2.61 – Swenson_W4 (S13) Stormwater Pond**

### 2.4.27 Hospital (S21A) Stormwater Pond

Stormwater Pond "Hospital" is identified in Parcel S21 – Snoqualmie Valley Hospital - design documents as Pond S12A, which provides Level 2 flow control with split outflow to Wetland S21 and a road ditch along SE 99th Street. Additional information on the pond and flow splitter designs is provided in Appendix B21.


**Figure 2.62 – Hospital (S21A) Stormwater Pond**

### 2.4.28 Jacobia_W1 (S15) Pond and Rain Garden

Stormwater Pond "Jacobia_W1" is identified in Jeanne Hansen Community Park design documents as Pond S15 which provides Level 2 flow control with split outflows to Wetlands B4, D52B, and D23. The park design includes a small (½" garden hose) washdown area which drains through a rain garden prior to flow spreader release to an adjacent forested area. Additional information on all of the Jacobia_W1 facilities is provided in Appendix B22.


**Figure 2.63 – Jacobia_W1 (S15) Stormwater Pond**

### 2.4.29 Planned Future SR II Facilities

Snoqualmie Ridge II original (2004) and amended (2008) Master Drainage Plan documents identified several facilities which had not been constructed as of the date of this report.

Appendix B15 includes plans for construction of Stormwater Pond S1C which were prepared in 2006 during development of Parcel S1A BSIP. Construction of this pond, or some functionally equivalent stormwater facility, will be required for the future development of MDP Parcel S23 located at the northwest edge of the intersection of the Parkway and SE 96th Street.

Future development of MDP Parcel S21B, located along the west side of the Parkway north of SE 99th Street will require extensive modifications to interim Pond S21B or construction of a suitable alternative permanent stormwater facility.

Future development of MDP Parcels N3 and N7 located south of SE Carmichael Street west of J-Creek will require construction of two additional ponds or equivalent substitute facilities.

## 2.5 Mill Planning Area (2012)

Future development will occur in the 593-acre Mill Planning Area of Snoqualmie's Urban Growth Area, which was annexed by the city in 2012. According to the city website, approximately 350 acres of the annexed area is zoned open space and 200 acres is zoned Planned Commercial / Industrial land. The annexation became effective September 28, 2012.

Stormwater infrastructure and system maintenance needs for the Mill Planning area are assumed to be minimal as of 2013, and are not discussed further in the present report.

# 3 PRIVATE FACILITIES INVENTORY

## 3.1 SNOQUALMIE RIDGE GOLF COURSE

### 3.1.1 Overview of Facilities and Maintenance Plans

The Snoqualmie Ridge Tournament Players Course (TPC) golf course is a major part of the original Snoqualmie Ridge development. Drainage infrastructure within the golf course provides water quality treatment and conveyance for runoff from the golf course as well as from adjacent residential areas. Except for facilities which have been explicitly conveyed to the city or some other entity, the golf course has ownership and maintenance responsibility for all stormwater facilities located on and beneath golf course property and also the offsite conveyance systems and outfalls from those facilities.

At the end of 2012, the only golf course drainage infrastructure that had been conveyed to the city was the portion of the North High Flow Bypass Line located on city-owned property north of the golf course. The golf course retains ownership responsibility for all parts of the North High Flow Bypass Line located on golf course land as well as for mixed use stormwater facilities on golf course land which include four stormwater ponds and the North Basin Drain Line. The golf course also retains ownership responsibility for all portions of the steep slope shunt/drain/outlet pipes which originate from the stormwater system at golf course Sand Filter 6 (Hole 6) and golf course Ponds M2 and M3, and which discharge to outfalls on public lands. Appendix G1 contains location maps of the golf course stormwater facilities as of 2001, including the shunt/drain/outlet pipes and outfalls.

Appendix G2 contains a scanned copy of the *Maintenance Plan for Golf Course Stormwater Facilities*, prepared to satisfy a requirement of the project approval. This plan is undated but was prepared prior to 2005 when the scanned copy was made. The plan provides a detailed description of recommended maintenance activities, including activity frequency. To date, the city has not monitored or enforced stormwater facility maintenance activity by golf course staff. An informal arrangement has evolved in which the golf course personnel have been responsible for above-ground maintenance activity including mowing and trash removal, and the city public works staff has periodically exercised valves and inspected below-ground elements such as catch basins and control structures. City inspections were most recently made in conjunction with the 2010 update of the North High Flow Bypass Isolation Manual which is presented in Appendix C.

Existing documents do not adequately describe storm drain facilities at the perimeter of golf course Holes 5 and 6 where there were steep slope landslides caused by water overflows during construction. Following the landslide at Hole 5, a curb grate inlet was installed in a sand trap adjacent to the steep slope, with a pipe connection to the main conveyance system. However, when inspected by city representatives (Bill Rozeboom and Mike Roy) in 2011, the Hole 5 curb grate inlet was not found, and the golf course superintendent was advised that this needed to be restored. Following the landslide at Hole 6, the downstream berm for a perimeter ditch was raised to prevent future overflows. The need for future maintenance to ensure the integrity of the Hole 6 perimeter ditch and berm was also brought to the attention of the golf course superintendent. There has not been any follow-up since 2011, and the

superintendent who was made aware of these facilities is no longer with TPC Snoqualmie Ridge.

Appendix G3 presents a scanned copy of the *Operational Golf Course Maintenance Plan* which was last updated in 2000 to satisfy a condition of project approval. The focus of the document is the golf course Integrated Pest Management (IPM) Plan, described as "*an adaptive process which maintains pest populations at sufficiently low levels to avoid economic damage to the golf course. This will be achieved using combined and balanced strategies of biological, cultural, genetic, chemical, and other control technologies.*" The plan identifies and describes specific landscape and pest control chemicals and application rates which are approved for use at the Snoqualmie Ridge golf course. It also describes a spill response plan and best management practices for chemical handling and maintenance area drainage control.

