APPENDIX C. EXAMPLE CASE FOR ASSESSING BACKGROUND SPECIFIC CONDUCTIVITY

C.1. INTRODUCTION

This appendix provides and illustrates a draft weight-of-evidence approach that can be used to assess whether the estimated background specific conductivity (SC) for an area represents a natural or minimally affected condition, or whether it has been significantly altered (see Section 3.7). This draft approach can be used to determine whether the calculated background in a new area is minimally affected prior to deriving a hazardous concentration (HC_{05}) using either the extirpation distribution (XCD) method (see Section 3.1) or the background-to-criteria model (see Section 3.7.2). This draft approach can also be used to assess the possibility that there are different SC regimes and ionic composition in different areas within an ecoregion (see Section 3.7.1).

The scope of this appendix is background SC, not the entire distribution of ambient SC measurements in a region. The ideal is natural background, which is the state of the environment in the absence of human disturbance. Natural background SC is likely to be similar throughout a Level III ecoregion, because stream SC is determined by climatic, geologic and physiographic characteristics, which are also important determinates of ecoregions (Omernik, 1987). Because natural background conditions are rare, this method addresses minimally affected background and least disturbed background. Minimally affected background is defined as the physical, chemical, and biological habitat found in the absence of significant human disturbance (Stoddard et al., 2006). It approximates natural background. Least disturbed background refers to the best available physical, chemical, and biological habitat conditions given today's state of the landscape or the least disturbed by human activities (Stoddard et al., 2006).

The example presented here is a supplement to the geographic applicability assessment for Case Study II (see Section 5.3). The draft weight-of-evidence approach described here is specifically used to verify that the example criteria derived in Case Study II using data from West Virginia ("original area") are applicable to the portion of Ecoregion 70 within the state of Ohio ("new area"). This demonstration of applicability was performed because the minimum SC value in the new area based on a small EPA (U.S. Environmental Protection Agency)-survey data set was 232 µS/cm ($N = 11$), which is higher than the estimated background for Ecoregion 70 (197 µS/cm), but within the 95% confidence bounds (135−240 µS/cm).

C.2. WEIGHT-OF-EVIDENCE ASSESSMENT METHOD FOR EVALUATING BACKGROUND SPECIFIC CONDUCTIVITY

The characterization of background SC depends on a series of inferences, each of which may involve multiple pieces of evidence. Hence, the overall inference concerning, in this case, the equivalency of the background SC in the new area to the original area should be performed by weighing the body of evidence. Weighing all available and relevant evidence provides greater confidence than one line of evidence, because it is more likely that the body of evidence will be adequate and the resulting inference will be reliable. Weighing a heterogeneous body of evidence cannot be performed quantitatively. However, the qualitative logical process of weighing a body of evidence can be made more rigorous by using a set of a priori considerations (Kahneman, 2011). A list of considerations was developed (see Table C-1) that relate to the following questions.

A. Is the background SC expected to be similar in the new area and the original area based on knowledge of the regional physical properties that determine background SC?

B. Is the statistical distribution of SC in the new area similar to the original area, particularly at the low end, which is indicative of background?

C. Is the apparent background SC (based on available measurements) spatially dispersed across the new area?

D. Are the biotic communities in the new area similar to those in the original area with respect to salt-intolerant taxa, which are indicative of background SC?

E. Do the available sampling methods, design, and sample size in the new area meet data quality needs for performing an assessment of the background SC regime?

Table C-1. Considerations for characterizing current background specific conductivity and for assessing its departure from natural or minimally affected background specific conductivity regimes, organized by assessment questions (A−E) and types of evidence (1−27)

	Type of evidence	Rationale
A	**Regional properties**	
1	Similar climate across the region(s).	Ecoregions are classified based on shared climate, so difference within an ecoregion is unlikely, but differences among ecoregions are more likely. Climate affects vegetative cover and precipitation, which could affect background levels.
2	Similar geology across the region(s).	Ecoregions are classified based on shared geology, so difference within an ecoregion is minimized, and differences among ecoregions are more likely. Geology and soils can affect the background level.
3	Similar physiography across the region(s).	Ecoregions are classified based on shared physiography, so differences within an ecoregion are minimized, but differences among ecoregions are more likely. Physiography can affect the hydrology and interaction time of water and minerals.
4	Geophysical modeling estimates low variance across the region(s).	Models that predict stream chemistry based on geology, climate, topography, and vegetation are not predicated on current conditions, so they should estimate background. Some models are available (e.g., Olson and Hawkins, 2012).
B	**Natural background levels**	
5	Lowest observed SC in the new area is at least as low as estimated background in the original area.	Low SC is indicative of a minimally affected (natural) condition.
6	Low SC at minimally affected sites in both areas.	Sites with natural vegetation and no or very little current or historical disturbance should have low SC relative to disturbed areas.
7	In a probability sample, 10% of measured sites are less than the upper 95% CL of estimated background SC from the original region. (In this case <210 µS/cm).	The greater the proportion of sites below this level (e.g., for the case example, 210 µS/cm), the more likely that the background is not different. When anthropogenic changes are widespread, the 25^{th} centile may not accurately reflect natural background.
8	The median of reference sites is less than the upper 95% CL of background from the original region. (In this case <210 µS/cm).	True reference sites typically have low SC relative to disturbed sites. However, when anthropogenic changes are widespread, best available or least disturbed sites may not accurately reflect natural background. In such cases, a description of the distribution may be more informative than classification as reference.
9	In mixed data sets, the minimum should be less than the field-derived criteria from the original region. (In this case, <340 µS/cm).	In targeted or mixed water quality data sets, even a few low SC sites may help to characterize natural background conditions. A map of streams with low SC may help to identify rare resources. In a targeted or mixed data set, centiles are not intended to be representative of the region overall; they are simply proportions of the data set.

Table C-1. Considerations for characterizing current background specific conductivity for assessing its departure from natural or minimally affected background specific conductivity regimes, organized by assessment questions (continued)

	Type of evidence	Rationale
C	**Distribution of background levels**	
10	Low SC sites are spatially dispersed. (In this case, <210 µS/cm).	Low SC sites dispersed throughout the new area suggest that background is low in the region.
11	Sites with SC less than the criteria from the original region (in this case, <340 µS/cm) are spatially dispersed.	Low SC sites dispersed throughout the new area suggest that background is low in the region.
D	**Biological evidence**	
12	Salt-intolerant genera (e.g., XC_{95} <340 µS/cm) are found in the historical record.	Historically, species adapted to the natural SC regime should have occurred in the region. The historical presence of salt-intolerant genera is indicative of low SC systems in the region in the past.
13	Salt-intolerant genera (e.g., XC_{95} <340 µS/cm) are found in recent records.	The current presence of salt-intolerant genera is indicative of low SC systems in the region. Sampling date is critical because most salt-intolerant taxa are more likely to be collected in the first half of the calendar year. Sampling natural substrates is necessary because many salt-intolerant taxa are shredders and grazers.
14	Regional biotas are similar.	If the genera are similar between the two areas, the physical habitats are expected to be similar.
E	**Data quality and sufficiency**	
15	Larger data sets are more reliable.	Large data sets provide more confidence in the evidence derived from them.
16	Quality assured instream chemical measurements are more reliable.	Meter calibration should be performed using appropriate standards. Otherwise, the measurements may be inaccurate.
17	Appropriate reporting units are required.	Units should be reported as specific conductivity. Otherwise, direct comparison of the measurements is inappropriate.
18	Comparisons are appropriate if ionic mixtures are similar.	Data sets should be checked to eliminate sites with dissimilar ionic mixtures. Otherwise, the background estimates in the new area may not be comparable or are less reliable. Dissimilar mixtures are also suggestive of anthropogenic sources.
19	Comparisons are more reliable if collection methods and sampling windows are similar.	Data should be collected in similar seasons or be normalized for Julian day. Biological sampling methods should be similar. Otherwise, the estimates may not be comparable or are less reliable.
20	Validation increases reliability.	If more than one data set is available or another method is available for analysis and they yield similar results, then the results are validated and are less likely to be due to chance alone.

Table C-1. Considerations for characterizing current background specific conductivity for assessing its departure from natural or minimally affected background specific conductivity regimes, organized by assessment questions (continued)

	Type of evidence	Rationale
21	Inclusion of likely background sites makes identification of background levels more probable.	Inclusion of headwater (low Stahler order) streams in the sample increases the likelihood that background SC is represented, because they tend to have fewer anthropogenic sources. Watersheds with native vegetation are also more likely to have background water quality. The proximity and proportion of point sources or anthropogenically altered subsurface or land cover near the sampling sites decreases the likelihood that a site represents background. Even if >90% of area is forested, proximity of a sampling site to a point source has a greater effect than the proportion of vegetated area in the catchment (Hopkins et al., 2013).
22	Abrupt changes in values at political boundaries makes it likely that differences among areas are not natural.	Abrupt changes in SC at political boundaries suggest that differences in SC are likely due to differences in methods or anthropogenic sources/practices and not natural causes. Such changes do not represent real differences in background and support the argument that SC is not different between two areas.
23	Reference site quality independently verified.	Reference sites may not be background. Because identification of reference sites may be subjective, independent verification or comparison to another reference data set is desirable.
24	Reference sites are selected in part based on presence of high biological diversity.	Biological conditions for reference sites are important for verification of reference status.
25	Reference sites have high quality instream and riparian habitat (e.g., RBP score >140; [Barbour et al., 1999]).	Unless habitat quality is high, sites are unlikely to represent true reference water quality.
26	At reference sites, water quality parameters other than SC should reflect minimally affected conditions.	Unless all water quality parameters reflect minimally affected conditions, sites are unlikely to represent background.
27	Reference sites have minimal human disturbance of geological parent material.	Geologic disturbances such as quarries and road cuts are likely to raise SC levels.

