verification inspection of the satisfactory growth after one complete growing season in fall 1976.

PROJECT 3, WITH A MANAGEMENT SUPPORT CONTRACT

In fiscal year 1976 Congress appropriated $1,500,000 for the Bureau of Mines to continue utilizing the pumped-slurry backfilling process in areas of Rock Springs, Wyo., where surface support would be beneficial to the city.

The sites selected for this, the third large-scale subsidence control project in the city, included critical areas 2, 9, 10, 12, 13, and 15 and the remaining portion of area 11. The objective of the project was to fill flooded and dry abandoned coal mine voids in the No. 1 and No. 7 Seams with solid material to support mine overburden and alleviate potential damage to surface structures, streets, and utilities. To accomplish this objective, it was estimated that approximately 350,000 tons of sand would be needed to fill the flooded and/or otherwise inaccessible mine voids beneath the critical areas enumerated above, a total area of about 90 acres. Figure 22 is a map of a portion of Rock Springs showing the location of the critical areas included in the project.

In planning for the project, the Bureau decided that extensive drilling operations to provide monitoring could be dispensed with because the nature of the pumped-slurry filling process had been made apparent in earlier projects and was predictable in similar circumstances. Information as to the position and attitude of the coal seams was determined from the drilling of numerous boreholes. Depths to the mine voids ranged from 64 to 293 feet, with depths of alluvium ranging from 15 to 60 feet. Only seven boreholes encountered mine voids, and these were used for both injection and monitoring. The money saved in this manner was diverted to filling more of the mine voids. Appreciable savings would also accrue to the project because two water wells, two injection boreholes, and some of the pipelines, which had reverted to the Bureau of Mines from the previous project (WHAN), would be made available to the contractor for the third large-scale project. Moreover, because some of these facilities remained on property of the Union Pacific Railroad and in strategic position with respect to the project areas, the Bureau indicated in the contract specifications that the slurry injection plant, sand stockpile, and some of the slurry distribution pipelines be established in the same general area as in the previous project. In due course, the project contractor made satisfactory arrangements with the railroad company in order to comply with the specifications.

Procurement of a contractor to do the specified work was again carried out under Federal Government competitive contracting procedures. On May 28, 1976, a contract to do the work was awarded to M. J. Bober Co., Littleton, Colo., in the amount of $1,043,650.00. This was increased by $1,353.00 to pay for the lease of the plant site on railroad property. Work on the contract was started June 4, 1976. Mobilization included preparation of a borrow pit, drilling to establish injection boreholes, and repair and modification of an existing water supply system, and pipelines. A mixing plant, slurry pumps, and recording equipment were also furnished and installed by the contractor.

