Abatement of Combined Sewer Overflow and Urban Runoff Pollution in Indianapolis, Indiana Using Deep Tunnel Conveyance and Storage

V. Peter Worland and Terry R. West, Department of Geosciences
Purdue University, West Lafayette, Indiana 47907

Statement of the Problem

Most large metropolitan areas in the United States are served, at least in part, by combined sewer systems. Such a system combines both the storm water from urban areas during rainfall events with the domestic, industrial, and commercial sanitary waste water.

At normal and low flow periods combined sewers route all the waste water to the sewage treatment plant where it is treated and subsequently returned to surface streams. During rainfall events of high intensity, the sewer system's capacity to transport the combined storm and sanitary wastes is commonly exceeded. At these times the excess, untreated waste water is released into rivers and ditches from overflow structures of the combined sewers. This is judged to be one of the most serious water pollution problems in the area.

At the present time a major underground construction project is underway in the Chicago area to collect, transport and store the combined-sewer overflow for various parts of the city (2). An extensive appraisal of a similar system for Milwaukee is also currently under investigation (5). For Indianapolis the problem is less-well publicized because of the smaller extent of the metropolitan area, but because of similarities in topography and geology, similar schemes for correcting the problem apply. This paper is a preliminary analysis of the problem to underscore the impending need for a solution.

In Indianapolis, Indiana 140 combined-sewer overflow structures are present. It is estimated that 45% of the waterway pollution originates from combined sewer overflows (2). Four Indianapolis waterways receive combined sewer discharges: West Fork White River, Fall Creek, Pogue's Run, and Pleasant Run.

Curative solutions for the abatement of combined sewer overflows normally require substantial physical facilities and large capital expenditures. The Department of Metropolitan Development in Indianapolis (1) studied three curative solutions:

1. Complete separation of storm and sanitary sewer systems.
2. Treatment at, or near, individual points of overflow.
3. Collection of combined sewer overflow followed by treatment at one site.

The plan proposed in this paper for the elimination of combined sewer overflows is of the "treatment at one site" variety. Verticial shafts, as depicted in (Fig. 1), located near the overflow points would be used to collect the waste water and drop it into tunnels which would convey the captured water to a subsurface storage reservoir. From this location, the polluted water would be

