

Isometric Projections and Other Study and Display Methods Used in Preliminary Design of I-70 Through Glenwood Canyon

JOSEPH R. PASSONNEAU

The designers of I-70 through Glenwood Canyon, Colorado, were responsible to reviewers from many backgrounds. All wanted to find a good fit between highway and natural landscape, but their definitions of "good fit" varied. Accurate graphic descriptions of the canyon and of alternative highway proposals were important to designers and reviewers. These were needed to show conventional highway plans, profiles, and sections; to show the appearance of the highway in the natural landscape; and to show the precise relation between highway alternatives and landforms and plant communities taken or impinged upon. Canyon and highway alternatives were described by using conventional artist's sketches, colored slides and black-and-white photographs, surveyed cross sections combined with perspective backgrounds, environmental maps, isometric drawings, composite drawings or "story boards", computer graphic cross sections at close intervals, highway representations painted into photographs, scale models, full-size mock-ups, and even diagrams and cartoons. An isometric projection technique developed for the project was particularly helpful in the design of the highway in the western half of the canyon. Both landscape and highway alternatives can be drawn in isometric with engineering accuracy and combined, with much of the realism of an architectural perspective. Highway designers and reviewers have traditionally come from similar backgrounds and have communicated through familiar methods. The Glenwood Canyon work was typical of recent projects in which unusual proposals were reviewed in a process more like a New England town meeting. In such a setting, the ability to communicate lucidly, in words and images, is an important aspect of highway engineering.

In the design of I-70 through Glenwood Canyon, Colorado, alternative proposals were examined in a series of iterations, each of which lasted about a month. The work was reviewed frequently by the district engineer and the project engineer for the Colorado Division of Highways (CDH), by representatives of other agencies and a Technical Review Group, and, finally, by representatives of all of these groups and the seven members of the Citizens Advisory Committee for Glenwood Canyon.

The design of a highway in mountain terrain is the problem of fitting a ribbon of concrete and asphalt, shaped by its own precise geometric rules, to a natural landscape shaped by the very different rules of geology. Whereas each of the reviewers was searching for a good fit between highway and landscape, their definitions of "good fit" varied dramatically and sometimes conflicted. The participants in this process brought many points of view to the work, and the designers were asked to investigate a large number of unusual alternatives. The presentation of these alternatives had to meet the following requirements:

1. Horizontal and vertical location, superelevation, and cut and fill were to be shown in conventional plans, profiles, and sections.
2. The appearance of the road was to be shown in its surroundings, unambiguously, to many people who were skeptical about both artists' renderings and engineering drawings.
3. The relation of each proposal to rock formations, talus slopes, watercourses, plant communities, and individual trees was to be shown precisely, and drawings were to identify each natural feature displaced or impinged upon.
4. Because the work, from start of design through the design public hearing, took just nine months, alternatives were to be described not through elabo-

ately contrived presentations but by using drawings peeled from the drafting boards at the beginning of each meeting.

This paper first summarizes study and display techniques used in the design of I-70. It then describes in detail an isometric method of drawing highway alternatives in a natural landscape that was developed for this project.

TECHNIQUES USED IN DESIGN OF I-70

Conventional Sketches of Existing Landscape

Conventional sketches of the existing landscape were used by the designers to educate themselves. Figure 1 shows an example of such a sketch of the canyon, looking west from just above the location of the recommended alignment of the westbound roadway. These sketches emphasized the plant communities typical of different slopes and elevations and showed, in ways the camera could not reveal, that the canyon is a sequence of great outdoor rooms with transitions that could be dramatized by highway design. The sketches also showed that the appearance of the canyon changes with the elevation of the viewer and that, from as little as 100 ft above the river, the traveler's view can be breathtaking. Sketches emphasized the damage that has been done to the river's edge by earlier road building and that a well-designed new road could partly correct this damage.