The introduction to the *Operational Golf Course Maintenance Plan* states, "*The Snoqualmie Ridge Golf Club has previously arranged a 1-year annual review with the City of Snoqualmie, at which time changes to the management chemicals may be proposed for City review and approval, per Condition 20 of the Mixed Use Approval. It is expected that annual review will continue after acceptance of this Operational GCMP."* The plan has not been reviewed or updated since 2000 and it is unknown whether the current golf course superintendent is familiar with this document. As of 2012, the city has not monitored golf course compliance with the Plan's requirements and restrictions.

### 3.1.2 Stormwater Ponds M1, M2, M3, and ED4

The golf course has four stormwater ponds, originally identified in the MDP documents as Ponds M1, M2, M3 and ED4, all receiving runoff from residential as well as golf course areas. These ponds are respectively described above in Sections 2.3.2 through 2.3.5 above as Eagle Lake (M1), Crestview (M2) Stormwater Pond, FairwayPl (M3) Stormwater Pond, and Isley2 (ED4) Stormwater Pond.

### 3.1.3 Enclosed Storage Sand Filters

The golf course has twelve enclosed storage sand filters which provide water quality treatment to runoff from golf course areas exclusively. These filters were designed and approved to satisfy regulatory water quality treatment requirements.

Appendix G4 contains design details for two types of enclosed storage sand filters constructed at the golf course. Filters were initially designed to use Maximizer© Chambers but, due to product availability problems, the design was later modified to use corrugated metal pipes. Maximizer© Chambers are installed at Holes 4, 5, 6, 16 and practice area (two filters). Corrugated pipe designs are installed at Holes 1, 8 (two filters) and 12. Appendix G4 also gives design details for a smaller "Type D" sand filter which is installed at each tee and green to provide water quality pre-treatment.

The long term maintenance of the enclosed storage sand filters is expected to involve periodic replacement of the sand filter media. A continuing long-term monitoring program is in place to identify when the enclosed storage sand filters overflow, as this would be an

indicator that the media is becoming plugged and in need of replacement or other suitable maintenance.

A review of enclosed storage filter monitoring results in 2008 by city and golf course consultants indicated acceptable performance at that time. Review of findings was complicated by changes in golf course drainage and runoff performance which is believed to be due in part to thatch buildup. Periodic city review of sand filter monitoring results is recommended to be done on at least a regular five year interval and is due in 2013.

### 3.1.4 Bioswales

The golf course has a total of three bioswales which are intended to provide water quality treatment before discharging to the East (Parkway) High Flow Bypass Line. All bioswales are in the vicinity of the golf course maintenance facility and Hole 2. Locations of the bioswales are shown and labelled as such on Drawing 1 in Appendix G1. The difference between the "bioswales" and the "swales" also shown on the drawing is that the bioswales were designed to provide conveyance and water quality treatment whereas the swales were designed only for conveyance.

The first bioswale begins about 100 feet due east from the SW corner of the maintenance facility pavement, and was designed to treat runoff from the maintenance building site. Subsequently, an equipment wash area was constructed within the maintenance area site and the wastewater was directed to the bioswale, exceeding its capacity. In an effort to improve bioswale performance, a bypass was constructed to a unique equipment wash wastewater treatment filter strip which reduces the wastewater flow and nutrient load to the bioswale.

The second bioswale is on the west side of the BPA power line access road and extends from the Parkway to the maintenance facility turnoff. This bioswale was designed to treat runoff from the east-draining portions of the maintenance facility site and access road.

The third bioswale is a compound facility with two "bubble-up" inlets which supply flow to two separate bioswales which eventually join and discharge to a common outlet. The connection of the two swales is located approximately 500 feet NW from the NW corner of the maintenance facility site. These two swales were constructed in 2001 to replace two enclosed sand filters at these locations which failed to perform satisfactorily. Design information is provided in Appendix G5. The retrofit has not performed satisfactorily because the "bubble-up" depth is too high and water typically leaks to a groundwater flow path before rising to the height necessary to exit the inlets and enter the swales.

### 3.1.5 Equipment Wash Wastewater Treatment Filter Strip

In 2006, a treatment filter strip was constructed east of the golf course maintenance facility to provide water quality treatment for equipment wash wastewater. This was constructed instead of a recycling wash system for the maintenance equipment, as was planned in the 1999 Operational Golf Course Maintenance Plan, to eliminate the wastewater drainage to the bioswale (see Page 11 of Appendix G3). The wastewater treatment filter strip design is shown in Appendix G6.

## 3.2 PRIVATELY OWNED FACILITIES

Additional stormwater flow control and/or water quality facilities exist which were not explicitly conveyed to the city and which are supposed to be privately maintained. City maintenance responsibilities begin at the catch basin in the city right of way where runoff enters the city system.

### 3.2.1 Kimball Creek Drive Subdivision Wet and Dry Ponds

A stormwater facility consisting of a 3-cell linear wetpond and normally-dry flow control pond exists at the east end of the Kimball Creek Drive Subdivision off 384th Ave. SE. The location is at Grid ID J10 on the city stormwater facility reference map. Appendix H1 contains an annotated satellite image of the facility location and available (incomplete) record drawings dated 1996. Figure 3.1 shows a 2009 satellite image of the facility.

