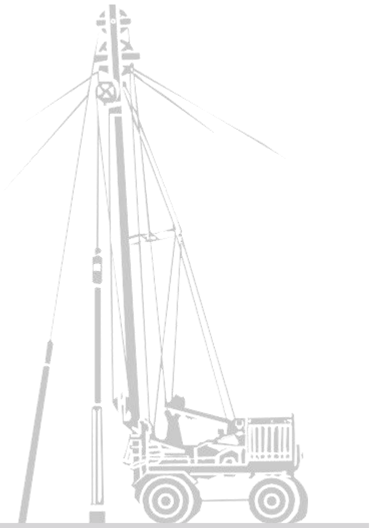
Hoelscher Ferrer North America

Problem? Analysis and Solution.
Orillia Sanitary Sewage Pumping Station

Low-Capacity Wells Dewatering in Ontario, Canada



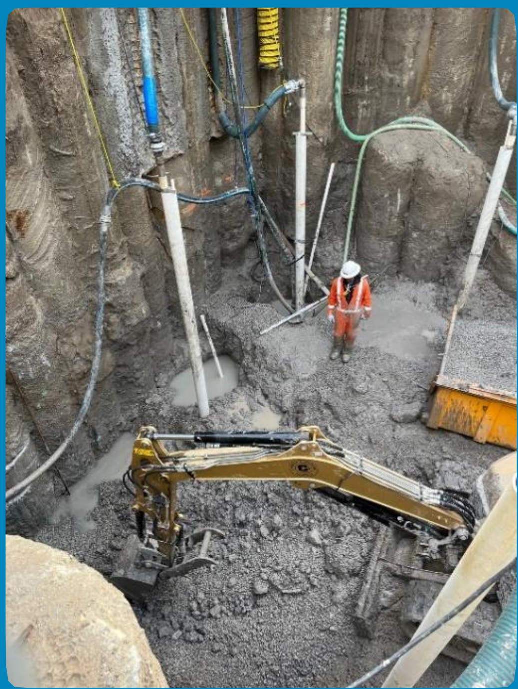
PROJECT OVERVIEW

The town of Orillia, located on the shores of lakes Couchiching and Simcoe, is growing at a fast pace and requires, among other municipal services, the expansion and upgrading of its sewage systems.

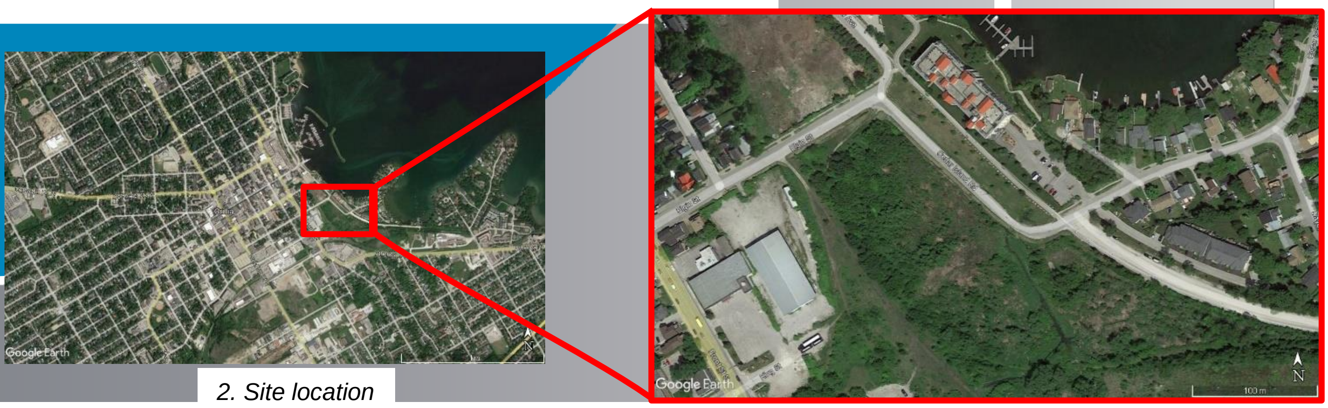
In response to this growth and as part of a larger project, the Orillia municipality awarded the contractor JB Enterprises the development of a sewage pumping station, which would replace the one that had been in use for over 90 years and with insufficient capacity for today's needs.

