WATER OPERATION AND MAINTENANCE BULLETIN

No. 183 **March 1998**

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UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Reclamation personnel and water user groups in operating and maintaining project facilities.

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Cover photograph: *New Waddell Dam and completed breach in historic Waddell Dam.*

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RECLAMATION EXPANDS THE CAPABILITIES OF ITS COMPUTERIZED FLOOD MAPPING PROGRAM

by Ron Miller[1], Kurt Wille, Diane Williams, and Doug Clark

In the December 1996 issue of the *Water Operation and Maintenance Bulletin*, the Bureau of Reclamation (Reclamation) announced that it had adopted new standards for producing dam failure and flood release inundation maps. These standards were in response to Commissioner Beard's directive to take reasonable and prudent actions to ensure the safety of the public and to protect environmental resources potentially affected by incidents at our facilities. Inundation maps, descriptions of potentially flooded areas, tables showing travel times, and other pertinent information are necessary for local emergency management officials to warn and evacuate possibly flooded areas.

Since that time, Reclamation's Remote Sensing and Geographic Information Group (RSGIG) has expanded its suite of flood mapping capabilities. This work has been subdivided into two tasks. The first task is production of a standard map product that can be used for standard operating procedures (SOP), emergency action plans, and risk assessments. The second task is analysis of Topologically Integrated Geographical Encoding and Referencing (TIGER) System census data. Analysis of affected critical infrastructure as well as social and economic impacts is also either under development or under consideration. These mapping and analysis efforts will potentially make significantly more data available to emergency managers than they have had previously. Moreover, since these data can be distributed in digital form on CD-ROM, users can make use of them interactively. Users will be able to locate features on the landscape, set up queries, experiment with "what-if" scenarios, and perform modeling functions.

For the purposes of inundation mapping, hydraulic engineers estimate potential dam breach and operational flood boundaries using the DAMBRK model developed by the National Weather Service (NWS). In addition, the DAMBRK INTERFACE (DBI) software, which was developed by Reclamation's Mid-Pacific Region Geographic Information System (GIS) Service Center, is also being tested and has actually been used in several DAMBRK studies. DBI is an Arc/Info based package designed to utilize GIS analytical capabilities to provide input data for the NWS DAMBRK finite difference model. A toolkit of UNIX scripts, Arc Macro Language (AML) routines and graphical user interface menus has been designed to work within the GIS environment. The digital elevation model and related ancillary data are used to construct transects required by the model. The incorporation of GIS technology makes "what-if" scenarios less cumbersome and reduces the subjectivity of deriving transect elevations and widths from topographic maps. Resulting output is in georeferenced digital

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form. These modeled inundation boundaries are delivered to RSGIG. If DBI software is not used, two additional steps are necessary. First, the hydraulic modeler must draft the inundation boundary onto quad sheets, and, second, the drafted output must be digitized in the RSGIG laboratory.

The flood inundation boundaries constitute the input data for the RSGIG "Dam Failure/ Operational Release Automated Mapping Program" (AMP) developed in house. The AMP is a fully automated collection of applications written in AML to guide the flood mapping process from start to finish. Major steps include:

A) Development of vector data set
    1. Generate registration tic files
    2. Create 7.5 minute U.S. Geological Survey (USGS) quadrangle boundaries
    3. Digitize, edit, and attribute inundation boundaries
    4. Digitize, edit, and attribute cross-sections
    5. Map panel index coverage creation and attribution
B) Development of 7.5 minute digital raster graphics (DRGs)
    1. Scan quadrangle
    2. Initiate DRG registration and clipping
    3. Create a DRG mosaic
    4. Develop map panel index clipping
C) Map composition
    1. Solid fill inundation polygons and place on DRG background
    2. Link flood and flow data to visible cross-section lines
    3. Create an index map relating each map panel to the entire flood zone
D) Data archiving
    1. Compress and backup completed mapping project
    2. Archive and unarchive finished projects

It is also possible for the AMP to use existing SOP paper maps as input data. In these instances, the existing SOP inundation maps are color-scanned to produce digital images, registered to the related DRGs, and used as a template for onscreen digitizing.

The AMP application ensures that each flood mapping project is completed in an ordered, consistent, and efficient manner. Quality control procedures are in place at major junctures of the suite of programs. AMP map compositions become part of the SOP manuals distributed by Reclamation. Figure 1 is a black and white rendering of a standard SOP map produced by D-8260.

