Marathon County Metropolitan Area Salt Use

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Final Report

Objectives

To combat the intense winter weather of Northern Wisconsin, road salt has been used throughout Marathon county as a cheap, effective means to melt snow and ice on roads, keeping drivers safe in potentially treacherous conditions. Recent discovery has revealed that this road salt application has potentially significant consequences on local ecosystems near roads. Our goal of this project is to find out what sensitive areas in the Marathon County Metropolitan area are impacted by road salt use.

Introduction

Despite road salts creating safe driving conditions for millions of people, this benefit coincides with a plethora of other environmental consequences that can have potentially drastic impacts on not only sensitive ecological communities, but also public health. The three most common road salt compounds all contain chlorine, an element that can have long lasting and pernicious effects when inserted in local ecosystems. For example, one New York study found that ninety-one percent of sodium chloride found in New York streams and rivers was deposited through road salt application, with forty percent of streams and rivers having chlorine levels that tested too high for many aquatic lifeforms to survive, reducing biodiversity and overall ecosystem health (Kelly et al, 2007). The negative effects of this chlorine are felt in terrestrial ecosystems as well. For example, many plant species, including grasses, mosses, and trees, are negatively affected by this chlorine. When chlorine enters these plants through root uptake, a phenomenon called browning occurs, killing much of the plants alongside roads and in low lying drainage areas near roads (MN Pollution Control Agency, 2020). Furthermore, excess salts and chlorine entering the soil column can have drastic effects on species composition and growth rates, affecting not only the plant communities, but the mammalian, reptilian, avian, amphibian, and entomological communities that reside in these areas as well. Being a Northern Mesic Forest, a transitional region between the deciduous forests of the south and the coniferous forests of the north, the Marathon County Region acts as a refuge for much of Wisconsin's notable flora and fauna. In order to protect these species, it is imperative that we understand where road salt enters the ecosystem and how to potentially mitigate its effects on population.

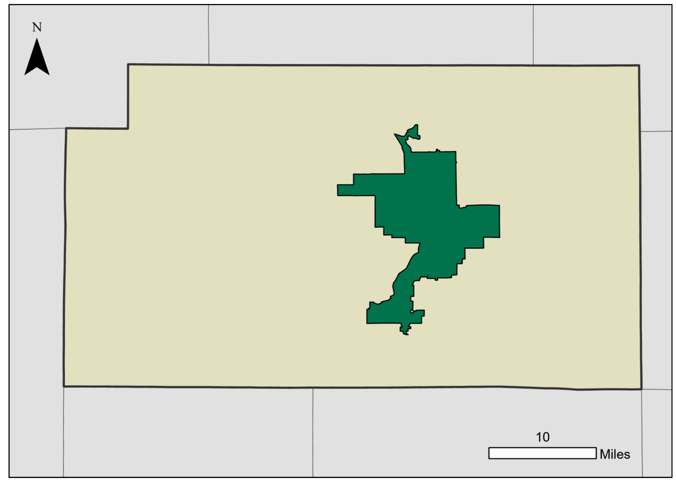


Figure 1 (left). Marathon County location in Wisconsin. Figure 2 (right). Highlighted study area within Marathon County

Ecological communities are not the only thing at risk to road salt application, however. Human health may also be at direct threat, as chlorine contamination of wellheads has become an increasingly common and pressing issue (Kaushal et al, 2005). Not only does chlorine enter the ecosystem via transfer of water above ground, It can also percolate through the soil column into underground aquifers, the source of most of the drinking water in Marathon County. Increased road salt application has consequential effects on both drinking water infrastructure and perceived human health, corroding pipes and causing seventy percent of well users to turn to alternative drinking water sources (Pieper et al, 2018).

Methodology

This project's purpose was to determine which sensitive areas are impacted by road salt use and the intensity that it is impacted. To establish this, we first had to determine and classify sensitive areas located within the Marathon County Metropolitan Area. We focused on wellheads, county parks, and state parks. The parks that were chosen to focus on were parks of significant area. These three layers were combined and classified as sensitive areas. After the sensitive areas were determined, road salt application use needed to be evaluated. This was accomplished by combining the Marathon County roads layer and our salt use data. Domain knowledge of how salt is used on roads was needed to properly create the salt use data. Finally, the sensitive areas, the digital elevation model, and the road salt application data were overlaid and analyzed to determine the impact of road salt use on sensitive areas located within the Marathon County Metropolitan Area.