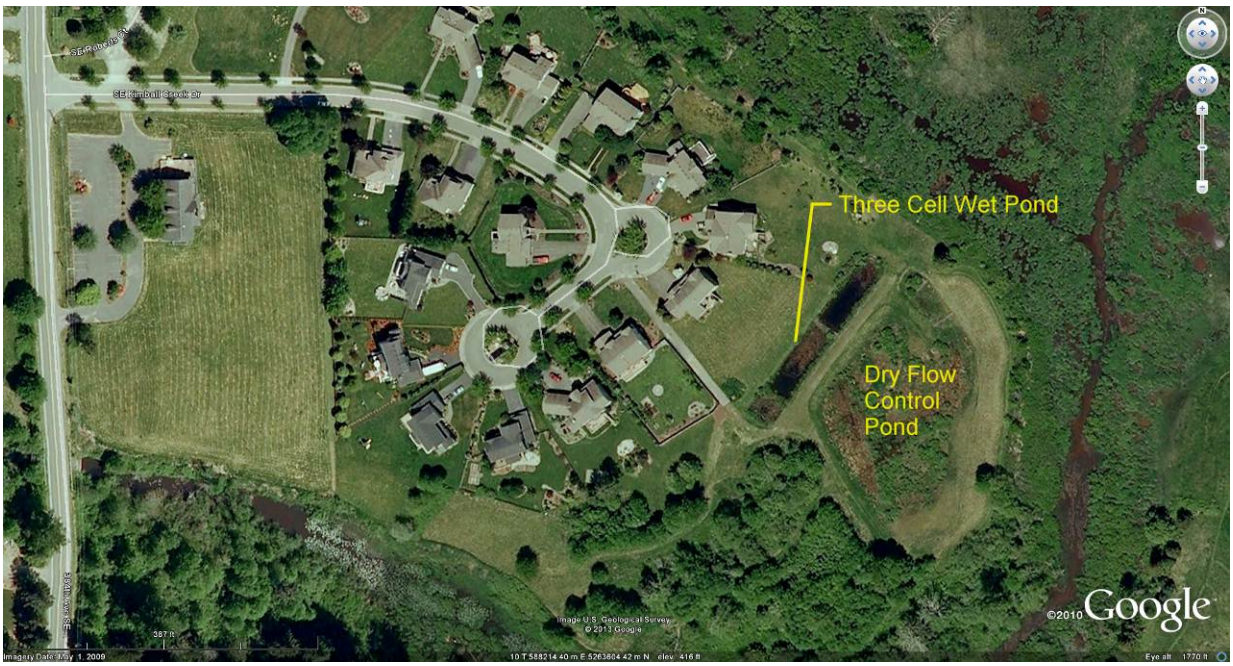


**Figure 3.1 – Kimball Creek Drive SubdivisionWet and Dry Ponds**

### 3.2.2 Peggy's Place Bioswale

A stormwater bioswale is located at the north end of Peggy's Place SE, approximately one block south of city hall. The location is at Grid ID H10 on the city stormwater facility reference map. Appendix H2 contains available (incomplete) design drawings dated 1997. Figure 3.2 shows a 2009 satellite image of the facility.


**Figure 3.2 – Peggy's Place Bioswale**

### 3.2.3 School District Bus Barns Swale

A stormwater swale which drains (and is presumed to treat) runoff from school district bus barns is located approximately two blocks north and west from city hall. The location is at Grid ID G10 on the city stormwater facility reference map. Outflow from the end of swale is conveyed by pipe to the city storm drain system. Design information is not available and year of construction is unknown. Figure 3.3 shows a 2009 satellite image of the facility.