Construction work began early last year 2021 but was interrupted for more than a year due to problems associated with water table control that prevented progress in the excavation. Initially, by a local company and as a subcontractor of JB Enterprises, inefficient Eductor and Sumps technologies and means were applied, which, by design and pumping incapacity, failed to cause a lowering of the water table by more than 6 meters.

In late September 2022, the contractor JB Enterprises requested design and execution support from HOELSCHER FERRER NORTH AMERICA, Inc. (HFNA), who after a thorough analysis and calculation proposed a dewatering system based on 10 low-capacity deep wells (LCW). The proposal was justified with a three-dimensional numerical calculation model (FEFLOW code) and accepted by JB Enterprises. The trust, support and collaboration demonstrated by the contractor resulted in the resolution and control of the problem in 45 days, which allowed the construction of the pumping station to proceed.



1. Photograph taken during excavation works.



2. Site location

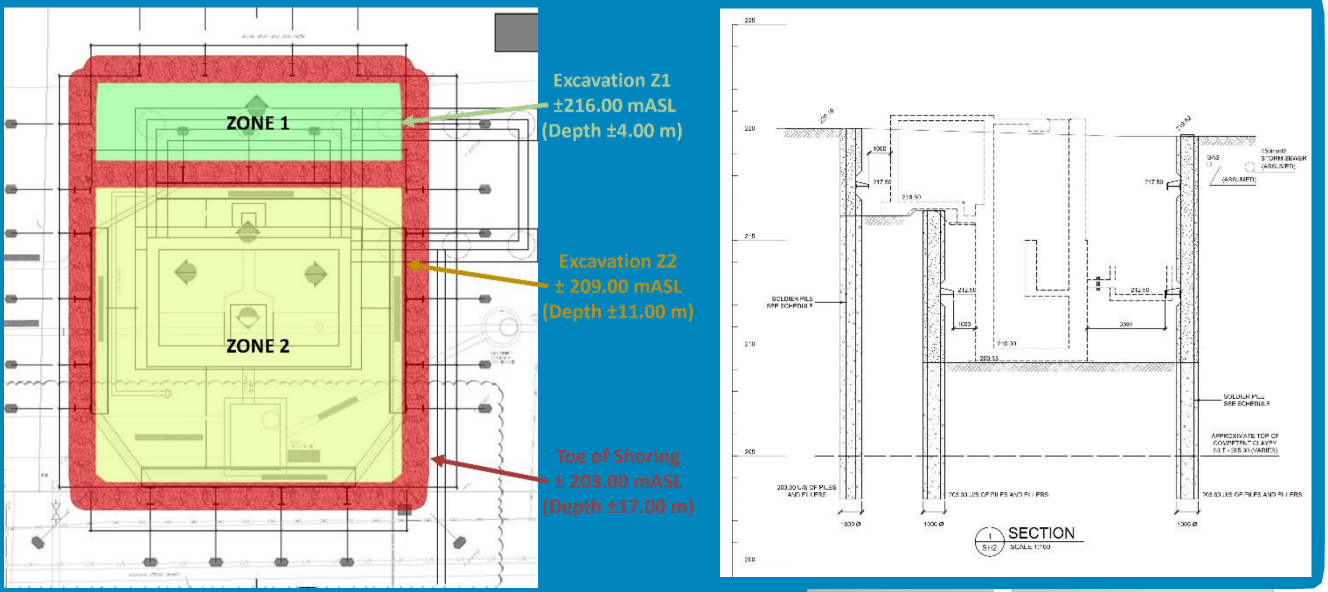
FUNDAMENTAL DESCRIPTION OF THE PUMPING STATION STRUCTURE

The project consists of a sewage pumping station as part of the renovation and expansion plan of the Orillia city sanitation project.

The pumping station, with construction dimensions of approximately 200 m^2 (16.5 x 12.0) m, requires excavation at two depth levels, zone 1 (green) and zone 2 (yellow). See Figure 3.

Zone 1 was to reach a depth of 4 meters, and Zone 2, 11 meters. Subsequently, it was decided to increase the excavation of Zone 2 by an additional one meter in depth.

