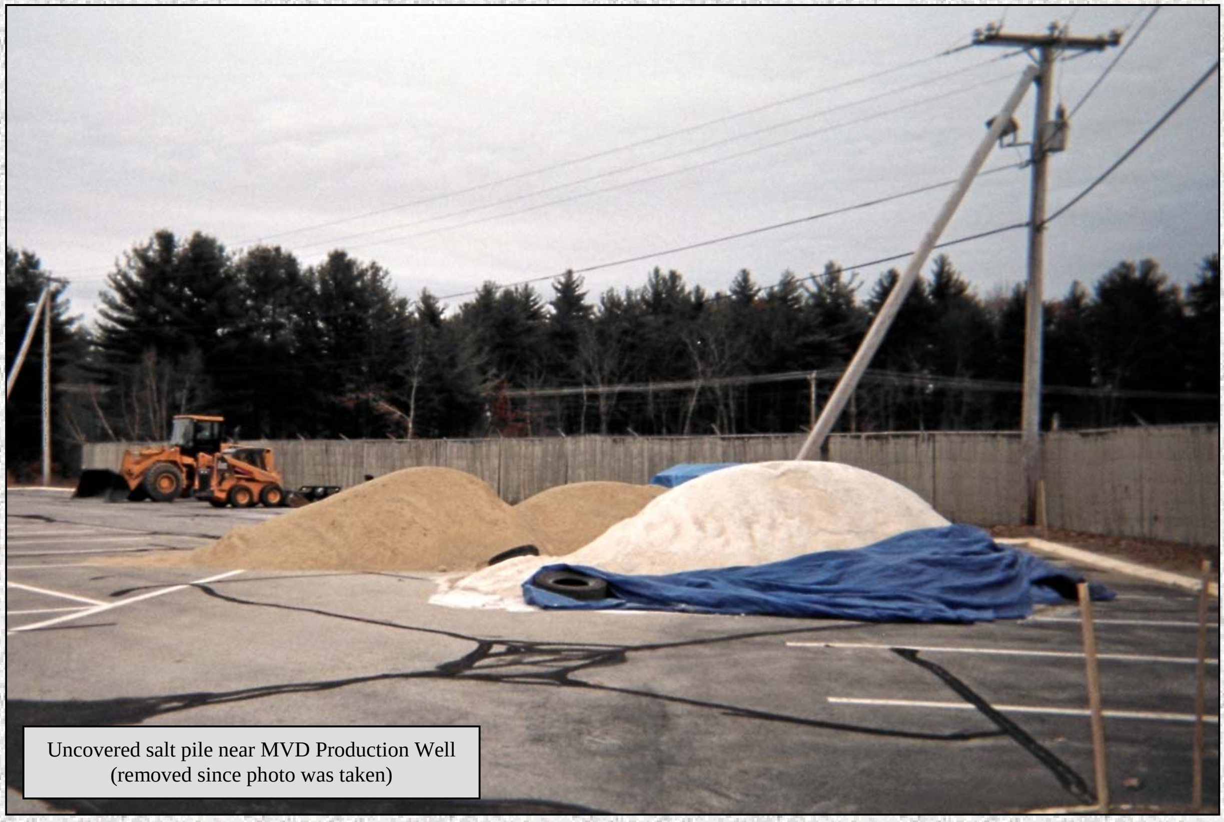
FINAL REPORT ON
2011 LOCAL SOURCE WATER PROTECTION GRANT SWP-223

SODIUM AND CHLORIDE LOADING STUDY OF THE MERRIMACK VILLAGE DISTRICT WELLHEAD PROTECTION AREAS (WHPAs)

MERRIMACK, NEW HAMPSHIRE



Uncovered salt pile near MVD Production Well
(removed since photo was taken)

May 2012

Presented to:

Mr. Ron Miner
Merrimack Village District

EMERY & GARRETT GROUNDWATER, INC.
56 Main Street • P.O. Box 1578
Meredith, New Hampshire 03253

New England **Mid-Atlantic** **South Atlantic**

Emery & Garrett Groundwater, Inc.
56 Main Street • P.O. Box 1578
Meredith, New Hampshire 03253
(603) 279-4425 *www.eggi.com* *Fax (603) 279-8717*

May 30, 2012

Mr. Ron Miner
Ms. Jill Lavoie
Merrimack Village District
2 Greens Pond Road
Merrimack, NH 03054

Re: Final Report on 2011 Local Source Water Protection Grant SWP-223

Dear Ron and Jill,

As you know, The Merrimack Village District (MVD) applied for and was awarded a Local Source Water Protection Grant (SWP-223) to evaluate salt loading in the three Wellhead Protection Areas (WHPAs) that have been designated around the seven Production Wells that serve the residents and businesses of the Town of Merrimack. Emery & Garrett Groundwater, Inc. (EGGI) is pleased to present to you this report that describes the 2011 sodium and chloride loading study that was performed for each of the Merrimack Village District (MVD) Wellhead Protection Areas.

We hope you find the information contained herein responsive to your needs. If you have any questions regarding this material, please do not hesitate to contact us.

Best regards,

Jeff Marts, P.G.
Geologist

Dan Tinkham, P.G.
Senior Hydrogeologist

James M. Emery, P.G.
President

Cc: New Hampshire Department of Environmental Services
Merrimack Department of Community Development
Merrimack Public Works Department
Merrimack Planning Board
Merrimack Town Manager
Merrimack Town Council

Emery & Garrett Groundwater, Inc.
56 Main Street • P.O. Box 1578
Meredith, New Hampshire 03253
(603) 279-4425 www.eggi.com Fax (603) 279-8717

FINAL REPORT ON
2011 LOCAL SOURCE WATER PROTECTION GRANT SWP-223

SODIUM AND CHLORIDE LOADING STUDY OF THE MERRIMACK VILLAGE DISTRICT WELLHEAD PROTECTION AREAS (WHPAs)

MERRIMACK, NEW HAMPSHIRE
May 2012

TABLE OF CONTENTS

Page

TABLES

FIGURES

APPENDICES

Emery & Garrett Groundwater, Inc.
56 Main Street • P.O. Box 1578
Meredith, New Hampshire 03253
(603) 279-4425 *Fax (603) 279-8717*

FINAL REPORT ON
2011 LOCAL SOURCE WATER PROTECTION GRANT SWP-223

SODIUM AND CHLORIDE LOADING STUDY OF THE MERRIMACK VILLAGE DISTRICT WELLHEAD PROTECTION AREAS (WHPAs)

MERRIMACK, NEW HAMPSHIRE

May 2012

I. INTRODUCTION

A. Background

The Merrimack Village Water District (MVD) relies exclusively on groundwater to supply nearly one billion gallons of water annually to over 9,300 connections in the Town of Merrimack, New Hampshire. Seven high-yield wells owned and operated by the MVD provide groundwater from glacial stratified drift deposits located in and around the Town of Merrimack (Figure 1). Over the years, sodium and chloride levels have increased in many of the MVD Production Wells. To determine the source(s) of the sodium and chloride, the MVD applied for a 2011 Local Source Water Protection Grant from the New Hampshire Department of Environmental Services (NHDES). This Grant has been used to evaluate the salt loading in the Wellhead Protection Areas (WHPAs) that surround the MVD Production Wells.

Sodium chloride is the most common deicing agent used in the State of New Hampshire because of its low cost and effectiveness (other agents melt ice at lower temperatures, but cost more). Demand for clear roads during or immediately after snow and ice events has led to increasing volumes of deicing material being applied to roadways. As the percentage of a watershed that is covered with roads, sidewalks, and parking lots increases, the amount of deicing material applied within the watershed also increases. Sodium and chloride readily dissolve in water and do not degrade in the environment like some other contaminants.

The NHDES adopted a Secondary Maximum Contaminant Level (SMCL) for chloride of 250 mg/l and 100-250 mg/l for sodium. The U.S. Environmental Protection Agency established a Drinking Water Advisory for sodium between 30 mg/l and 60 mg/l, based on taste thresholds. A Health Guidance Level for people on low sodium diets is set at 20 mg/l for sodium in drinking water by the EPA. *Two of the MVD's Production Wells have met or exceeded the NHDES SMCL for chloride. All of the MVD Production Wells have occasionally, if not repeatedly, exceeded the EPA Drinking Water Advisory for sodium, and all of the MVD Production Wells exceed the EPA Health Guidance Level for sodium. Furthermore, four of the six Production Wells currently in* *use show clear trends that sodium and chloride levels are continuing to increase on an annual basis (Appendix A).*

B. Scope of the 2011 Local Source Water Protection Grant

The MVD applied for a Source Water Protection Grant to evaluate salt loading in each WHPA and to develop mitigation strategies to stabilize or reduce salt levels in the groundwater. The study consisted of four primary tasks:

Task 1 – Inventory each WHPA for sources of sodium and chloride. *Available GIS datasets and imagery were compiled for each WHPA for use as the basis for completing an inventory of the sodium and chloride use within each WHPA. Current and historic salt use data were compiled for key users. Estimates of loading rates for other sources were developed based on published data and studies.*

Task 2 – Calculate annual mass loading. *Sodium and chloride loading within each WHPA was tallied on a source-by-source basis to determine the amount of salt entering each aquifer.*

Task 3 – Develop a detailed Mitigation Plan. *Based on the data and findings from Tasks 1 and 2, EGGI developed a detailed Mitigation Plan designed to reduce salt loading in each of the WHPAs to stabilize or reduce the concentration of sodium and chloride in each Production Well.*

Task 4 – Consult with key parties in the Town. *Two meetings were held as work progressed on this study that included members of the MVD, Merrimack Planning Board, Merrimack Department of Community Development, Merrimack Department of Public Works, Merrimack Police Department, New Hampshire Department of Transportation and the New Hampshire Department of Environmental Services. A draft version of the Mitigation Plan was circulated to key parties for review and input.*

This report summarizes our findings relative to these tasks and makes recommendations for steps that could be taken to mitigate elevated sodium and chloride concentrations in the aquifers near the MVD Production Wells.

II. SODIUM CHLORIDE TRENDS in the MVD PRODUCTION WELLS

The MVD has been collecting sodium and chloride data on a quarterly basis from its six active Production Wells (MVD-2, MVD-3, MVD-4, MVD-5, MVD-7, and MVD-8) since 2001 (Appendix A). Increasing sodium chloride levels in all three WHPAs presents a long-term threat to groundwater quality.

Over the past decade, sodium chloride levels have trended upward in the WHPA for Wells MVD-2 and MVD-3. Sodium commonly exceeds the 20 mg/l health advisory for sodium in MVD-2 and MVD-3, and sodium is particularly high in MVD-3 where concentrations of over 200 mg/l have been detected. Chloride levels in MVD-3 often approach, and have on occasion exceeded, the EPA and NHDES SMCL of 250 mg/l. Levels of chloride are much lower in MVD-2, though there is a gradual trend of increasing chloride punctuated by periodic chloride spikes.

Sodium and chloride concentrations have also increased over the past decade in the WHPA for Wells MVD-4 and MVD-5. Sodium consistently exceeds the EPA health advisory of 20 mg/l in both MVD-4 and MVD-5, sometimes containing levels two to five times higher than the health advisory. In 2004, chloride levels in both Wells began to rise, with concentrations spiking at or above 150 mg/l in MVD-4 and just below 250 mg/l in MVD-5. The highest chloride value recorded in an MVD Production Well was 397 mg/l in MVD-5 in 2009.

In the WHPA designated for Wells MVD-6, MVD-7, and MVD-8, sodium chloride levels are also increasing[1]. Sodium is consistently elevated above the EPA health based standard in MVD-7 and MVD-8. Chloride levels in MVD-7 began to spike above 150 mg/l in 2004, reflecting a nearly three-fold increase over the 2001-2003 time period. Chloride levels rose steadily in MVD-8 from 2001 through 2009; however, in 2010, chloride levels rose very quickly by 50 mg/l to nearly 150 mg/l.

III. SUMMARY OF SODIUM AND CHLORIDE SOURCE INVENTORY

A. State, Local, and Private Roads

EGGI obtained the New Hampshire Public Roads GIS dataset (NHDOT downloaded from NH GRANIT website) to identify and characterize state, local, and private roads within each Wellhead Protection Area (Figure 2). Spreadsheets were developed describing each road segment in the WHPAs and to calculate salt loading.

State roads within the MVD WHPAs are maintained by two Bureaus within the NHDOT - the Bureau of Turnpikes and Bureau of Highway Maintenance, District 5A. Historic salt use data for the previous 10 winters was obtained from the NHDOT for the Turnpikes and District 5 (Rodrigue 2012 Personal Communication). Salt application data provided by the NHDOT are averaged for all of the roads in each district.

NHDOT salt application varies significantly from winter to winter, ranging from about 13 tons / lane mile to over 30 tons / lane mile (Figure 3). Since the winter of 2007-2008, NHDOT salt use has generally declined in the Merrimack area. Comparing salt use to the NHDOT Winter Severity Index, salt use relative to the severity of each winter has generally declined over the past 10 years (Figure 4). Average winter salt application rates

[1] MVD-6 has been offline since 1988 so current quarterly sampling data is not available for this Production Well.

for District 5 and Turnpikes were calculated and applied to each road segment maintained by the respective bureau in the MVD WHPAs.

The Merrimack Public Works Department maintains most of the local roads within the MVD WHPAs. Portions of the MVD-6, 7, & 8 WHPA are located in Hollis, Amherst, and Nashua where local roads are maintained by each Town. Roads within Merrimack are prescribed different winter maintenance practices depending on the type of road, volume of traffic, specific site hazards (sharp curve or hill), and environmental / water quality concerns. Road salt purchasing data and winter maintenance procedures provided by the Merrimack Public Works Department (Jacobs 2012 Personal Communication) were used to assign estimated annual salt application rates for the different types of winter maintenance protocols as follows: Sand Only Routes = 1 ton / lane-mile; Subdivision / Unassigned = 4 tons / lane-mile; Light / Mix Routes = 7.5 tons / lane-mile; Primary Routes = 15 tons / lane-mile.

Private roads and local roads outside of Merrimack were assigned an annual average application rate of 17.8 tons / lane-mile as estimated by a Plymouth State University study (Sassan & Kahl 2007). Salt use data provided by the MVD obtained from a private contractor for two developments in the MVD-4 & 5 WHPA were used to estimate site-specific application rates for a small subset of the private roads in that WHPA only.

Annual salt application (tons / mile) is shown on Figure 2 for each road in the three WHPAs. These annual application rates were calculated by multiplying the number of lanes of each road segment by the application rate for each lane. Roads with higher overall application rates are represented by warmer colors (yellow to red) with application rates in the 12 to 104 ton per mile range, while the green colors represent lower loading rates. Total annual salt loading for roads ranged from 216 tons (WHPA for Wells MVD-4 & 5) to 275 tons (WHPA for Wells MVD-2 & 3) (Table I).

B. Parking Lots

Each MVD WHPA contains a number of commercial / retail parking lots of various sizes. High-resolution aerial photographs were used to digitize into GIS all of the parking lot boundaries within each WHPA (Figure 2). Areas of each parking lot were calculated using GIS and these data were exported to spreadsheets where loading rates could be assigned. Most parking lots were assigned an average loading rate of 6.4 tons/acre/year based on results of a Plymouth State University study (Sassan & Kahl, 2007). Parking lots that were represented by road segments in GIS were not digitized, as a truck applying salt would likely drive the road loop during an application trip. One private plowing contractor provided salt application data to the MVD, and these data were used to calculate site-specific loading rates for two developments within the MVD-4-5 WHPA. Salt used on parking lots contributed to 41 to 56% of the total amount of salt applied within each of the WHPAs (Table I).

C. Residential Driveways

Estimating salt use on residential driveways presented a particular challenge for this study. First, residential driveways were not represented in GIS in a way that would allow easy calculation of their area, and it would be too time consuming to digitize each driveway in the three WHPAs for this study. Second, residential salt use on driveways is not widely discussed in the published literature examined for this study. To overcome these difficulties, the area of the driveways needed to be estimated and an application rate determined.

According to published literature, 35.6% of the area of a residential lot consists of impervious cover (Giannotti and Others 2002) and driveways constitute about 20% of the impervious area (Stone 2004) or about 7% of the total area of the lot. To account for differences in zoning and development patterns between Merrimack and the study areas referenced in the published papers, EGGI determined the driveway area of a random sample of residential lots within each WHPA and calculated that the average driveway in the sample constituted 5.52% of the total lot area. The total area occupied by residential lots was determined for each WHPA, and this area was multiplied by 0.0552 to estimate the area of residential driveways in each of the three WHPAs. EGGI estimated that 10% of property owners apply salt to their driveways at a rate of 6.4 tons of salt / acre / year to their driveways.[2] Estimated salt application to driveways contributes 0.2 to 5.6% of the annual salt load in the WHPAs (Table I).

D. Residential Septic Systems

Residential septic systems contribute sodium and chloride directly to the groundwater. Salt loading varies by septic system depending on the number of people that occupy a home and whether a home has a water softener installed. The NHDES estimates that the average person contributes 20 pounds of salt per year to the septic system (Trowbridge 2007). Census data for Merrimack indicate that 2.7 people occupy the average home, so an average of 54 pounds of salt is loaded to each septic system annually in homes without a water softener. Elsewhere in Southern New Hampshire, the NHDES estimated that 25% of homes served by private wells have water softeners, and that a family of 2.3 people contribute 378 pounds of salt annually to the septic system from the softener (Trowbridge 2007). Therefore, EGGI estimates the average Merrimack family of 2.7 would contribute 454 pounds of salt to the groundwater from their water softener.