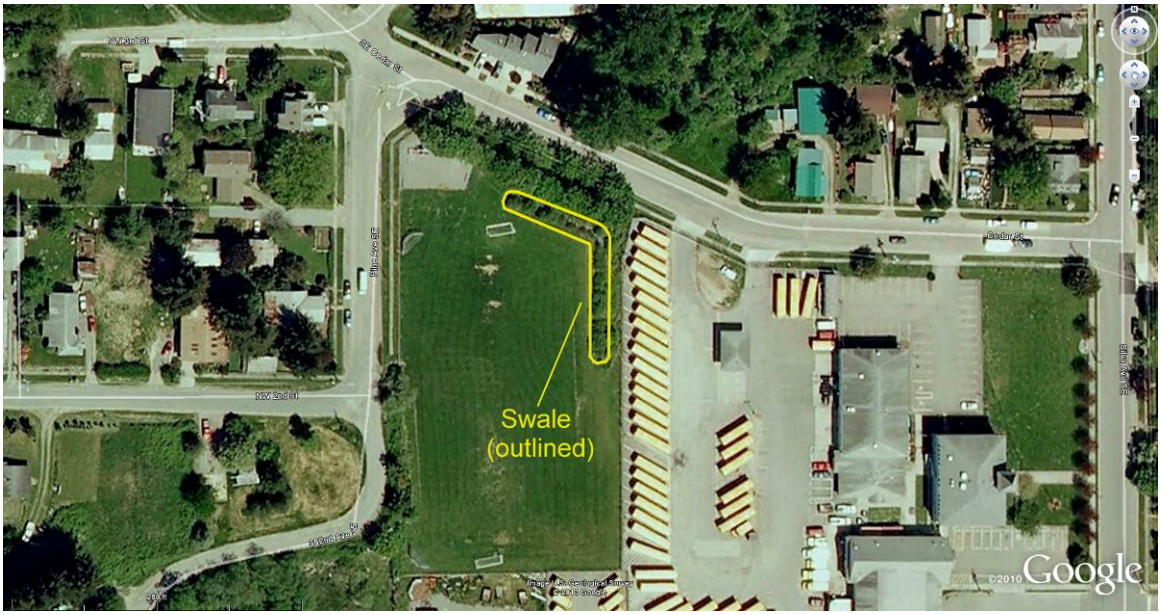


**Figure 3.3 – School District Bus Barns Swale**

### 3.2.4 Rattlesnake Mountain Trailhead Raingarden

A small infiltration cell, or rain garden, is located at the turnoff from Winery Road to the Rattlesnake Mountain trailhead. The location is at Grid ID M8 on the city stormwater facility reference map. Design drawings could not be located. From author memory, this facility was constructed to provide flow control via infiltration when the State of Washington paved the trailhead access road and parking lot sometime between 2005 and the trailhead grand opening in June 2007. Appendix H4 contains an agreement between the city of Snoqualmie and the state of Washington under which access road and drainage maintenance is performed by the city. Figure 3.4 shows a 2009 satellite image of the facility location.

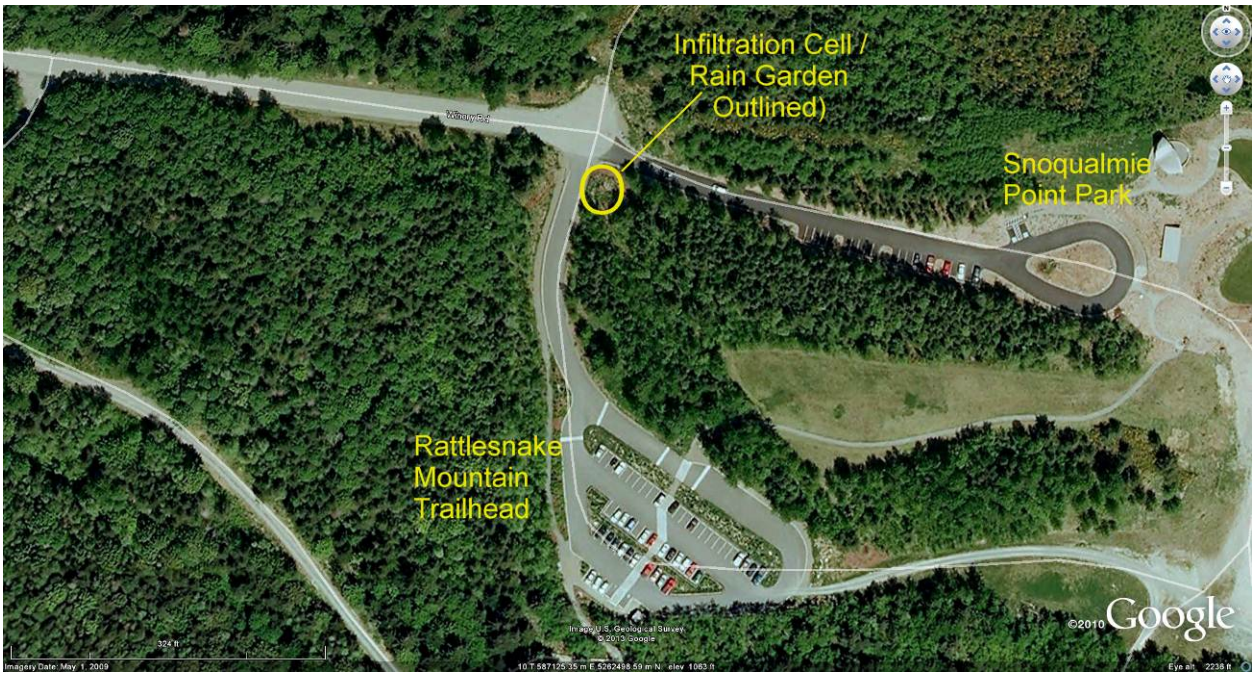


**Figure 3.4 – Rattlesnake Mountain Trailhead Raingarden**

# 4 STORMWATER SYSTEM MAINTENANCE

Stormwater conveyance systems and management facilities must be properly maintained to ensure that they operate correctly and provide the flow control and water quality treatment for which they were designed.

Routine inspections and preventative maintenance, performed on a regular scheduled basis, can help avoid more costly repairs that may be required when facilities are not adequately maintained. Routine maintenance includes activities such as mowing, litter control, street sweeping, and sediment removal from catch basins. It can also include minor repairs to damaged roads, berms, structures, or fencing, or other small-scale maintenance work to address specific operational problems.

The present report is focussed on routine maintenance and minor repairs. It does not address large-scale maintenance and major improvements to eventually replace or rehabilitate major components, or to address unforeseeable major failures of stormwater facilities. Also, the present report does not address the major drainage improvements that are proposed for the historic areas of the city. Major maintenance work is likely to require an engineering design with construction plans to be prepared for review and approval, and may be subject to permits.

## 4.1 GUIDANCE DOCUMENTS

City of Snoqualmie municipal code Chapter 15.18, Surface Water and Storm Water Management, states the intent and priority of applicable stormwater guidance documents as follows:

> *It is the intent of this chapter that all projects meet or exceed the thresholds, definitions, minimum requirements and exceptions/variance criteria of the following documents, all of which are hereby incorporated in this chapter as if set forth at length, in descending order of priority:*
>
> *1. Appendix I of the Western Washington Phase II Municipal Storm Water Permit;*
>
> *2. Appendix I-E, Flow Control Exempt Surface Waters, of the Washington State Department of Ecology Stormwater Management Manual for Western Washington, February 2005;*
>
> *3. The City of Snoqualmie Addendum to the 2009 King County Surface Water Design Manual; and*
>
> *4. The 2009 King County Surface Water Design Manual.*

