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Dewatering of the Construction Site for a 200-Foot Diameter Clarifier Tank Founded on Sand and Gravel
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SYNOPSIS. This paper presents the preliminary design, the field modifications applied to the final design, and additions made to the dewatering system for a wastewater treatment plant. The site history is described, as are the exploration, design and construction phases of the dewatering operation. The difference between the predicted results and the actual results and lessons learned from experience in the field are discussed. The data includes design parameters for hydrological applications derived from the site soils and the groundwater elevations from one month before the beginning of construction through the construction of the clarifier tank and an additional pump building.

INTRODUCTION

The dewatering by deep wells of the site of a 200-foot diameter clarifier tank and attached facilities is described in this paper. The area to be dewatered included the excavation for the clarifier tank, the main pump house next to the clarifier tank, and the trench for a pipeline connecting the clarifier tank to an existing pump pit.

The site is located at the confluence of two creeks and in a deposit of glacial sand and gravel which extends to siltstone bedrock at an average depth of 80 feet. The base elevation at the center of the clarifier tank is more than 20 feet below the average groundwater table and more than 30 feet below flood crest.

The clarifier tank and its attached facilities were important components of an expansion project for a paper mill located in southeastern Ohio. Despite the obvious complications for timely construction, it was essential that the construction of the clarifier tank and its associated structure should be completed on schedule, because the EPA had notified the paper mill that production from their additions to the existing mill would not be permitted until a wastewater treatment system for the entire plant was in operation. The clarifier tank was a major component of this system, and dewatering of the site was a major obstacle to timely construction of this project.

SITE EXPLORATION AND PLANNING

The site is located between two creeks (see Figure 1). Paint Creek flows west to east adjacent to and south of the site. It is a natural stream of some size whose volume of flow is controlled by a upstream dam managed by the Corps of Engineers. It flows into the Scioto River about 2.5 miles downstream from the site. Honey Creek also flows west to east. It is located due north and adjacent to the site. It is a man-made stream constructed to provide drainage of storm water runoff from the paper mill. It enters Paint Creek at a point adjacent to and east of the site.

Several aspects of the site's history would impact construction. When Honey Creek was constructed, the excavated surficial soils were deposited in the general vicinity of the location of the clarifier tank. Subsequently, this area continued to be a dumping ground for construction spoil from other projects required over the years for the paper mill. In addition, levees were constructed along the northern and southern perimeters of the site to protect a system of 65 wellpoints that were installed to provide make up water for the mill. Thus, there were potential soil and groundwater problems which could impact construction at the site due to disturbance and disposal. The owner of the paper mill being well aware of the potential for such problems requested technical assistance.

After a thorough review of the site history, a field exploration program was proposed and accepted. Six exploratory borings were drilled at the site from September through November of 1979. The borings were drilled by truck-mounted "Mobile B-611" boring rigs using hollow-stem augers and employed standard penetration resistance methods (SPT). The soils encountered during the field exploration phase were primarily granular in nature. Therefore, the laboratory soils testing of primary importance was the grain size distribution of the soils which would provide data for estimating the range of permeability of the site soils.

The location for the clarifier tank was finalized based on project requirements and results of the initial field exploration and laboratory testing phases. With the clarifier tank and appurtenant structures located, final planning for construction was completed. Several alternate sites for the clarifier tank were considered, but the requirement that the wastewater treatment system function by gravity flow as much as possible caused this site to be the only alternative. This site was large enough, and the general elevation of the site relative to the mill permitted the bottom of the column pit to be located at an elevation which allowed the wastewater treatment system to operate primarily by gravity flow.

In its final configuration, the proposed clarifier tank would be a circular shape, 200-foot diameter structure with vertical walls and a sloping floor (see Figure 1). The bottom of the column pit at the center of the clarifier tank would be at elevation 575.25 feet and the foundation elevation at the perimeter of the clarifier...
FIGURE 1

SITE PLAN

LEGEND

- WELL LOCATION
- BORING LOCATION
- PIEZOMETER LOCATION

EXISTING PRIMARY TREATMENT PLANT

36' LINE DISCHARGE

WELL #8

WELL #3

BORING #5

COLUMN PIT

BORING #1

BORING #4

WELL #9

WELL #1

P-1

P-2

P-3

SECONDARY PUMP BUILDING

WELL #4

WELL #7

WELL #6

BORING #2

WELL #5

PAINT CREEK

HONEY CREEK

FENCE LINE

WELL POINT LINE
would be 585.75 feet (see Figure 2). There would also be a pump building constructed adjacent to the northern edge of the tank. The pump building would be a rectangular structure measuring approximately 30 by 51 feet. The mat foundation for this structure was proposed at elevation 586.4 feet. Also, in the area southwest of the clarifier there would be a trench for a discharge line with a minimum invert elevation of about 575.0 feet that would require dewatering.