XC = extirpation concentration; CL = confidence limit; RBP = Rapid Bioassessment Protocol.

Table C-1 can be used to capture information by removing the text in the column labeled “Rationale” and entering relevant information for a particular assessment. Annotations or scores can weight the evidence to indicate how strongly that information affects the determination of background. The table may be used either to evaluate the quality of an assessment of background from a particular data set or to compare different data sets or different areas. For an example, see the completed table for the case example for Ecoregion 70 (see Table C-11).

Note that when applying this, or any other weight-of-evidence method, some evidence will be weak and other evidence will be strong. All evidence is presented, even weak evidence, so that the full body of evidence can be evaluated to determine the best-supported conclusion.

C.3. EXAMPLE CASE STUDY

The weight-of-evidence approach is used here to assess whether the example criteria derived for Ecoregion 70 in Case Study II ("original area") are applicable to the portion of Ecoregion 70 within the state of Ohio ("new area"). During the geographic applicability assessment (see Section 5.3), it was noted that the minimum value from a small probability survey ($N = 11$) in the portion of Ecoregion 70 in Ohio was 232 μS/cm which is greater than the estimated background for Ecoregion 70 (197 μS/cm), but within the upper confidence bound (240 μS/cm) (see Section 5.3). To determine whether the difference in estimates of background SC in the two portions of Ecoregion 70 was natural, an additional assessment of background was performed specifically for the new area in Ohio. This weight-of-evidence method may be used to assess applicability of field-derived SC criteria for any region where it is possible that fewer than 25% of streams are minimally affected (Stoddard et al., 2006) and have SC levels reflective of natural background.

C.3.1. Data Sets

Multiple data sets were used in this example demonstration of the weight-of-evidence approach to assess geographic applicability of criteria derived using the field-based method. To estimate background SC, the example Criterion-data set that was used for Ecoregion 70 in West Virginia and the EPA-survey data set for all of Ecoregion 70 was used. Those data sets are described in Section 5.3.1. An additional data set from the Ohio EPA was used to estimate SC in the new area, i.e., the portion of Ecoregion 70 within Ohio, which is depicted in Figure C-1 and described below. The statistical package R, Version 2.12.1 (December 2010), was used for all statistical analyses (R Development Core Team, 2011).

C.3.2. Ohio EPA Combined Wadeable and Headwater Stream Data Sets 1999−2013

The data set provided by the Ohio EPA included wadeable and headwater sites sampled between 1999 and 2013 (see Figure C-1). Several data filters were applied. First, samples from lakes, wastewater and industrial outfalls, and the Ohio River were excluded. Samples with low pH <6, and chloride-dominated sites (where $[HCO_3^-] + [SO_4^{2-}] \leq [Cl^-]$) (one station) were also excluded. If repeat samples were taken at a location on the same date, the minimum SC value was retained in the data set. The remaining data set contained 4,452 stream samples from 809 unique stations and is referred to as the Ohio 1999−2013 data set (see Figure C-1). Repeat samples (81.8%) within a year at a unique station (1−15 times per annum) were used to estimate annual SC for a site (see Table C-2). Catchment area ranged from 0.26 km^2 to 20,850 km^2 with 50% of sites sampled in drainages <32.1 km^2 and 8.5% >1,500 km^2 (see Table C-3). Most data entries included catchment area and chemical analyses. Extensive documentation of Ohio EPA field and laboratory methods is available from the Ohio EPA.[1]

[1]http://www.epa.state.oh.us/dsw/bioassess/BioCriteriaProtAqLife.aspx.

Figure C-1. Distribution of 809 unique sampling sites in wadeable and headwater streams in Ecoregion 70 in Ohio that constitutes the Ohio 1999−2013 case example data set.

Table C-2. Number of samples from Ohio 1999−2013 data set with reported specific conductivity meeting data acceptance criteria for the analysis. Number of samples are shown for each month.

	Month												
Number of	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Samples	101	118	151	132	167	666	890	957	643	380	119	128	4,452
Unique sites	14	22	27	35	21	248	181	90	46	103	6	16	809
Percentage of total	1.7	2.7	3.3	4.3	2.6	30.7	22.4	11.1	5.7	12.7	0.7	2.0	100

Table C-3. Catchment sizes represented in the Ohio 1999−2013 data set

Proportion represented in the data set based on centile	Drainage area (km^2)
Minimum	0.26
25th centile	13.7
50th centile	32.1
75th centile	158
Maximum	20,850

Unlike the EPA-survey data set (probability survey designed) and the example Criterion-data set (probability sampling plus some purposive sampling) (see Section 5.3.1), the available Ohio data sets were generated with their geometric sampling distribution, primarily above and below point sources. Therefore, the data sets cannot be directly compared; however, they can be used to determine whether low-end SC levels (e.g., from minimally affected sites) in Ohio are in the same SC range as similar sites in the rest of the ecoregion.

C.3.2.1. *Data Set Selection for Specific Conductivity Characterization*

Analyses were performed using the Ohio 1999−2013 data set because (1) the data set spanned Ecoregion 70 in the state (see Figure C-1), (2) the sampling window included samples throughout the year (see Table C-2) including headwater and wadeable streams making it more like the example Criterion-data set for Ecoregion 70, and (3) multiple samples in a single year at a site enable some analyses of seasonality (see Table C-2).

As part of the geographical applicability assessment in Case Study II, background SC of the new area was estimated at the 25th centile and compared with the background estimates for the original area used to derive the example criteria (see Section 5.3).

C.3.3. Ionic Mixture

The Ohio EPA 1999−2013 data set in Ecoregion 70 was used to assess background, annual average, and maximum SC of sites with $HCO_3^- + SO_4^{2-}$ concentrations on a mass basis greater than Cl^- (see Table C-4). Only 1 out of 601 sites was dominated by chloride in the Ohio data set and it had high SC (>1,000 µS/cm); it was removed from the data set.

Table C-4. Water chemistry measurements from sites in the Ohio EPA 1999−2013 data set for Ecoregion 70

Specific conductivity/ion	*N*	Min	Centile				Max
			10th	25th	50th	75th	
Specific conductivity (μS/cm)	809	49	163	244	387	586	6,838
HCO_3^- (mg/L)	550	3.05	34.37	69.97	114.1	179.3	380.6
SO_4^{2-} (mg/L)	560	5.2	23.7	35.33	61.1	141	1,720
Cl^- (mg/L)	601	2.5	2.5	7.9	14.1	26.3	259
Ca^{2+} (mg/L)	588	6	16	27	45	71	419
Mg^{2+} (mg/L)	586	2	7	9	14	21	218
Na^+ (mg/L)	588	2.5	5	8	12	24	328
K^+ (mg/L)	588	1	2	2	3	4	29
pH (SU)	809	6.05	7.26	7.61	7.85	8.13	9.18
$(HCO_3^- + SO_4^{2-})/Cl^-$ [a]	550	1.52	5.18	7.99	14.12	26.92	225.89

[a]Value within category calculated from individual sample ion concentrations.

C.3.4. Regional Characteristics as Evidence for Question A

It is expected that areas within the same ecoregions in different states will have similar characteristics with respect to the properties that control background SC; however, a natural gradient could lead to differences. The primary factors that affect natural SC are underlying geology, physiography, and climate. Secondary factors include soils and vegetative cover (Olson and Hawkins, 2012; Hem, 1985; Griffith, 2014; Anning and Flynn, 2014). Because ecoregions were delineated based on similar considerations (Omernik, 1987), the SC regime and ionic composition of dissolved salts in streams within an ecoregion tend to be similar throughout. Any degree of difference is affected by resolution of the geographical delineation and the homogeneity of the region. Level III ecoregions were judged to be a practical and reasonable level of aggregation for this approach. A detailed description of Ecoregion 70 in Ohio is provided in Appendix C.2 and is used to support the following conclusions.

The climate of Ecoregion 70 in Ohio and in adjoining states is very similar. No large mountains create elevational gradients or rain shadows and no large lakes create lake effect precipitation. The lake effect for Lake Erie extends into the northern portion of Ecoregion 61 but not into Ecoregion 70.

Groundwater associated with the weathered zone of rock is dilute, in terms of dissolved solids, because readily soluble products have been removed by chemical weathering (Brady, 1998, p 21). Weathering removes near-surface carbonates by dissolution and sulfide by oxidation. Weathered rock extends 6 to 12 meters below surfaces in the unglaciated portion of the Allegheny Plateau (Brady et al., 2000). Salt springs occur in Ohio Ecoregion 70, but they also occur in other states in Ecoregion 70.

Glaciation was evaluated as a possible natural cause of the apparent elevated background conductivity. There are two ecoregions in Ohio's Allegheny Plateau, the Western Allegheny Plateau (Ecoregion 70) and the Lake Erie Drift Plain (Ecoregion 61). Ohio Ecoregion 70 is in the southwestern unglaciated portion of the larger Allegheny Plateau, and so dissolution is not expected to be greater than the rest of Ecoregion 70. Some headwaters of the Muskingum River are located in the Lake Erie Drift Plain and then drain into Ecoregion 70 and may naturally influence downstream SC in that drainage. However, there was no empirical evidence of greater conductivity at the EPA-combined sites within the Muskingum drainage based on the Ohio 1999−2013 data set SC measurements in that drainage.

Ecoregion 70 has a hilly and wooded terrain in both areas. The local relief of the unglaciated Allegheny Plateau in southeastern Ohio and westernmost West Virginia typically ranges from 61 to 229 m, and peak elevations of around 610 m. Many of the rivers in this ecoregion are entrenched, as a result of the rugged, hilly terrain, particularly within the Permian Hills (70a) and Monongahela Transition Zones (70b). The ecoregion is predominantly forested, but also consists of a mosaic of urbanized areas, pastures, farms, and coal mines (Woods et al., 1999). Extensive mixed mesophytic forests and mixed oak forests originally grew in the Western Allegheny Plateau and, today, most of its rounded hills remain in forest; dairy, livestock, and general farms, with residential developments concentrated in the valleys.