Colored Slides and Black-and-White Photographs

Colored slide transparencies and black-and-white photographs also helped designers to understand the canyon and were essential in illustrating issues for reviewers and laypersons. They were also used in preparing perspective drawings of alternative designs. Figure 2 shows black-and-white reproductions from color slides used in the design public hearing, showing the different character of the western and eastern halves of the canyon.

Terrain Cross Sections

Terrain cross sections, with the natural background drawn in perspective, were prepared from a viewpoint about 25 ft above the existing road. These sections were taken at stations 1000 ft apart, at more than 60 locations, as well as at intermediate stations that presented special problems. The sketches were drawn from life and from photographs taken from a high lift. These perspective cross sections were used as base drawings for preliminary studies of highway alternatives. It was an advantage of these drawings that a large number of proposals could be sketched very rapidly and the alternatives that were most interesting could be examined at each location in the canyon. These drawings could be made precisely accurate at the cross-section line, but beyond this line accuracy depended on the skill of

Figure 1. Sketch of Grizzly Creek in Glenwood Canyon.



Figure 2. Black-and-white photographs of Glenwood Canyon showing (left) deep, V-shaped western section and (right) shallower, U-shaped eastern section.



Figure 3. Perspective cross sections used in preliminary studies: (top) immediate separation design and (bottom) maximum separation (Shoshone Powerhouse).

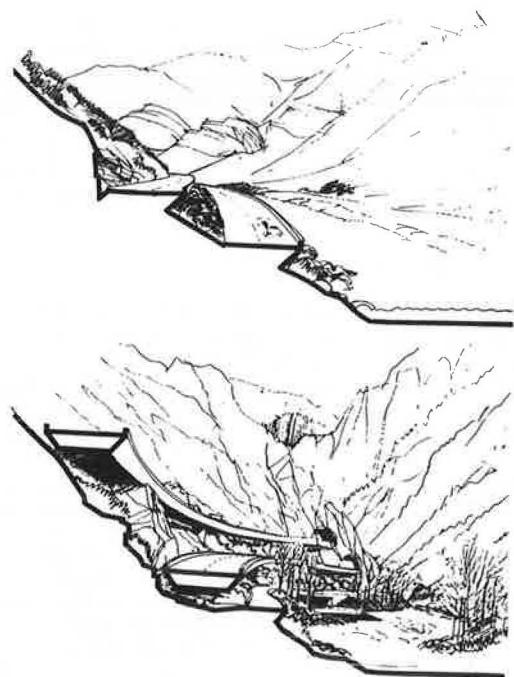


Figure 4. Section from environmental strip map just west of Shoshone Dam.



the artist. This technique was therefore useful for preliminary studies but not for design development. Figure 3 shows examples of these drawings.

Environmental Strip Map

An environmental strip map was prepared, in color (at 1 in = 100 ft), on dimensionally stable mylar. This map showed the four distinctly different kinds of plant communities found in the western half of the canyon, three kinds of rock formations, talus slopes, rock rivers, watercourses, and all man-made elements (buildings, roads, railroads, and the dam) plus scars in the landscape (cut talus slopes, cut rock faces, trails, and mine tailings). A section of this map near the Shoshone Dam is shown in Figure 4 at reduced scale. Highway alternatives were then drawn on translucent mylar (at 1 in = 100 ft); cut and fill slopes were shown in plan and overlaid on the strip map. The composite plan drawing showed, for each alternative, the effect of highway construction on landforms and plant communities.

I consider such strip maps to be, in urban work, the essential reference documents; one client described them, not entirely facetiously, as the "magic maps" and the "sacred scrolls". But in the Glenwood Canyon work the design problem was so emphatically three-dimensional that these two-dimensional reference drawings were not very helpful. This was unfortunate, since the amount of work involved in locating so much information so accurately is formidable.

Isometric Drawings

Isometric drawings of existing conditions were used as base drawings on which were overlaid isometric drawings of highway alternatives. These composite drawings, which were also helpful in describing alternatives to reviewers, were to the designers the

most useful of all graphics tools used in studying the western half of the canyon. (The low investment return on time spent in preparing the environmental strip maps was offset by the high return on time spent in preparing isometric base maps at 18 different locations in the canyon.) These drawings are described in the final section of this paper.