Field operations were suspended until the following spring, because of the potential for flooding, since the existing levee was in poor condition, and the water in Paint Creek was higher than average due to unusual amount of precipitation that winter. However, in the spring of 1980, three piezometers were installed at the site to provide subsurface hydrological data and as monitoring points for pump testing.

Results of the field exploration program and the data collected from the piezometers indicated that the dewatering of this site would be more difficult than expected. The exploratory borings revealed a soil profile that was overlain over most of the site by a layer of fill that was up to 15.5 feet deep. The fill consisted of a soft gray silt with some sand and trace quantities of organic matter (ML) or a loose brown and gray sand with some silt and gravel (SM). Beneath the fill, a thin stratum of soft alluvial gray organic silt (OH) that ranged in thickness from 3 to 6 feet was encountered. Below the overlying fill and alluvial organic silt, there was a stratum of dense to very dense gray sand and gravel (GW-GP) with some intermittent pockets of sand and silt (SM-ML). The sand and gravel strata is glacial in origin. It was deposited as glacial outwash during the Wisconsin age. The glacial outwash extends to siltstone bedrock at an average depth of 80 feet or about elevation 520 feet (see Figure 2).

In mid September and October of 1979, the average elevation of groundwater beneath the site was about elevation 599 feet. The elevation of the groundwater table had been somewhat affected by a system of 65 wellpoints installed to provide make-up water for the paper mill. This system had been designed to provide about 6,500 gpm. However, at this time, it was producing only about 2,200 gpm to 3,600 gpm, which resulted in a drawdown of 3 to 4 feet across the southern portion of the site when Paint Creek was at about elevation 595 feet. Thus, the predicted average groundwater elevation would be about 20 feet above the bottom of the column pit in the center of the clarifier tank.

It became obvious that dewatering of this site would be more difficult than initially predicted. The primary complications were that Paint Creek is subject to flooding and could crest as high as elevation 604 feet, and the existing wellpoint system was only functioning at 2,200 gpm. Instead of the 6,000 gpm design capacity, because the 6,000 gpm pump could not be secured from the manufacturer, and it would not be available prior to the initiation of excavation. Therefore, the potential for a high and fluctuating groundwater level and the permeable nature of the lower soil strata (see Table I) influenced the parameters (see Table II) derived to provide a basis for the initial design of the dewatering system.

### Table I. Soil Parameters Based on Grain Size Analysis

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Depth (ft)</th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>Permeability (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.0-7.5</td>
<td>28</td>
<td>62</td>
<td>10</td>
<td></td>
<td>6 x 10^-4</td>
</tr>
<tr>
<td>2</td>
<td>9.0-10.5</td>
<td>19</td>
<td>61</td>
<td>10</td>
<td></td>
<td>2 x 10^-4</td>
</tr>
<tr>
<td>3</td>
<td>14.0-15.5</td>
<td>25</td>
<td>67</td>
<td>8</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>19.0-20.5</td>
<td>20</td>
<td>70</td>
<td>10</td>
<td>0</td>
<td>4 x 10^-4</td>
</tr>
<tr>
<td>5</td>
<td>25.5-30.0</td>
<td>17</td>
<td>78</td>
<td>5</td>
<td>0</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>28.5-30.0</td>
<td>16</td>
<td>82</td>
<td>4</td>
<td>0</td>
<td>1.6</td>
</tr>
</tbody>
</table>

This system's initial design was based on the information listed in Table II.

### Table II. Design Parameters for Clarifier Tank Dewatering System

1. Permeability is 6 x 10^-1 inch/sec. at screen depths.
2. Saturated thickness of aquifer is about 70 feet.
3. Transmissivity equals 200,000 gpd/ft.
4. Storage coefficient is 0.2.
5. Paint Creek and to some extent Honey Creek are recharge boundaries.
6. Materials are uniform across the site.
7. Wells can be developed to 1,000 to 1,200 gpm in capacity.
8. The pool stage at Paint Creek will be about 596 feet.
9. Dewatering must result in a groundwater elevation of 573 feet at the center of the tank.
10. Work will not be possible if Paint Creek is at full flood crest.

