controlled to reduce infiltration into the landslide mass.

One landslide area was located between stations 415 and 425 (see Figure 10). Active bedrock landslides from either side of Black Gore Creek had their toes in the creek. The landslides on either side of the creek were instrumented, and their movement was monitored. The maximum movement occurred during the period of high groundwater levels, i.e., spring runoff. The solution to the stabilization of these two landslides was to fill the valley, transferring the thrust of one landslide against the other and putting the stream and the highway on the valley fill.

Slope stability was maintained by careful design of back slopes. The eastbound and westbound lanes were separated where space, line, and grade allowed, and the heights of back slopes and fills were kept to a minimum. Slopes in surficial material were laid back as far as was practical, contoured, covered with topsoil, and seeded. Particular care was taken to control surface and groundwater drainage on all cut-and-fill slopes. On bedrock slopes, the different types of material were treated differently depending on their ability to stand. The slopes in more competent units approached vertical, whereas those in less competent units were laid back and often seeded. The natural breakage of the rock—e.g., along joints—was followed, and the back slopes in bedrock conform in appearance to natural rock slopes.

One area of slope stability that was of particular concern was that between Gore and Bighorn Creeks. Along the alignment were surficial deposits, mostly glacial moraine, on Precambrian igneous rock. The surficial deposits were at their maximum angle of repose and were saturated with groundwater during most of the year. The choices for the placement of the highway were restricted by the presence of privately owned lands in the valley. Cuts in this area could have caused major slope failure. The solution was to put much of the highway on a structure.

ACKNOWLEDGMENT

In 1969, the Colorado Division of Highways entered into a contract with Charles S. Robinson and Associates, Inc., engineering geologists, and R.V. Lord and Associates, soils and foundation engineers, for an intermediate geologic study of the Vail Pass area. After completion of the geologic study in 1971, Charles S. Robinson and Associates were retained to work with International Engineering Company in the environmental studies of the Vail Pass area.

The geologic problems in the Vail Pass area were first recognized by R.K. Barrett of the Colorado Division of Highways (5). His report on the geology was the basis for the contract with Charles S. Robinson and Associates. The field investigations were conducted by Charles S. Robinson and Dale M. Cochran of Charles S. Robinson and Associates with the assistance of Gary T. Whitt of R.V. Lord and Associates. The contract was conducted under the supervision of Richard A. Prosence and Robert K. Barrett.

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U.S. Forest Service Involvement in and Overview of the Vail Pass Project

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The Vail Pass segment of I-70 was constructed across public land administered by the U.S. Forest Service. As the land-management agency, the Forest Service was responsible for ensuring that the construction would neither disrupt nor destroy the land's resources. The Forest Service carried out this responsibility by issuing environmental constraints for the construction, reviewing the construction plans and specifications in relation to these constraints, and periodically reviewing the construction work. A liaison officer was assigned to the project who, with the help of specialists, expressed the concerns of the Forest Service. This group assisted the Colorado Department of Highways in minimizing or eliminating the adverse environmental impacts caused by the construction of a highway to the standards of the Interstate system. Unique and innovative solutions to many sensitive environmental problems generated by the highway construction were found and applied through the effort and cooperation of many professionals and agencies. The result is an Interstate highway that lies lightly on the land and is compatible with the surrounding mountain environment.

The Forest Service of the U.S. Department of Agriculture is responsible for management of the national forests. This includes authorizing both occupancy and construction activities in these areas. This responsibility is carried out by issuing "stipulations" for the conduct of the work, reviewing the construction plans and specifications in relation to these stipulations, and periodically reviewing the work in progress. A right-of-way or ease-

ment is granted on completion of the work according to the plans and specifications.

During the course of the legal transfer of national forest lands to the Colorado Department of Highways for the construction of I-70 over Vail Pass, three sets of stipulations, or construction requirements, were agreed on and implemented. The first set, which was rather broad in scope, was written into the easement deed between the U.S. Department of Agriculture and the U.S. Department of Transportation. The second set of requirements, which was somewhat more specific, was written into the memorandum of understanding between the Colorado Department of Highways and the Forest Service. The third set of construction clauses was included with the interim letter of consent (for construction) issued by the Forest Service to the Colorado Department of Highways under the heading "Stipulation". These requirements were still more specific but needed interpretation as to exact meaning.

