



2022 Fall Conference at OC Fontainebleau Resort
Carroll County Chloride Investigative Procedure

Zachary Neal

September 30, 2022 10:30 to 11:30 am

BIOGRAPHY

- Hydrogeologist with over 10 years experience in MD (6 years private sector, 4+ years public sector)
- Oversee projects that involve or affect community water supply resources in Carroll County.
- Specific Duties:
 - Well drilling oversight & aquifer testing
 - Physical and chemical well investigations
 - Municipal support on groundwater resources issues



OBJECTIVES

Carroll County Chloride Investigative Procedure

Objectives:

- Provide an overview of how Carroll County investigates complaints of elevated chloride concentrations in groundwater wells where County deicing operations are the alleged source.
- Provide tools and considerations so other jurisdictions can craft their own investigative policies, if/where one does not already exist.
- Theme of resiliency:
 - County procedure is resilient in its adaptability to unique circumstances and challenging situations (i.e., making the most of [often] limited data). Same can be said for County staff carrying out investigations.
 - Ability to respond to disruptive processes (i.e., specific situational changes in de-icing operations)
- 1.0 PDH

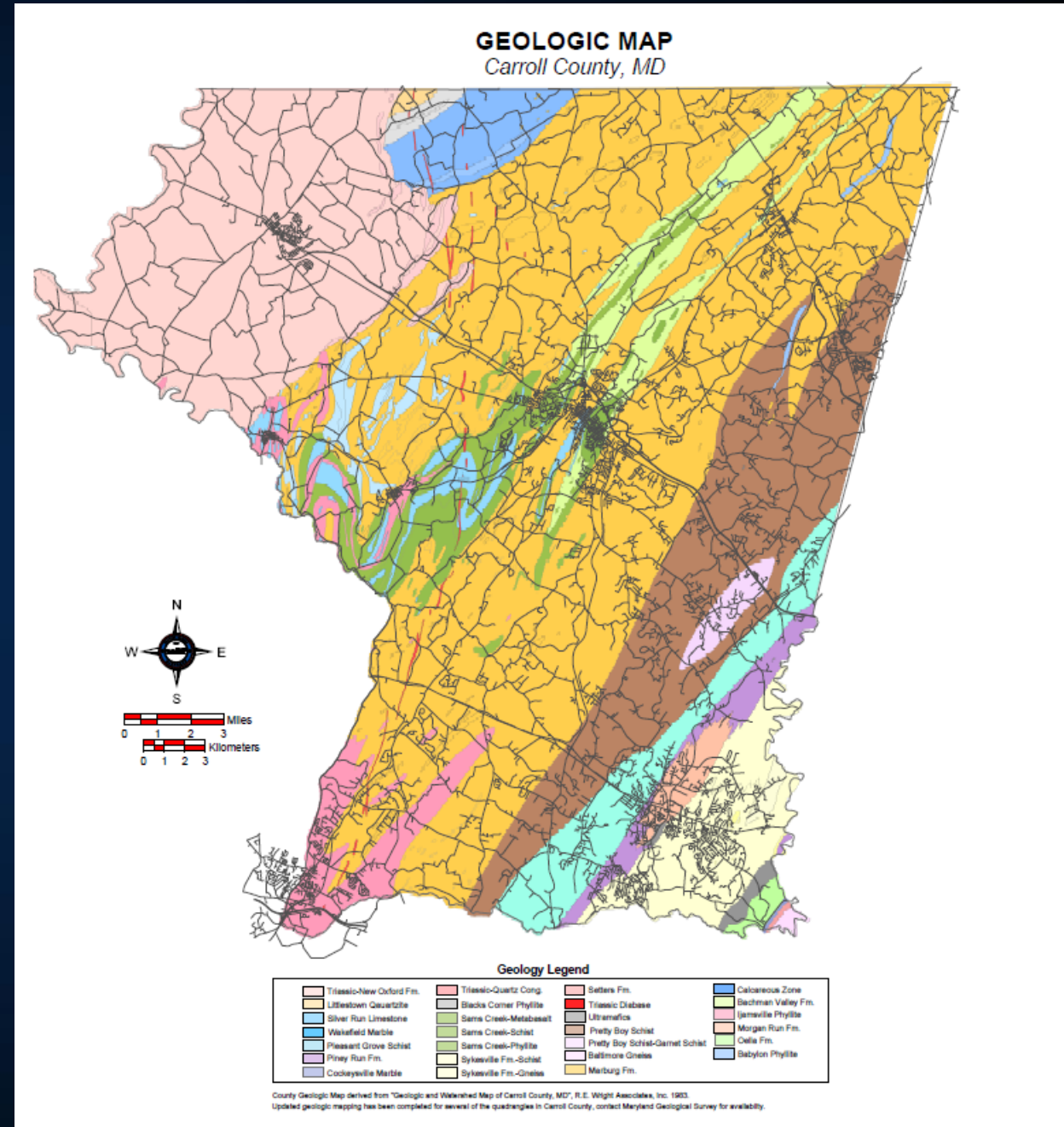
The Need For a Formal Investigative Procedure

- While County hydrogeologist position originated in 1988, a formal chloride investigative procedure did not exist. Inquiries/complaints were rare, and hydrogeologists responded on an as-needed basis.
- Zach started at County mid-January 2018
- 1st elevated chloride inquiry received 2/9/2018 (from CCHD)
 - Data review & desktop evaluation, with referral back to Health Department
 - Determined likely SHA source
- 2nd elevated chloride inquiry received 3/7/2018 (from CCHD)
 - Multiple potential overlapping sources of chloride introduction
- Determined that County needed a formal process for investigating elevated chloride inquiries
 - Desired standardized, repeatable (but flexible) process, utilizing best science and policy available at the time.

A Little Background
Before Jumping Into
How the Investigative
Procedure Was
Crafted

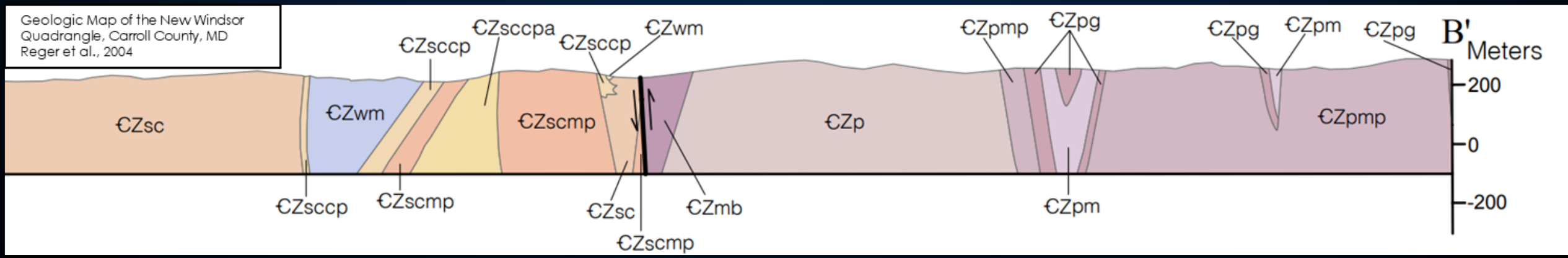
Carroll County Geology

- ~550 Million years in the making
- Rocks range in age from ~550 million to ~200 (or less) million years
 - Older rocks just over Balt. Co. line
- Complex geologic setting shaped by 3 different orogenies plus geomorphology & erosion
- Predominantly folded, faulted and fractured crystalline bedrock (gneiss, schist, phyllite)
- 2.5% carbonate rock (karst)
- Northwestern (Taneytown area) sedimentary bedrock environment



Challenges of Characterizing Fractured Bedrock Systems

- Groundwater transport occurs through isolated fractures or interconnected fracture systems, with storage (and some flow) in overlying saprolite
 - Role of these groundwater flow paths cannot be overlooked
- Bedrock systems are largely heterogeneous and anisotropic systems
- Fractures are not always easily identified by field expression
- Water table does not always mimic topography
- Complexity of geologic setting - Piedmont Plateau province consists of multiple, often steeply-angled formations of differing hydrologic properties in contact with one another



Salt isn't regulated. Why's it important?