Both zones are confined by a 17-meter-deep secant pile screen, highlighted in red.



3. Plan and Section of the pumping station

CONCEPTUAL ANALYSIS OF HYDROGEOLOGICAL AND BOUNDARY CONDITIONS

The conceptual analysis of the problem already showed the need to (1) apply a deep pumping system that would guarantee the stability of the bottom of the excavation, (2) select a system that would allow pumping a minimum of 50 to 60 l/s, and (3) consider a geometric elevation of the pumped water of 14 to 15 meters.

Based on the above, it was conclusive the need to apply a pumping system based on low-capacity deep wells. The proposal was endorsed, at least by:

(1) The significant energy savings that this option represented compared to other previously used systems.

(2) The versatility and ease of adaptation of the pumping system to possible deviations of the real (measured) flow rate from the theoretical (calculated) one.

(3) Robustness of the discretized and independent pumping system that, in the event of a pumping well failure, it would maintain the rest of the system operational.

(4) Ease of excavation, because although the HFNA design envisaged locating the wells inside the enclosure, its infrastructure is less than other systems previously used.

(5) Quick execution and installation of the system, except that, for its implementation, the excavated area had to be backfilled to allow access to the drilling machines and operators.

This approach was presented and explained to the contractor JB Enterprises, who accepted the conditions.

THEORETICAL SIZING AND QUANTIFICATION USING FEFLOW NUMERICAL CODE

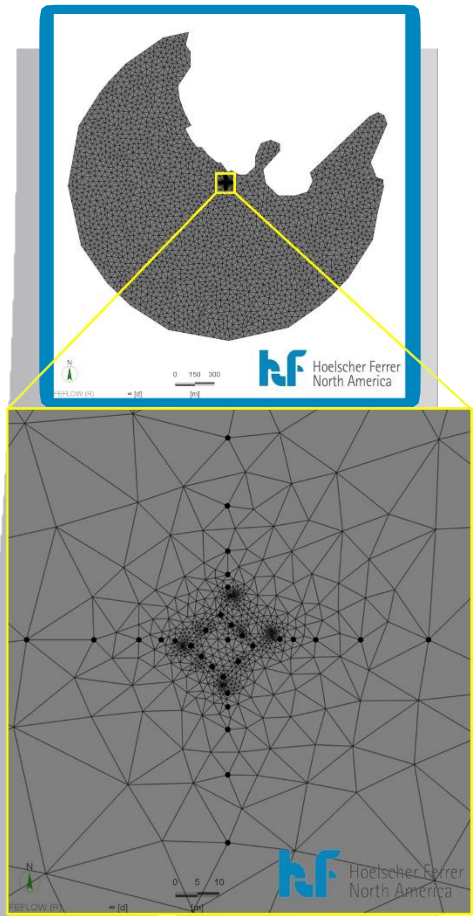
Once the system to be used (LCW) was determined, it was time to design it. To do this, the first step would be to quantify the expected flow and distribution as an extraction route, determining the number of pumping wells and their depths.

Due to the complex geometry, the heterogeneous conditions of the soil and its markedly anisotropic flow behavior, it would be necessary to use a numerical calculation model, simplified analytical calculations not being valid.

For the calculation of the flow in porous media, the three-dimensional numerical computer code FEFLOW, based on Finite Elements, was used under license. Table 5 shows the adopted values with which the model was input and their description.

After the calculation meshes, successive iterations and the application of the boundary conditions (recharge edges), the model was presented as shown in Figure 4.

The optimal iteration resulted in the operation of 10 deep wells in a permanent regime, with the calculated result shown in Figure 6.



