Special Investigation:
Ditch 6 Water Quality

SUMMARY

Chloride levels in Ditch 6 in Andover, Minnesota have been consistently high during past routine monitoring. The purpose of this study was to investigate the cause of high chloride levels in Ditch 6. We used a network of water monitoring stations and an inventory of the watershed to identify chloride sources. Chloride contamination can come from a variety of sources including road salts, industrial wastes, failing septic systems, and certain agricultural chemicals. We found two source areas. The first was a small sod farm, where it is suspected that potassium chloride fertilizer (potash) was excessively applied in the past or is currently. The sod farm operator did not respond to communication attempts. The second source area was the Highway 9 area, which has an increased density of roads including that highly traveled highway. It is suspected that road deicing salt application in this area is responsible. With increasing urbanization, chloride levels are expected to increase. This will lead to further impairment of stream biota, but will not likely pose a serious human health threat. Recommendations for minimizing chloride entering the environment are provided.

INTRODUCTION

Water quality monitoring conducted by the Anoka Conservation District (ACD) in 1998 found higher-than-expected chloride levels in Ditch 6, as well as two other nearby waterways, Ditches 3 and 66. While the chloride levels did not exceed US Environmental Protection Agency (EPA) water quality standards, the mean of 34 mg/l was four times greater than that of minimally impacted streams in the ecoregion (8 mg/l) and three times greater than the median for Anoka County streams (11 mg/l; summer measurements). The purpose of this study was to investigate the cause of high chloride levels in Ditch 6, Andover, Minnesota.

Chloride is often used as an indicator of water quality impairment from any of a variety of sources. The most common source of chloride is from road deicing salts. Other sources include failing septic systems, wastewater treatment effluent, animal waste, potash fertilizer (KCl), and other industrial or chemical wastes. Chloride is not naturally common in the study area (Anoka Sand Plain), but in other areas can be present from certain rock types. Chloride is persistent in the environment, not being used up or broken down by chemical or biological processes. It is very mobile and can easily reach groundwater.

Chloride can harm aquatic life, and at higher doses can be a human health concern. The EPA's Chronic Freshwater Quality Citeria is 230 mg/l (US EPA 1996). Sustained at these levels aquatic life is compromised. The US EPA's Acute Freshwater Quality Criteria is 860 mg/l. Even brief fluxes to this level will harm aquatic life. Both invertebrate and fish species richness and diversity is negatively correlated with chloride concentrations (Talmage et al. 1999; Lee 2001). The Secondary Maximum Contaminant Level is 250 mg/l (US EPA 1999). Concentrations below this level are safe for drinking water.

The chloride level for minimally impacted streams in the North Central Hardwood Forest Ecoregion where the study site is located is 8 mg/l. In the Twin Cities Metropolitan Area (TCMA) stream chloride levels range from 13-120 mg/l during late summer, but can exceed 500 mg/l during snowmelt events when road salts reach streams (Fallon and Chaplin 2001). Groundwater at the water table in the TCMA has chloride concentrations ranging from 4.3-330 mg/l (Fallon and Chaplin 2001). Chloride contamination is positively correlated with impervious surface (Fallon and Chaplin 2001). Low levels of chlorides do naturally occur.

METHODS

We investigated the source and degree of high chloride levels in Ditch 6 of Andover, Minnesota. Ditch 6 is small, having a width of about 10-15 ft and mean depth of about 2 feet during baseflow near its outlet to the Rum River. The stream length is 4.18 mi. The watershed is primarily residential or undeveloped. Several highways, including Round Lake Boulevard and Constance Boulevard cross the stream with culverts, as well as a number of other paved and unpaved roads Regionally, this watershed is within the North Central Hardwoods Ecoregion and the Anoka Sand Plain.

To determine the source of high chlorides in Ditch 6 we used an extensive water monitoring network and a watershed inventory:

Water Monitoring Network

We selected 6 sites, all at road crossings, to monitoring chemical water quality in 2002 (Map 1). A total of eight grab samples were taken, four during baseflow and four during stormflow conditions from April to September. These were kept on ice until sent to an independent laboratory (Braun Intertec, Minneapolis, MN) within 24 hours for chloride (Cl), total phosphorus (TP), and total suspended solids (TSS) analysis. During sampling, a portable electronic meter (Horiba U-10) was used to take measurements of pH, conductivity, turbidity, dissolved oxygen (DO), temperature, and salinity.