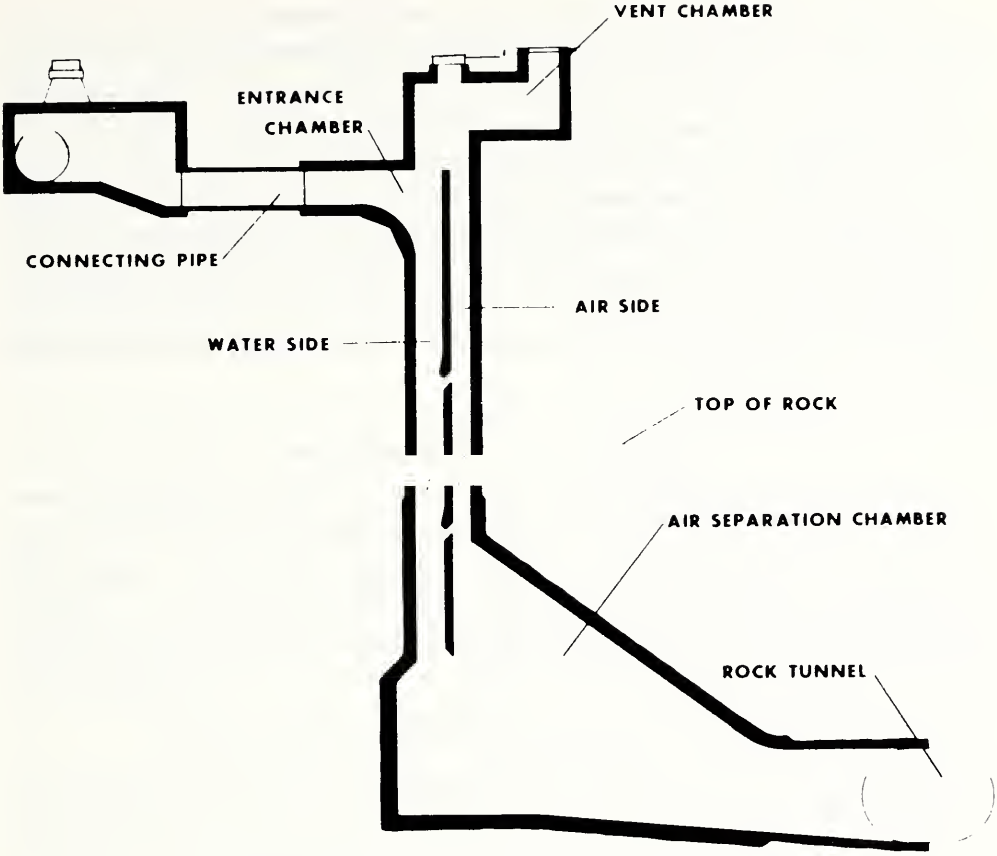

FIGURE 1. *Cross-section of a typical dropshaft structure.*

pumped during dry periods to the surface sewage treatment plant for proper treatment prior to entering the waterways. This would also provide a constant flow of waste water through the treatment facility which would optimize efficiency.

Geology and Hydrology of the Study Area

Because the proposed structures for collection, conveyance, and storage of the combined sewer overflows are all underground, a detailed knowledge of the soil, bedrock and ground water conditions for the area is necessary to insure success of this plan.

The surficial geology of Marion County is primarily a consequence of the several continental glaciers that covered the county during the Pleistocene epoch. These deposits consist primarily of till plus glacial outwash, the latter associated with the major streams in the county. The thickness of the glacial drift in the study area averages about 100 feet.

The bedrock formations lying immediately below the glacial drift in Marion County consist of a series of limestones and dolomites of Silurian and Devonian age in the central and eastern parts of the county, and shales and sandstones of Devonian and Mississippian age in the western part. These rocks dip gently to the southwest at a rate of 20 to 30 feet per mile with no major faults or deformations present.

In conveying and storing wastewater in underground structures, great care must be taken not to pollute the ground water. The potential for ground water contamination in the glacial till is much less than in the extensive sand and gravel deposits (outwash material) adjacent to White River and Fall Creek. The uppermost limestone and dolomite units are quite permeable within the first 100 feet of the bedrock surface, and thereby are susceptible to pollution. This high permeability is due, most probably, to solution channels which formed when the rock was exposed during pre-glacial times. Permeability of these limestone and dolomite units is greatly reduced in the western and southern parts of the county where they are overlain by the younger shales of Devonian and Mississippian age.

Hydrology of the Proposed Plan

An accurate knowledge of the quantities and rates of combined sewer overflow is vitally important to the development of this underground conveyance and storage plan. The storage capacity of the underground reservoir was designed for a year of high rainfall activity. In 1957 the Indianapolis area received approximately 55 inches of precipitation compared to the normal annual amount of 39 inches. In this study it was assumed that a day having greater than 1/4 inch of rainfall would produce overflows from the combined sewers. Fifty-nine days of greater than 1/4 inch of rainfall occurred in 1957. On days of greater than 1/4 inch rainfall, it was assumed that 50% of the rainfall for the area of combined sewers in Indianapolis would infiltrate into the ground or run off into streams, 25% would travel through the combined sewers to the sewage treatment plant, and 25% would overflow from the combined sewers into surface waterways. It is this last 25% of the flow that would be captured and stored by the proposed underground system.

(Fig. 2) shows the storage requirements of the underground reservoir in 1000's of acre-feet as related to different pumping rates to the treatment plant throughout the 1957 design year. As seen from the figure, higher pumping rates result in lower storage volume requirements. For a pumping rate of 125 cubic feet per second (cfs), a storage volume of 2250 acre-feet would be needed. This pumping rate would empty the reservoir each year without permitting a carry

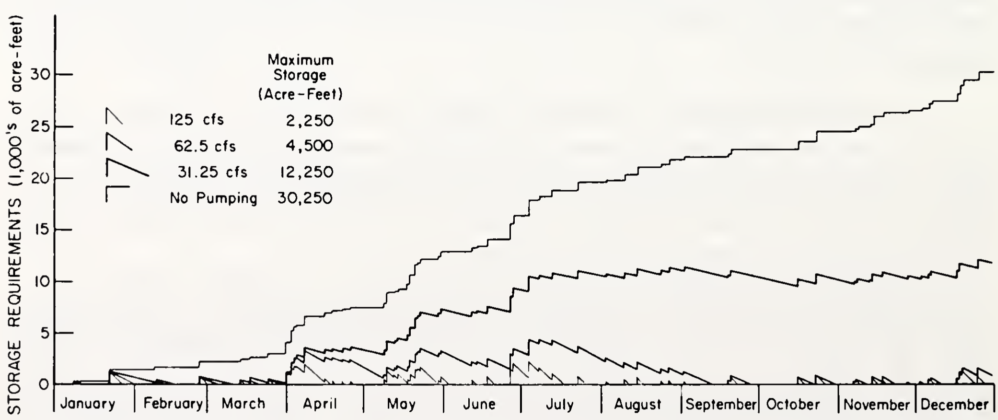

FIGURE 2. *Storage requirements of combined sewer overflows for 1957 rainfall year considering various pumping rates.*

over of one year's wastewater to the next. Such a carry over would reduce the reservoir's storage capacity for the following year's run off and hence be undersirable.

