Smart Dam Engineering: Urban Gravel Pit Water Supply Storage

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Introduction

The settlement and economic development of the Western United States was largely the result of successful development of the region’s water resources. Through the mid 1970s water agencies and the federal government primarily focused on development of large dam and reservoir projects to meet current and future water supply demands. Changes in regulatory requirements, federal funding and environmental interests during the last 30 years have significantly increased the cost and time needed to permit and construct a large dam project. A successful new water storage project must balance public sentiment, water supply security, fiscal resources, and show strong stewardship for the environment.

The day of large dams on main rivers to meet storage needs is probably over. However, water demands in the West, particularly in large urban areas, continue to increase and water agencies must combine new water management strategies and develop more storage. Smaller water storage facilities, or smart dams, which are mainly off-channel facilities, are being constructed. One type of smart dam, converting gravel pits into water reservoirs, is becoming a key component of future water management in the Denver Metropolitan area. There are currently about a dozen gravel pits, in the range of 1000 to 4000 acre-feet (af), in the Denver Metropolitan area that are being converted from a liability to a very valuable water supply and recreational asset in the middle of the urban water demand area. This innovative approach is proving to be very cost-effective and environmentally friendly. This paper examines the technical, water management, and environmental issues surrounding these new developments in the water storage business.

Background

Historically water supply in Metropolitan Denver has been reliant on dams in the mountains and foothill areas to the west. In fact, Denver receives only about 14 inches of rain, making it a high plains desert, with most of the water supply coming in a three-month window associated with spring snow melt. The highly variable precipitation levels in Colorado require that water be stored in times of plenty for use in times of drought. Past and present physical and legal wars over water rights highlight the importance of water in Colorado. The transfer of water rights from agricultural to municipal use, for example, continues to become more complex, partly because the Western Prior Appropriation Doctrine of “first in time/first in right” was not developed with environmental values or water quality issues in mind. With today’s regulatory, environmental, and societal needs, there is a strong call to strike a balance between water development, conservation and environmental needs. To meet these challenges, water agencies in

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Metropolitan Denver during the past decade have looked to non-traditional sources of storage and for opportunities to better manage a limited resource.

The South Platte River flows through Metropolitan Denver from the southwest to the northeast. Clear Creek flows from the western foothills east to its confluence with the South Platte about eight miles north of downtown Denver. Dozens of existing sand and gravel pits are located along a 35-mile stretch of the South Platte and along a 16-mile stream of Clear Creek as shown on Figure 1. The existing gravel pits are in the northern part of the Denver Metropolitan area from the confluence of Clear Creek to about Brighton. Historically, the saleable materials, which are sand and gravel, were wet mined to about five feet above the top of the bedrock and the pits filled with ground water.
Alluvial deposits that have been mined are generally 20 to 35 feet deep, and are underlain by claystone and sandstone bedrock of the Denver and Arapahoe formations. Ground water in the alluvium is tributary to the South Platte River and is generally located at five to ten feet below the ground surface. Alluvial ground water in Colorado is administered in the same manner as surface water due to the fact that pumping results in direct surface flow depletion.

After completion of mining, the area around the pit was graded and vegetated; the pit filled with ground water and the perimeter was fenced. The pit was an ongoing liability for the operator and rarely did pit operators have alluvial water rights. Therefore, pit operators are required to augment evaporative losses, which in greater Metropolitan Denver average about four feet annually.

Technical Requirements

To obtain a water storage right, a gravel pit needs to be lined to isolate the stored water from the alluvial ground water. State criteria limit ground water infiltration into a pit to be less than 0.03 ft³/day per square foot of vertical parameter around the pit. For example, the allowable infiltration into a 2500-af pit with a perimeter length of 8,000 lineal feet where the bedrock is 30 feet deep would be 38 gal/min.

Two types of liner systems are being used: soil-bentonite cutoff walls (slurry wall) and compacted clay liners. Soil-bentonite cutoff walls are generally two to three feet wide and penetrate into the bedrock five to 15 feet. Compacted clay liners are generally constructed with a 0.5H:1V outside slope and a 1H:1V inside slope (reservoir side) and are covered with a shell of sand and gravel with a slope of 3H:1V to provide adequate slope stability. A key trench is generally excavated four to ten feet into bedrock. The compacted clay liner is constructed using weathered bedrock excavated from the bottom of the gravel pit. Occasionally the soil-bentonite cutoff wall or the key trench needs to extend up to 20 feet into bedrock to reduce the seepage to the required level. Typical sections of a soil-bentonite clay liner and a compacted clay liner are shown on Figures 2 and 3 respectively.

Inlet and outlet facilities and a pump station are also required to convey water to and from the lined facility. Most facilities are filled by gravity using existing canals and river diversions. Pumping is usually required to draft collected water. Pumping for most applications is performed during off-peak electrical demand hours to reduce energy costs.
Figure 2
Typical Soil-Bentonite Cutoff Wall

LOCATE TO PROVIDE ACCEPTABLE SLOPE STABILITY FACTOR OF SAFETY DURING SLOPE RECONSTRUCTION

NORMAL RESERVOIR POOL

GROUND WATER LEVEL

OVERBURDEN

COMPACTED OVERBURDEN BACKFILL

RESERVOIR

BEDROCK

ALLUVIAL SAND AND GRAVEL

RANGE OF WALL PENETRATION INTO BEDROCK VARIES TYPICALLY 5 TO 15

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FIGURE 3
TYPICAL COMPACTED CLAY LINER

NORMAL RESERVOIR POOL

GROUND WATER LEVEL

OVERBURDEN

ALLUVIAL SAND AND GRAVEL

COMPACTED CLAYEY SAND OVERBURDEN SHELL

RANGE OF LINER PENETRATION INTO BEDROCK TYPICAL 4 TO 10 FEET

BEDROCK

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Water Resources Management

Lined gravel pit storage is rapidly becoming a key component of the water management tools in Metropolitan Denver. The location of gravel pits along rivers and in the heart of the Metropolitan area provides great flexibility in operation and can reduce the need to develop additional water supplies to meet the needs of a growing population.

