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RADON AND THE GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

As Washington State's lead agency for radon issues, the Department of Health is developing the analytical basis for establishing a public health policy regarding radon. A fundamental step in this analytical process is the development of a map of the geologic potential for radon occurrence. This map will serve as the base map for a series of data overlays. Through the application of a geographic information system, the Department of Health will perform an integrated analysis of the various elements contributing to our understanding of indoor radon. These elements include geology, geography, topography, and soil permeability; indoor radon test results; population density and distribution; and housing type and number.

IDENTIFYING THE PROBLEM

The Department of Health (DOH) has been studying radon in Washington since 1985. Previous studies have concentrated on epidemiological issues regarding radon and lung cancer. Ecological and case-control studies of miners provided the basis of the analysis.

The DOH initiated a state radon database in 1990, collecting data from various sources including Bonneville Power Administration (BPA), the Washington/EPA Residential Radon Survey, the U.S. Geologic Survey/EPA Mapping Project, and private laboratory test results. Currently there are over 23,000 radon test results in the database.

The DOH goal is to provide analysis of this data and policy recommendations, at the county level, to the local health districts. Previous limitations of the available data precluded a comprehensive county-by-county analysis of radon potential. New studies and analysis were needed to provide sufficient detail and accuracy at the county level. Attempts at manual manipulation produced unsatisfactory results; existing reports and studies were inconclusive and often raised more questions than they answered; hand-made maps were inaccurate and of poor quality. A new system was needed to co-ordinate data within the Division of Environmental Health and with other State Agencies and Local Health Districts, to provide better analytical tools, create better, easy-to-read reports and maps, and satisfy requests from the State Building Code Council and other agencies and organizations. A Geographic Information System (GIS) quickly emerged as the solution.

A GIS is a highly specialized collection of computer hardware and software. A GIS utilizes a database management system to collect and organize sets of data. The data can be queried and manipulated using database functions, or it can be transformed into graphical images and shapes to create maps. Integrated analysis, using many layers of data, is possible with a GIS by linking each layer of data with common reference points which orient the different layers into a single view.

The Radon Program turned to the development of a GIS capability in order to conduct the kind of integrated analysis necessary to understand the distribution of radon throughout the state. An interagency agreement with the Washington Department of Natural Resources (DNR) provides for as-needed, targeted training in the development and implementation of the GIS.

PLANNING AND SPECIFICATIONS

The GIS project was developed as part of the DOH Third Year State Indoor Radon Grant with the U.S. Environmental Protection Agency (EPA). DOH and EPA Region X have been working closely together since 1990, when the first Radon Grant was awarded.

A significant part of the Department's GIS planning was done with assistance from DNR staff. They provided knowledge and experience in cartography, geology, maps, and especially GIS. By describing the existing data and examining previous radon studies, it was possible to move on to new areas of study, namely the identification of high radon areas. DNR was tasked to produce a set of 1:250,000 scale maps showing the geologic potential for generation of radon in Washington. Five categories for geologic radon potential were devised (Table 1). Other data layers to be added in the future will include: indoor radon test results, soil permeability, soil moisture content and water table levels, National Uranium Resource Evaluation (NURE) data, geographic details such as state, county, and township boundaries, and U.S. Census population and housing data.

Once the tasks were defined, four general areas of staff responsibility were identified: Administrative, Technical, Analytical, and Support. Each area contains specific tasks or functions to be performed. In a large organization each area would be assigned to one or more staff members. The Department has two staff members working on GIS, so the duties are shared. Duties for each area are as follows:

Administrative

- Project Coordination
- User Access, User Responsibilities

Technical

- System Support
- Hardware and Software Installation, Configuration
- Hardware and Software Troubleshooting and Support
- Data Storage and User Access
- Special Projects
- GIS and Database Programming
- User Support
- Technical Documentation
- Data Conversion
    - Arc/Info Data
    - Database Data
    - Global Positioning System (GPS) Data
    - Digitized Data

Analytical

- Project Planning
- Arc/View Applications
- Review of Draft Applications
- Recommended Iterations
- Interpretation of Results, Including Text and Companion Analysis
- Implications
    - Users, Policy, Regulatory and Administrative

Support

- Data Entry and Quality Assurance
- Selected Outputs and Scale Variations
- Iterations

- ▸Use of Standard Data Sets
- ▸User Guidance and Documentation
- ▸Catalog of Data Sets
  - ▸Origin, Original Scale, Date, Etc.

