

VIEWIT Uses on the Wild and Scenic Upper Missouri River¹

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Abstract: This paper discusses a computer application approach to mapping the scenic boundaries on the Upper Missouri Wild and Scenic River. The approach taken in this effort was the computer program VIEWIT. VIEWIT, for seen area analysis, was developed over an eight-year period prior to 1968, by Elliot L. Amidon and Gary H. Elsner. This is the first attempt by the BLW to utilize this approach on a wild and scenic river. It began and was completed in the summer of 1977.

INTRODUCTION

In October of 1976, Congress recognized the historic significance and unique qualities of the Upper Missouri River by designating it a National Wild and Scenic River. The River is 149-miles long and is located in Montana between Fort Benton and the Fort Peck Reservoir. Lewis and Clark were the first explorers to document the scenic grandeur of the River. Congress required an overall management plan which provides a procedure to protect this natural resource.

One part of this management plan is the Visual Resource Management (VRM) of the River. By mapping and analyzing the areas that can be seen from the River, a management plan can be worked out which preserves the existing natural, primitive scenic quality along the River. This management plan will help to site future activities that must occur here, such as bridges, powerlines, or recreational buildings, to ensure minimum visual impacts on the scenic quality of the River.

The total area which can actually be seen from this 149-mile stretch of the River is called the viewshed of the River (Figure 1). This viewshed thus includes all the land which must be carefully managed to protect the scenic quality of the River.

^{1/} Submitted to the National Conference on Applied Techniques for Analysis and Management of the Visual Resource, Incline Village, Nevada, April 23-25, 1979.

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The edge of the viewshed farthest from the River is called the scenic boundary. This scenic boundary on each side of the River is called the rim-to-rim-boundary of the River. The Wild and Scenic Rivers Act requires us to locate and map this rim-to-rim boundary since it serves as the legal bounds for all lands which will be protected. Thus, the scenic quality of the River can then be protected.

DESCRIPTION OF THE METHODOLOGY

Mapping the viewshed of the River and locating the rim-to-rim boundary are difficult to carry out by hand. The accuracy of this method is ensured only by a generalization of detail.

Rather than the strict eye/hand method of viewshed mapping, this project was assisted by the computer system VIEWIT (Travis et al. 1975). The VIEWIT system aids visual resource analysis by its ability to locate and map visible terrain from a single location or series of locations, called viewpoints. By using a series of 450 viewpoints along the length of the River, and by merging the viewshed of each viewpoint into one total viewshed, the entire area which can be seen from the River was recorded.

As its most basic function, VIEWIT maps those areas which can be seen from user specified viewpoints. These visible areas are printed on maps which show the total number of times each area was seen, relative to the number of viewpoints and their location on the map. The visual analysis of the Missouri River in this project uses this basic function. The more times an area is seen, the more visually vulnerable that area is.

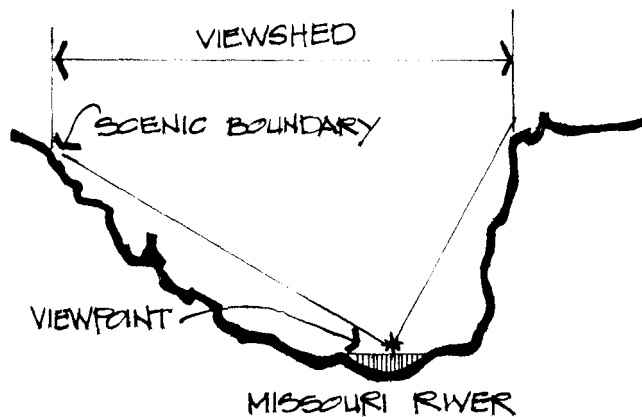


FIGURE 1

Elevation Base

Before using a computer system such as VIEWIT, the elevation information on a standard contour map must be converted to a form which can be recognized by the computer. VIEWIT uses a grid system topography in which each grid cell is 1/5" long and 1/6" high. On the standard USGS 7-1/2 minute quad maps used in this project, this translates to a scale of 333' x 400', or an area of 3.1 acres per grid cell. Thus, the transformed elevation map appears to be a giant blocked landscape where each block, or grid cell, has its own single elevation. (Figure 2)

The grid cell elevation base for this project was acquired from the Defense Mapping Agency (DMA) in the form of computer tapes. These tapes must be translated in order to produce the gridded elevation maps compatible with the VIEWIT system. This process is discussed in a later section.