At the time this study was performed, there were no complete datasets in GIS to identify which houses were served by public water and septic versus private wells and septic. EGGI examined real estate listings in each WHPA to determine which neighborhoods were served by public water and public sewer and created a GIS dataset to identify lots by the source of water and wastewater disposal. These data were used to calculate salt loading rates through septic systems (Figure 2). Compared to roads and parking lots, septic systems are a minor contributor of salt, ranging from an annual total load of 0 to 7.7 tons within each of the WHPAs (Table 1).

---

[2] Salt loading rate presented by Sassan and Kahl for parking areas.

E. Atmospheric Deposition

Sodium and chloride are present at very low concentrations in precipitation that falls from the atmosphere. EGGI selected two sites where sodium and chloride concentrations in precipitation is monitored by the National Atmospheric Deposition Program (NADP) to develop an estimate of how much sodium and chloride falls on each of the MVD WHPAs. EGGI averaged the annual chloride deposition at the NADP Quabbin Reservoir site in Massachusetts and the Hubbard Brook site in New Hampshire. The average annual chloride deposition (2.4 kg/hectare) was multiplied by 0.6066 (mass of chloride / mass of sodium chloride) to estimate the average mass of sodium chloride falling on a hectare (4.0 kg of sodium chloride per hectare). It was determined that salt loading in the WHPAs is negligible, ranging from 0.1 to 0.6% of the annual mass load in each of the WHPAs (Table I).

IV. MASS LOADING

A. General Sodium Chloride Mass Balance

Salt applied to a road, parking lot, or sidewalk surface can leave the surface via several different pathways as it travels through the MVD WHPAs. These can include the following:

- Salt laden snow and melt water can be jettisoned from the roadway onto the adjoining shoulder;
- Sheet runoff containing dissolved sodium chloride from the road surface can infiltrate into the ground at the edge of the road where no curb is present;
- Aerosolized brine can be blown off the road surface and deposited away from the road;
- Stormwater and snowmelt can be captured by catch basins and conveyed through the stormwater system. In some cases, stormwater collection systems convey salt-water runoff out of a WHPA, but some stormwater systems can also discharge salty water within a WHPA where it can infiltrate into the ground, thereby concentrating sodium and chloride loading at a point in the aquifer.

A literature review found that significant amounts (in some cases more than half) of road salt reaches the ground on the periphery of roads, even if a stormwater system is present, through a combination of jettisoned snow, sheet flows, and aerosols (Marts and Tinkham, 2007).

There are two primary means by which salt *leaves* an aquifer; groundwater removal via a well and natural discharge to a surface water body. The MVD removes significant volumes of groundwater each year from the three aquifers beneath the WHPAs. Each liter of groundwater contains a certain amount of dissolved salt and, over the course of a year, the amount of water pumped from the aquifer results in the removal of significant quantities of salt. Groundwater discharge to surface water bodies can also account for significant mass removal of sodium chloride from aquifers. In fact, one study found increased levels of sodium and chloride during summer time low flow conditions in a southern New Hampshire river, reflecting the contribution of salinized groundwater to base flow (Daley and others 2007).

Sodium chloride accumulates in an aquifer when the inputs of salt exceed the output of salt from the aquifer. Salt is stored in the aquifer in a dissolved state, so overall increases in the concentration of sodium chloride in groundwater samples reflect the storage of salt within the aquifer. If salt inputs exceed outputs, the overall salinity of the aquifer will increase; whereas, if salt outputs exceed salt inputs, overall sodium chloride concentrations in groundwater will decrease. In another stratified drift aquifer in New Hampshire, EGGI found that chloride concentrations increase with depth in the aquifer, indicating that substantial salt can be stored deep within the aquifer (Marts and Tinkham 2007). The amount of time it takes to flush existing salt out of an aquifer will depend heavily on the residence time of the water and how long it takes water to follow a particular flow path through the aquifer. Since water deep within the aquifer presumably follows long, slow flow paths, this deep water is expected to remain salty for longer periods of time. Flow path travel times are expected to be on the order of years to decades in the three WHPAs. If salt applications lessened or ceased within a WHPA, it is reasonable to expect sodium and chloride levels at the MVD Production Wells would begin decreasing within a few years, though it may take a decade or longer to return to natural sodium chloride levels as salt is slowly flushed from the longer, deeper groundwater flow paths.

B. Non-Grant Funded Sodium Chloride / Conductivity Measurements

Conductivity measurements can serve as a cost-effective proxy measurement for sodium and chloride concentrations (Marts and Emery 2007). EGGI measured field conductivity and collected samples for laboratory analyses of sodium and chloride at several surface water bodies, stormwater discharges, and one snow bank sample. The results of these data were used to develop a means of calculating sodium and chloride values from subsequent conductivity measurements, allowing for quick assessment of a variety of surface water samples using a hand-held field conductivity meter. A total of 58 conductivity measurements were made at several surface water sites in and around the three MVD WHPAs (Table II and Figure 5). Many of the sampling sites were evaluated up to four times between March 2011 and March 2012.

In the WHPA for Wells MVD-2 and MVD-3, surface water monitoring location NAT-4 is considered to provide a representative sampling location of water from the Naticook Brook just downstream of the entire aquifer / WHPA (Figure 5). In other words, this location monitors surface water and groundwater (groundwater that discharges to surface water as base flow) leaving the hydrogeologic system that is utilized by MVD-2 and MVD-3. Therefore, water passing by Station NAT-4 has *removed* sodium and chloride from the MVD-2-3 WHPA. When water was flowing at this site, chloride ranged from 30 to 58 mg/l.

Also, a sample collected from a snow pile (identified as 'Snow') adjacent to Continental Boulevard (Figure 5) in the WHPA for MVD-2 and MVD-3 contained only 5 mg/l of chloride, suggesting that little chloride was retained in the snow pack on this section of roadway and that other salt transport mechanisms (possibly sheet flow off the roadway) played a larger role in transfer of sodium chloride from the road surface to the groundwater.

Monitoring location 'Drain-4-5' in the MVD-4-5 WHPA represents the outflow from a major portion of the stormwater drainage system in the WHPA. A short distance downstream from the Drain-4-5 sampling site, the surface water joins with another tributary draining the WHPA before passing under the railroad trestle (see sample identified as 'Trestle' Table II) and discharging to the Merrimack River. Sodium chloride dissolved in the water at Drain-4-5 is leaving the WHPA. One conductivity measurement was collected from a stormwater basin (Parker Village Pond) that collects stormwater generated at the Parker Village Subdivision. This basin has a sandy bottom and a high level overflow pipe that discharges into the stream that flows toward the Merrimack River. Results of the conductivity sampling at the Parker Village Pond indicate that chloride concentrations are approximately 825 mg/l. It is not clear as to whether this basin has any type of liner to prevent infiltration. If it does not have a liner (or the liner leaks) this location could be a significant source of sodium chloride that would provide a salt load directly up hydraulic gradient from the Production Wells. A substantial portion of the salt load would subsequently enter the MVD-4-5 WHPA.

C. MVD-2-3 WHPA Loading Model

The MVD Production Wells MVD-2 and MVD-3 are installed in stratified drift sand and gravel deposits known as the Naticook Brook Aquifer. This Aquifer is directly connected to Greens Pond, a shallow pond underlain by sand and gravel of the Aquifer. The water level in Greens Pond lowers significantly on a seasonal basis as the water table in the Aquifer drops below the level of the Pond. Water discharges from the Aquifer (and out of Greens Pond) into Naticook Brook when the water table is high. Extensive studies have been performed on the Naticook Brook Aquifer, including groundwater modeling (EGGI 1998), which provided detailed information on the water budget and geometry of the aquifer system. The information provided by previous studies and the single surface water discharge point makes the MVD-2-3 WHPA ideal for determining how much salt is leaving the Aquifer.

On average, the MVD pumps 1,100 gpm (1,584,000 gpd) from the Naticook Brook Aquifer (Wells MVD-2 and MVD-3) and 803 gpm (1,156,300 gpd) discharges from the aquifer system via Naticook Brook (EGGI 1998). By applying a weighted average of the sodium and chloride levels in the two Production Wells and using the sodium chloride data obtained from surface water observation point NAT-4 (see discussion in Section IV-B), EGGI calculated that 495.9 tons of salt leaves the Aquifer each year. Since 513 tons of salt is applied within the WHPA (Table I), 18.1 tons of salt remain in the Aquifer (or, in other words, are added to the Aquifer). Approximately 880 million gallons of water are stored within the Aquifer, so adding 18.1 tons of salt would raise the concentration of sodium by 2 mg/l and chloride by 3 mg/l each year. *In fact, sodium and chloride levels in MVD-3 have increased 1.7 and 3.4 mg/l per year, respectively, suggesting that this salt loading model is reasonably well calibrated* (Appendix A).

Sodium and chloride levels in MVD Production Well MVD-3 are generally the highest in the MVD system (Appendix A). Well MVD-3 is situated down gradient of a section of Industrial Drive maintained by the NHDOT where approximately 50 tons of salt (about 10% of the total amount of salt applied in this WHPA) are used annually. Stormwater from this section of roadway either infiltrates into the ground adjacent to the roadway or is mobilized through the stormwater system of catch basins and piping that conveys it to a wetland near the intersection of Industrial Drive and Continental Boulevard (see star symbols for stormwater discharge locations on Figure 6). The overall Naticook Brook Aquifer is oriented along a bedrock trough that trends towards the northeast; however, a southeast trending bedrock trough extends from Production Well MVD-3 to the wetland area that receives the bulk of the stormwater from Industrial Drive (Figure 6). EGGI believes this bedrock trough funnels sodium- and chloride-laden water through the Aquifer directly towards the Production Well. In fact, water quality sampling results from two MVD monitoring wells confirms the presence of a plume of groundwater containing elevated sodium and chloride: Monitoring Well MER-3-40 had 200 mg/l of chloride and 120 mg/l of sodium; Monitoring Well MER-3-43 had 270 mg/l of chloride and 170 mg/l of sodium (Figure 6). The area contributing salt to the wetland above the bedrock trough has been designated a *'critical area'* with regards to mitigating sodium chloride inputs. Controlling salt use in this *'critical area'* is key to improving the overall water quality at Production Well MVD-3 (Figure 6).

D. MVD-4-5 WHPA Loading Model

Production Wells MVD-4 and MVD-5 are installed in coarse sand and gravel deposits and have a combined annual withdrawal equivalent to a constant pumping rate of 420 gpm (604,800 gpd) (based on pumping records from 1997 and 2001). The coarse sand and gravel deposits where the Production Wells are screened lie below finer terrace deposits that consist of reworked sediments from Glacial Lake Merrimack. Finer deposits extend to the Merrimack River, and it is believed the River is marginally connected to the coarse deposits of the Aquifer. Approximately two-thirds of the recharge to the Aquifer comes from direct infiltration of precipitation falling within the WHPA, the remainder comes from the infiltration of surface water, either from the Merrimack River or Baboosic Brook (EGGI 2003).

Under pumping conditions, recharge is induced from surface water bodies, and discharge from the Aquifer to the Rivers is thought to be minimal. Therefore, the primary pathway for salt to be removed from this Aquifer is via pumping by the MVD from the two Production Wells. Using weighted averages for sodium and chloride levels in the Wells, EGGI calculated that the Production Wells remove about 211 tons of salt annually from the Aquifer. Examination of GIS data sets, drainage studies (Comprehensive Environmental 2001), and field reviews suggest that the local stormwater runoff system directs some of the salt laden runoff from the WHPA to the Merrimack River[3]. However, increasing levels of sodium and chloride in the groundwater indicate some portion of the salt applied in the WHPA remains in the ground.

The MVD-4-5 WHPA has the highest density of commercial and residential development of the three WHPAs and has the highest annual salt load per acre (Table 1). As discussed in Section IV-A, salt can take several pathways off of the pavement as it travels through the WHPA. Sheet flow of salt laden water is thought to be the significant mechanism of travel in

[3] Quantification of the salt removed via stormwater runoff to the Merrimack River is difficult without continuous gauging and conductivity measurements of the outflows since stormwater flows and salt content are highly episodic and major salt run-off events are often measured on an hourly timeframe.

this area. Although the stormwater system is fairly well documented in the MVD-4-5 WHPA, the actual condition of the structural components of this system were not verifiable during this study and it is not known how much salt leaks from the stormwater runoff system into the Aquifer.

For example, a significant portion of the stormwater runoff from the WHPA passes through a stormwater detention pond adjacent to Front Street that is located west of the Production Wells (Figure 7). Observations from test pits indicate that the bottom of the pond is lined with a low permeability layer of silt and clay to minimize infiltration. At one time, this pond was overgrown with small trees and it is not known how the trees may have affected the hydraulic performance of the low permeability layer. It should be noted that during EGGI's field screening visits to this detention basin, there were no apparent losses of stormwater. Another stormwater basin is located north of the Production Wells and receives runoff from a subdivision. Stormwater in this basin (Parker Village Pond) had particularly elevated conductivity values and calculated chloride of 825 mg/l during an EGGI screening (Figure 7 and Table 2). It is not known whether this pond is lined or whether it is designed to allow a portion of the stormwater to infiltrate.

EGGI considers the entire MVD-4-5 WHPA to be a critical area for reducing salt. Since two thirds of the recharge for the two Production Wells comes from direct infiltration of precipitation, it is important to allow as much infiltration as possible within the WHPA to obtain the groundwater needed to sustain the withdrawals. *Therefore, the only feasible way to reduce salt loading in the Aquifer without decreasing recharge to the Aquifer is to reduce salt applications within the WHPA.*

E. MVD-6-7-8 WHPA Loading Model

Glacial sand and gravel deposits filled a bedrock trough forming the highly productive Witches Brook Aquifer that is the source of groundwater for Production Wells MVD-6, MVD-7, and MVD-8. These three Wells have a combined maximum pumping rate of 2,050 gallons per minute (nearly three million gallons per day). In the vicinity of the three Production Wells, a very productive layer of coarse sand and gravel extends approximately 60 to 80 feet below ground. A layer of fine sand and/or till exists above the bedrock surface and below the coarse aquifer deposits. Recharge to the Aquifer primarily occurs as direct precipitation. Groundwater flow under non-pumping conditions is generally toward Witches Brook, Pennichuck Brook, and the surrounding wetlands where the groundwater naturally discharges to the surface water bodies. Under pumping conditions, the three Wells serve as local groundwater sinks, with radial groundwater flow toward each Well. The composite cone of depression from the three Production Wells captures a large portion of the groundwater that would otherwise discharge to the surface water bodies. Although pumping induces some leakage from the wetland to the Aquifer, the low permeability of the wetlands results in a limited leakage rate spread out over a large area as the cone of depression spreads out laterally through the transmissive sand and gravel deposits (EGGI 2000). Leakage from the surface water bodies contains relatively low sodium and chloride levels and constitutes about half of the recharge to the Production Wells, helping to mitigate the overall concentration of sodium and chloride at the Production Wells.

A plume of sodium chloride laden water extends from the vicinity of the former Merrimack Industrial Metals (MIM) site (EGGI 2000) towards Production Well MVD-6 (Inset, Figure 8). During the pumping test performed in 1999 that was used to determine the WHPA for MVD-6, chloride levels started out above the SMCL at a concentration of 260 mg/l and declined to about 160 mg/l during the 29-day long test. The steady decline of chloride concentrations during the pumping test reflects the contribution of relatively fresh water from the wetlands and surface water bodies. Conductivity measurements of groundwater from surrounding monitoring wells indicate chloride concentrations in excess of 600 mg/l at the center of the plume, with the concentration of chloride typically increasing with depth in the Aquifer. It is believed the source(s) of this concentrated sodium chloride plume was the existence of a former salt pile located on the MIM site. In 2007, the NHDES observed an uncovered salt pile in the PC Connection Parking lot (Kernen personal communication 2007) that presumably contributed saline runoff to the ground in the general vicinity of the old sodium chloride plume identified in 1999. This pile was promptly removed upon its discovery and additional salt piles have not been observed since. Well MVD-6 has been off-line since 1988, though the MVD intends to bring it back online in the future. Results of the 1999 pumping test suggest dilution of the salt plume will occur with ongoing pumping.

There are two areas of heavy salt use within the MVD-6-7-8 WHPA, the Route 101A corridor, and the commercial/industrial zone along Northwest Boulevard in Nashua. The commercial/industrial zone in Nashua will present the biggest threat when Well MVD-6 is pumping again and its cone of depression has been re-established, as it will receive recharge from extensive parking lot areas. However, the estimated travel time of groundwater under pumping conditions is estimated to be years to decades and dilution of sodium and chloride due to leakage from the wetlands is expected to minimize the impact on the Production Wells from this source area of sodium chloride. Nevertheless, the Route 101A corridor and its related commercial activity presents the biggest active source of sodium chloride, with an estimated 60 tons of salt used on average on the State-maintained roads. This salt load will add to the salt applied to the numerous parking lots. Therefore, this area is considered a *‘critical area’* for reducing salt loading within the WHPA (Figure 8).

