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# Ecoregions and Subregions of Iowa: A Framework for Water Quality Assessment and Management

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Ecoregion frameworks are valuable tools for inventorying and assessing environmental resources, for setting resource management goals, and for developing biological criteria and water quality standards. In a collaborative project between the Iowa Department of Natural Resources (DNR) and the U.S. Environmental Protection Agency (EPA), we have refined boundaries of the EPA's five ecological regions of Iowa and defined six subregions of the Western Corn Belt Plains ecoregion within the state. Lists of candidate stream reference sites have been developed to date for the seven largest regions, and the sites were visited and evaluated by Iowa DNR and U.S. EPA personnel to determine their suitability for sampling aquatic biota. The Iowa DNR plans to use the ecoregions and reference sites to better understand regional variations in stream quality, to help define best-attainable conditions, to develop biological criteria, and as a framework to report on water quality.

INDEX DESCRIPTORS: Iowa, ecoregions, reference sites, water quality, biological criteria

Spatial frameworks are necessary to structure the research, assessment, monitoring, and ultimately the management of environmental resources. Ecological regions, defined here as regions of relative homogeneity in ecological systems and relationships between organisms and their environments, have been developed in the United States (Bailey 1976; Omernik 1987), Canada (Wiken 1986), New Zealand (Biggs et al. 1990), and other countries to address this need. Ecoregions subsume patterns of homogeneity in ecosystem components and the factors that are associated with spatial differences in their quality and quantity - factors such as soils, vegetation, climate, geology, and physiography. These regions also define areas within which there are different patterns in human stresses on the environment, different responses to similar stresses, and different patterns in the existing and attainable quality of resources. Ecoregion classifications are effective for conducting national and regional environmental resource inventory and assessment, for setting regional resource management goals, and for developing biological criteria and water quality standards (Gallant et al. 1989; Hughes et al. 1990; Hughes 1989; Environment Canada 1989; U.S. Environmental Protection Agency, Science Advisory Board 1991; Warry and Hanau 1993).

The ecoregions defined by the U.S. Environmental Protection Agency (EPA) (Omernik 1987) were shown to be useful for stratifying streams in Arkansas (Rohm et al. 1987), Nebraska (Bazata 1991), Ohio (Larsen et al. 1986), Oregon (Hughes et al. 1987; Whittier et al. 1988), Washington (Plotnikoff 1992), and Wisconsin (Lyons 1989). The 1987 ecoregion map was used to set water quality standards in Arkansas (Arkansas Department of Pollution Control and Ecology 1988), lake management goals in Minnesota (Heiskary and Wilson 1989), and to develop biological criteria in Ohio (Ohio EPA 1988). Many state agencies, however, have found the resolution of the regions in the 1:7,500,000-scale map to be of insufficient detail to meet their needs. This has led to several collaborative projects, with states, EPA regional offices, and the EPA's Environmental Research Lab in Corvallis, OR (ERL-C), to refine ecoregions and define subregions at a larger (1:250,000) scale. These projects currently cover Florida, Massachusetts, Pennsylvania, the Coast Range and Columbia Plateau of Oregon and Washington, and parts of Mississippi, Alabama, Virginia, Maryland, and West Virginia.

Regional reference sites within an ecoregion or subregion can give managers and scientists a better understanding of attainable water body conditions. Water quality legislation and regulations, with a mandate to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters," depend on some model of attainable conditions, that is, on some measurable objectives towards which cleanup efforts are striving (Hughes et al. 1986). The biota and physical and chemical habitats characteristic of these regional reference sites serve as benchmarks for comparison to more disturbed streams, lakes, and wetlands in the same region (Hughes et al., 1986; Hughes et al. 1993; Hughes in press). These sites indicate the range of conditions that could reasonably be expected in an ecoregion, given natural physical limits and present or possible land use practices. Attainable conditions do not refer to historic or pre-development conditions (although these are important to understand), but to desirable attributes or qualities of water bodies that are achievable currently or in the future, reflect cultural and ecological realities, and are defined in a process that is scientifically and politically acceptable.

Two studies in Iowa have suggested that there are distinguishable regional differences in distribution patterns of aquatic biota. Paragamian (1990) demonstrated that fish community composition and habitat varied among five landform regions, and Menzel (1987) suggested that the geology, topography, soils, vegetation, drainage features, and land use of each Iowa landform region has shaped the regional distribution of fishes. To date, however, there has not been an effort to assess these regional differences with least-disturbed, regionally representative reference sites using methods consistent with similar EPA and state projects in other parts of the country.

States are adopting biological criteria for surface waters to improve water quality standards. Biological criteria are defined as numeric values or narrative expressions that describe the reference biological integrity of aquatic communities inhabiting waters of a given designated aquatic life use (U.S. EPA 1990). To facilitate the development of biological criteria for streams and rivers of Iowa, the Iowa Department of Natural Resources (DNR), U.S. EPA Region VII, and U.S. EPA ERL-C have collaborated to define ecoregions and subregions and select stream reference sites. In this paper, we discuss the method and materials used to refine ecoregions and define subregions of the Western Corn Belt Plains Ecoregion in Iowa, and provide descriptions of the significant characteristics in these regions. We also discuss the candidate stream reference site selection process and potential applications of the regional framework.