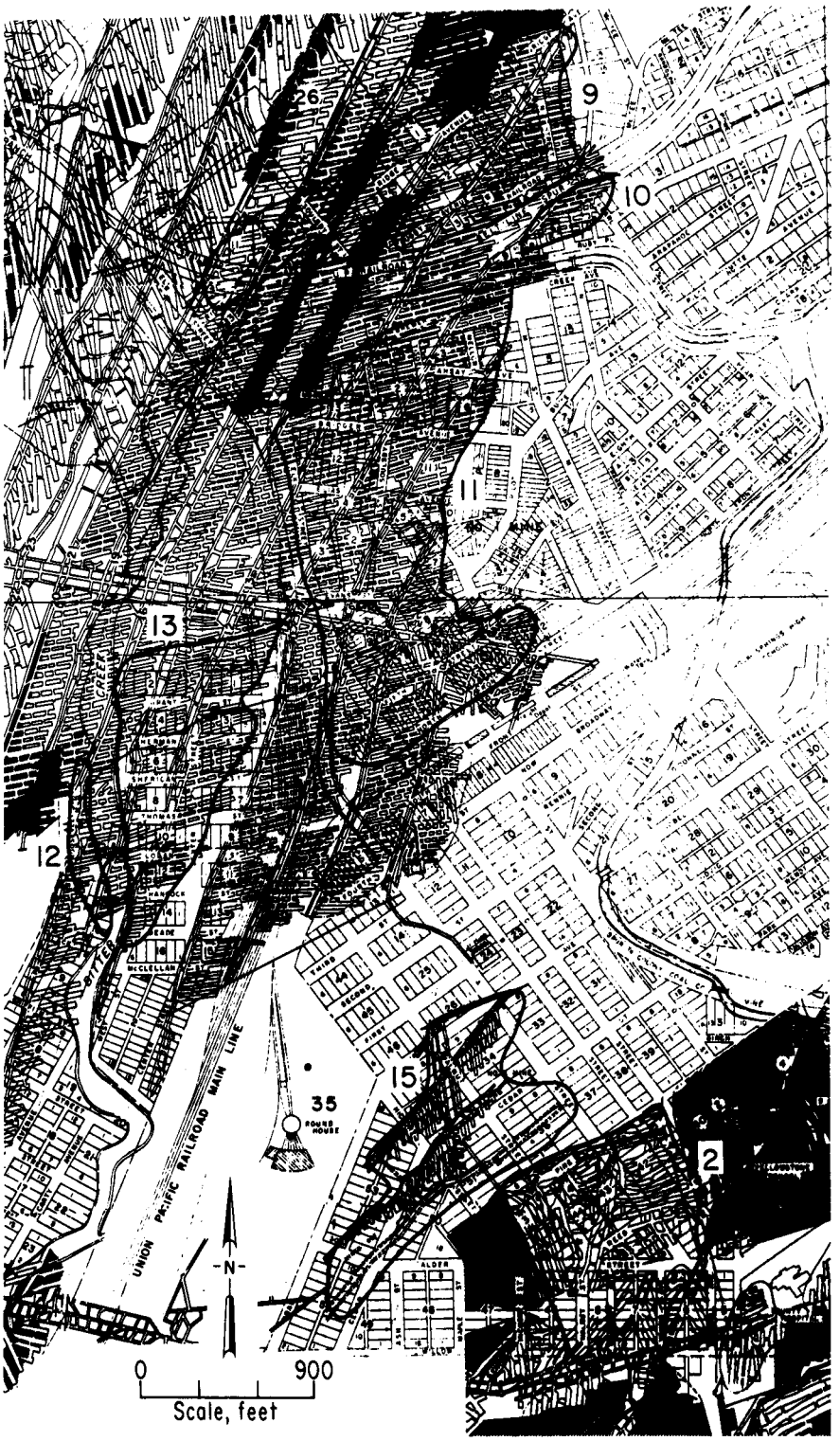

FIGURE 22. - Map of a large portion of Rock Springs showing location of critical area 2 in the No. 7 Seam and critical areas 9, 10, 11, 12, 13, and 15 in the No. 1 Seam in relation to underground mine workings.

The sandfill material was obtained from a Bureau of Mines designated site located about 4 miles from the mixing plant on federally owned land controlled by the Bureau of Land Management (BLM). This site was made available to the contractor through a "Free Use Permit" between the BLM and the Bureau, and had not been used as a source of material in any previous mine backfilling project. At the borrow site, the contractor furnished and installed screening and materials handling equipment adequate to remove rock and debris in excess of minus 5/8-inch size and produce sandfill at a rate of 2,800 tons per day. Shortly thereafter, under the terms of the contract, it was agreed to begin using progressively larger screen sizes (up to minus 2-inch) to assess the capability of the process in handling sand with larger size rock particles and other debris. It was transported to the stockpile adjacent to the mixing plant site in 30-ton bottom-dump trucks. Removal of the fill material and subsequent reclamation of the borrow pit site were conducted in accordance with stipulations required by the BLM.

The contractor purchased the installed deep-well pumps from the previous contractor (WHAN) and, after repairs and improvements, made operational a water-supply system using the existing wells and supply pipeline sufficient to deliver a minimum of 5,000 gpm to the designated mixing plant. The existing water well sites were located approximately 1,600 feet from the mixing plant site. The vertical distance from the top of the mine water pool in the No. 1 coal seam to the mixing plant site was approximately 75 feet. The two wells were 135 feet deep into a 7-foot mine void and cased with 18-inch-ID steel pipe to 95- and 98-foot depths.

The mixing tank, which was basically the same as those constructed for the previous projects, was fabricated of steel and arranged in such a manner that it would receive measured and weighed sand at a rate of at least 2,800 tons per day and water at a rate of at least 5,000 gpm. The water and sand were mixed to form a uniform slurry in the tank. Provisions were made to install the 12-inch-diameter intake pipe of the slurry pump in such a submerged position that it would withdraw the mixed material (slurry) from the tank. The tank was adequate in size to not only handle the designed quantities but also make sufficient allowance for surges and operational problems, thus helping to prevent overflows.

