WATER RESOURCES DEVELOPMENT

Review — Water Resources Development

by

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Introduction

For the past 15 years the possibilities of employing nuclear explosives to develop and manage water resources for the benefit of man have been studied. Experimental and theoretical studies of many types have been undertaken. Numerous applications have been considered including site studies for particular projects. Attention has been given to the economics of specific applications, to hazards and safety problems, to legal limitations, to geologic and hydrologic considerations, and to effects on water quality.

The net result of this effort has been the development of a large body of knowledge ready to be drawn upon wherever and whenever needed. Nuclear explosives are important tools for water resources development; they must be carefully selected so as to serve their intended purpose at minimum cost with few side effects.

Applications

Water resources management as we know it today embraces an ever-expanding field including supplying water for municipal, industrial, and agricultural needs, controlling too much water, overcoming problems of too little water, and regulating bacterial, chemical, and physical quality of water. In addition, there are concerns of water for power, water for navigation, and water for recreation. With a constant world supply of water facing multiplying and competing demands for water, the water resources engineer often feels like the circus juggler with too many china plates up in the air at one time.

Much of the responsibility for identifying potential applications of nuclear explosives to water resources has been carried by the U. S. Geological Survey. And of that organization my colleagues on this program, Mr. Arthur M. Piper and Mr. Frank W. Stead, stand out as the recognized national leaders in that effort. Their studies and publications in recent years on the principles, problems, and national canvass of projects relating to nuclear explosives applications are the guides we have today for interpreting and planning for the future.

A listing of the principal applications of nuclear explosives to the water resources field would include the following:

(a) Harbors. A series of cratering explosions, properly spaced according to known scaling curves, could create a harbor having an orientation perpendicular to the coast line. Precise predictions of crater or channel geometry are not essential for the functional success of such a harbor.

(b) Off-Channel Reservoirs. By one or more cratering explosions a surface reservoir could be formed near a stream or aqueduct and could be connected by a channel, weir, and control gates. The reservoir could be operated as a storage volume for flood control or for seasonal irrigation. An important advantage of such a reservoir is the fact that it could be constructed in a level area without the usual geologic and hydrologic constraints of a normal dam and reservoir system.

(c) Dams. With the selection of a favorable topographic site a row charge can be fired to create by upthrust and mass ejection an embankment to form a dam. Such a "crater-lip" dam is a relatively new engineering concept so that the conversion of an embankment produced by a nuclear explosive to an essentially watertight dam will require further study concerning its permeability and stability.

A second type of dam can be constructed by detonating nuclear explosives in the side of a steep valley to create a dam embankment either by gravitational flow or by directed bulking across the valley. Sealing of the new dam would be required, perhaps by sluicing of the rock structure with a sand, silt, or clay mixture. Under proper siting conditions such construction techniques can introduce substantial savings as compared to the cost of conventional dams.

(d) Canals. As in the harbors application a line of properly spaced cratering explosions can be employed to construct a canal for water supply or navigational purposes.

(e) Drainage. For small drainage basins where disposal of occasional runoff may present a local problem, a crater could provide the small volume of temporary storage required.

(f) Ground-Water Recharge. A nuclear crater filled with water which is permitted to infiltrate into the ground serves as an excellent structure for artificially recharging the underlying ground water. Because of the relatively large volume of a crater as compared to a conventional basin or pit, water can be stored intermittently and recharged more or less continuously. A further advantage of a crater is by its formation impermeable geologic strata which inhibit the downward percolation of water are fractured and thereby rendered more permeable. A rubble chimney resulting from a contained explosion can serve the same purpose.

(g) Waste Storage or Disposal. Concentrated wastes which cannot be discharged into streams and for which treatment may not be economically justified can be stored temporarily or permanently, depending upon local circumstances, in nuclear craters or rubble chimneys. Such wastes may include oil-field wastes, natural salt springs, radioactive wastes, harmful industrial wastes, and concentrates of treatment processes.