The code gives highest priority to Appendix I of the Western Washington Phase II Municipal Storm Water Permit, which is available online from the Washington Department of Ecology website. Section 4.6 of the permit includes a specific requirement that stormwater water quality treatment facilities shall be "*Maintained in accordance with the maintenance schedule in Volume V of the Stormwater Management Manual for Western Washington (2005).*" Section 4.9 of the permit requires that "*Permittees must require an operation and maintenance manual that is consistent with the provisions in Volume V of the Stormwater*

*Management Manual for Western Washington (2005) for all proposed stormwater facilities and BMPs.*"

Stormwater maintenance requirements are also presented in the 2009 King County Surface Water Design Manual (KCSWDM). The King County maintenance guidelines are believed to be generally consistent with those in Volume V of the Ecology 2005 Stormwater Management Manual for Western Washington, which has higher regulatory priority but is less comprehensive.

Several of the digital appendices to the present document contain maintenance procedures, prepared by ESM, that incorporate maintenance standards from earlier versions of the KCSWDM. In particular, standards are included in Appendix A which contains the 2003 Snoqualmie Ridge Stormwater Management Facilities Operations and Maintenance Manual, and also Appendix E which contains the Snoqualmie Ridge II North Stormwater Management Facilities Operations & Maintenance Manual. The routine maintenance procedures and standards presented in those documents are believed to be generally consistent with those in the Ecology 2005 Manual. There is one major exception in that detailed site-specific maintenance information is presented in Appendix E for the major infiltration ponds at Snoqualmie Ridge; this detailed information expands upon and supersedes the King County and Ecology general requirements.

Because the city municipal code effectively requires that stormwater operation and maintenance is performed in accordance with maintenance schedules and other maintenance provisions described in Volume V of the Stormwater Management Manual for Western Washington (2005), as well as the 2009 KCSWDM, those manuals are incorporated herein and adopted by reference.

Appendix I contains a complete copy of Volume V of the Ecology 2005 manual, which includes maintenance schedules for stormwater treatment facilities and discussion of other maintenance considerations. Appendix J contains the Maintenance Standards section of the 2009 KCSWDM, titled *Maintenance Requirements for Flow Control, Conveyance, and WQ Facilities*. It includes maintenance requirements for conveyance systems, landscaping, and access roads which are not specifically addressed in the Ecology manual.

## 4.2 ADOPTED 2009 KCSWDM MAINTENANCE REQUIREMENTS

For ease of reference, the 2009 KSSWDM maintenance requirements are attached to the present document in hard copy as well as in digital form in Appendix J. They provide detailed maintenance information for the following typical stormwater control facilities and components:

No. 1 – Detention Ponds
No. 2 – Infiltration Facilities
No. 3 – Detention Tanks and Vaults
No. 4 – Control Structure/Flow Restrictor
No. 5 – Catch Basins and Manholes
No. 6 – Conveyance Pipes and Ditches
No. 7 – Debris Barriers (e.g., Trash Racks)

No. 8 – Energy Dissipaters
No. 9 – Fencing
No. 10 – Gates/Bollards/Access Barriers
No. 11 – Grounds (Landscaping)
No. 12 – Access Roads
No. 13 – Basic Biofiltration Swale (grass)
No. 14 – Wet Biofiltration Swale
No. 15 – Filter Strip
No. 16 – Wetpond
No. 17 – Wetvault
No. 18 – Stormwater Wetland
No. 19 – Sand Filter Pond
No. 20 – Sand Filter Vault
No. 21 – Stormfilter (Cartridge Type)
No. 22 – Baffle Oil/Water Separator
No. 23 – Coalescing Plate Oil/Water Separator
No. 24 – Catch Basin Insert

For each facility component, the KCSWDM requirements describe: (1) the potential defect or problem; (2) conditions when maintenance is needed; and (3) the results expected when maintenance is performed. The Ecology maintenance standards for stormwater treatment facilities use equivalent headings and present similar information.

Neither the King County or Ecology maintenance standards specify the frequency with which maintenance inspections are required. However, many routine activities will be required on at least an annual schedule and some activities such as mowing, removal of trash and debris, and weed control may be required numerous times during the year, depending on local conditions. Appropriate scheduling of routine inspection and minor maintenance activities may help avoid more costly future major repairs.

The Ecology maintenance standards allow that the frequency of maintenance activity may be established and adjusted on the basis of local experience and conditions. Expectations are as stated in Section of 4.6 of Volume V of the Ecology manual, and reproduced below.

> *The facility-specific maintenance standards contained in this section are intended to be conditions for determining if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, exceedence of these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these standards. However, based upon inspection observations, the inspection and maintenance schedules shall be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action.*

## 4.3 FACILITIES AND DESIGNS UNIQUE TO SNOQUALMIE

### 4.3.1 Steep Slopes and Landslide Hazard Areas

Snoqualmie Ridge involved the development of lands adjacent to regulated steep slope and landslide hazard areas, especially in the northern part of the site. There is a possibility that future slope failures could occur which would present a threat to the integrity of stormwater facilities including but not limited to the North High Flow Bypass Line and stormwater ponds in proximity to steep slope areas. Slope failures may occur slowly by gradual weathering or episodically in response to earthquakes or severe weather conditions.

One of the recommendations from the Snoqualmie Ridge II Post-Construction Hydrology and Geomorphology Monitoring program (included as Appendix F) was that some level of geomorphic monitoring of the ravine channels in Landslide Hazard areas north of Snoqualmie Ridge should be continued in perpetuity as a city responsibility. The purpose of the monitoring would be to have early warning of slope stability or channel erosion issues which might benefit from early attention.