Composite Presentations

Composite presentations were used to describe particular issues. Figure 5, for instance, shows a section of a large "mural" study of the Colorado River's edge. This mural showed existing conditions of both natural and damaged landscape, as well as possible relations between highway edge and riverbank, and examined possibilities for at least partly restoring the river's edge to its original natural condition. The drawing combined sketches from nature; diagrams; plans, profiles, and sections; text; and perspective drawings of various alternatives. Such a drawing is a useful "story board," summarizing the thinking of designers and presenting a complex subject.

Computer Graphic Cross Sections

Computer graphic cross sections were useful--essential, in fact, in the western section--in the final stages of design development and in "fine tuning" the selected alignment. The initial preparation of computer graphic cross sections is laborious, time-consuming, and expensive. Terrain cross sections must be entered, highway templates must be prepared and entered, and each alignment to be printed out must be mathematized and entered. But, once initial preparation is complete, a number of iterations can be examined accurately and more rapidly than sections can be prepared by hand. The earthwork pro-

grams used as the basis for the Glenwood Canyon printouts were also adapted to printing computer perspectives, on either an oscilloscope or a CalComp plotter. Figure 6 shows two typical sections.

Composite Photograph-Drawings

Composite photograph-drawings, in which highway alternatives are painted in tempera into a photograph, can be made to look, to a layperson, like a photograph taken from "life". Because computer perspectives are unforgiving, the combination of photographs and computer perspectives is particularly reliable. The photograph and the perspective must be taken from the same point in space. This technique was most effective in presenting alternatives in the eastern half of the canyon, where particular views from particular locations were important in alignment comparisons. Many of the reviewers considered views from the driver's eye level to be the most significant views. The composite photograph-drawing is a good technique for displaying such views. This procedure has the disadvantage of being too laborious for study purposes and is most useful in comparing well-defined alternatives. Two alternatives for Blue Gulch are shown in Figure 7.

Full-Scale Mock-Ups

Full-scale mock-ups, one of which is shown in Figure 8, were constructed to test critically important proposals in difficult sections of the canyon. To many of the reviewers, these were the most useful of all of the study techniques. Such mock-ups are obviously expensive in money and time.

Small-Scale Sectional Model

A small-scale (1 in = 100 ft) sectional model was

Figure 5. Story board from river's edge study.