## ECOREGION/SUBREGION FRAMEWORK

The develoment of ecoregions in North America has evolved considerably in recent years (Bailey et al. 1985; Omernik and Gallant 1990). The EPA's first map of ecoregions of the conterminous United States was compiled at a relatively cursory scale, 1:3,168,000, and was published at a smaller scale, 1:7,500,000 (Omernik 1987). The approach recognized that the combination and relative importance of characteristics that explain ecosystem regionality vary from one place to another and from one hierarchical level to another. This is similar to the approach used by Environment Canada (Wiken 1986). In describing ecoregionalization in Canada, Wiken (1986) stated:

> "Ecological land classification is a process of delineating and classifying ecologically distinctive areas of the earth's surface. Each area can be viewed as a discrete system which resulted from the mesh and interplay of the geologic, landform, soil, vegetative, climatic, wildlife, water and human factors which may be present. The dominance of any one or a number of these factors varies with the given ecological land unit. This holistic approach to land classification can be applied incrementally on a scale-related basis from very site-specific ecosystems to very broad ecosystems."

## METHODS

In brief, the procedures used to accomplish the regionalization process in Iowa included compiling and reviewing relevant materials, maps, and data; outlining the regional characteristics; drafting the regional and subregional boundaries; digitizing the boundary lines, creating digital coverages, and producing cartographic products; and revising as needed after review by state managers and scientists. In our regionalization process, we employed primarily qualitative methods. That is, expert judgement was applied throughout the selection, analysis, and classification of data to form the regions, basing judgments on the quantity and quality of reference data and on interpretation of the relationships between the data and other environmental factors. More detailed descriptions on methods, materials, rationale, and philosophy for regionalization can be found in Omernik (1987), Gallant et al. (1989), and Omernik and Gallant (1990).

Maps of environmental characteristics and other documents were collected from the state of Iowa and from ERL-C. Those sources that played an important role in defining ecoregion patterns in Iowa are listed in the References section. Generally, the most useful types of mapped information for our ecoregion delineation are of soils, physiography or land surface form, vegetation, and land use. For this project, soils informaton was obtained from the U.S. Department of Agriculture (USDA) Soil Conservation Service county soil surveys, the USDA's 1:250,000-scale State Soil Geographic Database (STATSGO) maps, the 1:506,880-scale Iowa soil association map (Iowa Agriculture and Home Economics Experiment Station et al. 1978), and from several small-scale maps (Collins 1974; Oschwald et al. 1965; USDA 1960). The geology maps used included the small-scale state maps from Prior (1976, 1991), Hallberg et al. (1991), Ruhe (1969), and national scale maps such as Hunt (1979) and King and Biekman (1974). Physiographic and land surface form information were gathered from Prior (1976, 1991), Sinatra (1973), Fenneman (1938), and Hammond (1970). For land use/land cover we used the 1:250,000-scale maps from the U.S. Geological Survey (USGS) and the general classification of Anderson (1970). Also, for assessing variations in the mix of agriculture activities as an expression of land potential, many maps from the 1987 Census of Agriculture were analyzed (U.S. Department of Commerce 1990). Vegetation and forest cover maps were not as useful for defining ecoregions in Iowa compared to other parts of the U.S., but maps examined included Oschwald et al. (1965, fig. 9) and, from the national atlas, Kuchler (1970) and U.S. Forest Service (1970). Van der Linden and Farrar (1993) provide a useful summary and bibliography of Iowa's forests. We also used a map produced from composited multi-temporal Advanced Very High Resolution Radiometer (AVHRR) satellite data to assess boundaries and regional differences. These AVHRR NDVI (Normalized Difference Vegetation Index) data are currently being used by the USGS EROS Data Center to characterize land cover of the conterminous United States (Loveland et al. 1991).

We used USGS 1:250,000-scale topographic maps as the base for delineating the ecoregion and subregion boundaries. Although this map series is relatively old (based on interpretations of 1971-1974 aerial photography), it does provide quality in terms of the consistency and comparability of the series, in the accuracy of the topographic information portrayed, and in the locational control. It is also a very convenient scale. Fifteen of these maps provide complete coverage of Iowa.

## RESULTS AND REGIONAL DESCRIPTIONS

We have refined the Western Corn Belt Plains ecoregion boundaries in Iowa and have divided the ecoregion into six subregions (Figure 1). Although these subregions still retain some heterogeneity in factors that can affect water quality and biotic characteristics, the framework is an improvement on the national-scale ecoregions, and provides more homogeneous units for inventorying, monitoring, and assessing surface waters than the commonly used hydrologic unit frameworks. In addition to the Western Corn Belt Plains ecoregion, Iowa also contains portions of four other ecoregions: the Central Irregular Plains, the Northern Glaciated Plains, the Paleozoic Plateau, and the Interior River Lowland. The boundaries of these regions with the Western Corn Belt Plains ecoregion in Iowa have been refined during this project.

Some general characteristics of the subregions of the Western Corn Belt Plains Ecoregion and the other national level ecoregions within Iowa are presented in Table 1. Although it is sometimes useful to be able to compare regional characteristics at a glance, tables such as this have several shortcomings. It can only provide a crude generalization of a few characteristics that might or might not be important in distinguishing one region from another.