V. MITIGATION PLAN

A detailed Mitigation Plan was developed, with consultation and input from numerous interested parties (Tasks 3 and 4), that includes specific action items to address sodium chloride loading in the three WHPAs (Appendix B). Over the course of the project, two meetings were held at the MVD offices involving the following parties:

- MVD Board and Staff
- Merrimack Department of Community Development
- Merrimack Public Works Department
- Merrimack Planning Board
- Merrimack Conservation Commission
- Merrimack Police Department

- NHDES
- NHDOT

A draft version of the Mitigation Plan was sent to the following parties for review and comments:

- MVD Board and Staff
- Town Manager
- Town Council
- Merrimack Department of Community Development
- Merrimack Public Works Department
- Merrimack Planning Board

The Mitigation Plan, if fully implemented, is a stand-alone document with strategies designed to minimize sodium and chloride loading in each of the three MVD WHPAs and to ultimately reduce the levels of sodium and chloride in the MVD Production Wells. Successful implementation of this Plan will require partnerships and cooperation between both the public and private sector. This would include the Town of Merrimack and State governments/agencies and, of course, the citizens residing within the Town of Merrimack. Table 1 of the Mitigation Plan (Appendix B) outlines the proposed mitigation measures, key stakeholders involved, and a proposed timeframe for implementation.

VI. CONCLUSIONS and RECOMMENDATIONS

The MVD applied for and was awarded a Local Source Water Protection Grant (SWP-223) to evaluate salt loading in the three WHPAs, which have been designated around the seven Production Wells that serve the residents and businesses of the Town of Merrimack. EGGI has estimated the salt loading occurring on an annual basis in each of the three MVD WHPAs. Total annual salt loading in each WHPA ranged from 408 to 522 tons and ranged from 0.29 to 1.55 tons of salt per acre per year (Figure 2). EGGI developed salt loading models for each WHPA that take into account the mass amount of salt loading, site hydrogeology, groundwater flow paths, and known storm drainage features to identify *'critical areas'* where salt reduction efforts should be focused. This study culminated in the development of a detailed Mitigation Plan (Appendix B).

EGGI presents the following recommendations that is intended to reduce sodium and chloride loading into the local aquifer that supply critical public drinking water supplies to the Town of Merrimack and to monitor sodium chloride concentrations in these aquifers as a means of evaluating the performance/effectiveness of implemented salt reduction measures.

Recommendation #1 – Implement the specific action items outlined in the Mitigation Plan

Successful implementation and execution of the Mitigation Plan will require the long-term commitment and vigilance of several governmental and private sector parties, as well as the public. Efforts to implement elements of the Mitigation Plan should focus initially on the

Critical Areas identified for the three WHPAs (Report Section IV and Figures 6 – 8) and then expand to the entire WHPA.

Recommendation #2 – Perform conductivity profiling of the existing monitoring well network to identify key monitoring wells for long-term sodium chloride monitoring (Action Item 23 in Mitigation Plan).

A conductivity datalogger can be used to 'sound' a monitoring well and obtain foot-by-foot conductivity data for a well bore so that zones of high sodium and chloride can be detected. Such measurements can quickly be made by lowering a conductivity datalogger that is programmed to take measurements every second through the column of water in a well (only in the screened interval). Conductivity measurements can be converted to chloride concentrations.

Recommendation #3 – Select strategic locations for ongoing monitoring with conductivity dataloggers (Action Item 24 in Mitigation Plan).

Based on the results of the conductivity sounding, key monitoring wells should be selected for conducting continuous conductivity monitoring. Such conductivity monitoring is needed to provide valuable data to gauge the effectiveness of the sodium and chloride Mitigation Plan. EGGI further recommends installing equipment in each MVD Production Well that records the conductivity of the water pumped. Ideally, real-time conductivity data will be transmitted and stored via the existing SCADA systems for each Production Well.

Recommendation #4 – Expand GIS dataset for existing stormwater management system(s).

The GIS dataset used for stormwater features that was available at the time this study was performed did not include many of the private stormwater management systems. Ultimately, this will involve culling data from construction plans on file with the Town. Developing such a dataset will have many uses for wellhead protection efforts, in addition to sodium and chloride mitigation. For example, it could aid response teams in the event of hazardous material releases with the WHPAs by identifying sensitive stormwater outfalls and illustrating how the outfalls connect to the nearby catch basins. Emergency response personnel could deploy spill control measures, such as booms, at the appropriate outfall for catch basins affected by the hazardous material release.

VII. LIMITATIONS

EGGI has collected and evaluated the available technical data according to professionally accepted scientific standards. The recommendations provided herein represent EGGI's professional opinion based upon the hydrogeologic data collected and do not constitute a warranty written or implied.

VIII. REFERENCES

Comprehensive Environmental, Inc., May 2001, Merrimack Village District Wells 4 & 5 Drainage Evaluation.

Daley, Michelle L., Potter, Jody D., and McDowell, William H., 2009, Salinization of urbanizing New Hampshire streams and groundwater: effects of road salt and hydrologic variability. Journal of the North American Benthological Society: December 2009, Vol. 28, No. 4, pp. 929-940.

Emery & Garrett Groundwater, Inc., May 1998, Naticook Brook Aquifer Model Project Summary and Results, Merrimack Village District, Merrimack, New Hampshire.

Emery & Garrett Groundwater, Inc., March 2000, Final Well Siting Report, Establishment of the Wellhead Protection Area and Assessment of Existing Groundwater Contamination Near Public Water Supply Well MVD-6, Merrimack Village District, Merrimack, New Hampshire.

Emery & Garrett Groundwater, Inc., December 2003, Establishment of the Source Water Protection Area Merrimack Village District Wells MVD-4 and MVD-5, Merrimack, New Hampshire.

Giannotti, L, Prisloe, S., Do it Yourself! Impervious Surface Buildout Analysis, University of Connecticut Cooperative Extension Nonpoint Education for Municipal Officials (NEMO), Technical Paper Number 4, 2002.

Jacobs, 2012, Personal Communication regarding Merrimack Public Works Department deicing procedures.

Kernen, Brandon, 2007, Personal Communication via Email regarding salt pile at P.C. Connection.

Marts, J.M. and Emery, J.M., 2007, High Resolution Monitoring of Specific Conductivity as a Proxy for Chloride in a Valley-Fill Aquifer in Ashland, New Hampshire. Poster presentation at the 42nd Annual Meeting of the Northeastern Section of the Geological Society of America, University of New Hampshire, Durham, New Hampshire.

Marts, Jeffrey M. and Tinkham, D.J., 2007, Mitigating the Effects of Elevated Chloride Concentrations in a Valley-fill Aquifer. Oral presentation given at the Meeting of the New

England Water Well Association October 2006. Published in Journal NEWWA, December 2007, p. 286-294.

Rodrigue, Dave, 2012, Personal Communication via Email regarding NHDOT Historic Salt Use.

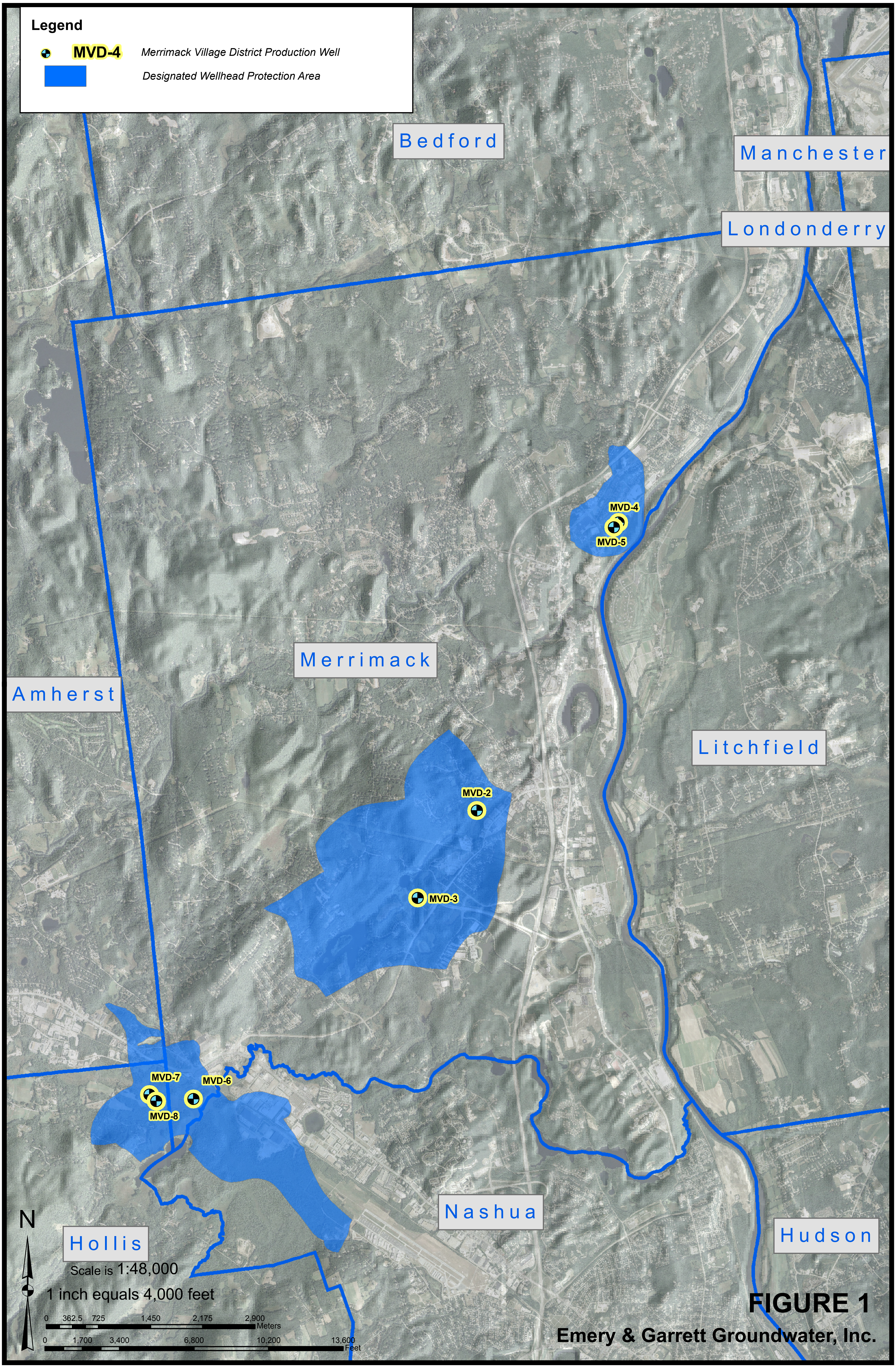
Sassan D.A. and Kahl S.K. 2007, Salt Loading Due To Private Winter Maintenance Practices. A final report from Plymouth State University, Center for the Environment, Plymouth NH to the NH Department of Environmental Services. June 30, 2007.

Stone, B. Jr., Paving Over Paradise: How Land Use Regulations Promote Residential Imperviousness, Landscape and Urban Planning Volume 69, p. 101–113, 2004.

Trowbridge, P., Data Report for the Total Maximum Daily Loads for Chloride For Waterbodies in the Vicinity of the I-93 Corridor From Massachusetts to Manchester, NH: Policy-Porcupine Brook, Beaver Brook, Dinsmore Brook, North Tributary to Canobie Lake, NHDES Publication NHDES-R-WD-07-40, December 2007.

FIGURES

Figure 1 - Merrimack Village District Production Wells and WHPAs



O:\nhMERRIMACKMCL_Sodium_Chloride_GrantMCL-Fig1_Overview.mxd

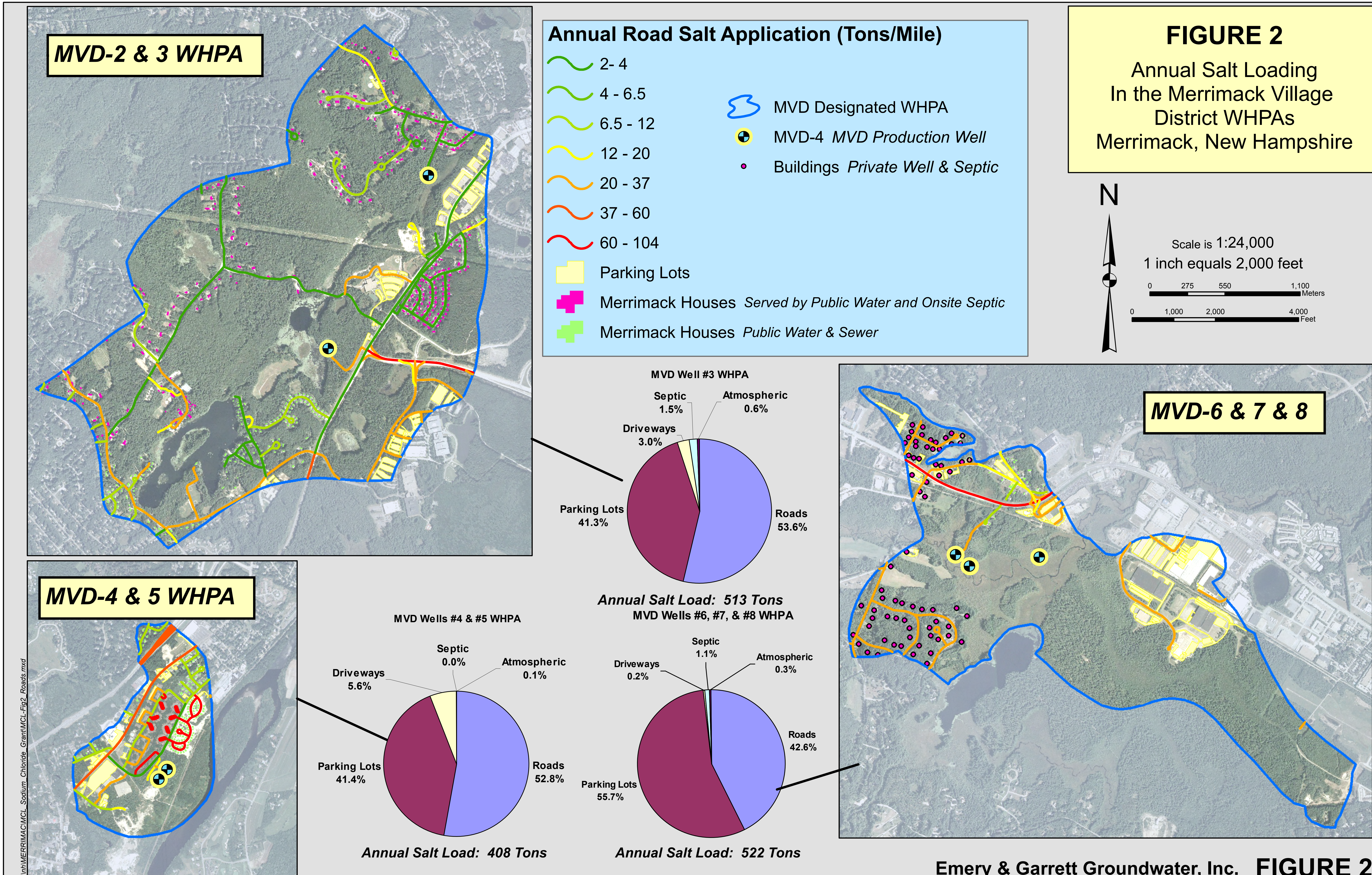
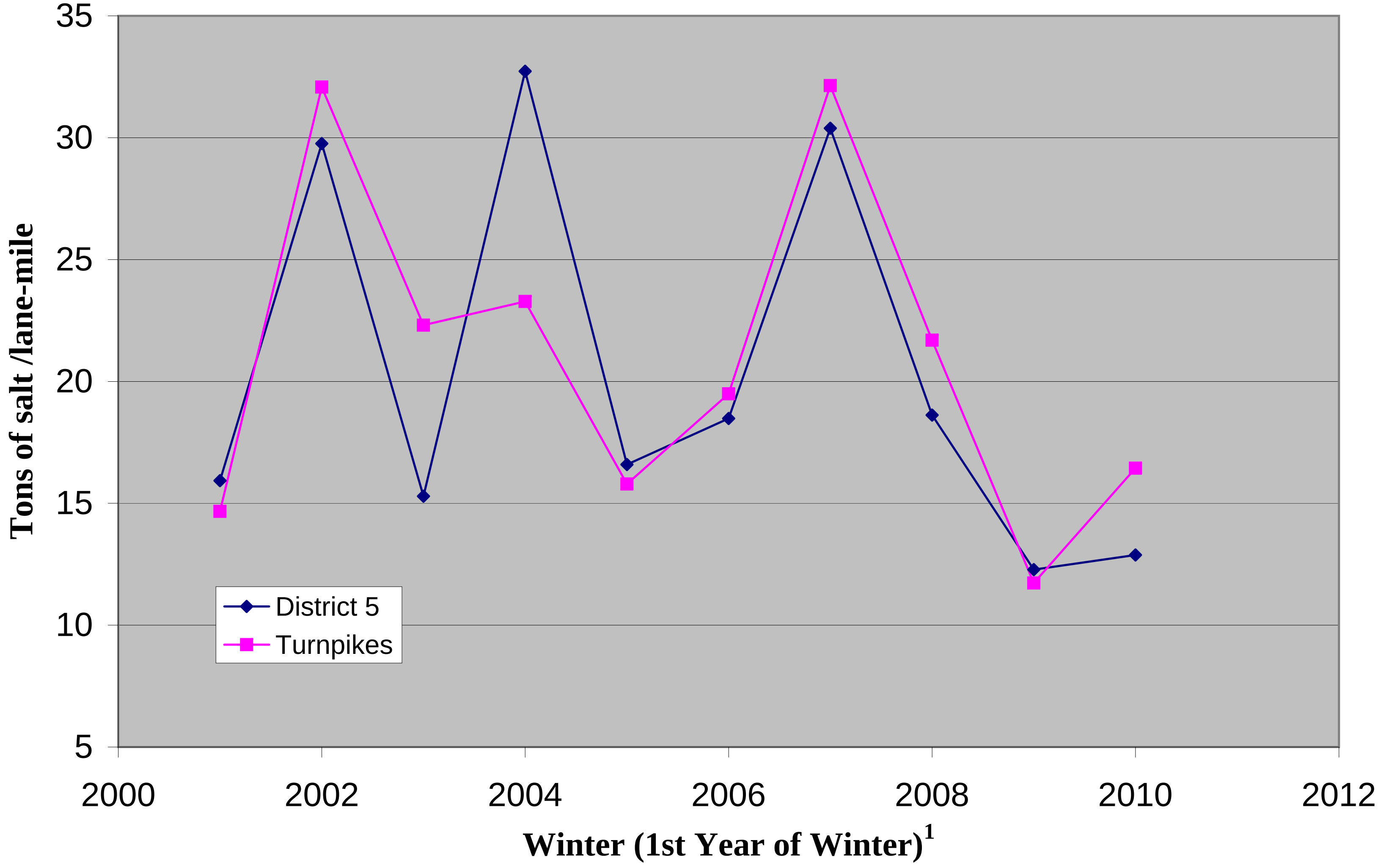