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**WELL #6 AS SEEN FROM BOTTOM OF EXCAVATION**

**EXPOSED CASING AND DISCHARGE LINES FOR WELLS #1, #2, #6**

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Based on these parameters, it was recommended that the site should be dewatered by a system of five wells (#1, #2, #3, #4, and #5) located along the northern perimeter of the clarifier tank and two wells (#6 and #7) inside the clarifier tank. The wells were designed to operate in conjunction with the existing wellpoint system (see Figure 1). The five wells on the outside of the northern edge of the clarifier tank were positioned to lower the groundwater level for construction of the major portion of the clarifier tank, and the two wells located inside the clarifier tank were positioned to dewater the deeper portion of the excavation for construction of the column pit in the center of the tank. It was expected that the existing wellpoint system would dewater the southern perimeter. The two internal wells were to be removed prior to construction of the clarifier floor.

Initially, it was recommended that wells #1 through #5 should be positioned in an arc along the northern perimeter of the clarifier tank with a closer spacing than illustrated on Figure 1, and that the wells should be installed to a minimum depth of 70 feet below the average surface elevation of 596 feet. Twelve hundred gallons per minute pumps would be installed in each of these wells. The recommended screen design was a 25-foot long, 18-inch diameter telescopic screen. It was further recommended that either well #1 or #2 should be constructed first, and pumping tests should be conducted to verify this design.

It was estimated that the recommended system of seven wells and the existing wellpoint line would produce a maximum drawdown of about 22.0 feet, or to about elevation 572 feet, at the center of the column pit. A drawdown of this magnitude would be required to lower the groundwater table two feet below the bottom of the column pit foundation where the excavation would be the deepest and, therefore, most critical portion of this project.

CONSTRUCTION OF AND FIELD MODIFICATIONS TO THE DWATERING SYSTEM

Construction was initiated in April of 1980. Well #1 was the first well completed and tested. It had a 12-inch diameter casing and a 24-inch diameter gravel pack. At the suggestion of the contractor, it was installed by air-rotary methods with a gravel pack as an experiment to determine if wells could be constructed at this site more quickly than by standard cable tool methods. However, subsequent testing of this well indicated that it had less capacity than desired, and it was inefficient.

As a result of the information derived from the construction and testing of Well #1, it was determined that the formation characteristics were about those expected with two exceptions.
To compensate for these factors, the following modifications were recommended, accepted, and incorporated into the design and construction of the remaining wells.

1) All wells, except for Well #1, would be constructed with the originally recommended 18-inch diameter telescopic screens.

2) All screens, except for Well #1, would be a minimum of 30 feet long.

3) All wells would be extended to rock to provide additional potential drawdown and to increase the radius of the cones of depression. This recommendation increased the total depths on the order of 10 to 20 feet per well depending upon the surface elevation of the individual well locations.

4) The spacing between wells #1 through #5 was increased, and they were located to reinforce the limited drawdown effects of the wellpoint line.

5) Two additional wells were added to counter the higher than expected recharge capacity of Paint Creek. Thus, there would be a total of nine wells (see Figure 3).

Utilizing this revised design, construction of Wells #2 through #9 began in mid April and continued to completion in mid July of 1980. Additional problems were encountered during construction.

Insufficient electrical power presented a problem. It was determined at the start of the project that electrical power would be available at the site by tapping into an existing substation for the originally proposed seven 25 horsepower motors. However, the final design required much additional electrical power that construction of a new transmission line was required from a larger substation located more than one-half mile from the site to supply the single 25 horsepower and the eight 40 horsepower motors required to operate the wells at final design capacities. The construction of the line required the building of a new substation at the site, connection to the main substation, and the laying of a 3-inch diameter copper line and its supports. The line was installed at considerable expense to the owner. However, the potential problems associated with overloading the electrical power system for a manufacturing facility were avoided.

Disposal of the water from the dewatering wells to Honey and Paint Creeks was another problem. Disposal of water from the wellpoints was not a problem, because all of this water was pumped directly to the existing paper mill for use as make up water. However, if the water from the nine dewatering wells was disposed of through individual lines, access to the site would have been restricted to such a degree that construction would have been virtually impossible. This problem was resolved in two ways: 1) the discharge lines for the wells were combined so a total of only four discharge lines traversed the site; and 2) flexible pipes were used as conduits, and they were adjusted and moved as circumstances demanded. These measures did not totally reduce the access complications, because the discharge lines for the interior wells continued to interfere with construction access. However, the problem was eliminated as excavation proceeded, because as the soils were excavated from around the well casings, the tops of the well casings were exposed for as much as 25 feet. This provided more than enough headroom for construction vehicles, construction workers, and equipment to enter and exit from the site.

