Technical Memorandum

To: Ann Soule, Clallam County

From: Peter Schwartzman, Pacific Groundwater Group

Re: Assessment of Baseflow in Small Streams of the Dungeness Watershed

Date: January 14, 2008

The purpose of this analysis is to evaluate groundwater derived baseflows in small streams on the Dungeness Peninsula. The streams are represented in a groundwater flow model that is currently under revision. After identifying reaches of perennial, intermittent and/or ephemeral flow, it is hoped that the extent to which these flow regimes are influenced by irrigation tailwater vs. groundwater discharge can be differentiated. Reaches supported by groundwater discharge in irrigated areas are expected to derive a portion of their groundwater from irrigated activities. However, baseflows derived from tailwater (or stormwater routing) should not be included in the groundwater flow model.

PGG collected available streamflow data from Clallam County Streamkeepers (SK), the Jamestown S'Klallam Tribe (JT), Graysmarsh (GM), Ecology (ECY) and the U.S. Geological Survey (USGS). The available data were compiled into a master database. **Table 1** lists all the streamflow measurement locations represented in the database. As some of the stations are located very close to others, PGG analyzed baseflow by combining nearby stations into "map groups" and assessing flows both at and between group locations. **Table 1** lists the map groups attributed to each measurement location, and **Plate 1** shows the general location of groups.

This document incorporates information regarding the flow regime and irrigation inputs to streams discussed at a meeting of project partners and concerned organizations conducted on September 25, 2007. The meeting was attended by representatives of the Jamestown S'Klallam Tribe (Hansi Hals and Lori DeLorm), Clallam County Conservation District (Joe Holtrop), Irrigation Districts (Gary Smith and Steve Gaither), Clallam County (Ann Soule), and Dungeness River Audubon Center (Welden Clark). Additional conversations with Gary Smith (Sequim Prairie Tri Irrigation Association), Steve Gaither (Highland Irrigation District), Mike Jeldness (Agnew Irrigation District) and Ed Chadd (Streamkeepers) were used to supplement the available information. Pacific Groundwater Group (PGG) worked closely with Ann Soule in refining this memorandum.

Several points should be noted regarding PGG's review of the available data:

1. In most cases, the available data are comprised of sparse sets of miscellaneous measurements. Such data sets are commonly insufficient to define the flow hydrograph, making it difficult to interpret individual points (i.e. whether they occur during a runoff event or as part of baseflow). PGG had no prior knowledge of whether data were collected with any particular bias (e.g. to capture low flows, irrigation influences, or storm event responses).
2. Although miscellaneous flow data may not represent the "typical" stream hydrograph, the lower flow values may provide reasonable definition of stream low flows.

3. The groundwater flow model will first be calibrated to "annual average" conditions. Optimally, baseflow calibration targets would represent annual average baseflows. Review of the Ecology 2003 model suggests that it was largely calibrated to available understanding of low flows. However, the degree to which the seasonal baseflow regime can be defined based on miscellaneous data is questionable in some cases.
4. PGG's analysis took some note of the timing of observed flows (e.g. winter, spring, summer, fall) but did not attempt to analyze this element in great detail. Such detailed analyses are complicated by the sparse data set, and the budget limitations of the task.
5. Given the changes to the irrigation system over the past decade, it is reasonable to expect changes in the baseflow regime of small streams in irrigated areas. As the model is going to be calibrated to the USGS study period (12/95-9/97), PGG's analysis will attempt to make note of conditions during this period. In some cases, data specific to the calibration period are unavailable.
6. PGG's analysis also evaluates the spatial distribution of noted baseflows in order to recommend spatial distributions for model calibration targets. Areas where streams flow over bedrock terrain are considered in this analysis. Surficial geology, including bedrock exposures, is shown on **Plate 2**.

1.0 MORSE CREEK

1.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Morse Creek is the largest of the independent drainages to salt water between the Dungeness and Elwha rivers, entering the Strait of Juan de Fuca approximately two miles east of Port Angeles. The stream extends 16.3 miles from its headwaters in the Olympic National Park and is the easternmost watershed of East WRIA 18. Its moderate watershed (52.7+ mi^2)1 drains steep headwaters, including Hurricane Ridge, Mount Angeles, and Deer Park. Natural falls at RM 4.92 divide the watershed, posing an impassable barrier to anadromous fish (Haring 1999). The major stream crossings occur at RM 2.1 where a bridge spans the stream at 4 Seasons Park, RM 1.2, where Highway 101 spans the creek, at RM 1.0, where an old railroad trestle crosses, and at the 4 Seasons Ranch bridge at RM 0.5.
>
> The watershed's upper boundaries lie at elevations exceeding 6000 feet, well above timberline (Perry 2001). The southern, high-elevation bounding divide is primarily defined by Hurricane Ridge. North-trending tributary valleys extend from this highland divide, typically glacial, stepped valleys with very steep north-facing headwall slopes. These steep north-facing slopes lie in daylong shade most of the year and may not become snow-free until late summer to mid-fall (Perry 2001).
>
> The upper reaches of Morse Creek are steep and confined, flowing through forested and alpine meadow vegetation. The middle reaches below the National Park boundary at RM 9 flow through heavily forested foothills, passing through moderately incised canyons with a number of falls and cascades. Although Morse Creek continues to be confined in a ravine-like canyon through large portions of its lower reach, between RM 3 and RM 1 flat bottomland occurs along the creek. Below approximately RM 1.7, the valley broad-

ens into a relatively wide floodplain. The lowest, coastal subwatershed has a channel gradient ranging from 1% at the mouth to 4% at Four Seasons Park. The gradient increases to 6% at the upstream extent of the subwatershed, at the Mining Creek confluence with Morse Creek, with short stretches of 10 to 12% gradient. The average gradient for the entire length of Morse Creek is greater than 6% (Ecology 1983)."

Plate 1 indicates that Morse Creek is far from mapped irrigation ditches. Its flow regime is therefore not influenced by irrigation. Bedrock is exposed in the middle and upper reaches of the Morse Creek channel, and isolated local exposures are noted in the lower reach (**Plate 2**).

1.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. While four of the stations provided miscellaneous data, continuous gages were operated at RM 0.5 and RM 6.5.

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0.3	SK	13	yes	7/22/1997	10/7/2006
0.5	ECY	2420	yes	8/9/2000	3/28/2007
1.1	SK	3	no	8/17/1999	8/6/2005
1.8	SK	10	yes	10/3/1999	10/16/2004
4	SK	4	No	10/6/1999	10/6/2006
6.5	ECY	1564	Yes	3/1/2003	ongoing
6.5	USGS	3723	Yes	7/30/1966	10/7/1976

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

1.3 FLOW ANALYSIS

The Watershed Plan notes much higher precipitation in the Morse Creek watershed (58 in/yr) than on the Dungeness lowlands. Flow is described as bimodal, accommodating winter storms and spring snowmelt. The lowland has a poorly developed drainage network, and is reported to contribute relatively small amounts of flow to the stream. Low flows in the highland sub-watershed are reported to be in the 25-30 cfs range between September and November, and the lowest flow in August was reported as 41 cfs. The Watershed Plan notes that Ecology calculated annual runoff between the USGS gage at RM 6.4 and the highway 101 bridge (the "lowland" watershed) contributes 11.1 percent of the total discharge measured at the gage. However, the Watershed Plan also notes that Perry states that the stream may be losing water to the valley-fill alluvium in the lowermost ("coastal") portion of the watershed.

Wilson (1988) reported an average flow of 135 cfs at a site within ½ mile of the mouth, based on weekly measurements between mid-June and mid-July 1988.

Figure 1 presents hydrographs from the entire record on Morse Creek. Low flows are typically within the 20-30 cfs range and there is little relative difference between gages. **Figure 2** provides a close-up of the more recent data record. Miscellaneous measurements were rarely taken on the same day; however, comparison of miscellaneous measurements from "near same" days on RM 1.8 and RM 0.3 suggest variability between gaining and losing conditions between these two points. Similarly, **Figure 3**, a comparison of streamflow gain between RM 6.5 and RM 0.5, shows variable gain/loss at most streamflow conditions but consistent gains (presumably from runoff) at higher flows (>600 cfs). The USGS observed a minor loss between two sites on lower Morse Creek during spot measurements on 9/29/97; however, the loss (1.2 cfs) was smaller than the measurement error, and was therefore non-conclusive.

1.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Morse Creek as a drain, with a target gain of 1.6 cfs. The data suggest that Morse Creek should be modeled as a "river" rather than a drain, as it always has flow from a source area upgradient of the model domain and can therefore either gain or lose streamflow freely. Morse Creek flows over bedrock from its headwaters to approximately RM 3.2 (**Plate 2**). River cells should therefore be represented by the model from RM 3.2 to the mouth of the creek.

2.0 BAGLEY CREEK

2.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Bagley Creek is a medium-sized independent drainage to salt water, entering the Strait of Juan de Fuca approximately two miles west of Green Point. It is the westernmost watershed of East WRIA 18. The Bagley Creek drainage has approximately 9.5 miles of streams and tributaries. It was closed to new appropriations in 1948. The predominant land use in the drainage is commercial forest or private woodlots, with pasture/grassland representing 12% and rural residential representing 5% (PSCRBT 1991)."

Plate 1 indicates that Bagley Creek is far from mapped irrigation ditches. Its flow regime is therefore not influenced by irrigation. A small, isolated exposure of bedrock is noted at the headwaters of Bagley Creek (**Plate 2**).

2.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. All of the data were obtained via miscellaneous measurements, and most of the data were collected by Streamkeepers. Few data were collected within the study period of the USGS study by Thomas et al (12/95-9/97).

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0.1	SK	7	yes	7/26/1997	1/12/1999
0.7	SK	23	yes	4/26/2000	10/9/2006
1.2	SK	20	yes	8/26/1997	4/27/2002
1.3	SK	12	yes	7/23/1991	7/26/1992
1.4	ECY	19	yes	4/7/1988	9/19/1991
1.8	SK	16	yes	7/26/1997	4/10/2001
4.6	SK	16	yes	8/25/2001	10/10/2006

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

2.3 FLOW ANALYSIS

The Watershed Plan notes that quarterly flow measurements collected by Streamkeepers for July 1997 – April 1999 indicate a high flow of 36 cfs (1/24/98), a low flow of 1.7 cfs (7/26/97), and a mean flow of 7.4 cfs. Wilson (1988) reported an average flow of 0.78 cfs at Hwy. 101 (~RM 1.3), based on weekly measurements between mid-June and late August 1988.

Figure 4 presents the entire data record from Bagley Creek, and shows that low flows in the lower portion of the creek (≤RM 1.4) noted during miscellaneous measurements generally range from about 0.7 to 1.5 cfs. On an annual basis, miscellaneous measurements of streamflow on this reach typically fall between 1 and 5 cfs. Flows farther upstream (RM 4.6) are typically significantly lower than those lower in the watershed, with observed flows as low as 0.1 cfs.

Available data show gaining conditions between RM 4.6 and the lower watershed gages. Given the relatively low flows at RM 4.6 during the low-flow season, it appears that much of the low flow discharges to Bagley Creek below RM 4.6. Gains between RM 4.6 and the lower watershed derived from days with contemporaneous measurements range from 0.5 to 6 cfs, although higher values may be influenced by stormwater runoff. PGG also compared data from contemporaneous measurements to evaluate gains/losses within the bottom 1.4 miles of the creek. Out of 13 days with simultaneous data, losing conditions were observed on 8 days. Many of the calculated gain/loss values were likely within the error inherent in the measurements. Thus, the actual distribution of streamflow gain below RM 4.6 cannot be well defined based on existing miscellaneous flow data. The USGS measured flow at four locations during a seepage survey in late September 1997. Two locations were near the headwaters, and two were in the lower two river miles of the creek. Gaining conditions were observed between all stations from the headwaters to near the mouth, with a total gain of about 2.7 cfs.

2.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Bagley Creek as a drain, with a target gain of 2.7 cfs. Given the range of low flows in the lower reach (0.7-1.5 cfs), the typical range of seasonal variation (1-5 cfs), and the lack of irrigation influence, this value appears to be an appropriate target, with an acceptable range of uncertainty from about 1 to 3 cfs. The majority of this targeted gain should occur below RM 4.6.

3.0 SIEBERT CREEK

3.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Siebert Creek, 12.4 miles long, drains 19.5 mi^2 of the northwest flank of Blue Mountain and is a significant independent drainage to salt water, entering the Strait of Juan de Fuca at Green Point. The Siebert Creek watershed includes 31.2 miles of mainstem stream and tributaries, much of which is well incised, with its upper watershed reaching an elevation

of 3,800'. It is the westernmost stream influenced directly by Dungeness area irrigation flows and was closed to new appropriations in 1973."

According to Ecology (2004), Siebert Creek receives irrigation tailwater at only one location: near the mouth at approximately RM 0.5. Bedrock is noted locally along reaches of various lengths on Siebert Creek, except in its lower 2 miles (**Plate 2**).

3.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. Continuous stream gaging was performed by the USGS at RM 3.1[1] in the 1950's and 1960's, and was initiated in 2002 by Ecology at RM 1.3. Five other sites have miscellaneous measurements collected by streamkeepers, and Ecology measured flows at seven other sites, three to four times each, during the summer of 2003 (Larson, 2004). Ecology's miscellaneous summer 2003 data were not directly reviewed as part of this report. No data were collected within the study period of the USGS study by Thomas et al (12/95-9/97).

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0	SK	6	yes	7/23/1991	5/20/1992
0.6	SK	33	yes	11/4/1997	4/9/2007
1.3	ECY	1771	yes	8/24/2002	ongoing
3	SK	21	yes	11/4/1997	10/4/2004
3.1	USGS	6331	yes	6/1/1952	9/30/1969
3.8	SK	19	yes	11/5/1997	10/4/2004
W. Fork (~12)	SK	21	yes	9/24/2001	4/9/2007

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

3.3 FLOW ANALYSIS

The Watershed Plan notes that annual flows from 16 years of gaging by the USGS (1952-1969) averaged 17 cfs, with a peak instantaneous flow of 1,620 cfs recorded in November 1955 (DQ Plan 1994). Ecology (2004) compared May-September average flows from this same record of USGS data to unpublished data collected in 2003 at a nearby location (RM 3.6), and found that the earlier USGS May-September average (6.2 cfs) was greater than the 2003 average (3.0 cfs) which occurred in an extremely dry year. Wilson (1988) reported an average flow of 4.44 cfs at Old Olympic Hwy. (RM 1), based on weekly measurements between mid-June and late July 1988.

PGG divided the flow stations into three groups: lower (≤RM 1.3), middle (between RM 3.0 and RM 3.8), and upper (West Fork). Flows in the lower reach are exhibited on **Figure 5**, which shows low flows typically occurring in September and declining flows typically occurring during the irrigation season. Low flows in the lower watershed appear to range from 1 to 3 cfs, whereas seasonal baseflows may range from about 1 to 10 cfs. **Figure 5** also includes flows at RM 3.0 for comparison to the lower reach, and shows similar flows to the downstream gages with a somewhat inconsistent gain/loss relationship between the

[1] Ecology (2004) states that the USGS gage is located at RM 3.4. If this is actually the case, the Streamkeepers gage believed to be at RM 3.0 may be closer to RM 3.3.

two reaches and a bias suggesting gaining conditions[2]. **Figure 6** presents flow data from the middle reach, and shows that low flows during the 1953-1969 data record appear slightly higher than more recent low flows. Group discussion on 9/25/07 indicated that the similarity between recent flow in the middle reach (RM 3.0) and the lower reach, and the similarity of historic flows at RM 3.1 with recent flows at RM 1.3, reflect the fact that the flow regime of Siebert Creek is strongly influenced by flows from upstream. Evaluation of miscellaneous measurements from the west fork show flows typically less than 1 cfs, with low flows on the order of 0.1 cfs. Three miscellaneous summer-2003 measurements on both the east and west forks just above their confluence showed flows ranging from 0.5 to 1.6 cfs, (Larson, 2004). As 2003 was a very dry year, it is possible that perennial flows occur at the confluence and somewhat farther upstream.

The USGS measured flow at two locations within the lower 2 miles of Siebert Creek on 10/7/97, and found 2.3 cfs gain relative to approximately 10 cfs of overall flow.

3.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Siebert Creek as a drain, with a target gain of 3.2 cfs. Given that Siebert Creek appears to contain consistent flow downstream of the confluence of the east and west forks (and potentially further upstream), we recommend that the creek be represented with Modflow river cells (which can either gain or lose water) from the mouth at least up to the confluence. In addition, much of the creek above RM 2.0 shows spotty exposures of bedrock in its channel (**Plate 2**). Despite the spotty presence of bedrock outcrops, the possibility of a hydraulic connection between the stream and adjacent alluvium or shallow glacial sediments still exists. During calibration, we recommend initially representing the creek with river cells from the east-west fork confluence down to the mouth, but also exploring the use of river cells on the entire stream length as a possible alternative interpretation. We recommend using a target baseflow gain of 3 cfs; however, model results between 2 and 5 cfs are considered acceptable.

4.0 MCDONALD CREEK

4.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "McDonald Creek is a significant independent drainage to salt water, entering the Strait of Juan de Fuca between the western end of Dungeness Spit and Green Point. It is 13.6 miles in length, draining ~23.0 mi^2 of the northeast flank of Blue Mountain. With its headwaters originating at ~4,700 feet, McDonald Creek flows through a deeply incised coastal upland and marine bluff to the Strait of Juan de Fuca. Significant erosion and storm damage has been reported associated with winter storms. It was closed to new appropriations in 1946. Primary land uses in McDonald Creek are commercial timber (83%) and private woodlots (9%) (PSCRBT 1991)."

[2] Analysis of 13 days with simultaneous data between the lower and middle reaches shows 4 events with losing conditions (or zero gain) and 9 events with gaining conditions. Most measurements occurred at moderate flow, as opposed to low flow conditions.

Plate 1 shows several irrigation ditches nearby to McDonald Creek. Two siphons transport ditch water from the east to the west side of the creek, at RM 4.7 and approximately RM 3. The Creek has been used since 1927 for irrigation conveyance between RM 4.7 and RM 3.2. McDonald Creek receives tributary inflow from Pederson Creek. It also receives stormwater runoff intercepted by the Agnew Ditch, which intecepts flows from upper Bear and upper Matriotti creeks (Dungeness tributaries) and from Cassidy Creek (a McDonald Creek tributary). Spotty occurrences of bedrock are noted above the confluence with Pederson Creek (**Plate 2**).

4.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. A few miscellaneous flow measurements were taken by Streamkeepers soon after installation of Ecology's gaging station in 2003.

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
3.1	ECY	1581	yes	3/1/2003	ongoing
4.2a	SK	5	yes	5/2/2003	6/5/2003
4.2b	SK	5	yes	5/2/2003	6/5/2003

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

4.3 FLOW ANALYSIS

The Watershed Plan notes: "flows have been recorded in a range from less than 1 cfs in late summer and early fall to 25 cfs in June. Irrigation practices likely affect salmon presence, indirectly, and abundance in McDonald Creek. The section of McDonald Creek from RM 5.0 to 2.0 is used for conveyance of irrigation water by the Agnew Irrigation District[3]. Dungeness River water is conveyed through the Agnew ditch to RM 5.0, where it is dumped into McDonald Creek. This conveyed water is subsequently removed from McDonald Creek at RM 2.0. Although there is no appreciable loss of flow, this practice may cause Dungeness River fish to home into McDonald Creek and reduce the homing ability of native McDonald Creek fish (McHenry et al. 1996)."