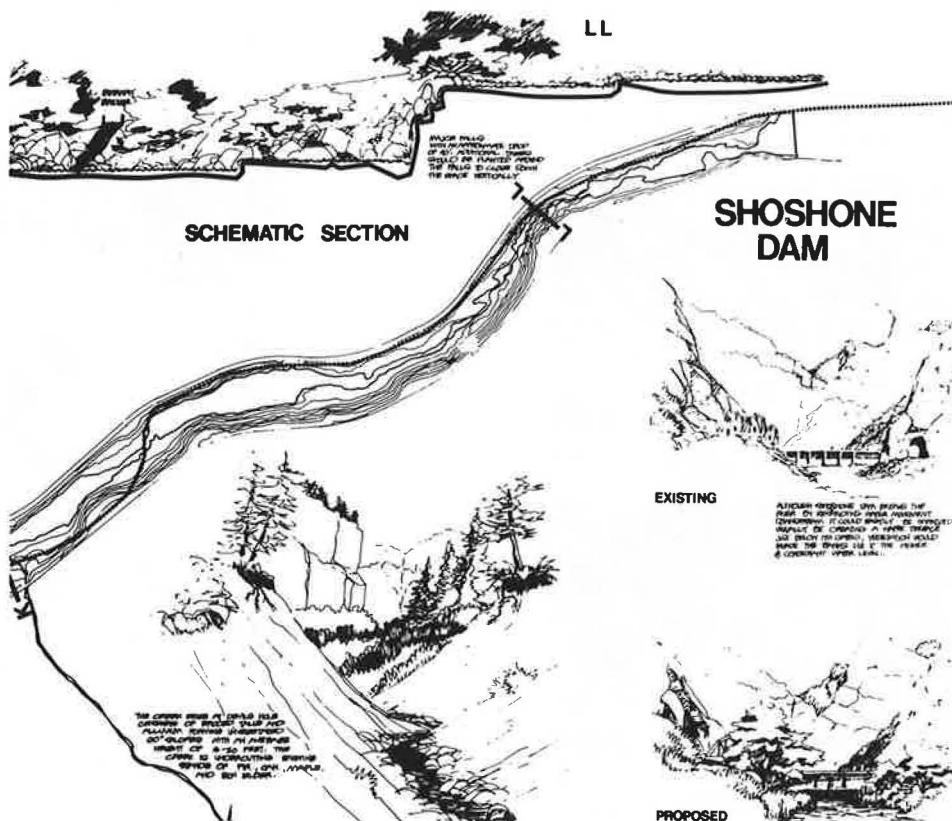


Figure 6. Computer graphic cross sections of recommended alignments: (top) near No Name Creek and (bottom) near West End.

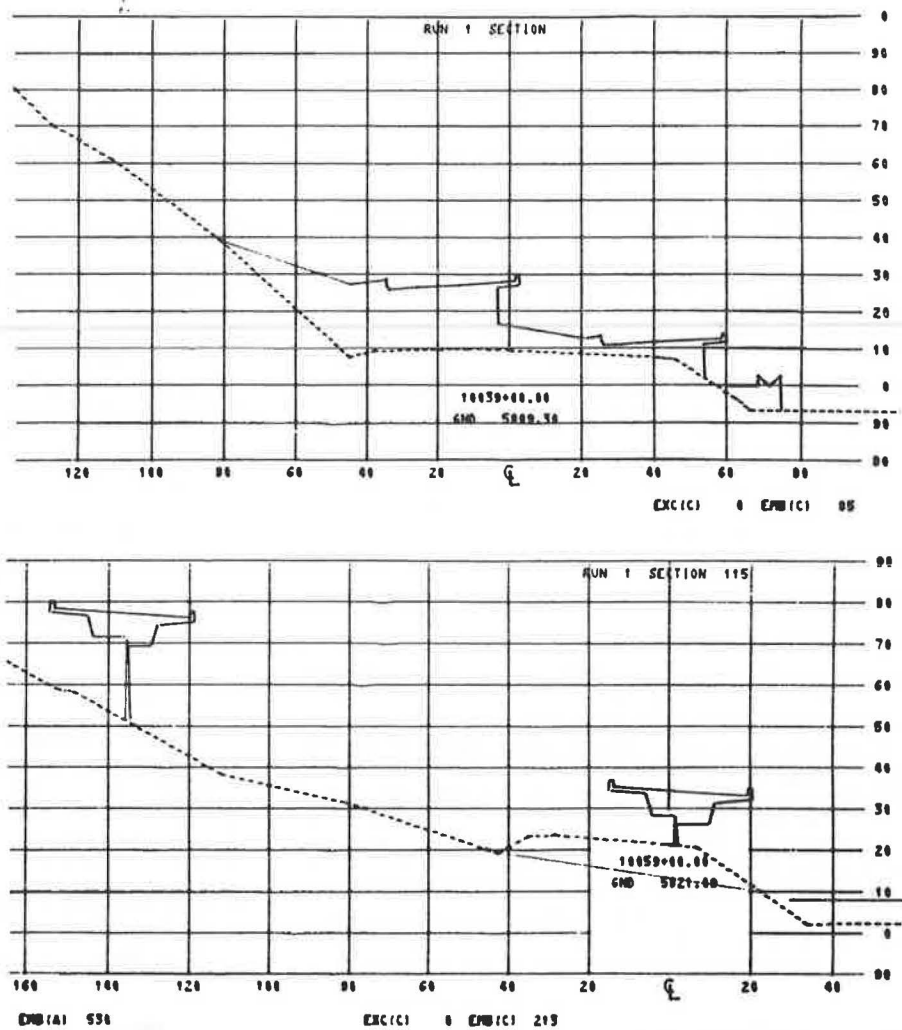


Figure 7. Composite photograph-drawings of Blue Gulch alternatives.