FIGURE 2
Annual Salt Loading
In the Merrimack Village
District WHPAs
Merrimack, New Hampshire

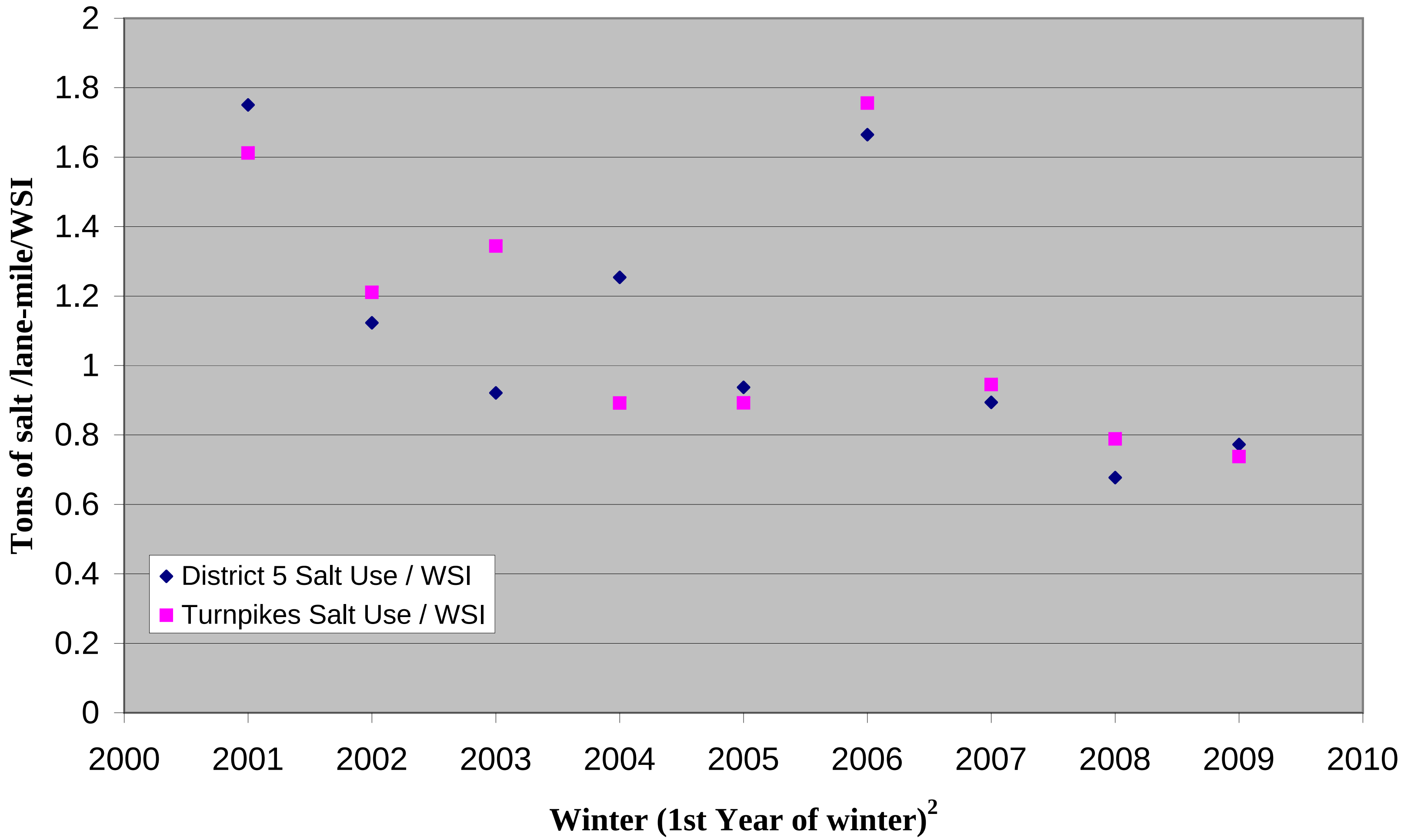
FIGURE 2

Figure 3 - Historic NHDOT Salt Use on State Roadways Within MVD WHPAs
Merrimack, New Hampshire



[1] The years on the x-axis correspond to the first year of a winter. For example, the points on the graph at year 2002 represent salt applied from Fall 2002 to the Spring of 2003.

Figure 4 - Plot of NHDOT Salt Use Divided by Winter Severity Index Value[1]
Merrimack, New Hampshire

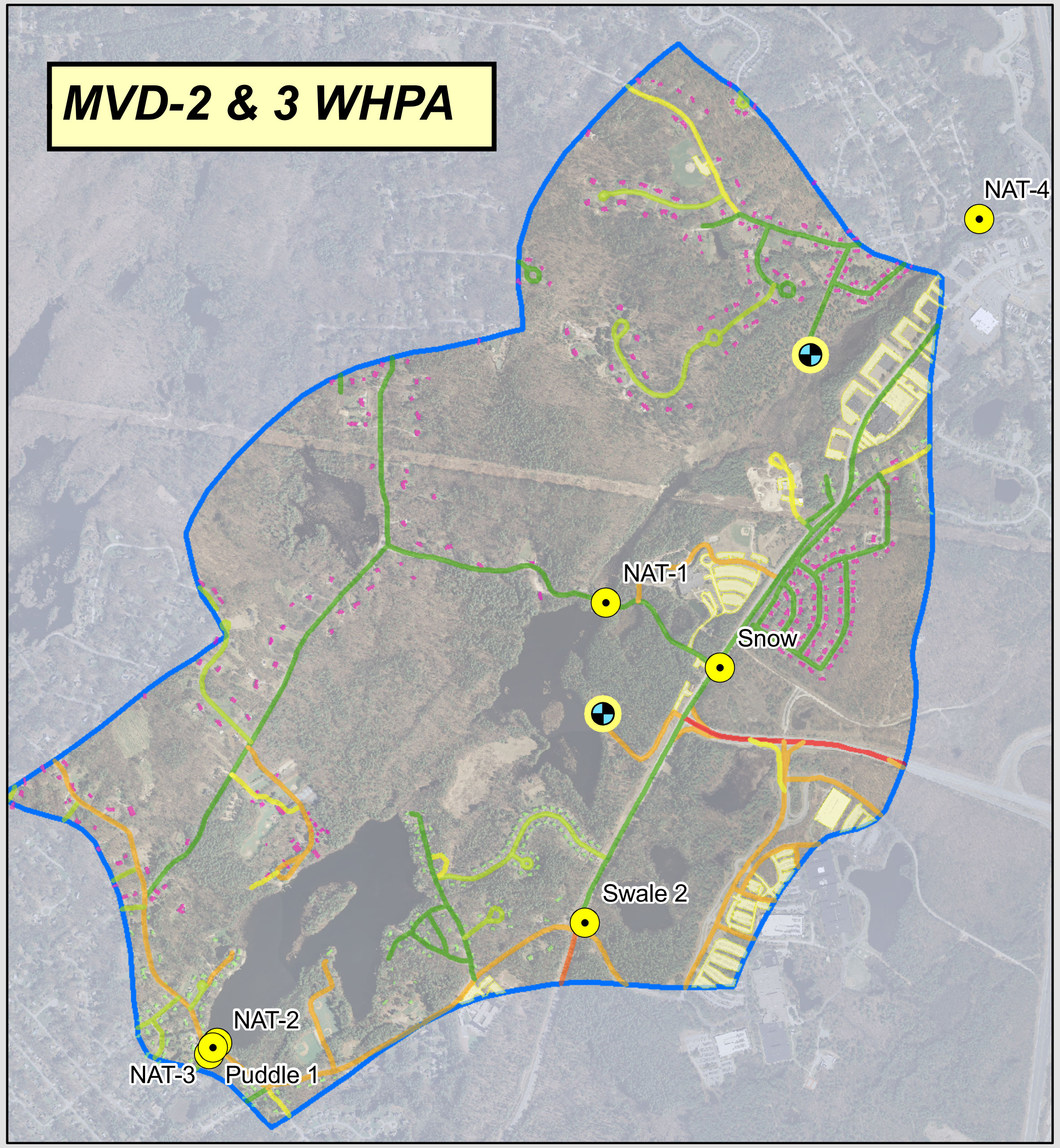


[1] The winter severity index (WSI) is a measure of the intensity of the winter used by the NHDOT. It is based on temperature and precipitation measured in Concord, New Hampshire.

[2] The years on the x-axis correspond to the first year of a winter. For example, the points on the graph at year 2002 represent salt applied from Fall 2002 to the Spring of 2003.

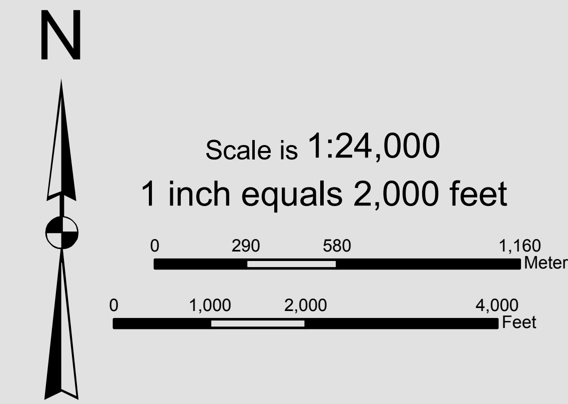
FIGURE 5

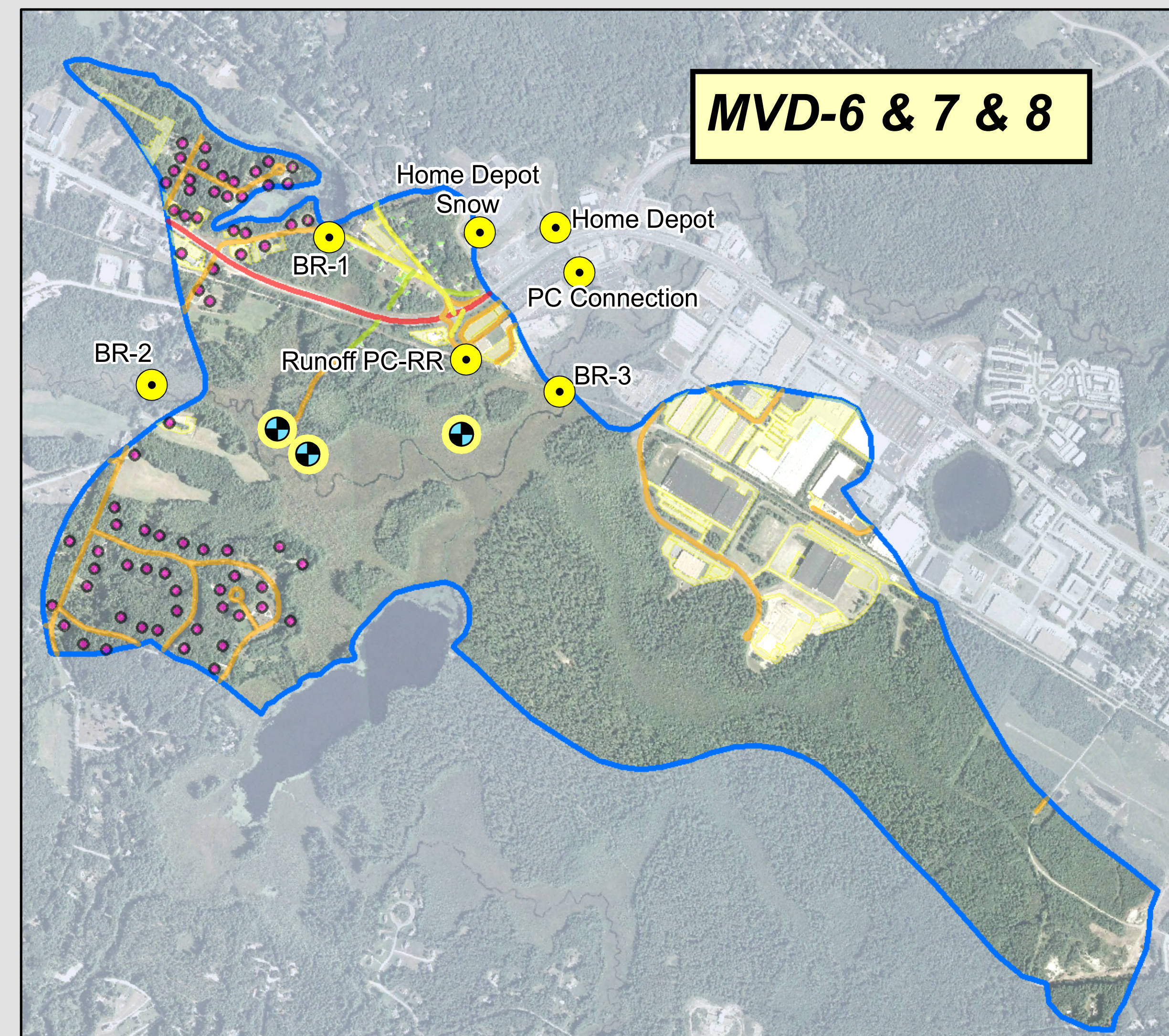
Conductivity, Sodium and Chloride
Surface Water Measurement Locations
Merrimack, New Hampshire

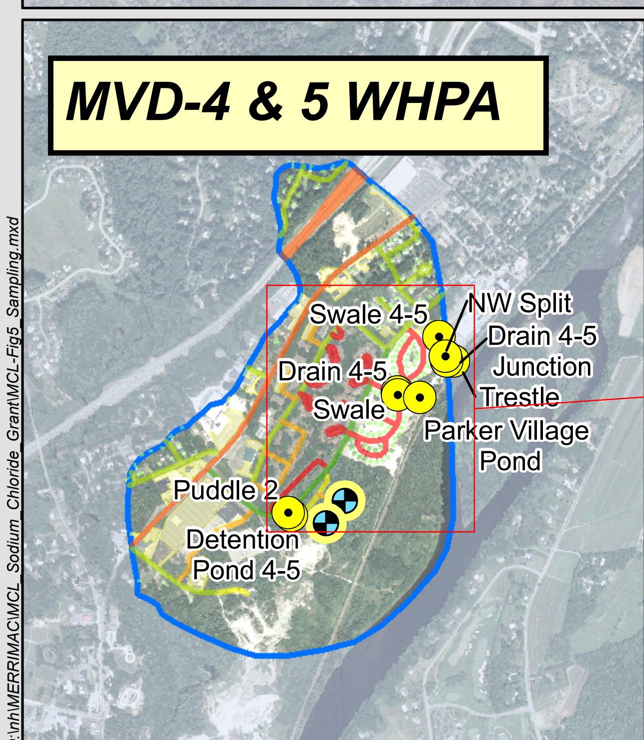


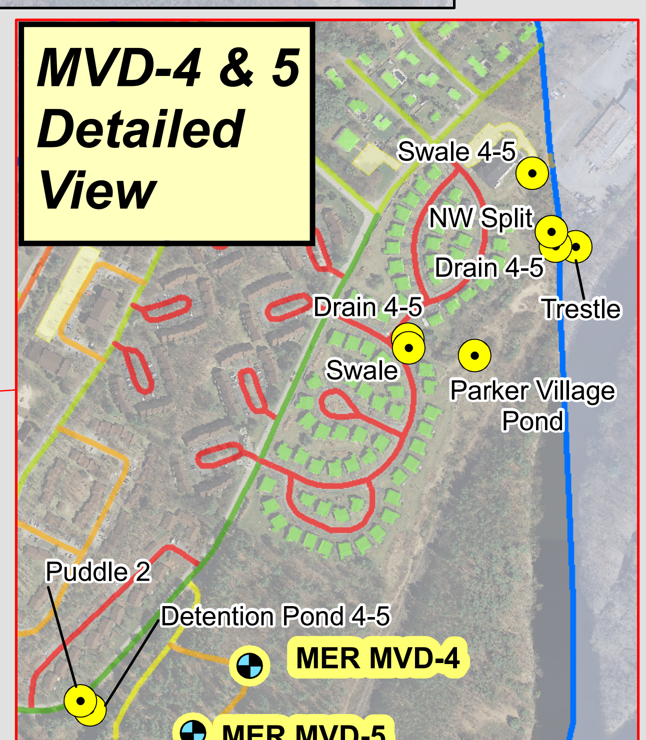
Annual Road Salt Application (Tons/Mile)