- There are many types of salts. The best known is halite, or sodium chloride (NaCl). Other well-known salts include magnesium chloride (MgCl_2), calcium chloride (CaCl_2) and potassium chloride (KCl).
- Dissociation (separation when dissolving in water) splits the cation (e.g., sodium) from the anion (chloride). Chloride is a conservative ion in the environment; it does not break down or sorb to soil/rock and is difficult to remove from water.
- Human Health – Those on low sodium diets may be affected by drinking water with elevated concentrations. Chloride also gives water a salty taste over 250 mg/L.
- Infrastructure and Transportation – Elevated chloride concentrations can corrode plumbing and appliances. It's corrosive nature also decreases the lifespan of roadways, bridges and walkways, and damages vehicles, etc.
- Environment – Elevated salt concentrations in waterways can decrease biodiversity, stunt growth, interfere with osmoregulation, and/or kill flora and fauna, though some of these impacts are associated with other factors related to urbanization (not just salt).

Where's all this salt coming from?

- Natural Sources:

- There are not any naturally occurring salt deposits or basin brines in Carroll County, MD
 - This will differ for other counties, especially those in the Coastal Plain and Western MD
- Naturally occurring sources are predominantly limited to atmospheric deposition and chemical weathering of soil and rock. These sources generally contribute very low concentrations of sodium and chloride to water.
 - In Coastal Plain, there are brackish water areas and saltwater intrusion.
 - In Western MD, possible deep basin brines

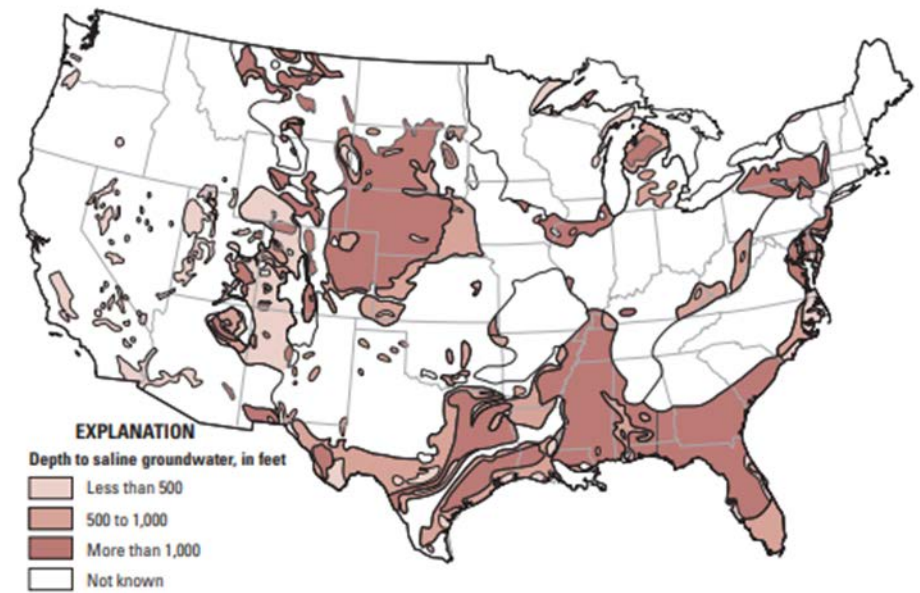
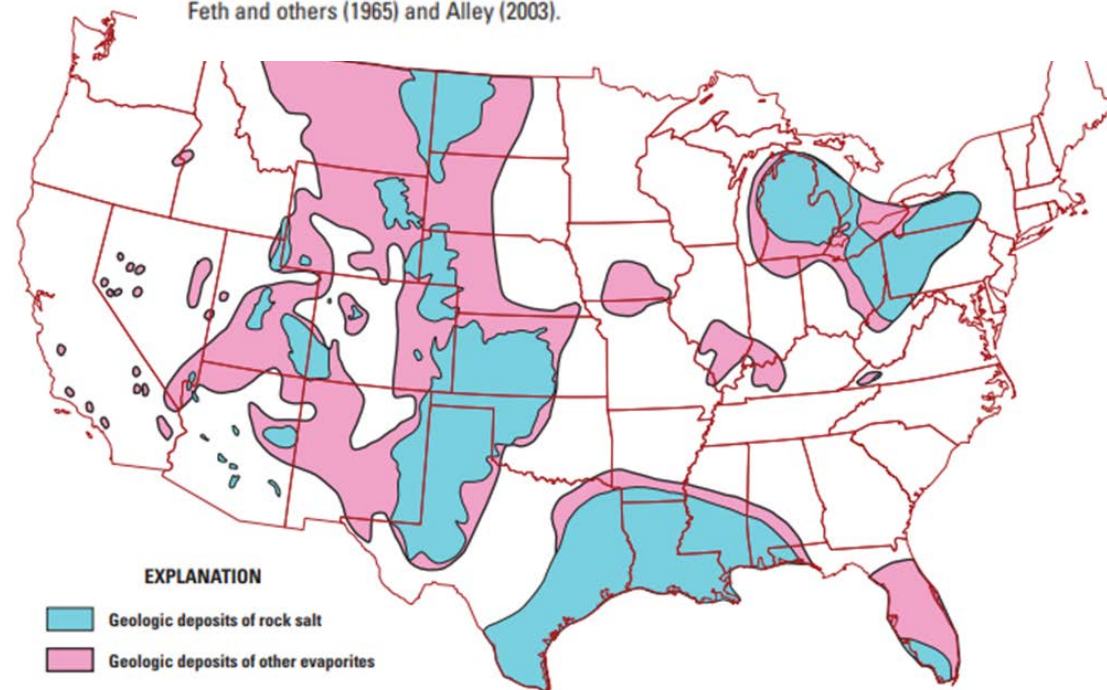


Figure 4. The depth to saline groundwater in the conterminous United States. Modified from Feth and others (1965) and Alley (2003).



Anthropogenic Sources



- Most salt in Carroll County is associated with man's activities.
- While many people tend to focus on "road salt" (a bit of a misnomer), there are many additional sources that contribute to overall chloride loads, including:
 - De-icing salts; the better representative term (highways, roads, parking lots, driveways, walkways)
 - Water treatment (water softening systems, disinfection)
 - Wastewater (from human diet, industrial processes, consumer products, disinfection, etc.)
 - Landfills (food wastes and consumer products)
 - Agriculture (animal waste and fertilizer)
- While these likely constitute many of the most frequent sources in the County, their method of introduction and control, along with hydrogeology, all influence fate, transport and potential impact.

Crafting the Procedure

Literature Review – Policies of Others



- Massachusetts Department of Transportation (MASSDOT) – One of the more detailed & documented procedural policies online
- For private wells, MASSDOT will investigate if:
 - Chloride concentration > 250 milligrams per liter (mg/L), which is the secondary maximum contaminant level (MCL)
 - Sodium exceeds 20 or 40 mg/L, and the resident is on a doctor-ordered and documented sodium restricted diet.
- Resident must submit form (personal information, well information, etc.), accredited water quality results, right of entry agreement
- MASSDOT determines need for investigation and may collect monthly samples
- MASSDOT may deny based on well construction, other water quality violations, other chloride sources, deviation from well/septic setbacks

Useful MASSDOT Links

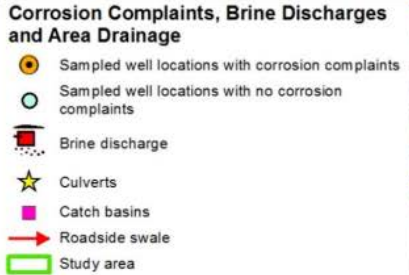
Publicly Available Information, **Post-Presentation Use**

- Salt Remediation Program Application: <https://www.mass.gov/how-to/salt-remediation-program-application-for-acceptance>
- Full Investigative Policy: <https://www.mass.gov/doc/massdot-water-supply-salt-complaint-policy/download>
- Private Well Data Form: <https://www.mass.gov/doc/private-well-data-form-salt-remediation/download>
- Remediation Program Overview (at time of CC Policy development): <https://studylib.net/doc/13043505/salt-remediation-program-dedicated-to-safe-roadways-andamp%3B>

Investigation Review – Bow, NH

Brown Hill Road Area Water Quality Study

- Residents in Brown Hill Road area voiced concerns about corrosion from salt contamination of private wells since 1990's
 - Town evaluated and implemented corrective actions, including reduced salt application practices (140 lbs/lane mile) and assistance with water treatment
- Residents voiced concerns again in 2013. Town launched investigation in 2014.
 - 158 area homeowners surveyed; 79 responded and granted access for sampling
- Findings:
 - Road salt and softener brine were sources of chloride
 - Low pH and chloride contributed to corrosivity
 - Older wells (pre-dated standards) had higher chloride and lower pH
 - Chloride levels were similar to 1990s – no appreciable increase in road salt loading