A slurry pump was installed to withdraw the slurried sand and water from the mixing tank and impel it through the existing and constructed slurry distribution pipelines to one of the two existing or one of the five new injection holes. The pump was capable of moving a minimum of 2,800 tons of sand slurried with the required amount of water per day and was equipped in such a manner that the delivery rate of the pump could be regulated by a system of valves. The pump was designed to pump the required amount of slurry through a maximum distance of approximately 6,000 feet of pipeline to the various injection boreholes at a minimum velocity of 10 feet per second. It developed 25 psi pressure at the top of each injection borehole when required.

All operations involved in the mixing and injection processes were controlled from an instrument panel located in a building supplied by the contractor adjacent to the mixing tank. Metering devices recorded the following

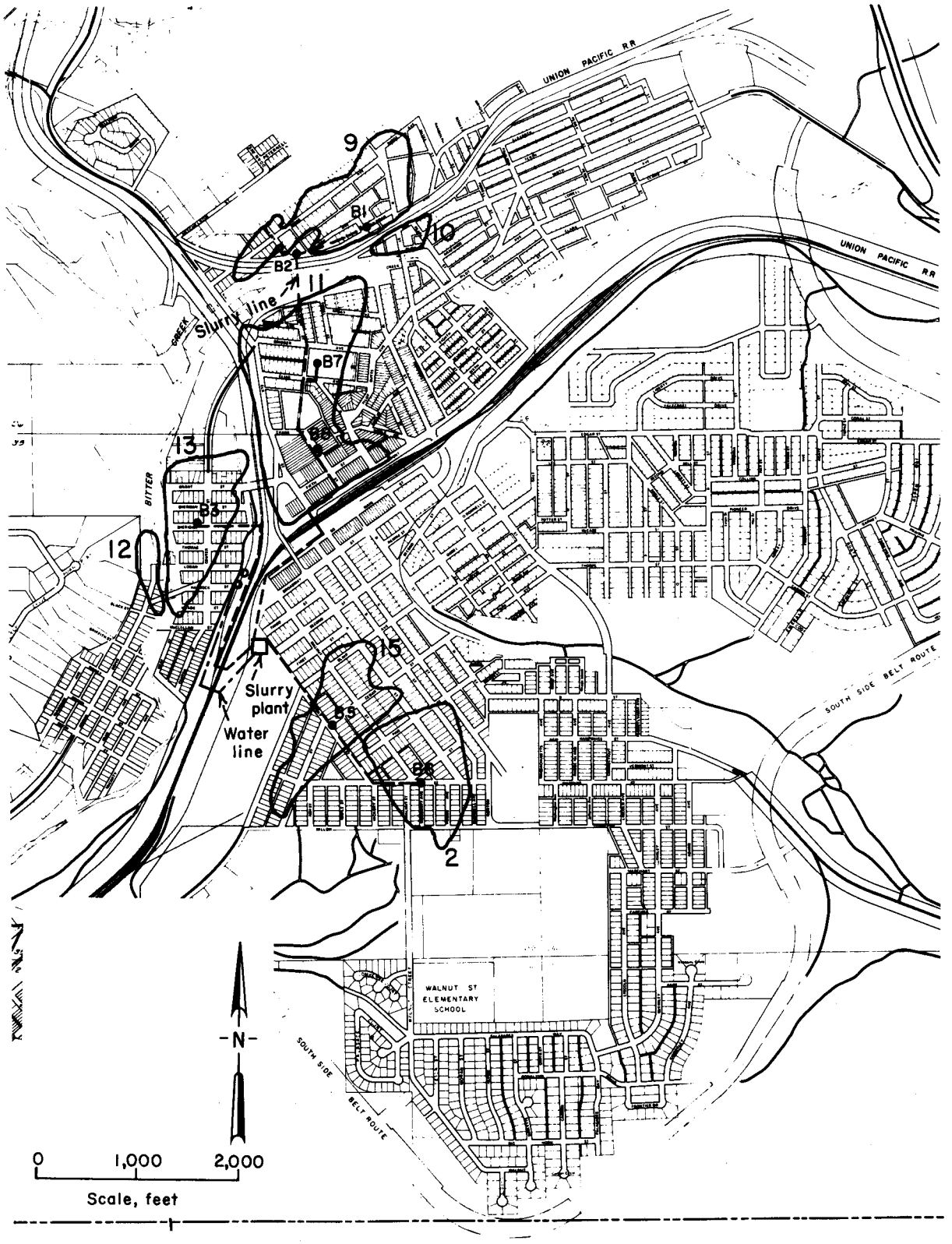

FIGURE 23. - Map of a portion of Rock Springs showing the location of Project 3 installations.