At the Valley Drive monitoring station, the station nearest the outlet to the Rum River, we conducted biological monitoring of aquatic macroinvertebrates on October 21, 2002. We sampled with a "D" Frame net using the US EPA Multihabitat Method for low gradient streams. The invertebrates captured were identified to the family level, with QA/QC performed by the Volunteer Stream Monitoring Partnership housed at the University of Minnesota Water Resources Center. The resulting data were interpreted using taxa richness measures (# taxa, # EPT), a tolerance metric (Family Biotic Index), and population attribute metrics (% EPT, %Dominant Family).

Shallow groundwater monitoring for chlorides was conducted on one occasion in the second week of September 2002 (see Map 1 for locations). A small well was driven to a depth of 4.5-5 ft and a hand pump used to extract a sample. Analysis procedures were the same as for stream water samples. Three sites were attempted for this monitoring but only two were successful in obtaining a sample.

During groundwater sampling, a water sample was obtained from a pond near the Ditch's 164th Ave NW crossing. This sample was analyzed for chlorides.

Watershed Inventory

In concert with stream water quality monitoring, we inventoried landuse throughout the watershed to find possible chloride sources. We began by delineating the watershed, with the assistance of the City of Andover. Using 2001 aerial photographs we mapped all landcover to level four of the Minnesota Land Cover Classification System (MLCCS) using ArcView 3.1 software. This landcover was verified by ground-truthing.

Additionally, we conducted a review of past and current waste generators in the watershed. The list of hazardous waste generators was obtained from the Metro County Hazardous Waste Office at the Anoka County Government Center. A list of current and closed landfills was obtained from the Minnesota Pollution Control Agency.

RESULTS

Water Monitoring Network

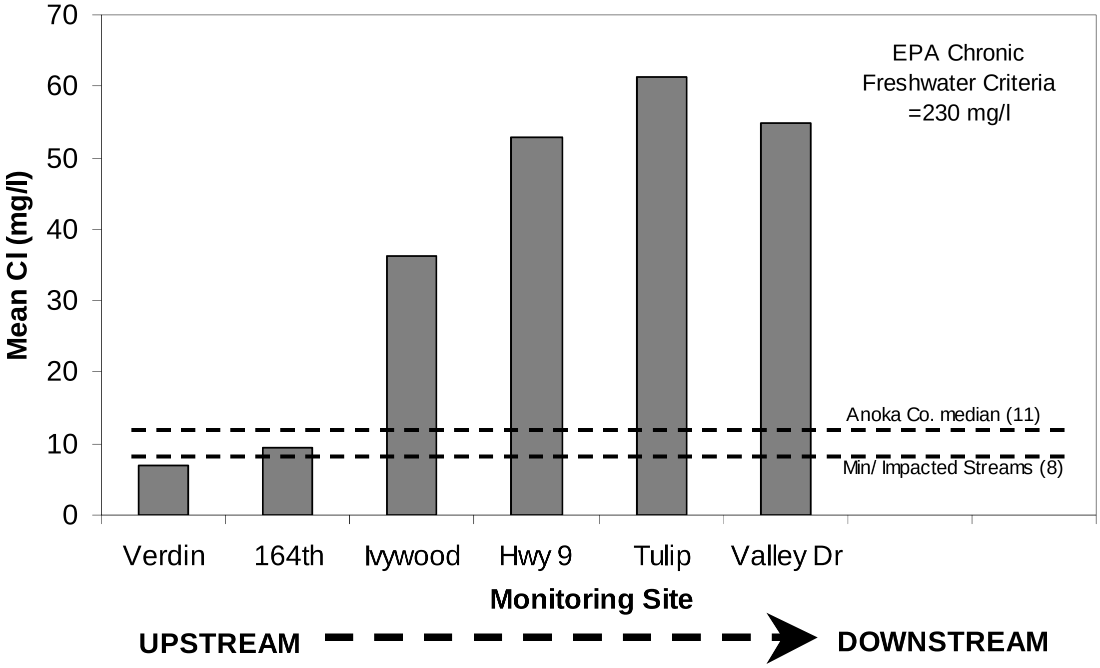
Chloride levels at the outlet of Ditch 6 to the Rum River were higher than detected during reconnaissance monitoring in 1998 (Table 4-2). The mean chloride concentration at Valley Drive was 54.88 mg/l. Chlorides during baseflow conditions were only slightly higher than during stormflow conditions, averaging 56.50 and 53.25 mg/l, respectively. Chloride did not fluctuate widely, ranging from 48-63 mg/l.