The CIDMP (2003) states the following:

"Several miles downstream of the Dungeness River diversion along the Agnew main canal, the District spills water into McDonnell Creek[4] at RM 4.7. The District estimates flow conveyance between 0.5 and 2.5 cfs. The District operates a small diversion dam on the creek at RM 3.2 located just upstream of Hwy 101 that picks up the spilled flow and McDonnell Creek flow. Although information is lacking, the District believes the volume of conveyed water is generally in line with the withdrawal volume. The Agnew Irrigation District is currently installing measurement equipment to assess input and withdrawal of water in McDonnell Creek. The District holds a 5 cfs water right for diversion from McDonnell Creek and a legal right to use natural channels for conveyance of irrigation water. Flow conveyance has occurred in the creek since 1927 and it is considered part of the background conditions."

[3] These RM values are inaccurate. Correct numbers are provided in the paragraphs which follow.
[4] Alternate name used by certain entities.

"The source of irrigation water from the Agnew main canal, includes water from the Dungeness River, but it also includes infiltration water from Bear, Matriotti and Cassidy creeks. Flow conveyance can occur annually from mid-April through mid-September, however, mid-June to mid-September is more typical. During peak spring runoff McDonnell Creek runs upward to 25 cfs. The peak rate of flow conveyance would be on the order of 10 percent of the natural flow rate in the creek. In the summer, McDonnell Creek has a low flow discharge of approximately 1 cfs. During these periods peak flow conveyance in the creek can run 2.5 times the natural flow rate."

Wilson (1988) reported an average flow of 2.23 cfs at Old Olympic Hwy. (~RM 1.25), based on weekly measurements between mid-June and late August 1988

Figure 7 presents a hydrograph from Ecology's gage at RM 3.1. During the measuring period, the lowest flows occurred within the irrigation season with values ranging from about 0.4 to 1.7 cfs. Seasonal baseflow appears to range from these low-flow values to approximately 10 cfs. The USGS measured flows at 3 mainstem locations on 10/7/97: 1 site near the confluence with Pederson Creek, 1 site in the middle of the lowland watershed, and 1 site near the mouth. With almost 10 cfs passing by the uppermost site, about 1.8 cfs was gained between the upper and middle sites, and another 2.3 cfs was gained between the middle site and the mouth.

4.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented McDonald Creek as a drain, with a target gain of 2.3 cfs. This target value may have been derived from the USGS observed gain in the lower reach; however, the USGS noted a total gain of 4.1 cfs in October 1997. Given the USGS observation, and a seasonal range of baseflow from 1 to 10 cfs, we recommend a target value of 4 cfs and an acceptable range between 1 and 7 cfs.

5.0 MATRIOTTI CREEK

5.1 GEOGRAPHY

The Watershed Plan does not provide a specific description of the geography of Matriotti Creek, except that it joins the Dungeness near its mouth and that it receives stormwater and irrigation inflows. Matriotti Creek receives tributary inflow from Beebe Creek (between RM 0.1 and 0.3), Lotzgesell Creek (formerly known as Twin Brooks Creek, near RM 0.4), Mud Creek (near RM 2.0), and Bear Creek (near RM 3.4). Lotzgesell Creek is fed, in part, by irrigation tailwater. Beebe Creek reportedly gains its baseflow from groundwater discharge and is not fed by irrigation tailwater (pers. comm., Hansi Hals). Mud Creek received significant tailwater inflow in its middle reach; however, this was discontinued in 2001. Tailwater from the Cline irrigation system also entered Mud Creek from the northwest around RM 0.1. The Cline irrigation ditch crosses over Matriotti Creek near RM 3.2 (near group 28 on **Plate 1**), and leaked considerably until it was piped in 1998. Upper Matriotti Creek was used for irrigation conveyance prior to 2003-4; however, associated effects on downstream reaches are unknown. WDOT changed the course of Matriotti Creek at Hwy. 101 (approximately RM 5.5) in 1987-88, and construction at the former Costco site (same area) in 1993-94 also involved re-routing, which may have had some effect on streamflow regime. In 2005, when irrigation diversions were reduced to zero or very low levels during late summer to restore Dungeness streamflow for fish passage, Matriotti Creek was dry at Woodcock Rd. (approximately RM 3). The Agnew District tightlined laterals that previously fed into the Creek, especially in the past 2-3 years. After Sept. 15th, the end-date of the irrigation season, much of the middle and upper creek dries up. (pers. comm., Hals and Jeldness, 2007). Bedrock is absent in the Matriotti Creek channel, except near its headwaters (**Plate 2)**.

5.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. No stream gages are established on Matriotti Creek; thus, all of the data are collected through miscellaneous measurements. Few data were collected within the study period of the USGS study by Thomas et al (12/95-9/97).

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0.1	JT	42	yes	11/30/2000	7/19/2007
0.3	JT	5	yes	1/15/2004	7/12/2004
0.3	SK	21	yes	7/23/1991	6/21/1996
0.4	JT	24	yes	2/9/2005	7/19/2007
0.4	SK	3	yes	6/5/2007	6/29/2007
0.7	JT	17	yes	10/27/2004	5/22/2007
0.7	SK	2	yes	6/21/2007	6/29/2007
1.4	ECY	62	yes	7/1/1986	10/22/1991
1.9	JT	2	yes	3/25/2004	5/18/2004
1.9	SK	21	yes	7/23/1991	6/21/1996
2	SK	3	yes	6/5/2007	6/29/2007
3.2	JT	20	yes	4/13/2004	7/19/2007
3.2	SK	4	yes	6/5/2007	6/29/2007
3.4	JT	13	yes	1/9/2006	2/8/2007
3.4	JT	5	yes	3/13/2007	7/19/2007
3.4	SK	1	yes	6/5/2007	6/5/2007
3.5	JT	2	yes	9/12/2006	12/4/2006
3.7	JT	5	yes	8/29/2006	2/8/2007
3.7	JT	4	yes	3/13/2007	7/19/2007
4.6	SK	8	yes	8/20/1991	8/18/1992
4.8	JT	1	yes	5/18/2004	5/18/2004

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

5.3 FLOW ANALYSIS

The Watershed Plan notes that: "Occasional measurements of Matriotti Creek have shown values as high as 20 cfs, but more frequently in the range of 5 to 10 cfs (DQ Plan 1994). Matriotti Creek was listed for low flow on the Surface Water Source Limitation (SWSL) list in 1952. There are two tributaries to Matriotti Creek, between Hooker and Atterberry roads that are currently captured by the Dungeness Irrigation Company. Reconnection of these tributaries to Matriotti Creek would provide small amounts of additional habitat, wetlands, and flow to Matriotti Creek. Stormwater flows and high fine sediment loads are conveyed to Matriotti Creek through irrigation delivery systems. These may be Dungeness River water early in the storm season, and/or they may be stormwater runoff into the main irrigation canals once the outtake from the Dungeness River is shut down (pers. com., Jeldness, 2007). Matriotti Creek would otherwise not normally be significantly affected by stormwater flows (Haring, 1999)."

Wilson (1988) reported an average flow of 17.8 cfs near its confluence with the Dungeness River, based on weekly measurements between mid-June and late August 1988; these would have been highly influenced by irrigation inputs and withdrawals.

PGG grouped the flow data into 3 reaches. The lower reach includes all streamflow measurement sites ≤RM 0.7; the middle reach includes all sites between RM 1.4 and 2.0, and the upper reach includes all sites between RM 3.2 and 4.8. Data from the lower reach presented on **Figure 8** show consistent streamflow gain from RM 0.7 to RM 0.3-0.4 to RM 0.1 for the period of overlapping miscellaneous data ranging from 2004-2007[5]. Total gains appear to be on the order of about 10 cfs, and could be influenced by inflows from Beebe and/or Lotzgesell Creeks.

The data suggest that low flows in the lower reach may have decreased between 1991 and 2007; however, the "spotty" nature of miscellaneous data make it difficult to draw solid conclusions. Group discussion identified possible changes as: lining of nearby irrigation ditches (reduced groundwater recharge) starting in 2000, changes in conveyance and tailwater management starting in 1995, reduction in leakage from the Cline crossing at RM 3.2 in 1998, and possibly the re-routing work done at RM 5.5 between 1987 and 1994. Zero flow values at RM 0.7 suggest that groundwater support of baseflows at this location is intermittent, or that baseflows are supported entirely by irrigation water. A single near-zero flow value at RM 0.1 is also noted.

Lower watershed effects from flood irrigation practices in the mid-1900s included an artificially- raised water table and higher baseflows, which persisted into the 1980s, long after sprinkler irrigation replaced flooding (pers. comm., Holtrop, 2007). Since 2000 the piping of many reaches of irrigation ditch has resulted in continued drop of the water table.

The data from the middle reach, presented on **Figure 9**, are fairly inconclusive. However, PGG's comparison of contemporaneous data from RM 1.9 and RM 0.3 (lower reach) show gains ranging from around 4 to 22 cfs during the miscellaneous measurement events. (Bias of measurement dates was not evaluated in any of our analyses.) No zero flow days were noted in the dataset for the middle reach. However, the occurrence of isolated low-flow measurements that differ from the rest of the data set bring to question whether the available miscellaneous data adequately represent low flows in the middle reach. Data from the upper reach (**Figure 10**) also provide limited information. However, several zero flow days are noted, suggesting that this reach may be intermittent with respect to groundwater supported baseflows.

The USGS measured flow at 3 sites along Matriotti Creek on 10/7/97. No significant gain was noted between two sites located in the upper reaches of the creek; however streamflow increased from 0.1 cfs to 8.1 cfs from the upper reaches to the lowermost station located just above the confluence with the Dungeness River.

5.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Matriotti Creek as a drain, with a target gain of 8.0 cfs. Other streams receiving inflow from groundwater, such as Beebe Creek, were not represented. Given the complexity of the Matriotti Creek catchment, with several sources of irrigation inflow and other tributary inflows, the USGS measurements represent the only existing attempt to assess groundwater inflow. The USGS observed gain of 8.0 cfs appears to be consistent with PGG's observation of 10 cfs gain during

[5] This observation was verified through comparison of simultaneous measurement days.

miscellaneous simultaneous measurements in the lower reach. Due to lack of more specific information regarding irrigation and stormwater inflows, we recommend that the model be calibrated in the steady state to observed baseflow gains of 8 to 10 cfs. During model calibration, addition of drain cells at Beebe and Lotzgazelle should explored.

6.0 MEADOWBROOK CREEK

6.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Meadowbrook Creek is a relatively small low elevation drainage immediately east of the mouth of the Dungeness River that historically drained variably into either the mouth of the Dungeness River or directly to Dungeness Bay. It is fed by steep-gradient groundwater discharge from the north slopes of the Olympic Mountains and drains a watershed of only 0.5 mi^2. The stream is generally low gradient, with limited flushing capability. This tributary, located near the mouth of the Dungeness River, is identified in the 1855 depiction as being an independent tributary to Dungeness Bay (Figure 23, Haring 1999). In recent years, the mouth of Meadowbrook Creek has been either tributary to the lower Dungeness, or opening into Dungeness Bay immediately adjacent to the Dungeness River. In the spring of 1999, shoreline erosion east of the mouth of the Dungeness River broke through a meander in lower Meadowbrook, moving the mouth of the creek approx. 1,400 ft. to the east, and eliminating 15 acres of intertidal estuary from direct connection with Meadowbrook Creek. The mouth now opens directly into Dungeness Bay."

Plate 1 shows an irrigation ditch connecting to Meadowbrook Creek near the intersection of Sequim-Dungeness Way and East Anderson Road (near RM 2). Tailwater inflow occurred at this location prior to 2002, after which the discharge point was moved farther downstream. The Dungeness Irrigation District discharges tailwater from stock water to the stream relatively steadily from the end of the irrigation season (September 15) through February or March, when the ditch is shut down for maintenance prior to the beginning of the irrigation season in April. During the irrigation season, tailwater discharges (for stock *and* irrigation) are more intermittent due to the fact that much of the time all or nearly all of the water in the ditch is being withdrawn for irrigation. A water right on Meadowbrook Creek for habitat enhancement involves a small diversion at RM 0.5 periodically during spring and summer (since the early 1990s), with overflow returning to the creek at about RM 0.4; however, uses of the water suggest relatively low diversions (pers. comm., Jones, 2007).

The creek is located far north of areas of bedrock exposures on the Dungeness Peninsula (**Plate 2**).

6.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. Miscellaneous data from RM 0.3 and RM 1.3 were taken within the study period of the USGS study by Thomas et al (12/95-9/97).

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0.1	SK	17	yes	7/23/1991	6/21/1996
0.3	JT	19	yes	5/18/2004	7/19/2007
1.3	ECY	63	yes	7/1/1986	11/7/1997
2	JT	21	yes	8/23/2005	7/19/2007

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

6.3 FLOW ANALYSIS

The Watershed Plan notes that instream flows in Meadowbrook Creek may be influenced by groundwater return flows from irrigation. This condition is expected for all stream located in irrigated areas. Flows were also affected by (assumedly low) tailwater for stock uses during the non-irrigation season and (intermittent and infrequent) tailwater for irrigation during the irrigation season, first below RM 2.0 (pre-2002), and later farther downstream. Wilson (1988) reported an average flow of 3.85 cfs near a bridge at the Dungeness Grocery Store (est. RM 0.3), based on weekly measurements between mid-June and late August 1988.

A plot of the miscellaneous data from the four gages is presented on **Figure 11**. Prior to 1998, miscellaneous low flow measurements generally range from 2.4 to 3.7 cfs, with fairly similar flows between the RM 0.1-0.3 and the RM 1.3 data sets (limited comparison available). The data may indicate a decrease in miscellaneous low flow values at RM 0.1-0.3 for the post-2003 data (again limited by sparse data), with later flows generally range from 1.5 to 3.5 cfs. The majority of miscellaneous flow measurements occur within a range of 2 to 7 cfs. A comparison of contemporaneous miscellaneous flow data between RM 2 and RM 0.3 shows gaining conditions across this reach for 10 out of 12 days, with gains generally ranging from 0.8 to 4 cfs. The USGS measured flow at 2 locations in the bottom half of the creek on 10/07/97 and noted a 1.37 cfs gain over a 0.65-mile reach.

6.4 MODELING RECOMMENDATIONS

The Ecology 2003 model did not represent Meadowbrook Creek. However, based on winter baseflows on the order of 4 cfs (assuming little influence of stock tailwater) and two measurements of summer baseflow on the order of 1 cfs, we recommend that the creek be represented by drain cells with a target baseflow of between 1 to 4 cfs.

7.0 CASSALERY CREEK

7.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Cassalery Creek is a relatively small independent drainage to salt water on the east side of the Dungeness plateau, entering salt water between Sequim Bay and the Dungeness River. It is approximately 4 miles in length, draining a 3.2 mi^2 watershed of low elevation land on the east side of the lower Dungeness Valley. Cassalery Creek is fed by steepgradient groundwater discharge from the north slopes of the Olympic Mountains. The stream

itself is low gradient, with low velocity flows, flowing primarily through rural agricultural land. The Clallam Conservation District has implemented several habitat improvement/fencing projects, and more are planned."

Although **Plate 1** shows several irrigation ditches in the vicinity of Cassalery Creek, the group discussion indicated that tailwater inflows have been insignificant both currently and during the calibration period (1995-1997). Many ditches occur near the headwaters; however, the soil in that area is very permeable and tailwater is not discharged. Infiltration of irrigation water likely influences flows in the stream. During historic times, flood irrigation was common and perennial flow occurred near the headwaters. However, during the calibration period, perennial flow reportedly began in the area near the word "creek" on the **Plate 1** and continued downstream. In the mid-1990s a major leak (which infiltrated to groundwater) was repaired in a Dungeness Irrigation District siphon located upgradient of the western tributary near Woodcock Rd. (pers. comm., Holtrop, 2007). A tributary enters Cassalery Creek from the west above the upstream gages (near Woodcock Road) and is reportedly not influenced by irrigation. The creek is located far north of areas of bedrock exposure on the Dungeness Peninsula (**Plate 2**).

7.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. Miscellaneous data are available at RM 0 within the study period of the USGS study by Thomas et al (12/95-9/97).

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0	SK	18	yes	7/23/1991	6/21/1996
0	ECY	47	yes	7/1/1986	9/23/1991
0.5	SK	16	yes	9/18/1997	8/24/2002
0.6	SK	5	yes	5/17/2002	8/22/2006
0.6	ECY	21	yes	3/29/1988	6/19/1989
1.1	SK	19	yes	8/1/1997	8/26/2003
1.6	SK	22	yes	8/3/1997	8/22/2006
1.7	SK	15	yes	9/24/1991	6/21/1996

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

7.3 FLOW ANALYSIS

The 2005 Watershed Plan notes that: "Cassalery Creek is predominantly spring-fed, with limited inputs from the irrigation system; flow is fairly uniform throughout the year. Streamkeepers noted increasing use of creek water by landowners for irrigation purposes and for maintenance of ponds, but noted a lack of data on effects to instream flow. North of Jamestown Road, there are several manmade diversions which divert stream flow into the adjacent fields. The creek was listed for low flow in 1985 and residents of the upper watershed reported low or no flow in the creek in the summers of 1999 and 2000." Recent observations indicate continued lack of flow in the upper reaches of the creek.

Wilson (1988) reported an average flow of 3.14 cfs near its mouth, based on weekly measurements between mid-June and late August 1988.

A plot of the available miscellaneous data is presented on **Figure 12**. Near the mouth (≤RM 0.6), 1988-89 streamflow data at RM 0.6 appear to correspond fairly closely to data at RM 0 collected over the same time frame. These data show summer low flows typically ranging from 2 to 4 cfs. In contrast, data collected post-1999 show low flows typically ranging from 1 to 2.5 cfs. This reduction in flow was also noted by Ecology, who compared miscellaneous flow data at RM 0.5 to RM 1.1 for various time periods from 1988 through 2003. Group discussion indicated that the change in flow regime looks like it may have occurred in 1999, about the same timeframe that a restoration project was performed on Cassalery Creek. The majority of miscellaneous data collected near the mouth range between 1 and 7 cfs.

Farther upstream, data are available later in the overall record for RM 1.1 and 1.6-1.7. A few occurrences of near-zero flow are noted at these two measurement areas. However, post-1998 data do not show dramatic differences in flow between these sites.

PGG evaluated gains/losses between sites from contemporaneous miscellaneous data. Miscellaneous measurements from RM 0.5-0.6 and RM 0 overlap during 1988-1989, and show consistent gains ranging from 0 to 1.2 cfs in this reach. Comparing data over a longer distance, from RM 1.6-1.7 to RM 0, shows variably gaining and losing trends from 13 measurements taken between 1991 and 1996. Eight contemporaneous data points from RM 1.1 to RM 0.5-0.6 (1999-2002) suggest variably gaining and losing conditions. Thirteen data points from RM 1.6 to RM 1.1 (1998-2005) show consistently losing conditions. These miscellaneous comparisons suggest that while gains may occur in the lower 0.6 miles of the stream, gaining/losing conditions upstream to RM 1.6 are variable over time and between unique reaches.

The USGS measured flow at two locations on Cassalery Creek on 10/6/97. One station appears to be located near RM 1, and the second is located above RM 3 (**Plate 1**). The measurement showed a gain of 3.55 cfs over this reach.

7.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Cassalery Creek as a drain with a target gain of 3.5 cfs. Given that irrigation has had little influence on the flow regime for well over a decade, and that low flows near the mouth typically ranged from 2 to 4 cfs prior to 1999, it is likely reasonable to set a modeling baseflow target of 3 cfs with an allowable range of 2 to 4 cfs. The geographic distribution of this baseflow is uncertain, as group discussion suggests intermittent conditions in the upper watershed (see Section 7.1), zero flow has been noted at RM 1.6-1.7, yet the USGS observed 3.55 cfs gain in the middle watershed.

8.0 GIERIN CREEK

8.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Gierin Creek is a relatively small independent drainage on the east side of the Dungeness plain, entering salt water between Sequim Bay and the Dungeness River. It is fed by steep-gradient groundwater discharge from the north slopes of the Olympic Mountains. There are 8.3 miles of streams and tributaries in the 3.1 mi^2 Gierin Creek watershed. Primary land uses in the watershed are pasture/grassland (2%) and commercial timber (19%) (PSCRBT 1991).