The specifications of these DMA tapes do not exhibit a great degree of accuracy or detail. Large projects requiring less detail will find these tapes to be an acceptable source of elevation data, especially in terms of cost. Alternate means of acquiring a topographic data base include in-house hand digitizing and contract digitizing. Though the accuracy achieved with these options can be greater, time and money costs are also much greater, being prohibitive in a project as large as this. Small projects needing a great degree of accuracy and detail are best suited to these alternatives.

When choosing an analytical tool, such as VIEWIT, and a source of the base data, such as DMA tapes, it is important that both serve the intents and purposes of the final analysis. Therefore, balancing the analytical tool with the final product it is necessary to match the detail of the project's input to the detail of decisions which have to be made using that product.

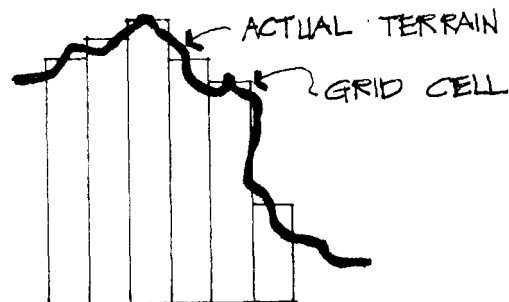


FIGURE 2

Dma Character

DMA information has been interpolated from USGS 1:250,000 scale maps. Each 1:250,000 map is 1 degree in latitude by 2 degrees in longitude. The DMA tapes are set up so that each file on the tape contains a 1-degree by 1-degree portion of the earth's surface, that is, two files for each 1:250,000 map (fig. 3). These are specified as map-half east or map-half west.

The files specify elevation values on a 200' grid. To convert this 200' grid to the 333' x 400' rectangles, the TOPAS computer program COPYNCIC was used, which is simple to use, but quite expensive.

A complex situation occurs when the study area is contained within two or more adjacent map-halves, thus different data files. Joining the east and west portions of the study area is most easily accomplished. Since the data on the tapes are stored by columns, the east portion of the study area can be added to the west portion by using the Univac Text Editor. It becomes most difficult to join concurrent north-south map halves due to this "by column" format of data. The TOPAS programs SCANDTIS and ARRAY can be used to accomplish this step. Because of the time and cost parameters of this project these programs were not used for this study. This has implications in the final uses of the output, and will be discussed later.

In more detail, DMA information has a maximum deviation of no more than 400' for any spot elevation on the horizontal plane. When considered in light of our grid cell size, this

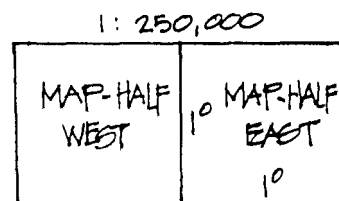


FIGURE 3

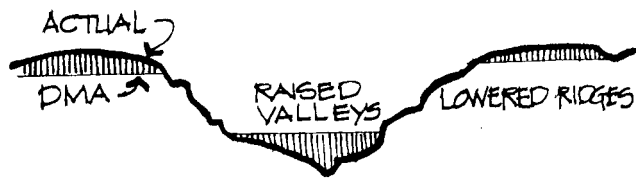


FIGURE 4

means that any cell may be off no more than one cell in any direction. Also as specified, the error in the vertical dimension may be off no more than 100'.

When these error margins are considered within the steep topography of the Missouri River Basin Landscape, the total effect on the accuracy of the mapped viewshed will generally be insignificant. This error margin could obviously be much more devastating on a flatter, undulating landscape.

Another problem we observed in using DMA information is that of truncation. For example, a V-shaped valley may be interpolated to a trapezoidal shaped valley within the DMA tape (Figure 4). This problem should be remembered in reviewing the final VIEWIT maps.

Also, the first elevation maps from the DMA tapes should be carefully checked to make sure the topography has not shifted to an incorrect location. Spot checking major land forms, and high and low elevations will quickly aid in this process.