(h) Recreation. The demand for water-based recreation in arid and semiarid regions of the United States is extremely high. To meet this need nuclear craters designed for surface storage of water could provide an attractive environment for boating, swimming, water skiing, fishing, and picnicking. With proper location and design a group of craters could be supplied by water from a nearby aqueduct and also return the water to the same source at a point farther downstream. The chief water loss would be by evaporation as seepage from the craters could be minimized by installing impermeable blankets.

Problems

A primary question of concern in applying nuclear explosives for water resources development is that of safety. Evaluation of hazards, including ground motion, earthquake generation, air blast, and atmospheric fallout, is a matter of common concern to all nuclear explosives engineering. Because these problems have been studied extensively and are not generally regarded as insurmountable for specified site conditions, they do not require discussion here.

A second important problem is that of the cost of nuclear explosives relative to conventional construction techniques. Definitive cost data are difficult to obtain because of the lack of a commercial market for nuclear explosives at present and also because the AEC will cooperate financially in any initial demonstration projects. Limited economic studies of creating dams or craters for water storage have indicated that nuclear explosives can be feasible in many situations.

Finally, a most important problem in water resources applications is that of ground water contamination. Radionuclides released from large underground nuclear explosions are distributed initially by direct action in the immediate vicinity of the explosion. If the shot point is near or below the water table, the nuclides may be transported by ground water in possibly hazardous concentrations.

Because ground water generally moves at velocities measured in terms of feet per year, only long-lived radionuclides are important in water transport. The biologically significant radionuclides in this category include H^3 (tritium), Ca^{45}, Co^{60}, Sr^{90}, Cs^{137}, Ru^{106}, and Ce^{144}. Laboratory and field experiences have demonstrated that all of these nuclides except tritium are strongly adsorbed by exchange with cations on the surfaces of clay materials; consequently, their movement is only an insignificant fraction of that of the ground water with the result that their concentrations fall below the maximum permissible concentration (MPC) within a short distance from ground zero. However, the disposition of radionuclides in limestone or dolomite is more complex and in these rocks the adsorption may be substantially less than in volcanic rock. For tritium, a negligible exchange between tritiated water and the rock matrix must be assumed. Thus, in terms of curies of activity tritium represents the most abundant nuclide in ground water from a large fusion-fission explosion and becomes the primary contaminant in ground water.

Assuming tritium moves as an ideal tracer with ground water, it will travel in the direction of the local water table gradient and at a velocity governed by the magnitude of the gradient and the permeability of the aquifer. Although average values of gradients and permeabilities in a particular medium can be determined from well data, movements of tritium one to two orders of magnitude greater than the average ground water velocity can be expected as a result of 1) local heterogeneities in aquifers, particularly openings such as solution tubes, fractures, and faults, and 2) dispersion resulting from hydrodynamic mixing as water travels through an actual porous media. Transport can be most rapid through formations such as limestones, basalts, and coarse-grained alluvial deposits which contain large openings.

Experience gained from waste disposal operations at Hanford shows that maximum ground water velocities can be several-fold greater than the average velocity and that without extensive subsurface information the location and direction of these high-velocity tongues are impossible to predict. Similarly post-shot field tests at Project Gnome revealed velocities some 25 times greater than expected values.

At the Nevada Test Site subsurface hydrological investigations have defined the regional ground water flow pattern and average rates of flow. Water tables in the area are deep, exceeding 1600 feet, because of drainage to the south through underlying carbonate formations. Although permeabilities are large, water table gradients are low and consequently velocities are small. Exploratory well data have thus far revealed no evidence of continuous underground conduits which could permit high ground water velocities; nevertheless, the possibility of such heterogenities must be recognized and an active program of testing maintained. There is no reason, based upon evidences collected to date, to believe that tritiated ground water will reach the discharge areas, some 50 miles south of NTS, at concentrations above the maximum permissible concentration (MPC).

Conclusions

(1) Although there are important environmental limitations, no major technical obstacles exist to the creation of properly located nuclear craters or chimneys for water resources management.

(2) Nuclear craters and chimneys have potentially important applications for a variety of water resources purposes.

(3) The economic feasibility of constructing nuclear craters and chimneys for water resources projects can be demonstrated in many situations.

(4) More definitive information should derive with time from test detonations and related studies which are underway in fields other than water resources.

References

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