DESIGN

System design is one of the more challenging tasks for a GIS manager to confront. Logical data models provide general guidance, but effective operational models evolve as staff members analyze the data. Trends, surprising results, and conformity to assumptions all affect the flow of GIS data manipulation and display. Unexpected results often create a new set of criteria from which to make new assumptions and test other hypotheses.

The GIS task schedule (Table 2) provides a list of tasks to be accomplished and products to create. The tasks were then prioritized and additional research and development was undertaken to more fully define the most important tasks.

Design criteria will vary depending on the hardware platform, the GIS software, and the experience and knowledge of the GIS staff. GIS software is available from a variety of vendors. Most packages employ one of three types of spatial data models linked to a relational database to form a GIS. The three types of spatial data models include:

- ▸ Layer Based
- ▸ Feature Based (or Object Based)
- ▸ Network Based

DOH chose a layer based system, Arc/Info, by Environmental Systems Research Institute (ESRI). Many agencies within Washington state government have already implemented GIS, most using Arc/Info. The DOH contract with DNR provided ready to use data, already in the Arc/Info format, and removed many of the design questions. The relational data in Arc/Info is stored using dBase IV conventions. Much of the existing DOH data is also Dbase-compatible, and is therefore easily transferred into Arc/Info.

ACQUISITION

When researching GIS components, it was critical to purchase equipment and software compatible with existing MS-DOS computers and peripherals. The DOH is implementing a plan to install a Local Area Network (LAN) to connect approximately 180 staff members electronically. Arc/Info is available in a DOS format that is acceptable for use on the LAN.

Initial Equipment Purchased Included:

- ▸ 80486 Computer, 16Mb RAM, 320Mb Hard Drive.
- ▸ Arc/Info Software
- ▸ Arc/View Software
- ▸ Calcomp Model 33600 Digitizer, 44" x 60"
- ▸ Hewlett Packard Draftmaster MX Plotter Allows Plots up to 36" Wide
- ▸ 250Mb Tape Backup

Software and Data Sets Consist of:

- Arc/Info Coverages from DNR
  - State Outline
  - County Outline
  - Township Outlines
  - Roads and Rivers
- NURE Data
- Soils Data from Soil Conservation Service
- U.S. Census Data
- U.S. Census Topological Integrated Geographic Census Files (TIGER)

IMPLEMENTATION

Implementation of Arc/Info was begun by transferring the DNR data into the Radon Program GIS. By loading the state and county boundary sets first, simple GIS commands and processes were learned. The DNR trainer explained each data set and demonstrated basic editing and manipulation features. Existing BPA test results were converted to GIS format and loaded next. BPA uses USGS township/range as the location identifier. The average radon level was computed for each township, and the results were displayed with the county boundaries shown.

DNR supplied tracings of their geologic maps. Using existing maps, they labeled each geologic unit using a radon potential category described in Table 1. Common units were grouped together and the resulting map is currently being digitized into the GIS system.

The NURE data was supplied by U.S. Geologic Survey as an ASCII data file and subsequently loaded and converted. Soils data, in Arc/Info export file format, can be ordered from the U.S. Soil Conservation Service.

Arc/Info will be used by the Radon Program technical staff to design and develop data sets, but it is much too difficult for the average computer user to master. End users will retrieve the data sets into Arc/View. Arc/View was designed by ESRI as an analytical tool for use by average users and can be used to query Arc/Info data and produce simple maps and reports. Complex maps and analysis not available from Arc/View will be created on a case-by-case basis using Arc/Info.

Output from Arc/View can be printed or captured as disk files. Printed output includes reports and maps. Maps can be of any scale and up to 36" X 48" in size. Disk output can be used to create or supplement word processing documents and can be seen as text, graphics, or maps.