For continuity and to build upon prior monitoring results, it would be desirable for Associated Earth Sciences Inc. (AESI) to be involved with the steep slope inspections, either performing the monitoring directly, or working with city staff or consultants during a transition period. The nature of the ongoing monitoring will need to be determined, but at a minimum should include regular periodic inspections every one to five years to document and record channel and landslide conditions. The inspection frequency could be revised on the basis of past observations and/or occurrences of severe weather conditions or earthquake events. Inspections of K-Creek and M-Creek were last made in 2004 and are past due as of 2013.

In addition to hazards associated with natural steep slope areas, several of the Snoqualmie Ridge ponds were graded with high cut and/or fill slopes which were designed to be just below the threshold at which steep slope regulations would apply. It is recommended that city inspectors or maintenance contractors receive periodic training on the sorts of conditions at pond slopes which, if observed, should be reported back to the city to arrange for a geotechnical assessment.

### 4.3.2 Flow Splitters and Manifold Outlets

Stormwater controls at Snoqualmie Ridge use a large number of flow splitter devices which direct flow to multiple destinations. The flow splitters are a form of manifold outlet device which is not normally allowed under the KCSWDM because the ability to ensure that water is discharged at the natural location will depend on the flow splitter performance and also the ability of the conveyance system to consistently deliver water to the splitters with minimal leakage or other losses from upstream ponds or pipes.

Most of the flow splitters installed during the first phase of Snoqualmie Ridge development were in areas that drain to one of the site's two high flow bypass line. The stormwater systems in high flow bypass service areas were designed to provide water quality treatment, but not peak flow control. The purpose of these flow splitters was to limit the creek return

flow to non-erosive rates and to divert the erosive high flow to the bypass pipeline. The splitters are within enclosed structures, receive only "clean" water, and are not expected to require special maintenance.

Most of the flow splitters installed during the second phase of Snoqualmie Ridge development were in areas with multiple wetlands. Here, the flow splitters are below stormwater ponds which provide Level 2 flow control. The splitters are in open manhole structures which are intended to facilitate visual inspection and easy cleaning. These splitters will be prone to blockage by organic debris, particularly during the fall and during windstorm events. Frequent inspection and maintenance will be required to ensure that the weirs are not obstructed by debris and that water is delivered to the intended destination points.

The following list summarizes the flow splitters which are expected to require relatively frequent inspection and maintenance. Most of the splitters are identified by design drawing information. It is planned that these splitters will in the future be identified with a unique identifier in the city GIS database.

Parcel W
- Structure with splitter below Isley2 (ED4A) Stormwater Pond.

Parcel S21
- Structure CB #S21A-03 on sheet PN-03 of Snoqualmie Valley Hospital Overall Grading
- Structure for Pond S21B (not yet designed)

Collector Road C
- Structure CB#P-8 on sheet PN-03
- Structure CB#34 on sheet DT-03

South Collector Road
- Structure #43-Creek5 on sheet 24

P-Plat 19 (also in North Collector Road Plans, sheet 14 of 35)
- Structure CB#31 on sheet DT-02 (weir design makes this less prone to clogging)

School Site in Parcel N7 (not yet developed)
- Structure for Pond N3A (not yet designed)

P-Plat 20
- Structure CB#8-1 on sheet PND-28

P-Plat 24
- Structure Vault#S2C-1 on sheet PN-14
- Structure CB#S4-53 on sheet PN-14
- Structure CB#S3-22 on sheet PN-14
- Structure CB#S4-56 on sheet PN-15
- Structure CB#S4-54 on sheet PN-15
- Structure CB#P-8 on sheet PN-16

P-Plat 25 Div 1
- Structure CB#S20-31 on sheet PN-05

P-Plat 25 Overall Grading

- Structure Vault #S13-08 on sheet PN-08
- Structure CB#S13-05 on sheet PN-08

P-Plat 25, Swenson Avenue
- Structure CB#S14-03 on sheet PN-08

P-Plat 25, Jeanne Hansen Community Park
- Structure CB#S15-11 on sheet C2.2 (draft plans)
- Structure CB#S15-02 on sheet C4.1 (draft plans)

### 4.3.3 Roof Drain Bypass and Dual Conveyance Systems

In both phases of Snoqualmie Ridge, dual conveyance systems were constructed in many areas to convey presumably-clean roof runoff separately from ground runoff for which regulations require water quality treatment.

Most of the roof drain bypass systems were constructed to maintain a water supply to wetlands located within and adjacent to development areas. The simplest of the systems involved lots adjacent to wetlands, in which case each roof is separately drained to an outfall at the wetland. There are also many (between 10 and 20) more complex roof drain collection systems which combine the runoff from numerous roofs and discharge to a single wetland outfall. Generally, but not always, these roof drain conveyance systems are constructed within the road right-of-way, parallel to the main stormwater conveyance system.

In the service area for the Snoqualmie Ridge East (Parkway) high flow bypass line, there is at least one roof drain bypass system which was constructed to bypass the water quality pond and drain via flow splitter to the high flow bypass line.

The roof drain bypasses and dual conveyance systems should not require special routine maintenance. However, it is important to recognize the purpose of these systems and to ensure that future repairs preserve the integrity of the separate systems. Because the connections from the roofs to the bypass conveyance systems occurs on individual private lots, affected homeowners should be informed about these systems and be required to notify the city if they experience roof or lot drainage problems requiring repairs that could potentially disrupt or result in a cross-connection between the two systems.

# 5 COST OF MAINTENANCE

## 5.1 APPROACH

The budget needed to maintain the city stormwater system to meet regulatory objectives can be determined by an analysis of the following five factors:

- types of system components;
- maintenance activities for each component;
- the size (or quantity) of each component type;
- frequency of occurrence of each maintenance activity; and
- the unit cost of each maintenance activity.