> Once a saltwater marsh, the mouth of Gierin Creek is artificially maintained as a freshwater marsh today by the presence of a tidal gate. The majority of the lower portion of the Gierin Creek watershed is in single, private ownership and called “Graysmarsh”, which is the approximately 140-acre fresh/brackish water marsh maintained by the tidal gate and associated agricultural uplands. The size of the marsh may be similar to historic, but the tide gate was installed at the mouth of the creek in approximately 1919 for agricultural purposes. In contemporary times, Graysmarsh has been managed exclusively for wildlife and fish habitat. Livestock are not allowed access to the marsh, nor do any agricultural practices occur within the marsh. There is some agriculture on Graysmarsh uplands immediately adjacent to its marshlands.”

Plate 1 shows several irrigation ditches immediately adjacent to Gierin Creek (not designated as piped or open). These ditch locations suggest that baseflows in Gierin Creek may be, or have been, influenced by irrigation activities. Graysmarsh reports that flow at RM 1.57 is predominantly irrigation water (upper gage near map unit 18). No tailwater enters the stream where the ditch joins the stream at RM 1.4 (lower gage near map unit 18). A tailwater ditch near RM 0.8-0.9 (near map unit 17) was built in 2006, and therefore does not influence most of the streamflow data. Tailwater inflow near the mouth of the creek (near map unit 16) is also not substantial. Although some irrigation water does discharge to the stream below RM 1.4; the discharge is reportedly spotty over time and therefore unlikely to significantly impact the stream hydrograph over time. Gierin Creek is located north of areas of bedrock exposure on the Dungeness Peninsula (**Plate 2**).

8.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG’s analysis. Almost all of the data were collected by Graysmarsh. Graysmarsh collects continuous data at the tidegate (RM 0) and weekly data at the other locations. Some of the weekly data occur within the study period of the USGS study by Thomas et al (12/95-9/97).

River_Mile	Data_Source	Graysmarsh ID	CountOfFlow	Include	MinOfDate	MaxOfDate
0	SK	n/a	12	yes	7/23/1991	8/18/1992
0	GM	10	2375	yes	2/1/1998	8/31/2006
0.82	GM	5	242	yes	4/1/1997	3/13/2007
0.94	GM	3	240	yes	4/1/1997	3/13/2007
1.4	GM	2	240	yes	4/1/1997	3/13/2007
1.57	GM	1	228	yes	4/1/1997	3/13/2007

In addition, Wilson (1988) summarized data collected by the Clallam Conservation District in the summer of 1988.

8.3 FLOW ANALYSIS

The Watershed Plan notes that “Flows in Gierin Creek are thought to be heavily influenced by groundwater return flows from irrigation diversions from the Dungeness River. Irrigation conservation in the Dungeness River and reduction in the amount of irrigated acreage have likely resulted in decreased flows in Gierin Creek, particularly during low flow periods.” Most small streams in irrigated areas are expected to be influenced by subsurface irrigation return flows. The Watershed Plan does not specifically mention direct tailwater discharge to Gierin Creek (discussed above). Wilson (1988) reported an average flow of 2.86 cfs at Holland Rd. (est. RM 1.4), based on weekly measurements between mid-June and late August 1988.

Figure 13 presents daily flows at the tide gate. Monthly average flows follow daily flow trends relatively well, and show low monthly averages ranging from around 2-4 cfs and most seasonal variation between 3 and 8 cfs. Daily flow measurements at the tide gate show considerable variability, including some negative flows when saltwater enters the marsh. **Figure 14** presents flows on the lower reach of Gierin Creek (RM 0.82 and RM 0.94), which generally range from about 0.2 to 1.5 cfs. **Figure 15** presents flows on the upper reach (RM 1.4 and 1.57), which generally range from 0 to 1 cfs.

PGG evaluated gains/losses between the Graysmarsh measuring stations, as shown on **Figure 16**. Gains between RM 0.82 and RM 0 (plotted on a separate scale) typically range from around 2 to 8 cfs when the higher "spikes" are discounted. Gains/losses between pairs of nearby stations (RM 0.82-0.94 and 1.4-1.57) are variable, but the longer reach between RM 1.4 and RM 0.94 shows a fairly consistent gain ranging from about 0 to 1 cfs. The USGS measured streamflow on Gierin Creek on 10/7/97 at locations similar to the RM 0.82-0.94 and RM 1.4-1.57 groups and noted a 0.84 cfs gain over this reach.

Aspect Consultants recently supplied Clallam County with analysis of groundwater discharge to both Gierin Creek and Graysmarsh (**Appendix A**) Aspect concluded that average groundwater inflow to Gierin Creek between RM 1.4 and RM 0.8 averaged 0.7 cfs between 1997 and 2007, and that 1997 may best be represented by 0.9 cfs. Aspect also concluded that groundwater inflow to Graysmarsh averaged 6.2 cfs between 1997 and 2007, and that 1997 may be best represented by 7.4 cfs.

8.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Gierin Creek as a drain, with a target gain of 0.8 cfs. While the 0.8 cfs gain may reasonably represent conditions between RM 0.82-0.94 and 1.4-1.57, considerable additional gain occurs to Graysmarsh below RM 0.8. Based on recommendations by Aspect Consulting, we recommend a steady state groundwater inflow target of 0.9 cfs between RM 1.4 and RM 0.8, and of 7.4 cfs for the marsh, to represent the 1995-1997 study period. Aspect's analysis shows the marsh area to be represented by drain cells (**Appendix A**).

9.0 BELL CREEK

9.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Bell Creek is a relatively small independent drainage to salt water on the east side of the Dungeness plain, entering Washington Harbor on the marine shoreline just outside (north) of the mouth of Sequim Bay. It is 3.8 miles long and drains a watershed of over 3100 acres (8.9 mi^2). Bell Creek flows from the uplands of Happy Valley and the north flank of Burnt Hill through the eastern portion of the City of Sequim and into a lagoon at Washington Harbor. During at least one time in its geologic history, it is believed to have been the active channel of the Dungeness River. In more recent times, it probably operated as an ephemeral stream fed by precipitation runoff. Bell Creek has served histori-

cally as a conveyance channel for irrigation water. Much of the creek has been heavily altered by rural and urban development. The lower 2.0 miles of Bell Creek are channelized and the lower 0.25 mile is diked. The creek is thought to be primarily spring fed, with stable flows and a limited floodplain.

A wetland complex at the base of Bell Hill was connected to the creek for efficient irrigation water transfer. An unscreened irrigation diversion is said to take up to half the flow of the creek (Haring 1999)."

The course of Bell Creek has been altered as part of the WDOT mitigation project (Smith, 2007) for the Hwy. 101 By-Pass. Near map group 6 on **Plate 1**, the creek now flows north and northeast, ultimately flowing into the mapped tributary that enters Bell Creek downstream of map group 6. This allows Bell Creek to bypass a portion of the WDOT mitigation site.

Bell Creek is influenced by both irrigation and stormwater runoff. Bedrock exposures occur along the headwaters of Bell Creek (**Plate 2**).

9.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. Data are generally absent within the period of the USGS study by Thomas et al (12/95-9/97), but are available during both preceding and following periods.

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0.1	SK	43	yes	8/18/1986	5/2/2004
0.1	SK	44	yes	4/8/1987	4/24/2002
0.16	JT	33	yes	9/22/2004	6/20/2007
0.2	ECY	39	yes	4/23/1987	10/22/1991
0.8	JT	17	yes	10/27/2004	7/19/2007
0.8	SK	7	yes	1/13/2001	10/17/2003
1.32	JT	1	yes	4/14/2004	4/14/2004
1.4	JT	3	yes	6/21/2006	11/20/2007
1.4	SK	14	yes	4/17/1991	8/17/1992
1.5	SK	1	yes	10/20/2004	10/20/2004
1.7	SK	4	yes	2/13/2002	4/15/2005
1.8	SK	25	yes	1/29/1987	10/21/2004
2.2	JT	21	yes	6/15/2005	7/19/2007
2.3	SK	6	yes	1/10/2002	10/11/2006
2.4	JT	1	yes	3/24/2005	3/24/2005
2.5	JT	3	yes	1/19/2005	2/8/2005
2.7	JT	28	yes	4/14/2004	7/19/2007
2.9	JT	9	yes	1/29/2004	7/6/2005
3.2	JT	4	no	3/13/2007	6/20/2007
3.8	JT	2	yes	11/30/2005	8/29/2006
4.2	JT	22	yes	1/19/2005	7/19/2007

9.3 FLOW ANALYSIS

The Watershed Plan notes that:

> "Flows in Bell Creek are heavily influenced by groundwater return that is, in turn, influenced by recharge from the irrigation network that originates with the Dungeness River. Reduction of irrigation acreage and reduced conveyance loss through leakage have decreased groundwater infiltration to Bell Creek, particularly during low flow periods, with an associated reduction in surface water flows. During low flow periods, instream flow is further compromised by a chronically unscreened irrigation diversion[6] just upstream of Carrie Blake Park, which diverts up to 50% of the water. Stormwater runoff from developed areas is an increasing concern in Bell Creek, with increased incidence of flood events in Sequim in recent years. Effects of stormwater runoff are expected to increase significantly as the basin is further developed. The primary impacts at this time are from runoff from the Bell Hill development."

The City of Sequim began releasing treated Class A water from the City of Sequim wastewater treatment plant to Bell Creek at Carrie Blake Park near RM 1.4 in 2001. The City typically releases 0.1 cfs of water into Bell Creek year round.

PGG grouped the available streamflow data into a lower reach (RM 0 – 0.8), a middle reach (RM 1.3 – 1.8), and an upper reach (RM 2.2 – 4.2). The lower reach includes gauging locations at the WDOT mitigation site and gauging locations near the mouth of Bell Creek. **Figure 17** presents data from the lower reach, and shows low flows at RM 0-0.2 typically ranging from 2-3 cfs prior to 1993, and then reducing to between 0.5 to 1.5 cfs after 2001. The sparse timing of the miscellaneous flow data does not allow identification of a "transition period" between these two low-flow regimes; however, several data points from 1998-2001 appear to be more similar to the earlier period than the latter period. The overall range of flows at RM 0-0.2 typically extends from about 2 to 7 cfs prior to 1993, compared to about 0.2 to 4 cfs after 2001. Ecology analyzed changes in streamflow at RM 0.1-0.2 between 1987-97 and 1999-2004, and also noted reductions in flow (Caldwell,2007). Flows at RM 0.8 appear considerably less than flows at RM 0-0.2, with instances of zero or near-zero flow noted (**Figure 17**).

Discussion with Gary Smith indicates that a portion of baseflow in the lower reach emerges outside the actual creek channel as springs with discharge routed to Bell Creek (pers. comm., Smith, 2007). Mr. Smith notes two off-channel spring sources. On the south side of Bell Creek, there is a set of springs just north of West Sequim Bay and Rhodefer roads which flows into a ditch and is conveyed easterly along the break of the hill. This southern spring complex originates along the ditch located southeast of map group 7 at the 300-degree turn shown on **Plate 1**. Springflow enters the ditch and ultimately discharges into Bell Creek about 1800 feet west of Schmuck Road. The ditch also receives a combination of tailwater and irrigation conveyance from the Highland Irrigation Company (downstream irrigators draw water from Bell Creek). On the north side of Bell Creek, a drainage ditch follows the base of Gierin Hill flowing east, and then turns south to join the Bell Creek in its new channel (mapped as a tributary on Plate 1). The ditch gathers spring discharge along its east-west course, and sometimes also contains conveyance water from Highland Irrigation Company. Both of these spring sources flow year round, with natural (non-irrigation) flows sometimes exceeding 1 cfs (each) during the wet season and less during the dry

[6] This diversion is now screened (Gaither, 2007).

summer months. Gary Smith has observed that flows appear to be diminishing from these spring sources in recent years[7].

The middle reach includes the City of Sequim Demonstration Site at Carrie Blake Park (map group 7) and upstream sites at map group 8. Based on discussion at the group meeting, flow is intermittent at Carrie Blake Park. **Figure 18** presents available miscellaneous flow data from the middle reach. While the data are too sparse to adequately define flow hydrographs for this reach, the common occurrence of zero (or non-zero) flow days shows that Bell Creek is intermittent in the RM 1.3 – 1.8 vicinity. **Figure 19** presents miscellaneous flow data from the upper reach, and shows a similar sparse data set indicative of intermittent flow between RM 2.2 – 4.2.

Discussion with Steve Gaither indicates intermittent flow conditions in the middle and upper reaches, and provides additional details about the timing of seasonal baseflow in Bell Creek (pers. comm., Gaither, 2007). Mr. Gaither notes that extended periods of baseflow have been observed during wet winters between the SR101 bypass and Carrie Blake Park. Whereas wet years have exhibited baseflow over 8 to 9-month periods, dry years may only exhibit flow after storm events (i.e. no extended baseflow). On average, baseflow may occur in this reach for about 5 months out of the year. In the mid 1990's, the estimated magnitude of seasonal baseflow during wet years may have been on the order of at least 1-1.5 cfs during the wet season. During the dry summer months, streamflows were limited to tailwater inflows[8] which typically did not extend more then several hundred feet downstream from the tailwater source before seeping into the streambed. Mr. Gaither observes that baseflows in this reach have declined from the mid 1990's to current conditions.

Mr. Gaither also notes that upstream of SR-101, a trickle of perennial flow is observed at Brownfield Road. Bell Creek occupies a canyon between Happy Valley Road and Brownfield Road, and flow in this canyon is intermittent, with perennial conditions occurring immediately upstream of Brownfield Road, and seasonal baseflow extending as far upstream as Happy Valley Road (near map group 11) during at least 4 months out of the year. Thus, the occurrence of baseflow in this reach expands and contracts upwards from Brownfield Road on a seasonal basis. Available data from map group 11 support that there are small flows at Happy Valley during winter and zero flows at summer.

The USGS measured flow at the headwaters and the mouth of Bell Creek on 10/6/97 and observed a gain of 2.35 cfs.

9.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Bell Creek as a drain, with a target gain of 2.3 cfs. Given that perennial baseflow occurs over most of the lower reach of Bell Creek and intermittent baseflow is noted to occur in both the middle and upper reaches, PGG recommends that Bell Creek be represented by drain cells from the uppermost noted occurrence of intermittent flow (Happy Valley Road) down to its mouth. Drain cells should also be represented at the two spring sources that are tributary to the lower reach. Cumulative baseflow targets for calibration should range from between 2 to 3 cfs between RM 0.8 and the mouth, between 0 to 1.5 cfs between SR-101 and RM 0.8.

[7] Given that flows were on the higher end during the calibration period, a 1 cfs target may be appropriate for model calibration to this period.
[8] Mr. Gaither reports that after the QFC shopping center was constructed (early/mid 1990's), the reach between SR-101 and Carrie Blake Park was no longer used for irrigation conveyance

10.0 JOHNSON CREEK

10.1 GEOGRAPHY

The following description is excerpted from the Watershed Plan:

> "Johnson Creek is the third largest stream within the Sequim Bay watershed (~6.2 mi^2) and the westernmost stream of WRIA 17. Johnson Creek flows in a northeast direction from the foothills of the Olympic Mountains into the west side of Sequim Bay at Pitship Point (near the John Wayne Marina). The east branch originates near the top of Burnt Hill, at an elevation of approximately 2200 ft. The west branch drains an unnamed pond/lake located at an approximate elevation of 400 ft. The total length of Johnson Creek is ~ 7.4 miles. Five river miles are attributed to the mainstem, while two miles consist of tributaries (Parametrix 2000 and WCC 2002). The upper creek flows through a substantial ravine, while the lower two miles are low gradient, rising ~400 feet in two miles (WCC 2002)."

Plate 1 shows an irrigation ditch adjacent to lower Johnson Creek. This is one site where tailwater from the Highland Irrigation District enters the Creek. Bedrock outcrops are fairly abundant in areas surrounding the upper portion of the creek, and an isolated bedrock outcrop near RM 1.7 (map group 22) suggests the presence of shallow bedrock in areas near the lower reach.

10.2 AVAILABLE DATA

The following table summarizes the data collected, the organizations holding the data, the number of measurements, and whether the data were included in PGG's analysis. Miscellaneous data were not collected within the period of the USGS study by Thomas et al (12/95-9/97); however, data are available both before and after this period.

River_Mile	Data_Source	CountOfFlow	Include	MinOfDate	MaxOfDate
0.05	ECY	53	yes	7/1/1986	10/22/1991
0.1	JT	32	yes	10/27/2004	7/19/2007
0.6	SK	17	yes	2/23/1987	2/5/2000
1.4	SK	3	yes	9/1/1997	2/10/1998
1.7	SK	2	yes	8/12/2005	8/21/2006

The Watershed Plan notes that streamflow data were collected prior to 1977 by the USGS and Reid, Middleton & Associates. PGG did not encounter any of these data in our searches of online resources.

10.3 FLOW ANALYSIS

The Watershed Plan notes:

> "Periodic streamflow data has been collected on Johnson Creek from 1952 to 2002. According to the PSCRBT (1988) historic flow measurements were recorded for Johnson Creek by the USGS from July through October 1952 and May through September 1961, and by Reid, Middleton & Associates in 1976 (frequency of data collection was not pro-

vided). The highest flow recorded in 1952 was 5.77 cfs (in July) and the lowest was 0.24 cfs (in August). In 1961, the highest recorded flow was 6.89 (in June) and the lowest was 0.28 cfs (in July). A flow of 8.0 cfs was recorded in August of 1976. The 1994 DQ Plan indicates Ecology took over 100 flow measurements on Johnson Creek mainly from April through October 1968 through 1991.

Limited streamflow data collected by Clallam County is also available for Johnson Creek from 1999 through 2002. As summarized by Foster Wheeler (2002), Streamkeepers recorded a flow range of 1.7 to 6.3 cfs at RM 0.0 (from fall 1999 through spring 2002) and a range from 1.3 to 4.9 cfs at RM 0.6; these numbers are generally consistent with historic ranges.

The USGS (Thomas et al. 1999 as cited in Parametrix 2000) and the Sequim-Dungeness Valley Agricultural Water Users' Association (Jeldness 1996-1998) have reportedly collected periodic data on Johnson Creek beginning in 1996. Some of that data is also summarized in MWG (1999). The DQ Plan (1994) characterized flows in Johnson Creek as generally in the 2 to 5 cfs range, with peaks near 10 cfs and fall low flows of less than 1 cfs. It is the easternmost stream directly influenced by irrigation flows and was closed to new appropriations in 1983. Additionally, Parametrix (2000) indicated that measured flows for Johnson Creek range from less than 0.1 cfs to about 10 cfs and summer flows generally range from 0.1 cfs to 1.5 cfs. However, dates and actual flow records were not provided."

Figure 20 presents all flow data compiled by PGG for Johnson Creek. The data show low flows ranging from several tenths of a cfs to about 1.5 cfs near the mouth at RM 0-0.1. Most of the miscellaneous flow data near the mouth range from 1 to 6 cfs. Sparse flow data from upstream locations (RM 0.6 and RM 1.4-1.7) did not support analysis of flow regimes, but also did not reveal the occurrence of zero-flow days. PGG compared flow data at RM 0.6 and RM 0-0.1 and found 12 contemporaneous data pairs which showed gaining conditions on 11 of 12 days. Gains in the lower 0.6 miles of Johnson Creek ranged from 0.2 to 1.4 cfs, with most of the data collected either outside of the irrigation season or during the beginning or end of the season.