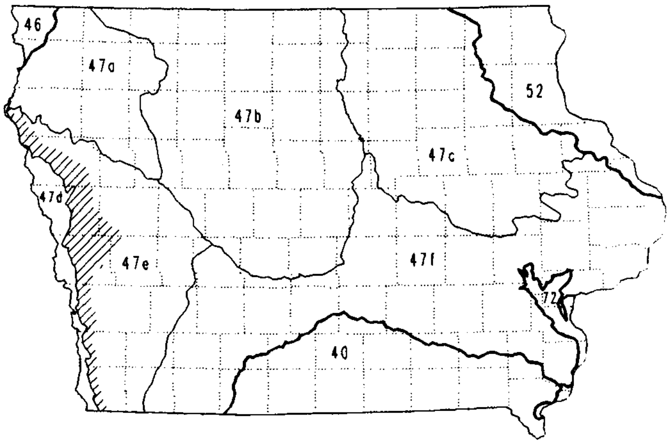

**Fig. 1. Ecoregions and Western Corn Belt Plains subregions of Iowa: Central Irregular Plains Ecoregion (40); Northern Glaciated Plains Ecoregion (46); Western Corn Belt Plains Ecoregion (47); Northwest Iowa Loess Prairies (47a); Des Moines Lobe (47b); Iowan Surface (47c); Missouri Alluvial Plain (47d); Loess Hills and Rolling Prairies (47e) (Western Loess Hills - hachured); Southern Iowa Rolling Loess Prairies (47f); Paleozoic Plateau ("Driftless Area") Ecoregion (52); Interior River Lowland Ecoregion (72).**

**Table 1. General characteristics of ecoregions and subregions of Iowa.**

| Subregion | Landform | Surficial Materials | Soils* | Climate | Potential Natural Vegetation | Land Use/ Land Cover |
|---|---|---|---|---|---|---|
| **Central Irregular Plains (40)** | Irregular plains, open low hills. Elevation 700-1200ft. (213-366m). Relief 100-300ft. (30-91m). | Moderate loess over loamy till and clay loam till | Mollisols (Argiudolls) {Shelby-Grundy-Haig, Shelby-Seymour-Edina} | Annual precip. 32-36 in. (81-91cm). Freeze free: 170-180 days | Mosaic of bluestem prairie and oak-hickory forest | Cropland and pasture, deciduous forest |
| **Northern Glaciated Plains (46)** | Irregular to smooth plains. Elevation 1200-1500 ft. (366-457m). Relief 100-200 ft. (30-61m) | Moderate to thick loess over clay loam till | Mollisols (Hapludolls) {Moody} | Annual precip. 25-26 in. (63-66cm). Freeze free: 140-150 days. | Bluestem prairie | Cropland |
| **Northwest Iowa Loess Prairies (47a)** | Irregular plains. Elevation 1200-1600 ft. (366-488m). Relief 100-200 ft. (30-61m). | Moderate to thick loess over clay loam till | Mollisols (Hapludolls) {Galva-Primghar-Sac} | Annual precip. 27-29 in. (69-74cm). Freeze free: 140-150 days | Bluestem prairie | Cropland |
| **Des Moines Lobe (47b)** | Smooth to irregular plains. Elevation 900-1500 ft. (274-457m). Relief 50-100 ft. (15-30m) | Loamy till with no loess | Mollisols (Hapludolls) {Clarion-Nicollet-Webster} | Annual precip. 28-31 in. (71-79cm). Freeze free: 145-160 days | Bluestem prairie | Cropland |
| **Iowan Surface (47c)** | Irregular to smooth plains. Elevation 900-1200 ft. (274-366m). Relief 50-100 ft. (15-30m). | Thin loess over loamy till | Mollisols (Hapludolls, Argiudolls) {Kenyon-Floyd-Clyde} | Annual precip. 31-33 in. (79-84cm). Freeze free: 145-155 days | Bluestem prairie, oak-hickory forest | Cropland |
| **Missouri Alluvial Plain (47d)** | Smooth to irregular plains. Elevation 900-1100 ft. (274-335m). Relief 0-50 ft. (0-15m) | Alluvium | Mollisols (Haplaquolls) {Luton-Onawa-Salix} | Annual precip. 26-28 in. (66-71cm). Freeze free: 150-160 days | Oak-hickory forest, northern floodplain forest | Cropland |
| **Loess Hills and Rolling Prairies (47e)** | Open low hills. Elevation 1000-1500 ft. (305-457m). Relief 100-300 ft. (30-91m). | Thick loess | Mollisols (Hapludolls) {Monona-Ida-Hamburg} | Annual precip. 27-32 in. (69-81cm). Freeze free: 150-160 days | Bluestem prairie, oak-hickory forest | Cropland, some deciduous forest on hills |
| **Southern Iowa Rolling Loess Prairies (47f)** | Irregular plains to open low hills. Elevation 700-1300 ft. (213-396m). Relief 100-300 ft. (30-91m). | Moderate to thick loess | Mollisols, Alfisols (Argiudolls, Hapludalfs) {Shelby-Sharpsburg-Macksburg, Tama-Muscatine, Otley-Mahaska-Taintor} | Annual Precip. 30-35 in. (76-89cm). Freeze free: 160-170 days | Mosaic of bluestem prairie and oak-hickory forest | Cropland, small areas of deciduous forest |
| **Paleozoic Plateau ("Driftless Area") (52)** | Open hills, irregular plains. Elevation 700-1200 ft. (213-366m). Relief 300-500 ft. (91-152m). | Thin loess and patches of drift over bedrock | Alfisols (Hapludalfs) {Fayette-Dubuque-Stonyland} | Annual precip. 32-34 in. (81-86cm). Freeze free: 140-155 days | Maple-basswood forest | Cropland and pasture, decidous forest |
| **Interior River Lowland (72)** | Smooth to irregular plains. Elevation 500-700 ft. (152-213m). Relief 0-50 ft. (0-15m). | Alluvium | Alfisols, Mollisols (Hapludalfs, Haplaquolls) | Annual precip. 34-36 in. (86-91cm). Freeze free: 165-175 days | Oak-hickory forest | Cropland, deciduous forest, forested wetlands |