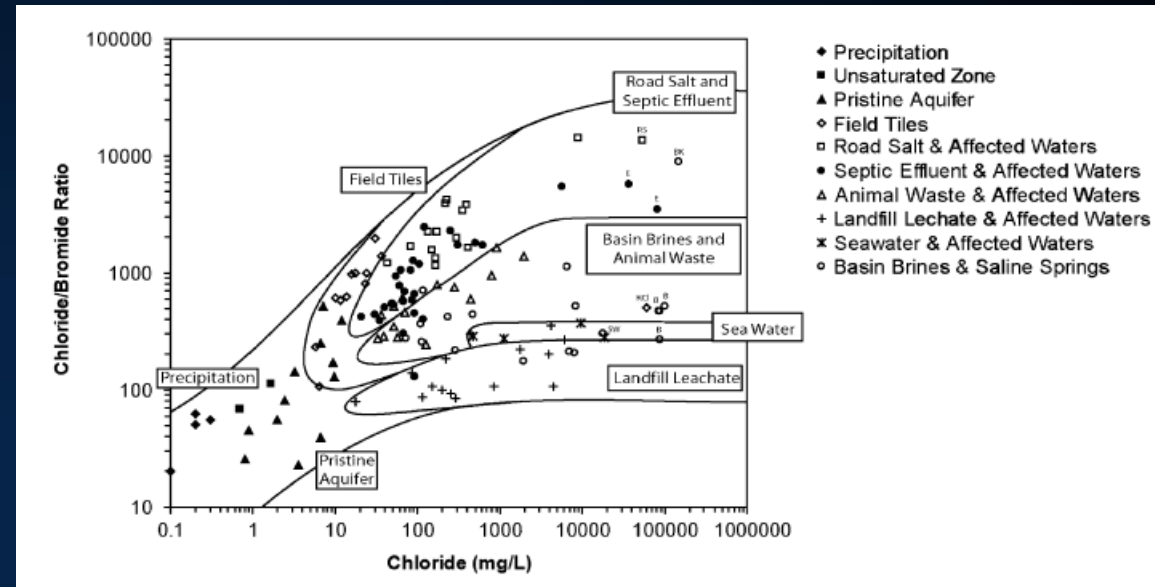
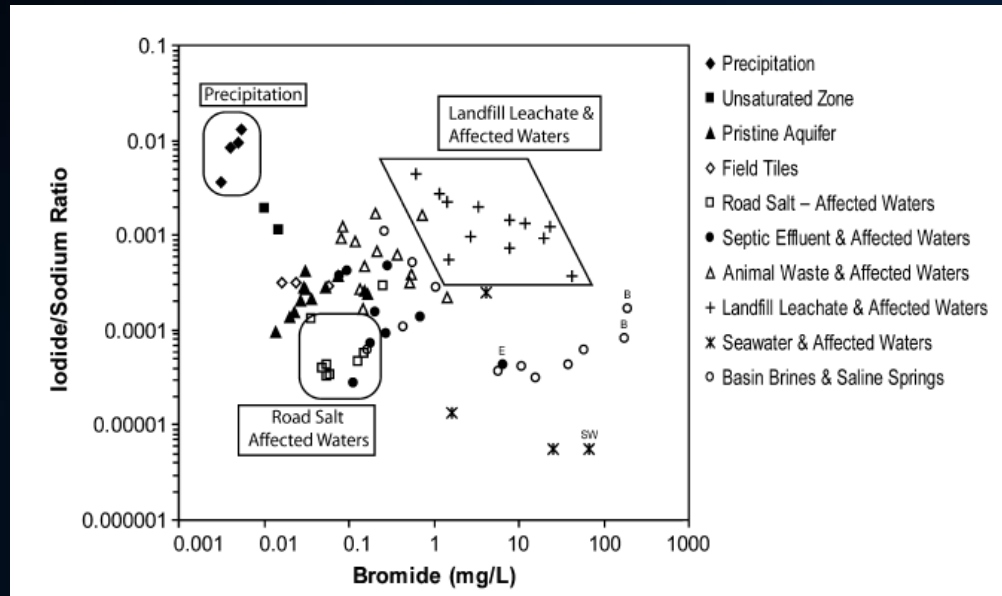
- 30% (24 of 79) report issues with corrosion
- Both pH and salt contribute to water corrosivity
- Salt sources = road salt drainage and softener brine
- Low pH = acid rain infiltration older wells

- **Power Point:** <http://www.bownh.gov/DocumentCenter/View/382/Brown-Hill-Road-Area-Water-Quality-Study---PowerPoint-Presentation-PDF?bidId=>
- **Report:** <http://www.bownh.gov/DocumentCenter/View/383/Brown-Hill-Road-Area-Water-Quality-Study---Report-PDF?bidId=>

Literature Review – Characterization & Identification of Na-Cl Sources in Groundwater

- Study by Samuel Panno (Illinois State Geological Survey) and others to characterize most prevalent natural and anthropogenic sources of sodium and chloride in Illinois groundwater
- Considered 7 potential sources: Agricultural chemicals, septic effluent, animal waste, municipal landfill leachate, sea water, basin brines and road deicers.
- Found that the halides chloride, bromide and iodide were useful indicators of sources of salt contamination
 - Total nitrogen also diagnostic
- Chloride-to-bromide ratios plotted against chloride concentrations revealed clear, but overlapping, separation of sample groups

Panno continued



USGS has published similar, citing Panno

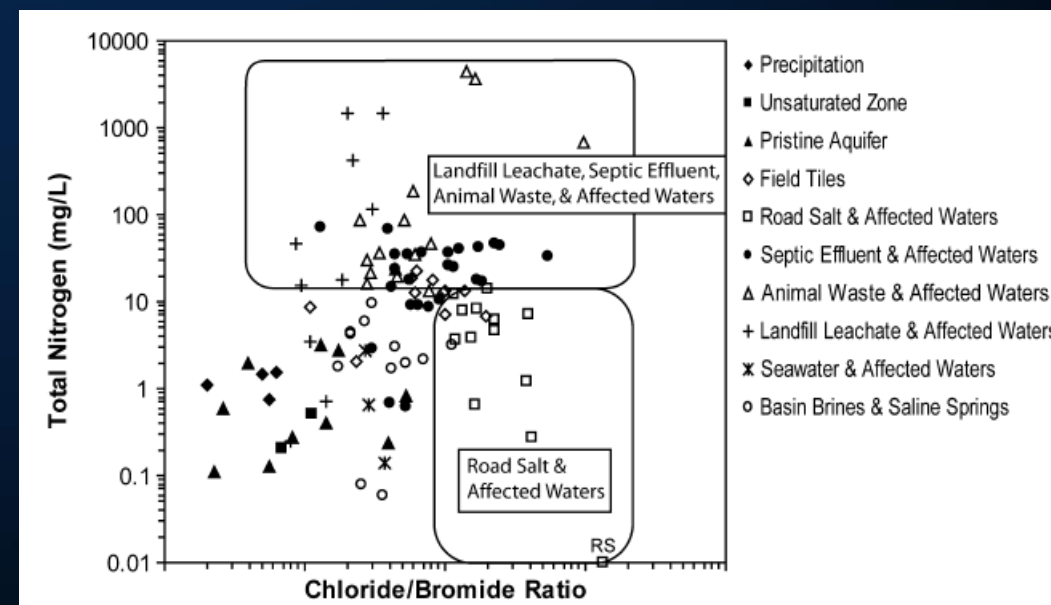
1.) Chloride in GW and SW (Mullaney et al., 2009)

<https://pubs.usgs.gov/sir/2009/5086/pdf/sir2009-5086.pdf>

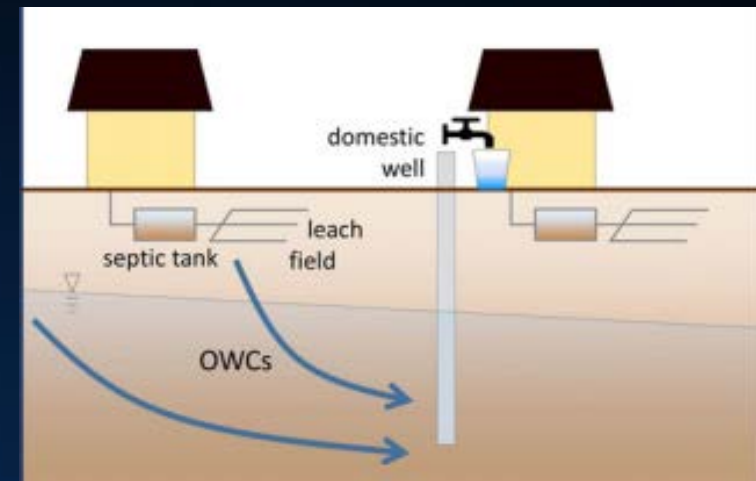
2.) Methods for Evaluating Potential Sources of Chloride in SW and GW (Granato et al., 2015)

<https://pubs.usgs.gov/of/2015/1080/ofr20151080.pdf>

Both were also reviewed when crafting procedure utilized in Carroll County.