Discussion with Steve Gaither (pers. com., 2007) indicates that tailwater ditches of Highland canal discharge into Johnson Creek. The main Highland canal discharges into Johnson Creek near the gaging station just south of map-group symbol 22 (**Plate 1**). Discharge from the main canal ranges from about 0.5 to 1 cfs during the winter and about 0 to 1.5 cfs during the irrigation season. In addition, during the 1990's up through 2005, a 2" pipe discharged approximately 25 to 30 gpm (0.07 cfs) (year-round) into Johnson Creek near the gaging station directly east of map-group symbol 22. The lowermost tributary entering the creek (**Plate 1**) was fed by three 2-inch pipes which discharged about 100 gpm (0.2 cfs) via gravity flow year-round up through 2005. After 2005, discharge was reduced to a single pipe that supplies stock water and discharges about 25 to 30 gpm (0.07 cfs). All of the remaining irrigation ditches shown on **Plate 1** have been piped.

Based on the information provided by Mr. Gaither, it is worthwhile to note that the sparse data available at the middle gaging site (RM 0.6) shows flows ranging from 1 to 5 cfs (**Figure 20**), of which a maximum of 1.5 cfs is supplied by irrigation ditches (and typically much less in the absence of storm events). The remainder is associated with natural flows, which include a combination of groundwater-fed baseflow and stormwater events. Available data for RM 0.6 may not be sufficient to represent low flows at this location. Downstream near the mouth, a maximum of about 1.75 cfs was supplied by irrigation (prior to 2005) with the remainder attributed to natural flows. Mr. Gaither notes that flows in Johnson Creek are fairly consistent, and he hasn't observed zero flow days anywhere on Johnson Creek.

The USGS did not measure gains/losses in Johnson Creek during their 12/95-9/97 study period.

10.4 MODELING RECOMMENDATIONS

The Ecology 2003 model represented Johnson Creek as a drain, with a target gain of 0.6 cfs.

Johnson Creek occupies a deep ravine in its middle and upper reaches, and zero-flow days are generally not observed. Based on incision of the ravine and perennial flow, much of the creek should be represented as drain cells. Given the magnitude of low flow observed near the mouth (up to 1.5 cfs), the range of irrigation inflow (0 to 1.5 cfs), and the range of total flow (1 to 6 cfs, possibly reflecting storm flow events), it appears reasonable to allow modeled groundwater inflow to Johnson Creek to range from 0.5 to 1.5 cfs. The upper portions of the Johnson Creek watershed are dominated by bedrock, and while it may still be reasonable to represent the creek with drain cells, modeled groundwater inflow to those drain cells should remain relatively low.

11.0 REFERENCES:

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Table 1 - Stream Measurement Locations at Map Groups

Stream	River Mile	Data Source	Flow Measurements	Group	x	y	Location
Bagley	0.7	SK	23	1	1028570	413107	
Bagley	1.2	SK	20	2	1030080	410994	
Bagley	1.3	SK	12	2	1030480	410500	Approximate
Bagley	1.4	ECY	19	2	1030570	409630	Approximate
Bagley	1.8	SK	16	3	1031110	408228	
Bagley	4.6	SK	16	4	1031370	398078	
Bell	0.1	SK	43	5	1097340	403058	
Bell	0.1	SK	44	5	1096950	403085	
Bell	0.2	JT	33	5	1097370	403036	
Bell	0.2	ECY	39	5	1096800	403080	Approximate
Bell	0.8	JT	17	6	1093730	403080	
Bell	0.8	SK	7	6	1093730	403080	
Bell	1.3	JT	1	7	1091230	402370	Approximate
Bell	1.4	JT	3	7	1090930	402463	
Bell	1.4	SK	14	7	1090930	402463	
Bell	1.5	SK	1	7	1090480	402559	
Bell	1.7	SK	4	8	1089160	401804	
Bell	1.8	SK	25	8	1088370	401300	
Bell	2.2	JT	21	9	1086300	400364	
Bell	2.3	SK	6	9	1086380	400441	
Bell	2.4	JT	1	9	1085860	400123	
Bell	2.5	JT	3	10	1085330	399870	Approximate
Bell	2.7	JT	28	10	1085340	399108	
Bell	2.9	JT	9	10	1085020	398150	Approximate
Bell	3.8	JT	2	11	1085260	394080	Approximate
Bell	4.2	JT	22	11	1086410	392682	
Casselary	0.0	ECY	47	12	1087790	421947	Approximate
Casselary	0.0	SK	18	12	1087790	421947	Approximate
Casselary	0.5	SK	16	13	1086860	419625	
Casselary	0.6	ECY	21	13	1086890	419100	Approximate
Casselary	0.6	SK	5	13	1086910	419102	
Casselary	1.1	SK	19	14	1087240	416869	
Casselary	1.6	SK	22	15	1085130	415668	
Casselary	1.7	SK	15	15	1084670	415330	Approximate
Gierin	0.0	GM	2375	16	1096440	414573	
Gierin	0.0	SK	12	16	1096400	414626	Approximate
Gierin	0.8	GM	242	17	1093020	410694	
Gierin	0.9	GM	240	17	1092080	409815	
Gierin	1.4	GM	240	18	1088710	407086	
Gierin	1.6	GM	228	18	1086870	406611	
Hurd	0.0	SK	17	19	1076350	418443	Approximate
Johnson	0.0	SK	73	20	1100630	395182	
Johnson	0.1	ECY	53	20	1100610	395210	Approximate
Johnson	0.1	JT	32	20	1100700	395139	
Johnson	0.6	SK	17	21	1097500	395181	
Johnson	1.4	SK	3	22	1095680	392391	
Johnson	1.7	SK	2	22	1095040	391064	
Matriotti	0.1	JT	42	23	1076780	422904	
Matriotti	0.3	JT	5	24	1075730	422974	Approximate

Table 1 - Stream Measurement Locations at Map Groups

Stream	River Mile	Data Source	Flow Measurements	Group	x	y	Location
Matriotti	0.3	SK	21	24	1075730	422974	Approximate
Matriotti	0.4	JT	24	24	1075560	422661	
Matriotti	0.4	SK	3	24	1075230	422936	Approximate
Matriotti	0.7	JT	17	25	1073810	422664	
Matriotti	0.7	SK	2	25	1073810	422673	Approximate
Matriotti	1.4	ECY	62	26	1071170	421031	Approximate
Matriotti	1.9	JT	2	27	1070900	420014	Approximate
Matriotti	1.9	SK	21	27	1070900	420014	Approximate
Matriotti	2.0	SK	3	27	1070930	419468	Approximate
Matriotti	3.2	JT	20	28	1069070	413199	
Matriotti	3.2	SK	4	28	1069070	413199	Approximate
Matriotti	3.4	JT	13	29	1067440	411908	
Matriotti	3.4	JT	5	29	1067440	411908	
Matriotti	3.4	SK	1	29	1067440	411937	Approximate
Matriotti	3.5	JT	2	29	1067140	412017	Approximate
Matriotti	3.7	JT	5	29	1067020	411952	
Matriotti	3.7	JT	4	29	1067020	411952	
Matriotti	4.6	SK	8	30	1067170	406573	Approximate
Matriotti	4.8	JT	1	30	1067550	405234	Approximate
McDonald	3.1	ECY	1581	31	1053160	406535	Approximate
McDonald	4.2	SK	5	31	1052690	401797	
McDonald	4.2	SK	5	31	1052920	401857	
Meadowbrook	0.1	SK	17	32	1081790	428183	Approximate
Meadowbrook	0.3	JT	19	32	1081760	428167	Approximate
Meadowbrook	1.3	ECY	63	33	1080910	425746	Approximate
Meadowbrook	2.0	JT	21	33	1081570	424119	Approximate
Morse	0.3	SK	13	34	1025270	417086	
Morse	0.5	ECY	2420	34	1025200	415220	Approximate
Morse	1.8	SK	10	35	1023900	409788	
Morse	6.5	ECY	1564	36	1024720	388646	Approximate
Morse	6.5	USGS	3723	36	1024740	388653	
Siebert	0.0	SK	6	37	1040580	418240	Approximate
Siebert	0.6	SK	33	38	1042110	414966	
Siebert	1.3	ECY	1771	38	1042990	413150	Approximate
Siebert	3.0	SK	21	39	1041810	405261	
Siebert	3.1	USGS	6331	39	1041900	404624	
Siebert	3.8	SK	19	40	1041660	400639	
Siebert	12.0	SK	21	41	1035830	373034	

Note: Data do not include USGS seepage study measurements published in Thomas et al., 1999.

Figure 1: Morse Creek Record

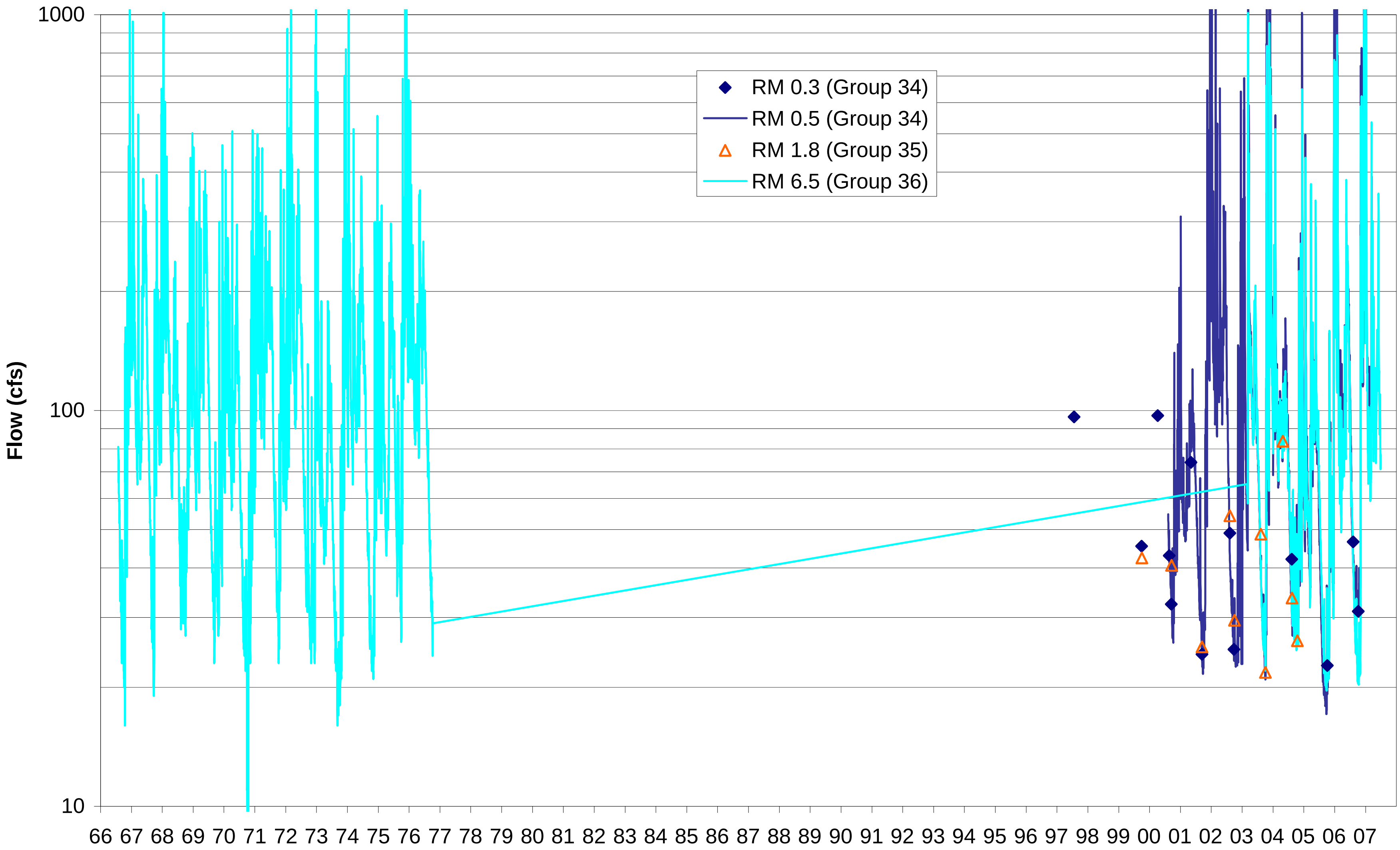


Figure 2: Morse Creek 1997-2008

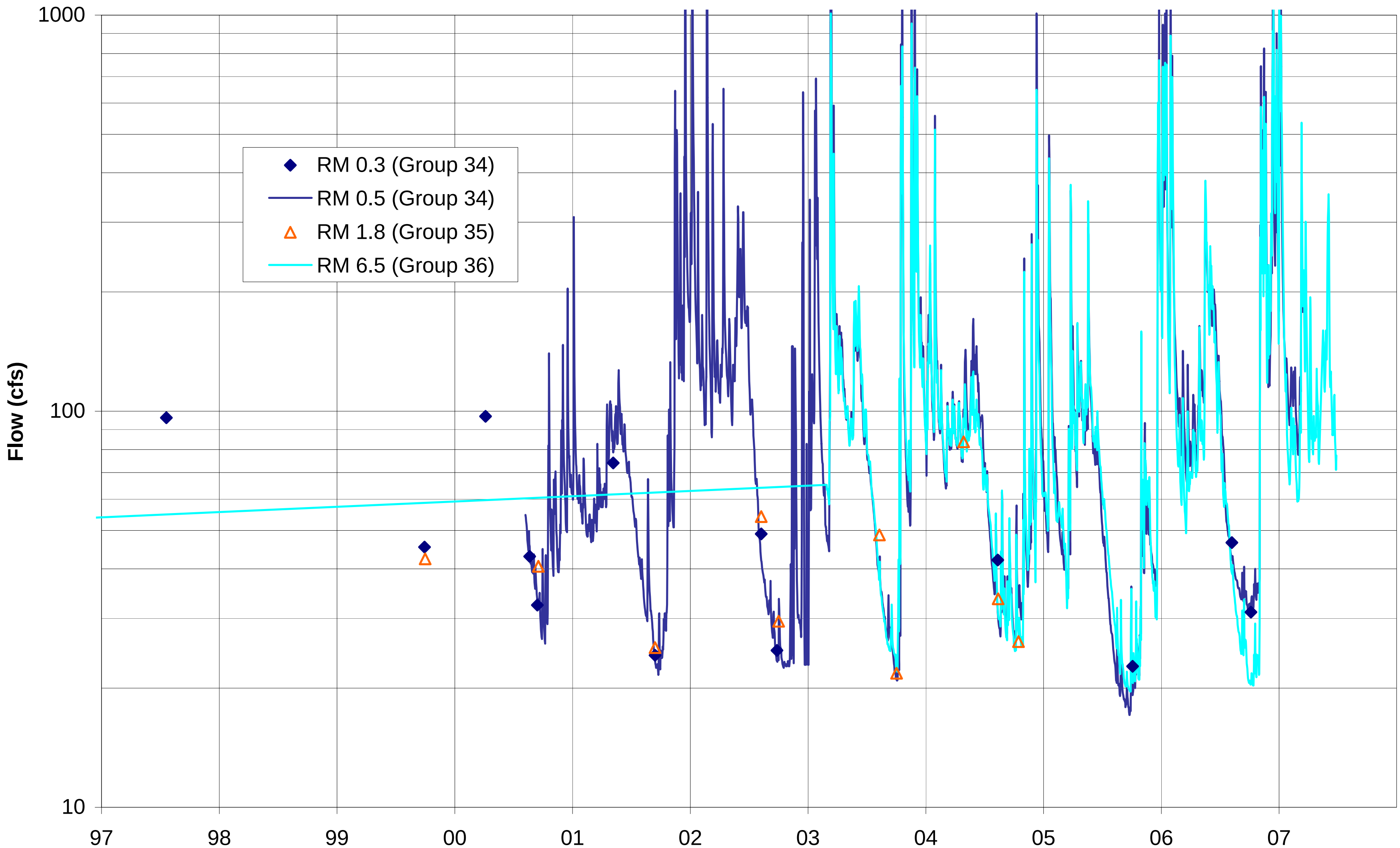


Figure 3: Morse Creek Streamflow Gain Between RM 6.5 and RM 0.5

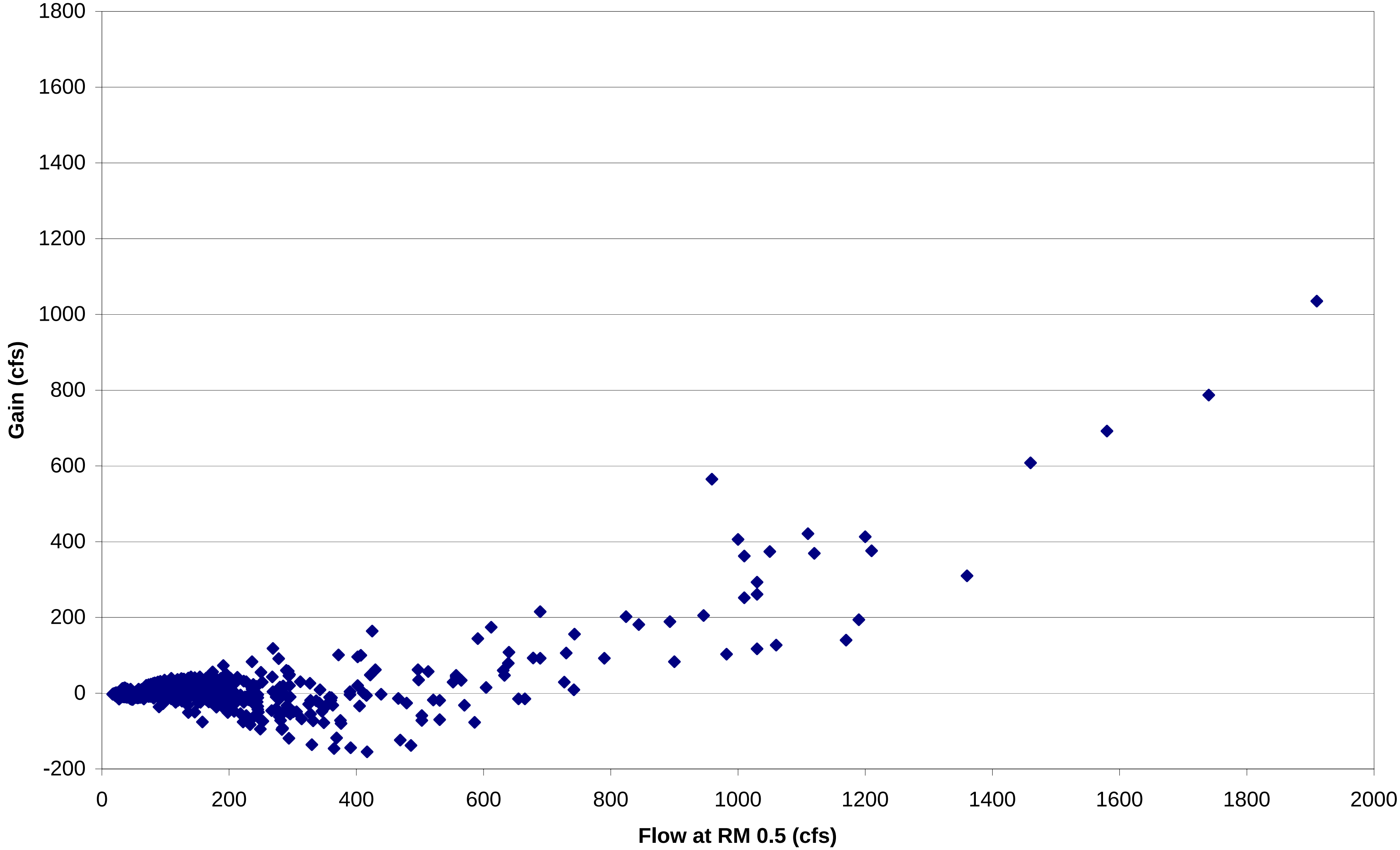
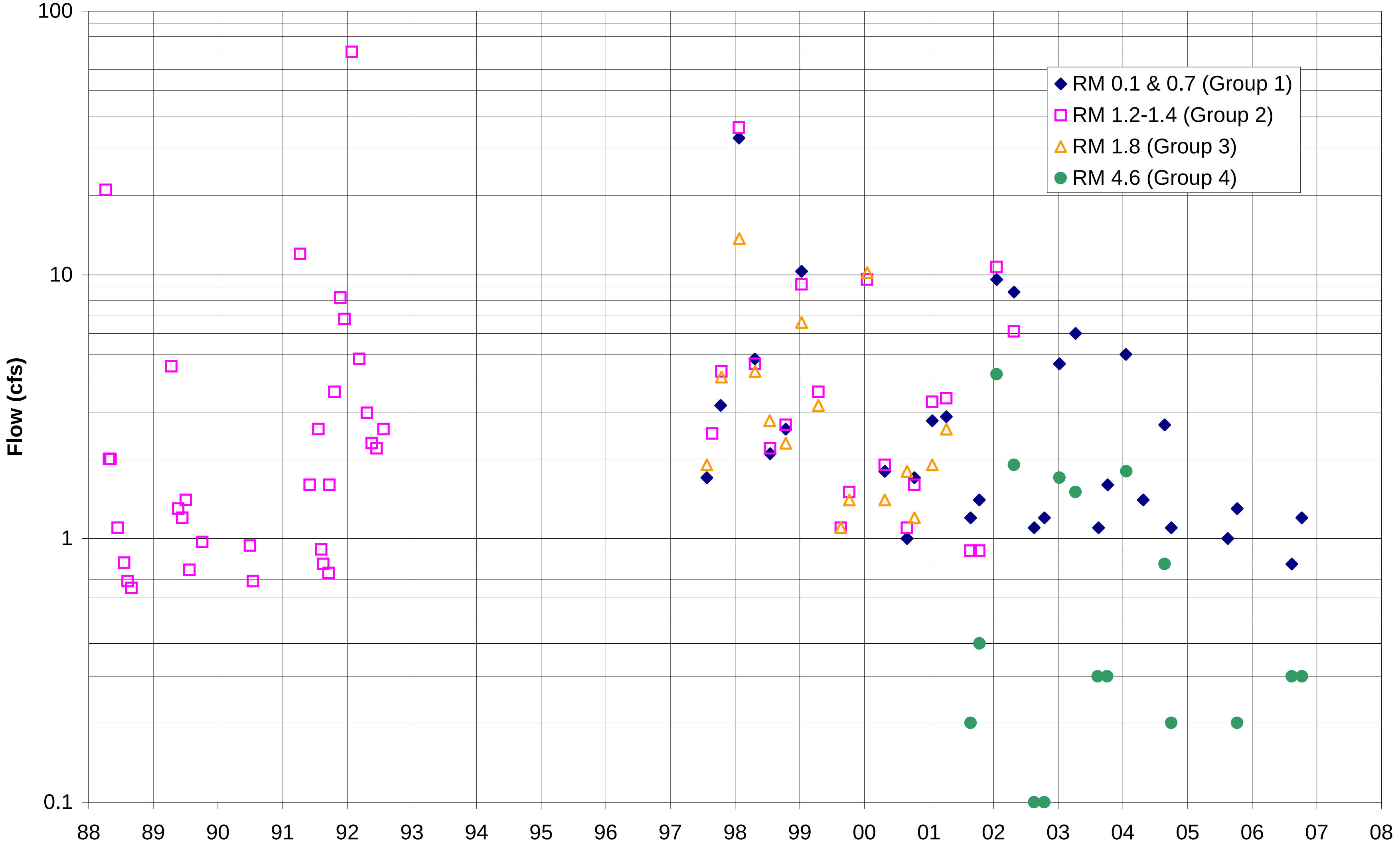