*Order, (Great Group), {Association}

Ecoregion boundaries are often portrayed by a single line, but in reality they are transition zones of varying widths. In some areas the change is distinct and abrupt, for example where the Missouri Alluvial Plain meets the Western Loess Hills. In other areas, such as the division between the Iowan Surface and the Southern Iowa Rolling Loess Prairies, the boundary is fuzzy and more difficult to determine. The fuzzy boundaries are areas of uncertainty or where there may be a heterogeneous mosaic of characteristics from each of the adjacent areas. Figure 2 shows the relative widths of the ecoregion and subregion boundaries in Iowa.

Our regional framework has many similarities to other regional schemes that have been defined for Iowa, such as those of Prior (1991; 1976), Barnes and Marschner (1933), Sinatra (1973), and USDA-SCS (1981). An overlay of these four schemes (Figure 3) illustrates that there is some consensus on the general regions, but not always good agreement on where the boundaries should be drawn. The boundaries of the Des Moines Lobe, for example, coincide quite closely, but there are differences of opinon on how to divide much of southeastern Iowa. This illustration has similarities to the fuzzy boundary map (Figure 2), and for some areas can help depict transitions and areas of uncertainty.

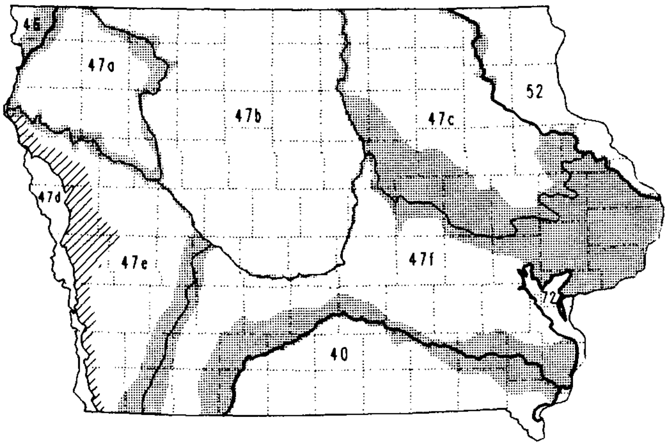

Fig. 2. Ecoregion and subregion "fuzzy" boundary transition widths of Iowa.

## Western Corn Belt Plains Ecoregion (#47)

This ecoregion covers most of Iowa and parts of Minnesota, Illinois, Missouri, Kansas, Nebraska, and South Dakota. The regional landscape can be characterized as extensive cropland on nearly level to gently rolling dissected glacial till plains, hilly loess plains, and morainal hills with broad smooth ridgetops; elevation ranges from less than 600 feet (183 m) to about 1700 feet (518 m) with local relief typically less than 100 feet (30m) (Omernik and Gallant 1988). Mollisols are the main soil order, consisting mostly of Hapludolls and Argiudolls (USDA, SCS 1970). Average annual precipitation is 25-35 inches (63-89 cm), occurring mainly during the growing season. There is extensive acreage in corn, soybeans, feed grains, and forage for livestock.

From a national perspective, this ecoregion appears relatively homogeneous in its characteristics. To state resource managers in Iowa, however, it was obvious that significant differences existed in resource types and characteristics within the ecoregion. We have divided the Iowa portion of the Western Corn Belt Plains ecoregion into six subregions: Northwest Iowa Loess Prairies, Des Moines Lobe, Iowan Surface, Missouri Alluvial Plain, Loess Hills and Rolling Prairies, and Southern Iowa Rolling Loess Prairies.

### Northwest Iowa Loess Prairies (47a)

This subregion is generally level to gently undulating with a moderate to thick layer of loess. It is the highest and driest subregion of the Western Corn Belt Plains, as it steps up to meet the Northern Glaciated Plains of the Dakotas. Elevations are generally 1300 - 1500 feet (396-457 m), and the valleys are wide and shallow with long, gentle uniform slopes. The underlying glacial materials deposited in this region are classified as clay loam till and loamy till (Hallberg et al. 1991). Although loess covers almost all of the broad upland flats, ridges, and slopes, minor glacial till outcrops occur near the base of some of the side slopes (Oschwald et al. 1965). Silty clay loam soils have developed on the loess, with the principal soil association being Galva-Primghar-Sac (Oschwald et al. 1965). The subregion is mostly treeless, except for the more moist areas along some stream corridors and on farmstead windbreaks. The dominant land use is row crops with some pasture and cattle feedlots.