The Western Allegheny Plateau is composed of horizontally bedded sandstone, shale, siltstone, limestone, and coal. The horizontally-bedded sedimentary rock underlying the region has been mined for bituminous coal (Woods et al., 1996). The similar physiography in the two areas is expected to lead to similar surface and groundwater hydrology and the relatively uniform degree of deformation of the land should result in similar flow paths.

It should be noted that local anomalies occur but do not contradict the general uniformity of ecoregions identified by Fenneman and Johnson (1946) and described by Omernik, Wood, Griffith, Bailey, and others. For example, whereas in most fresh waters Ca^{2+}, Mg^{2+}, HCO_3^-, and SO_4^- ions dominate, there are natural salt (NaCl) springs in Central Appalachia. Also, because stream networks cross ecoregional boundaries, they may carry more dilute water into an area of higher SC or higher SC water into an ecoregion with a lower natural background (e.g., Erie Drift Plain draining to the Western Allegheny Plateau, glaciated headwater draining to an unglaciated region).

Base flow SC was estimated for Ecoregion 70 using a geochemical and geophysical model that predicts natural base-flow SC using geology, climate, soil, vegetation, topography, and other factors calibrated with references sites (Olson and Hawkins, 2012). See Appendix D for methods. The predicted stream average base flow SC was 180 μS/cm for the entire Ecoregion 70, 195 μS/cm for Ohio, 164 μS/cm for Pennsylvania, 176 μS/cm for West Virginia, and 172 μS/cm for Kentucky in portions of Ecoregion 70. Figure C-2 shows the predicted SC for streams in Ecoregion 70. The 75th centile for the reference sites in the Criterion-data set was 201 (95% confidence interval [CI] 164−210 μS/cm). The stream predicted mean base-flow is less than the upper 95% confidence limit (CL) of reference SC (210 μS/cm) in 84.9% stream segments (miles) of Ecoregion 70 and 76.2% of Ohio Ecoregion 70 stream segments. The model suggests that there is a slightly higher average base flow SC in Ohio Ecoregion 70 (8.3% higher than the ecoregion average and 10.8% higher than West Virginia).

Natural dissolution of minerals and dilution in surface and groundwater are expected to be similar throughout Ecoregion 70, because similar climate, rock strata and physiography occur throughout the ecoregion (see Figures C-3 and C-4). The bedrock formations in Ecoregion 70 in West Virginia are nearly a mirror image of those in Ohio (see Figures C-3 and C-4) (Schruben et al., 1997; WVGES, 2011) and are reflected in the subecoregions (see Figure C-10).

The evidence based on ecoregional characteristics is summarized in Table C-5.

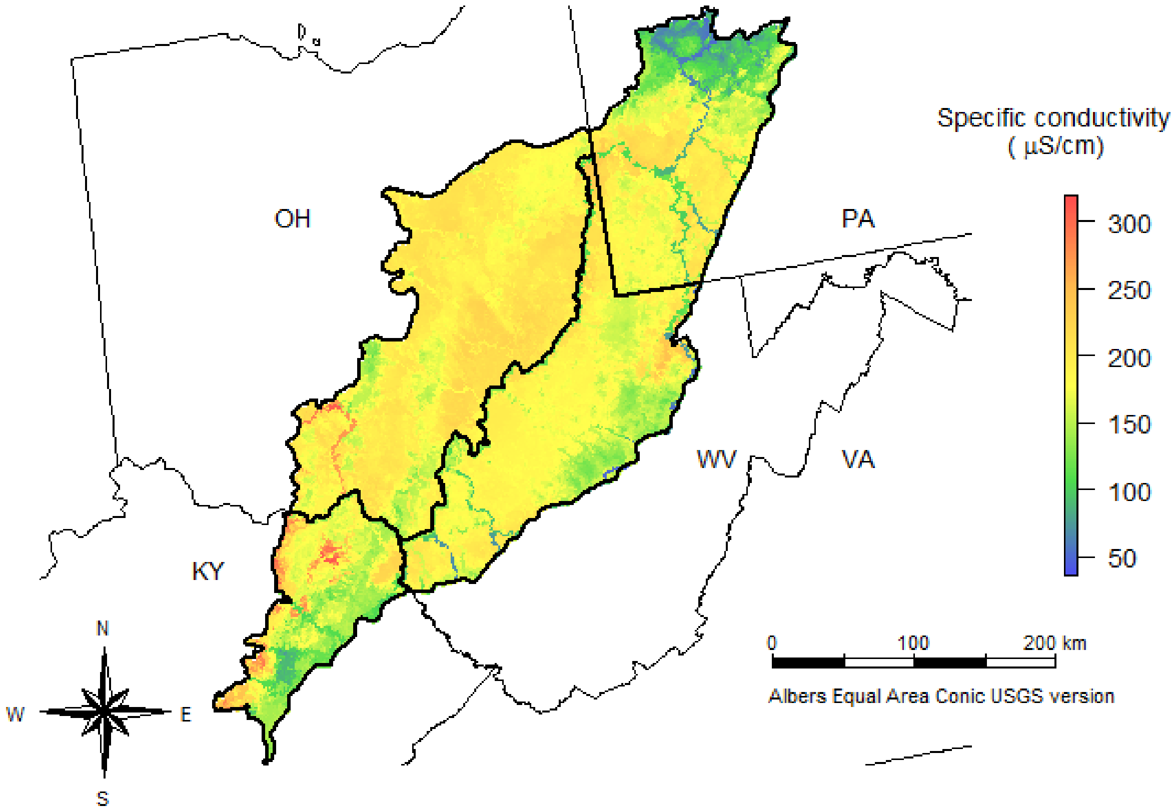

Figure C-2. Predicted base flow SC for streams in Pennsylvania, Ohio, West Virginia, and Kentucky. The SC range in the central portion of the ecoregion is expected to be between 161 and 230 µS/cm.

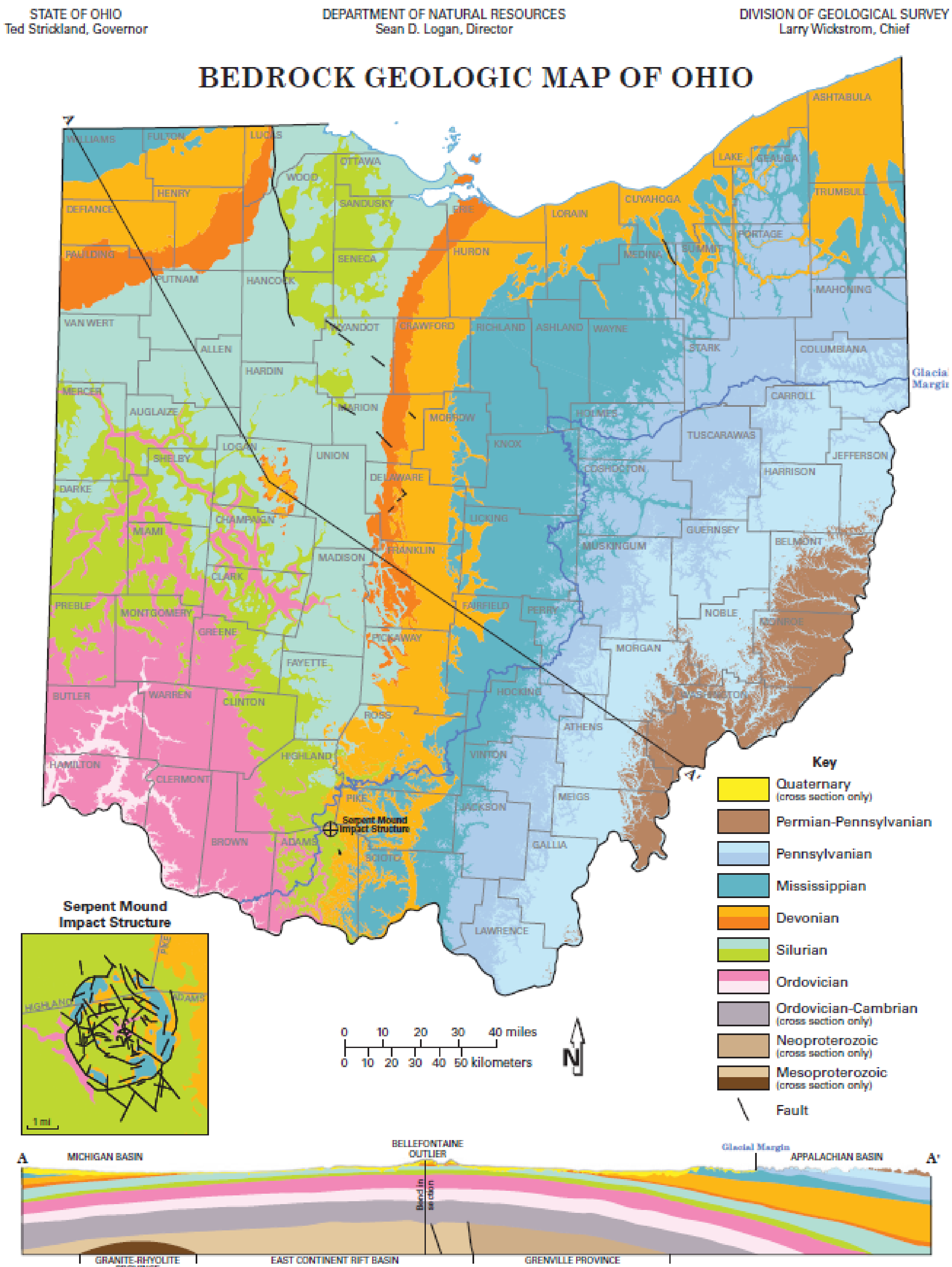

Figure C-3. Caption on following page.