Figure 4: Bagley Creek Record



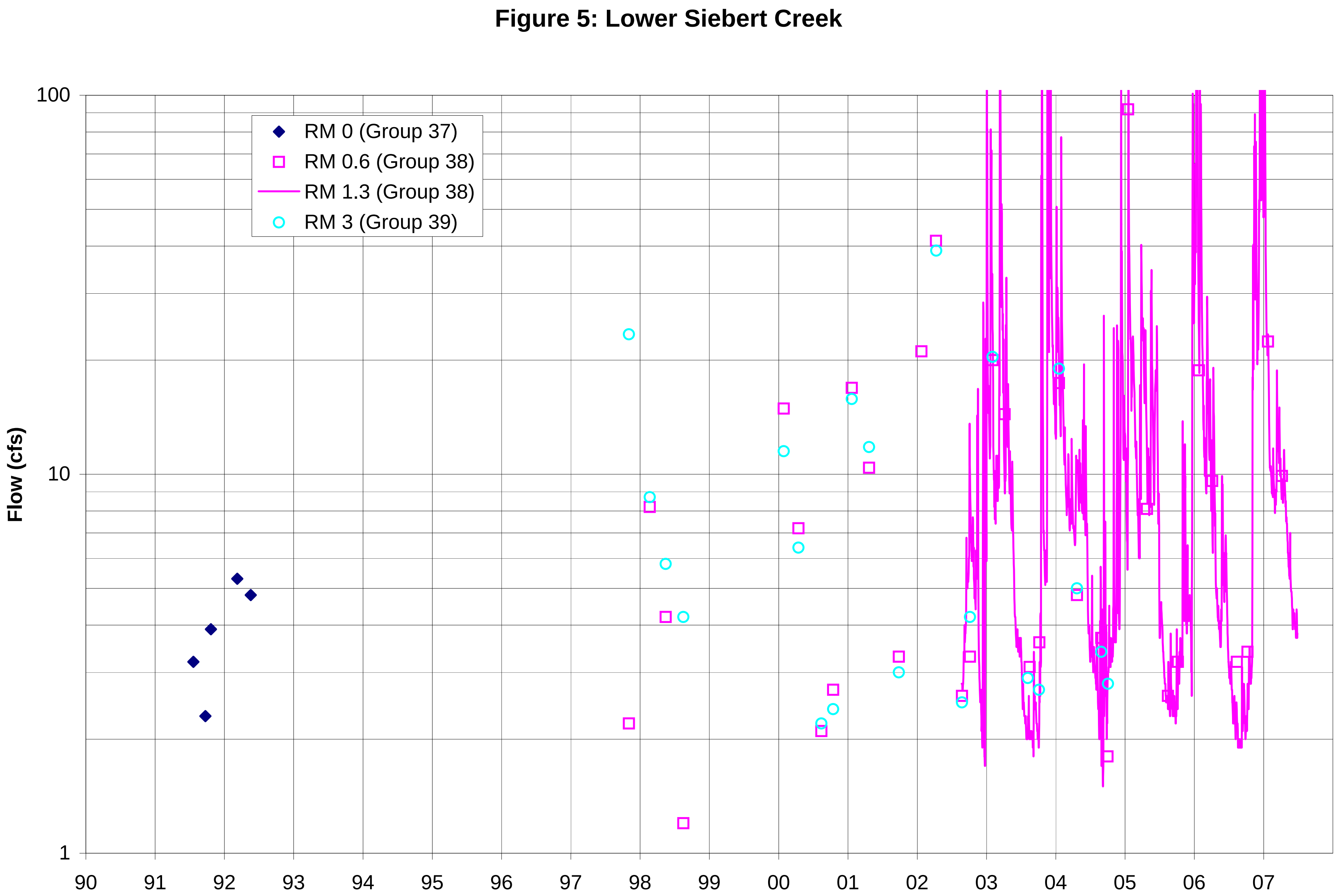


Figure 5: Lower Siebert Creek
Flow (cfs)
100
10
1
RM 0 (Group 37)
RM 0.6 (Group 38)
RM 1.3 (Group 38)
RM 3 (Group 39)
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07

Figure 6: Middle Siebert Creek

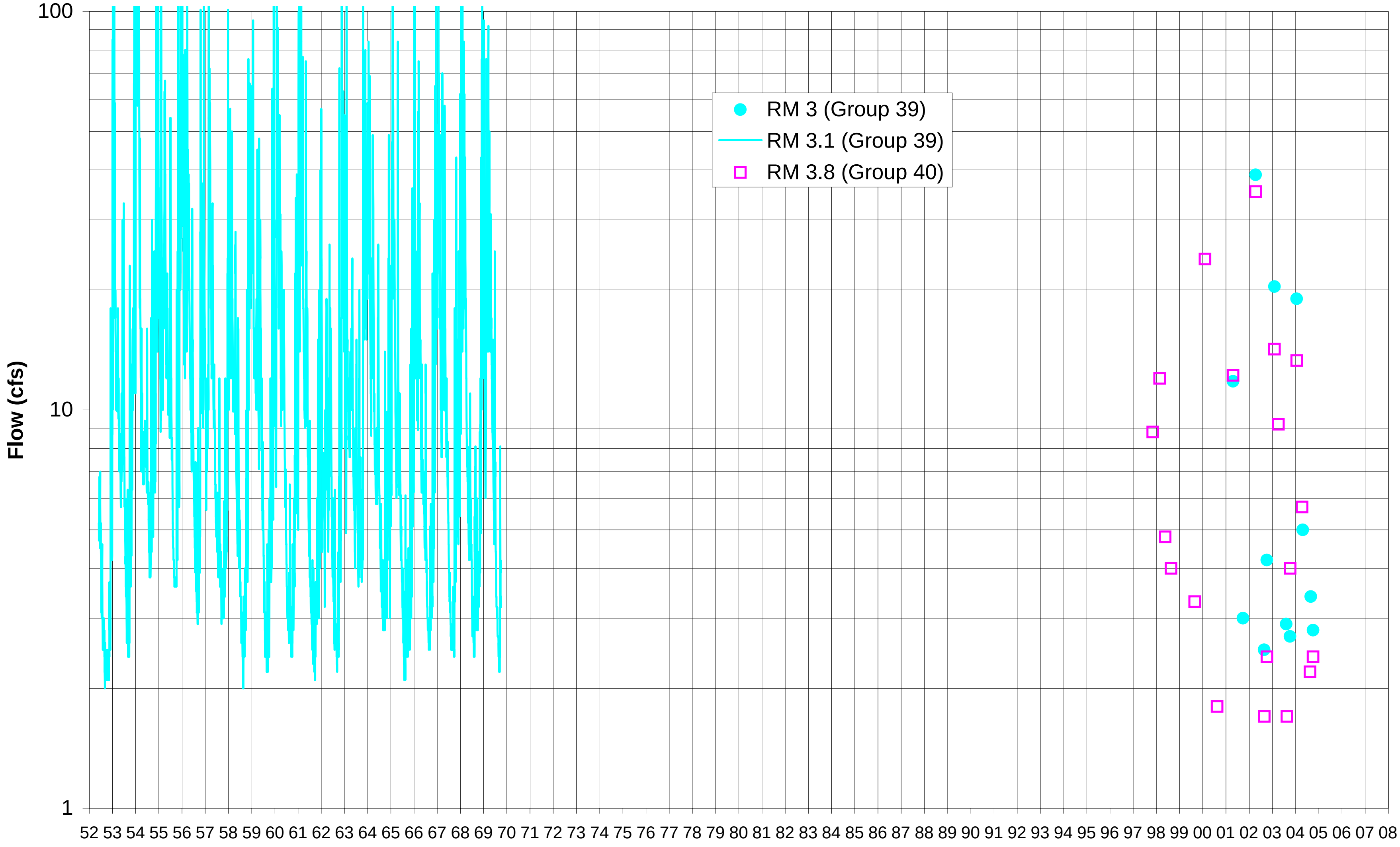


Figure 7: McDonald Creek at RM 3.1

Figure 8: Lower Matriotti Creek

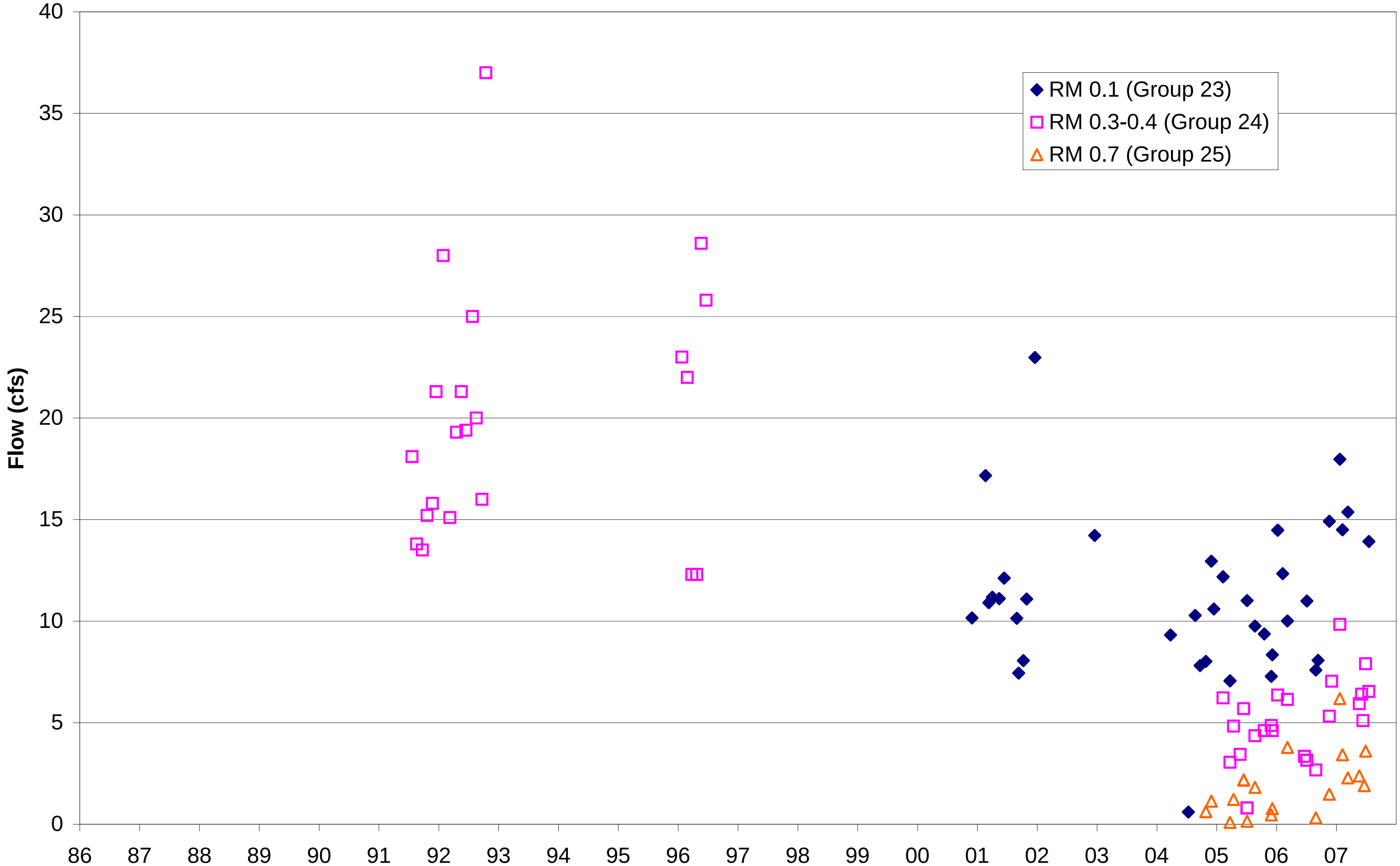


Figure 9: Middle Matriotti Creek

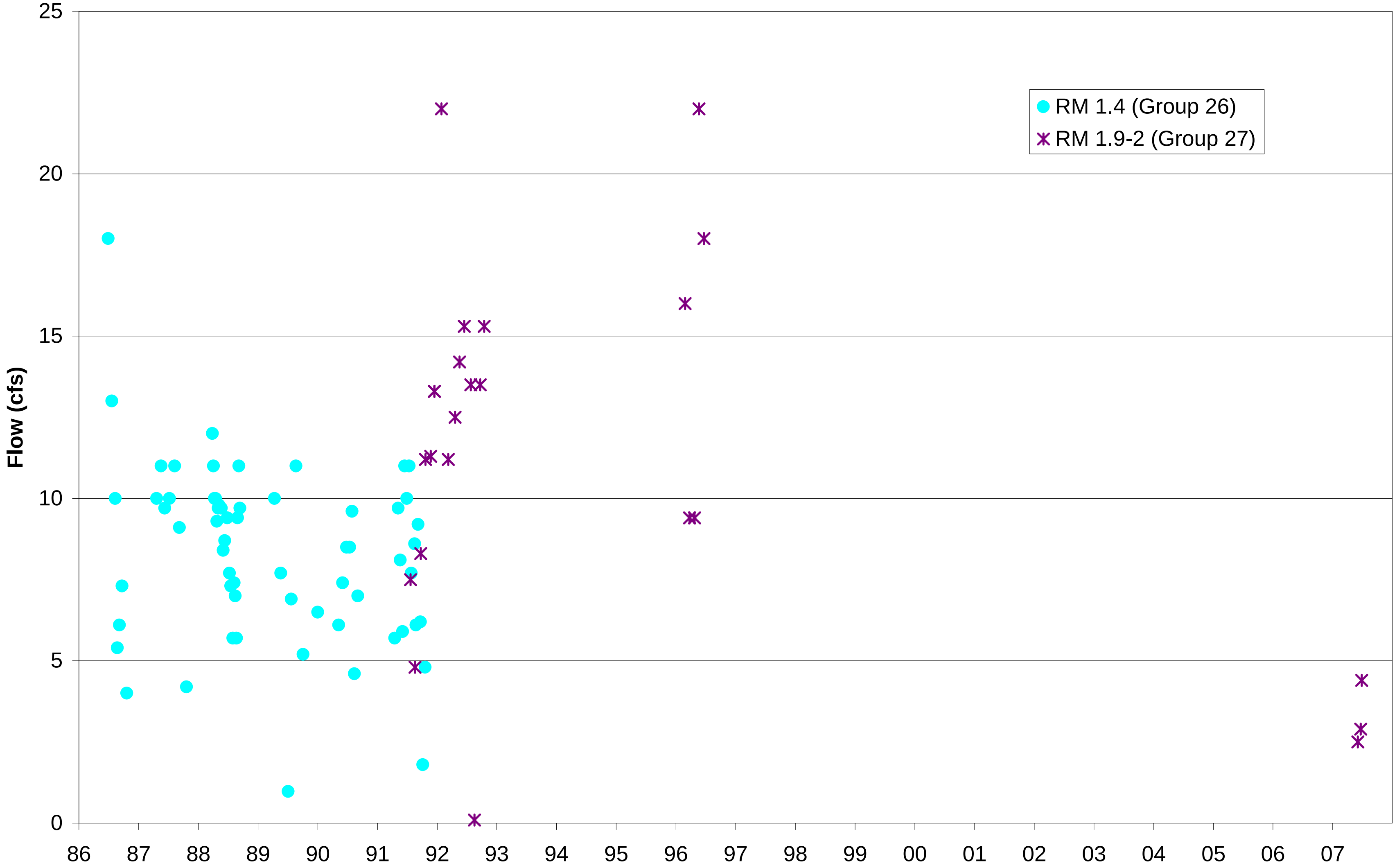
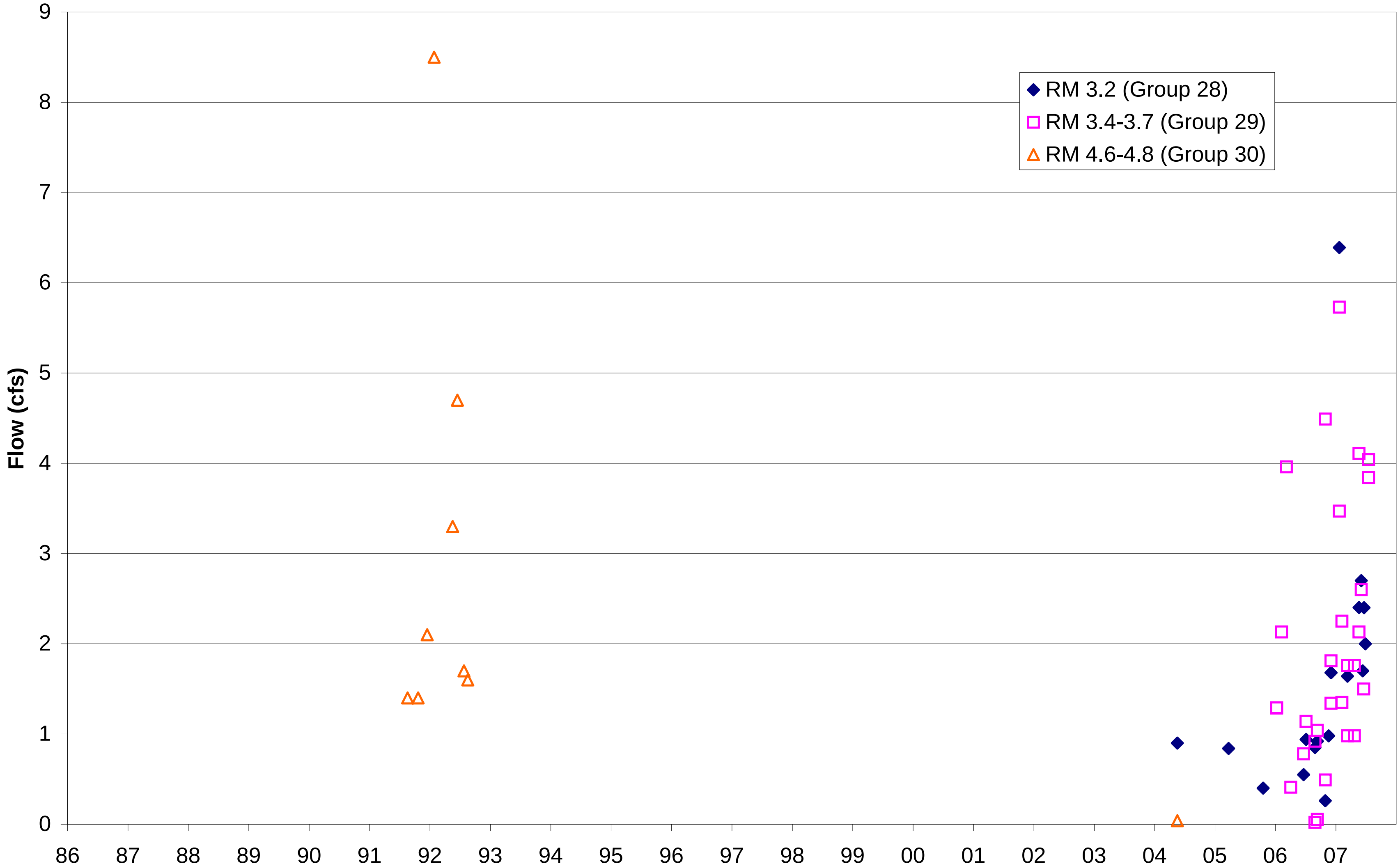