daily activity: total slurry pumping time, time to purge pipelines, gallons per minute of water and slurry pumped, tons of solid material injected, and pipeline pressures at the slurry pump and at the injection boreholes. Figure 23 is a map showing the location of the project facilities. Figures 24, 25, and 26 are views of the equipment that was being used at the borrow pit and at the slurry mixing plant.

The fiscal funding constraints imposed by the Congressional appropriation for the Rock Springs backfilling work prevented the Bureau from providing its own personnel for managing and monitoring the contract activities beyond September 30, 1976. Because of this, the Bureau awarded a $15,000 contract to Johnson-Fermelia and Crank, Inc., Rock Springs, Wyo., on July 26, 1976, to provide the necessary daily onsite project management and monitoring services as required for the backfilling contract work in order to insure that the project work was being conducted in accordance with the contract specifications.

The consulting firm of Johnson-Fermelia, and Crank, Inc., possessed a working knowledge of the Rock Springs backfilling project work. The firm was located in Rock Springs in about the center of the project work area and had an excellent rapport with the city of Rock Springs, utility companies, Wyoming State Highway Department, Union Pacific Railroad, and all other necessary Federal, State, and local organizations. In addition, Wayne Johnson, a principal of the firm, was the City Engineer for Rock Springs and had been actively associated with the backfilling work since its beginning in 1970. As City Engineer, Johnson had approved all previous and current project work plans and had maintained for the city a close watch on all previous project work.

On September 29, 1976, a second project management contract for $16,000 was awarded to Johnson-Fermelia, and Crank, Inc., to provide for necessary extended onsite project management and monitoring services to project completion.

Specific monitoring services that were performed included, but were not limited to, the following:

1. Intermittent or continuous daily inspection of the project work as directed by the Bureau representative and daily verification of completed work on the prime contractor's prepared daily work report sheets.

2. Identifying and notifying the Bureau, including the authority to stop the work, of any potential project-related public health and safety hazard and/or any work being performed in violation of Federal, State, or local law or regulation.

3. Performance of periodic borehole monitoring measurements with Bureau-provided equipment.

4. Continuous inspection during the injection pumping operations, including performing periodic calibration checks of the fill material weighing scale.