- 2- 4
- 4 - 6.5
- 6.5 - 12
- 12 - 20
- 20 - 37
- 37 - 60
- 60 - 104
- MVD-4 *MVD Production Well*
- Sample Point
- Buildings *Private Well & Septic*
- MVD Designated WHPA
- Merrimack Houses *Served by Public Water and Onsite Septic*
- Merrimack Houses *Public Water & Sewer*
- Parking Lots









O:\nh\MERRIMAC\MCL_Sodium_Chloride_Grant\MCL-Fig5_Sampling.mxd

Emery & Garrett Groundwater, Inc. **FIGURE 5**

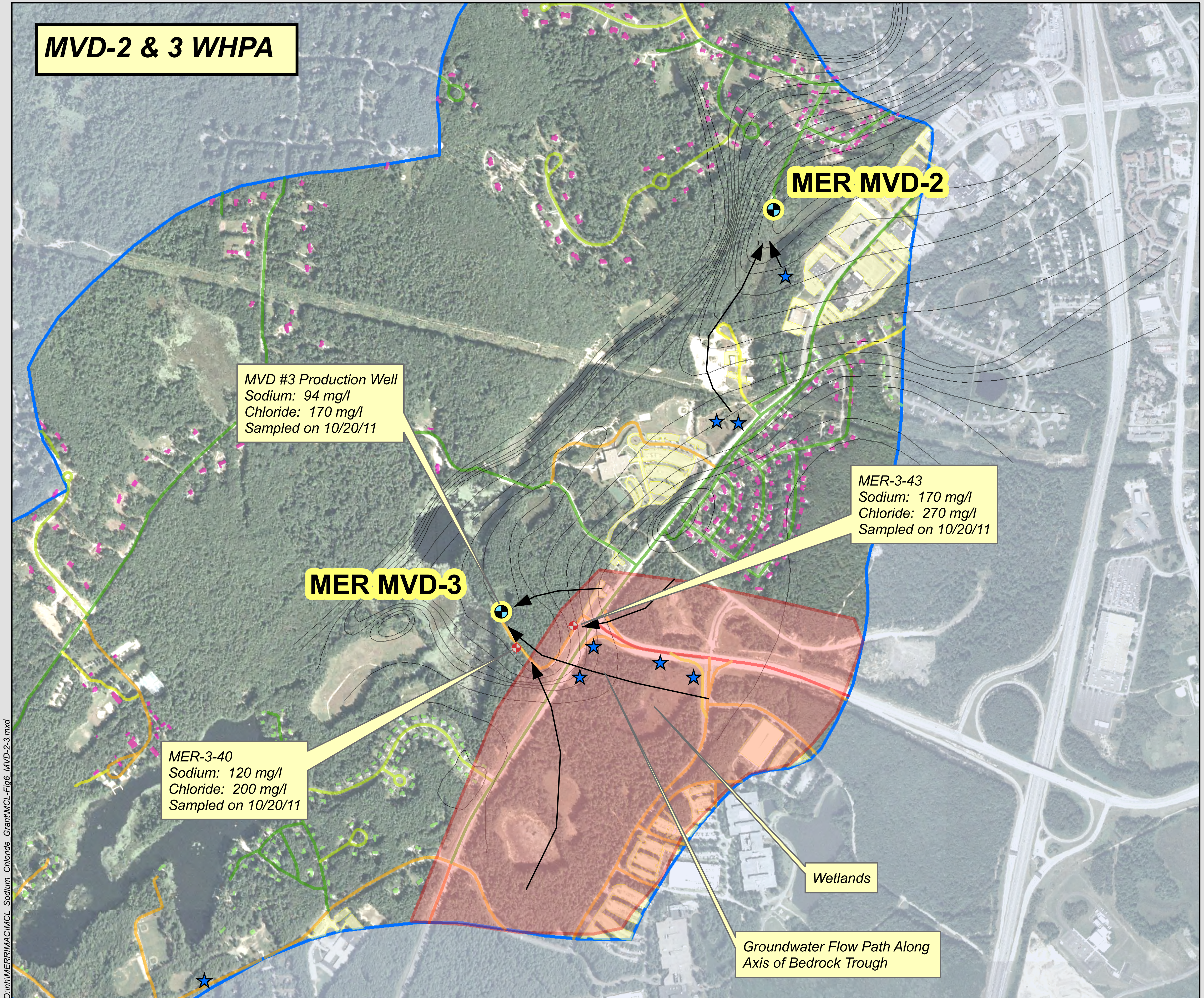


FIGURE 6

Critical Salt Loading Areas in the MVD-2-3 WHPA
Merrimack, New Hampshire

Legend

Annual Road Salt Application (Tons/Mile)

- 2- 4
- 4 - 6.5
- 6.5 - 12
- 12 - 20
- 20 - 37
- 37 - 60
- 60 - 104
- MER-3-40 *MVD Monitoring Well*
- Groundwater Flow Paths
- MVD-4 *MVD Production Well*
- Areas of Substantial NaCl Concentrations
- *Critical Area* *Where Reductions in Sodium Chloride Must Occur*
- Aquifer Bottom Contour
- Merrimack Houses *Served by Public Water and Onsite Septic*
- Merrimack Houses *Public Water & Sewer*
- Parking Lots

N

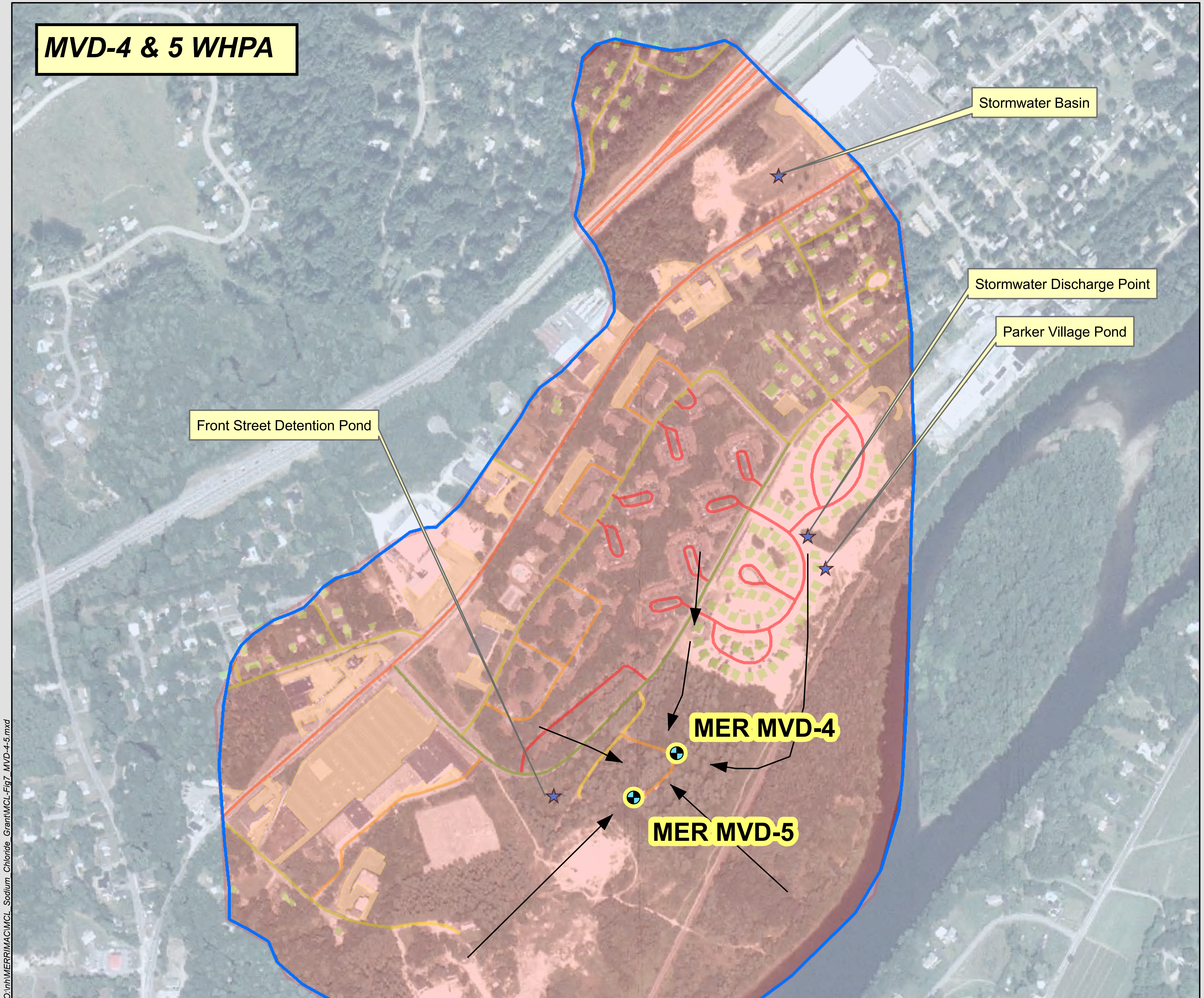
1:12,000
1 inch equals 1,000 feet

0 125 250 500 750 1,000 Meters

0 375 750 1,500 2,250 3,000 Feet

FIGURE 7

Critical Salt Loading Areas in the MVD-4-5 WHPA
Merrimack, New Hampshire



Legend

Annual Road Salt Application (Tons/Mile)

- 2- 4
- 4 - 6.5
- 6.5 - 12
- 12 - 20
- 20 - 37
- 37 - 60
- 60 - 104
- Groundwater Flow Paths
- MVD-4 *MVD Production Well*
- Areas of Substantial NaCl Concentrations
- *Critical Area* *Where Reductions in Sodium Chloride Must Occur*
- Merrimack Houses *Served by Public Water and Onsite Septic*
- Merrimack Houses *Public Water & Sewer*
- Parking Lots

N

1:6,000
1 inch equals 500 feet

0 62.5 125 250 375 500 Meters

0 200 400 800 1,200 1,600 Feet

O:\nh\MERRIMAC\MCL_Sodium_Chloride_Grant\MCL-Fig7_MVD-4-5.mxd

Emery & Garrett Groundwater, Inc. **FIGURE 7**

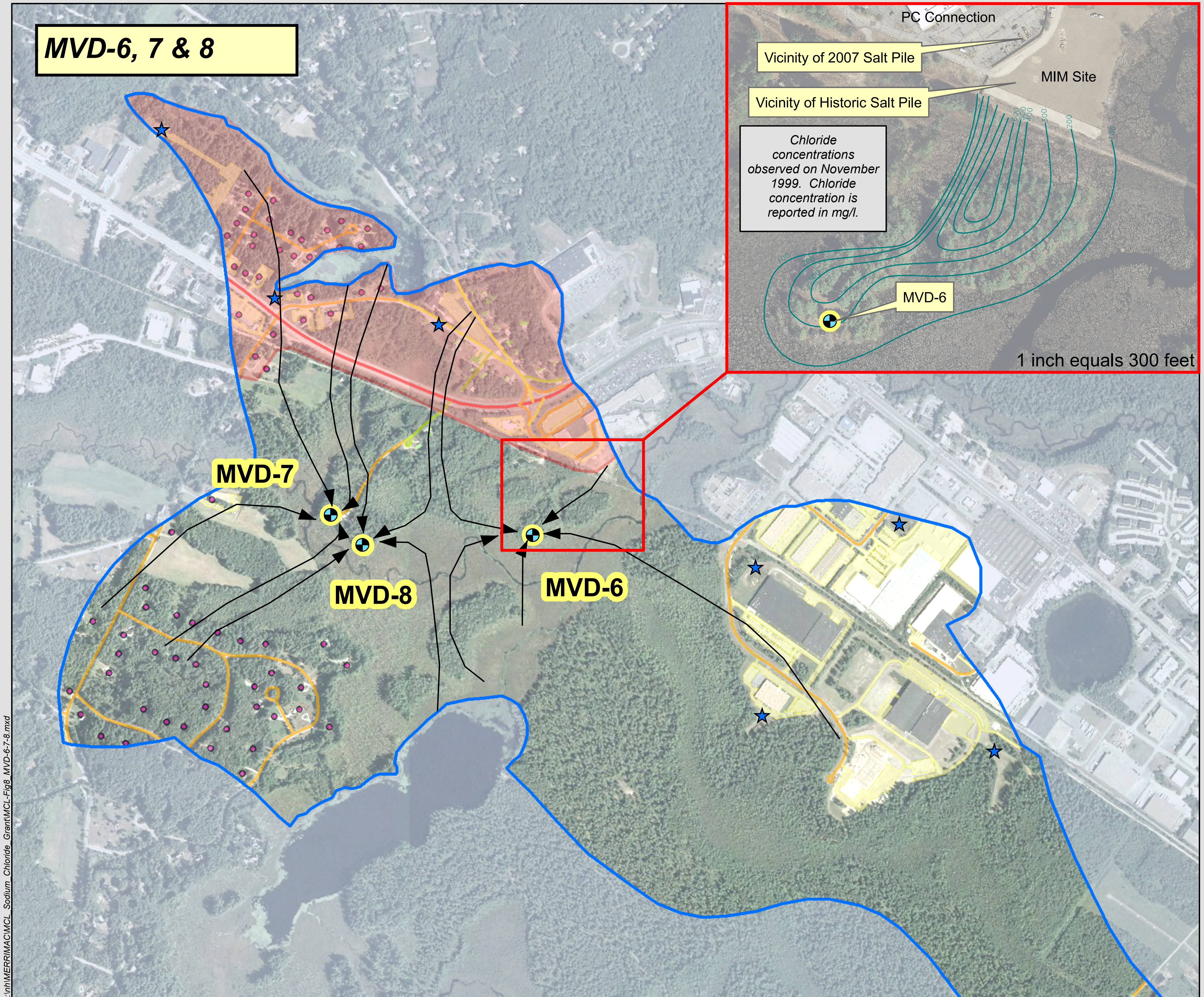


FIGURE 8

Critical Salt Loading Areas in the MVD-6-7-8 WHPA
Merrimack, New Hampshire

Legend

Annual Road Salt Application (Tons/Mile)

- 2- 4
- 4 - 6.5
- 6.5 - 12
- 12 - 20
- 20 - 37
- 37 - 60
- 60 - 104

Groundwater Flow Paths

MVD-4 *MVD Production Well*

Areas of Substantial NaCl Concentrations

Critical Area

Where Reductions in Sodium Chloride Must Occur

Merrimack Houses *Served by Public Water and Onsite Septic*

Merrimack Houses *Public Water & Sewer*

Parking Lots

N

1:12,000

1 inch equals 1,000 feet

0 125 250 500 750 1,000 Meters

0 375 750 1,500 2,250 3,000 Feet

O:\nh\MERRIMAC\MCL_Sodium_Chloride_Grant\MCL-Fig8_MVD-6-7-8.mxd

Emery & Garrett Groundwater, Inc. **FIGURE 8**

TABLES

TABLE I
Sodium Chloride Loading Estimates for Each WHPA
Salt Loading Study
Merrimack, New Hampshire

		Tons of Salt Loaded Annually in WHPA											
WHPA	**Area (acres)**	**Roads**	**%**	**Parking Lots**	**%**	**Driveways**	**%**	**Septic**	**%**	**Atmospheric Deposition**	**%**	**Total Tons**	**Tons per Acre**
MER-2-3	1,744	275	54%	212	41%	15.55	3.0%	7.70	1.5%	3.11	0.6%	513	**0.29**
MER-4-5	263	216	53%	169	41%	22.93	5.6%	0.00	0.0%	0.47	0.1%	408	**1.55**
MER-6-7-8	1,017	222	43%	291	56%	0.92	0.2%	5.86	1.1%	1.81	0.3%	522	**0.51**