Literature Review – Septic System Focus



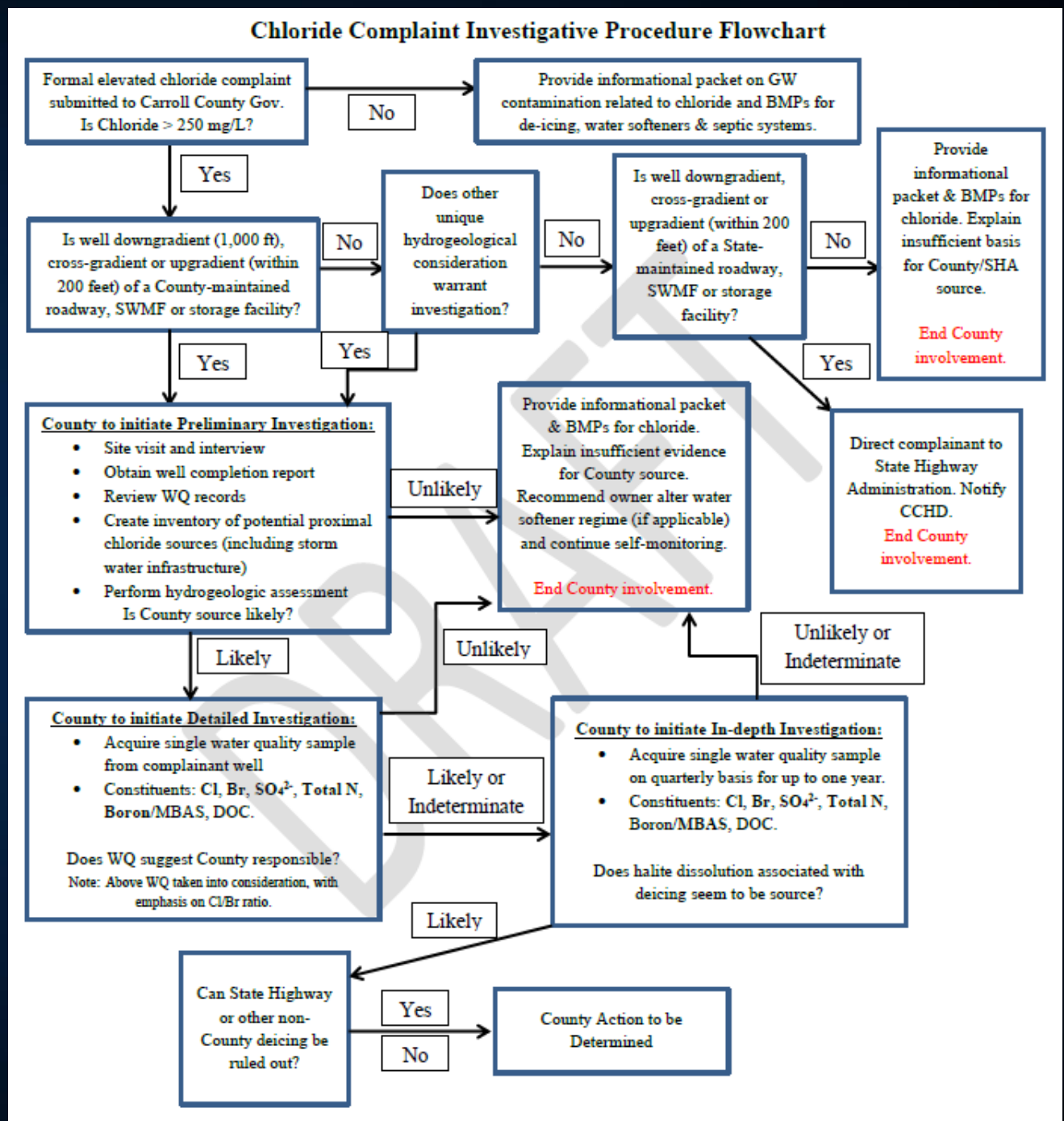
- # 1 – Using Cl/Br ratios and other indicators to assess potential impacts on GW quality from septic systems (Katz et al., 2011)
 - Data review from principal aquifers in the United States
 - Found Cl/Br ratios were cost-effective potential screening tool for possible contamination from septic
 - Utilizing other indicators would help increase certainty in discriminating sources
 - Recommended boron, sulfate, DOC, nitrate, organic wastewater compounds
- # 2 – Septic systems as sources of organic wastewater compounds in domestic drinking water wells... (Schaidt et al., 2016)
 - Presence of organic wastewater compounds correlated with nitrate, boron and acesulfame (artificial sweetener) and inversely correlated with well depth.

Other Considerations

- Chloride Threshold – Like MASSDOT, decided that Secondary MCL (250 mg/L) would serve as threshold at which Carroll County would investigate a complaint.
- Proximity Threshold (Between complainant and County infrastructure [not just roads!])
 - Within 1,000 feet downgradient of a County roadway, SWMF, or storage facility
 - Cross-gradient (parallel contour)
 - 200 feet upgradient of County infrastructure (based on typical fracture angles, well depths, etc.)
- Unique Hydrogeological Conditions (Proximity Consideration)
 - May deviate from above listed thresholds for other settings, including sedimentary bedrock and karst areas, especially those near pumping centers

Putting it all together – Flow Chart

Details are on the next few slides



County Consensus

- Following drafting of the pilot procedure (no longer in pilot), met with other County agencies, including:
 - Bureau of Roads Operations
 - Department of Public Works
 - Risk Management
- Presented flow chart, written procedure and one case example
- Explained scientific basis for different components of the procedure and sought concurrence before implementation
- All agencies signed off on policy and implemented one year-long case study for a particular complaint.



Preliminary Investigation – Site Visit & Interview

ELEVATED CHLORIDE INVESTIGATION QUESTIONNAIRE

Owner Name: _____ Well Tag No. _____

Premises Address: _____

Owner Contact Information

Phone: _____ Email: _____ Other: _____

Description of Complaint:

When did you first notice a problem with your water?

Has the quality of your water changed since you initially noticed the problem?

Does the taste/quality of the water vary throughout the year, or under certain conditions?

Have any of your neighbors reported a similar problem?

Do you have any historic water quality results you can provide for the well?

What can you tell me about your well? Do you have, or have you ever had any issues with bacteria? What about discoloration, odor or other tastes?

Have any modifications or repairs been made to your well? If so, can you explain why?

Do you have any treatment systems installed? Are they actively used? If not, when were they last utilized?

Do you know if your neighbors have treatment systems installed?

How much salt do you use annually? How much for your driveway vs. treatment systems?

Is there anything else we should know about your complaint or related observations you've made?

- Meet with complainant and explain process
- Complete questionnaire with complainant
- Acquire water quality data (if it exists)
- Review and document:
 - Homeowner treatment system
 - Lot layout (well and septic locations, discharge locations)
 - Well condition/integrity
 - Configuration of County infrastructure and other potential chloride sources



Preliminary Investigation – Acquire and Review Health Department Info.