Figure 8. Full-scale test mock-up east of Hanging Lake.



prepared by the eastern design group to illustrate alternative proposals at Hanging Lake, just east of Shoshone Dam. The model could be assembled in three different ways to show the particularly complex solutions for this important section of the canyon. Viewers (who would get down and squint) could see the appearance of the canyon from many eye-level viewpoints; the model also showed the overall character of each proposal. Such scale models and the study models that precede them are helpful to both designers and reviewers. They often provide

Figure 9. Diagrams of highway alternatives west of Shoshone Dam.

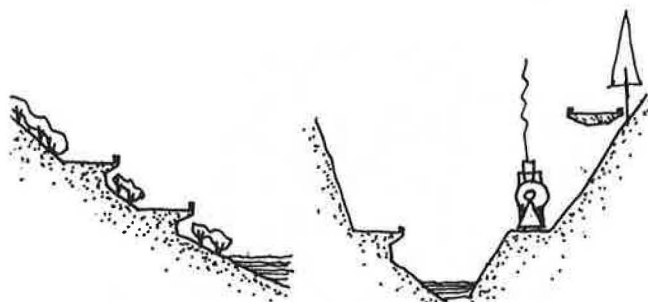
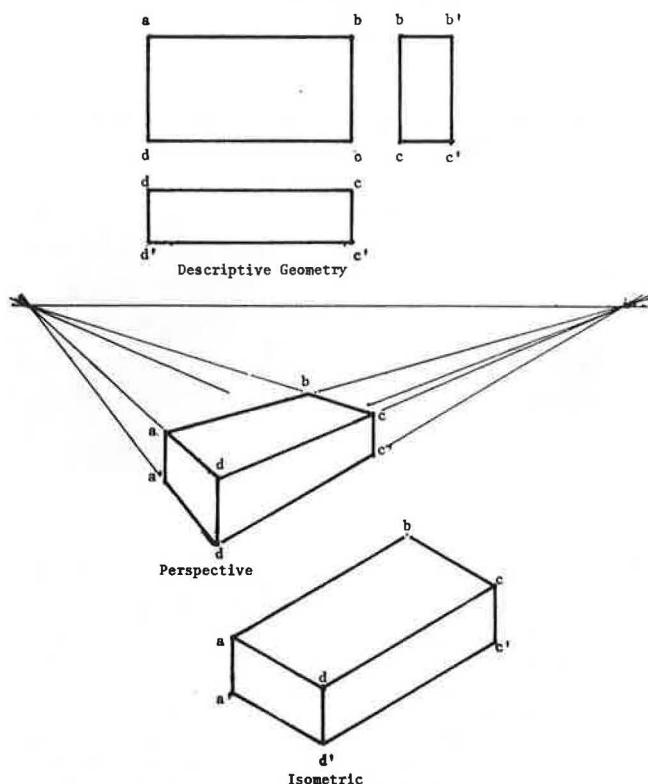


Figure 10. Three ways of drawing a rectangular solid: (top) descriptive geometry, (middle) perspective, and (bottom) isometric.



the most effective way to present complex three-dimensional problems to laypersons. They are generally extremely expensive.

Cartoons

Diagrams, or "cartoons", summarizing and simplifying complex issues were presented frequently, in chalk on blackboards and colored markers on sketch pads. This simple technique was used naturally in meetings in which ideas were exchanged and proposals criticized in round-table seminars. Such diagrams were also used in more formal meetings. Figure 9 shows sketches used in the design public hearing to summarize highway location possibilities in the western half of the canyon.