TABLE II

Monitoring Locations Sodium and Chloride Results

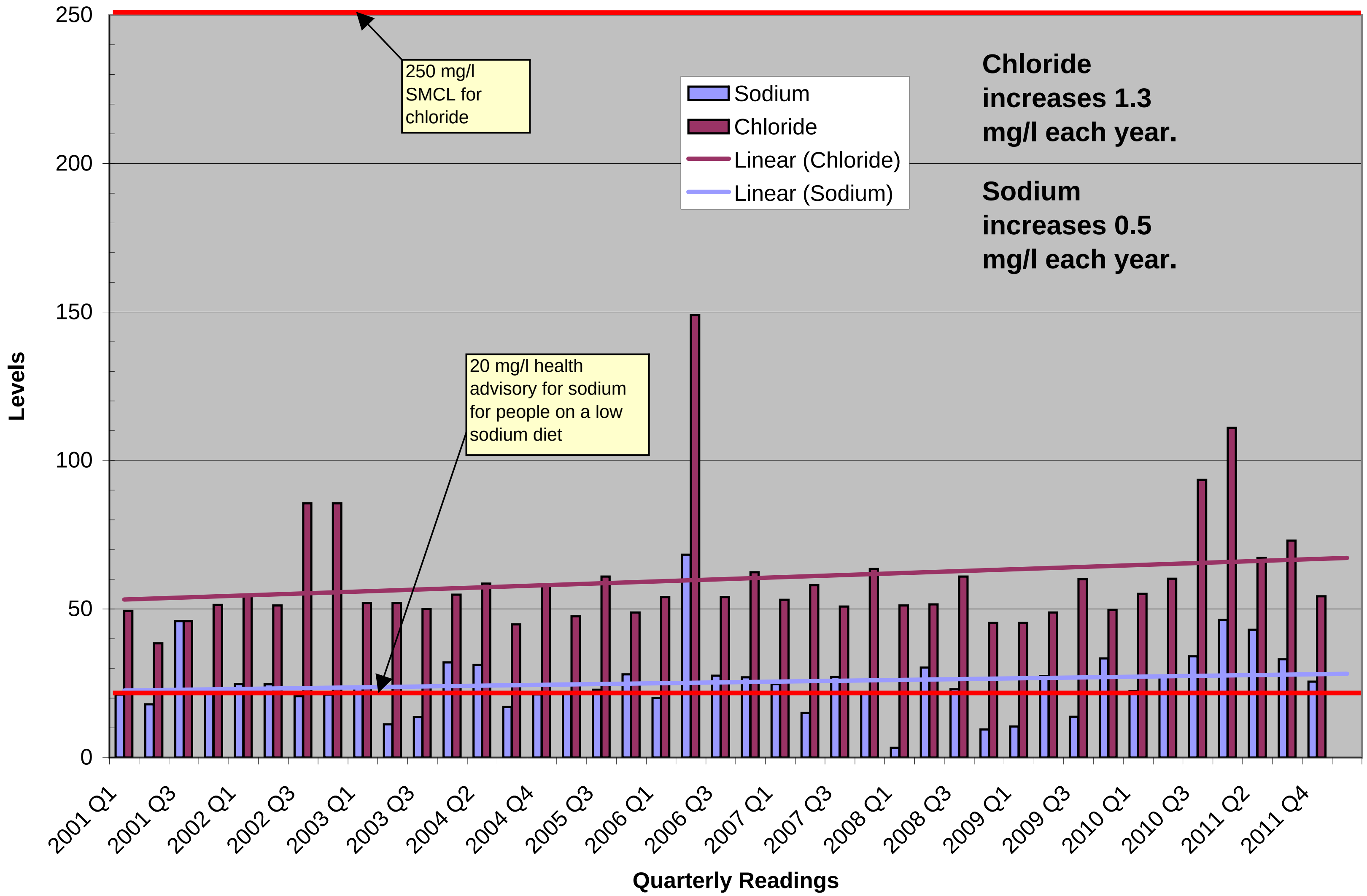
Salt Loading Study
Merrimack, New Hampshire

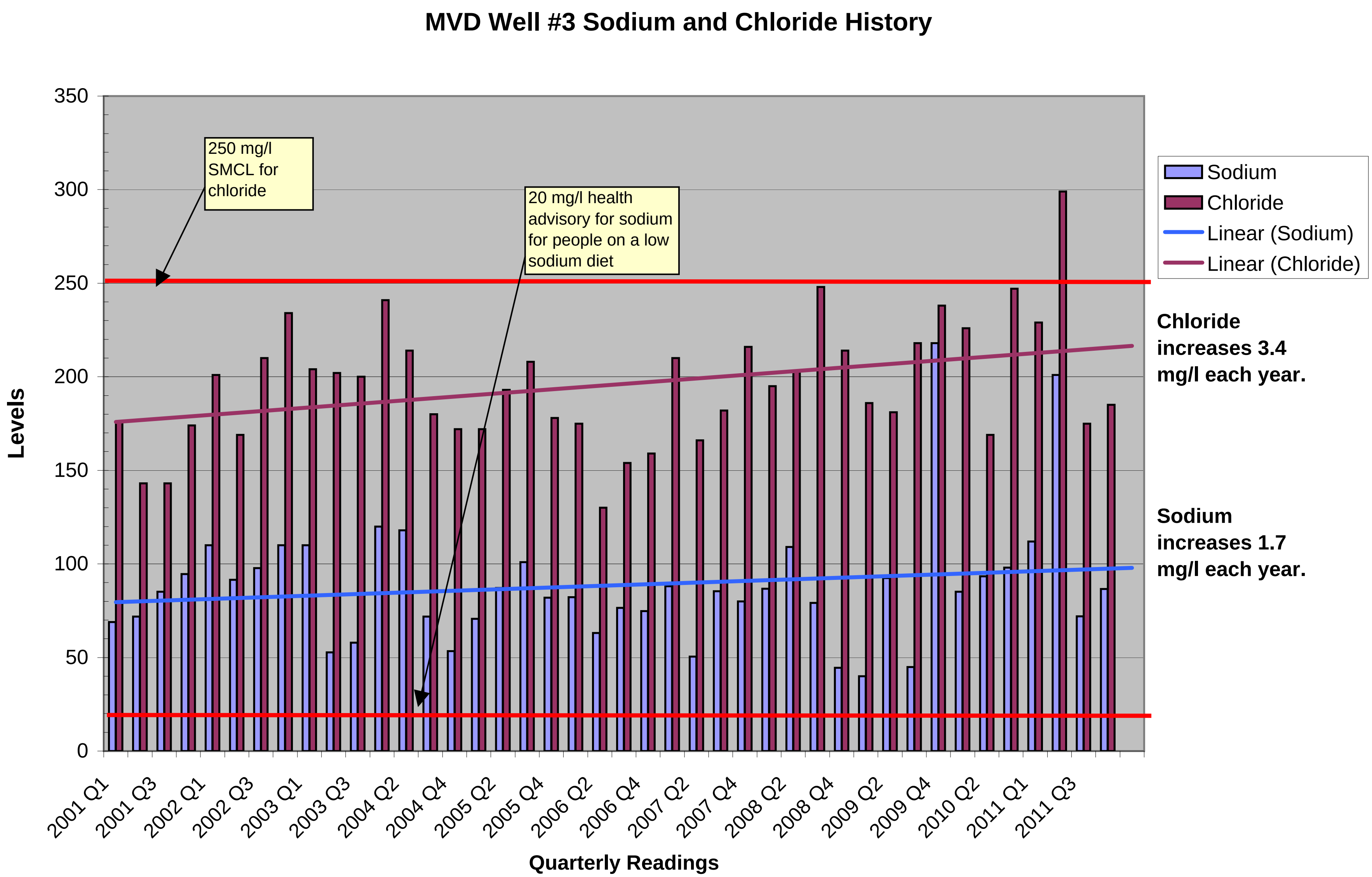
Monitoring Location	Date of Sampling	Estimated Discharge / Flow (gallons per minute)	Temperature (degrees C)	Specific Conductance (microsiemens)	Laboratory		Calculated	
					Sodium (mg/l)	Chloride (mg/l)	Sodium (mg/l)	Chloride (mg/l)
MVD Well #2 & #3 WHPA								
NAT-1	3/11/2012	2500	2.0	161.2	17	30	19	32
"	5/13/2011	250	19.2	316	--	--	44	74
"	8/31/2011	20	22.0	216	--	--	28	47
"	3/9/2012	1500	7.8	279	--	--	38	64
NAT-2	3/11/2012	None	5.8	165	--	--	20	33
"	5/13/2011	None	19.7	215	--	--	28	47
"	8/31/2011	None	23.6	202	--	--	26	43
"	3/9/2012	None	6.7	78.9	--	--	6	10
NAT-3	3/11/2012	None	4.8	108	--	--	10	18
"	5/13/2011	None	14.5	47.2	--	--	1	1
"	8/31/2011	None	19.6	58	--	--	2	4
"	3/9/2012	None	13.5	45	--	--	0	1
NAT-4	3/11/2012	500	0.5	154	17	30	18	30
"	5/13/2011	300	15.1	233	--	--	31	52
"	8/31/2011	Dry	--	--	--	--	--	--
"	3/9/2012	2000	7.0	257	--	--	35	58
Swale 2	3/11/2011	75	1.2	326	48	74	46	77
Snow	3/11/2012	None	0.1	30	4	5	-2	-3
Puddle 1	3/9/2012	3	4.8	265	--	--	36	61
MVD Well #4 & #5 WHPA								
Detention Pond 4-5	3/11/12	35	6.3	56.4	7	12	2	4
"	5/13/11	None	19.1	78.4	--	--	6	10
"	8/31/11	Dry	--	--	--	--	--	--
"	3/9/12	30	11.2	165	--	--	20	33
Swale 4-5	3/11/12	10	5.2	1314	210	350	207	345
"	5/13/11	2	10.2	503	--	--	75	125
"	8/31/11	1	17.5	465	--	--	69	115
"	3/9/12	60	8.9	330	--	--	47	78
Drain 4-5	3/11/12	100	4.4	72.6	10	16	5	8
"	5/13/11	15	10.9	656	--	--	100	167
"	8/31/11	10	17.7	428	--	--	63	105
"	3/9/12	60	9.8	326	--	--	46	77
Swale	3/9/12	1	11.0	2820	--	--	452	754
Parker Village Pond	3/9/12	None	13.0	3080	--	--	495	825
Drain 4-5 Junction	3/9/12	60	9.8	326	--	--	46	77
Trestle	3/9/12	70	10.7	551	--	--	83	138
NW Split	3/9/12	25	10.5	624	--	--	95	158
MVD Well #6, #7, & #8 WHPA								
BR-1	3/11/12	1500	0.5	216	28	48	28	47
"	5/13/11	> 1000	18.6	235	--	--	31	52
"	8/31/11	600	23.1	156	--	--	18	31
"	3/9/12	1000	4.2	208	--	--	27	45
BR-2	3/11/12	>> 1000	0.2	114	12	21	11	20
"	5/13/11	> 1000	17.2	170	--	--	21	35
"	8/31/11	> 1000	19.9	139	--	--	16	26
"	3/9/12	>> 1000	8.0	160	--	--	19	32
BR-3	3/11/12	>> 1000	0.8	127	--	--	14	23
"	5/13/11	>> 1000	17.5	158	13	21	19	31
"	8/31/11	>> 1000	21.5	133	--	--	15	25
"	3/9/12	>> 1000	7.1	146	--	--	17	28
Home Depot	3/11/12	175	1.8	166	14	24	20	34
"	5/13/11	20	16.9	349	--	--	50	83
"	8/31/11	25	19.4	173	--	--	21	36
"	3/9/12	150	5.6	202	--	--	26	43
Home Depot Snow	3/9/12	--	--	747	--	--	115	191
PC Connection	3/11/12	--	3.8	326	34	64	46	77
"	5/13/11	1	22.1	579	--	--	87	146
"	8/31/11	--	19.2	470	--	--	69	116
"	3/9/12	50	7.0	257	--	--	35	58
Runoff PC-RR	3/9/12	1	--	423	--	--	62	103