In the final review, the DMA tapes serve the functions of this project within the allowable error margins. The combined error margin within the DMA detail, both horizontal and vertical, will probably never exceed three cells. Rather than producing a boundary "line" for the River's viewshed, a zone of three or four cells exists along the mapped rim-to-rim boundary (Figure 5). Since the low elevations of the River are mapped somewhat higher and the high elevations of the rims are mapped somewhat lower, the mapped viewshed is a maximum viewshed. This then ensures that the total viewshed has been mapped.

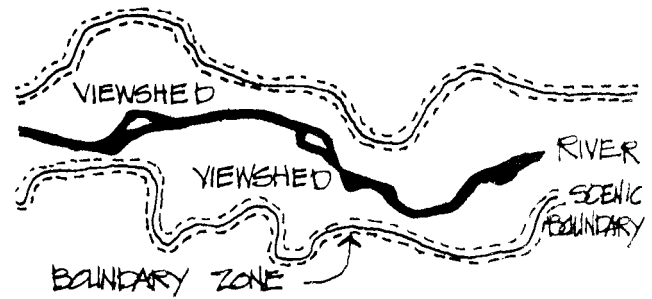


FIGURE 5

DOCUMENTATION OF THE PROCESS

Because DMA data and VIEWIT could be used most easily at the USGS 7-1/2 minute quadrangle scale, the study area was based on the entire quadrangle maps which contained the River in order to map the probable viewshed and boundary determination.

A quad by quad review of the area was initiated by marking highest and lowest elevations and the difference between the two, along with an estimate of what areas might occur in the viewshed. A preliminary estimation of where the most appropriate viewpoints would occur in the viewshed was recorded for each quad as shown in table 1.

The purpose of this record was to assist in selecting elevation intervals, and to keep a running total of the viewpoints for cost estimates and later project evaluation.

Upon completing this review, we then considered the total number and area of the aggregate maps we would use in the project. This presented a problem in study area continuity since the area of the project was so large.

The storage capacity in using VIEWIT limited us to a total map area of four total quads. Since there are 26 quads to be used in this long, linear study area, the how and where of joining these maps had to be considered next. This presented an important problem. If viewpoints are placed to the very edge of a map, the areas which can be seen from that viewpoint, but exist on an adjacent map, will remain unrecorded (fig. 6). In order not to lose this information and to maintain a high level of accuracy, a system of overlap was developed. The area of overlap consists of entire quad maps.

Table 1

VIEWPOINTS			Quad Name	ELEVATIONS		
3rd	2nd	1st		High	Low	Diff.
	15	21	P & N Ranch	3400'	2400'	1000'

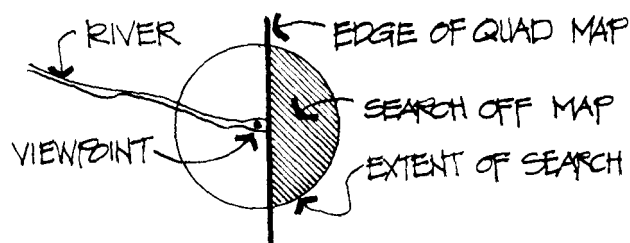


FIGURE 6

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Using this system then, the radius of the search from a viewpoint (r), should equal the distance that last viewpoint is placed from the edge of an overlapping map. A seen area is never lost by a viewpoint "looking off the map." By overlapping map one onto map two, the total seen area along that section of the River is accurately recorded. (Figure 7)

The disadvantage of this method occurs as the total number of aggregate maps for the study area is almost doubled. Also, when figuring the total number of times seen for a cell within the overlap, we are forced to add the numbers from both maps using a light table. This is time consuming. The greater accuracy achieved overrode this inconvenience and slightly higher costs for this project.

Also, due to the problem of overlapping the 1 degree by 1 degree DMA map halves as discussed earlier, the overlap of aggregate maps was not always possible for this project. Several joints do occur which must be interpolated for purposes of continuity.

Elevation Maps

As mentioned before, the DMA elevation information is converted to the grid cell size of 3.1 acres by using the TOPAS program COPYNCIC. A map of the coordinates of each quad in the DMA 1 degree by 1 degree file can be obtained by using the TOPAS program PRINT.