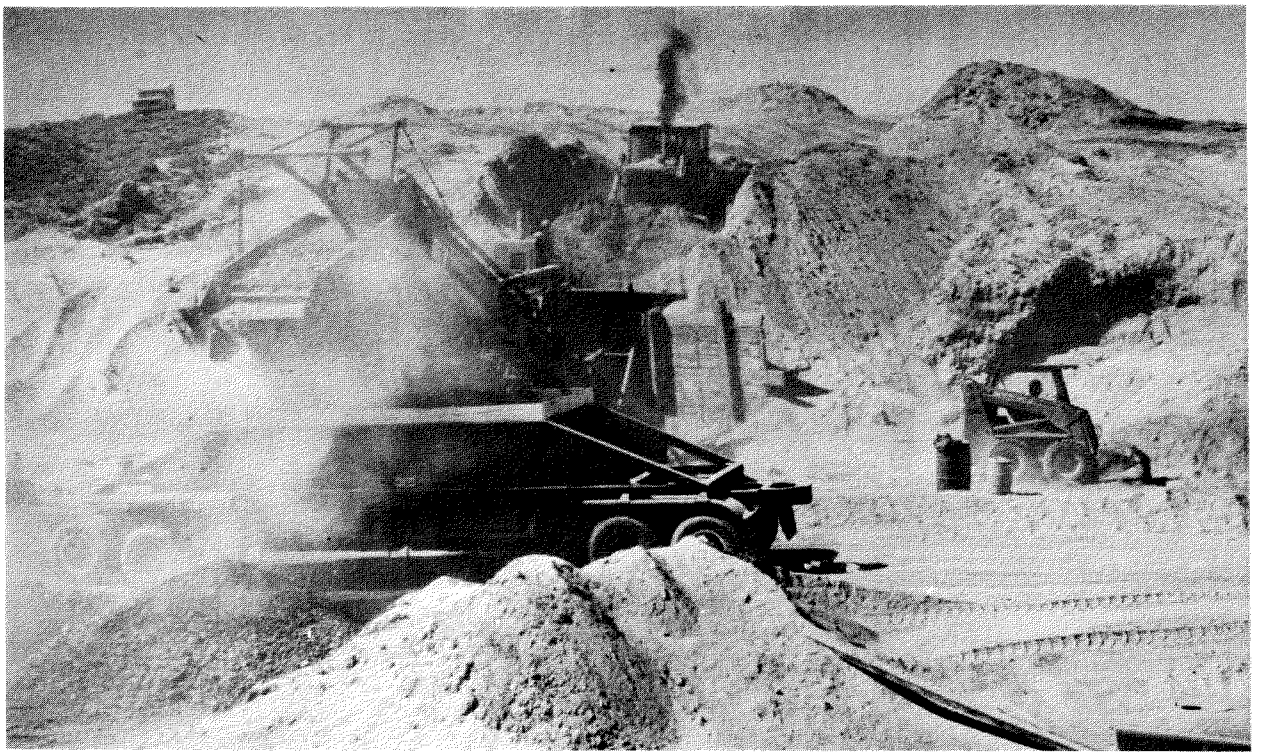

FIGURE 24. - View of earth-moving and screening equipment being used in the borrow pit.

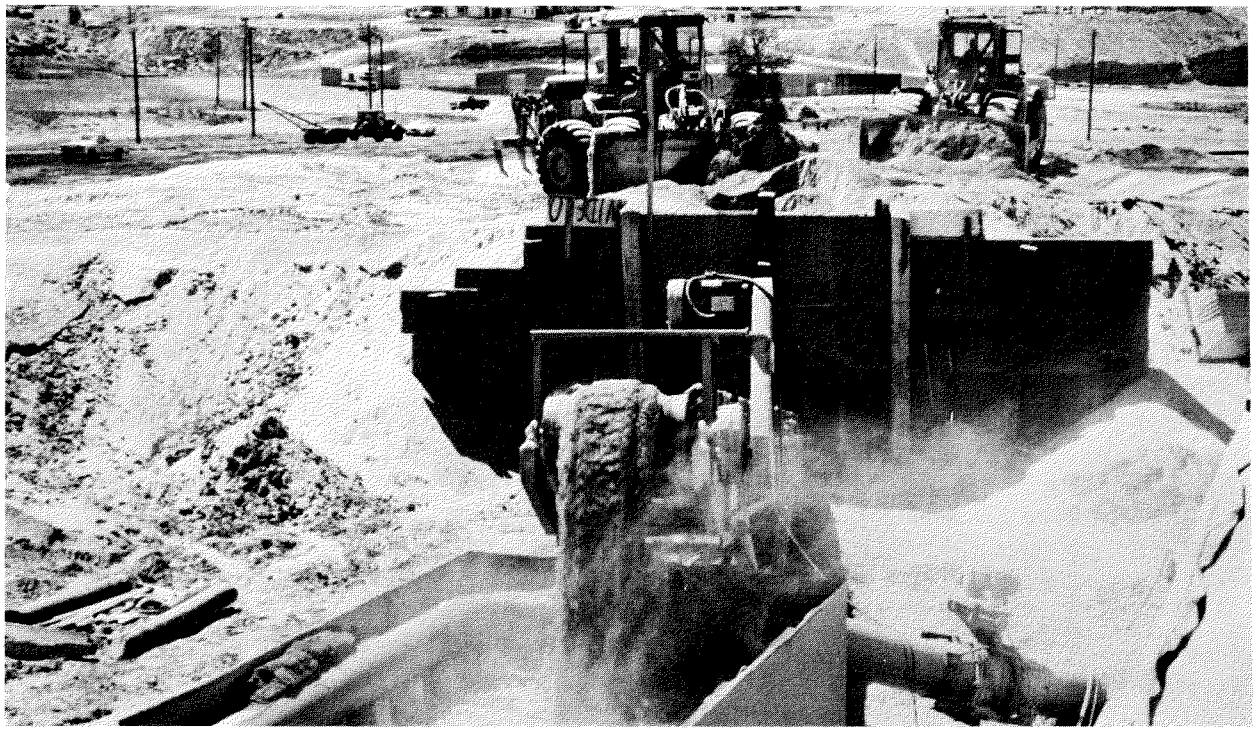

FIGURE 25. - Photograph of sand being bulldozed into hopper and fed from conveyor into mixing tank. (Note jet action at side of tank creating turbulence.)