Figure C-3. Bedrock geology of Ohio. Ecoregion 70 is south and east of the glacial margin. Ample time has passed for weathering to occur. The youngest bedrock in the area is about 298−302 million years old and consists of shale, sandstone, siltstone, mudstone, and coal and is indicated in brown. The Pennsylvanian rocks shown in light and darker blue were deposited in freshwater and marine systems between 302 and 318 million years ago. They contain shale, sandstone, siltstone, mudstone, limestone, conglomerate, and coal. The Mississippian (322−359 million years) and Devonian (359−385 million years ago) sedimentary rocks are both marine to marginal marine in origin. Permian-Pennsylvanian and Pennsylvanian strata contain coal. Cross-sectional insert shows bending of strata. Deep valleys (seen as light blue peaks in inset) in Ecoregion 70 were formed by the Teays River that changed course when glaciers blocked its northern course and redirected it west to form the Ohio River.

Source: ODGS (Ohio Division of Geological Survey, 2006).

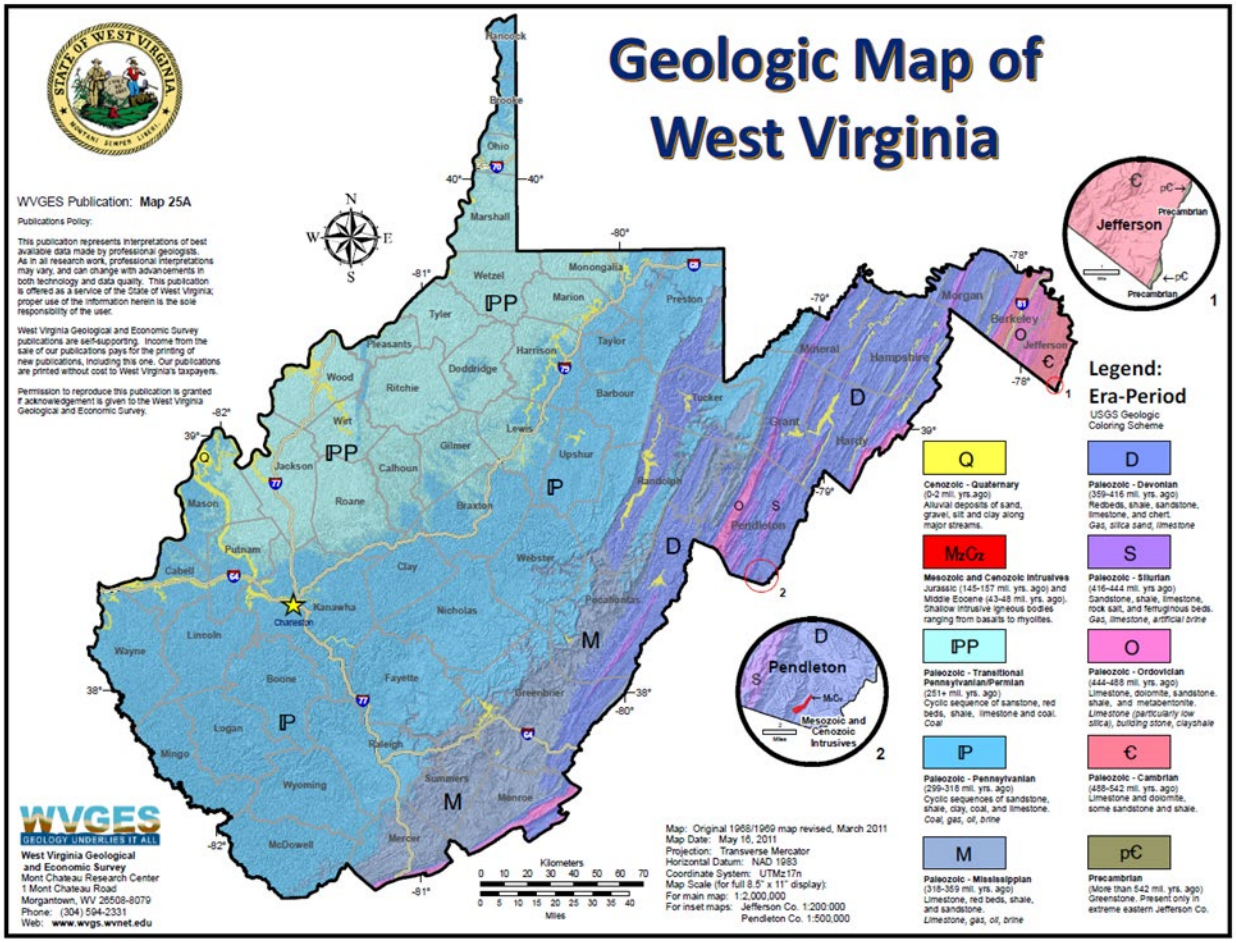

Figure C-4. Map of bedrock geology in West Virginia. Ecoregion 70 in West Virginia (upper left of the map), as in Ohio (lower right of Figure C-3), is on Paleozoic rock. The pale blue area on this map and the brown area across the Ohio River in Figure C-3 (the center of Ecoregion 70) are transitional Pennsylvanian-Permian and the adjoining areas of Ecoregion 70 (darker blue here and pale blue in Figure C-3) are Pennsylvanian. Source: WVGES (2011).

Table C-5. Summary of regional characteristics evidence for Question A

	Evidence	Results
1	Similar climate across the region.	Climate is similar across the ecoregion.
2	Similar geology across the region.	Geological strata are similar and shared across the ecoregion, consisting of mixtures of freshwater to marine sedimentary rocks (shale, sandstone, siltstone, mudstone, limestone, conglomerate, and coal). The bedrock formations in Ecoregion 70 in West Virginia are nearly a mirror image of those in Ohio (see Figure C-3 and C-4) (Schruben et al., 1997; Cardwell et al., 1968; WVGES, 2011) and are reflected in the subecoregions (see Figure C-10).
3	Similar physiography across the region.	The similar physiography in Ohio and West Virginia Ecoregion 70 is expected to lead to similar surface and groundwater hydrology and the relatively uniform degree of deformation of the land should result in similar flow paths.
4	Geophysical modeling estimates low variance across the region.	Base flow estimated by a geophysical model for Ohio Ecoregion 70 (195 µS/cm) was 10.8% higher than in West Virginia (176 µS/cm). Model predicted that 76.2% of Ohio Ecoregion 70 streams has mean baseflow SC less than the upper 95th CL SC for reference sites in the original area.
Summary.		The geology, climate and physiography are similar throughout Ecoregion 70. Therefore, the processes that determine natural background are shared throughout the ecoregion.

C.3.5. Specific Conductivity at Background Sites as Evidence for Question B

If the lowest observed SC values in Ohio Ecoregion 70 are similar to those elsewhere (e.g., in the example Criterion-data set), that would suggest that background SC is similar. Minimally affected sites across the ecoregion should have similar low SC levels. Minimally affected reference sites across the ecoregion should be similar with regard to SC. However, there may be some variation in background estimates among the lowest SC measurements, even at a single location, due to the amount of time water is in contact with unweathered minerals, and due to dilution by rainfall (Hem, 1985; Schneider, 1965). Several thresholds were used to evaluate the prevalence of different SC levels and the results are summarized in Table C-7.

C.3.5.1. *Specific Conductivity Characterization Using Targeted Data*

There are 4,452 samples in 809 unique stream sites in the Ohio Ecoregion 70 1999−2013 data set (see Figure C-1) with SC levels ranging from 49 µS/cm to 6,838 µS/cm (see Figure C-5). Cumulative distribution plots and box plots were used to compare the measured SC in Ohio Ecoregion 70 with measured SC in the example Criterion-data set in Ecoregion 70 (see Figure C-6 and C-7). Descriptive statistical values are provided in Table C-4.

The occurrence of low SC was assessed with respect to the upper CL of the estimated background for reference sites from the example Criterion-data set (210 µS/cm) (see Section 5.3). The annual average SC of unique Ohio sites was assessed with respect to the case example criterion continuous concentration (CCC) for Ecoregion 70 (340 µS/cm).

Numerous low SC streams occur in Ohio Ecoregion 70. More than 19% of unique sites in the 1999−2013 data set from Ohio Ecoregion 70 have measured SC ≤ 210 µS/cm, the upper confidence bound of reference sites in the example Criterion-data set (see Table C-6). More than 43% of measured Ohio stream reaches have an annual minimum SC less than the case example water quality criteria for Ecoregion 70 (340 µS/cm). These results are reasonable estimates of background SC but do not represent a census or proportional estimate of low SC streams, because the samples are not randomly selected. Rather, they are results of available measurements taken from various monitoring programs in the Ohio Ecoregion 70.