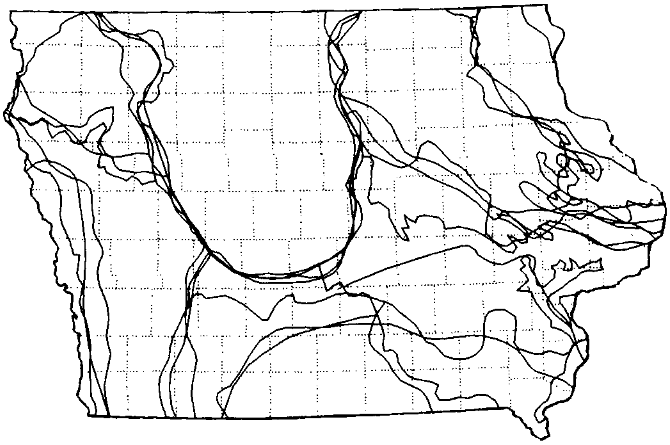

Fig. 3. Overlay of Iowa regional schemes (Barnes and Marschner 1933; Prior 1991; Sinatra 1973; USDA 1981).

### Des Moines Lobe (47b)

The Des Moines Lobe, one of the younger and flattest subregions in Iowa, is a distinctive area of Wisconsinan glacial stage landforms currently under intensive agriculture. There is generally good agreement on its boundaries among the various regional schemes (Figure 3). While the subregion as a whole is sufficiently homogeneous for our purposes, there are several different landform types and regions within the Des Moines Lobe (Prior 1991; Palmquist and Connor 1978). In general, the land is level to gently rolling with some areas of the end moraines having the most relief. The morainal ridges and hummocky knob and kettle topography contrast with the flat plains of the ground moraines, former glacial lakes, and outwash deposits. One of the main distinguishing characteristics from other subregions is the lack of loess over the glacial drift. Clarion-Nicollet-Webster soils are the most extensive in this area (Oschwald et al. 1965).

The stream network is poorly developed and widely spaced. Ruhe (1952, 1969) illustrated the dramatic decrease in the drainage density pattern from the Northwest Iowa Loess Prairie to the Des Moines Lobe for three contiguous counties. The drainage density in Cherokee County is 3 - 5 times greater than in the Des Moines Lobe's Pocahontas County (Ruhe 1969). The major rivers have carved valleys that are relatively deep and steep-sided. Almost all of the natural lakes of Iowa are found in the northern part of this subregion, an area Roosa (1982) calls the Prairie Pothole Section. Most of this subregion has been converted from wet prairie to agricultural use with substantial surface water drainage. Only a small fraction of the wetlands remain and more than half of the 100 or so natural lakes have been drained by ditches and stream channelization (Menzel 1987).

### Iowan Surface (47c)

This geologically complex region is located between the bedrock-dominated landforms of the Paleozoic Plateau and the relatively recent glacial drift landforms of the Des Moines Lobe. While the combination of landforms, materials, and processes of this area has not been easily explained, it is currently believed that the last glaciers over the area were Pre-Illinoian in contrast to the Des Moines Lobe's more recent glaciation (Prior 1991). The landforms here are not a result of glacial deposition, however, but have evolved from "episodes of more accelerated erosion," (Prior 1991). The cold-climate weathering and erosion during the Wisconsinan helped flatten earlier contours, and the region is now characterized by stepped erosion surfaces with restrained, subtle landforms of low relief. It is generally level to gently rolling, with long slopes and more open views as compared to the Southern Iowa Rolling Loess Prairies.

The southern and southeastern border of this region is irregular and crossed by major northwest to southeast trending stream valleys. Also in the southern section are numerous paha (elongated hills or ridges) that are often parallel to and near the river valleys or are found along the interstream divides. These ridges have been protected from some erosional processes by thick caps of loess and wind-blown sand (Prior 1976, 1991). Characteristics of the Iowan Surface extend beyond its boundaries to the south and southeast. Many of these areas contain transitional soils rather than the Kenyon-Floyd-Clyde association common to the Iowan Surface, but some of the flat areas east into Cedar and Clinton Counties tend to be more similar to the region to the north than to the Southern Iowa Rolling Loess Prairies. Although regional frameworks such as Prior (1976, 1991) and Barnes and Marschner (1933) show arms of the Iowan Surface area extending east to the Mississippi River, this is a fuzzy transitional area with characteristics of several surrounding regions.

In the northern portion of the subregion, the glacial deposits are thin, and shallow limestone bedrock creates karst features such as sinkholes and sags in the landscape. Groundwater from the limestone bedrock aquifers also contributes to the flow of rivers such as the Cedar, Wapsipinicon, Shell Rock, and Winnebago during dry periods (Prior 1991). Stream gradients are generally low, with poorly drained soils in the swales. There are no natural lakes of glacial origin in this region, but overflow areas and backwater ponds occur on some of the larger river channels contributing to some diversity of aquatic habitat and a large number of fish species (Menzel 1987).

### Missouri Alluvial Plain (47d)

When the Missouri River was wild and free-flowing, it meandered, braided, and spread out across its floodplain, depositing silt, sand, and gravel in an everchanging biologically-rich bottomland environment. Today, with dams upstream and a channel contained within fortified banks, most of the oxbow lakes, sloughs, and wetlands have been drained, ditched, and converted to rich agricultural land. Streams that flow out of the Loess Hills are channelized across this alluvial plain. The Luton-Onawa-Salix is the principal soil association, and the soils may vary widely in short distances because of variation in the deposited sediments (Oschwald et al. 1965). The flat topography and low relief contribute to the intense agricultural land use in this subregion. The region is also used as a railroad, highway, and barge transportation corridor.