APPENDIX A

SODIUM AND CHLORIDE HISTORY

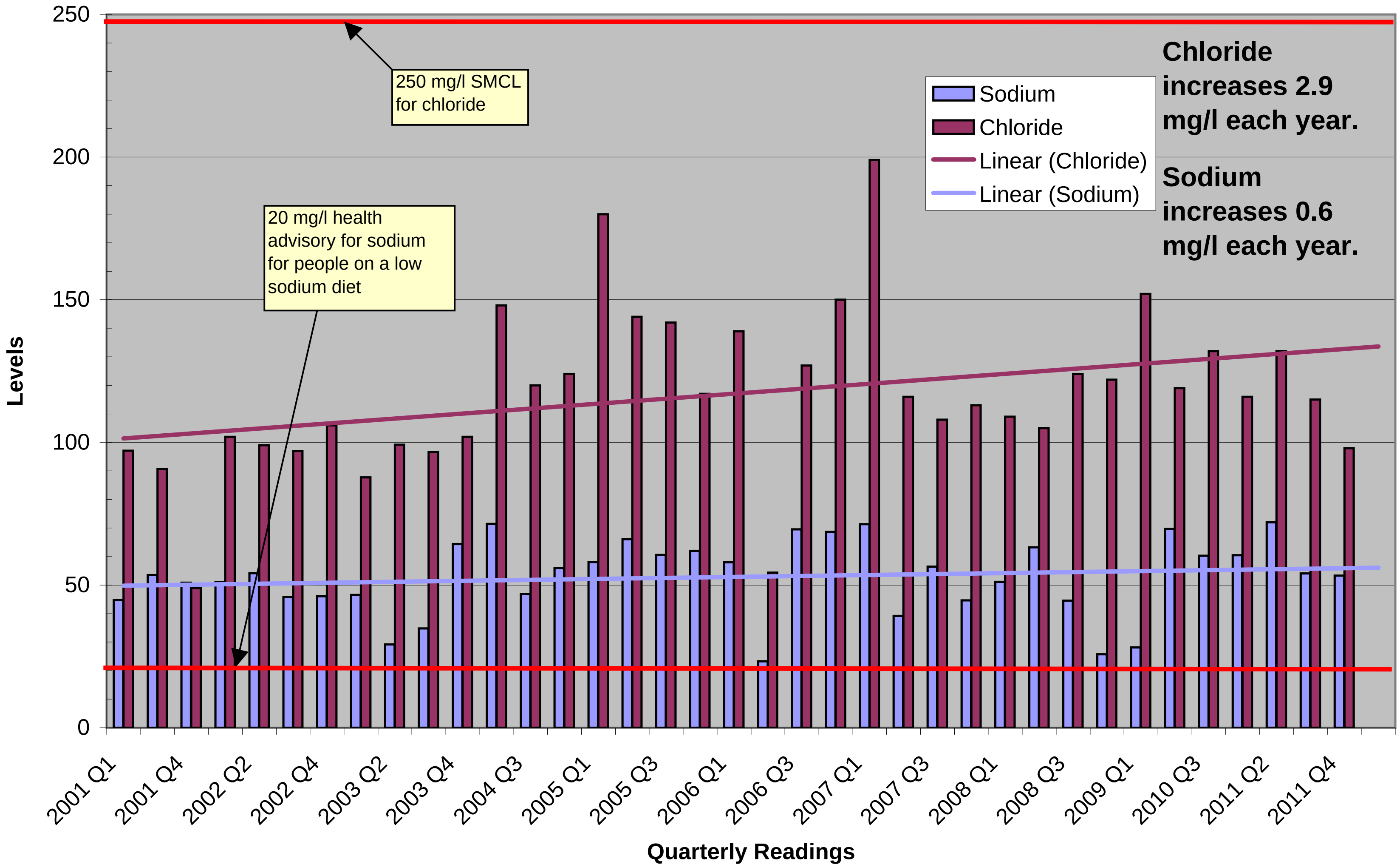
MVD Well #2 Sodium and Chloride History

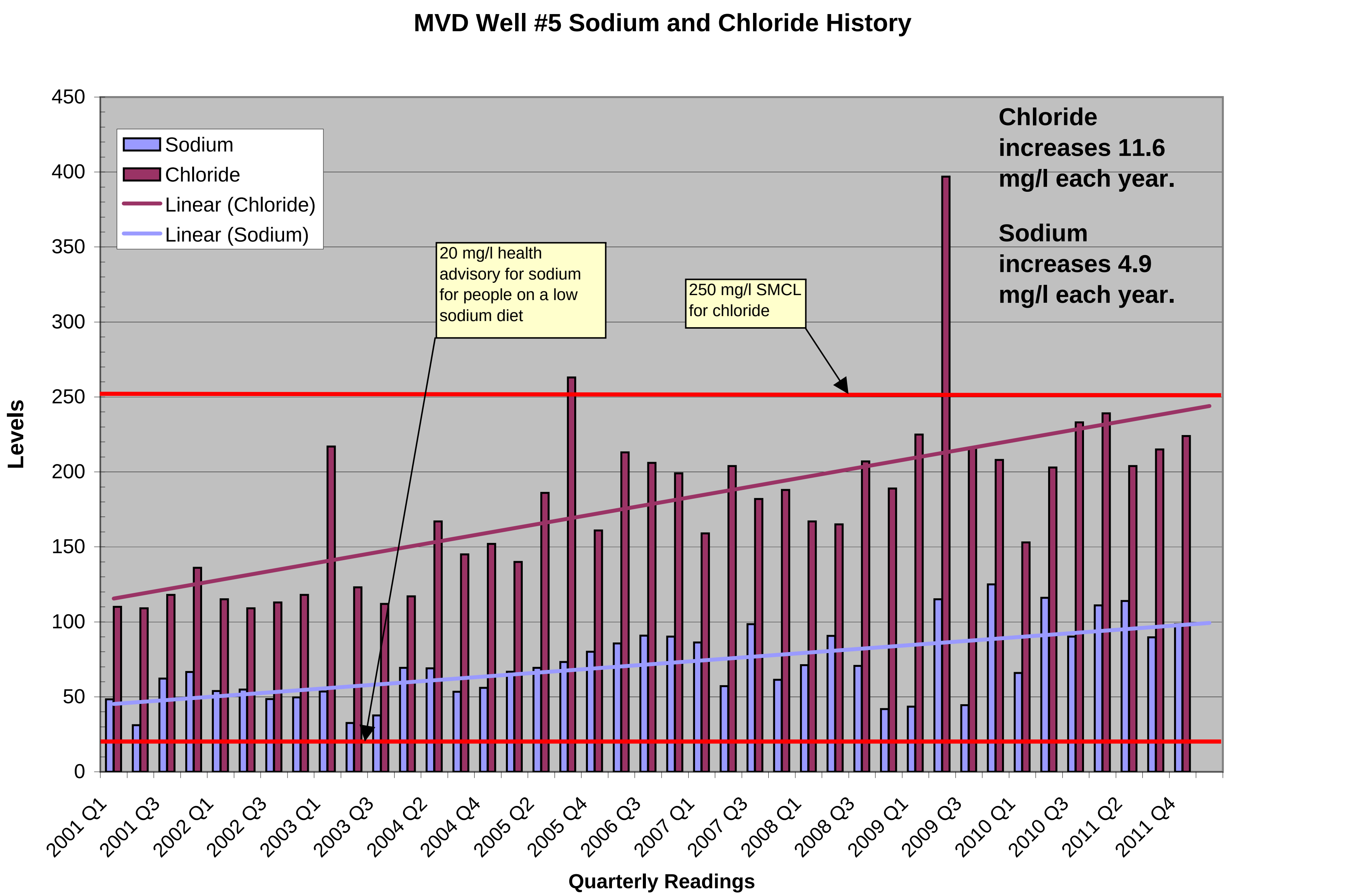




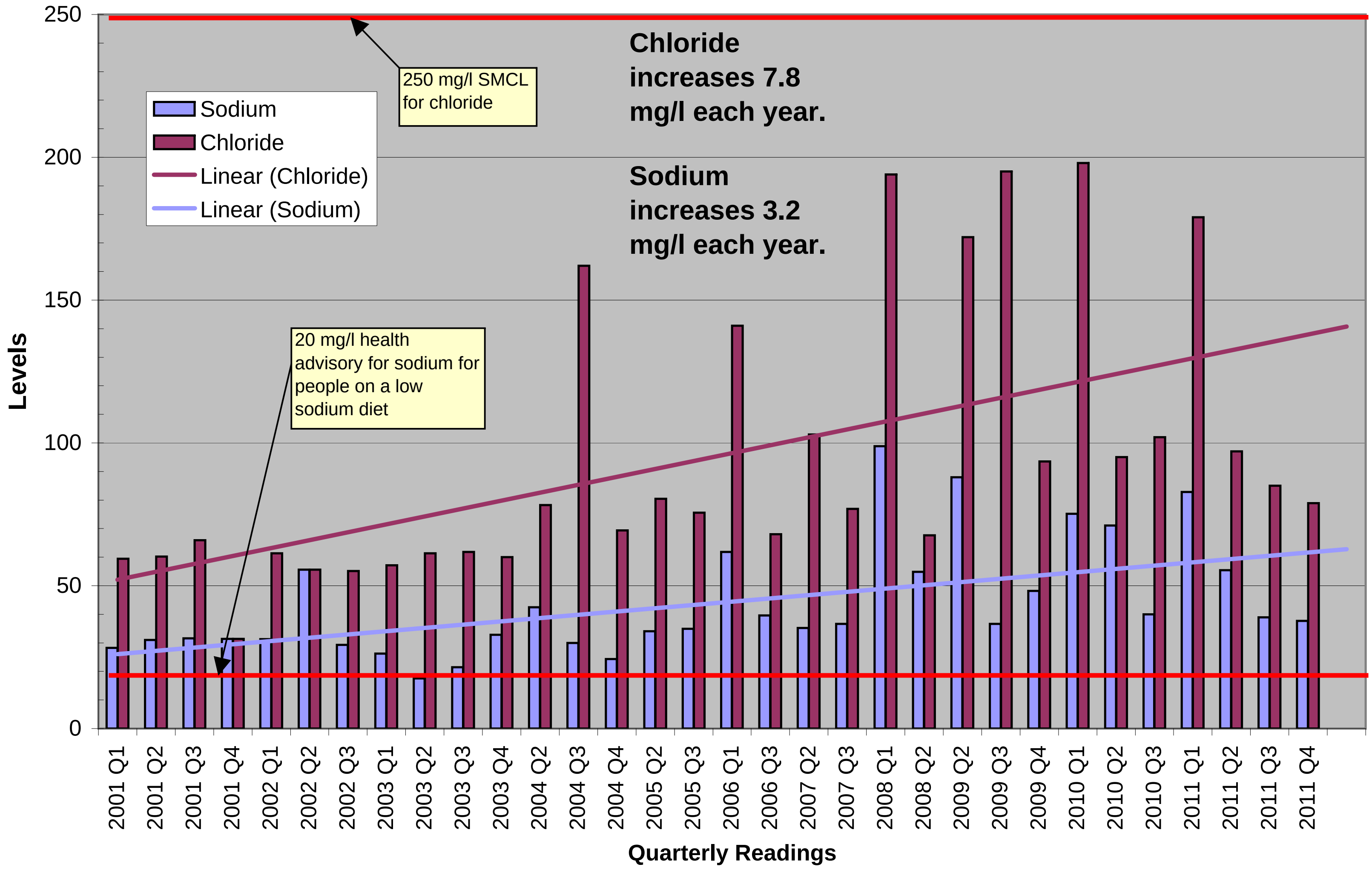
MVD Well #3 Sodium and Chloride History
350
300
250
200
150
100
50
0
Levels
250 mg/l SMCL for chloride
20 mg/l health advisory for sodium for people on a low sodium diet
Sodium
Chloride
Linear (Sodium)
Linear (Chloride)
Chloride increases 3.4 mg/l each year.
Sodium increases 1.7 mg/l each year.
2001 Q1
2001 Q3
2002 Q1
2002 Q3
2003 Q1
2003 Q3
2004 Q2
2004 Q4
2005 Q2
2005 Q4
2006 Q2
2006 Q4
2007 Q2
2007 Q4
2008 Q2
2008 Q4
2009 Q2
2009 Q4
2010 Q2
2011 Q1
2011 Q3
Quarterly Readings

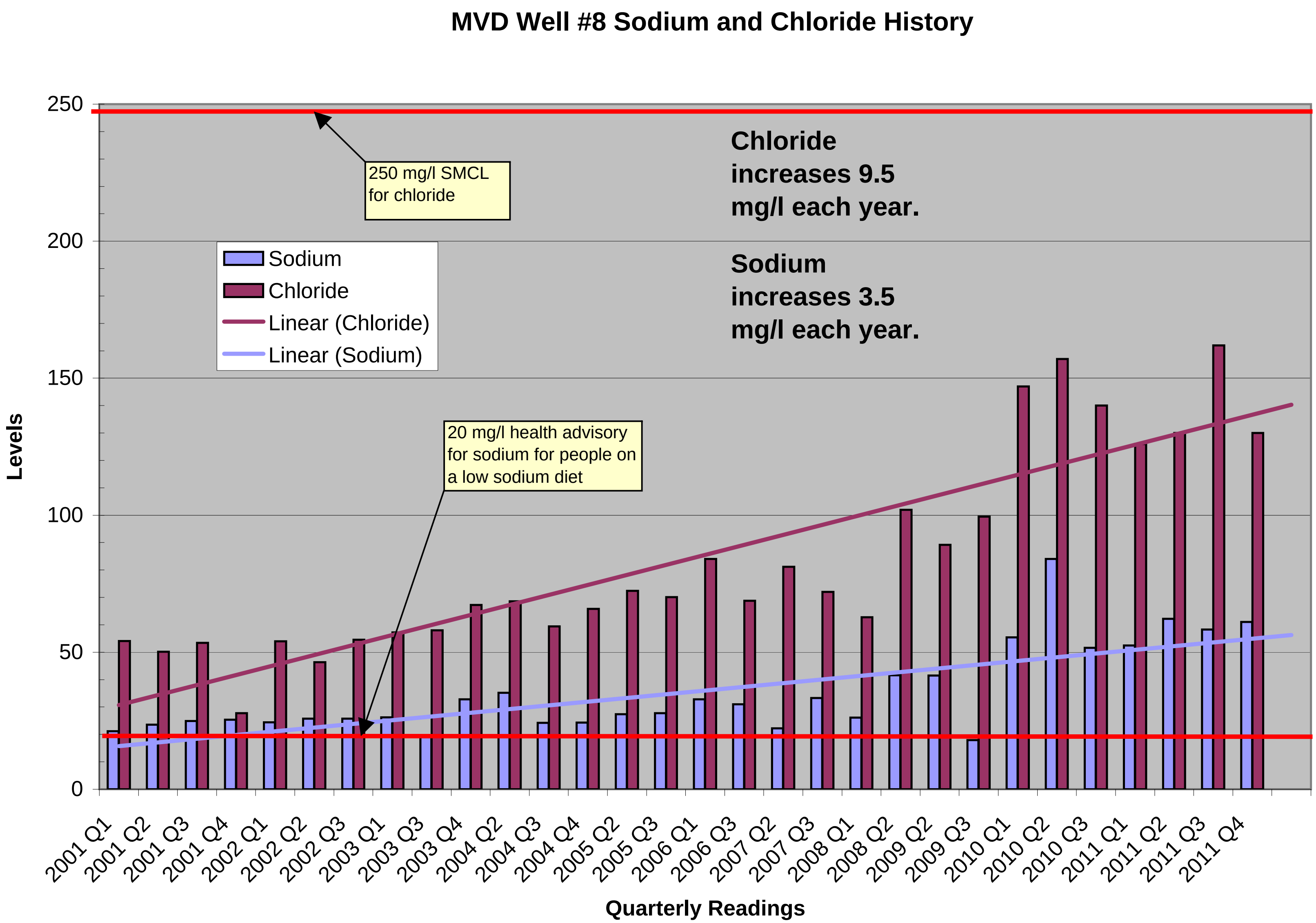
MVD Well #4 Sodium and Chloride History




MVD Well #5 Sodium and Chloride History
Levels
450
400
350
300
250
200
150
100
50
0
Sodium
Chloride
Linear (Chloride)
Linear (Sodium)
20 mg/l health advisory for sodium for people on a low sodium diet
250 mg/l SMCL for chloride
Chloride increases 11.6 mg/l each year.
Sodium increases 4.9 mg/l each year.
2001 Q1
2001 Q3
2002 Q1
2002 Q3
2003 Q1
2003 Q3
2004 Q2
2004 Q4
2005 Q2
2005 Q4
2006 Q3
2007 Q1
2007 Q3
2008 Q1
2008 Q3
2009 Q1
2009 Q3
2010 Q1
2010 Q3
2011 Q2
2011 Q4
Quarterly Readings

MVD Well #7 Sodium and Chloride History




MVD Well #8 Sodium and Chloride History
Levels
250
200
150
100
50
0
250 mg/l SMCL
for chloride
Chloride
increases 9.5
mg/l each year.
Sodium
increases 3.5
mg/l each year.
Sodium
Chloride
Linear (Chloride)
Linear (Sodium)
20 mg/l health advisory
for sodium for people on
a low sodium diet
2001 Q1
2001 Q2
2001 Q3
2001 Q4
2002 Q1
2002 Q2
2002 Q3
2003 Q1
2003 Q3
2003 Q4
2004 Q2
2004 Q3
2004 Q4
2005 Q2
2005 Q3
2006 Q1
2006 Q3
2007 Q2
2007 Q3
2008 Q1
2008 Q2
2009 Q2
2009 Q3
2010 Q1
2010 Q2
2010 Q3
2011 Q1
2011 Q2
2011 Q3
2011 Q4
Quarterly Readings

<u>APPENDIX B</u>

SODIUM CHLORIDE MITIGATION PLAN

Emery & Garrett Groundwater, Inc.
56 Main Street • P.O. Box 1578
Meredith, New Hampshire 03253
(603) 279-4425 www.eggi.com Fax (603) 279-8717

SODIUM CHLORIDE MITIGATION PLAN
MERRIMACK, NEW HAMPSHIRE

HILLSBOROUGH COUNTY, NEW HAMPSHIRE
May 2012

I. INTRODUCTION / BACKGROUND

The Merrimack Village Water District (MVD) relies exclusively on groundwater to supply nearly 1 billion gallons of water annually to over 9,300 connections in the Town of Merrimack, New Hampshire. Seven high-yield wells owned and operated by the MVD provide groundwater from glacial stratified drift deposits located in and around the Town of Merrimack. Over the years, sodium and chloride levels have increased in many of the MVD production wells. To determine the source(s) of the sodium and chloride, the MVD applied for a Local Source Water Protection Grant from the New Hampshire Department of Environmental Services (NHDES). This grant has been used to evaluate the salt loading in the Wellhead Protection Areas (WHPAs) that surround the MVD Production Wells and to develop this Mitigation Plan.

Sodium chloride is the most common deicing agent used in the State of New Hampshire because of its low cost and effectiveness (other agents melt ice at lower temperatures, but cost more). Demand for clear roads during or immediately after snow and ice events has led to increasing volumes of deicing material being applied to roadways. As the percentage of a watershed that is covered with roads, sidewalks, and parking lots increases, the amount of deicing material applied within the watershed also increases. Sodium and chloride readily dissolve in water and do not degrade in the environment like some other contaminants.

The NHDES adopted a Secondary Maximum Contaminant Level (SMCL) for chloride of 250 mg/l and 100-250 mg/l for sodium. The U.S. Environmental Protection Agency established a Drinking Water Advisory for sodium between 30 mg/l and 60 mg/l, based on taste thresholds. A Health Guidance Level for people on low-sodium diets is set for 20 mg/l for sodium in drinking water by the EPA. *Two of the MVD's Production Wells have met or exceeded the NHDES SMCL for chloride. All of the MVD Production Wells have occasionally, if not repeatedly, exceeded the EPA Drinking Water Advisory for sodium, and all of the MVD Production Wells exceed the EPA Health Guidance Level for sodium. Furthermore, four of the six Production Wells currently in use show clear trends of increasing sodium and chloride levels.*

This Mitigation Plan, if fully implemented, is designed to minimize the sodium and chloride loading in each of the three MVD WHPAs and to ultimately reduce the levels of sodium and chloride in the MVD Production Wells. The most effective way to improve water quality in the WHPAs is to eliminate the use of salt as a deicing product; however human safety and economic concerns make this option impractical. Therefore, a combination of methods to reduce salt use within each WHPA is proposed in this Plan. Successful implementation of this Plan will require partnerships and cooperation between both the public and private sector. This would include the Town of Merrimack and State governments / agencies and, of course, the citizens residing within the Town of Merrimack. Table 1 outlines the proposed mitigation measures, key stakeholders involved, and a proposed timeframe for implementation.

II. PRE-CONSTRUCTION and PROJECT DESIGN

A. Minimize New Pavement and Walkways

One of ways to reduce the amount of deicing materials applied within the WHPAs is to minimize the area that requires treatment – in other words, minimize the amount of pavement and concrete subject to winter maintenance. The best protection for an aquifer is to conserve as much land as possible in the WHPA. If development is going to occur within the WHPA, the developer and the Planning Board should work together during the planning and design phase to minimize the amount of impervious cover that will have be maintained in winter.

Action Items are presented throughout this document in ***bold italics*** and are summarized in Table 1:

> ***Action Item #1:* MVD should provide input on groundwater protection issues to the 2012 Master Plan Steering Committee with an emphasis on preserving open space and minimizing the construction of new impervious surfaces within each WHPA that will be maintained in winter.**

> ***Action Item #2*: The Planning Board, in conjunction with the Community Development Department, should review and revise the Merrimack Subdivision Regulations to remove regulatory roadblocks to reducing the amount of treated surfaces[1] required for new construction. In particular, parking space requirements represent an area where considerable reductions in new treated surfaces can be achieved.**

> ***Action Item #3*: The developer / architect should design buildings and grounds to minimize the total area of surfaces to be treated with sodium and chloride. The Planning Board should review plans with the goal of limiting new treated surfaces.**

[1] The term 'treated surfaces' collectively refers to impervious pavement and concrete roads, parking lots, driveways, sidewalks and outside stairs that are treated with deicing chemicals.

B. Direct Drains / Runoff to Reduce Icing

Snowmelt occurring during warm days produces runoff that can refreeze on treated surfaces when the temperature drops at night. Design of buildings and grounds should consider where snowmelt from roofs and snow piles would travel. Roofs, sidewalks, roads, parking lots, and drains should be designed such that runoff is directed away from treated surfaces to minimize the need for repeated treatment with deicing chemicals during freeze-thaw cycles.