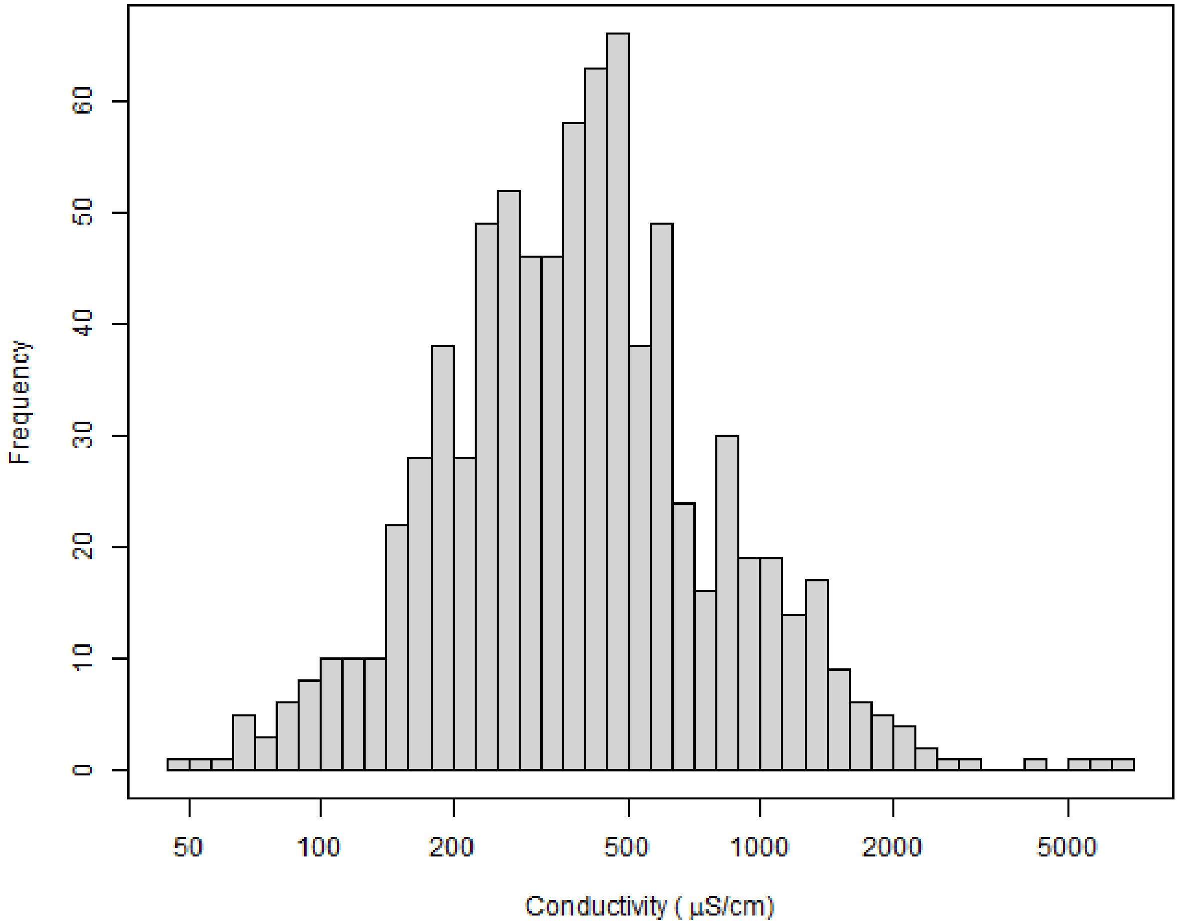

Figure C-5. Histogram of minimum specific conductivity values measured at 809 sites represented in the Ohio EPA 1999−2013 data set in Ecoregion 70.

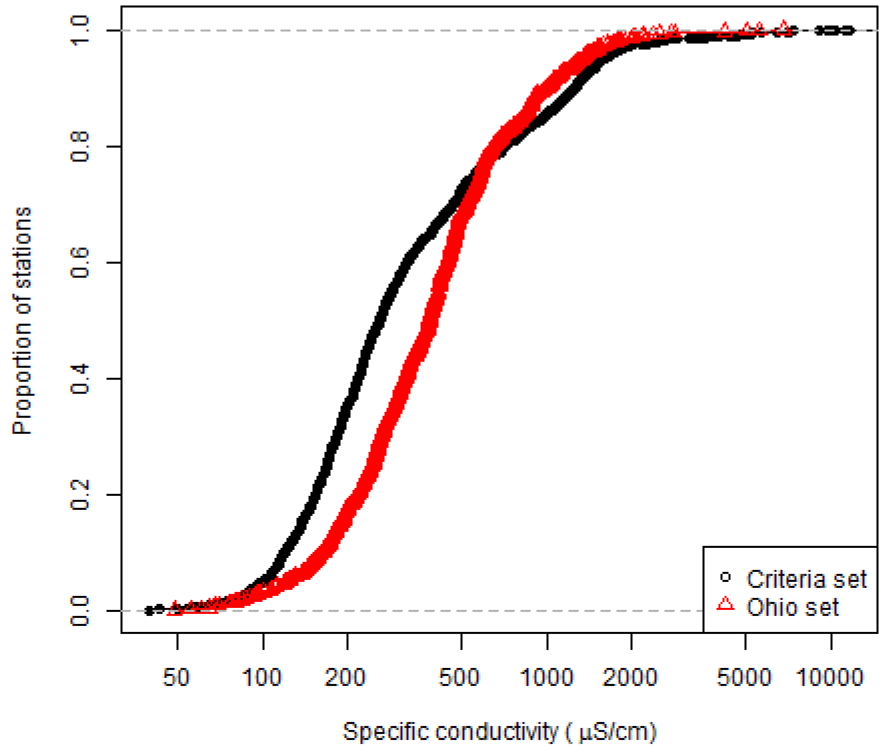

Figure C-6. Cumulative distribution function of specific conductivity (SC) measurements from the example Criterion-data set and the Ohio 1999−2013 data set in Ecoregion 70. At the lowest background SC (<100 µS/cm), the data distributions overlap, but Ohio levels are higher above the 5th centile.

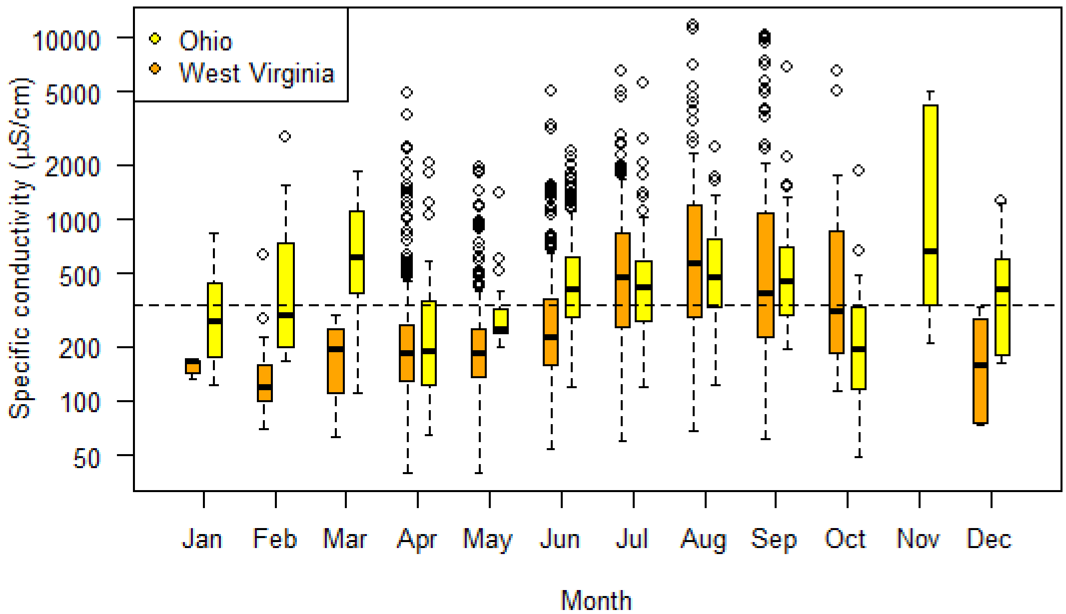

Figure C-7. The distributions in the example Criterion-data set and the Ohio 1999−2013 data set from Ecoregion 70. The distributions overlap and ranges of the lowest specific conductivity values also overlap. The horizontal line is the HC_{05} for West Virginia Ecoregion 70.

Table C-6. Number of sites in the Ohio 1999−2013 data set with measured specific conductivity values less than estimated background from the example Criterion-data set and less than the HC_{05} for Ecoregion 70

Threshold description	Specific conductivity threshold (µS/cm)	Number of unique Ohio sites below threshold
Upper 95% CL for reference sites in Criterion-data set for Ecoregion 70	≤210	154/809 (19.0%)
Example HC_{05} for Ecoregion 70	≤340	353/809 (43.6%)

Table C-7. Summary of natural background levels as evidence for Question B

	Evidence	Results
5	Lowest observed SC in the new area is at least as low as estimated background in the original area.	49 µS/cm in new area compared to the original area background of 201 µS/cm (the 75th centile of field data from reference sites of the original area) with 95% CI 164−210 µS/cm, and 169 µS/cm (from the example Criterion data set) with 95% CI 161−171 µS/cm.
6	Low SC at minimally affected sites in both areas.	NE. Neither percentage land cover nor confirmed reference sites were available for Ohio.
7	In a probability sample, 10% of measured sites are less than the upper 95% CL of background from the original region (210 µS/cm).	Probability sample not available. From a mixed data set, 19.0% of unique sites in Ohio Ecoregion 70 have measured SC ≤210 µS/cm.
8	The median of reference sites is less than upper 95% CL of background from the original region (210 µS/cm).	NE. Confirmed reference sites not available from the Ohio data set.
9	In mixed data sets, the minimum should be less than the field-derived benchmark from the original region (340 µS/cm.)	43.6% of unique sites in the new area have measured SC ≤340 µS/cm.
	Summary.	The estimated natural background is only a little higher in the new area compared to the original area (see Figure C-7). The minimum measured SC is 49 µS/cm in Ohio, but almost 20% of sites are within the 95% CL for the 25th centile of sites in the WABbase data set for Case Study II Ecoregion 70. The similarity of the seasonal conductivity regimes in the two areas (see Figure C-7) is supportive of the similarity of background.

NE = no evidence.

C.3.6. Distribution of Low Specific Conductivity Sites as Evidence for Question C

If the sites with low SC are distributed across the new area, that suggests a broad distribution of sites representing background conditions across the area. If, on the contrary, they existed only on the margins of the area, then that might suggest that they are associated with conditions in the adjoining area. If they occurred only in a few locations, then that would suggest that they are a result of local anomalies. In this example, low SC sites in the portion of Ecoregion 70 within Ohio show a similar distribution to all sampled locations, except for the density of low SC to the southwest of the Scioto River (see Figure C-8). The results are summarized in Table C-8.