Chloride levels increased from upstream to downstream (Map 2; Fig. 4-12). At it's headwaters, the Ditch 6 has chloride concentrations about equal to that of minimally impacted streams for the ecoregion (8 mg/l). The largest increases were between 164th Avenue and Ivywood Street (27 mg/l), and Ivywood Street and Highway 9 (17 mg/l). At five of the six monitoring locations the baseflow chloride concentration was higher than for stormflow (Table 4-2).

Table 4-2. Water quality results for Ditch 6, Andover Minnesota 1998-2002.

			Means									Max	
Year	Site	Type	pH	Conductivity mS/cm	Turbidity NTU	DO mg/l	Temp C	Salinity %	TP mg/l	TSS mg/l	Cl mg/l	Cl mg/l	# samples
1998	Valley Dr	overall	7.63	0.47	8.00	8.56	17.28	0.01	0.07	8.00	34.75	38.00	4
1999	no monitoring												0
2000	169th Ln	Overall	7.40	0.47	12.69	9.05	16.14	0.01	0.07	10.38	41.00	49.00	8
		base	7.55	0.48	2.63	7.39	15.13	0.02	0.05	5.50	42.50		4
		storm	7.25	0.45	22.75	10.71	17.15	0.01	0.09	15.25	39.50		4
2001	no monitoring												0
2002	Verdin	overall	6.77	0.22	13.00	3.08	16.69	0.00	0.66	45.80	7.03	9.00	9
		base	6.83	0.29	14.25	0.44	19.88	0.01	1.04	49.75	7.00		4
		storm	6.72	2.53	12.00	5.20	14.14	0.00	0.29	30.00	7.05		5
	164th	overall	7.23	0.29	7.25	4.10	17.04	0.01	0.19	80.00	9.36	13.00	8
		base	7.18	0.26	8.00	1.60	19.13	0.01	0.20	110.00	10.75		4
		storm	7.28	0.31	6.50	6.61	14.95	0.01	0.18	20.00	7.50		4
	Ivywood	overall	7.71	0.46	6.50	8.45	16.55	0.02	0.07	6.00	36.14	42.00	8
		base	7.92	0.49	7.50	6.99	18.65	0.02	0.08	6.00	40.50		4
		storm	7.39	0.40	7.25	9.71	14.75	0.01	0.07	<5.0	30.33		4
	Hwy 9	overall	7.78	0.52	5.22	7.61	16.74	0.02	0.07	13.25	52.88	61.00	9
		base	7.87	0.56	4.50	6.10	19.33	0.02	0.08	9.50	57.25		4
		storm	7.70	0.50	5.80	8.83	14.68	0.02	0.07	17.00	48.50		5
	Tulip	overall	8.14	0.58	10.40	7.22	19.72	0.02	0.10	14.50	61.20	65.00	8
		base	8.20	0.58	10.00	6.93	20.28	0.02	0.10	11.00	60.25		4
		storm	8.03	0.57	11.00	7.81	18.60	0.02	0.09	25.00	65.00		4
	Valley Dr	overall	7.87	0.62	7.25	8.86	16.39	0.02	0.08	12.25	54.88	63.00	9
		base	8.34	0.65	3.33	8.25	18.80	0.02	0.05	6.00	56.50		4
		storm	7.59	0.60	9.60	9.35	14.46	0.02	0.10	18.50	53.25		5

Figure 4-12: Ditch 6 mean summertime chloride levels, 2002



Other water quality parameters monitored also showed trends from upstream to downstream (Table 4-2). Conductivity followed the same trend as chloride. pH also followed the chloride trend. Salinity was also higher downstream, but the salinity meter was not sensitive enough to detect small changes found in conductivity and chloride tests. Turbidity, total suspended solids, and total phosphorus were all many times higher at the headwaters at Verdin Street, where stagnant conditions often dominated, than farther downstream.

The two shallow groundwater samples successfully taken are not, by themselves enough to draw firm conclusions. At the upstream-most site, on the north side of 164th Ave, chloride was 5 mg/l. At the site on the east side of Round Lake Boulevard chloride was 33 mg/l.

Biological data indicated an impaired water body (Table 4-3). The invertebrate community was not even or rich (9 families). All families found were at least moderately pollution-tolerant. 75% of all captures were Family Hydropsychidae, a caddisfly which thrives in sub-standard waters. No pollution intolerant families were found. One indice, the Family Biotic Index, did indicate above average conditions, but considered together the biological data reflect an impaired condition.

Table 4-3: Biomonitoring results for Ditch 6, Andover, October 2002.