ISOMETRIC DRAWINGS AS A TOOL FOR STUDYING HIGHWAY ALTERNATIVES IN A NATURAL LANDSCAPE

Isometric drawings have the following characteristics:

Figure 11. Isometric armature of Bear Creek: (top) terrain and (bottom) existing conditions.

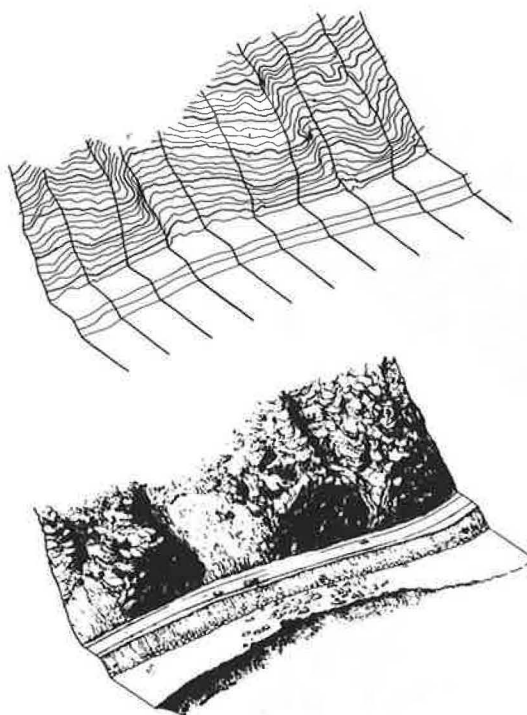
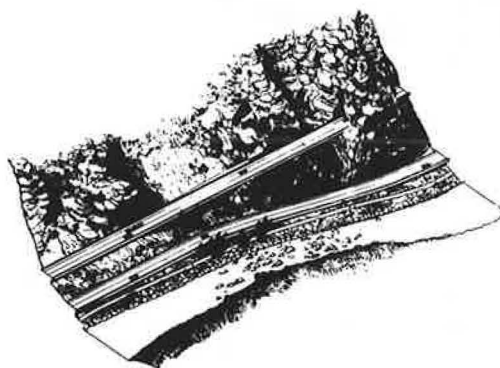


Figure 12. Isometric projection of alignment at Bear Creek recommended in design public hearing.



1. Highway and landscape can be drawn with engineering accuracy.

2. Such drawings have much of the realistic character of architectural perspective sketches.

3. The preparation of base drawings of existing conditions is a laborious process but, once base drawings are completed, prints can be made for as many alternative studies as the problem demands.

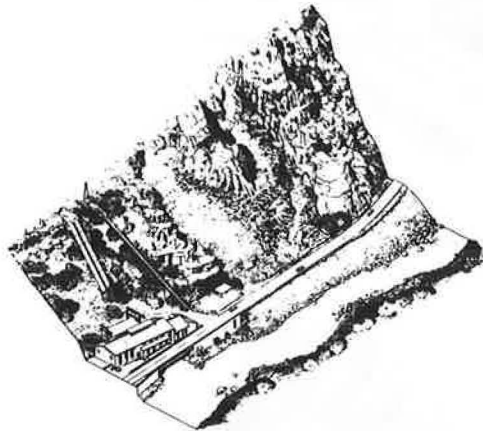
4. The extent of the area to be studied is not limited by the projection technique (as with perspective drawings); because the scale remains unchanged throughout the drawing, it can be extended as far as the size of the paper and the energy of the draftsman permit.

Figure 10 shows (a) a rectangular solid drawn in plan and elevation by using the basic technique of descriptive geometry, (b) the same solid drawn in perspective, and (c) the solid drawn in isometric projection. In this particular isometric projec-

Figure 13. Isometric projection of original conditions near Shoshone Powerhouse.