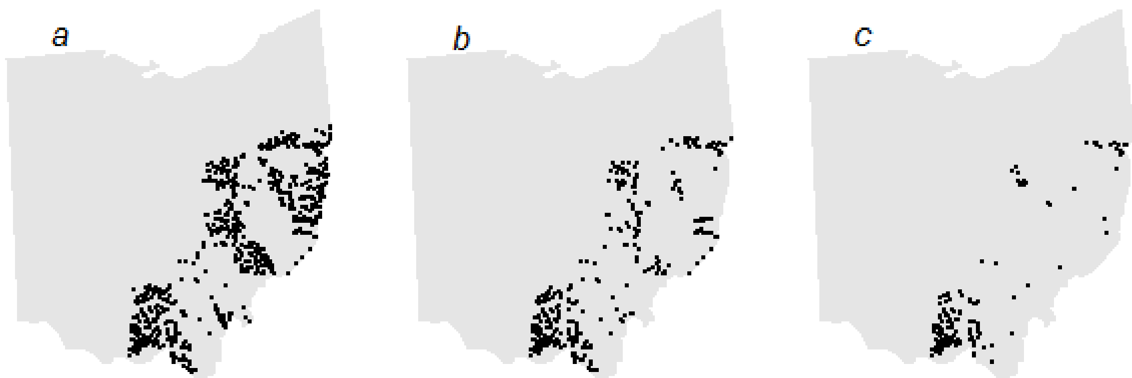

Figure C-8. Distribution of sampled sites in Ohio 1999−2013 data set. Low specific conductivity (SC) sites are representatively dispersed throughout the sampled areas. (a) All sites from the Ohio EPA 1999−2013 data set (N = 809), (b) samples less than 340 µS/cm, the example ecoregional criteria, (N = 353), and (c) all samples less than the upper CL (210 µS/cm) of reference sites in the example Criterion-data set (n = 154). More low conductivity sites occur west of the Scioto River.

Data source: Jonathan Burian, EPA.

Table C-8. Distribution of natural background levels as evidence for Question C

	Evidence	Results
10	Low SC sites (<210 µS/cm) are spatially dispersed.	Low SC sites are widely distributed across Ohio Ecoregion 70 in approximately the same pattern as all sites, suggesting that they represent the regional background (see Figure C-8). The base flow SC is predicted to be higher north of the Ohio River (see Figure C-2).
11	Sites with SC less than the benchmark from the original region (340 µS/cm) are spatially dispersed.	Low SC sites are dispersed throughout the region and the evidence does not show that the background is different from the rest of Ecoregion 70.
	Summary.	The distribution of low SC sites is consistent with residual natural background for the area. However, the data set is not optimal in either coverage or sampling of smaller streams.

C.3.7. Biological Characteristics as Evidence for Question D

The presence of obligate low SC species indicates that low SC streams occur in the sampled region, because they cannot survive without them. The ionic niche inhabited by species can be narrow or wide and often extends above the background SC estimated at the 25th centile. So, the extirpation concentration (XC_{95}) for most species tends to be somewhat higher than background SC.

If salt-intolerant species have historically occurred in an area, then the natural background should have been low enough to accommodate them. If salt-intolerant species currently occur in an area, the current background SC should be low enough for them to survive. Absence of salt-intolerant species or genera alone is not definitive evidence that the regions are different, because historical records are often incomplete, other factors may limit occurrence, and current conditions may not allow recolonization. Furthermore, the SC tolerance of species varies within a genus and benthic invertebrate samples are often identified to genus.

Quality assurance (QA) should consider the comparability of field methods and taxonomic identification. In particular, sampling date is critical because the most salt-intolerant taxa are more likely to be collected in the first half of the calendar year. Sampling natural substrates is also necessary because many salt-intolerant taxa are shredders and are less likely to colonize deployed substrates.

In this example, invertebrate genera that require low SC waters occur in the new area (Ohio Ecoregion 70), and therefore, low SC conditions should occur in that region (see Table C-9). Four of the seven genera that are extirpated below 340 µS/cm in the example Criterion-data set for Ecoregion 70 (see Appendix B.3), (*Alloperla, Diploperla, Heptagenia*, and *Ephemerella*), occur in Ohio Ecoregion 70 (Ohio EPA, 2013). Of the 176 XC_{95} values calculated from the example Criterion-data sets for Ecoregions 69 and 70 (see Appendix E), there are a total of seven genera reported in Ohio (Ohio EPA, 2013), (*Lepidostoma, Alloperla, Diploperla, Ephemerella, Clioperla, Heptagenia,* and *Nixea*), with XC_{95} values less than 340 µS/cm (see Appendix E.4).

Table C-9. Summary of biological evidence for Question D

	Biological evidence	Results
12	Salt-intolerant genera (XC_{95} <340 µS/cm) are found in the historical record.	Not examined.
13	Salt-intolerant genera (XC_{95} <340 µS/cm) are found in recent records.	Seven genera occur in Ohio with XC_{95} values less than 340 µS/cm (the Case Study II example CCC).
14	Regional biota is similar.	Of the 139 genera included in the Case Study II XCD, 90.6% are represented in the new area.
Summary.		Ninety percent of the genera in Case Study II's original area occur in the new area. Salt-intolerant SC genera are present; therefore, some places are believed to have low SC. However, species within a genus in the new area could be different from the rest of the ecoregion, so results are supportive but not conclusive.

Of the 139 genera included in the Ecoregion 70 genus XCD, 90.6% are represented in the Ohio data set, indicating similarity of the biotas across state lines. The presence of genera that require low ion concentration levels indicates that low SC habitats occur in Ecoregion 70 in Ohio.

C.3.8. Data Sufficiency and Quality as Evidence for Question E

Characterizing natural background and current conditions requires quality assurance and proper preparation of a data set for analysis. In addition to quality assurance of the field and laboratory measurements, the sampling design and sample size of the data set may affect the analysis and interpretation. For example, if most samples are collected in the summer, then this will likely bias the samples toward higher estimates of SC, whereas samples collected during precipitation events will tend to bias toward lower estimates. Historical measurements represent conditions at that time and land uses may have changed (Schneider, 1965).

In the characterization of background SC, sample methods and sample designs can affect results. Evidence of questionable data quality would suggest that the reported background may be inaccurate or biased (see Section E of Table C-1). The quality of the SC measurements is evaluated by checking QA records and standard operating procedures for calibration of SC meters with solutions prepared for dilute waters, (i.e., low SC), and by examining the data for apparent discrepancies. For example, if the lowest reported specific SC level is consistently the same round number (e.g., 100 μS/cm), this may be a detection limit, so SC levels below this value may not have been accurately measured and confidence in the data set is lessened (Helsel, 2012). Conductivity meters should report specific temperature and be equipped with an automatic temperature compensation capability. Older equipment may have been used and measurements reported as electrical conductivity, rather than SC which is normalized for temperature.

When comparing two areas, the data should be derived under the same conditions in both places. For example, when data have not been collected in similar seasons, it may be necessary to normalize the data for Julian day (see Appendices A and B for example methods). Most importantly, the samples should include minimally affected or reference sites. Watersheds with >90% native vegetation are more likely to have low SC than areas that are highly developed. Even if >90% of area is forested, proximity of a sampling site to a point source can have a greater effect than the proportion of the catchment in forest (Hopkins et al., 2013). Headwater streams are more likely to represent background SC, because there are likely to be fewer nonpoint and point sources.

Natural SC regimes are the result of natural causes. Abrupt changes at political boundaries may indicate that results from the two regions are not comparable. For example, differences could be due to sampling methods, different sampling teams, anthropogenic sources/practices, or other factors.

Results can be verified or validated in several ways. One way to validate is to use an independent data set, to validate with respect to sampling variance, or reserve part of a larger data set to validate the other. Alternatively, models that predict stream chemistry based on geology, climate, topography, and vegetation can provide an independent characterization and may even be useful for estimating natural background for smaller geographical areas (Olson and Hawkins, 2012).

In this example, the 1999−2013 data set was used to assess SC regimes in Ohio. The combined wadeable-headwater 1999−2013 data set contained at least some samples distributed through the year representing the full range of SC, which can vary with season (see Table C-1, and Figure C-7). The quality was assessed as good with respect to seasonal distribution. Based on this and other considerations described in Table C-10, the Ohio EPA data set from 1999−2013 was judged to be suitable for characterizing background in Ohio Ecoregion 70.

Table C-10. Summary of Ohio EPA Data Set Quality and Suitability for Analyses for Question E

	Data attributes	Results	
15	Larger data sets are more reliable.	The number of samples (4,452) and sites (809) in the new area is sufficient to estimate background; however, the spatial distribution was uneven.	
16	Quality assured instream chemical measurements are more reliable.	Meter calibration and other good field and laboratory practices are required by Ohio EPA standard operating procedures.	
17	Appropriate reporting units are required.	Units are reported as specific SC. Other units and detection limits are designated.	
18	Comparisons are appropriate if ionic mixtures are similar.	Included samples are dominated by salts of HCO_3^- plus SO_4^{2-} (Cl^- represents less than 50% of anions by weight).	
19	Comparisons are more reliable if collection methods and sampling windows are similar.	The combined wadeable-headwater Ohio 1999−2013 data set was collected throughout the year but was concentrated in June and July; whereas, the Criterion data set was more evenly distributed over time. However, 36% of samples were taken in April and May in the Criterion data set and only 7% in the Ohio 1999−2013 data set. These differences in sampling may have led to higher average SC measurements in Ohio. Also, the spatial distribution of samples in Ohio was not from a probability design.	
20	Validation increases reliability.	More than one data set is available in the new area, but they are very small, <20 samples, so no validation was attempted.	
21	Inclusion of likely background sites makes identification of background conductivity more probable.	Small catchments, which tend to be in higher elevation and less disturbed sites, are included in all data sets. The proportion of land cover in native vegetation is not known.	
22	Abrupt changes in SC values at political boundaries makes it likely that differences are not natural.	Because of the sampling pattern in Ohio (see Figure C-1), it is not possible to determine whether there is an abrupt change at a political boundary that would account for the slightly higher background estimate.	
23	Reference site quality independently verified.		NE
24	Reference sites are selected in part based on presence of high biological diversity.		NE
25	Reference sites have high quality instream and riparian habitat (e.g., RBP >140).		NE
26	At reference sites, water quality parameters other than SC should reflect minimally affected conditions.		NE
27	Reference sites have minimal human disturbance of geological parent material.		NE
	Summary.	The Ohio Ecoregion 70 data set is suitable for analysis as a mixed or targeted data set, but requires caution when comparing to other data sets.	