Order	Family	# Captures
Tricoptera (caddisflies)	Hydropsychidae	97
	Limnephilidae	11
	Phryganeidae	1
Odonata (dragonflies, damselflies)	Calopterygidae	1
	Coenagrionidae	1
Amphipoda (scuds)	Talitridae	12
Isopoda (aquatic sowbugs)	Asellidae	1
Hirundinea (leeches)		1
Gastropoda (snails)		4

Watershed Inventory

Map 3 shows landcover for the Ditch 6 watershed. About half (45%) of the watershed is built up, being used primarily for single family residential. This development occurred from 1940 to present (Map 4). The only industrial area is 26.5 acres in the southern part of the watershed just east of Round Lake Boulevard. Most of the remainder (43%) is vacant forests, shrubland, herbaceous, or woodland. More detailed data can be queried from the MLCCS landcover data upon request.

Two notable landscape features are a sod farm between 164th Ave and Ivywood Street and a large vegetable farm at the bottom of the watershed just upstream of Valley Drive. Water quality was monitored just up- and downstream of these sites. Chlorides increased markedly as water flowed through the sod farm (Jordan Turf Farms), but decreased as water flowed through the vegetable farm (Dehn Farms). The vegetable farm is partially certified organic, and operates on a low environmental impact philosophy. Multiple attempts were made to contact Jordan Turf Farms, but with no response.

Our review of waste generators in the watershed showed that only non-point source inputs of chlorides are likely at significant levels. Waste generators are not in close proximity to the ditch and are small. No closed landfills are within the watershed. A likely non-point source of chlorides is runoff of road deicing salts. Just west of Round Lake Boulevard (Highway 9) is a moderate density development. Drainage from these roads as well as Round Lake Boulevard is to Ditch 6, either directly or indirectly through shallow groundwater. Salt is applied to these roads by the county and city.

Our inventory of the watershed also included a soils (Map 5) and wetlands review (Map 6).

DISCUSSION

We identified two probable sources of chlorides entering Ditch 6. Both are diffuse, or non-point sources that enter the stream slowly through shallow groundwater or surface runoff. These two probable sources are:

1. the turf farm between 164th Lane and Ivywood Street and
2. road salt runoff from roads between 164th Lane and Tulip Street.

The first probable chloride source is from a sod farm owned by Jordan Turf Farms. Water was monitored just before it entered the farm and just after it exited. Mean chlorides increased from 9.36 to 36.14 mg/l (n=8). Potassium chloride (KCl), or muriate of potash, is the most likely chemical from a sod farm to affect stream or groundwater chloride levels. Potash is used as a potassium source in inexpensive turfgrass fertilizers. We suspect that KCl was, and perhaps still is, applied in excess. To date, attempts to contact the farm manager to verify this have been unsuccessful.

The second probable chloride source is road salts. Chloride levels remain low or even decline by dilution in stream segments that do not cross paved roads. The stream segments with the 2nd and 3rd highest chloride increases are adjacent to the most-traveled highway in the watershed, Round Lake Boulevard. Ditch 6 receives direct runoff from a considerable length (>1 mi) of Highway 9 because the road slopes consistently and steeply upward from the ditch from either direction. Roads salts can enter the stream either directly by runoff into storm drains or indirectly by infiltration into shallow groundwater which feeds the ditch.

A large portion of chlorides entering the ditch are from the shallow groundwater that feeds the ditch, not runoff. Chlorides during baseflow and stormflow were similar and consistent throughout the summer, suggesting chloride is from the shallow groundwater which consistently feeds the ditch, rather than the more periodic stormflows. In fact, chlorides were slightly higher at baseflow than at stormflow at four sites, suggesting that stormwater was more dilute in chloride than shallow groundwater.

Accumulation of chloride in shallow groundwater and slow release to waterways is common. Chlorides are soluble in water and move through the water table easily. 45-55% of road salts enter groundwater and are eventually discharged into streams as baseflow (Bowen and Hinton 1998). Infiltration rates for chlorides from agricultural sources are probably even greater because fertilizer is not applied to an impervious surface. Once present in shallow groundwater, chloride's retention time is much longer than for water (Mason et al. 1999). Chloride will increase in soils and groundwater until it reaches a steady state with applications, while continually releasing some to streams in baseflow (Mason et al. 1999). Chloride levels in the ditch were probably also dampened by the presence of numerous ditch widenings (in-line ponds).

Other studies throughout the temperate U.S. have found similar results to those documented here for Ditch 6, particularly regarding road deicing salt (Bowen and Hinton 1998, Fallon and Chaplin 2001). Stream chlorides are positively correlated with increasing urbanization and road density. Streams and groundwater just downstream of major roadways are particularly impacted. The chloride levels found in Ditch 6 are about in the middle of the range for Twin Cities Metropolitan Area streams (13-120 mg/l; Fallon and Chaplin 2001), but exceed the median value for Anoka County streams (11 mg/l). Because chlorides are closely tied to urbanization, stream chlorides can be used as an indirect measure of many effects of urbanization that degrade streams.