The task now is to create the four-quad aggregate maps on which VIEWIT can function. The STAR*GRID program (PSW*VIEWIT.DMA) groups this information into the desired aggregate maps, and stores them under a user-specified name. In

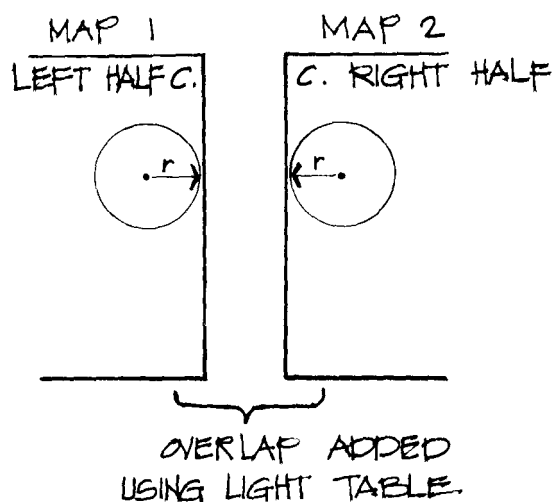


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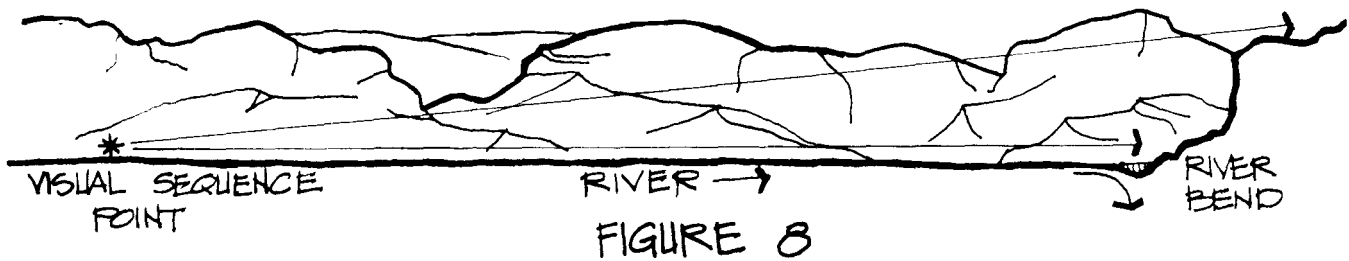
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gate, and whether it is an east or west data file. The number of rows and columns which appear on this map must also be specified. An example of this computation also appears in the appendix. The x,y coordinates of the southwest corner of the desired aggregate map must also be specified as they appear on the PRINT output, expressed in hundredths of an inch.

When STAR*GRID has been successfully performed to create the new base map, we have the option of immediately specifying elevation classes, and producing an elevation map. This map is numerically coded, based on our elevation classes. A cell in interval "1" receives a "1," a cell in interval "2" receives a "2" and so on.

The purposes of producing these elevation maps from the newly created files which contain them are first, to ensure that the desired area has been correctly transferred from the DMA map-half, and secondly, to check the accuracy of the elevation information (by class) with the correct placement of major landforms. Finally, to provide a gridded base map of the area with which the user can accurately determine the x,y coordinates of the viewpoints which are to be specified in the subsequent VIEWIT runs.

Selecting Viewpoints

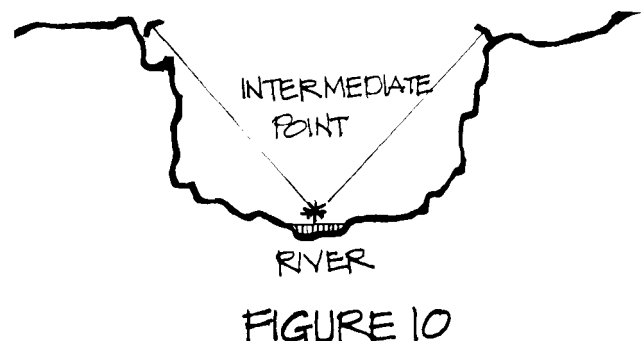
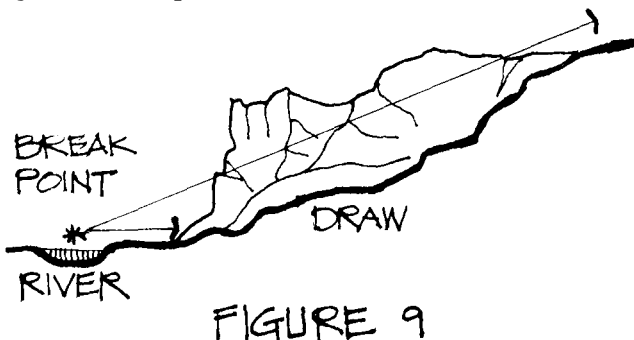
When the elevation maps had been produced and verified, the next step was to determine the final viewpoint locations for use in the VIEWIT runs. This selection process is perhaps the most critical step in the entire project process. Since the final VIEWIT output is the direct result of the combined functions of each viewpoint, its own location and relation to the adjacent viewpoints.