A second advance in inundation analysis is the calculation of resident populations living in the inundation zone. Reclamation recently gained access to TIGER files census block data from the U.S. Census Bureau that were reprocessed and put into Arc/Info format by the Environmental Protection Agency’s (EPA) Office of Information Resources Management. These files contain 1990 total resident population at the block level.

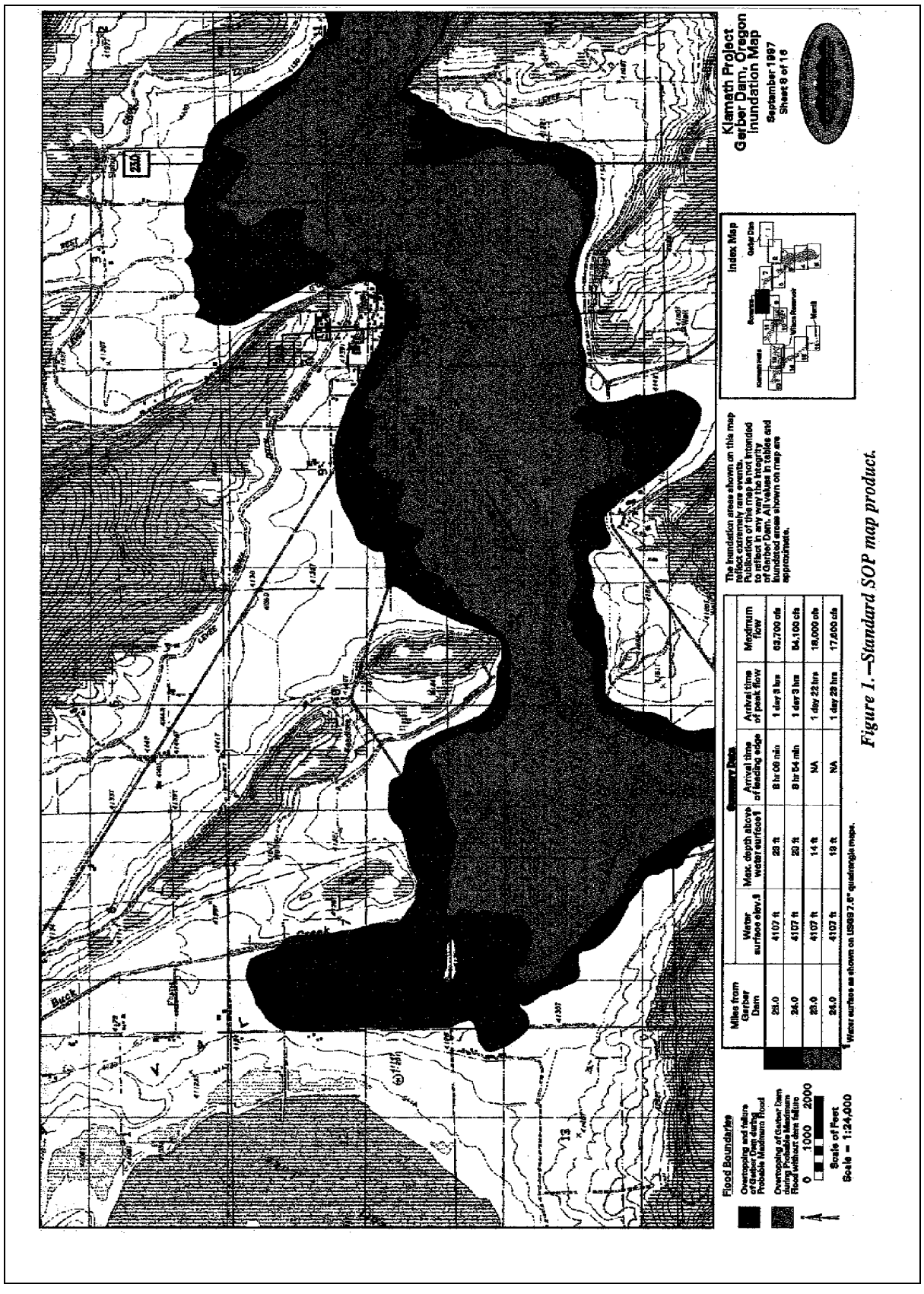

Figure 1.—Standard SOP map product.