Figure 14. Isometric projection of existing conditions near Shoshone Powerhouse.



tion, angles $b a d$ and $b c d$, which are right angles in reality, are drawn as 60° angles. Angles $a d c$ and $a b c$, which are right angles in reality, are drawn as 120° angles. Therefore, the rectangular cube is distorted in the drawing to a diamond shape, somewhat as it appears in perspective. However, all dimensions scaled along lines parallel with the x , y , and z axes are true scalar dimensions.

In an isometric projection, all lines that are parallel in reality remain parallel in the projected drawing; in a perspective drawing, they converge.

Steps in Development of Isometric Drawings

The development of isometric drawings for highway studies proceeds in three steps.

In step 1, an isometric armature is prepared. Terrain cross sections are drawn in isometric convention, parallel with the $x y$ plane of the projection. Contours are then drawn in isometric convention, parallel with the $x z$ plane. The result, shown at the top of Figure 11, is the isometric armature of the terrain as surveyed. In the Glenwood Canyon isometric drawings, sections and contours were taken at 50-ft intervals and intermediate contours at 10-ft intervals.

In step 2, an artist sketches an isometric base drawing of the existing terrain over the isometric armature. In the Glenwood Canyon work, the artist climbed up and sat on a rock on the opposite wall of

Figure 15. Isometric projection of alignment alternative near Shoshone Powerhouse.

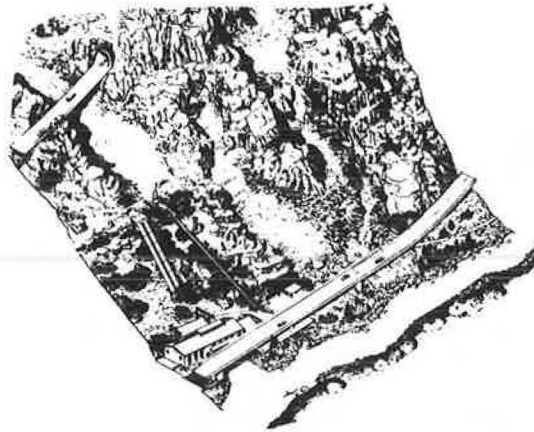
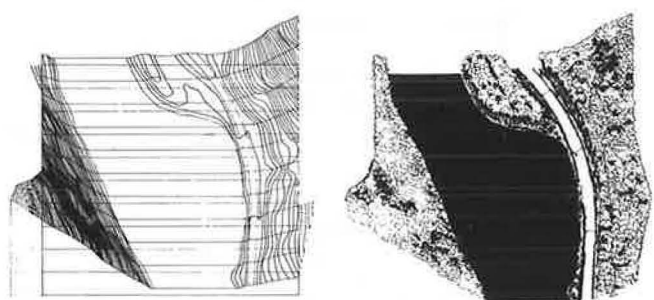


Figure 16. Profile Lake, Franconia Notch, New Hampshire: (left) axonometric armature and (right) axonometric projection.



the canyon, approximately 60° in plan and section from the center of the area covered by the armature. From here, he sketched the topography and vegetation over a print of the armature. Because the arid canyon vegetation is sparse, talus and rock surfaces could be accurately displayed. Stakes in the ground at the intersections of grid lines were used where the relation between terrain and armature seemed ambiguous. The bottom portion of Figure 11 shows the base drawing prepared over the armature. Prints were made from the base drawing as needed for the study of various alignment alternatives.

In step 3, isometric drawings of highway alternatives can then be prepared to the same scale as the base drawings, from conventional highway plans, profiles, and cross sections. These can be printed, cut out, and stripped into prints of the base drawing. Figure 12 shows the alignment alternative at Bear Creek that was recommended in the design public hearing.

Figure 13 shows an isometric drawing of the vicinity of the Shoshone Powerhouse, in which the original character of the canyon has been reconstructed with the help of late 19th century photographs. Figure 14 shows existing conditions at the powerhouse. These drawings emphasize that the choice is not between a primeval wilderness and a wilderness scarred by man but between two different combinations of wilderness and artifacts. Figure 15 shows one of the alternative alignments at the Shoshone Powerhouse.