In the preliminary review, more viewpoints were included than are really necessary for optimal coverage of the viewshed in the most efficient means. The mind cannot see, from the plan view, the complete potential of each viewpoint with the same totality and speed characteristic of the computer. This limitation creates a tendency for the user to oversaturate the study area, not allowing for maximum efficiency.

The goal in this selection process is to strike the balance between input and output, to reach the fine line where total coverage of the viewshed is contained without unnecessary, repetitious viewpoints. Two factors were considered.

The first factor was the characteristics of our elevation base data which VIEWIT uses. The complex features of the DMA terrain were averaged into a single elevation for each cell. This becomes, in fact, one advantage of this system. A total approach to the landscape ignores the tiny details by reviewing the whole. These small deviations would most likely be included in the final viewshed even if considered, but since they are averaged out, allow the system to function at a more simple, less costly level, with comparable results.

Secondly, a more important consideration in choosing viewpoints is the actual character of the study area terrain. Within the Missouri River Basin, a viewer is dominated by steep slopes and cliffs which rise ruggedly from the River in a closed rim-to-rim landscape. The viewer is inferior, that being the position from which he must look upwards to perceive the landscape.



From this position, and within this terrain, we found that there are three basic types of views perceived from the River. We used these three types of views in a methodology for placing viewpoints along the River. The three basic types of views are from Visual Sequence Points, Intermediary Points and Break Points.

Visual Sequence Points (Figure 8)

From the visual sequence points, the observer can see the longest views possible along the River corridor. These points occur at the locations where the River bends, opening up new and distant views parallel with the River. And since the views are long, the angle of observation is the smallest. Thus, a distant, potentially grandiose view is possible, providing a wide lateral angle which allows a more comprehensive perception of the landscape whole. There is not a large number of views along the River, and those views that do occur are even more important to map because of this unique visual experience in a closed landscape.

Break Points (Figure 9)

The break points occur at those locations where the eroded draws have broken the immediate wall-like topography of the River landscape. The observer has moderate distance views towards areas beyond the River landscape, but more narrow in scope. The frequency of the views allows for a more varied visual experience along the river. These areas of visual variety should be carefully mapped in order to include them within the viewshed, even though the actual amount of time they can be observed may be relatively short.

Intermediate Points (Figure 10)

The coverage of the total viewshed was completed by using the intermediary viewpoints. These points function in order to fully scan the immediate topography along the River, generally occurring in those intervals between the previously mentioned types. During the initial review of the terrain in this River region, the maximum interval between viewpoints averaged 4 per mile.

By more strategically placing viewpoints, based on view types as defined by the possible views within the terrain, the 149 mile stretch of the River was mapped by using a total of 450 viewpoints. Thus, averaging 3 viewpoints per mile.

It becomes obvious also that the role of a single viewpoint can encompass any combination of the roles described above. And certain viewpoints even act as all three. This overlap allows elimination of duplicating viewpoints.

Selecting Radii

Keeping in mind the three basic types of viewpoints and the role of each, the radius (limit) of the search for visible terrain which the computer uses in the VIEWIT run was determined. Since the role or roles of each viewpoint have been determined in the placement methodology, the farthest possible viewing distance from the viewpoints can be measured to determine the radius of search.

In this project, the maximum radius was ten miles and the smallest three miles. The visual sequence points, by definition, had the largest radii, being six, eight or ten miles. The break points were generally assigned a more moderate distance, usually four or six miles, with some three, eight and ten mile searches for unique situations. The intermediate points were always assigned a three mile radius of search.

Due to the rugged topography and ambiguous viewshed judgements caused by such a topography, the three mile minimum was set. This system of assigning radii for each viewpoint helped to maintain as accurate and complete a set of final views as could be achieved using the VIEWIT method.