Figure 10: Upper Matriotti Creek



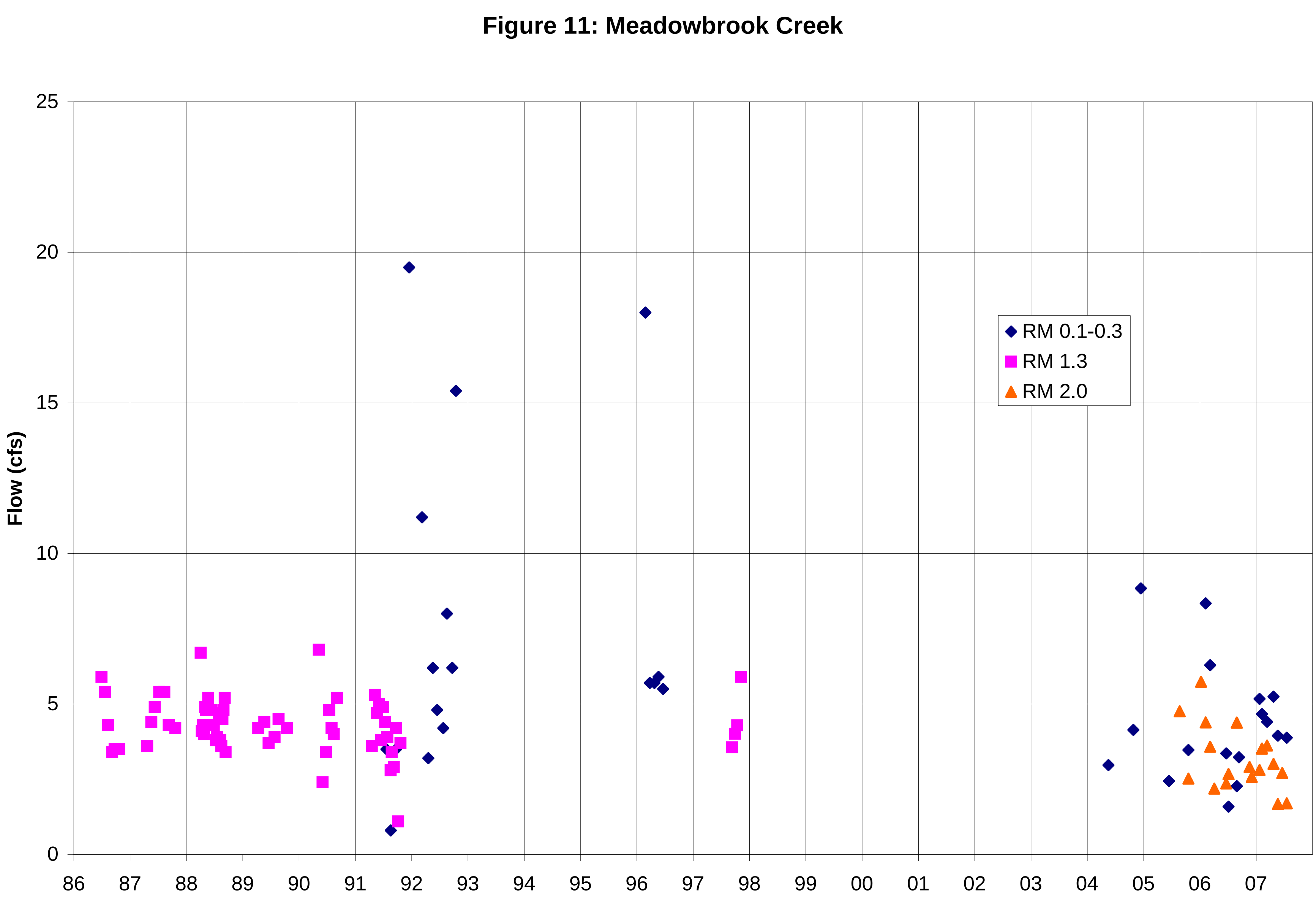


Figure 11: Meadowbrook Creek
Flow (cfs)
25
20
15
10
5
0
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
RM 0.1-0.3
RM 1.3
RM 2.0