### Loess Hills and Rolling Prairies (47e)

One of the Iowa's most abrupt regional boundaries occurs at the eastern edge of the Missouri Alluvial Plain where a prominant band of steep bluffs, ridges, and valleys form the Loess Hills. The steep-sloped prairie-covered ridges with wooded backslopes contrasts dramatically with the flat cultivated alluvial plain. In addition, although several subregions of Iowa are covered by loess, the distinguishing feature here is the thickness of these wind-blown deposits and the relatively high relief and more rugged terrain caused by subsequent erosion. Loess thickness is generally more than 60 feet (18 m) in the Loess Hills with some depths recorded to 200 feet (61 m) (Prior 1991), but it thins to less than 15 feet (5 m) as one moves east into the rolling prairie.

The soils derived from the loess tend to be well-drained with a high water-holding capacity (Oschwald et al. 1965). Some areas are subject to rapid erosion, with a history of gully cutting and filling. The principal soils are silt loams of the Monona-Ida-Hamburg association for the slopes and ridges of the Loess Hills, with entrenched streams and gullies in alluvial valleys. The soils gradually change to the Marshall association in the more rolling topography to the east and these tend to be silty clay loams (Oschwald et al. 1965).

As Prior (1991) pointed out, "The eastern boundary of the Loess Hills is not easily defined, as the hills merge gradually with the more rolling landscapes of the Southern Iowa Drift Plain." Our Loess Hills and Rolling Prairies subregion is similar to Sinatra's (1973) deep loess region, being wider and more inclusive than the Loess Hills landform region of Prior (1991, 1976). The eastern boundary of our subregion is also similar to Barnes and Marschner's (1933) and the Major Land Resource Area (MLRA) boundary (USDA, SCS 1981). This placement occurs roughly where the Marshall soil association blends into the Shelby-Sharpsburg soils and where a change is detected by the AVHRR-NDVI data.

We have delineated the Western Loess Hills as a region within the Loess Hills and Rolling Prairies subregion. This area, hachured on the map (Figure 1), encloses the loess hills of relatively higher drainage density, greater relief and hillslope steepness, and a more mixed land use with woody vegetation. It is similar to the Loess Hills region shown by Prior (1991) and the Iowa State Preserves Advisory Board (Farrar et al. 1985), although our region covers slightly more of Harrison County and extends into the southwest corner of Crawford County. Recognition of the importance and unique nature of the specialized ecological habitats of the western more-dissected loess hills portion of the subregion has led to efforts of study, inventory, and protection (Farrar et al. 1985; Roosa et al. 1986). An unusual mosaic of microenvironments is found here due to contrasts in slope aspect and different exposure to sun, moisture, and wind. South and west facing slopes support short-grass and mixed-grass prairie communities similar to Great Plains areas much farther west, and several xerophytic species more typical of areas to the southwest are found here (Novacek et al. 1985). Many of the steep side slopes and ridges are characterized by terracettes, also called cowtours or catsteps. These step-like slump scarplets are natural features, but can be enhanced or created by livestock movement (Butzer 1976). Although historically nearly treeless, woody vegetation in the hilly part of the region has increased dramatically with the suppression of prairie fires (Roosa et al. 1986; Schennum 1984), even leading to the recent establishment of the Loess Hills Pioneer State Forest.

### Southern Iowa Rolling Loess Prairie (47f)

With a broad east to west spatial extent, this is a heterogeneous subregion of Pre-Illinoian glacial deposits where generalizations are often inadequate to describe the area. The landscapes, shaped by glacial drift, are also mantled by loess that is thick in the west, thins in the central portion, and thickens again near the Mississippi. In the southeast, there are some flat tabular uplands, the Yarmouth-Sangamon surface (Prior 1991), and the valleys can be relatively steep and forested. Toward the central and western portions, the land becomes more hilly and dissected, some areas having long parallel crests with broad troughs between them. The mosaic and extent of flat uplands, rolling hills, and valley floors resulting from different erosional periods varies in complex ways throughout the subregion.

There are several soil associations in this subregion. The Shelby-Sharpsburg-Macksburg association found in the western portion of the subregion such as Taylor, Adams, Adair, and Madison counties, consists of loams and silty clay loams. Soils on the lower slopes tend to be derived from till, and those on the upland ridges and side slopes and upland flats are generally formed in loess. The fertile soils of the Tama-Muscatine association occur in several parts of central and eastern Iowa, and the topography and loess depths vary (Oschwald et al. 1965). The Otley-Mahaska-Taintor association is mostly loess-derived soils in southeast Iowa that occur in several elongated areas that are divides between some of the larger rivers.

### Central Irregular Plains Ecoregion (#40)

This ecoregion covers most of northern Missouri, extending in an arc into south central Iowa. Compared to the Western Corn Belt Plains ecoregion, which is generally all intensive cropland, this ecoregion has a mix of land use types and tends to be topographically more irregular. The potential natural vegetation of the Central Irregular Plains is a grassland/forest mosaic with wider forested strips near the streams compared to the Western Corn Belt Plains where prairie grasslands predominate. The boundary between the Central Irregular Plains and the Western Corn Belt Plains in Iowa corresponds to differences in patterns on the AVHRR-NDVI imagery, on most of the soil maps, and on many of the maps of agricultural land use, crop acreage, and animal density in the Census of Agriculture (U.S. Department of Commerce 1990).