PERFORMANCE AND RESULTS

In spite of the problems and complications involved during the installation of the dewatering system, the construction of the system was eventually completed in mid July of 1980, and within three days the system had produced the drawdown required for the initiation of excavation. The full system was operated over a period of approximately three months, and near the end of construction, selected wells were shut off. The interior wells (Wells #6 and #7) were shut off in mid October. Their casings were filled with concrete and the tops sealed. The floor of the clarifier tank was then poured over the casings. The estimated drawdown for the system was within a few feet of the drawdown achieved in the field, and groundwater was never a problem during the construction phase of the project. When the excavation for the column pit was at its deepest (i.e., elevation 574.0 feet) an exploratory excavation was made in the sand and gravel in the center of the column pit to determine the elevation at the top of groundwater. Groundwater was encountered at a depth of 6 inches or at elevation 573.5 feet. An exploratory hole was also made in the bottom of the trench for the pipeline connecting the clarifier tank to an existing pump pit, and groundwater was encountered at a similar depth. Table III presents a summary comparing predicted and actual drawdowns and Figure 4 is a graphical representation of the drawdown in the vicinity of the piezometers.

<table>
<thead>
<tr>
<th>Piezometer Location</th>
<th>Predicted Drawdown (ft)</th>
<th>Actual Drawdown (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>20.0</td>
<td>574.0</td>
</tr>
<tr>
<td>P-2</td>
<td>19.0</td>
<td>575.0</td>
</tr>
<tr>
<td>P-3</td>
<td>14.0</td>
<td>580.0</td>
</tr>
<tr>
<td>Column Pit</td>
<td>22.0</td>
<td>572.0</td>
</tr>
</tbody>
</table>
As construction proceeded into the summer and the level of Paint Creek dropped to a low point of 586.0 feet, personnel were trained and assigned to adjust the pumping rates of the individual wells to maintain the system in balance and to minimize interference from well to well, while maintaining sufficient magnitude of drawdown across the site to allow construction to proceed. The wells were controlled by adjusting check valves that were installed during construction of the dewatering system. At times as many as three wells, in addition to the two wells that were filled and sealed, were either completely shut down or operating at less than one-third of capacity. Despite the problems encountered, the dewatering system operated to expectations and construction was completed on schedule.

**ADDITIONAL UTILIZATION OF THE SYSTEM**

During the design phase of the dewatering project the paper mill decided to retain dewatering wells #2, #3, #4, and #5 for permanent use, and the original design included different specifications for the wells that would be retained. These wells are being used to supply additional make up water for the new paper machine, and they are available for pressure relief, if the site should be flooded. When these wells were installed, they were provided with stainless steel screens to inhibit corrosion, instead of the galvanized screens specified for the temporary wells. After construction of the site was completed, the temporary submersible pumps used during the dewatering program were replaced with permanent submersible pumps.

Retention of the dewatering wells resulted in an additional benefit after completion of the initial phase of construction. It became necessary to construct an additional pump house. The additional pump house had dimensions of about 9 feet by 20 feet, and it was constructed between the existing pump house and the clarifier tank with a space of 1.7 feet between the additional and the original pump house and a space of 1.2 feet between the exterior of the clarifier tank wall and the additional pump house. The new structure was founded at elevation 574.4 feet; or about 1 foot below the maximum depth of the clarifier tank column pit. The excavation for the structure was supported by sheet piles which was retained as the exterior framing for the walls of the pump building.

The analysis for the estimated depth of water in this area with wells #2 through #5 running at full capacity and with Paint Creek at elevation 586 feet indicated that the maximum drawdown at the bottom of the new excavation would be at elevation 574 feet or about 1 foot below the bottom of the excavation. In addition, the dewatering system was thought to be a potential problem. To solve these problems, the sheet piles were embedded about 1.2 feet below the bottom of the excavation. For this purpose, a subsidiary pump installed within the sheet piles was recommended to draw down the 2 feet of water in the bottom of the new excavation.