EASEMENT DEED

The procedure for authorizing the transfer of lands to a state for construction of an Interstate highway was established by an Act of Congress dated August 27, 1958 (23 U.S.C., §§317, 107d), and amended October 15, 1966 (80 Stat. 931, 937, §6a1A; 49 U.S.C. §1651). Briefly, the Act states that, if the U.S. Department of Transportation (DOT) deems it necessary for an Interstate highway to cross federal lands, the Secretary of Transportation requests an easement from the agency that is responsible for managing the lands and DOT grants the right-of-way to the state after the easement is issued.

The granting of the easement to DOT, in this case by the U.S. Department of Agriculture, carries with it certain considerations, obligations, and responsibilities. An easement deed contains 11 stipulations agreed on by the two agencies. These stipulations must be executed by the state highway agency involved before the easement deed is consummated. The implementation of the stipulations becomes the responsibility not only of the state highway agency involved but also of DOT, working through the Federal Highway Administration, and the U.S. Department of Agriculture, working through the Forest Service.

The stipulations in the easement deed include the following:

1. The state and the Forest Service will determine the need for archeological surveys.
2. The easement will be used only for Interstate highway construction in accordance with the approved plans.
3. The highway will be built to Interstate standards.
4. The plans and specifications will be reviewed by the Forest Service and, if necessary, changes will be made to protect national forest interests.
5. The final plans and specifications must be approved by the Forest Service prior to construction.
6. Natural resources outside the construction limits must be protected during construction operations.
7. Erosion must be prevented during construction, and construction scars must be revegetated when the work is completed.
8. Facilities such as borrow areas, camps, and storage areas may not be established unless they are approved in final plans or unless approval is given by the regional forester after approval of the final plan.

MEMORANDUM OF UNDERSTANDING

Under the law, a further delegation of responsibility is given to the regional forester of the Forest Service. A memorandum of understanding must be executed between the Forest Service and the state highway agency responsible for the construction of the highway—in this case the Colorado Department of Highways. This was accomplished in June 1970.

The memorandum of understanding establishes procedures and responsibilities from the inception of federal-aid highway construction or reconstruction through the location and planning stages, the environmental impact statements, on-the-ground survey and joint reviews, preconstruction meetings, and construction activities. It includes the procedures for coordinating the transfer of national forest lands to the state for the construction of an Interstate highway. The memorandum elaborates on the stipulations already established by the easement deed between DOT and the U.S. Department of Agriculture. In this case, it recognized the need for cooperation to solve the problems of building a highway to the demanding standards of the Interstate system through the mountainous terrain of Colorado. Some of the features recognized by this memorandum are

1. The need for joint cooperation to locate the highway in order to satisfy the objectives of both agencies;
2. Forest Service review of the preliminary plans and specifications of the Colorado Department of Highways;
3. A joint office review to resolve any differences or make changes in the plans and specifications;
4. The need for sections of the plans and specifications to recognize Forest Service land-management concerns, such as (a) disposition of merchantable timber, (b) fire protection, (c) locations of detours and construction standards for haul roads, (d) control of air and water pollution and erosion, (e) aesthetic features in harmony with the surrounding terrain, and (f) restoration of disturbed areas;
5. Participation by the Forest Service during the preconstruction conference with the contractor;
6. The need for a Forest Service liaison officer to work with the state; and
7. The need for Forest Service representatives to make joint on-the-ground reviews with the Colorado Department of Highways during construction.

The magnitude of the problem of fitting an Interstate highway into the Vail Pass corridor became evident during the location phase of the project. The mountainous terrain within the corridor was steep and unstable. The route paralleled streams from which communities took their water supplies, and the corridor passed through the fragile subalpine ecosystem at 3230-m (10 600-ft) Vail Pass. The growing season was short, the weather was unpredictable, and construction operations would have to be limited to the summer months. Because of these restrictions, it was necessary to establish criteria to implement the conditions of the memorandum of understanding between the Colorado Department of Highways and the Forest Service.

Opinions varied on the interpretation of the memorandum of understanding and how to accomplish the goals it described. Many agencies were involved in reaching final procedural decisions, including the Colorado Division of Wildlife, the Federal Highway Administration, the U.S. Geological Survey, the Colorado Department of Public Health, and the U.S. Environmental Protection Agency. Innovative ideas were expressed and welcomed. The final decisions were agreed to and incorporated into the construction.

FOREST SERVICE STIPULATIONS

Before construction of the highway over Vail Pass began, an interim letter of consent agreeing to the use of the land for the construction was given to the state of Colorado by the Forest Service. Included with the interim letter was a standard stipulation required by U.S. Department of Agriculture regulations and implied in the stipulations of the easement deed between DOT and the U.S. Department of Agriculture. Special clauses or requirements could also be included in the stipulation for specific items unique to the project, but these first had to be approved by the Chief of the Forest Service.