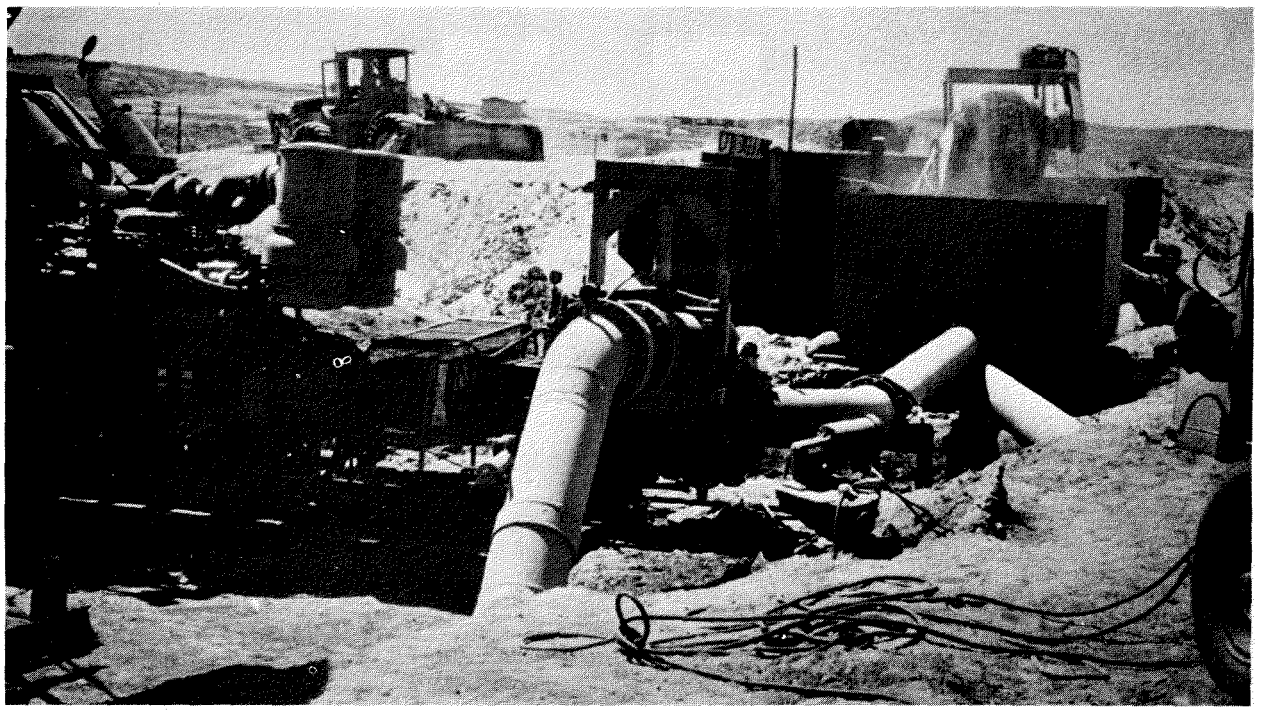

FIGURE 26. - View of mixing plant operation: note suction line at bottom of mixing tank leading to slurry pump with pump motor in left foreground.

5. Conveying Bureau work directives to the prime contractor as necessary and as directed by the Bureau representative.

6. Taking photographs of the project equipment and operations representative of the contract work progress.

The monitoring services were performed by an engineering technician and/or an engineer with a vehicle as deemed necessary by the Bureau representative.