Methodology: Classification of Roads

The first step in assessing the impact on an area is to identify the source of the contamination. Different levels of roads would have different amounts of salt used to prevent them from freezing to ensure the safety of driving. The higher the level of a road is, the more salt is applied. However, we cannot get the exact amount of salt that was applied to roads. Therefore, we assign roads into 3 classes to have high, medium, and low salt intensity individually. This can let us know the relative high and low salt impact on the sensitive area in the metropolitan region of Marathon county.

In our road data, we have Arterial Road, Collector Road, and many null value labels in our attribute table. After comparing the geometry with the actual roads and confirming the road types with the transportation agent of Marathon county, we know that the roads with null values contain state highways and US highways, which are considered higher-level roads compared to arterial roads and collectors roads. Thus, we set a high salt amount for roads with a null value, a medium salt amount for arterial roads, and a low salt amount for collector roads.

Methodology: Creating Drainage Basins

The salt used on roads will flow into water bodies or the ground, which will impact groundwater. In order to calculate the amount of salt that would impact a specific area, we have to identify the drainage basin for every target area. A drainage basin is an area where precipitation collects and drains into a common outlet. The drainage basin allows us to visualize the extent of the flow that drains into a single point.

When the salt seeps into groundwater, it will only affect the areas that have lower elevation. We chose to use the D8 flow method (Figure 3) on a 30-meter DEM from the Wisconsin Department of Natural Resources(WiDNR) to derive the water flow direction (Figure

4). The D8 flow method referred to the eight-direction flow model. It models the flow direction from each cell to its steepest downslope neighbor. This would allow us to know how the contaminated water will affect its surrounding area.

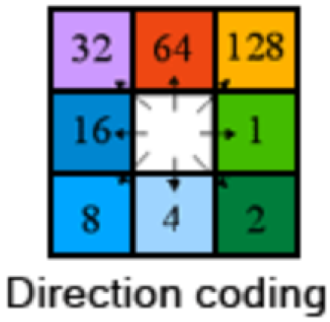


Figure 3. Eight-direction flow model.

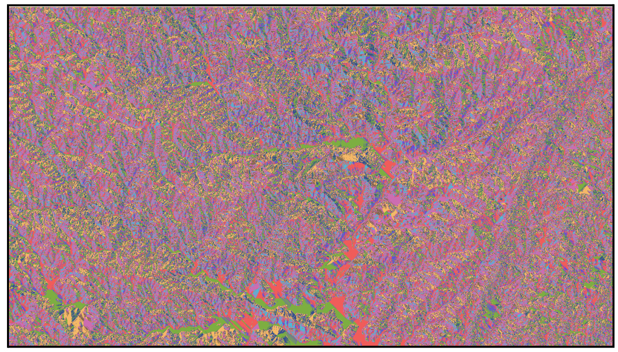


Figure 4. Waterflow direction in Marathon County.

After getting the water flow direction in Marathon county, we would be able to derive flow accumulation for the whole of Marathon county. We can also visualize the result of water flows (Figure 5).

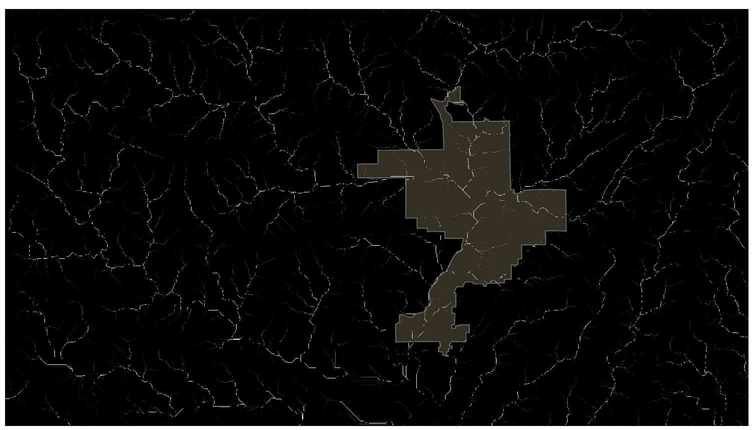


Figure 5. Visualized water flows in Marathon County.

With the data on water flows in Marathon county, we can derive a watershed for a specific point based on the model that we have acquired. The individual lowest points in each sensitive area are the point that all the water of its watershed goes in, which means that we can get the total amount of water or contamination for those sensitive areas in this way. These watersheds are the drainage basins for our sensitive areas (Figure 6).