Implementation of VIEWIT

With the locations and radii of the viewpoints finalized, these points were transferred onto the elevation maps which were created earlier. This was done on a light table by overlaying the USGS quad map transparencies (with viewpoints drawn on) onto the elevation map computer printouts. Then the row and column number of the viewpoint, along with its radius, can be entered into a VIEWIT run-stream. A ZBIAS of six feet was set. This command allows raising viewpoints six feet above the surface of the river which would be a more real-life situation, as if a floater were to be in a canoe or boat on the river.

Map Preparation

With the completion of this process, the final output is in the form of a numeric map which shows the viewshed of the Missouri River.

In order, to provide orientation and scale to major topographic features, such as the River, color-code viewpoints (the color denotes various radii) were added to the computer maps. With these, any user can quickly understand the basic information which produced the map. To aid the interpretation process further, both acetate grids and acetate USGS quad maps are provided for the user. These allow more detailed examination of the maps, enabling a deeper understanding of the implications and possible uses of this output.

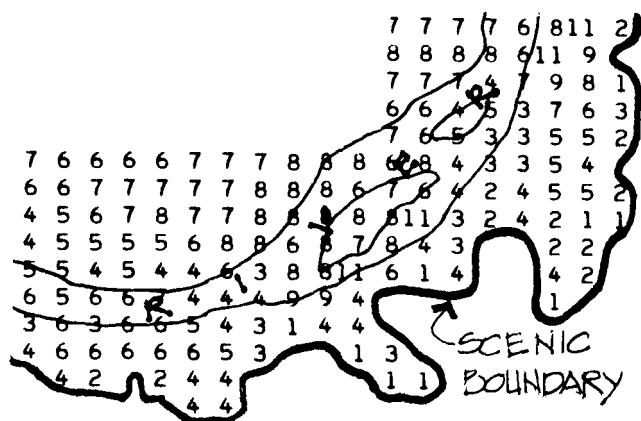


FIGURE 11

By using this simple computer map preparation, a user can better understand how the maps were made, what they mean and how they can be used.

SYSTEM USES

There are several specific uses of this data which relate to the intents of this project. The following are those used during this project and as ongoing possibilities with a system such as VIEWIT.

Scenic Boundaries (Figure 11)

This application of the viewshed maps is perhaps the simplest, but by no means the least important. This, in fact, was the major objective of this project, with the alternate uses being beneficial potential by-products of this system.

In its simplest form, VIEWIT mapped the viewsheds along the River based on the viewpoints as specified. The farthest extent of this viewshed from the River is the Scenic Boundary, that being the rim-to-rim boundary we were to locate and map.

Before using this system, scenic boundaries were determined by hand/map methods, based on field and topographic map observations. By floating down the River and spot checking with a helicopter, general "seen areas" are noted on a base map of the region. Unlike the computer method, this system does not allow for a complete and comprehensive scan from a large number of viewpoints.

There is a tendency with this method to consider only the shorter views. This means that many areas which can only be seen from greater distances will remain unmapped. Also, it becomes hard to map the landscape seen in three dimensions onto a two-dimensional base map.

Table 2

Class	Times Seen	Length of time visible in minutes ^{1/}
1	1	5
2	2-3	10-15
3	4-5	20-25
4	6-7	30-35
5	8-10	40-50
6	11-14	55-70
7	15-18	75-90
8	19+	95-2 hr +

^{1/} based on a river speed of 4 miles per hour and approximately, 3 viewpoints per mile

These judgment errors make necessary more generalized scenic boundaries. The scenic boundaries interpreted from VIEWIT viewshed maps are based on a much greater degree of detail (Litton 1973).

As a comparison, the scenic rim-to-rim boundaries mapped with the eye/hand method were overlaid with the boundaries derived from the VIEWIT viewshed maps. Overall, the two boundaries were more similar than different. In conflict areas, field checks were necessary.

In a practical sense, seen areas from the final scenic boundary should be included. This could mean that a land use could occur in that area which would be unregulated and remain unmanaged. Thus it could potentially have an adverse impact on the scenic quality of the River. By the same right, including areas within the scenic boundaries which are not visible means unnecessary acquisition costs, restrictions and management costs.