A "block" is the smallest geographic unit for which the U.S. Census Bureau gathers demographic data. These blocks are usually "small areas bounded on all sides by visible features such as streets, roads, streams, and railroad tracks, and by invisible boundaries such as property lines, legal limits, and short imaginary extensions of streets and roads" (*Technical Documentation: TIGER/Line Census Files*, 1992). The average population size of a census block is about 100 persons, but there can be considerable variation.

An extensive set of AML programs has been developed to capture, integrate, reproject, and analyze these data to produce tables of the estimated numbers of persons living in the inundation zone by cross-sectional distance and leading edge arrival time. These basic data also become one of the inputs for population at risk and loss of life assessments. Figure 2 is a plot of census blocks in the inundation zone in proximity to Miles City on the Yellowstone River in Montana.

Emergency officials require information about a wide variety of data themes in order to manage an emergency incident adequately. In recognition of this, Reclamation has begun to gather a variety of other attributed data themes. For instance, persons at risk are often crossing bridges, camping in recreation areas, or traveling on roads. Knowledge of which of these will be inundated is vital for purposes of evacuation. These themes have been gathered from the U.S. Department of Transportation via the Federal Emergency Management Agency (FEMA) and from EPA. Knowledge of the location of other transport facilities is also vital because they can both bring in supplies and assist in evacuation efforts. The location of airports has been provided by FEMA, and the rail network comes from EPA sources.

During an emergency crisis, the location of and information about certain critical facilities is also vital. In view of this, Reclamation is gathering location and attribute information on hospitals, including name, address, number of beds, existence of a blood bank, total number of registered nurses, existence of burn care units, and so on. Reclamation is also gathering information on schools, communication towers, and military installations. If funding becomes available, these basic data can be provided on CD-ROM to Reclamation area offices to assist them in their emergency management efforts. Figure 3 is a plot of critical infrastructure in the flood inundation zone near Miles City, Montana.

Other data vital to emergency management efforts will soon become available, if funding is approved. Data themes such as electric powerplants; geological faults; gas pipes, plants, and storage facilities; nuclear powerplants; water supply plants; oil refineries; seismic risk zones; superfund sites; sewer plants; tank farms; toxic release inventory sites; utility lines; non-Reclamation dams; custodial facilities such as nursing homes, orphanages, and correctional facilities; and religious institutions are currently available at nominal cost.

The data that Reclamation currently provides, along with other data which may soon become available, could become part of an Environmental Systems Research Institute ArcView "project." According to a recent survey, the vast majority of Reclamation regional and area offices now own some version of Arc/Info, ArcCad, or ArcView software. With this software, emergency managers can interactively query the data for their own needs. In