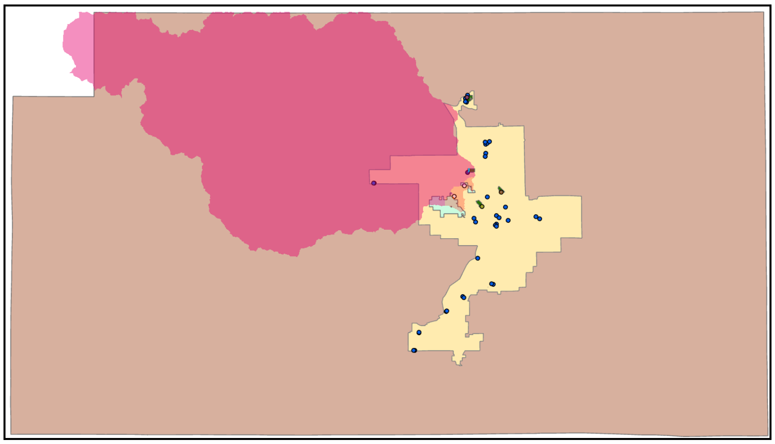


Figure 6. Lowest points and corresponding drainage basins of selected wellheads and parks.

Methodology: Calculating Salt Intensity

To assess the effect of road salt on sensitive areas, it is critical to calculate the relative salt intensity. This was computed by dividing the salt amount by the area of the sensitive area. To calculate the relative salt intensity, it is necessary to calculate the salt amount for each sensitive area. The salt amount is calculated by adding the salt intensity value of each road layer pixel located within the drainage basin. This tells us how much salt is applied as a surrogate. Each pixel was assigned a high value of three, a medium value of two, and a low value of one. Using a statistical tool, the salt amount in each sensitive area was determined.

This statistical method is called Zonal Statistics (Figure 7), it refers to a kind of statistical method in which we predefine a layer of shapes or locations for our target area combined with the other layer of values. This method will calculate a value for a specific zone. In our project, the predefined layer is the watersheds and the value layer would be our salt intensity layer, which is derived from the road layer.

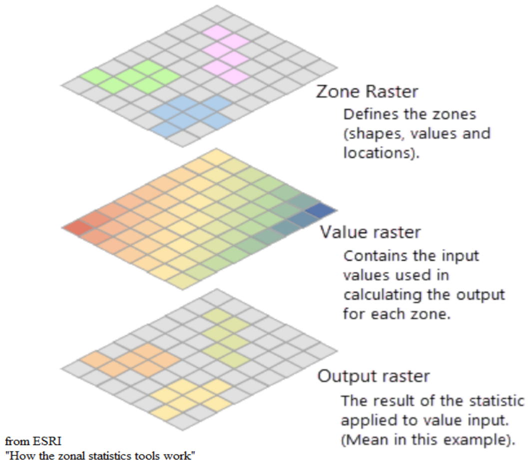


Figure 7. Zonal statistics concept.

The next step to calculate the salt intensity was to calculate each sensitive area. The data layer used for this project is a raster layer. The DEM used was a 30-meter DEM from the Wisconsin Department of Natural Resources. To calculate the area of each sensitive area, it is critical to count the number of pixels that makes up each sensitive area. Once the number of pixels is determined, to get the true area of the sensitive area, the number of pixels must be multiplied by the pixel size. In this case, the multiplication factor would be 900 (30 meters multiplied by 30 meters). Finally, the salt intensity value is computed by dividing the calculated salt amount by the area of the sensitive area. This is to be repeated for each sensitive area within Marathon County Metropolitan Area

Results

The majority of sensitive areas analyzed, 41 out of 47, were found to have no impact from road salt use. The impacted areas, four wells and two state parks, all produced drainage basins with salt intensity values less than 3%. The impacted areas are primarily in the central region of the metropolitan area and near US Highway 51, which was classified as the highest impact type of road (Figure 8). One wellhead is further north than the other impacted areas, but is still along US Highway 51. On average, the drainage basins produced for parks were much larger than those produced for wellheads, and the salt intensity values calculated for parks were also larger on average than those calculated for wellheads.