In order to calculate the tunnel distance, it was necessary to determine the surface area served by the combined sewers within the drainage basins for those streams in Indianapolis which experienced overflows. This information was used to determine the volume of wastewater that would be dropped to and conveyed through the tunnels beneath each stream. The size of the tunnels to convey these wastewater flows is related to the velocities that can be attained in the tunnel. In rocks similar to the carbonates beneath Indianapolis, Harza Engineering in a study for the Chicago area (3) estimated that for a 10 year return period storm, the safe maximum velocity in a moled, unlined tunnel would be 28 feet per second (fps).

The Indianapolis tunnel system was designed to accomodate the discharge rates of a 10 year return frequency storm with a 30 minute duration. Table I summarizes the maximum diameters of each waterway tunnel needed to provide for such rates of flow. The calculations used to estimate the volumes required for the storage reservoir and tunnel diameters, velocities, and slopes are developed by Worland (6).

TABLE I *Diameters of moled, unlined tunnels beneath waterways.*

Waterway	Diameter (ft)
White River	19.0
Pleasant Run	17.1
Fall Creek	14.3
Pogue's Run	9.2

Engineering Geology and Construction

Grouting the surrounding rock and lining of the tunnels are methods used to reduce seepage through the tunnel and reservoir walls. If such seepage is outward, it can pollute the aquifer, and if inward, the effect would be a loss of ground water and an increased volume of water for treatment. Grouting consists of injecting a mixture of cement and water into the rock to plug water-transmitting passages. Grouting would be used as the major deterrent to seepage in the structures proposed in this paper. Observations of completed tunnels in similar rock beneath Chicago, Illinois indicate that grouting can reduce infiltration to about 0.05 million gallons per day per mile of tunnel (3).

Dropshaft construction in the glacial deposits would involve the use of either soldier pile and lagging, or steel sheet pile supports depending upon the depth and characteristics of the soil. Excavation through the bedrock would be performed by either drilling and blasting or raise borings. The raise boring technique involves the drilling of a 12 inch pilot hole into a prepared chamber at the base of the shaft and upward reaming of the hole, in one or more passes, until its full size is reached.

The 27 miles of tunnels proposed for the Indianapolis plan are to be excavated by tunnel boring machines (TBM) and left unlined with rock bolts used for crown support. Drill and blast techniques would be used to excavate transition sections between different size tunnels and to excavate the initial reach of each tunnel and thereby provide an assembly chamber for the TBM.

For the mined storage reservoir (or chamber) it is anticipated that the room and pillar mining techniques would be employed, creating a comparatively close spaced, mined network of passageways as displayed in (Fig. 3). Room sizes would be 35 feet wide by 50 feet high with pillar sizes being 100 feet square. A grout curtain would be needed to encase the reservoir in order to prevent outward seepage and thereby provide aquifer protection.

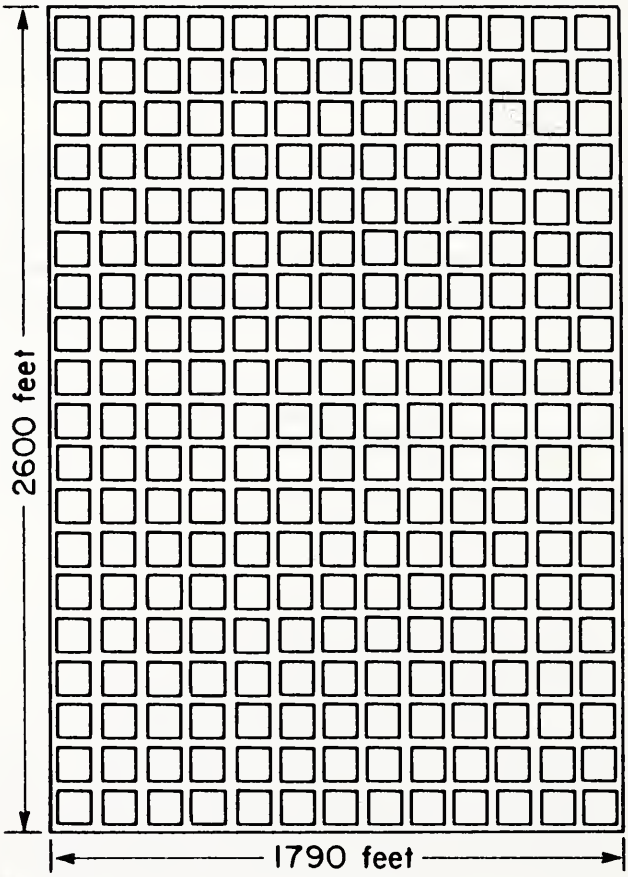

FIGURE 3. *Areal view of 2,500 acre-foot storage reservoir with 100 foot square pillars.*