An isometric projection is a perspective projection from a particular point of view—in the words of one of the reviewers, "from the viewpoint of an

eagle at infinity" (with superior eyesight). Therefore, the computer program could be modified to prepare the isometric armatures and the isometric roadway drawings from terrain data, mathematized alignments, and highway templates.

The 60°-120°-60°-120° isometric was tailored to studies of the western section of Glenwood Canyon because the highway alternatives were built on a canyon wall that sloped about 60° from the vertical. However, other conventions could be selected to fit other problems. For instance, in preliminary work on the Franconia Notch Parkway in New Hampshire, an axonometric armature was drawn (at 1 in = 50 ft) for the entire 12-mile length of the Notch. An axonometric drawing is an isometric in which the angles b a d, b c d, a d c, and a b c are right angles in reality (see Figure 10) and remain right angles in the drawing; that is, plan sections remain plan sections. Because there is a mantle of trees over the entire floor of Franconia Notch, a drawing convention was needed that would permit the viewer to look down into the channel cut through the woods to make room for the road. Figure 16 shows an axonometric armature of the terrain at Profile Lake, looking north, and a base drawing drawn over that armature, showing existing terrain and vegetation.

SUMMARY

Designers and reviewers of roadway designs have traditionally come from similar backgrounds, with homogeneous values and objectives. The Glenwood Canyon process was not conventional in that sense. It was typical of more recent projects to which a variety of participants have brought a variety of interests. In the Glenwood Canyon process, which has been described elsewhere from several points of view (1-3), design review was more like a New England town meeting. In such a setting, the ability to communicate lucidly, in words and images, is an important aspect of highway engineering.

My son, who is deaf, has grown up in the middle of a controversy between those educators intent on teaching deaf children to speak orally and those who favor manual communication by the deaf. One participant in this heartrending debate has put forward this proposition, which also summarizes one of the arguments of this paper: "People communicate in many ways. People communicate with sounds in many languages, with their hands, with facial expressions and body movements, and through writing and drawing—all in a myriad of subtle combinations. The important thing is simply to communicate in whatever way best serves the message, the sender, and the receiver, and the more ways that are available for communication, the more likely it is that the message will get through."

There is a second argument in favor of a "kit" of graphic techniques for designers wrestling with unusual highway problems. How can various locations

of that ribbon of asphalt be described? How can they even be imagined? Fleeting images are not good enough. Alternative highway locations in relation to landforms must be postulated, recorded, and reflected on, with enough facility so that they can be discarded without regret, while the designer pushes on toward a better alternative. The need is so fundamental that it is often overlooked, and designers may at times be content with ways of thinking that are not up to the job.

The importance of means of communication is underestimated. The essential communication is with oneself. Without methods of communication, a person would have no access to history, could not compare experiences, could not combine abstract ideas in new permutations, and would therefore be cut off from the world of art and invention and design.

ACKNOWLEDGMENT

I was consultant to the prime contractor, Daniel Mann Johnson and Mendenhall, on the Glenwood Canyon I-70 project and was project director for the design group responsible for the western half of the canyon. Leigh Whitehead took the black-and-white photographs. Laurie Olin and Edgar Haag did the landscape sketches, and Edgar Haag drew the perspective cross sections and prepared the "River's Edge Study". The isometric base drawings were sketched by Leavitt Dudley. Gruen Associates was the prime contractor for the design of the eastern section; Edgardo Contini was the project director. DeLeuw, Cather, and Company advised the Colorado Division of Highways in the review of the work and was responsible for interchange and landscape design.

For the work at Franconia Notch, Daniel Mann Johnson and Mendenhall was the prime contractor, and I was project director as consultant to that firm. Kiley Walker was the landscape consultant, Tadihiro Kozawa prepared the isometric armatures, and Alastair McIntosh prepared the base drawings.

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