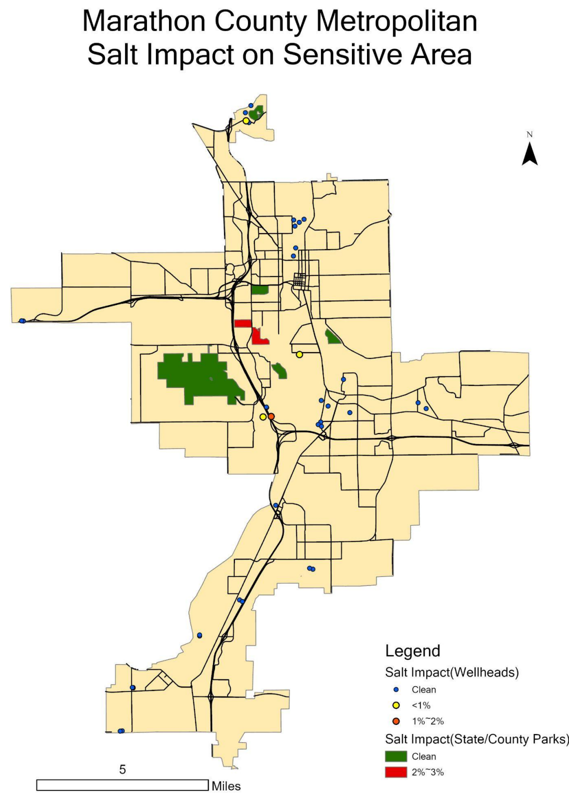


Figure 8. Impact of road salt use on sensitive areas in Marathon County Metropolitan Area.

Results: Wellheads

From the analyzed drainage basins and calculated salt intensities, it was concluded that 4 of the 37 wellheads were impacted by road salt use. Most wellheads were calculated to have salt intensities of zero, but four had larger salt intensity values, ranging from 0.03% to 1.20% (Figure 10). The low salt intensity values may be due to the generally low, flat area the wellheads are located on, thus producing small drainage basins with little to no overlap with roads.

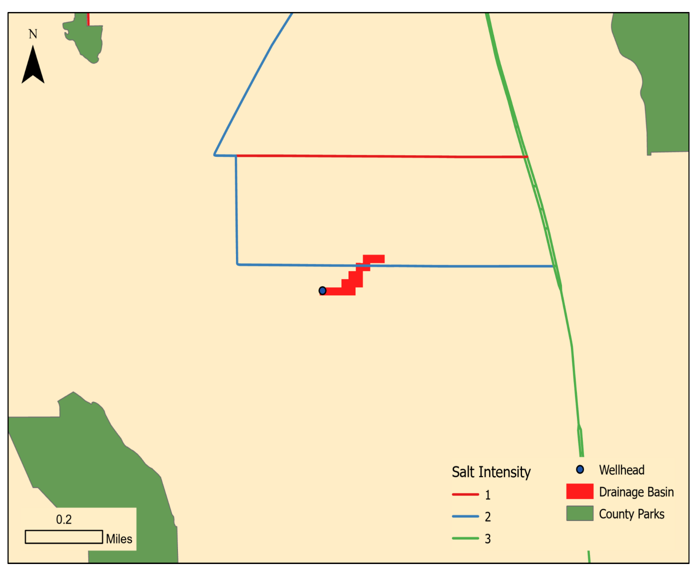
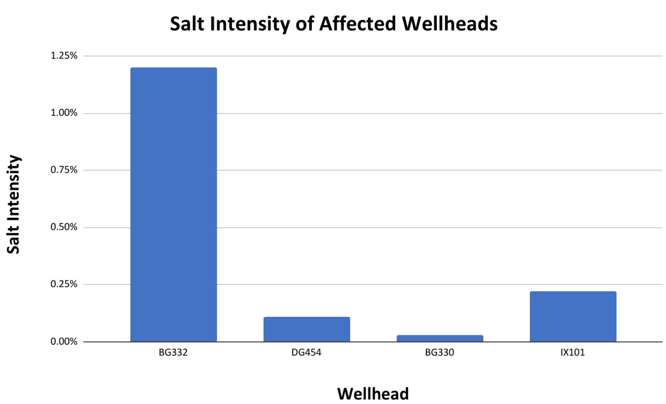


Figure 9. Drainage basin for wellhead BG330.

Wellhead BG330 is one of the impacted wellheads and is located in the center of the metropolitan area in a flat area at low elevation. The wellhead produced a relatively small drainage basin with a size of 15 pixels that was intersected by an arterial road (assigned a medium impact in salt intensity calculation) (Figure 9). These factors combine to produce a small, but non-zero salt intensity value and a conclusion that this wellhead is affected by road salt use to some degree.



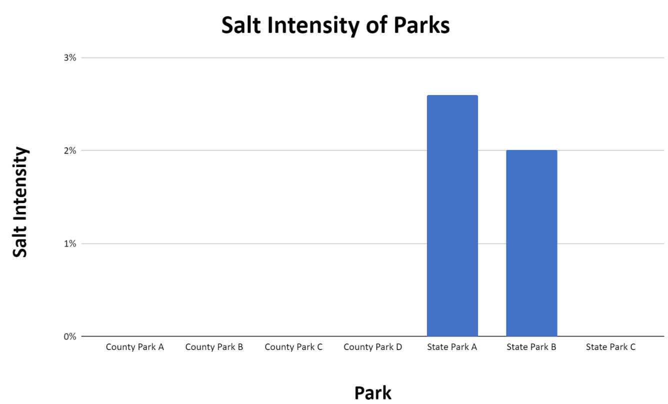


Figure 10 (left). Impacted wellheads by salt intensity value; Figure 11 (right). Impacted parks by salt intensity value. County Parks A-D: Blue Gill Bay Park, Brokaw County Park, Marathon Park, Peoples Sports Complex. State Parks A-C: Lake Wausau Area (N), Lake Wausau Area (E), Rib Mountain State Park.