C.3.9. Summary of Example Assessment

Background stream SC in the new area (Ecoregion 70 in Ohio) was not found to be substantially different from the original area (the rest of Ecoregion 70). The evidence is collated and weighed in Table C-11. The ionic mixture in nearly all streams is dominated by $[HC0_3^-] + [SO_4^{2+}] > Cl^-$. SC measurements in Ohio Ecoregion 70 ranged from 49 µS/cm to >3,000 µS/cm (see Figure C-5), and were higher at effluent outfalls. Greater than 19% of sites sampled in the Ohio 1999−2013 data set had measured SC less than the upper confidence limit of the background estimated from reference sites in the example Criterion-data set. Different sampling densities and designs and different land uses may account for differences between Ohio and the Original Area Ecoregion 70 in the relative number of sites in the 200−300 µS/cm range. Furthermore, there is no evidence of a natural physical cause of a higher background for Ecoregion 70 in Ohio than in the rest of the ecoregion. According to a predictive model, there may be more watersheds with higher mean natural baseflow in Ohio than in Ecoregion 70 in the other four states, but the differences are less than 20 µS/cm (see Table C-5). Because this is a regional assessment of background in Ohio Ecoregion 70, some higher and lower natural SC regimes may occur and require site-specific evaluation of applicability of a regionally derived criterion, but overall a single criterion would be practical.

Table C-11. **Considerations for characterizing current background specific conductivity in Ohio Ecoregion 70 and to assess its similarity to the original area (Ecoregion 70 in West Virginia) organized by assessment question**

	Data attribute	Results
A	**Is the background SC expected to be similar in the new area and the original area based on knowledge of the regional physical properties that determine background SC?**	
1	Similar climate across the region.	Climate is similar across the ecoregion.
2	Similar geology across the region.	Geological strata are similar throughout the ecoregion.
3	Similar physiography across the region.	The ecoregion has a hilly physiography.
4	Geophysical modeling estimates low variance across the region.	Base flow SC estimated by a geophysical model for Ohio Ecoregion 70 (195 µS/cm) was only 10.8% higher than in West Virginia (176 µS/cm). Model predicted that 76.2% of Ohio Ecoregion 70 has baseflow SC less than the upper 95th CL SC for reference sites in the original area.
B	**Is the statistical distribution of SC in the new area similar to the original area, particularly at the low end, which is indicative of background?**	
5	Lowest observed SC in the new area is at least as low as estimated background in the original area.	49 µS/cm in new area compared to the original area background of 201 µS/cm (estimated to be 201 µS/cm at the 75th centile of field data from reference sites of the original area).
6	Low SC at minimally affected sites in both areas.	NE. Neither percentage land cover nor confirmed reference sites were available.
7	In a probability sample, 10% of measured sites are less than the upper 95% CL of background from the original region (210 µS/cm).	Probability sample not available in Ohio. From a mixed data set, 19.0% of unique sites have measured SC ≤210 µS/cm.
8	The median of reference sites is less than upper 95% CL of background from the original region (210 µS/cm).	NE. Confirmed reference sites not available from the Ohio data set.
9	In mixed data sets, the minimum should be less than the field-derived benchmark from the original region (340 µS/cm.)	43.6% of unique sites have measured SC ≤340 µS/cm.
C	**Is the apparent background SC (based on available measurements) is spatially dispersed across the new area?**	
10	Low SC sites are spatially dispersed.	Low SC sites are widely distributed across Ohio Ecoregion 70, suggesting that they represent the regional background (see Figure C-8). The base flow SC is predicted to be higher north of the Ohio River (see Figure C-2).

Table C-11. Considerations for characterizing current background specific conductivity and to assess its departure from natural or minimally affected background conductivity regimes, organized by assessment questions (continued)

	Data attribute	Results
11	Sites with SC less than the benchmark from the original region (340 µS/cm) are spatially dispersed.	Low SC sites are dispersed throughout the region and the evidence does not show that the background is different from the rest of Ecoregion 70.
D	**Are the biotic communities in the new area similar to those in the original area with respect to salt intolerant taxa, which are indicative of background SC?**	
12	Salt-intolerant genera (XC_{95} <340 µS/cm) are found in the historical record.	Not examined.
13	Salt-intolerant genera (XC_{95} <340 µS/cm) are found in recent records.	Seven genera occur in the new area with XC_{95} values less than 340 µS/cm (the Case Study II example CCC).
14	Regional biota is similar.	Of the 139 genera included in the Case Study II XCD, 90.6% are represented in the data set for the new area.
E	**Do the available sampling methods, design, and sample size in the new area meet data quality needs for performing an assessment of the background SC regime?**	
15	Larger data sets are more reliable.	The number of samples (4,452) and sites (809) in the new area is sufficient to estimate background.
16	Quality assured instream chemical measurements are more reliable.	Meter calibration and other good field and laboratory practices are required by Ohio EPA standard operating procedures.
17	Appropriate reporting units are required.	Units are reported as specific SC. Other units and detection limits are designated.
18	Comparisons are appropriate if ionic mixtures are similar.	Included samples in both areas are dominated by salts of HCO_3^- plus SO_4^{2-} (Cl^- represents less than 50% of anions by weight).
19	Comparisons are more reliable if collection methods and sampling windows are similar.	The Ohio 1999−2013 data set was collected throughout the year but was much more temporally concentrated and was not spatially distributed by a probability design.
20	Validation increases reliability.	More than one data set is available for the new area, but they are very small (<20 samples) so no validation was attempted.
21	Inclusion of likely background sites makes identification of background conductivity more probable.	Small catchments, which tend to be in higher elevation and less disturbed sites, are included in all data sets. The proportion of land cover in native vegetation is not known.

Table C-11. Considerations for characterizing current background specific conductivity and to assess its departure from natural or minimally affected background conductivity regimes, organized by assessment questions (continued)

	Data attribute	Results
22	Abrupt changes in SC values at political boundaries makes it likely that differences are not natural.	There are no abrupt changes in SC measurements between the new area and the rest of the ecoregion.
	SUMMARY	Background stream SC in Ohio Ecoregion 70 appears to be a little higher than in the original area, but the difference is not substantial. The most prominent differences are the undesigned spatial distribution of sampling in Ohio and the high proportion of June−July sampling.

C.4. BACKGROUND INFORMATION ON ECOREGION 70

Ecoregion 70 (see Figure C-9) has been classified into six EPA Level 4 ecoregions (see Figure C-10). Level 4 ecoregions in Ohio include the Permian Hills (70a), Monongahela Transition Zone (70b), Pittsburgh Low Plateau (70c), Lower Scioto Dissected Plateau (70d), Unglaciated Upped Muskingum basin (70e), and Ohio/Kentucky Carboniferous Plateau (70f). Only 70e occurs exclusively in Ohio. A brief description of each Level 4 ecoregion is excerpted from the EPA map Ecoregions of Indiana and Ohio. (ftp://ftp.epa.gov/wed/ecoregions/in/ohin_front.pdf).