Figure 12: Cassalery Creek

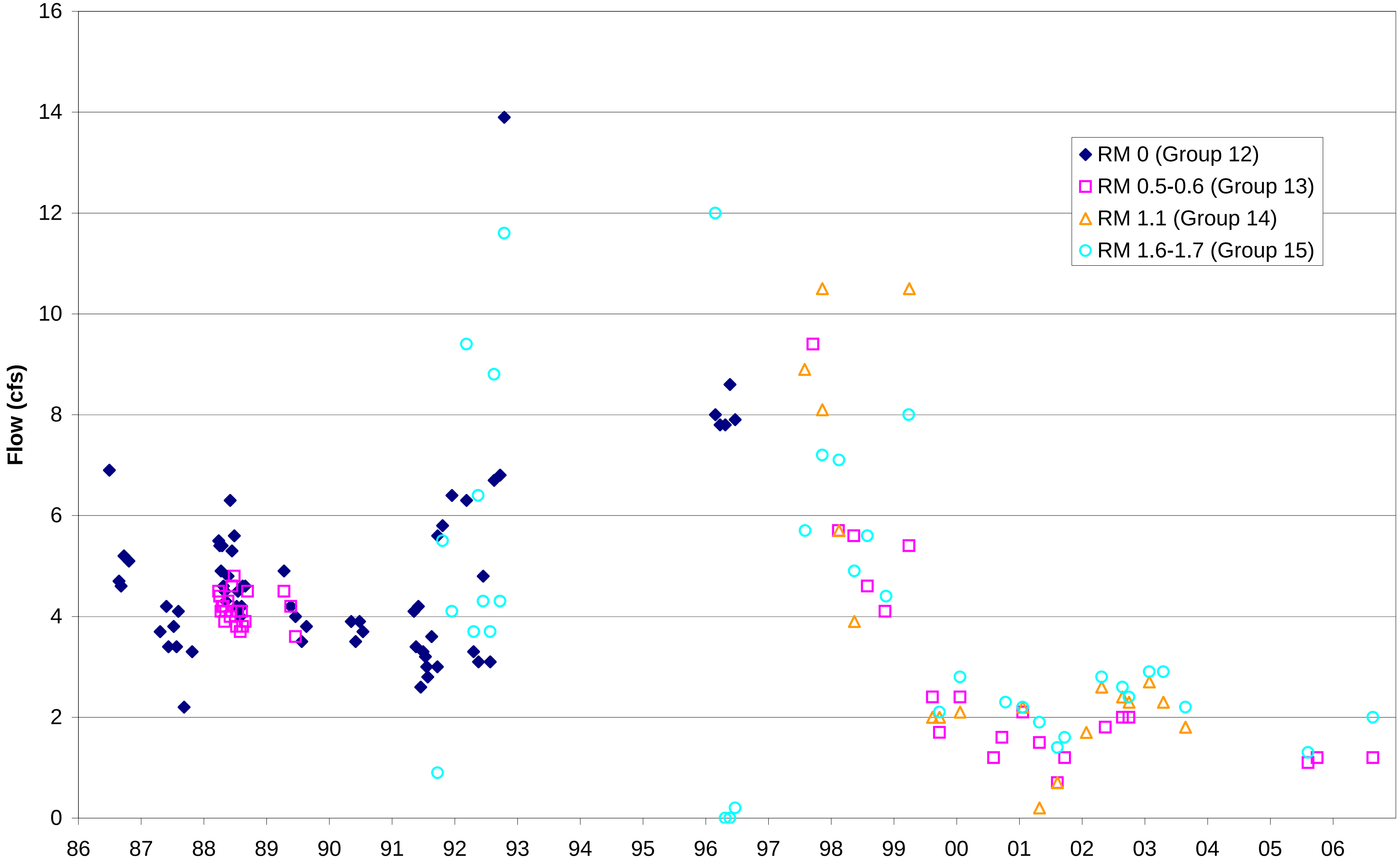


Figure 13: Flows at the Gierin Creek Tidegate

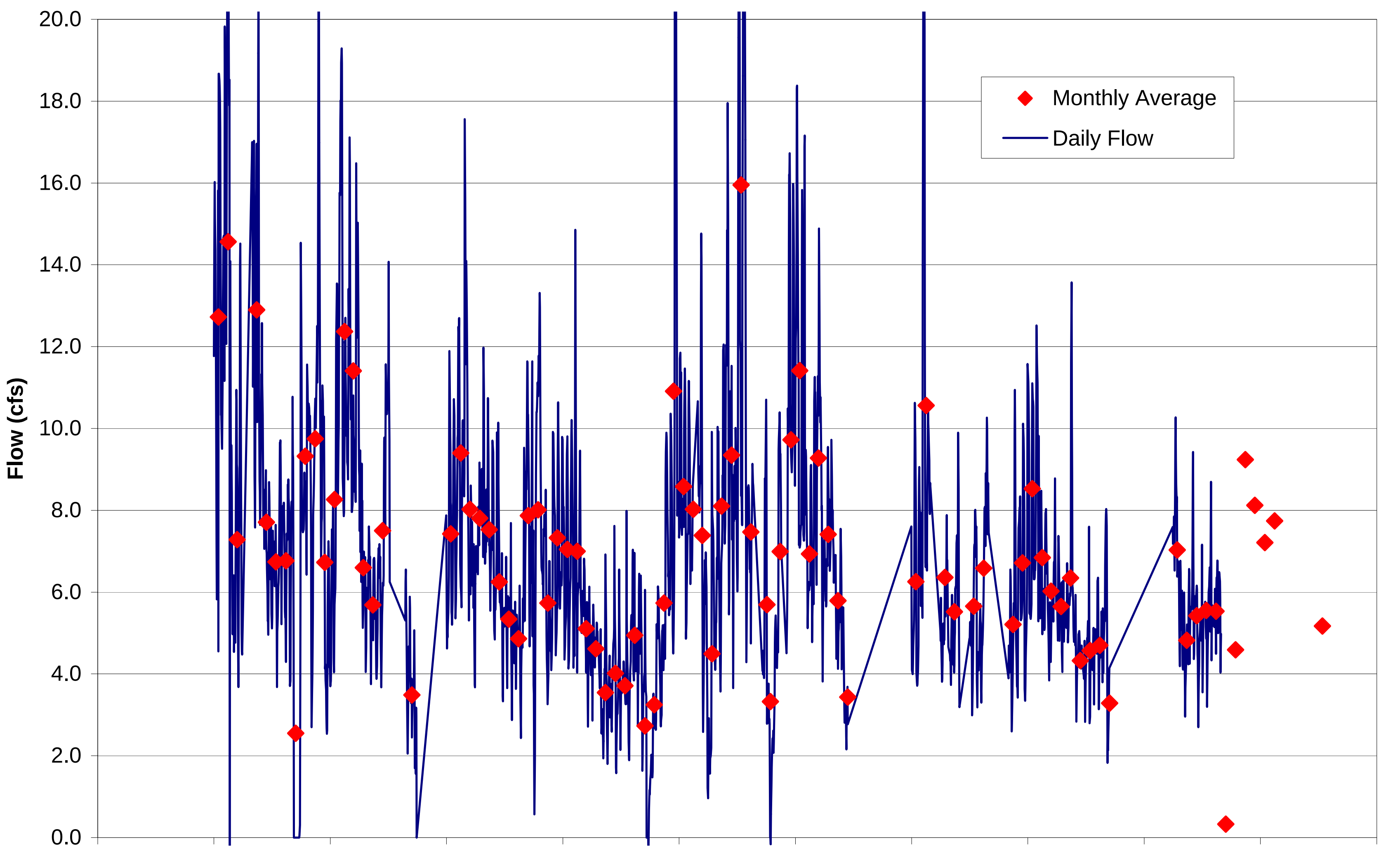


Figure 14: Flows on Lower Gierin Creek

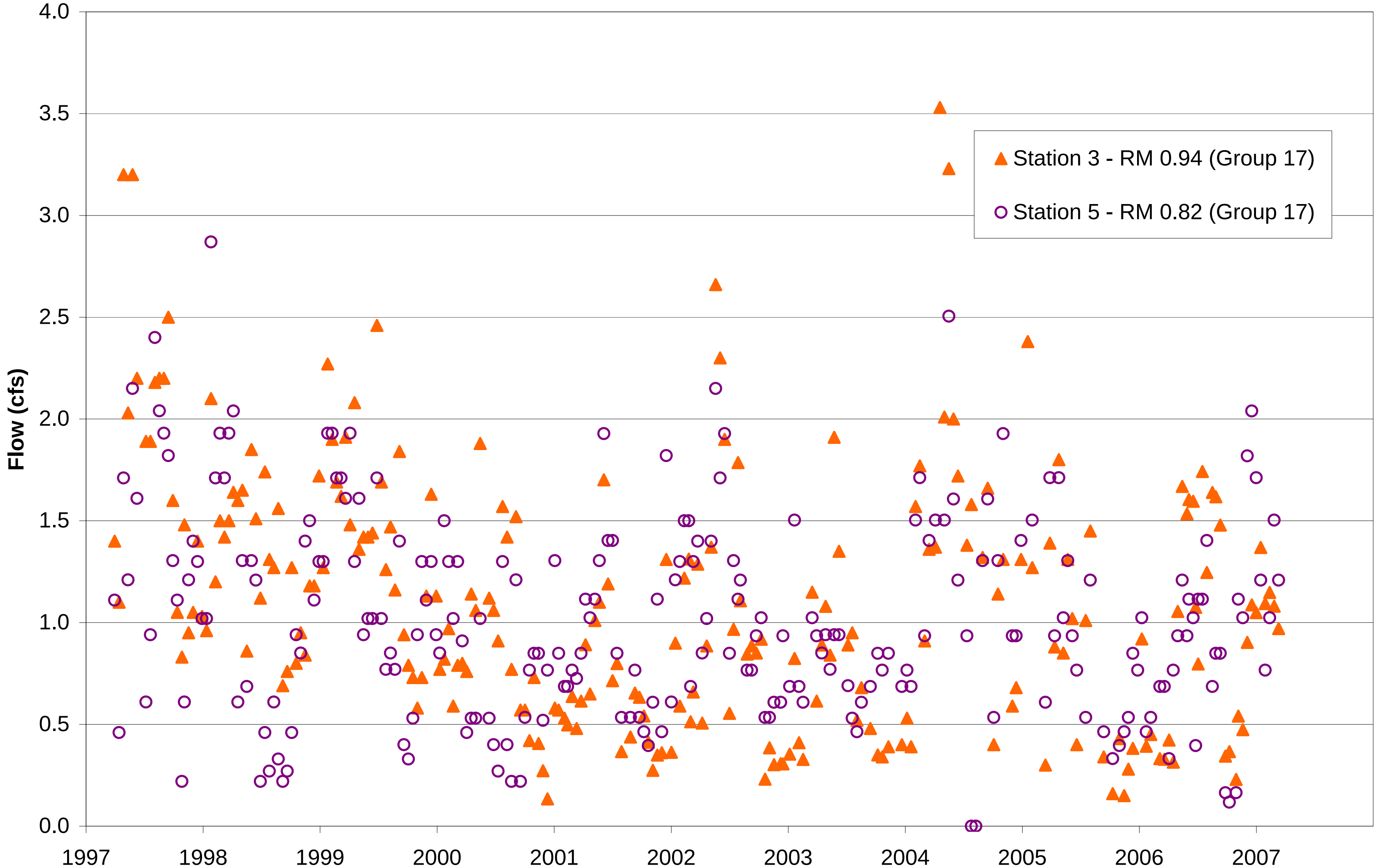


Figure 15: Flows on Upper Gierin Creek

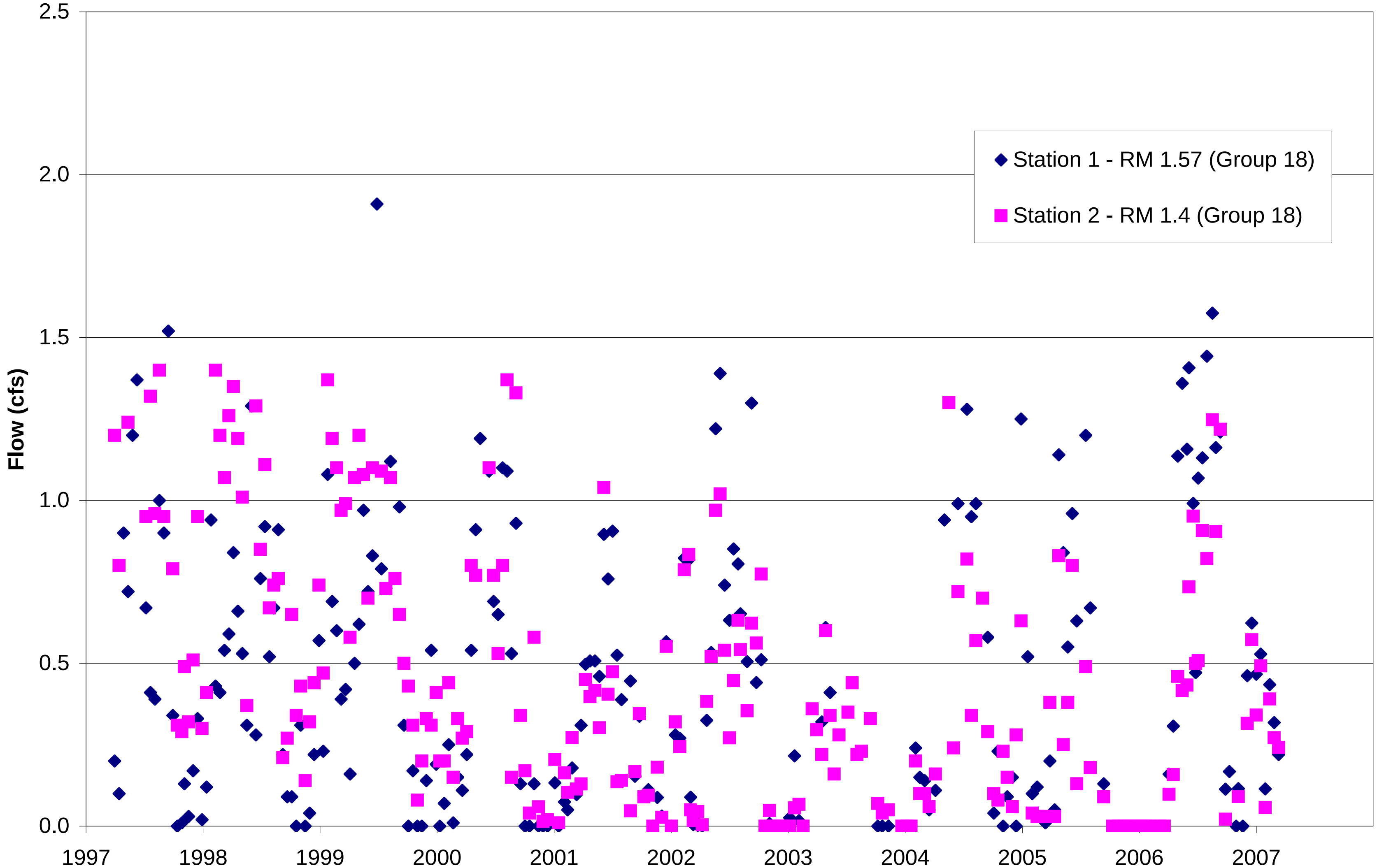


Figure 16: Gierin Creek Gain Between Stations

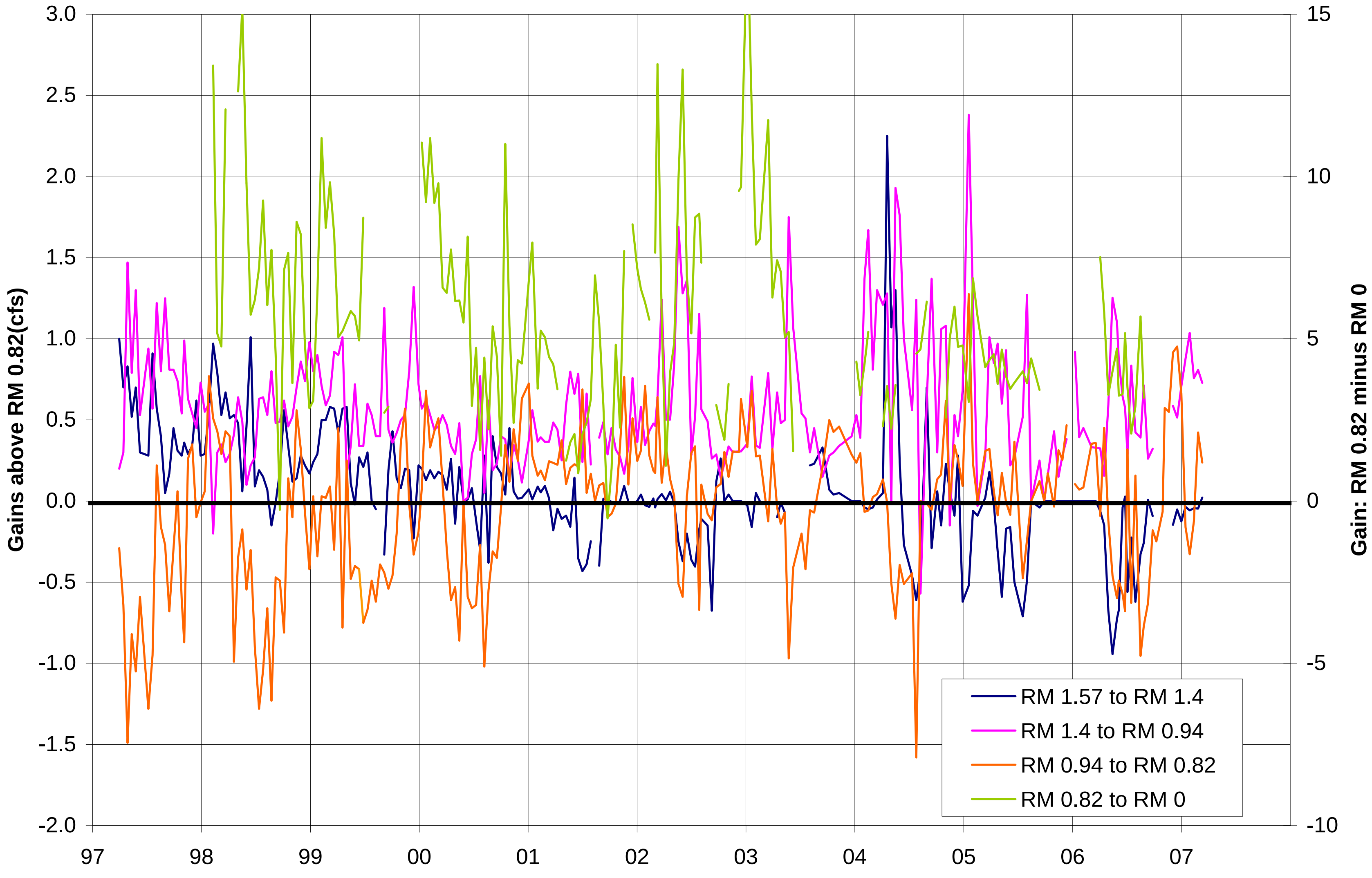


Figure 17: Lower Bell Creek

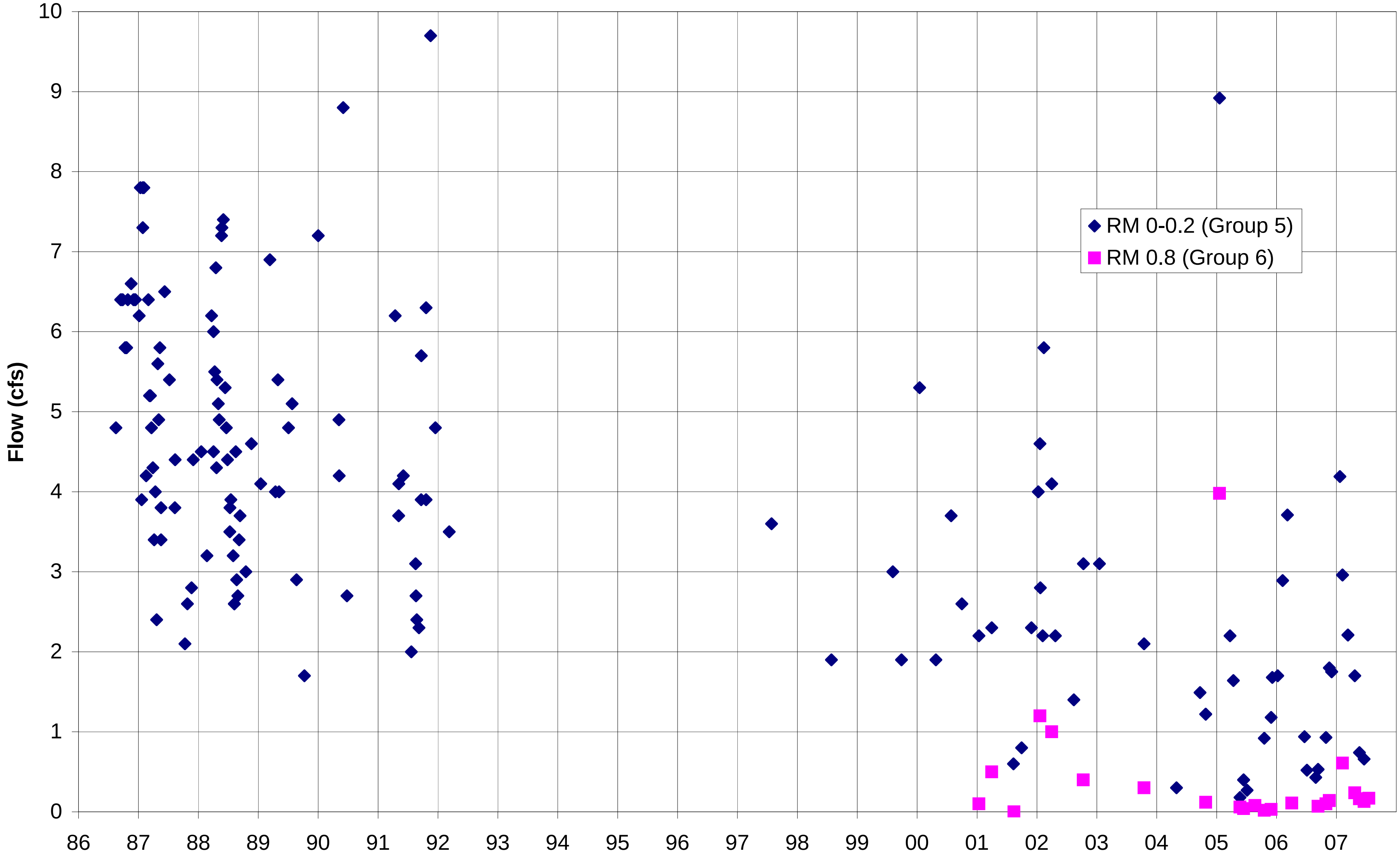


Figure 18: Middle Bell Creek

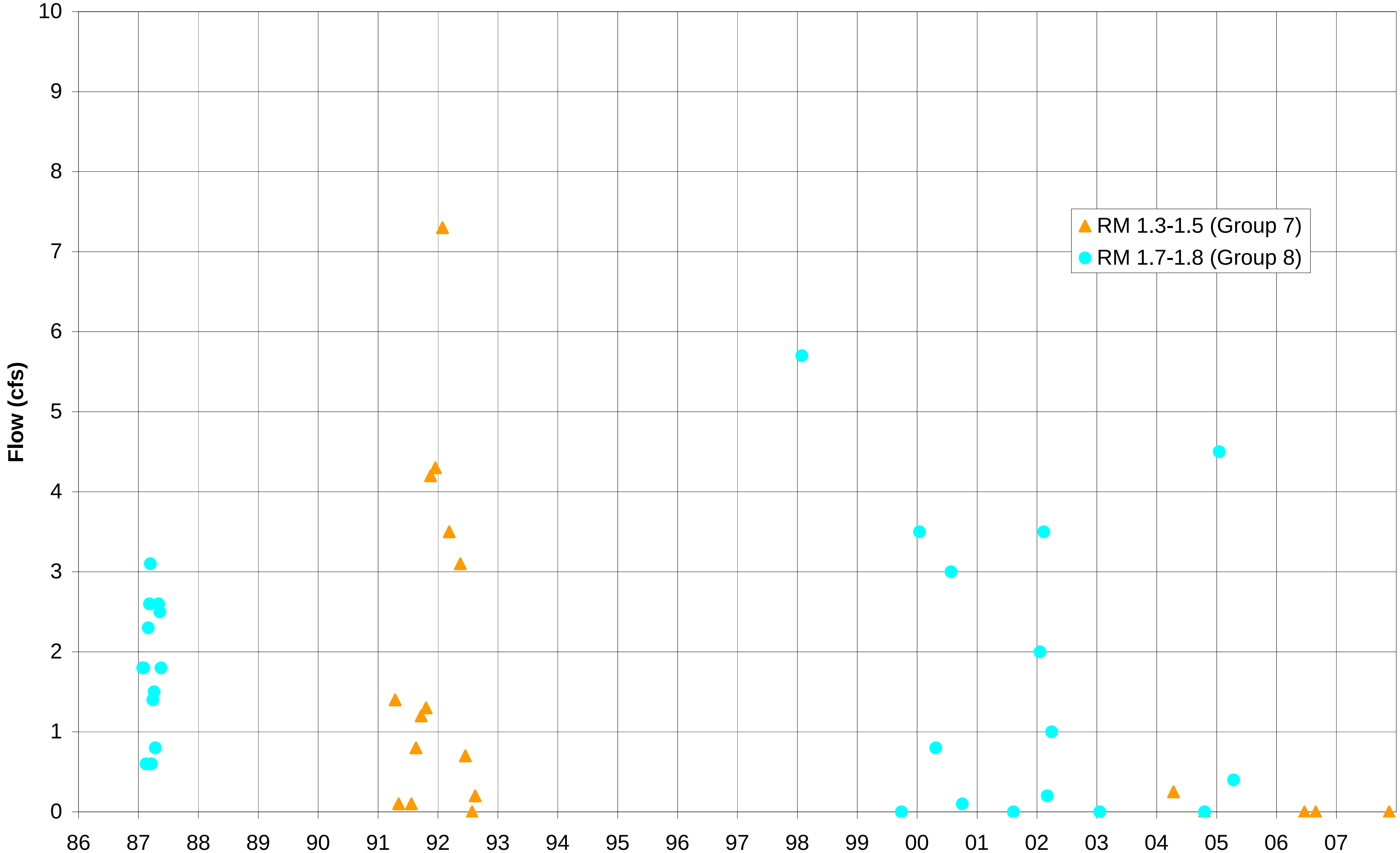


Figure 19: Upper Bell Creek

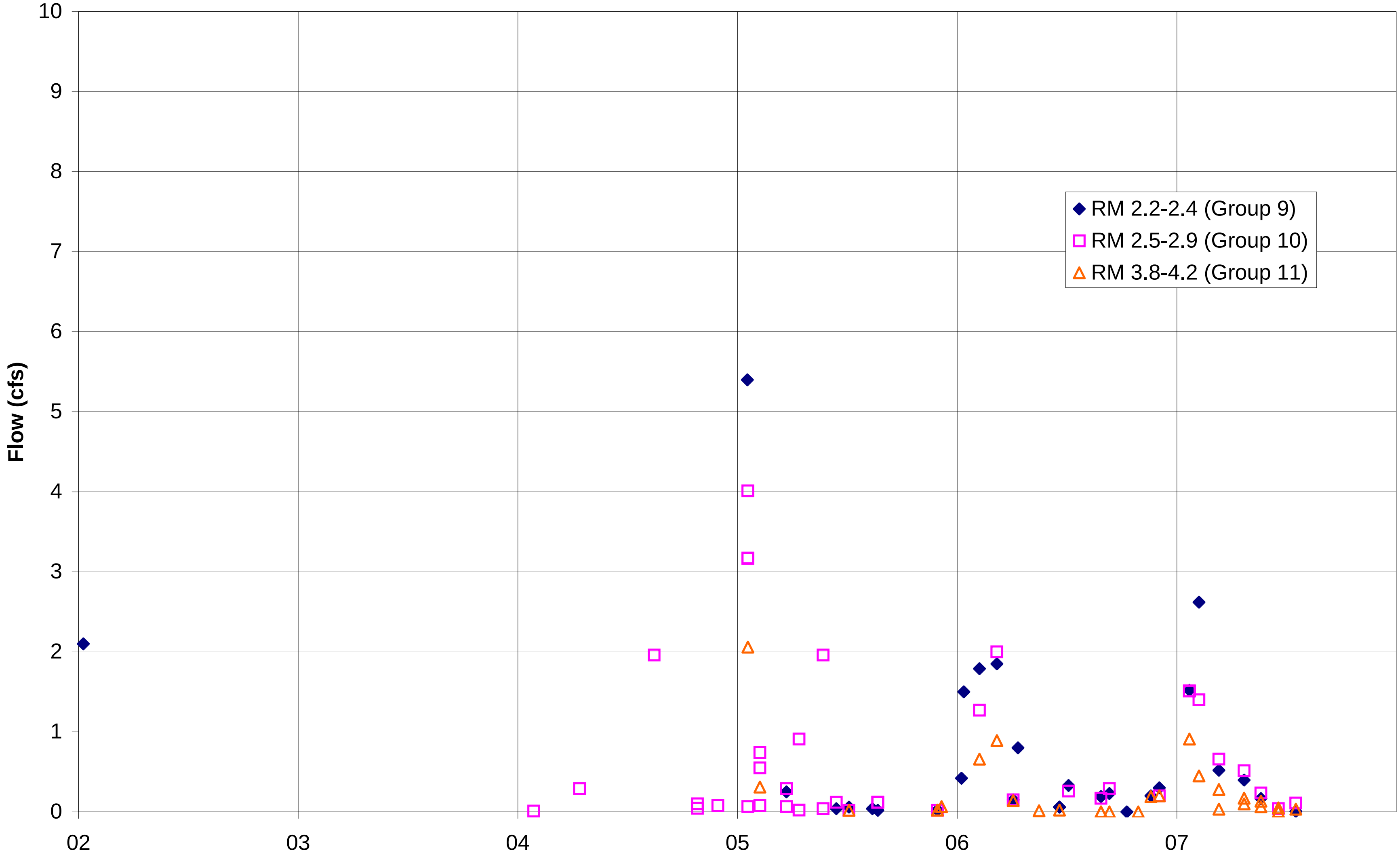
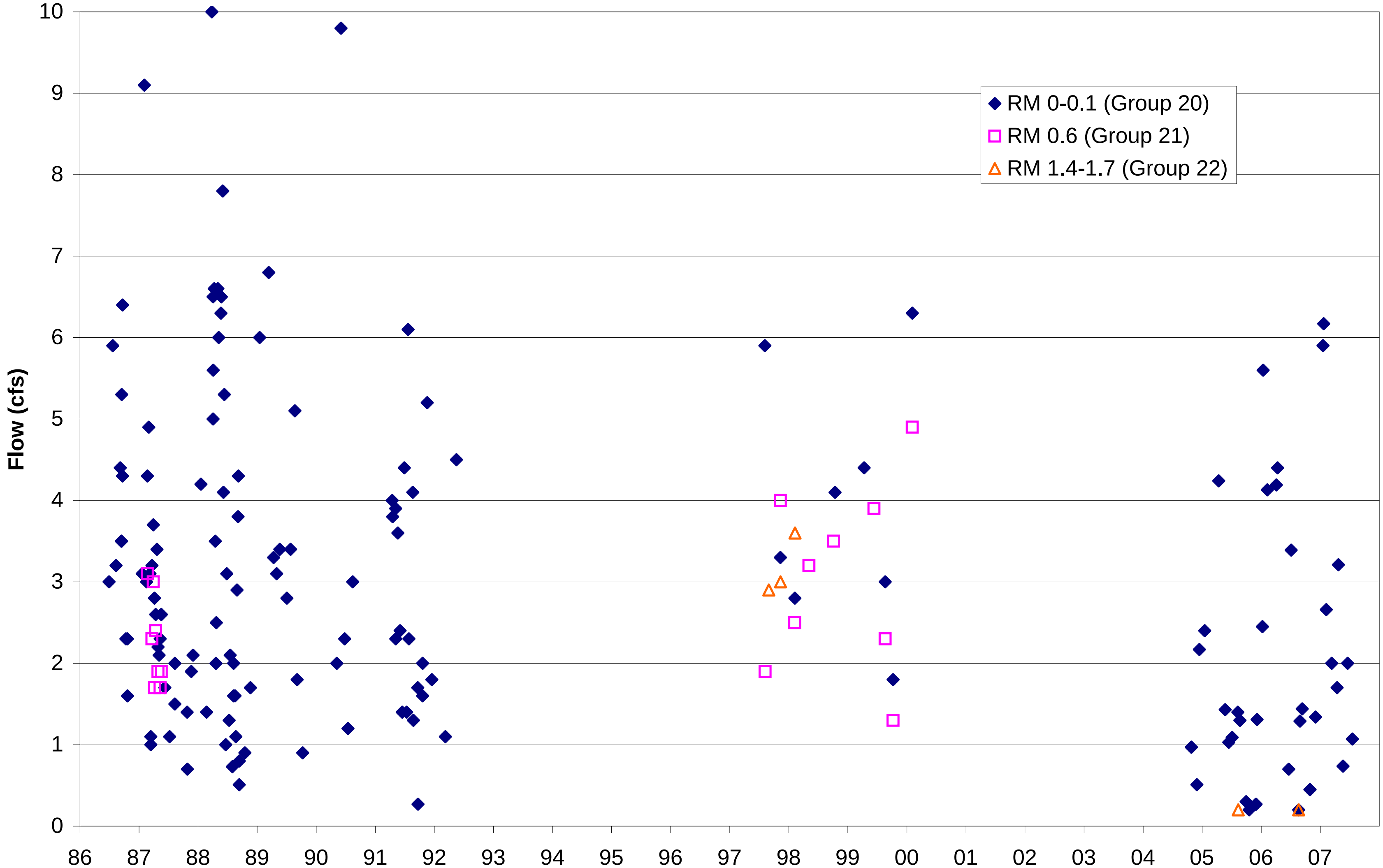