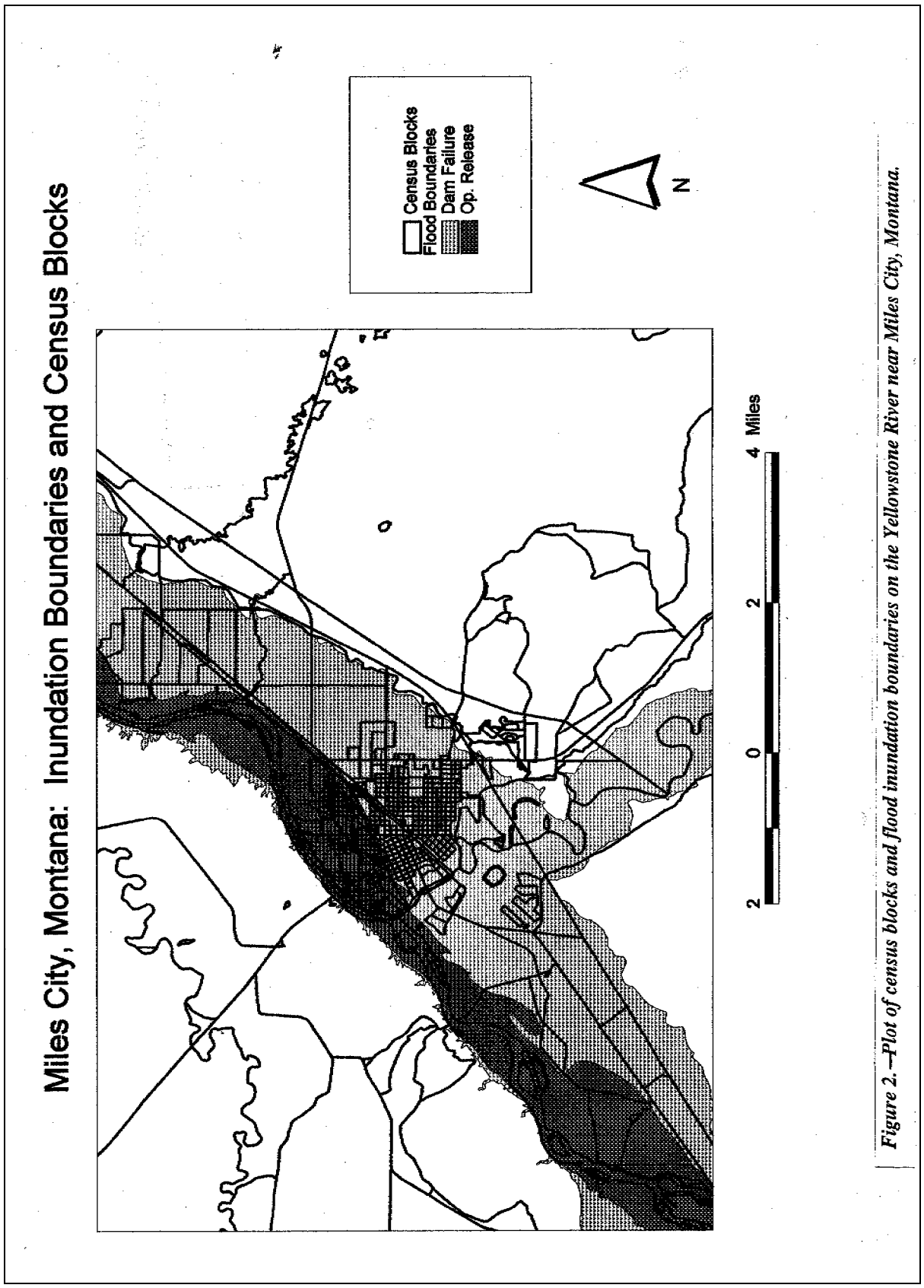

Figure 2.—Plot of census blocks and flood inundation boundaries on the Yellowstone River near Miles City, Montana.