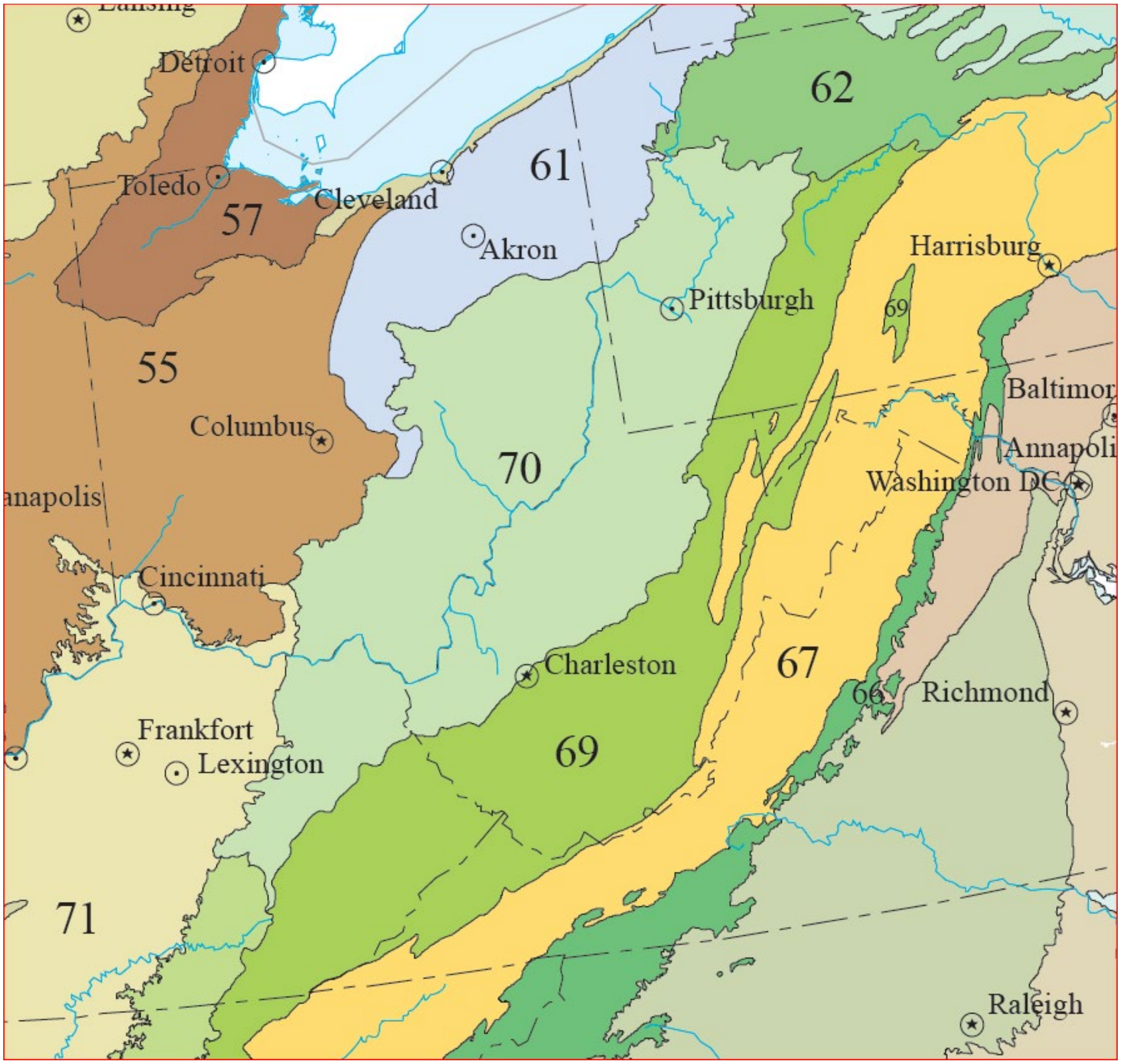

Figure C-9. Ecoregion 70 (pale green) is obliquely bisected by the Ohio River which flows through Pittsburgh and westward along the Ohio−Kentucky border. The Erie Drift Plain (Ecoregion 61) to the north of Ecoregion 70 has some geological similarities to Ecoregion 70, but was glaciated during part of its recent geological history. This assessment deals with Ecoregion 70 in Ohio, the pale green area above the blue Ohio River line.

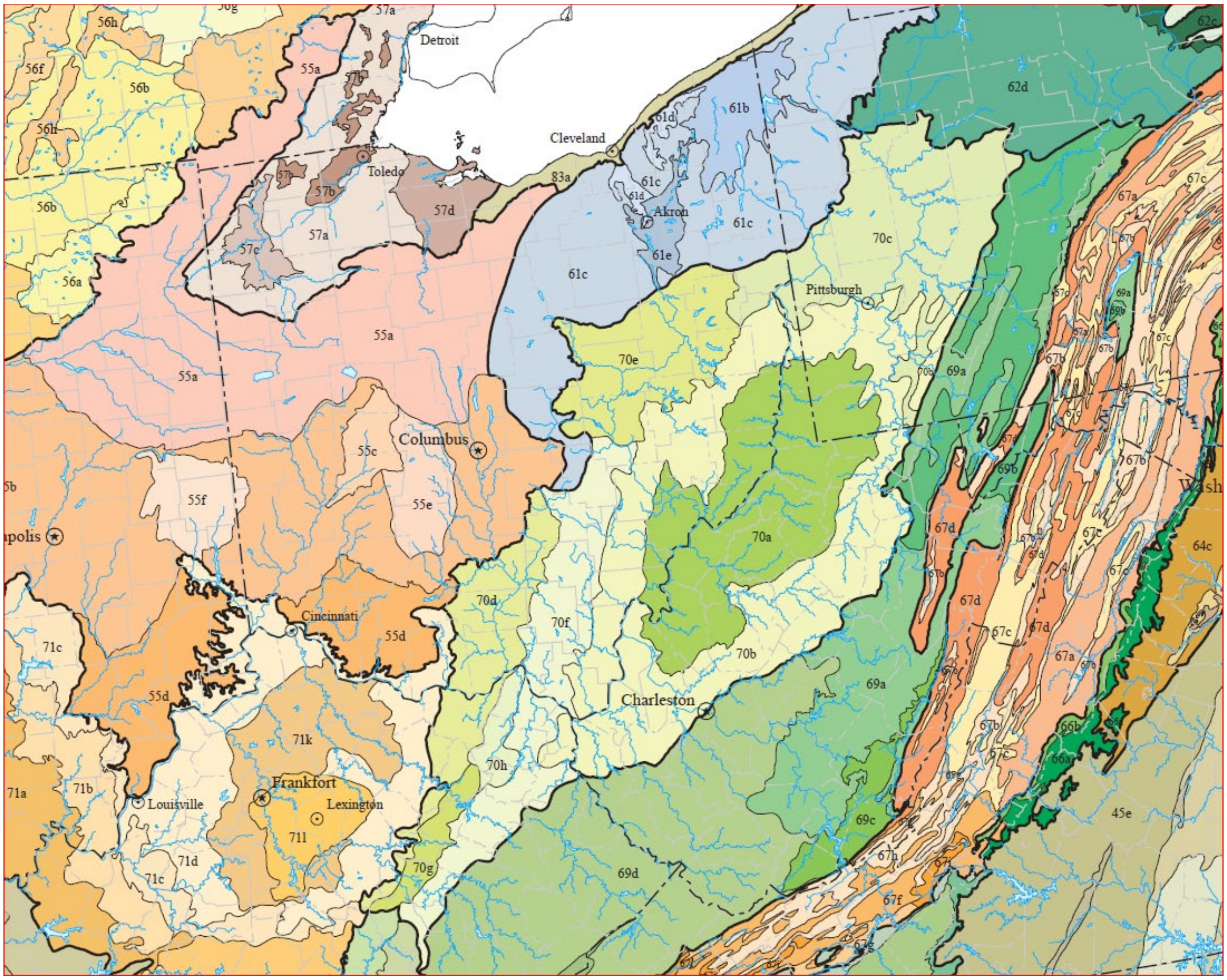

Figure C-10. Ecoregion 70 subregions are shaded in yellow and greens in the center of the map. Some streams in Ecoregion 70 may have headwaters in Ecoregion 61c (the Low Lime Drift Plain) lying to the north[2]. Only Ecoregion 70e occurs exclusively in Ohio. The boundaries of Ecoregion 70 are primarily defined by the underlying geology (see Figure C-3), glaciations to the west and north, and older higher elevation Appalachian Mountains to the east.

C.4.1. Western Allegheny Plateau

The hilly and wooded terrain of Ecoregion 70 was not muted by glaciation and is more rugged than the agricultural till plains of Ecoregions 55 and 61. Extensive mixed mesophytic forests and mixed oak forests originally grew in Ecoregion 70. Today, most of its rounded hills

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[2]Although not a part of Ecoregion 70, The Low Lime Drift Plain (61c), some headwaters may drain from this area into Ecoregion 70 and may have a different natural SC regime. The ecoregion has a rolling landscape with scattered glacial end moraines and kettles.

remain in forest; dairy, livestock, and general farms. Residential developments are concentrated in the valleys. Horizontally-bedded, sedimentary rock underlies the region and has been mined for bituminous coal.

70a. The **Permian Hills** Ecoregion is rugged, wooded, and, commonly, too steep to be farmed. High gradient streams without acidity problems are characteristic and have developed on the underlying Permian shale, sandstone, and coal; on shale, the streams are often ephemeral and without large riffle-inhabiting fish populations.

70b. The **Monongahela Transition Zone** has rounded hills and ridges that are generally less rugged than Ecoregion 70a but are still steep. Unstable, clayey regolith has developed on the underlying coal bearing strata but is largely absent from Ecoregions 70c, 70d, and 70f. Gas wells, coal mining, and reclaimed land are locally extensive and associated stream degradation is common. Forests occupy steeper areas; dairy, livestock, and general farms also occur.

70c. The **Pittsburgh Low Plateau** Ecoregion has rounded, forested hills and narrow, agricultural valleys; it is largely unglaciated in contrast to neighboring Ecoregion 61c. Medium textured soils are common and are markedly different from the clayey soils of Ecoregion 70b. High gradient streams with rocky bottoms and associated fauna contrast with the lower gradient, silty or sandy channels of Ecoregion 70e. Coal mining and associated stream acidity problems are present but less common than in Ecoregions 70b and 70e.

70d. The **Lower Scioto Dissected Plateau** Ecoregion is rugged, dissected, and underlain by Mississippian-age shale and sandstone. It is characterized by steep ridges, high relief, and streams without acidity problems. Low gradient, broad valleys also occur. Originally, mixed oak forests and mixed mesophytic forests were widespread and bottomland hardwood forests were restricted to broad, flat-bottomed valleys. Today, the steep areas are still wooded; livestock, general, and tobacco farming occurs in less rugged areas.

70e. The **Unglaciated Upper Muskingum Basin** Ecoregion is a dissected plateau with streams that are less degraded by coal mine effluent than those of Ecoregions 70b or 70f. Originally, mixed oak forests and mixed mesophytic forests were widespread. Underfit, low gradient rivers occur in broad, silt-filled, Wisconsonian-age valleys.

70f. The **Ohio/Kentucky Carboniferous Plateau** Ecoregion is characterized by extensive bituminous coal mining and associated stream degradation; mining and its effects are less prominent in Ecoregion 70e and absent from Ecoregion 70d. The ridges of Ecoregion 70f are forested while its floodplains and broad, clay-filled, flat-bottomed, preglacial valleys are used for general farms. Originally, the hill slopes had mixed oak forests, while the broad, Teays-age valleys supported mixed mesophytic forests.

C.5. REFERENCES

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