- Maintain good working relationship with CCHD personnel
 - Working towards common goal. Send cases to each other as determined.
- Secure copy of complainant's well completion report
 - Confirm geologic strata encountered
 - Determine key water bearing zones and well yield
 - Determine casing depth and construction details
 - Other records (historic quality issues, well replacements, etc.) as available
- Secure copies of well and septic layout for complainant and surrounding area, especially upgradient watershed area
 - Key to generating a conceptual site model of complainant area
 - Subdivision plans also reviewed, when available
 - Data incorporated into GIS with other available data for next phase (potential chloride source inventory)

Carroll County
Health Department



Public Health
Prevent. Promote. Protect

Preliminary Investigation – Potential Chloride Source Inventory

- Review data from Bureau of Permits and Inspections
 - County maintains permit records for water treatment infrastructure and swimming pools, among other things
 - Overlay data on septic layout secured from CCHD
- Map stormwater infrastructure
 - Stormwater management facilities (with emphasis on those that promote groundwater recharge)
 - Storm drain lines and age (field inspected)
- Review/map roadway curbing (or lack thereof)
- Review drainage gradients and patterns from County and other roadways, including state highways
- Review and/or map other private chloride sources:
 - Commercial de-icing operations
 - Residential de-icing (driveways, walkways, etc.)
 - Swimming pools (emphasis on saltwater pools)
 - Other potential contributing factors (e.g., wastewater discharge), as needed

Preliminary Investigation Determination

- By end of Preliminary Investigation, County will have:
 - Met with owner
 - Reviewed hydrologic and topographic information
 - Mapped available, applicable data
 - Determined data deficiencies and need for other potential data
- Having reviewed data, County will determine likeliness it contributed to complainant issue
 - If likely, In-Depth investigation
 - If unlikely, end County involvement and provide information & basis for decision to homeowner. Owner can appeal if additional information collected.



Detailed Investigation

- Preliminary Investigation was essentially a hybrid evaluation; predominantly desktop with a non-quantitative field component
- Detailed Investigation builds upon preliminary investigation by incorporating one-time direct water quality sampling
 - Sampling is funded by Carroll County Government. Costs ~ \$300/sample.
 - Water quality sample is collected directly by an independent and certified water quality laboratory so bias/claims of interference are negated
- Sample includes:
 - Major cations and anions found in natural waters (looking at anomalies, cation/anion balance to determine error & characterization, etc.)
 - Conductivity and pH
 - Bromide – For Cl/Br ratio analysis
 - Boron – Wastewater indicator; typical detergent ingredient
 - Dissolved Organic Carbon (DOC), Total Nitrogen – Additional potential wastewater indicators, especially for failing systems for DOC
- Results allow refinement of conceptual site model



In-Depth Investigation

- Incorporates a quarterly (or more frequent) County-funded water quality sampling program for a year
 - Completed if County de-icing operations are a suspected contributor to complainant issue or if results of detailed investigation are not definitive
 - Permits analysis of seasonal fluctuations in geochemistry
 - Option to terminate sampling earlier and initiate appropriate response if County deicing operations determined to be source
- During in-depth investigation, also periodically have the ability to adjust County-controlled variables (when safe to do so) and monitor response
 - E.g., For one study, terminated deicing operations and switched to a chloride-free anti-skid agent to help assess geochemical response in domestic well
 - If/when needed, have option to expand study area (incorporate other wells as additional monitoring points)

Case Studies

Case Study # 1 – South Westminster (Outside City)

- Commissioners Office received call from a resident experiencing issues with corrosion from elevated chloride (qualitatively reported by a water treatment company).
 - SHA referred complainant to CCHD, who began simultaneous investigation
 - CCHD requested resident have quantitative analysis performed
- While County roadway was downgradient, complainant still qualified for preliminary investigation in accordance with procedure
- Lot located on upgradient side of intersection of State Highway and County Roadway

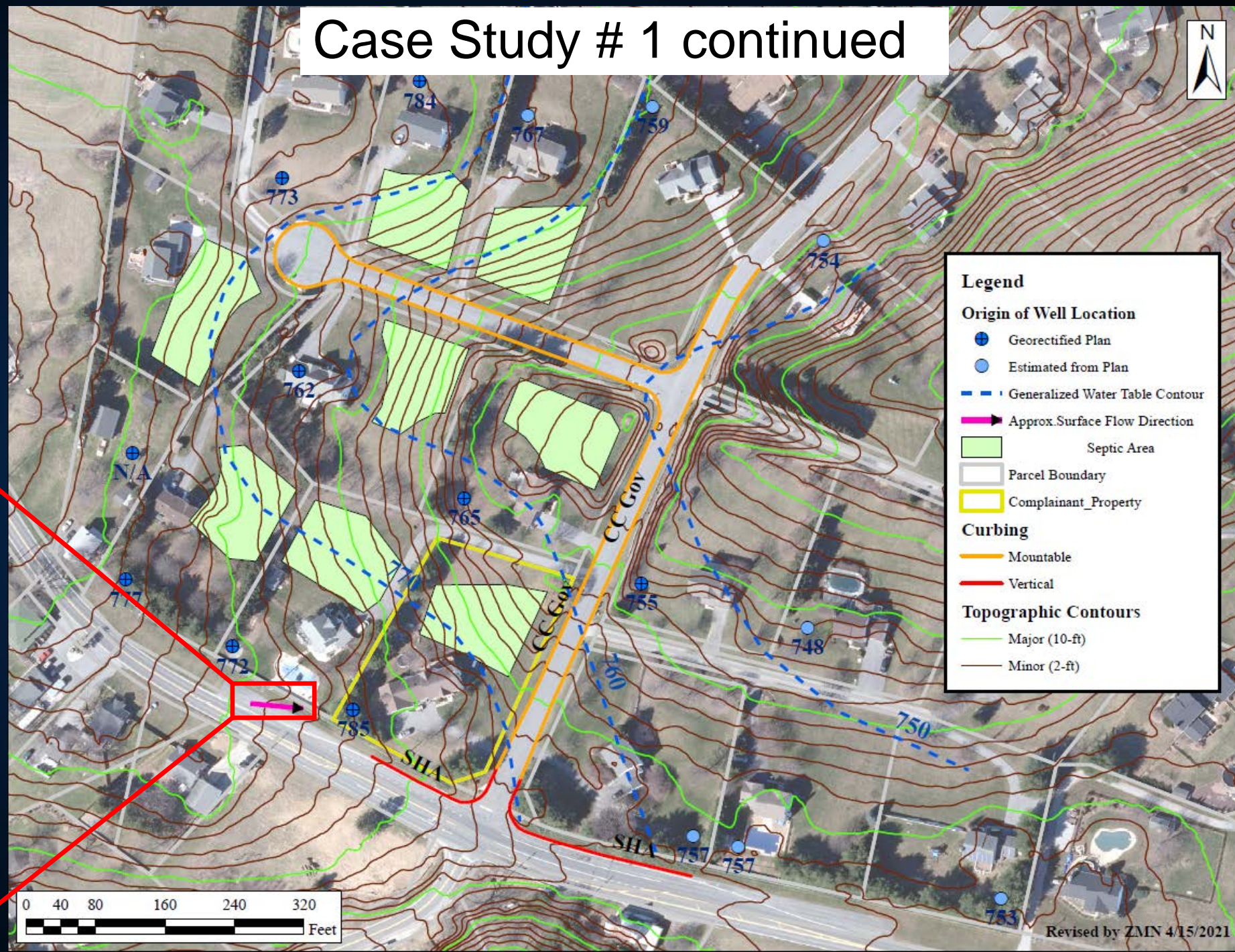


Case Study # 1 continued

- Actions Performed:
 - Reviewed well completion report
 - Reviewed topographic and geologic maps
 - Located in phyllitic area, with naturally acidic pH, soft water with low natural ion concentrations.
 - Requested well/septic layout from CCHD and mapped in GIS
 - Well located in upgradient SW corner, proximal to state highway
 - Mapped County and SHA stormwater infrastructure
 - Reviewed water treatment permits for area and inventoried potential chloride sources
 - Performed field investigation
 - Walked roadways to investigate surficial runoff patterns and collection points. Poured water to document flow off state highway.
 - Spot check investigation of storm drain integrity – no significant corrosion/breach.
 - Reviewed well completion reports for surrounding area
 - Noted wells were drilled days-to-months apart
 - Able to compare static water levels from completion reports to land surface at CCHD data points and generate a generalized water table map to determine general groundwater flow directions.