The GIS system was implemented with no direct, prior experience in that specialty but with a significant level of experience in related fields. The need for user-friendly procedures to guide staff through the GIS development and use is recognized. As staff begin to interact with the GIS, in a phase of moving from the developmental to operational mode, the following sequence of tasks will be followed:

Project Origination

- User Identifies Needs and Presents them to GIS Administrator

GIS Consultation

- GIS Staff and User Determine Project Scope and Appropriate Actions

Project Planning

- ▸Coordinate Data Requirements, GIS Staff Time, and Analytical Staff Time
- ▸Determine User Contributions (Data, Analysis, Technical Support)
- ▸Identify Expected Outputs (Maps, Analyses)
- ▸Establish Relationships with Other Projects (Priorities, Collaboration, Joint Purchases)
- ▸Identify User Responsibilities

Project Implementation

- ▸Data Input
- ▸Creation or Update of Data Sets
- ▸End-User Arc/View Orientation and Training
- ▸Analytical Considerations
- ▸Draft Output

Iterations

- ▸User Revisions
- ▸Analytical Interpretations
- ▸Accompanying Text, and Companion Analyses
- ▸Implications (Other Users, Policy, Regulatory, Administrative)

AUDITING

Auditing will be an ongoing process within the GIS system. Issues dealing with the day-to-day operation will be monitored through staff input and interaction. A catalog of available data and printed user guides will be supplied to GIS users. E-mail on the network will be used to query staff members for input and provide a direct link to the GIS staff.

Organizational issues will be presented to the DOH management team. Periodic reviews of GIS procedures will be conducted to ensure compliance with DOH policy.

CONCLUSION

While still in the developmental phase, the GIS system, as a tool for defining radon potential areas, delivers everything necessary to achieve the best yet understanding of radon within Washington State. Regardless of the status of the governmental radon activity, a legacy is left for all those with future questions about radon location in the state as well as a model for policymakers in a variety of disciplines to which the GIS system could also be applied

Table 1. Uranium Occurrence Probability Mapping for Radon Susceptibility Assessment Based on Uranium Occurrences and Geology of Washington

I.	High Potential-Rock units that host uranium mines and prospects or that assayed at $\geq$50 ppm uranium. Includes late stage magmatic differentiates, pelitic metamorphic rocks, carbonaceous, pyritic, or marine metasedimentary rocks, and some alluvium.
II.	Moderately High Potential-Same rock units as those above but without mines and prospects or rock units that assayed at $\geq$30 and$<$50 ppm uranium.
III.	Moderate Potential-Rock types that are known worldwide to contain uranium or rock units in Washington that assayed at $\geq$20 and$<$30 ppm uranium. Included are felsic volcanic rocks, continental sedimentary rocks derived from granitoids, and marine sedimentary rocks.
IV.	Moderately Low Potential-Glacial sedimentary units of northern source, Missoula flood deposits, rock units that are commonly low in uranium content but have sporadic high concentrations, and rock units that assayed at $\geq$10 to $<$20 ppm uranium.
V.	Low Potential-Rock units for which there are no data or that assayed at $<$10 ppm uranium and that are not associated with uranium occurrences on a worldwide basis. Columbia River basalts and other mafic igneous rocks fall into this category.

National Uranium Resource Evaluation (NURE) data are used as a qualitative guide for all categories.

Assays are from Washington Department of Resources, Division of Geology and Earth Resources uranium data base.

Table 2. GIS Task Schedule

	MONTH											
DESCRIPTION	1	2	3	4	5	6	7	8	9	10	11	12
PLANNING AND SPECIFICATION	■	■										
DESIGN		■	■	■	■							
ORDER/ACQUISITION	■	■	■									
INSTALLATION												
TUTORIAL LESSONS		■										
ARC/EDIT		■	■	■	■	■	■	■	■	■	■	■
ARC/PLOT		■	■	■	■	■	■	■	■	■	■	■
ARC/VIEW									■	■	■	■
CREATE DATA LAYERS												
STATE BOUNDARY			■	■								
COUNTY BOUNDARY				■	■							
TOWNSHIP BOUNDARY					■	■						
RADON TEST RESULTS	■		■		■		■		■		■	■
POPULATION (CENSUS)											■	■
TIGER FILES (CENSUS)											■	■
SOIL PERMEABILITY											■	■
GEOLOGIC POTENTIAL									■	■	■	■
NURE											■	■
ANALYSIS/REPORTS/MAPS												
STATE MAP											■	■
COUNTY MAPS											■	■
REGIONAL MAPS											■	■