These factors yield a total maintenance cost for each unique combination of facility type and maintenance activity. A total operations and maintenance budget is produced by adding up the costs of the component parts.

The focus of this document is on costs of routine maintenance including facility inspections, regularly scheduled mowing and cleaning, and minor repairs for all areas of the city. This report does not address costs of major repairs and improvements proposed for the historic areas of the city as described in the city's 2010 Stormwater Management Plan. Other costs which are not addressed in this report but which should eventually be assigned as stormwater operation costs include: (1) applicable portion of overhead cost to maintain and operate the public works building, (2) applicable portion of burdened salaries of public works staff, and (3) costs of complying with NPDES Phase II permit requirements.

## 5.2 SYSTEM COMPONENTS AND MAINTENANCE ACTIVITIES

For purposes of cost analysis, system components were aggregated into categories that are described below.

### 5.2.1 Catch Basins

The number, location, and type of catch basins within the city, including manhole structures, is identified from information in the city GIS database. Catch basins have a single routine maintenance need which is to be inspected and cleaned. Costs of catch basin maintenance include related costs for disposal of wastes and decanted liquids which result from the cleaning process. Disposal costs can be included in contractor charges for catch basin cleaning, or identified separately if catch basin cleaning is performed by city staff and equipment.

For estimating the appropriate level of maintenance activity and hence cost, catch basins are subdivided into sub-categories listed below. Old town areas are identified separately from the ridge because of likely differences in land use, water quality, and sediment load which are expected to affect the required frequency of cleaning and volume of materials removed. Pollution control CBs and those with oil-water separators are identified separately from

"ordinary" CBs because these may require a higher frequency of service or different equipment.

- Catch basins – standard – old town.
- Catch basins – pollution control – old town. The GIS identifies these as distinct components.
- Catch basins – standard – ridge.
- Catch basins – oil-water separators – ridge. This category will include the Stormtech filter cartridge. GIS information needs to be verified.
- Catch basins – flow splitters. These are the splitters described in Section 4.3.2 which must be properly functioning for water to flow to the designated natural discharge locations and will require relatively frequent inspections.

### 5.2.2 Pipe Conveyance

The location and length of storm drain pipes in the city is identified from information in the GIS database. Two routine maintenance activities are identified for pipes: (1) video inspection; and (2) cleaning when required.

Pipes are subdivided into two general sub-categories by geographic area: (1) old town and (2) ridge or upland areas. Maintenance needs for the historic old town portion of the city are expected to be different from upland areas because of the system age, exposure to periodic Snoqualmie River flooding, and flat grades. In contrast, the storm drain pipe servicing Snoqualmie Ridge and sloping upland areas should be self-scouring as required by current design standards, and should require relatively little maintenance. The Parkway high flow bypass line is included as part of the conventional storm drain system for the upland part of the city.

The North High Flow Bypass Line (HHFBL) is identified as a specific stormwater facility for maintenance purposes because of its location with difficult access in proximity to steep slope and landslide hazard areas. It is recommended that the scheduled maintenance activities for the NHFBL should include/trigger periodic geotechnical inspections of all northern steep slopes and ravines which drain Snoqualmie Ridge, not limited to the NHFBL right-of-way.

### 5.2.3 Ditches and Culverts

The location and length of ditches in the city is identified from information in the GIS database. Ditches have a single routine maintenance need which is to be inspected and cleaned. Inspection and cleaning of road culverts (and debris barriers) along ditches and at watercourse crossings is included in this activity.

For estimating the level of maintenance activity and hence cost, ditches are subdivided into sub-categories based on whether they are rock lined. Rock lining is expected to affect the frequency and level of vegetation control as well as the effort required for litter removal.

### 5.2.4 Stormwater Ponds

For initial maintenance cost estimates, stormwater ponds with all types of flow control are aggregated into a single group. Locations and number of ponds are as described in Section 2 of this report and identified in the city GIS database. The group includes water quality ponds with no flow control function, and both Level 1 and Level 2 flow control ponds. The major infiltration facilities that are constructed below a water quality pre-treatment pond are each counted with the water quality cell as a single facility. Similarly, the treatment train sand filter Swenson_W3 is counted with the associated Swenson_W2 pond as a single facility.

It is recognized that the level of effort to maintain the various facilities will vary due to many factors and that the basis for cost estimation could be improved in the future. However, as of 2012, the pond facilities have been grouped as described above. This can be refined in the future if defensible unit costs become available which would make refinement worthwhile.

Three routine maintenance activities are identified for ponds: (1) outlet control structure inspection and cleaning; (2) vegetation and litter control; and (3) pond bottom sediment removal. An existing program to repair and upgrade pond perimeter fencing and gates is included as a minor repair activity in Section 5.2.8. Current practice is for city staff to provide routine facility inspections. Vegetation and litter control is generally being performed by contractors to the city. The ponds are relatively new and have not yet required cleaning of control structures or sediment removal from pond bottoms.

### 5.2.5 Bioswales and Rain Gardens

For initial maintenance cost estimates, all water quality bioswales and rain gardens are aggregated into a single group. Locations and number of bioswales and rain gardens are as described in Section 2 of this report and identified in the city GIS database.

As with ponds, it is recognized that the level of effort to maintain the various bioswales will vary due to many factors and that the basis for cost estimation could be improved. The initial estimation has been based on a count of the number of bioswales and raingardens. The estimation procedure can be refined in the future by estimating costs on the basis of bioswale (or rain garden) length/extent or other defensible unit costs which might be identified.