Findings:

- **Unlikely County source**
 - E-NE GW flow
- SHA Vector Exists
 - CCHD assist. owner
- Can't rule out private treatment
 - Significant treatment system to west
 - Swimming pool proximal



Case Study # 2 – Northwest Finksburg (off High Traffic Commercial Corridor)

- In October 2021, DPW received inquiry from new homeowner (purchased August 2021) of elevated chloride concentrations
- Homeowner provided water quality records from home closing (not chloride related) documenting plumbing and sewerage repairs
- Homeowner had water tested in early October 2021
 - No coliform or E. coli (previous detection at closing)
 - Chloride = 460 mg/L
 - Sodium = 55.7 mg/L (County staff noted concentration was atypically low for such an elevated chloride concentration)
- Property positioned along an uncurbed County roadway, downgradient of: a state highway, numerous commercial businesses, other residential dwellings.

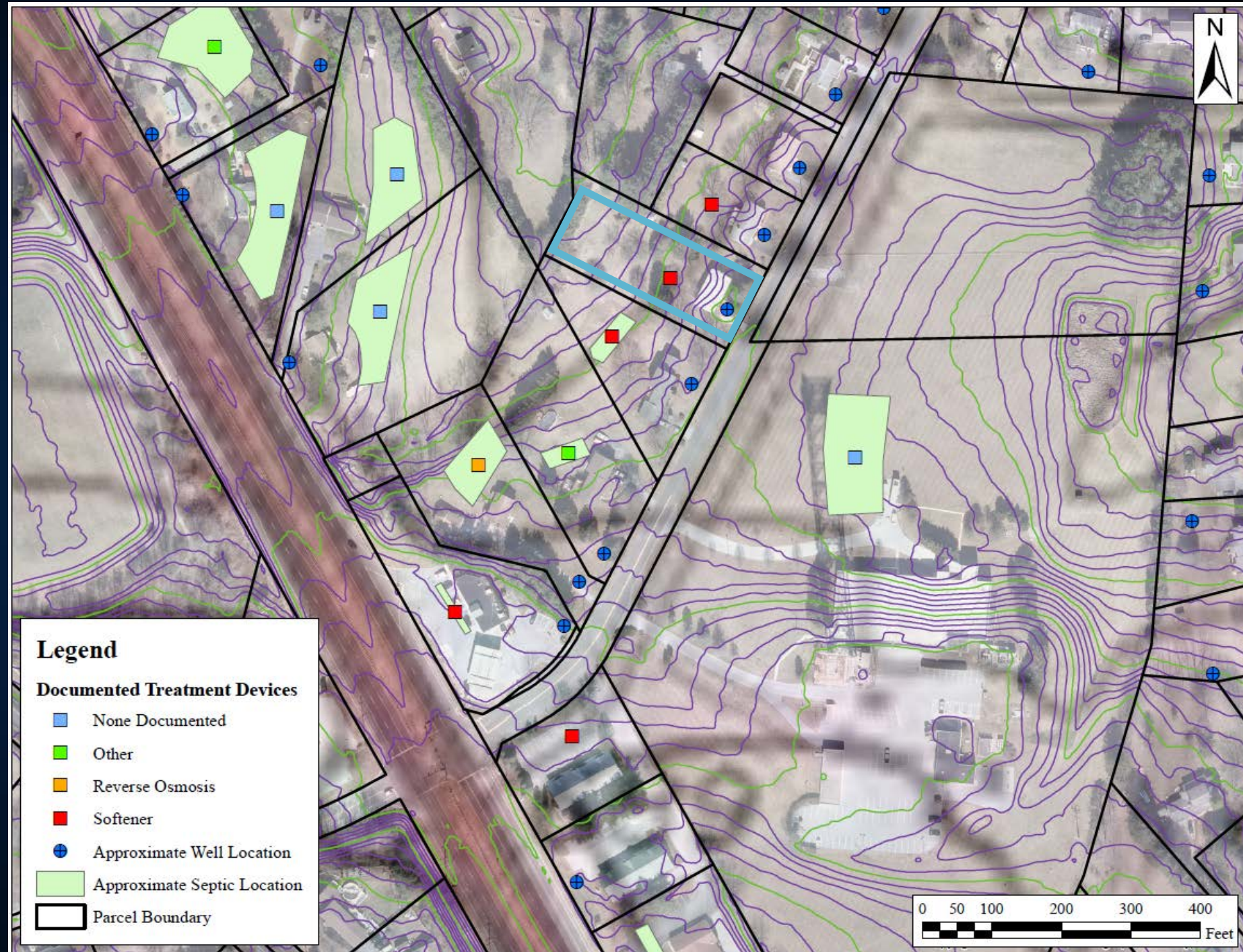
Case Study # 2 continued

- Like Case Study # 1, completed tasks standard of the County's Preliminary Investigative phase, plus site interview and water quality record review
- Well completed in the Prettyboy Schist
 - Typically, naturally acidic pH, soft water with low natural ion concentrations
- Investigative process identified the following potential chloride sources:
 - Numerous upgradient water treatment devices, including three water softeners
 - Originated from County permit records
 - County roadway de-icing operations
 - State highway de-icing operations
 - Commercial parking de-icing operations
 - Residential de-icing

Case Study # 2 Early Layout

- Permit records indicated the previous presence of “twin carbon filters” in wells along the County roadway.
- Audience Question: What is the potential significance of the “carbon filters”?

Hint: Permit records reference “contamination”



Another Critical Data Source

(Case Study # 2 continued)



- Commercial facility at the intersection of the County roadway and State Highway is (and has been) a gas station
- Maryland Oil Control Program (OCP) records for the referenced address had an entry indicating a historic (closed case) release and cleanup effort related to the gas station
- Inquiry made to MDE OCP case manager about types of records potentially available. Explained purpose of investigation/request.
 - Case manager indicated annual reports were available (including maps and water quality sampling records)
 - One example shared, with a groundwater contour map showing a flow direction generally paralleling the County roadway
- Formal PIA request submitted to MDE for available reports

Case Study # 2 Cont'd – Advancing to Detailed Investigation

- After briefing DPW, determined a one-time water quality sample would be diagnostic given:
 - Number of potential chloride sources and their ability to be overlapping
 - Complexity of study area
 - Time MDE needed to process such a robust PIA request
- Sampled for all parameters listed in the detailed investigation phase
- Compared to historic water quality records (1950's – 1980's) from same geologic formation, which County staff separated into likely natural vs anthropogenic

Parameter	County Sample	Background (Lit.)	Anthropogenic (Lit.)
Calcium (mg/L)	131	7.97	17
Magnesium (mg/L)	52.9 Wow!	2.32	12.25
Chloride (mg/L)	510	6.14	55
Sodium (mg/L)	55.0	4.45	32
Hardness (mg/L)	544 (calc.) But little bicarbonate!	28.86	93.5
pH	5.40	6.47	5.7

Yet Another Data Source! (Case Study # 2 continued)