Visual Vulnerability

Using VIEWIT maps, this analysis can be taken one step farther. On these maps, the number of viewpoints which "see" an area is recorded in every cell of the viewshed. Though this does not take into account the quality of the view, it does make it possible to rank these areas based on how often, thus how long they can be seen. By this principle, if an area is seen more times, it is seen longer and is consequently more visible. Based strictly on time, the areas which are most visible have a higher visual vulnerability than those areas which are less visible. These areas must then be more carefully managed since an activity which occurs in those highly visible areas could have a greater impact on the scenic quality of the River.

er. Though oversimplified, this concept can be useful in the management activities along the River.

In mapping relative visual vulnerability along the River, we assumed that:

- A To be used as a planning tool for siting necessary structures and activities in the viewshed, areas of lowest visual vulnerability should be shown in more detail. More distinctions should be drawn at this end of the scale between the number of times seen as low number of times seen means less amount of time visible with lowest possible impacts on scenic quality making more attractive sites for an activity; and, the converse is also assumed.
- B. Management on areas of higher visual vulnerability requires fewer distinctions. Lengths of time seen tend to lose significance as they increase. The difference between 60 and 70 minutes of visibility is academic for siting and controlling impacts on scenic quality.

Applying these basic assumptions, the visual vulnerability zones were based on the classes as shown in table 2.

Planning/Design, Decisions

When a siting decision for a land use or activity has been made within the viewshed of the River, its visibility and visual impact can be measured with the help of VIEWIT. If a viewpoint is placed on the uppermost structure of a land use, like the top of a utility pole, bridge or well, all areas from which that structure is visible would be mapped. This can be the base from which other issues can be considered such as possible versus probable perception, screening and the like.

This technique can be used for choosing several possible sites and then narrowing them down to the one at which the visual impacts on the River will be the least. This should be an important part of the site analysis and selection criteria.

It should also be noted that detailed decisions such as these probably necessitate more exact elevation data such as that produced by hand digitizing methods.

CONCLUSION

In the final review of this project, the DMA data proved to be an adequate source of elevation information for the purposes of this project. Data orientation, that being the actual spatial placement of the correct eleva-

tions on the map was quite accurate. It was found that because of the truncation problems as discussed earlier, the extreme high and low elevations in the landscape tended to disappear. The high and low elevation checks as built into the assignment of elevation classes were in fact never violated. Instead, the elevation class for the River often disappeared, as did the #9 class containing the highest elevations. This made it all the more necessary actually to draw the River onto the elevation maps to provide for basic orientation.

This tendency to raise the River and lower the ridges implies that the mapped viewshed may be somewhat larger than the viewshed which actually exists. This problem was not critical for the project. In this region, and for this resource, the exclusion of visible areas from the viewshed is a more serious problem than the inclusion of a slight area of nonvisible cells. The generalized 40 acre grid used for final legal boundary definition also negates this problem.

When reviewing the final VIEWIT maps, it was found that the viewshed in several flatter areas appeared to be less accurate than the viewsheds for the steep areas. It appears that caution should be used when DMA data is applied for flatter, undulating landscapes. Both truncation and error margins have a much more pronounced effect in these landscapes. A test of accuracy should be made to ensure the effective use of DMA data for these areas.

The steep terrain of the Missouri River landscape served as an optimal use situation, that being one in which the effects of both truncation and specified vertical and horizontal error margins are reduced. This advantage, along with the relative ease of operation and economic advantages made the DMA source a good alternative for this project.

In producing the final viewshed maps, the methodology for viewpoint selection proved to be successful. When comparing the VIEWIT viewsheds with the USGS quads and the eye/hand boundary maps, there was a general correlation and verification of information.

In mapping the final scenic rim-to-rim boundaries, the user should keep in mind the error margins as discussed earlier. The outer edge of the viewshed delineates a boundary "zone," rather than a distinct line. This zone must be kept in mind when the final 40 acre legal boundary is mapped. Field checks should be made to verify any questionable situations.

The far reaching implication of the viewshed and system data shows the advantage of using a computer system such as VIEWIT. Its potential

goes beyond strictly delineating viewsheds and scenic boundaries, being able to perform also as a planning/management tool.

This was the first time that actual graduations of visual vulnerability within the scenic boundaries were mapped. Also, a quantitative measure was assigned to the viewpoints along the River since the total acreage of seen areas is recorded for each separate viewpoint.

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