Figure 20: Johnson Creek



APPENDIX A

SUPPLEMENTAL INFORMATION FROM ASPECT CONSULTING

-----Original Message-----
From: Erick W. Miller [mailto:emiller@aspectconsulting.com]
Sent: Friday, October 05, 2007 2:27 PM
To: Soule, Ann
Cc: rberry@simpson.com; Peter S. Bannister
Subject: Graysmarsh comments on baseflow memo

<<Figure 3 - Drain Cells.pdf>> <<GWInflowsToGierinCk.pdf>>
<<GWInflowsToGraysmarsh.pdf>>

Ann - Thanks for the opportunity to provide comments on the draft PGG memorandum Assessment of Baseflow to Small Streams on behalf of Graysmarsh. Our review focuses on calibration targets for Gierin Creek flow system in the groundwater model. Our comments are discussed using the three supporting figures attached to this email:

Figure 1 - Groundwater Discharge to Gierin Creek - Station 2 (RM 1.4) to Station 5 (RM 0.8) - This figure presents a statistical analysis of groundwater gains above RM 0.8 on Gierin Creek. A box plot presenting the minimum, 25%, average, 75%, and maximum groundwater inflow along this reach is shown for each month. The statistics represented by the box plots are based on the gaging period from 9/97 to 3/07, with 115 of 115 months of data. Station locations are shown on Figure 3. The Station 2 to 5 reach was selected in place of Station 1 to 5 reach to eliminate the need to account for irrigation withdrawals that occur between Stations 1 and 2. The groundwater gain along the Station 2 to 5 reach was computed as the difference in flow between Station 2 and combine flow from Stations 5 and 6. Gieren Creek flows into a pond that has two outlets gaged by Stations 5 and 6. The total pond outflow is the sum of Stations 5 and 6. The outflow at Station 6 was shut off in September, 2000. Station 6 was gaged beginning in September 1997.

The crosses in Figure 1 present the 1997 data, one month (9/97) of which overlaps with the transient model period of 12/95 to 9/97. As such reliance on measured flow data for calibration during the transient model period is not possible. The 1997 data are best approximated by the 75%tile data. For the period from September 1997 to December 1997 the average groundwater gain was 1.1 cfs which is very close to the 75%tile for all data over the same period (1.0 cfs). We recommend that the monthly 75%tile groundwater inflow estimates be used as the monthly calibration target for the transient period.

Because the system is dynamic and flows on Gierin Creek have been declining since gaging began in 1997, the period represented by the steady state model should be defined. We assume that the steady state model will target conditions during the 1997 model period. As discussed above, the 75%tile appears most representative of groundwater inflow during 1997 period. The mean 75%tile groundwater inflow is 0.9 cfs which we recommend for use as a target steady state groundwater inflow between RM 1.4 and 0.8.

Figure 2 - Groundwater Discharge to Graysmarsh - Station 5 (RM-0.8) to Station 10 (RM 0) - This figure presents the same statistics described above for Figure 1. The statistics represented by the box plots are based on the gaging period from 4/97 to 3/07, with 98 of 120 months of data (about 80% of the period of record). Groundwater inflow was computed as the difference between Stations 5 and 10. Water diverted at Station 6 does not enter the marsh and is not included in this calculation. Similar to the Gierin Creek inflow, the 75% values present the best representation of the steady state and transient model periods. The April through December 1997 average groundwater inflow of 6.8 cfs is very close to the 75%tile for the same months using all years (7.1 cfs). The 1997 data that overlap the model period (April though September 1997) should be used in the transient model calibration. For the remaining months of the transient model period where no measured data is available, we recommend that the 75% groundwater inflows be used as the monthly calibration target.

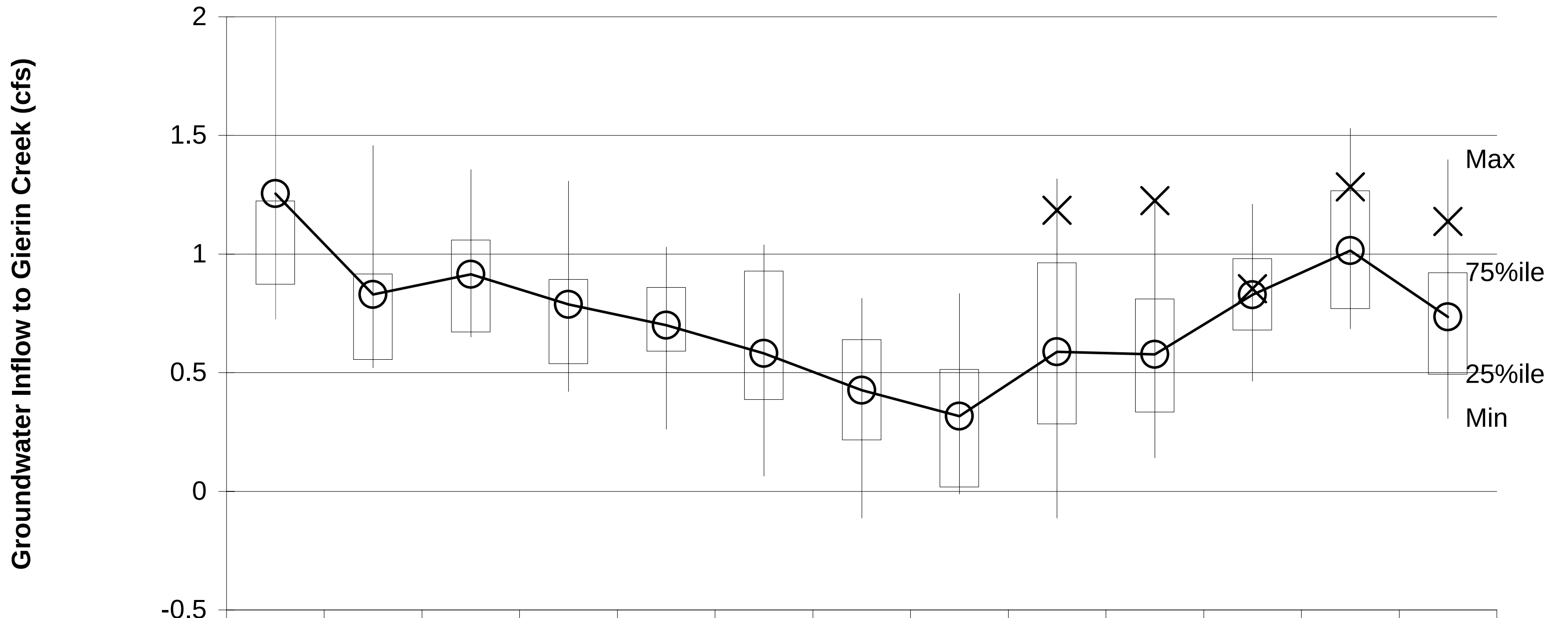
We recommend the mean of the 75% data be used for the steady state model calibration (again assuming the period for steady state conditions is to be representative of the transient period conditions, i.e. ~1996/97). The steady state groundwater inflow calibration target to the marsh should, therefore, be 7.4 cfs.

Figure 3 - Marsh Drain Cell Area - This map presents the area of the marsh that should be modeled as drain cells. Discharge to the marsh occurs at discrete springs such as Einarsen Springs (in the vicinity of Stations 8 and 9 in Figure 3) and in several more diffuse areas of discharge informally named Honey Hole, Wrong Way Creek and No Name Creek. Other areas of groundwater discharge are also likely present throughout the marsh. The area recommended for drain cells is based on encompassing these areas of the marsh as well as the marsh perimeter where groundwater discharge may be occurring.

You or Peter Schwartzman should feel free to contact us with any questions you may have. Thanks again for the opportunity to provide input.

Regards,

Peter Bannister and Erick Miller



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
75%ile	1.2	0.9	1.1	0.9	0.9	0.9	0.6	0.5	1.0	0.8	1.0	1.3	0.9
Max	3.7	1.5	1.4	1.3	1.0	1.0	0.8	0.8	1.3	1.2	1.2	1.5	1.4
Min	0.7	0.5	0.6	0.4	0.3	0.1	-0.1	0.0	-0.1	0.1	0.5	0.7	0.3
25%ile	0.9	0.6	0.7	0.5	0.6	0.4	0.2	0.0	0.3	0.3	0.7	0.8	0.5
Average	1.3	0.8	0.9	0.8	0.7	0.6	0.4	0.3	0.6	0.6	0.8	1.0	0.7
1997									1.2	1.2	0.9	1.3	1.1

Month

Groundwater discharge computed as flow difference between Station 2 (RM 1.4) and Stations 5 and 6 (RM 0.8).
Station 6 measured diversions from Gierin Creek from September 2, 1997 to September 19, 2000. Thereafter, diversions at Station 6 ended.
Data analysis period September 2, 1997 through March 13, 2007.
September - December 1997 Average = 1.1 cfs
September - December 75%ile Average= 1.0 cfs

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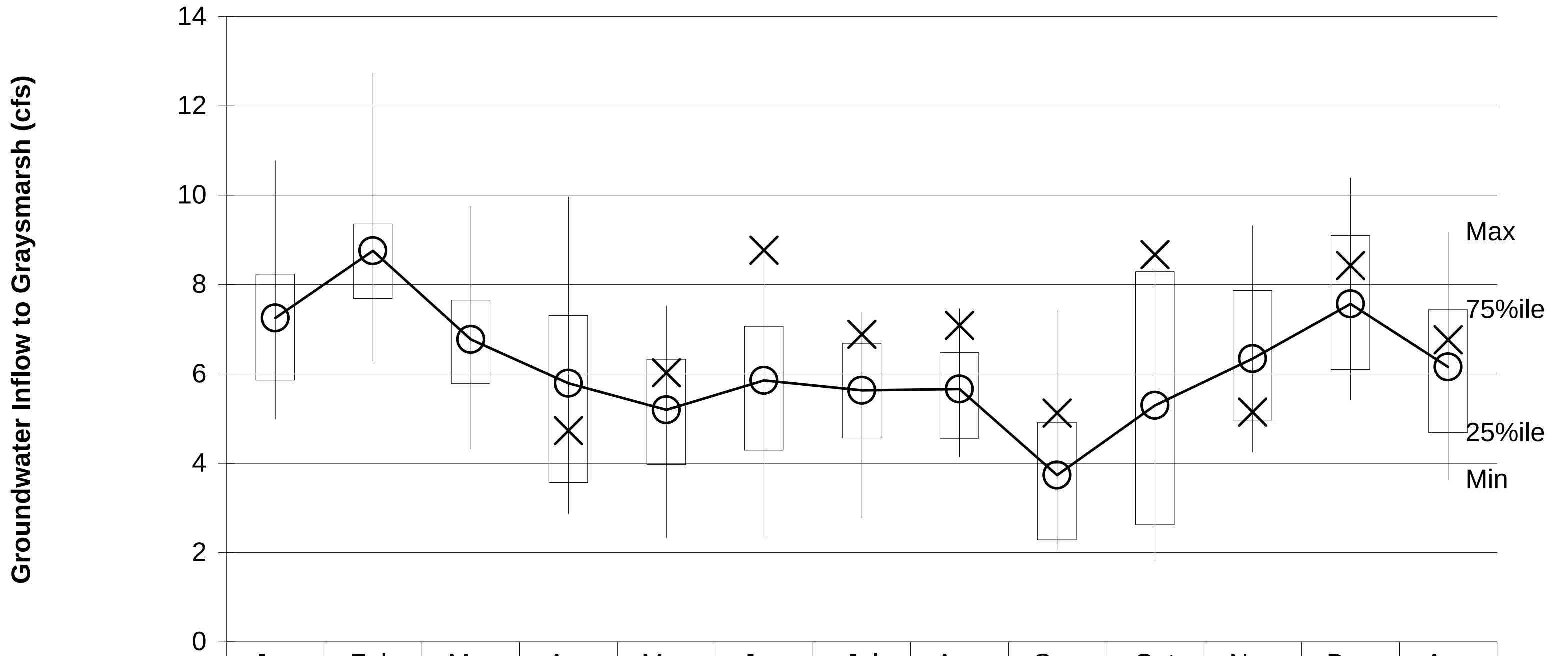
P:\Graysmarsh II\GM monitoring data\GraysmarshGWInflowsAnalysis.xls

Figure 1
GW Discharge to Gierin Creek from Station 2 to Station 5
Graysmarsh



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
75%ile	8.2	9.4	7.7	7.3	6.3	7.1	6.7	6.5	4.9	8.3	7.9	9.1	7.4
Max	10.8	12.7	9.8	10.0	7.5	8.8	7.4	7.5	7.4	8.7	9.3	10.4	9.2
Min	5.0	6.3	4.3	2.9	2.3	2.3	2.8	4.1	2.1	1.8	4.2	5.4	3.6
25%ile	5.9	7.7	5.8	3.6	4.0	4.3	4.6	4.6	2.3	2.6	5.0	6.1	4.7
Average	7.3	8.8	6.8	5.8	5.2	5.9	5.6	5.7	3.7	5.3	6.3	7.6	6.2
1997				4.7	6.0	8.8	6.9	7.1	5.1	8.7	5.1	8.4	6.8

Month

Groundwater discharge computed as flow difference between Station 5 (RM 0.8) and Station 10 (RM 0).
Data analysis period April 1, 1997 through March 13, 2007.
April - December 1997 Average = 6.8 cfs
April - December 75%ile Average = 7.1 cfs

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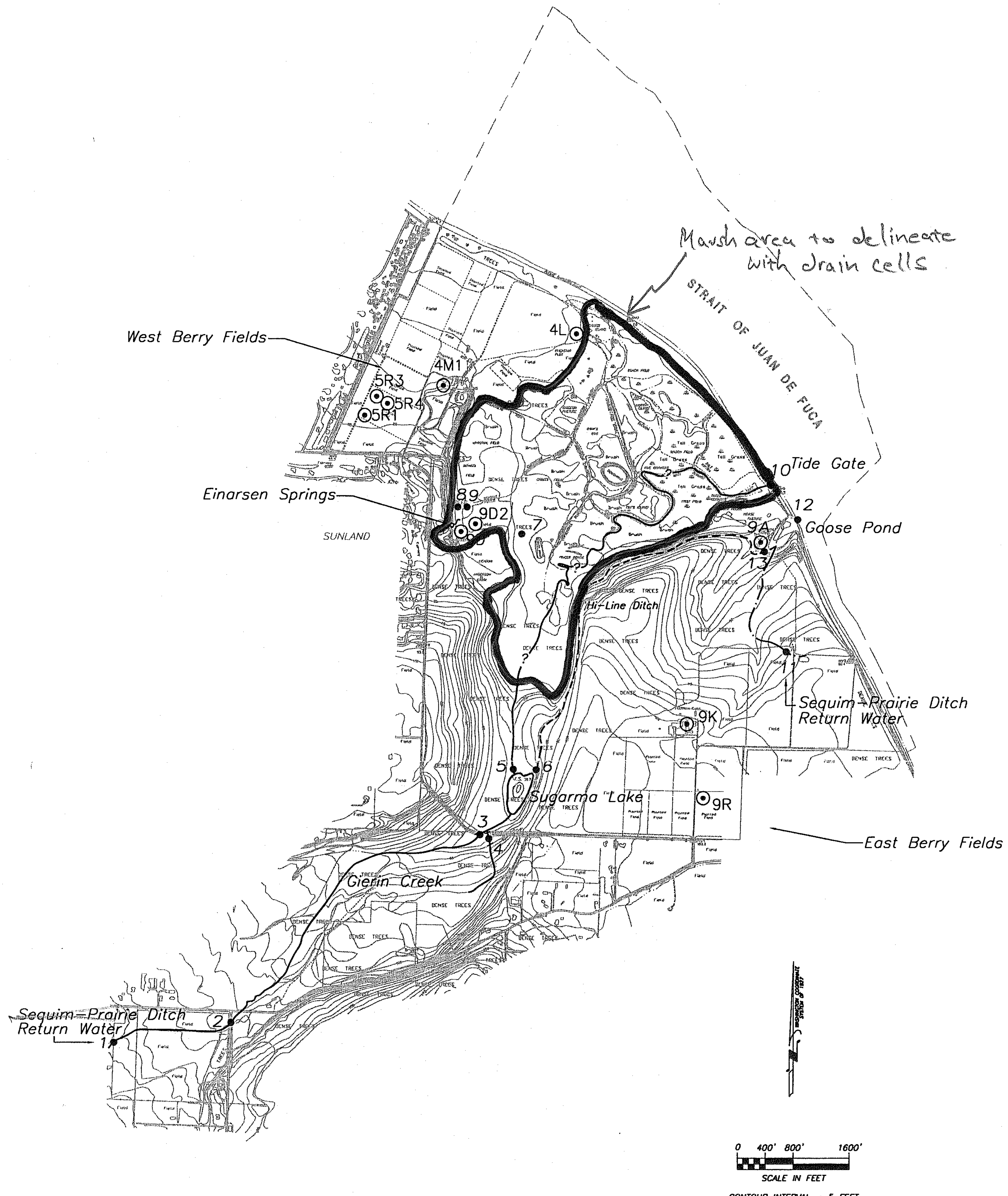
Figure 2
GW Discharge to Graysmarsh from Station 5 to Station 10
Graysmarsh

BH9628E-17dwg 01/12/99 1:1



Note:
Hi-Line Ditch location and ditch location downstream of Station 11 are shown approximately.

LEGEND

- • 2 SURFACE WATER GAUGING LOCATION.
- ⊙ Well Location
- 5R1 — Well Identifier

Figure 3 - Marsh Drain Cell Area

Reference: Northwestern Territories Inc. Graysmarsh topographic Survey, 1/17/93

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DESIGNED E.W.M.	GRAYSMARSH WELLS AND SURFACE WATER GAUGING LOCATIONS	PROJECT NO. WB9628E	
DRAWN B.L.B.	IRRIGATION EXPERIMENT MEMORANDUM	FIGURE NO. 3	
CHECKED M.E.S.			
APPROVED E.W.M.			