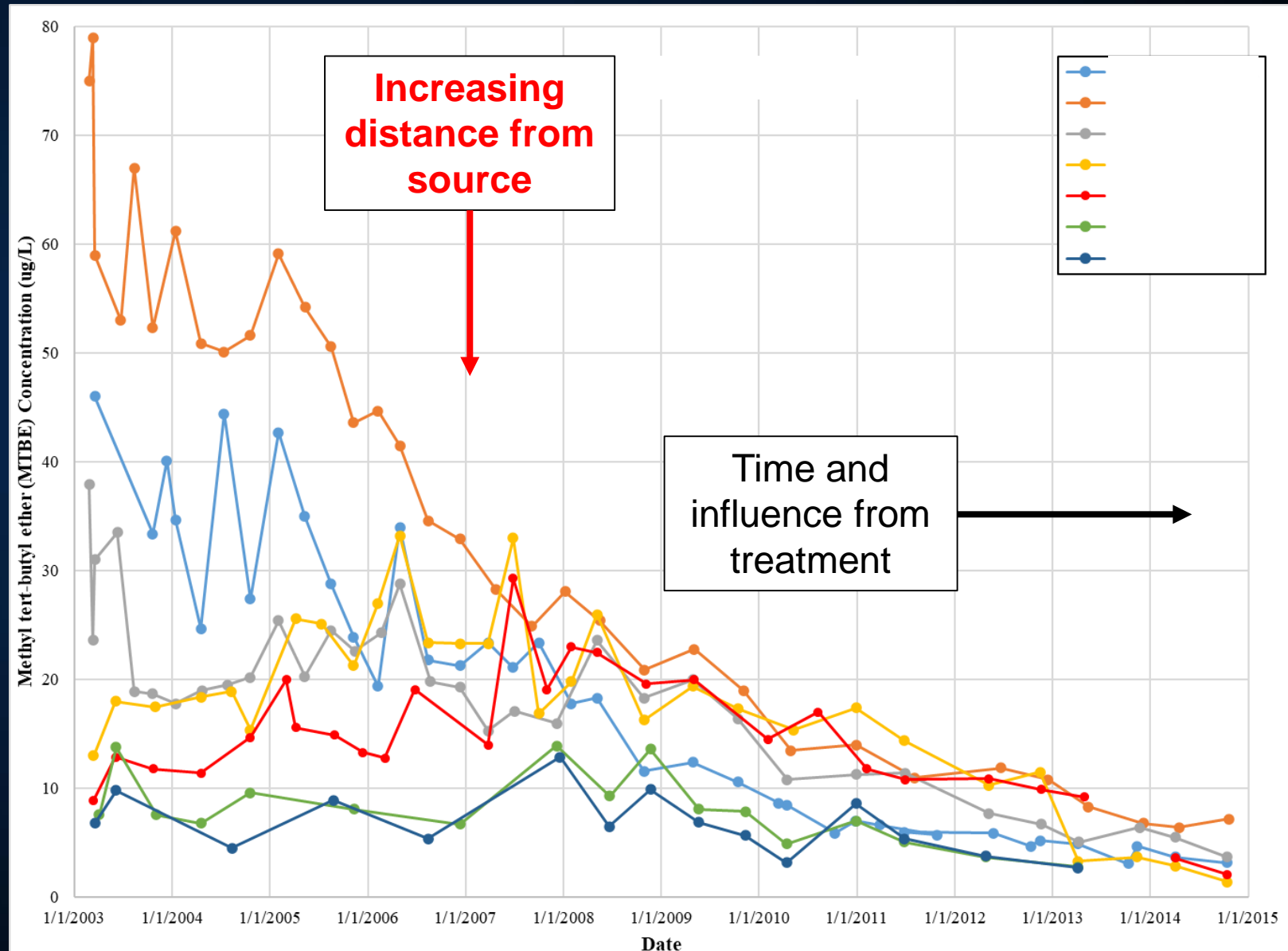
- Review of County records showed a previous upgradient elevated chloride investigation occurred at the location of the gas station
 - Gas station owner alleged elevated chloride at gas station and downgradient rental properties (two) was attributable to de-icing operations along state highway
 - SHA investigated and determined SHA source was unlikely. Documented presence of advanced water treatment system, including acid neutralizer, water softener, reverse osmosis system, etc.
 - SHA sampled well
 - Neutral pH
 - Calcium (150 mg/L), magnesium (41 mg/L), sodium (100 mg/L), chloride (630 mg/L), hardness (550 mg/L), Alkalinity (43 mg/L)
 - Do these numbers look familiar? Complainant appears to be affected by same source as previously documented at gas station.
- Former County hydrogeologist received copy of SHA report and was asked to opine/offer assistance to determine if County roadway could have contributed.
 - County hydrogeologist determined that there was significant possibility of recirculation from septic (treatment discharge) to supply well. Would result in elevated calcium, magnesium, sodium and chloride, but not alkalinity (consumed in neutralization).

MDE OCP PIA Results (Case Study # 2 continued)

- Multiple maps furnished by gas station consultant depict groundwater flow generally paralleling (eventually cutting under) County roadway
- Graph to right depicts MTBE concentrations through time
 - MTBE generally moves at same rate as groundwater
 - MTBE resistant to degradation
- Shows groundwater vector exists from suspected recirculated treatment discharge area to (and beyond) complainant

Finding:

Complainant well likely affected by one or more upgradient private water treatment devices, not de-icing.



Case Study # 3 (Predates Case Studies 1 & 2 in Time)

- In September 2018, received elevated chloride complaint via CCHD for resident east of Westminster, MD
- Complainant was at downhill end of cul-de-sac, not curbed/guttered
- Complainant provided water quality results from August 2018:
 - pH = 5.9
 - Sodium = 282 mg/L
 - Chloride = 500 mg/L
- Homeowner alleged County de-icing resulted in elevated chloride causing corrosion of plumbing fixtures and appliances (hot water heater, etc.)
- Preliminary Investigation suggested County roadway de-icing operations a possible vector, as well as upgradient water treatment
- Detailed investigation determined to be warranted
 - Conflicting results from sample – very high TOC (suggesting septic influence) plus boron, but other ions (calcium, magnesium) not overly elevated; akin to anthropogenic
 - In-Depth Investigation determined to be warranted by multiple County departments

In-Depth Investigation (Case Study # 3)

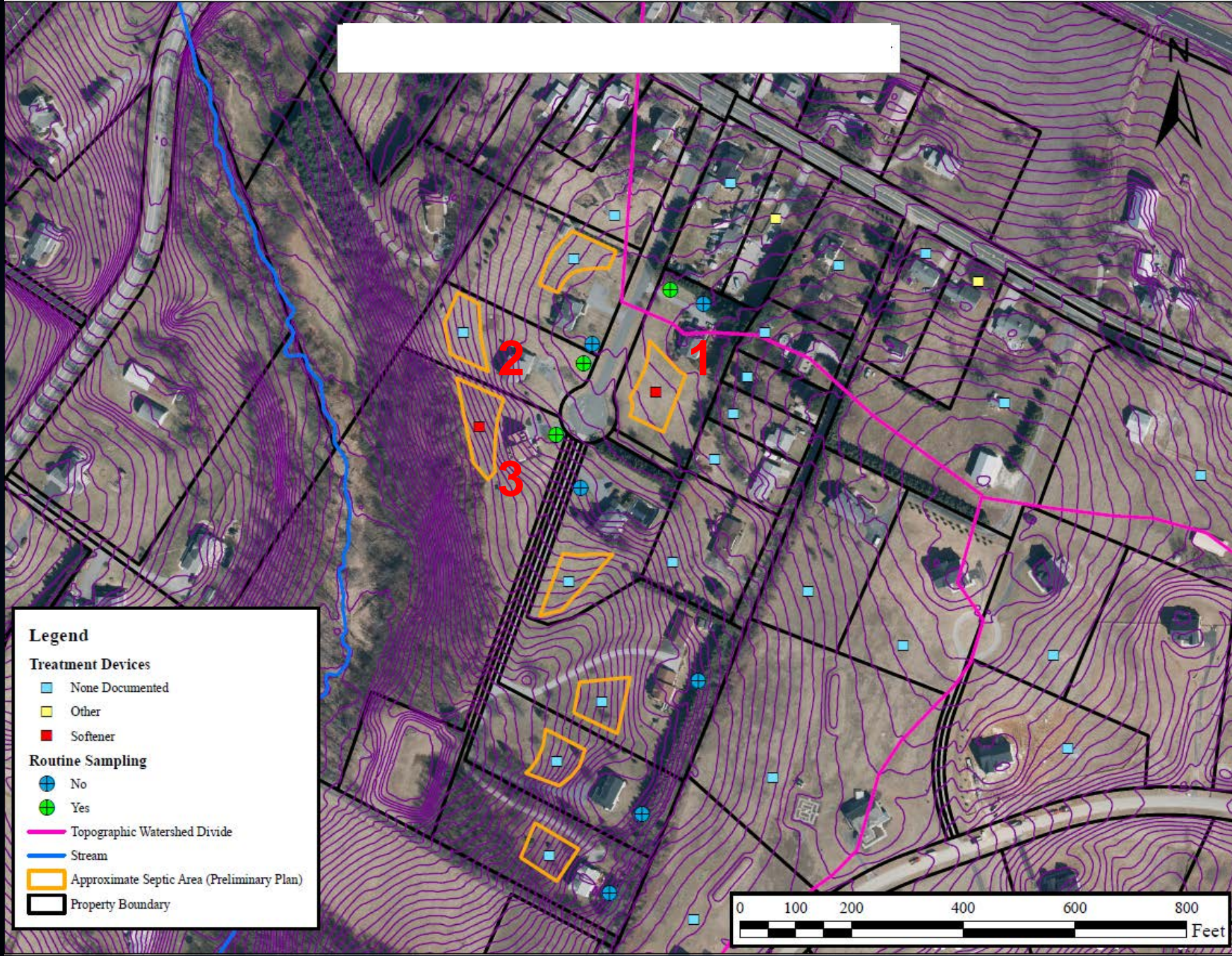
- County determined year-long study appropriate, broadened to include additional surrounding residences.
 - All homeowners contacted, many attended public meeting. Only two others agreed to County-funded water quality sampling. One upgradient, one adjacent to complainant.
- Adjustment of Variable – County suspended standard de-icing operations during study. Given south facing slope, use of a chloride-free anti-skid agent was determined to be appropriate.
- Up to 8 samples collected from complainant and volunteers over course of a year, alternating between parameter list from the detailed investigation phase and a sub-set of those parameters.
- Potential complicating factors:
 - Unusually wet 2018-2019
 - Residents aware of purpose of study and potential implications (potential bias?)