The mix of land use activities in this region also includes mining operations of bituminous coal in the Pennsylvanian age bedrock. The disturbance of these high-sulfur coal strata in south central Iowa and northern Missouri has degraded water quality and affected aquatic biota (Detroy et al. 1983; Powell 1988).

### Northern Glaciated Plains Ecoregion (#46)

This ecoregion covers only a small slice of the dry northwest corner of Iowa, covering the western half of Lyon County and the northwest corner of Sioux County. The ecoregion boundary is a gradual transition from the Western Corn Belt Plains ecoregion, but overall there are some distinct differences in soils and moisture. The drier Moody soils and diminished precipitation to the west are also reflected in land use and agricultural activities, as there tends to be less corn production and more barley, wheat, and cattle feedlots. A distinctive feature in the extreme northwest corner of Iowa is the outcrop of Precambrian Sioux Quartzite bedrock. This area contains lichen, mosses, and vascular plants that are rare and unique in Iowa (Roosa 1982).

### Paleozic Plateau ("Driftless Area") Ecoregion (#52)

The bedrock-dominated terrain of this region is strikingly different from the rest of Iowa. Although there is evidence of glacial drift in this region, the glacial deposits do little to affect the landscape compared to the subduing influences in other regions of Iowa. {"Driftless Area" is a geologically incorrect term, especially in Iowa (Hallberg et al. 1984; Prior 1991). We retain it in the title in reference to the ecoregion name appearing on the national ecoregion map (Omernik 1987). Although geologically incorrect, the general regional term often persists in common usage. If conducting a literature search on the region, for example, "Driftless Area" would likely be an important key term or index descriptor.}

The relative lack of glacial effects, compared to surrounding areas, and the different topographic and ecological characteristics found here, distinguish this ecoregion. Steep slopes and bluffs, higher relief, sedimentary rock outcrops, dense forests, and unique boreal microhabitats differentiate this ecoregion from the Western Corn Belt Plains. The Silurian Escarpment, a prominant physiographic feature that helps define the southern and western boundary of this ecoregion, separates the mostly cropland area of the Western Corn Belt Plains from the mixed land use of the Paleozoic Plateau.

Dissolution of the limestone and dolomite rocks results in karst features such as sinkholes, caves, and springs, and makes groundwater vulnerable to contamination. The streams in the Iowa portion of this region occupy entrenched valleys, and have cool waters with high gradients flowing over rocky substrates (Eckblad and Coon 1984). The fish communities found here reflect this preference for cool clear water with relative constancy of flow (Menzel 1987).

### Interior River Lowland Ecoregion (#72)

This ecoregion covers lower sections of the Ohio, Wabash, Illinois, and Missouri rivers as these waters flow toward the central section of the Mississippi River. In the southeast corner of Iowa, the alluvial floodplain ecoregion extends up the lower Iowa and Cedar Rivers from the Mississippi. Terraces of silt, sand, clay, and gravel of generally level topography are often put to agricultural uses, with only remnants of the original biologically diverse forested bottomlands remaining.

## STREAM REFERENCE SITE SELECTION

To develop biological criteria and evaluate polluted or degraded water bodies, it is important to establish reference conditions that are suitable for comparison. A key function of an ecoregion framework is its use in selecting regional reference sites and facilitating the assessment of regionally attainable conditions. Ideally, control sites for estimating attainable conditions should be as minimally disturbed as possible yet representative of the streams for which they are to be controls (Hughes et al. 1986). Although no two streams are alike, we hypothesize that similar-sized streams within an ecoregion or subregion will have generally similar characteristics compared to streams within a state or larger area.

General guidelines for selecting reference sites have been given in Hughes et al. (1986) and by Gallant et al. (1989). The process, however, is being refined as experience is gained in current and ongoing ecoregion/reference site projects (e.g., Alabama/Mississippi, Florida, Massachusetts, the Coast Range of Oregon and Washington, and EPA Region III). For any given project it may be necessary to modify or expand general procedures; due to varying characteristics or objectives in different areas, it is difficult to follow strictly a detailed rule-based approach that will be applicable to all regions. Our process of selecting candidate reference sites in Iowa is outlined below:

1). We defined regions and subregions within which there is apparent homogeneity in a combination characteristics that are likely to be associated with resource quality, quantity, types of stresses, and biological responses.

2). We generally characterized disturbance (such as areal or nonpoint source pollution, and local or point sources of pollution) in each ecoregion and subregion and analyzed geographic characteristics to better understand representative or typical conditions. Although most Iowa streams drain areas of intensive agriculture, the level of disturbance may vary from one region to another. Some regions appear to have more stream channelization and intentisty of agriculture than other regions, for example. Reference streams in such a region comprise those with few if any point sources of pollution, lack of recent channelizaton activity, and riparian zones with a relatively large percentage of woody vegetation.