Results: Parks

Four county parks and three state parks located in the Wausau Metropolitan area were analyzed including Blue Gill Bay Park, Brokaw County Park, Marathon Park, Peoples Sports Complex, Lake Wausau Area (N), Lake Wausau Area (E), and Rib Mountain State Park. None of the county parks produced drainage basins that overlap with roads, and therefore all county parks were calculated to have salt intensity values of zero, or no impact. Out of three, two state parks were impacted by road salt, though both experienced relatively minimal impact. The northern Lake Wausau Area produced a salt intensity value of 2.60% while the eastern Lake Wausau Area produced a salt intensity value of 2.01% (Figure 11). Both types of parks covered generally elevated or irregular terrain, producing drainage basins that varied significantly in size and shape.

The northern Lake Wausau Area, one of the impacted areas, is located in the north-central part of the metropolitan area and covers land, wetland, and parts of Lake Wausau east of US

Highway 51. The drainage basin that covers 321 pixels is intersected by various collector, arterial, and major highway roads. The large basin and proximity to influential roads gave this state park its relatively high salt intensity value and therefore our conclusion that is impacted by road salt use.

Discussion

One area of potential error is the inability to fully incorporate all roads due to lack of data. Besides arterial and collector roads (medium and low impact in this study), local roads exist as another class of roads. Local roads are neighborhood streets which are the smallest road type, and therefore inferred to be least impactful, but were unable to be included in analysis. Inclusion of local roads could have increased the average salt intensity value of the drainage basins due to the higher number of roads present.

In addition, the major roads that were given the highest impact value were classified through inference and comparison, but this could have included roads with varying sizes. Since the roads were generalized, the highest impact classification could include a variety of road sizes that might differ in salt intensity. This would impact the zonal statistics calculations for the drainage basins of wellheads and parks that include these roads.

Due to time constraints of the study, groundwater dynamics were not able to be included in analysis. The impact of runoff on wellheads was not able to be fully examined and other water inputs to wellheads could impact the quality of the water from the wellhead. One example of this is the surrounding area of wellheads. Runoff onto nearby land could infiltrate and affect the groundwater that mixes with that drawn on by the wellhead. Since there are many roads near wellheads, considering the surrounding area may increase the number of wellheads impacted by road salt use and the overall average salt intensity value for wellheads.

In summary, the complex dynamics of water movement from roads throughout the landscape are difficult to generalize and the amount of data that could be included is vast. Further study should attempt to include more thorough road data and classifications as well as additional considerations of how runoff containing salt might flow into sensitive areas.

Conclusion:

Our findings show that road salt application has a relatively limited effect on the state and county parks of Marathon County, as well as limited impact on wellheads with less than twelve percent of wellheads registering a salt intensity value. Many of the park and wellheads analyzed in the project were in areas with higher elevation, and drainage basins into these areas are much more limited as a result. The lower lying parks such as the two state parks in north central Marathon County registered a far greater salt intensity value given the extent of their drainage basins were significantly larger than the parks located on higher ground. In addition, wellheads located in the vicinity of Major Highways registered salt intensity values while those located near collector or arterial roads were much less impacted.

While road salt use creates safer driving conditions for many during the winter months, it also causes a variety of other environmental conditions that can have potentially drastic impacts on both sensitive ecological communities and public health.

Future Efforts

Future efforts to expand this project could be to expand the types of sensitive areas analyzed. Due to the time constraints of this course, we were unable to explore and include other sensitive areas that we originally planned. Some of these sensitive areas include wetlands, rivers, floodplains, etc. If more types of sensitive areas are analyzed, it would give a more accurate representation of how road salt use affects sensitive areas within the Marathon Metropolitan Area. Moreover, this project only used the wellhead location as the drainage point for the drainage basin, but the area surrounding wellheads could also be considered. This is due to the likelihood of runoff on surrounding land impacting the groundwater that mixes with that drawn on by the wellhead. Additionally, the scope of the analysis could be expanded to the entire county or other areas of interest.

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