Case Study # 3 Configuration

1 = Upgradient
2 = Adjacent
3 = Complainant

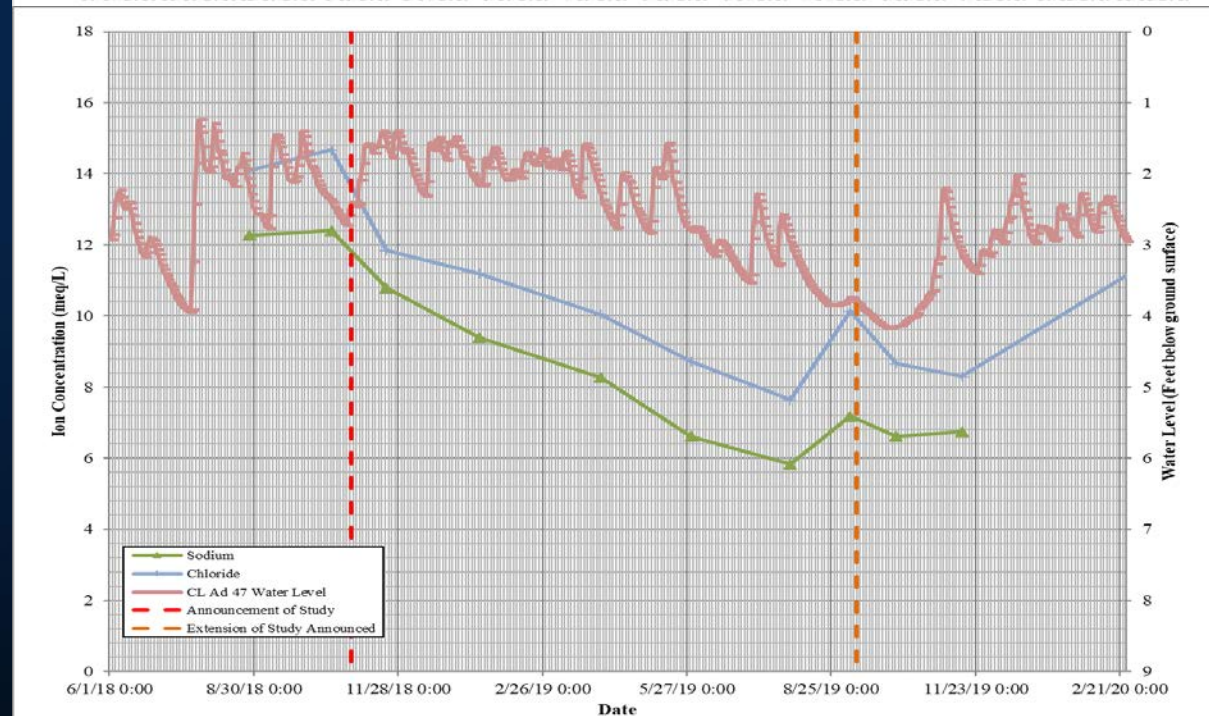
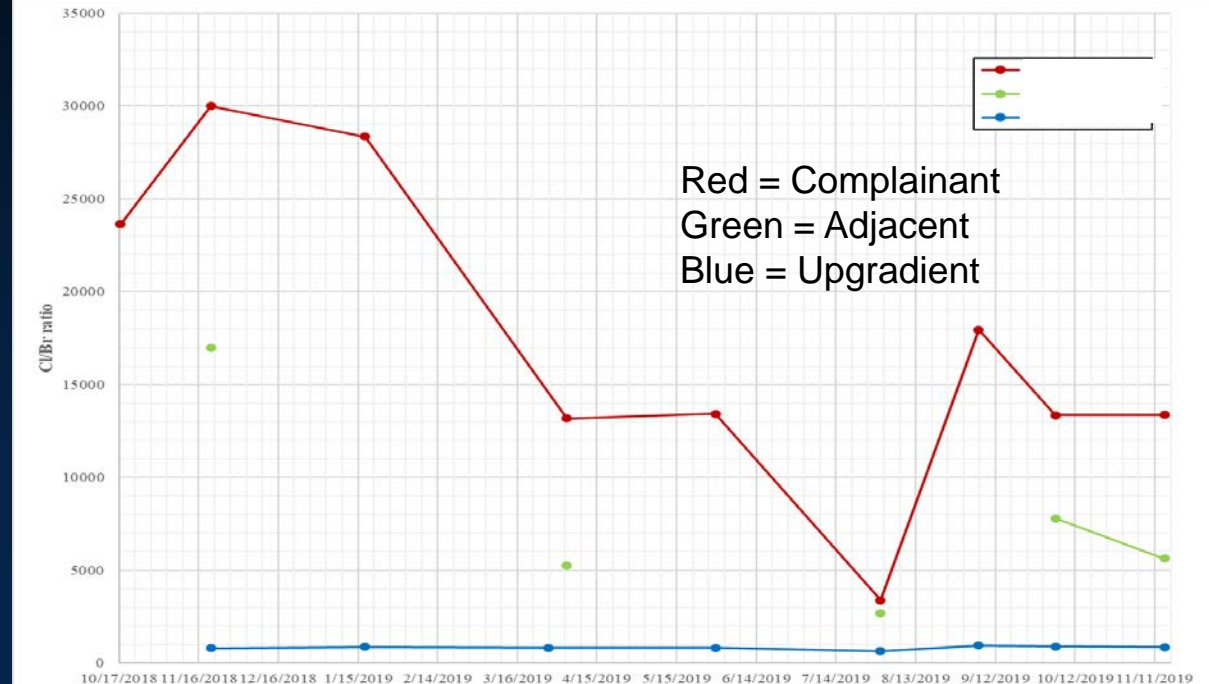
Groundwater generally
conceptualized as
moving southwest in
study area

Runoff generally
directed south-
southwest. Overland
sheet flow and culvert.



Observations (Case Study # 3)

- Cl/Br ratios at complainant well and adjacent well were higher than literature values
- Cl/Br ratios at complainant well and adjacent depict shift halfway through study
 - Suggests different chloride sources started to become dominant
- Cl/Br ratio diagnostic in upgradient well – suggested septic impact
 - Well had highest boron concentrations
 - Well had high nitrate (13-17 mg/L)
 - Not adversely affected by chloride (~30 mg/L)
- While complainant well chloride decreased, it quickly leveled off at concentrations in excess of Secondary MCL, then rebounded into the 400 mg/L range after study concluded.
- Finding: Well likely affected by two sources
 - County de-icing operations (reimbursed for damages that occurred during de-icing)
 - Upgradient water softener influence



Considerations for Other Entities

- For those interested in diagnostic water quality sampling:
 - The parameter list presented generally works well but is not definitive by any means. Sampling parameters should factor in geologic and other local considerations.
 - Carroll County will continue to reassess parameter list and potentially add to it as database is developed
 - Those in Coastal Plain and Western Maryland may want to consider incorporating elements to assess for natural saline waters (Cl/Br, other halides)
 - Brackish water and saltwater intrusion in Coastal Plain. Consider referencing known seawater ratios, as well as MGS water quality data. See MGS Publications (VanDerwerker)
 - Possible upwelling of deep basin brines in Western MD. While literature could be utilized, may be worth developing local (County) water quality database. See also MGS RI 85.
- Protocol Flexibility – While repeatable protocols are desirable, investigative process should still allow for flexibility and incorporation of other potential tools and data sources on a case-by-case basis.
 - While not covered in these case studies, County has investigated utilizing other tools like dye tracing in the past.

QUESTIONS?

Contact:

Zachary Neal

Carroll County Department of Land and
Resource Management

Phone: 410-386-2868

E-mail: zneal@carrollcountymd.gov