The proposed storage chamber would require excavation involving conventional drill and blast techniques. The upper part of the chamber would be excavated as as large tunnel and the lower part, constructed by bench excavation which is essentially a quarrying operation. Smooth wall blasting methods would be required to minimize disturbance of the chamber arch and side walls. Rock reinforcement using rock bolts and shotcrete would be accomplished during excavation.

Overall Details of Project

Approximately 58 dropshafts located along White River, Fall Creek, Pogue's Run, and Pleasant Run would drop the overflows from combined sewers 250 feet vertically to conveyance tunnels located 75 to 150 feet into the limestone and dolomite rocks of Silurian and Devonian age. These tunnels would transport the flow to a 2500 acre-foot mined out, room and pillar storage reservoir lying below a geologic section consisting of 100 feet of glacial drift, 75 to 100 feet of New Albany Shale, and 100 feet of limestone. The areal location of this reservoir would be immediately southwest of the junction of Meridian Street and I-465 on the south side of Indianapolis. From this reservoir the stored waste water would be pumped to the Southport sewage treatment plant for processing before it is released to surface waterways. (Fig. 4) is a cross-section of the main tunnel route beneath White River showing the tunnel orientations and storage reservoir location.

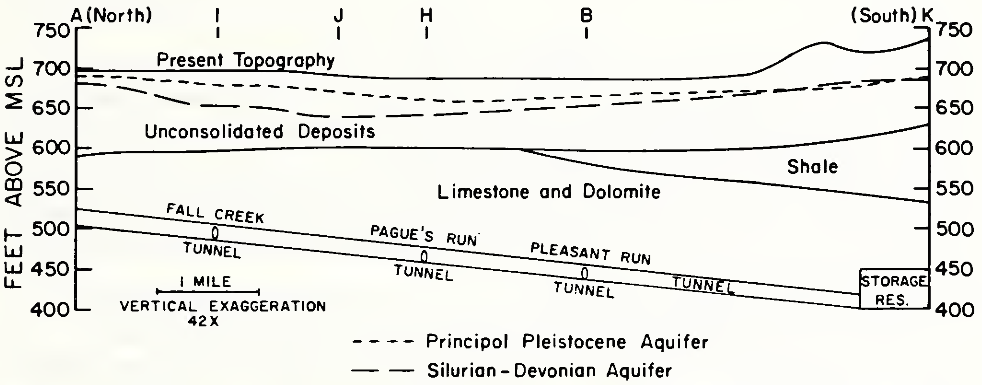

Figure 4. *Cross-section of the tunnel and storage reservoir for area beneath White River.*

The estimated total cost of such a project as shown in Table II is $533,386,707 relative to 1979 figures.

Table II *Estimated Total project cost (1979 dollars)*

Tunnels		$249,832,995
Storage reservoir*		104,901,325
Dropshafts		22,376,250
Pumps		8,840,000
Hardware		44,200,000
	Subtotal	$430,150,570
Subsurface exploration (10%)		43,015,057
Contingencies (8%)		34,412,046
Engineering, legal, administrative (6%)		25,809,034
	Total Cost	$533,386,707
Total minus cost of reservoir*		$403,309,064

If it is economically feasible to develop the storage reservoir as an underground limestone mine as suggested by Hartke (Indiana Geological Survey, personal communication), then much of the expense of the storage reservoir would be removed from the project cost. This does seem possible as French and Carr (4) suggested some years ago that underground limestone mines in Marion County should become economical as crushed stone becomes more scarce in the area. The total cost for the project would then approach $403 million which is economically competitive with the other methods of eliminating combined sewer overflows proposed for Indianapolis.

Conclusions

1. A major surface-water pollution problem exists in Indianapolis, Indiana because of overflow from combined sewers during periods of high rainfall intensity.

2. The problem could be solved by construction of an underground conveyance and storage system which would be located in bedrock to minimize ground water pollution.

3. Preliminary design calculations show the proposed system to be feasible and economically competitive with other methods for elimination of this pollution.

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