Action Item #4: ***The developer / architect should design buildings and grounds to prevent runoff from repeatedly refreezing on treated surfaces. The Planning Board should review plans with this consideration in mind.***

C. Situate Treated Surfaces To Receive Direct Winter Sunlight Exposure

Sidewalks and pavement exposed to direct sunlight in winter require less deicing material than areas that remain shaded. Evaporation of snowmelt occurs more quickly in direct sunlight, resulting in dry pavement sooner and less refreezing. In fact, tree clearing along State and Local roads has taken place to effectively reduce the amount of deicing material applied along previously shaded roadways.

Action Item #5: ***The developer / architect should design buildings and grounds to maximize exposure of treated surfaces to winter sunlight. The Planning Board should review plans with this consideration in mind.***

D. Separate Foot Traffic from Parking Areas

Most parking lots in use today combine foot traffic and car traffic together in the same place. Out of concern for lawsuits from slips and falls, heavy salt applications often occurs over large portions of the parking areas to make pavement clear as soon as possible for pedestrians. New parking lots should be designed to separate foot traffic from vehicular traffic, providing for better pedestrian safety and allowing for different levels of winter maintenance (i.e., pavement would not need to be “black” after a winter storm simply for vehicular traffic).

Action Item #6: ***The developer / architect should design parking lots to separate foot traffic from vehicular traffic. The Planning Board should review plans with this consideration in mind.***

III. PRIVATE PARKING LOTS AND SIDEWALKS

A. Encourage voluntary training and certification for operators[2] and property managers to track trends in the use of deicing products

Deicing of private parking lots, sidewalks, and roads contributes a large portion of the sodium chloride loaded into each MVD WHPA. Significant reductions in salt use on privately maintained surfaces can be achieved through training and education of operators and property managers in the best practices of winter maintenance. The UNH Technology Transfer Center developed a "Green SnowPro Certification"[3] course to educate people on salt minimization techniques.

<u>Action Item #7:</u> MVD should compile a list of private property managers that maintain large areas of parking lots, roads, and sidewalks in each WHPA. MVD should contact the property managers to inform them about the sodium and chloride problem in each WHPA and encourage them (and or the plow operators) to participile in the Green SnowPro Certification program (or similar training programs).

<u>Action Item #8:</u> MVD should develop an outreach program (starting with a presentation / forum) to discuss the benefits and techniques of reducing salt use and why it is important from a water quality standpoint. MVD should maintain a dialog with the property managers to encourage product usage record keeping and monitor progress in salt reductions.

<u>Action Item #9:</u> MVD should add a section to its web page devoted solely to sodium and chloride reduction with links to Best Management Practices (BMP) regarding salt use and operator training.

B. Techniques to Reduce Salt Use for Private Operators

There are several innovative ways to cut salt use while still providing the same level of service to the customer. Although many of the items listed here require up-front equipment costs, people who have implemented such strategies elsewhere report net savings due to reduced materials cost (less salt applied = less material purchased), less time applying materials (time = money), and in the case of some alternate deicing products, reduced corrosion of equipment. Such items include:

- Training and certification of plow operators.
- Use of calibrated spreaders to spread deicing materials at the appropriate application rate for the conditions.
- Use of pre-wet salt – wet salt melts ice significantly faster than dry salt. A pile of salt can be pre-wet with brine prior to loading. Also, on-board brine

---

[2] The term 'operators' refers to the people directly responsible for performing winter maintenance such as plowing and application of deicing materials.
[3] See the following website for certification program details: www.t2.unh.edu/green-snowpro-certification.

tanks and spray systems can wet the salt during application (a 30% savings in materials have been reported using these techniques).

- Anti-icing – apply salt or brine to the roadway *prior* to a storm event to prevent snow and ice from adhering to the pavement. Anti-icing can be performed up to a few days before a storm during normal operating hours, minimizing overtime. Some operators report using a quarter of the material with an anti-icing approach compared to trying to remove the snow and ice off the pavement with a conventional deicing approach.
- Salt alternatives / additives – The addition of distillery by-products to conventional salt significantly lowers the effective melting temperature. Although the treated salt costs more, some operators in New Hampshire report a net savings because less material is required to perform the same job. Another side-benefit of the distillery by-products is that they inhibit rust, which can lengthen the service life (and decrease maintenance costs) of salt spreading equipment.
- Record keeping – is very difficult to gauge the effectiveness of salt reduction efforts without keeping good records on how much salt is actually applied. Tracking the use of salt can provide valuable information to operators as they determine which application techniques are most effective at the properties they maintain.

IV. PUBLIC ROADS

A. Merrimack Town Roads

The Merrimack Public Works Department maintains numerous roadways in each WHPA and understands the importance of minimizing the application of salt to protect groundwater quality. Several reduced salt or no-salt plow routes already exist in portions of the WHPAs. The Department operates 13 out of its 15 trucks with ground-control salt spreaders to accurately apply the proper amount of salt regardless of the speed of the truck. In 2011, the Department fabricated a brine-mixing tank and began experimenting with anti-icing brine applications prior to storm events. Right-of-way tree pruning / clearing activities are coordinated with PSNH to save both the Town and the utility money while increasing the winter sun exposure to local roads.

***<u>Action Item #10:</u>* The Public Works Department should review existing plow routes within each WHPA and determine whether reduced salt or no salt application areas can be expanded.**

***<u>Action Item #11:</u>* The Public Works Department should continue to refine its brine anti-icing / pre-wetting operation and expand it to all areas of the WHPAs that require salt treatment with the goal of reducing overall salt use while still providing for public safety.**

<u>Action Item #12:</u> ***The Public Works Department should proceed with its plan of contacting a local business to see if a source of "distillery-byproduct" is available for making an alternative salt additive in-house.***

Action Item #13: Perform in-house training of employees in deicing best practices on an ongoing annual basis.

B. MVD to Contact Adjoining Towns in the WHPA For MVD Wells 6, 7, 8 to Encourage Reduced Salt Use.

A significant portion of the WHPA for MVD Wells 6, 7, and 8 is located in the adjoining municipalities of Amherst, Hollis, and Nashua.

<u>Action Item #14:</u> ***MVD should contact the municipalities of Amherst, Hollis, and Nashua to encourage reduced salt application on local roads within the WHPA and to find out if any salt reduction measures have already been implemented.***

C. State Roads

The NHDOT Bureau of Turnpikes and District 5 maintain State roadways in each of the three WHPAs. After the NHDOT successfully reduced its salt use from 250 lbs per lane mile to 150 lbs per lane mile by performing anti-icing brine application, the Department will now expand its anti-icing capability with the addition of five new brine trailers. One of the new brine trailers will be assigned to the Merrimack District 5 patrol shed and will be capable of applying the 80:20 sodium chloride brine / Ice-B-Gone solution. The brine solution can be applied to roadways up to two days before a winter storm event for effective anti-icing and can be used as a salt pre-wetting agent. At the second stakeholders meeting held on March 8, 2012, the NHDOT representative indicated that the Department is open to developing Memorandums of Agreement (MOA) for reducing salt applications in sensitive areas.

<u>Action Item #15:</u> ***MVD, the Town, and NHDOT should develop a Memorandum of Agreement to establish low salt areas on the sections of Route 3, Route 101A, and Industrial Drive that are located within the WHPAs.***

D. Salt Use Tracking

In order to gauge the effectiveness of salt-use reduction strategies, it necessary to know how much salt is applied at a given location from year to year. For example, the NHDOT tracks salt use and calculates the tons/lane-mile applied each winter on a district-by-district basis. Average salt use for each winter can be compared to the winter severity index used by the NHDOT to evaluate the effectiveness of salt reduction efforts. Presently, the Merrimack Public Works Department does not have a formal system of tracking salt use. Although it is very difficult, to identify the exact salt use on any given road without costly truck-mounted GPS equipment connected to the salt spreader, the Public Works should begin to work toward that end and at least track yearly salt use on a town-wide basis. It would be ideal if salt use could be tracked on a plow route basis to obtain tons/lane mile applied each winter.

Action Item #16: ***The Merrimack Public Works Department should develop and implement a system to track winter salt use. Ideally, such a tracking system would differentiate each plow route or geographical area.***

V. PUBLIC POLICY, EDUCATION, AND OUTREACH

A. Mailings to MVD Customers

The MVD serves over 9,000 customer accounts, including residential and business connections, which comprise approximately 95% of the population of Merrimack. Regularly scheduled mailings to the customers reach numerous people and businesses within the three WHPAs.

Action Item #17: ***The MVD should include educational materials to its customers along with one of its regularly scheduled quarterly mailings. Customers should be informed about the problems associated with road salt, the need to use less salt in the winter, and inform them of reduced or low salt zones. Recommendations for home driveway and sidewalk salt use should also be included.***

B. Town-Wide Website Postings

Action Item #18: ***The Town should include a section on its website devoted to the issue of sodium chloride in groundwater and include suggestions for residents to reduce their salt use and to make them aware of low salt or no salt areas and appropriate winter driving strategies.***

C. Local Media

Press releases can serve as a cost effective means to convey information to the public. Short articles provided to local media can help tell the story of sodium chloride reduction efforts and the importance of protecting groundwater quality.

Action Item #19: ***The Town and MVD should issue periodic press releases to local media outlets on the topic of sodium and chloride reduction.***

Action Item #20: ***The MVD (or Town) could prepare a presentation on salt reduction for Merrimack public access television.***

D. Automated Signs and Permanent Signs For Low Salt Zones

When roads are newly designated low or no salt zones, automated signs should be temporarily deployed to educate motorists about the change in winter maintenance practices and to encourage appropriate driving during winter events. Reduced or no salt zones should be marked with permanent street signs.

Action Item #21: ***The NHDOT or Merrimack Public Works Department should deploy automated signs when roads are newly designated low or no salt zones to alert motorists to the change in winter maintenance policy and to encourage safe winter driving. Permanent signs should be installed for reduced or no salt zones.***

E. Perform PowerPoint / Presentations To Citizen Groups / Property Owners

The MVD should develop and prepare a presentation that can be delivered to citizens groups and property owners regarding the problem of sodium and chloride in the groundwater. Emphasis should be on defining the problem, why it matters to citizens, and what can be done to resolve the matter.

Action Item #22: ***The MVD should prepare and present an educational PowerPoint presentation on the sodium and chloride groundwater issue and present it to interested citizens groups and property owners.***

VI. EVALUATE AND MONITOR GROUNDWATER

The use of conductivity dataloggers can be a very effective tool for monitoring sodium and chloride levels in groundwater. Conductivity readings can serve as a cost-effective proxy measurement for sodium and chloride (as opposed to collecting a sample and sending it off to a laboratory). As part of the next step in refining our understanding of the distribution and movement of sodium and chloride in the aquifer, two tasks are recommended.

A. Perform Conductivity Profiling of Monitoring Well Network

A conductivity datalogger can be used to 'sound' a monitoring well to obtain foot-by-foot conductivity data for a well bore so that zones of high sodium and chloride can be detected. Such measurements can quickly be made by lowering a conductivity datalogger that is programmed to take measurements every second through the column of water in a well (only in the screened interval).

Action Item #23: ***The MVD should sound all of its monitoring wells using a conductivity datalogger to obtain conductivity profiles. This work should be performed on all wells that the MVD uses for its long-term water level monitoring program.***

B. Select Locations For Ongoing Monitoring With Conductivity Dataloggers

Based on the results of the conductivity sounding, key monitoring wells should be selected for ongoing conductivity monitoring. Such conductivity monitoring can provide valuable data to gauge the effectiveness of the sodium and chloride Mitigation Plan.

***Action Item #24:* The MVD should install conductivity dataloggers in several key monitoring wells for ongoing sodium and chloride data collection to gauge the effectiveness of salt reduction strategies.**

VII. CONCLUSION

This Mitigation Plan presents 24 specific Action Items to reduce salt use within the Merrimack Village District WHPAs and provides responsible parties / key stakeholders with a proposed timeframe for implementation. Since the public plays a crucial role (as primary user of the public roads, groundwater consumer, and taxpayers), many of the Action Items involve education and outreach to encourage public awareness and participation.

Table 1 Salt Reduction Action Items
Sodium Chloride Mitigation Plan
Merrimack, New Hampshire

Action Item	Report Section	Task	Responsible Party / Key Stakeholder	Proposed Timeframe	Estimated Cost
1	II A	Provide input on Groundwater Protection priorities to the 2012 Master Plan Steering Committee	MVD, Community Development	6 Months	Low - Staff Time
2	II A	Review and revise existing Subdivision Regulations to remove regulatory roadblocks to reducing impervious cover subject to winter maintenance activities.	Planning Board / Community Development	1 Year	Low - Board & Staff Time
3	II A	Design buildings and grounds to minimize the area that will be treated with sodium chloride.	Architect / Developer / Planning Board	Ongoing	Design Cost expected to be offset by reduced ongoing maintenance costs
4	II B	Design buildings and grounds to minimize meltwater drainage onto treated surfaces in order to prevent freeze thaw cycles requiring frequent salt treatments.	Architect / Developer / Planning Board	Ongoing	Design Cost expected to be offset by reduced ongoing maintenance costs
5	II C	Design buildings and grounds to maximize direct winter sunlight exposure to the areas that will be treated with sodium chloride.	Architect / Developer / Planning Board	Ongoing	Design Cost expected to be offset by reduced ongoing maintenance costs
6	II D	Design parking lots such that foot traffic and vehicular traffic are separated.	Architect / Developer / Planning Board	Ongoing	Design Cost expected to be offset by reduced ongoing maintenance costs
7	III A	Compile a list of property managers for major private facilities in each WHPA and inform them (at a presentation / forum) about ongoing sodium chloride issues. Recommend voluntary training and certification for winter maintenance practices.	MVD / Property Managers	12 Months	Staff Time - Nominal registration fee and operator time - cost expected to be recovered by savings in materials.
8	III A	Conduct ongoing outreach to the property managers identified in Action Item 7 to encourage record keeping to track salt use reductions.	MVD / Property Managers	Ongoing	Low - Staff Time
9	III A	Develop a web page devoted to education about salt reduction with links to best practices and training.	MVD	6 Months	Low
10	IV A	Review existing plow routes within each WHPA and determine whether reduced salt or no salt application areas can be expanded.	Merrimack Public Works Dept.	6 Months	Low - Staff Time
11	IV A	Refine brine anti-icing / pre-wetting operation and expand it to all areas of the WHPAs that require salt treatment for public safety.	Merrimack Public Works Dept.	12 Months	Low - Moderate Staff Time and Equipment Costs
12	IV A	Contact local businesses to see if a local source of “distillery-byproduct” is available for use as an alternative salt additive.	Merrimack Public Works Dept.	4 Months	Low - Staff Time
13	IV A	Perform in-house training of employees in deicing best practices on an ongoing annual basis	Merrimack Public Works Dept.	Ongoing	Low - Staff Time
14	IV B	Contact the municipalities of Amherst, Hollis, and Nashua to encourage reduced salt application on local roads within the WHPA and to find out if any salt reduction measures have already been implemented.	MVD	6 Months	Low
15	IV C	Develop a Memorandum of Agreement to establish low salt areas on the sections of Route 3, Route 101A, and Industrial Drive that are located within the WHPAs.	MVD / Town of Merrimack / NHDOT	12 Months	Low - Moderate
16	IV D	Develop and implement a system to track winter salt use. Ideally, such a tracking system would be broken down by plow route or geographical area.	Merrimack Public Works Dept.	12 Months	Low - Moderate
17	V A	Accompany regularly scheduled mailings with educational materials to inform customers about the problems associated with road salt use, the need to drive slower in the winter, reduced or low salt zones, and to provide recommendations to reduce salt use at home / business.	MVD	6 Months	Low - Moderate
18	V B	Include a section on the Town website devoted to the issue of sodium chloride in groundwater and provide suggestions for residents to reduce their salt use and to make them aware of low salt or no salt areas and appropriate winter driving strategies.	Town of Merrimack	6 Months	Low
19	V C	Issue periodic press releases to local media outlets on the topic of sodium and chloride reduction.	MVD / Town of Merrimack	Ongoing	Low
20	V C	Prepare a presentation on salt reduction for Merrimack TV.	MVD / Town of Merrimack	12 Months	Low - Moderate
21	V D	Deploy automated signs when roads are newly designated low or no salt zones to alert motorists to the change in winter maintenance policy and to encourage safe winter driving. Permanent signs should be installed for reduced or no salt zones.	Merrimack Public Works Dept. / NHDOT	Ongoing	Moderate
22	V E	Prepare and present an educational PowerPoint presentation on the sodium and chloride groundwater issue and present it to interested citizens groups and property owners.	MVD	12 Months	Low - Moderate
23	VI A	Sound monitoring wells using a conductivity datalogger to map sodium and chloride in the groundwater. This work should be performed on all wells that the MVD uses for long-term water level monitoring.	MVD	6 Months	Moderate
24	VI B	Install conductivity dataloggers in several key monitoring wells for ongoing sodium and chloride data collection to gauge the effectiveness of salt reduction strategies.	MVD	12 Months	Moderate - High

EMERY & GARRETT GROUNDWATER, INC.
56 Main Street • P.O. Box 1578
Meredith, New Hampshire 03253
www.eggi.com