The stipulation in the interim letter of consent was broad in scope, but most of the environmental concerns were included. Briefly, the standard requirements and conditions to be met by the Colorado Department of Highways were as follows:

1. Before any construction begins, prepare a fire protection plan, a clearing plan to include disposal of merchantable timber, a landscape and erosion-control plan, and a construction plan that specifies restrictions and delineates methods of construction to avoid environmental damage;
2. Comply with recommendations of the Colorado Division of Wildlife and the Forest Service for wildlife and fish management, such as (a) avoiding damage to fish habitats, (b) protecting live streams from soil deposits, (c) installing temporary bridges for hauling material across live streams, (d) prohibiting operation of mechanized equipment in live streams, (e) preventing oil or greasy substances from being washed into live streams, (f) permitting no construction activity within 7.6 m (25 ft) of the edge of a major stream, and (g) setting up a cooperative agreement with the U.S. Geological Survey to monitor the water quality in streams;
3. Dispose of waste materials from slides and surplus material from construction activities in areas approved by the Forest Service;
4. Return abandoned roads to a natural configuration;
5. Provide standard highway signs to identify Forest Service boundaries and features;
6. Permanently monument the right-of-way; and
7. Establish or restore public-land monuments disturbed or destroyed during construction.

COOPERATION OF AGENCIES

One unique aspect of the Vail Pass project was the opportunity for many government agencies to provide input into the project plans. When discussions first began, ideas were zealously argued. Later, as rapport and trust developed, the pros and cons of each idea were considered objectively and a decision was made. Generally, these decisions were agreeable to everyone. Many sound, innovative ideas evolved from this approach.

LANDSCAPE AND EROSION-CONTROL MANUAL

A Landscape and Erosion-Control Manual was prepared for the Colorado Department of Highways by International Engineering Company. Input for the manual was received from several sources, including the Forest Service, the Colorado Division of Wildlife, the Soil Conservation Service, and the U.S. Geological Survey. The manual addressed specific environmental problems associated with Vail Pass. It provided concepts to be followed for landscaping and erosion control and emphasized the molding of land forms such as rounded or undulated slopes, staggered benches, and accentuated draws or ridges. It discussed leaving rock in place to blend with the natural surroundings and specified methods for erosion control and treatment of sediment-laden water.

Although the information contained in the manual was conceptual, it stimulated the innovative thinking needed to develop procedures to mitigate particular problems. Each problem, whether in landscaping or erosion control, was different and had to be dealt with individually. The manual became an integral guideline for the environmental work done on Vail Pass. The Colorado Department of Highways used the concepts set forth in the manual to develop contract specifications. The manual was a useful tool, and a similar approach is recommended for any project in which environmental problems are critical.

SPECIFICATIONS

It is imperative that correct, concise specifications relating to environmental concerns be written for a project such as that at Vail Pass and that the specifications be explained so that they are understood by everyone involved. With assistance from the Forest Service, the Colorado Department of Highways wrote special specification provisions to cover the stipulation in the interim letter of consent. Information for the specifications came from the Landscape and Erosion-Control Manual, specialists' proposals (modified by engineering concerns), and engineers who understood the problems involved and how to cope with them.

Without the specifications, planning, memorandums of understanding, and stipulations would have been fruitless. It was essential that the specifications be carefully written to avoid confusion and to indicate to the contractor precisely what was required. A great deal of time was spent on making the specifications as clear as possible. As the project progressed and unforeseen misinterpretations were encountered, alterations were made to the specifications. The specifications were also modified to fit the different locales.

DESK REVIEW OF PLANS

A desk review of plans was an essential part of the memorandum of understanding between the Forest Service and the Colorado Department of Highways. It was important for the Forest Service to provide an experienced engineer who could interpret the plans and specifications and understand what was proposed. Cross sections were not included with the preliminary plans, so it was necessary to interpret from the plan and profile sheets the extent of cuts and fills and their locations. Topography and the boundaries of existing vegetation were included on the plan sheets. By extrapolating from elevations shown on the profile sheet, it was possible to determine the dimensions of cuts and fills so that erosion treatments could be planned for a particular area or landscaping could be conceptually planned before the area was seen. If there were specific questions regarding cuts or fills, cross sections were available at the desk review. In one instance, the cross sections showed that long sliver fills were planned. The length of the sliver fills was shortened considerably by placing a 1.2- to 1.5-m (4- to 5-ft) timber crib retaining wall at the point at which the natural ground line approached the face of the fill. In another instance, the grade was raised to accommodate the extra fill material that would be generated because of an extensive rock cut.