Primary ways that lined gravel pits are being used to maximize existing water supplies are:

- Skimming peak flows when the diversion right is in priority.
- Storing winter highly reclaimed wastewater effluent to be used as an argumentation supply during the summer months. This facilitates out of priority water supply diversions upstream to be replaced by drafting the lined pit.

The net result is an increase in the firm yield of the water agency without developing any new water rights.

Environmental Permitting

The challenges of siting, permitting and constructing new water-supply dams continue to become restrictive. Most major project development efforts wind up with long delays, escalating permitting expenses, compiled with extreme frustration on the professionals charged with meeting their fiduciary responsibility of providing adequate resources to meet future potable water supplies. Typical dam projects require five to ten years to obtain the required permits and often are denied.

Permitting to convert a gravel pit into a lined water-storage facility is predictable, quick, and inexpensive. Permitting issues such as land use, cultural resources, wetlands, and threatened and endangered species, if applicable, were resolved during application for the mining permit. The water agency needs to apply for an amendment to the reclamation plan, which is part of the mining permit, to convert the pit into a lined water-storage facility.

The reclamation plan for most existing gravel pits requires the sides of the pit be graded to uniform slope (usually between 2H:1V and 3H:1V), the slopes and ground surface around the pit revegetated, and evaporative losses from the water that collects in the pit replaced. Evaluations, preparation of revised reclamation plans, and permit amendments can usually be completed in less than three months for less than $5,000 to $10,000. Legislative amendment to the permit usually takes less than three months.

Environmental Enhancements

Traditionally access to areas around gravel pits and mining have been restricted from public access and these areas are considered undesirable by the general public. However, areas around some of the gravel pits are very scenic because of the proximity to the South Platte River. They
are also some of the largest blocks of non-urbanized land in Metropolitan Denver. Gravel pits also provide excellent habitat for waterfowl. Converting gravel pits into water-storage facilities provides many opportunities for environmental and recreational enhancements to the urban environment. Current environmental and recreational components in ongoing projects include:

- Hiking and biking trails around the perimeter of the reservoir connected to a regional trail system.
- Enhanced waterfowl habitat.
- Tranquil areas for wildlife viewing.

Future projects may include opportunities for surface water activities such as fishing and operation of small non-motorized boats.

Costs

Total costs, which include land, lining, and hydraulic facilities to convert existing gravel pits into lined water-storage facilities, are currently about $1800 to $2500 per acre foot. Higher unit costs are for facilities where:

a) liners need to extend more than about eight feet into bedrock;

b) material with no commercial value remains in the pit;

c) reconstruction of the sides of the pit are required to provide stability for reservoir operation; or

d) the pit is far from existing hydraulic facilities and lengthy new transmission facilities are needed.

Future

Costs, operational flexibility, environmental interests, and recreational opportunities can all be enhanced when the final site (lined water storage facility) is incorporated into the initial planning and development of a new pit. Water agencies and the sand and the gravel mining industry are currently working on several new pits where the final site usage is an important consideration in project planning.

The development of a new gravel pit should result in a successful project for all involved if these steps are followed:

- Install a soil-bentonite cutoff wall or other seepage barrier that will meet the requirements for a lined water-storage facility before mining begins. Early installation of cutoff walls significantly reduces dewatering and evaporative losses during mining resulting in savings to the pit operator.
• Remove from the site or stockpile excavated material that is not part of the commercial sand and gravel deposit at locations where it will not affect final site usage.

• Excavate slopes in the pit to an angle or replace excavated material in slopes with compacted backfill that will be stable for the final reservoir configuration.

Storage volume can also be enhanced by construction of a dam around the perimeter of the pit. Typically, material that is too fine to have commercial value as an aggregate can be used to construct most of the embankment. Most existing and proposed pits are over 100 acres, so 100 acre-feet of storage can be created for each foot of embankment height.

Conclusions

The ability to permit and construct large dam projects is becoming difficult, unpredictable, expensive, and lengthy. The successful water manager must respond to the societal pressures to be more sensitive to our environment. The key for new water projects is to strike a balance between water and environmental needs, leading to preservation of our quality of life. The key elements shared by a successful water project include:

a) a pressing need for water,
b) fiscal responsibility,
c) recognizing and following regulatory requirements, and
d) commitment to environmental and recreational enhancements.

The practice of dam engineering has always adjusted to the emergence of new technical concepts, with answers like converting gravel pits to storage reservoirs.

Converting gravel pits into water-storage facilities meets the requirements of a successful project and, as an added benefit, provides an opportunity to transform a liability into a valuable asset. Gravel pit water storage will be one key component in an integrated water resources management system to meet long-term water supply and environmental objectives of Metropolitan Denver.