3). A set of stream sites with approximated surface watersheds that appear relatively undisturbed and completely within the ecoregion or subregion was chosen. The actual number of sites/watersheds selected was a function of the apparent homogeneity or heterogeneity of the region, the size of the region, hydrologic characteristics, and simply how many stream sites/watersheds were available for selection. The point of diminishing returns, regarding the number of streams necessary to address regional attainable quality and within-region variability, may be reached with only a few sites in regions that are relatively homogeneous and/or small. Complex regions, on the other hand, are likely to require a large number of reference sites. Disturbance and typicalness were interpreted from information shown on 1:250,000-scale and 1:100,000-scale USGS topographic maps, land use and soils maps. The existence of populated areas, industry, agricultural land use, mining, and transportation routes were interpreted from mapped information. To gain insight into general quality and aquatic life uses, referral was made to a list of streams and their water use designations from Iowa's water quality standards. Reference site selection guidelines developed by the DNR were also followed, such as minimum watershed sizes for each region. The minimum watershed size of candidate stream reference sites was generally smaller in the eastern portion of the state, e.g., in the Paleozoic Plateau, than in western Iowa regions such as the Northwest Iowa Loess Prairies or the Des Moines Lobe. (Streams of northeast Iowa are fed by more constant groundwater flow than other regions of the state and consequently less surface watershed area is needed to provide habitat for aquatic communities during dry periods). A list of 110 candidate sites was developed that included the subregion, site number, stream name, county, 1:250,000-scale and 1:100,000-scale map names, estimated watershed area, and additional comments. This list was given to the state biologists along with photocopies of the exact site locations.

4). Each set of sites was reviewed by state biologists, and sites were visited during ground reconnaissance to get a sense for the usefulness of the regions, the characteristics that comprise reference sites in each region, the range of characteristics and types of disturbances in each region, and how site characteristics and stream types vary between regions. During this process, sites that were found unsuitable were dropped (because of disturbances not apparent on the maps or due to anomalous situations) and alternate sites were added and visited. Sites were most often dropped because of obvious ongoing or remnant disturbances in the riparian zone such as row cropping or livestock grazing, or because of poor instream qualities such as excessive sedimentation. All candidate reference sites were reviewed in the office by DNR staff and were screened after review of previous stream assessment data bases.

It should be remembered that all of the reference sites have some level of disturbance. There are no pristine, unimpacted watersheds in Iowa, or, considering atmospheric deposition of contaminants, anywhere else in the U.S. The least or minimally impacted sites were sought, but levels of impact are relative on a regional basis. The characteristics of appropriate reference sites will be different in different ecoregions and for different water body and habitat types. It is desirable, therefore, to have a large number of candidate reference sites for each region to help define the different types of streams, to illustrate the natural variability within similar stream types, and to clarify the factors that characterize the best sites from factors present in the lower quality sites.

## CONCLUSIONS

The ecoregion/subregion framework developed for the state of Iowa is a general framework to be used for environmental resource assesssment and management. Because regions are mental constructs (no matter what the method of construction) and boundaries are defined with certain purposes in mind, the interest in such a framework should be in its potential usefulness rather than the "absolute truth" of line placement on the ground. The "correctness" of ecoregion boundary placements, as tested by any particular characteristic or combination of characteristics, is an issue that can be endlessly debated, with as many outcomes as there are debaters or methods of tests. While such a debate is enjoyed by geographers and others interested in regions, it can become a trivial pursuit that sidetracks us from the more important environmental issues and resource management problems. Does the map provide a mechanism to better understand spatial variations in the nature or quality of environmental resources? We believe that the framework presented here along with the selection of stream reference sites can help build the foundation for a better understanding of regional differences and attainable water quality. The ecoregion map is a formalization of commonly recognized regions of Iowa, and our results, although not matching exactly, have similarities to other frameworks of the area.

The primary task of this project was to subregionalize the Western Corn Belt Plains ecoregion within Iowa. These regions are consistent with the framework being developed and used in other parts of the United States and Canada, allowing biologists and water resource managers to share and compare data and methods within regions that cross political boundaries. Although the other ecoregions in Iowa are relatively small, the state may find a need for subregions of the Paleozoic Plateau and the Central Irregular Plains ecoregions. The possibility of conducting such work is being discussed with Missouri, Wisconsin, Minnesota, and the regional EPA offices. It may also be of benefit to Iowa to continue communication with neighboring states regarding sampling methods and comparability of data across state boundaries. In particular, Minnesota data might be useful for a better understanding of streams in the Des Moines Lobe and Iowan Surface subregions, and northern Missouri data would be helpful for the Central Irregular Plains ecoregion.

While the primary motivating force behind the ecoregion refinement project in Iowa has been development of stream biological criteria, application of the regional framework to other areas of surface water resource management should be considered. Three promising uses that have been demonstrated in other states are: (1) lake classification and development of eutrophication criteria; (2) refinement of chemical water quality standards for surface waters; and (3) statewide status reporting on attainment of water use goals. The ecoregion framework presented here might also prove to be a useful tool for programs addressing wetland classification and management.

The hypothesis that a regional framework and sets of regional reference sites can give managers and scientists a better understanding of the spatial variations in the chemical, physical, and biological components of streams in Iowa is intuitive but must be tested. Significant time and effort is required for the collection and creative analysis of data to develop biological criteria and more fully understand attainable water quality conditions. To use that knowledge to actually improve the quality of water bodies in Iowa will be a continuing challenge requiring the cooperation and coordination of federal, state, and local interests. But it is primarily Iowans, after all, who must reach a consensus on the importance of and need for adequate riparian habitat and healthy aquatic ecosystems in their state.

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