The slurry operation began on July 15, 1976, and was completed on October 12, 1976. A total of 397,464 tons of solids was injected into the seven separate areas of the No. 1 and No. 7 mined coalbeds. The total surface area overlying the backfilled portions of the coalbeds was estimated to be approximately 90 acres, which included an expanded portion of area 11. Here, as in project No. 2, the sand was migrating into voids west of area 11, where it was known that surface support would also be needed. A total of seven injection boreholes, including two from the previous project, were used in the backfilling. Injection boreholes B-1, B-2, B-3, B-7, and B-8 in the No. 1 bed and B-6 in the No. 7 bed were located in inundated mined areas, and borehole B-5 in the No. 1 bed was in a dry area. A total of 378,712 tons of fill material was injected into inundated mine voids, and a total of 18,752 tons was injected into dry voids. The progress of backfilling is summarized in table 4.

TABLE 4. - Injection data on the third large-scale demonstration project, 1976

Project area and acreage	Injection borehole	Approximate injection periods, 1976	Total injections, tons
9, 17.70 acres....	B-1.....	July 15-25.....	52,807
10, 1.50 acres....	B-2.....	July 29.....	3,176
12, 3.30 acres....	B-3.....	Aug. 3-31.....	116,346
2, 22.40 acres....	B-6.....	Sept. 2-11, 13, and Oct. 8..	41,262
15, 10.50 acres...	B-5.....	Oct. 4, 7-8.....	18,752
11,[1] 20.10 acres..	B-7.....	July 30-31, Aug. 31-Sept. 2, and Sept. 13-Oct. 1.	114,194
	B-8.....	Oct. 5-6, 7-12.....	50,927

[1]Expanded area 11.

In order to provide pipeline access to areas 9 and 10, it was necessary to cross Wyoming State Highway 430 and Bitter Creek. Because of the anticipated relatively brief time of injection into boreholes B-1 and B-2 (15 days), the Wyoming Highway Department allowed the contractor to lay the slurry pipeline across Highway 430 but required construction of a ramp over the pipeline so as to maintain the flow of traffic. In crossing Bitter Creek the city

FIGURE 27. - View of slurry pipeline on the pedestrian foot bridge over Bitter Creek.

allowed the contractor to lay the pipeline on an existing pedestrian foot bridge, a less expensive and more convenient procedure than providing a supporting trestle (fig. 27). While the pipeline could have followed the ground in and out of the deep ravine, the number of vertical bends required would not only have increased the cost but also have added greatly to the friction head.

On one occasion an accumulation of entrained air in the mine cavity exhausted with high velocity through injection borehole B-6 back through the open-ended pipeline at the pumping plant site. Although no damage resulted from the air discharge, it was concluded that in future projects a pressure release valve should be installed in the pipeline at the top of all the injection boreholes to avoid similar occurrences.

When pumping through boreholes B-5 into rather shallow mine workings that were believed to be isolated from the main part of the mine, water was reported seeping to the surface near the pumping plant site. This water was determined to be the mine water that was being used for the backfilling operation, and therefore pumping was stopped in borehole B-5 prior to the planned completion.

In September, after the 350,000 tons of sand had been injected under the critical areas, it was noted that the mine voids, particularly in the north part of area 11, were accepting the sand slurry easily at less than atmospheric pressure. It was decided, therefore, to continue injection under the highly vulnerable downtown area until funds available to the Bureau were exhausted. This amounted to an additional $150,024.14, bringing the total cost of project work to $1,195,027.14. On October 12 the slurry pumping operation was completed, with a total of 397,464 tons of fill material having been injected into the old mine workings throughout an area of about 90 acres.

A total of $29,959.00 was paid to the firm of Johnson-Fermelia and Crank, Inc., for providing the necessary onsite management and monitoring services, bringing the total cost of the project to $1,224,986.14, or $3.08 per ton. This compares with the $3.54 per ton cost of the previous or second large-scale demonstration project and $5.07 per ton for the first project.

The demobilization of the operation, including cleanup and restoration of all project work areas, was conducted in accordance with the contract specifications. Restoration of the borrow pit was completed in accordance with the stipulations set forth by the Bureau of Land Management and included seeding of the borrow area in fall 1976 and a verification inspection of the satisfactory growth after one complete growing season in spring 1978.

CONCLUSIONS

In positioning injection boreholes for the critical areas in the three large-scale projects, Bureau engineers assumed that the slurried backfill material would be distributed in the flooded mine workings more or less in equal distances from the points of injection. For dry mine voids, the injection boreholes were placed at higher levels in the workings to be filled. These assumptions were apparently realistic, according to observations from