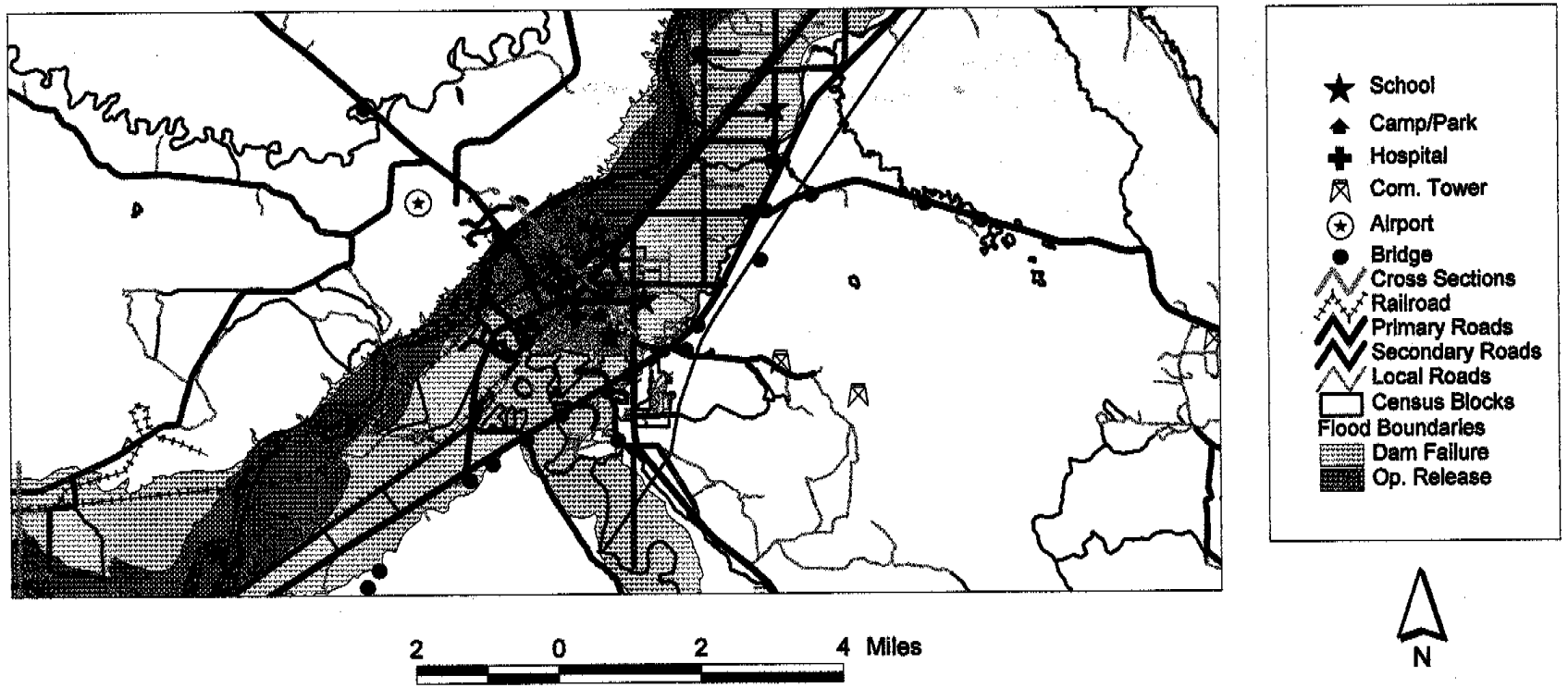

Figure 3.—Plot of critical infrastructure and flood inundation boundaries near Miles City, Montana.

addition, they will be able to supplement the basic package of data themes the Denver Office is providing with others of local importance. Finally, it is entirely possible, using the Avenue programming capability associated with ArcView, to customize each project to suit the very specific decisionmaking needs of each office.

These data and Reclamation's GIS capabilities may also be useful for facilitating other emergency planning activities such as population at risk and loss of life assessment; training emergency management personnel; and performing orientation, table top, and functional emergency exercises. Beyond this, GIS data can be integrated with other electronic decision-making and resource management tools such as an emergency information system for use in an actual disaster response situation.

Glossary of Terms

Computer, GIS, Mapping, and Modeling Terms

***Cartography*:** The art and science of representing the features of the Earth's surface graphically. Synonymous with map making.

Census Block: The smallest geographic area for which the U.S. Census Bureau gathers population data. These blocks are generally rather small areas "bounded on all sides by visible features such as streets, roads, streams, and railroad tracks, and by invisible boundaries such as property lines, legal limits, and short imaginary extensions of streets and roads" (*Technical Documentation: TIGER/Line Census Files*, 1992). This is the spatial unit of analysis for dam breach population at risk studies.

***Compact Disc Read-Only Memory (CD-ROM)*:** An optical data storage medium, readable by a computer having a CD-ROM disc drive.

DAMBRK: A flood model program that analyzes dam failure scenarios and uses hydro-dynamic theory to predict dam-break flood wave formation and routing; also known as the National Weather Service Dam-Break Flood Forecasting Model. An enhanced user interface version, developed by the BOSS Corporation, has been used for studies in the Denver Office.

Dam Break Interface (DBI): GIS front end for the DAMBRK model designed by the Mid-Pacific Region GIS Office to enable users to identify and visualize the cross-sections (including 3-D) and generate a set of input files for loading into DAMBRK. The DBI is designed to substantially reduce the time it takes to get cross-section data into DAMBRK, while enabling users to exercise more judgment on cross-section placement and other items. Users can visually inspect and edit the cross-sections before entering them into the model.

This GIS-based software (Arc/Info) can make DAMBRK run and then produces a digital coverage of the inundated area within a relatively short period of time. Improvements are still being made to the program.

Data Set: A collection of similarly formatted records having like information (from one or more data sources). Data sets contain columns and rows. The columns contain the data subject. Examples might be census tract identifier, population, area, and fertility rate. The rows contain observations with measurements on each of the data subjects. Thus, census tract 22.05 might have 3975 inhabitants, an area of .025 square mile, and a fertility rate of 10 children per 1,000 women aged 15 to 45.