At this time, stream water quality is moderately degraded in Ditch 6. Chloride levels do not exceed EPA standards for drinking water or for impairment of biota. However, it is clear from biomonitoring data that macroinvertebrates are impaired, though perhaps not due entirely to chlorides. It may also be that the primary impairment occurs during spring melt events when chlorides are typically highest from road salt runoff, which was not monitored. During those times it is quite possible that chloride levels exceed standards. Fish communities are also probably impaired due to chlorides and other factors related to increasing urbanization. Deeper water supplies, such as those used for drinking and irrigation are also at risk for chloride contamination, though this was not studied. This is especially true in areas with porous soils such as those found in the study area. Water quality is likely to worsen as the area continues to develop.

RECOMMENDATIONS

No method of pre-infiltration or runoff treatment is available for chlorides. Our recommendations focus upon minimizing salt entering the environment, and upon how and where it enters. Currently the City of Andover and Anoka County Highway Departments have commendable measures in place to minimize and control salt application. Some of these include underbody plows that scrape the surface before salt application, programmable plows which allow the driver to control dispersal rate, and use of brine solutions that work quickly and do no bounce off the road. Still, each department should review their practices with respect to other agency's practices and recommendations listed below.

Our recommendations are:

- Contact Jordan Turf Farms and request that they obtain a soil test to determine fertilization rates necessary to maximize turf development while minimizing over-application. Salt-free fertilizers should also be explored as an alternative.
- Utilize measures to minimize road salt application.
    - *Ground-Speed Sensors* - Equip road deicing trucks with ground-speed sensors that control application rates (less application at slower speeds).
    - *Zero Velocity Spreaders* - Equip road deicing trucks with zero velocity spreaders. These spreaders sense truck speed and spread salt so it lands with no velocity relative to the ground. This mimimizes material bouncing off the road.
    - *Application Timing* – Apply deicers before snowfall, thereby reducing the amount of deicing material needed to melt the snow. A disadvantage of this is that if a forecasted storm does not occur deicer has been applied unnecessarily.
    - *Graduated application rates* – Adopt lower application rates for lightly traveled roads.
    - *Salt-free Areas* – Applying no salt in areas near streams and other key water bodies.
- Avoid disposing of snow from treated surfaces near water bodies.
- Sweep salt and sand from streets as soon as possible after roads are clear and dry.
- Train employees to implement the above measures.
- Consider alternative road deicers, especially a sand/salt mixture. Many chemical alternatives are much more expensive than NaCl, and have their own set of environmental concerns. We also recommend keeping abreast of innovative deicing chemicals being developed.

When considering the cost of implementing these practices, highway departments are encouraged to consider the wide benefits of these practices. The following table shows some of the seldom-considered costs of road salting (US EPA 1976). The cost of salt purchase and application is perhaps only 7% of the cost to society. Practices to reduce excess salt application yield large benefits to the community and environment.

Factor	**Explanation**	**Cost Nationwide** (1976 dollars)
Salt Purchase and Application		$200 million
Highway Structures	Corrosion damage to bridges and other highway structures.	$500 million
Vehicles	Corrosion damage hastening auto depreciation by 20%.	$2,000 million
Utilities	Corrosion to buried utilities.	$10 million
Vegetation	Damage to roadside vegetation, especially shade trees.	$50 million
Fish and Wildlife	Degradation of habitat.	not quantified
TOTAL		>$2.76 Billion/year

While the complete costs of using salt as a road deicer are great (see table above), the benefits are not always as certain. Salt hastens melting at temperatures down to about 12°F, but at lower temperatures makes snow shiny and more slippery. It also prolongs street wetness. Salt also permits faster driving, and accidents tend to be more serious. In snow people tend to drive slower and mainly have fender-benders. Therefore, any benefit of salt in reducing accidents is small. A benefit does exist for emergency vehicles, which are allowed to travel faster on salted roads.

While these recommendations are applicable to any municipality that applies road salts, they are especially important to those cities within the Lower Rum River Watershed and adjoining areas. The area is rapidly developing and because of increasing road densities road salt applications are increasing regardless of application procedures. Additionally, soils in this area are sandy and very permeable, making groundwater especially susceptible to contamination.

ACKNOWLEDGEMENTS

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