This phase of the project was considered to be potentially dangerous. If the existing permanent wells were not in working order, or if all the permanent wells were not running, groundwater could boil up through the saturated soil and with Paint Creek at elevation 586.0 feet, the maximum drawdown at the bottom of the excavation would be at elevation 574 feet, or about 1 foot below the bottom of the excavation. In addition, the dewatering system was thought to be a potential problem. To solve these problems, the sheet piles were embedded about 1.2 feet below the bottom of the excavation. For this purpose, a subsidiary pump installed within the sheet piles was recommended to draw down the 2 feet of water in the bottom of the new excavation.

With all preparations complete, the author was ready for the pouring of the floor slab for this phase of the project. The following procedure was followed. First, the excavation was excavated from within the sheet piles and the saturated soil was removed. Then a sump and subsidiary pump were installed in the bottom of the excavation. The water level was drawn down an additional 2.5 feet. When the water level was lowered, the last 2 feet of soil was excavated from the bottom of the excavation. Finally, the excavation was completed, and a pre-fabricated reinforcement mat was placed. The sump and subsidiary pump were then installed. Finally, as the sump and subsidiary pump were withdrawn, the pouring of the floor slab was conducted simultaneously. The floor slab poured was about 4.5 feet thick.

Thus, the original well system designed to dewater the site was modified and utilized for additional pump house. Improvisation and flexibility produced a significant economic return for the paper mill and permitted construction projects that had been deemed impossible to complete. However, these projects were completed, and they were completed on schedule.
SUMMARY AND CONCLUSIONS

Based on the results and the experiences of this project, several aspects generally applicable to the design and conduct of dewatering projects are notable. One problem frequently encountered in the design and installation of dewatering systems is the lack of freedom to locate and install wells where they will have maximum effect. This problem is usually encountered in the vicinity of existing structures. The prevalence of underground utilities and the orientation and size of an existing structure can prevent the effective placement of dewatering wells. When encountered, the importance of this problem cannot be sufficiently emphasized, since a project may become very expensive or difficult if the number of wells must be increased, or if they cannot be placed in potentially effective locations. Maximum effort should be expended during the planning phase to investigate previous structures or past site usage that could potentially interfere with or complicate the placement of dewatering wells and their associated appurtenances.

Another potential problem, when planning, designing, and constructing large dewatering systems for construction sites, is the location and coordination of the electrical power supply for the dewatering system, since construction sites are usually located in remote areas, or they have limited access. Again, one cannot emphasize enough, the importance of pre-planning that should go into this portion of the work. For projects in the vicinity of existing structures, especially industrial structures, it is usually not too difficult to tap into existing power supplies unless the existing electrical power supply is of the wrong voltage or is already at or close to capacity. However, for remote sites, dewatering systems are usually powered by expensive diesel generators. This mode of power is labor intensive and usually involves maintenance and mobilization problems.

Disposal of water produced by dewatering systems can also be a challenge. The disposal of water from wells installed in built-up areas can sometimes be accomplished by tapping into the existing storm sewer lines. However, if existing storm sewers are already over capacity, local authorities may require construction of an entirely new line to dispose of the water from the dewatering system. The disposal of water from remote construction sites is sometimes less complicated, since it may be possible to divert the water into existing streams or ditches. However, as experienced at this site, the channeling of the water in such a manner that construction operations are not inconvenienced can be a challenge.

Finally, it is of interest to examine the nature of the initial planning and design of this dewatering system. The initial design was based on permeabilities and aquifer characteristics derived from grain size analyses and knowledge of the area. This quality of information proved sufficient to produce a preliminary design that was within the correct order of magnitude to provide a basis for proceeding with construction. Thus, since expensive pumping tests and elaborate field explorations were not performed, extra funds were available for construction of the operational system. However, without detailed preliminary pumping tests and elaborate field exploration programs, there must be flexibility in the design of the dewatering system, because even if a project design is refined to a high degree, there is always
the possibility that an unexpected occurrence, condition, or restriction can cause a complete redesign of the system. At this site, the potential for flooding due to high water in Paint Creek could have destroyed the usefulness of a finely detailed design. Alternatively, projects conducted in areas of high visibility can have public relations considerations that may require the system to be concealed, as much as possible, from public view. Thus, resulting in the relocating of wells and/or discharge lines. In some cases, there are design considerations and requirements that cannot be predicted ahead of time. They can invalidate the usefulness of a rigid design. Further, mechanical, electrical, and institutional factors will almost always affect any design in ways that are not directly related to the hydrology of the site, or to the actual technical requirements of the dewatering program. Therefore, since it is almost impossible to design and refine the dewatering system in advance, flexibility and improvisation should be major guidelines for any dewatering system design.