A desk review of project plans with all interested parties is highly recommended. It is also recommended that the representatives who attend have a background in

engineering so that they can intelligently respond to the plans.

FIELD REVIEW

In conjunction with a desk review of the plans, it is essential that a field review be made with the plans in hand. It is not necessary to cover the entire project, but critical areas should be seen on the ground to visualize what the final product will look like. It is easier to do this after the road is staked for construction; however, if the guide is someone who is familiar with the project, it is possible to get an idea of what is intended.

It was important that someone from the Forest Service who had an engineering background be a member of the field review. The field review was also the time for hydrologists and landscape architects to contribute their ideas. On Vail Pass field reviews, it was often necessary for a geologist to identify potential problems of instability attributable to a north-south-oriented fault that parallels the highway location.

During the construction phase of the project, periodic field reviews were continued because of changing field conditions. Latent problems developed that could not be foreseen during the initial design. A spring might be uncovered, an additional culvert needed, a culvert moved to a different location to be more effective, or landscaping altered from the original plan to better harmonize with the surroundings. Sometimes there was excess material to dispose of, and at other times additional borrow had to be obtained. Topsoil for revegetation was scarce, and sources had to be identified and saved. Decisions for these problems had to be made on the ground, immediately, so as not to impede the contractor's progress. Most of the decisions were made after a multidisciplinary review governed by engineering constraints. A background in engineering aided the decision-making process.

PRECONSTRUCTION CONFERENCE

The memorandum of understanding stipulated that the Forest Service participate in the preconstruction conference held with the contractor. Much of the conference pertained directly to the construction itself, but it also afforded an opportunity to discuss the concerns of the Forest Service as expressed in the specifications written by the state. The specifications were unfamiliar to the contractors. It was usually necessary to emphasize and explain their purpose and the final result that was expected.

There were questions concerning fire control, such as who should be contacted in case of fire, when and how to burn during the clearing operation, and what fire equipment should be on hand at all times within the construction area.

It was necessary to point out to the contractor the role of each of the agencies during construction. The contractor was to deal with the state project engineer, who in turn was to respond to Forest Service concerns and requests. On rare occasions the contractor might respond directly to the Forest Service representative. These requests were limited to emergency situations when the project engineer was unavailable. Contacts with the contractor by the Forest Service representative were limited to problems involving aesthetics, pollution or erosion control, and water quality. Every request was later coordinated with the project engineer. These situations are usually unavoidable, but precautions should be taken to limit their occurrence.

During the preconstruction conference, the contractor was responsible for furnishing a plan for erosion control and water quality on the project. The plan was then discussed and sometimes changed to better fit the situation on the ground. The contractor was also obligated to designate one person to assume responsibility for the implementation of the plan. The specifications stated that, in case of an emergency involving water quality, equipment and personnel would be furnished immediately to correct the problem.

Preconstruction conferences proved valuable, not only to explain the various roles but also to emphasize resource-protection requirements and the methods to be used. The conference also gave the representatives of the various agencies a chance to become acquainted with the contractor.

USE OF SPECIALISTS

Forest Service specialists were used during the planning and construction phases of the project. Primarily, these specialists were limited to hydrologists, landscape architects, and geologists. Occasionally, the advice of a forester or a range conservationist was sought. The problems encountered during construction were multidisciplinary, and it was not expected that any one person could furnish expertise in all areas. Specialists were therefore consulted on how best to accomplish the objectives. Conflicts occurred when implementation of an idea was not feasible. Most of the ideas expressed were good, but many could not be executed without compromising engineering quality. Although specialists were consulted and their opinions were evaluated, all modifications recommended to the state project engineer were made by the Forest Service representative.

It is mandatory that the initial design of such a project include input from landscape architects. The Colorado Department of Highways recognizes this and now makes the landscape concept a part of the plans, with the understanding that these plans will be flexible as the project evolves.

One recurring problem was that slopes were finished by the excavation contractor before the landscape architects made their proposals as to what had to be changed to conform to the natural environment. Their proposals could usually be accomplished, but cost could have been reduced if the clearing limits and cut-and-fill stakes had initially been placed to include the landscaping.