Two routine maintenance activities are identified for bioswales: (1) mowing and (2) sediment removal. Mowing (with removal of clippings) is required at least annually but has been neglected at several bioswales not previously known to city public works staff. As of 2012, sediment removal has only been required along the Parkway bioswales where sediment has accumulated in the turf at edge of pavement.

### 5.2.6 Outfalls

The location and number of storm drain outfalls is identified from information in the GIS database. As of 2012, the GIS information had not been updated to easily identify outfalls other than to the Snoqualmie River. However, the remaining minor outfalls from Snoqualmie Ridge (and subsequent developments) to destinations other than the Snoqualmie River are expected to require little or no maintenance. This is for two reasons: (1) the minor

outfalls are to small stable streams or wetlands; and (2) the minor outfalls are from relatively-new storm drain systems which provide both water quality treatment and peak flow control.

The routine maintenance activities required for outfalls are (1) inspection and (2) cleaning. Periodic repairs may be needed in association with cleaning to address river shoreline erosion or sedimentation.

### 5.2.7 Streets

Street sweeping is a cost-effective method to keep sediment out of stormwater system catch basins and water quality facilities where it is more difficult to remove. The location and extent of the city's street network is determined from the city GIS database.

### 5.2.8 Minor Repairs

Minor repairs will be determined through the results of routine inspections, and the specific nature of repairs will vary over time. Initial budget estimates for minor repairs are recommended to assume an annual level of effort consistent with ongoing activities to fix and upgrade fencing and gates at existing stormwater ponds, and a one-time restoration to improve the water quality treatment performance of the Carmichael3 (J4) bioswale.

## 5.3 FREQUENCY OF ACTIVITY

Frequency of maintenance activities is determined by the effort necessary to achieve performance objectives and has a direct effect on the total costs. Inspection and maintenance schedules are to be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action, and are not required to eliminate deficiencies entirely.

Section 4.6 of Volume V of the Stormwater Management Manual for Western Washington provides a summary of Maintenance Standards for Drainage Facilities which does not specify maintenance frequency. However, recommendations for maintenance frequency are presented in other sections of the Volume V document for some types of facilities and in the companion Volume III document. Instances where frequency of maintenance is discussed are cited below. Note that the recommendations use the terms "may" and "should" rather than "shall" or other prescriptive language.

- Volume III Page 3-35 regarding detention ponds states, "*Since decomposing vegetation can release pollutants captured in the wet pond, especially nutrients, it may be necessary to harvest dead vegetation* ***annually*** *prior to the winter wet season*" and "*Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be* ***continually*** *monitored in the basin".*
- Volume III Page 3-55 regarding catch basins states, "*Control structures and catch basins have a history of maintenance-related problems and it is imperative that a good maintenance program be established for their proper functioning. A typical problem is that sediment builds up inside the structure which blocks or restricts flow to the inlet. To prevent this problem these structures should be routinely cleaned out* ***at least twice per year****."*

- Volume III Page 3-96 regarding infiltration facilities states, "*Removal of accumulated debris/sediment in the basin/trench should be conducted* ***every 6 months or as needed*** *to prevent clogging.*"
- Volume V Page 8-18 regarding sand filters states, *"Inspections of sand filters and pretreatment systems should be conducted* ***every 6 months*** *and after storm events as needed during the first year of operation, and* ***annually thereafter*** *if filter performs as designed."*
- Volume V Page 9-19 regarding bioswales states, *"Inspect biofilters at least once* ***every 6 months****, preferably during storm events, and also after storm events of > 0.5 inch rainfall/ 24 hours."*

The above excerpts indicate that facilities which are intended to provide water quality treatment or which may capture sediment and debris should typically be inspected and maintained at least once and preferably twice per year. Other routine maintenance which involves mowing, vegetation control, and litter removal should similarly be performed at least once or twice per year.

Budget and staff resource constraints may limit the frequency of maintenance activity which can initially be achieved following the completion of this document and the start of expansion of the maintenance program. It is anticipated that appropriate levels of service will be defined and refined over time as the city gains experience with the actual performance of its facilities and conveyance system. As a Western Washington Phase II Municipal Stormwater Permit permittee, the frequency of inspection and maintenance will be affected by the requirements of the Municipal Stormwater Permit in effect at any given time.

## 5.4 COST SUMMARY

Total costs are determined by the type, quantity, frequency, and unit cost for each of the required maintenance activities. Activity types, quantities, and frequencies were discussed above.

Initial estimates of unit costs have been derived by city public works staff based on interviews with contractors, discussion with public works staff at other cities, and review of city of Snoqualmie contracts for maintenance work performed by private firms. As of 2012, most of the stormwater system maintenance work in the city of Snoqualmie was being performed by outside contractors. The maintenance program will need to be significantly expanded to meet the expectations of the state and county stormwater management documents that are incorporated in the city municipal code.

Initial values to quantify the frequency of maintenance activities, unit costs, and total costs are presented in a companion spreadsheet which was developed as a concurrent but separate work product. This was done to allow for ease of updating for changes to the city stormwater system inventory, GIS database, activity frequency, and unit costs, all of which will change over time. It also facilitates consideration of budget constraints on stormwater maintenance activity during a transition period while the program is ramped up to meet the requirements of the Western Washington Phase II Municipal Storm Water Permit.

# APPENDIX J

King County 2009 Surface Water Design Manual Appendix A:
Maintenance Requirements for Flow Control, Conveyance, and Water Quality Facilities

(other appendices are provided only in digital format)

**REPORT SLEEVES:**

**FACILITIES LOCATION MAP**

**AND**

**DVD WITH DIGITAL APPENDICES**