Digital Elevation Model (DEM): A raster (row and column) array of elevation values.

Digitizer: A device that converts analog information into a digital format. For flat graphic material, such as maps, a digitizer can either be flatbed or scanning.

Digital Raster Graphics (DRG): Digital Raster Graphics file format. A 4-bit TIFF raster image of scanned and geocorrected 7.5 minute quads or other scale topographic maps, for example, 1:100,000 and 1:250,000 scale maps.

Finite Difference Model: A particular kind of digital computer model based upon a rectangular grid that sets the boundaries of the model and the nodes where the model will be solved.

Flood Inundation Boundary: Polygon delineated around the outer edge of a flood inundation area.

Format: The physical organization of data elements within a data set.

Geographic Information System (GIS): A complete sequence of computer and human elements for acquiring, processing, storing, and managing spatial data.

Georeference: Raster image data or vector elements that have been registered to create a direct spatial relationship to actual ground features. A georeferenced soft copy or hard copy feature must contain a map projection and scale.

Graphical User Interface (GUI): A software capability that uses pictures, buttons, menus, and icons to generate program input and output. Runs on a windows computer platform.

Hard Copy: Graphic and textual features that are plotted on paper, mylar, or other material.

Hardware: The physical components of a computer: central processing unit, memory, disk storage, tape drives, etc.

Image: A two-dimensional data representation. Examples include a photograph or a multi-spectral imaging sensor's data output.

Map: Usually a two-dimensional representation of all or part of the Earth's surface, showing selected natural or manmade features or data, preferably constructed in a definite projection with a specified scale.

Mosaicing: An assemblage of images whose edges are clipped and matched to form a continuous representation of a portion of the Earth's surface.

Population at Risk: All individuals who, if they took no action to evacuate, would be exposed to flooding of any depth. The population at risk is dependent on the dam failure or flooding event analyzed.

Projection: A systematic construction of features on a plane surface to represent corresponding features on a spherical surface. Common types are conic, cylindrical, and azimuthal. Each has strengths and weaknesses in terms of showing true distance, true area, and true shape.

Raster: A cellular data structure or organization of spatial data. In a raster structure, a value for the parameter of interest (elevation in feet above some known point, land use class from a specified list, etc.) is developed for every cell in an array over space.

Registration: Superposition of locations on an image or map with coordinate values associated with one of a variety of projections which model locations on the Earth's surface.

Scale: The ratio of map distance to Earth distance. Thus, in a 1:24000 scale map, one centimeter, inch, or foot equals 24,000 centimeters, inches, or feet on the ground. Graphic scales typically show equivalent map and ground distance in the form of a line or bar.

Topologically Integrated Geographic Encoding and Referencing System (TIGER): A geometric and tabular representation for demographic data that can be used for flood inundation impact analysis.

Topography: The collective features of the surface of the Earth, especially the relief and contour of the land.

Travel Time: Time measured from the dam breach location to flooding at a particular location. The flood level corresponding to that travel time is usually either the arrival of the leading flood wave or the peak flow at that location.

UNIX: A computer operating system which is interactive, time-sharing, multiple user, and multiple tasking.

Vector: Generally, a quantity possessing both numerical value and direction. In terms of GIS, typically representing a boundary between spatial objects. Vector GISs typically display spatial data in terms of points, lines, and polygons, as opposed to raster data, which display them as picture elements.

Emergency Response Terms

Emergency Information System (EIS): An emergency management computer application. EIS integrates maps, data bases, models and sensors, and communications all into one package. The mapping capabilities range from USGS maps on CD-ROM to photographs or satellite images calibrated to their proper latitude and longitude. EIS supports TIGER line files from the U.S.Census Bureau and nearly 20 GIS formats converted through the utility in ArcView and scanned maps or images (PCX, TIFF, BMP, and CUT). The data bases include hazard site analysis, census data, emergency plans, special needs, incident logs, incident actions, and incident situation reports.

The communications package is titled ECOMM. This module allows for the exchange of maps and data with any EIS user and commercial programs using the Xmodem, CRC, and Kermit protocols, National Weather Service Wire, cellular and landline telephone systems, packet radio systems, flood warning systems, and meteorological towers and sensors.