The use of specialists is recommended. But the proposals put forth by specialists must be governed by sound engineering judgment.

LIAISON OFFICER

A liaison officer was assigned to the I-70 Vail Pass project by the Forest Service. All contacts with the Colorado Department of Highways were made through the liaison officer. It was his responsibility to review all plans and specifications and to attend the desk review of the plans and the preconstruction conferences. He received and reviewed the opinions of the Forest Service specialists and passed the applicable ideas on to the state. It was also his job to keep the land managers (district rangers and forest supervisor) informed of what was happening and express their concerns in correspondence with state officials. In turn, he received correspondence pertaining to the Forest Service from state officials. In this way, the state had to deal with but one Forest Service representative.

The liaison officer acted as an inspector for procedures taken to mitigate the environmental impacts of Vail Pass projects. He was expected to have multidisciplinary expertise, to be well aware of Forest Service concerns, and to apply this knowledge to the project.

The liaison officer spent three or four days each week at the construction sites. As many as a dozen projects were under construction at one time. This allowed little time to seek out the help of a specialist for each problem that arose. Most of the problems that came up required an immediate response. Likewise, little time was available for consultation with land managers, and the liaison officer had to respond to the state by using the broad objectives set forth by the land managers.

When more than two or three projects were going at the same time, the liaison officer was often hard pressed to accomplish his assignment. In these situations, assistants were used to help monitor the construction as it progressed. Most of these people, however, had to be trained before they were capable of performing adequately. The liaison officer position could be strengthened considerably by assigning qualified people, rather than trainees, as assistants.

Since road construction is primarily an engineering function, it is essential that the liaison officer have an engineering background to properly interpret the plans and specifications and, perhaps more important, to respond intelligently to other agency representatives. As an engineer, he or she is able to differentiate which ameliorative measures are feasible. Although the liaison officer may not be a specialist in hydrology, he or she needs a background in the principles of hydrology. On this project, it was easier for an engineer to recognize proper construction of erosion-control structures. It is also beneficial for the liaison officer to have a background in geology or geological engineering. On the Vail Pass project, this knowledge was needed on several occasions. For example, when the state project engineer wanted to cut the toe of a series of slumps—a procedure that could have triggered a chain reaction of earth slides—the liaison officer explained the possible consequences and the project engineer decided not to make the cut.

The use of a liaison officer is an integral part of any project like the one at Vail Pass. It is recommended, however, that he or she be an engineer, preferably a civil or geological engineer, and that trained assistants be provided, preferably people trained in engineering, hydrology, or landscaping. Ideally, the liaison officer should have one assistant in each of these disciplines.

EVALUATION AND SUMMARY

A key element to a successful project is early planning and preparation before the project is designed. This point cannot be overemphasized. The groundwork must be laid so that there are fewer misunderstandings during construction. Another key element is cooperation and coordination among interested parties. All effort should be directed toward accomplishing the final objective. Everyone has something to contribute and everyone should contribute. This cannot be done if one agency feels it has final control and is jealous of ideas supported by another agency. Such a project is so large and complex that no one agency or person can have all the answers. The success of the Vail Pass project was predicated on the idea that all interested parties were to participate and contribute toward the final goal.

The goal of the Vail Pass project was to construct across a major mountain range an Interstate highway that would be compatible with the mountain environment. The completed highway speaks for itself. The success of the project lies in cooperation and coordination among many individuals and government entities. The entire operation was not smooth; it was often fraught with argument and frustration. But from this apparent chaos emerged innovative ideas and understandings that can be used in future projects of this magnitude. Certainly not everything tried at Vail Pass was successful but, overall, I would recommend few changes.

The Forest Service has officially commended the Colorado Department of Highways for its effort to cooperate in mitigating environmental damage in a very sensitive corridor of public lands.

Abridgment

Meeting the Challenges of Environmental Restrictions in the Vail Pass Project

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Although many procedures for complying with Colorado water-quality-control regulations were developed in advance of actual construction of I-70 at Vail Pass, daily observation of the project revealed one thing clearly: Compliance is easier said than done. The actual work situation often dictated procedures other than those specified. Many problems were encountered that had not been anticipated. Meeting environmental requirements on the actual jobsite became a process of finding, analyzing, and solving problems on a continual basis. This resulted in a remarkable effort of cooperation among agencies and contractors.

The purpose of this paper is to provide a contractor's view of the problems encountered and the solutions developed during the Vail Pass experience so that future projects of this nature can be accomplished with greater efficiency and at lower cost to taxpayers.