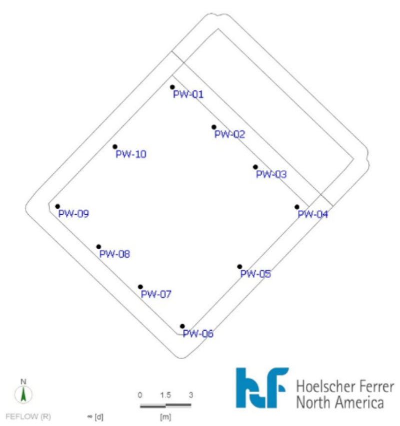
4. Numerical-computation-model generated meshes

Level (masl)	Depth (m)	Slice	Layer	Elevation	Observation/Justification	Calculated Kh (m/s)	Calculated Kv (m/s)	F.S. 1 Kh (m/s)	F.S. 1 Kv (m/s)	Stratum
219.00	1.00	S1		219.00	Groundwater Level	1.00E-04	5.00E-05	1.00E-04	5.00E-05	FILL
216.90	3.10	S2	L1	216.90	Stratigraphic Change					
215.40	4.60	S3	L2	215.40	Stratigraphic Change	6.00E-06	1.80E-06	6.00E-06	1.80E-06	PEAT
213.90	6.10	S4	L3	213.90	Stratigraphic Change	1.00E-05	3.50E-06	1.00E-05	3.50E-06	SILT & CLAY
209.30	10.70	S5	L4	209.30	Stratigraphic Change	2.00E-04	1.20E-04	2.00E-04	1.20E-04	SANDY SILT
209.00	11.00	S6	L5	209.00	Excavation Z2	4.00E-04	3.20E-04	4.00E-04	3.20E-04	GRAVELY SAND & SILT GLACIAL TILL
208.00	12.00	S7	L6	208.00	Target level					
204.80	15.20	S8	L7	204.80	Stratigraphic Change					
203.00	17.00	S9	L8	203.00	Toe of Pumping Well Z2 and Toe of Wall	2.70E-04	1.89E-04	2.70E-04	1.89E-04	SANDY SILT
201.70	18.30	S10	L9	201.70	Stratigraphic Change					
200.90	19.10	S11	L10	200.90	Stratigraphic Change	2.00E-06	5.00E-07	2.00E-06	5.00E-07	CLAYEY SILT
200.20	19.80	S12	L11	200.20	Stratigraphic Change	2.70E-04	1.89E-04	2.70E-04	1.89E-04	SANDY SILT
180.00	40.00	S13	L12	180.00	Impermeable Base	2.00E-05	8.00E-06	2.00E-05	8.00E-06	SAND &ROCK FRAGMENTS
						5.00E-09	5.00E-09	5.00E-09	5.00E-09	Secant Pile Wall

5. Elevations, values and description considered in the numerical computation model

TOTAL PUMPING FLOW (STEADY FLOW) WOULD BE BETWEEN 2,409,092.12 L/d (27.88 L/s) AND 2,944,445.93 L/d (34.08 L/

MATHEMATICAL RESULT = 2,676,769.03 L/day (30.98 L/s)



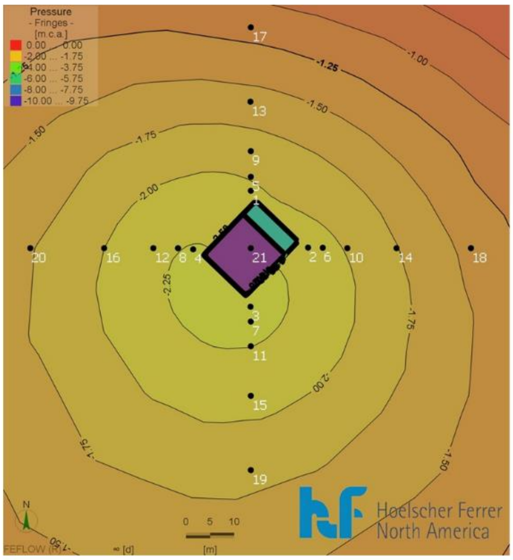
Flow distribution in each well

Pumping Well	X	Y	Z	Node	Slice	Flow (L/s)	Pressure (mWC)
PW-01	5181.53542	1873.82267	203.00	23876	9	3.36	4.50
PW-02	5183.97383	1871.47811	203.00	23762	9	2.60	4.50
PW-03	5186.41223	1869.13355	203.00	23784	9	2.36	4.50
PW-04	5188.85063	1866.78899	203.00	23811	9	3.41	4.50
PW-05	5185.48622	1863.28991	203.00	23858	9	3.27	4.50
PW-06	5182.12181	1859.79084	203.00	23756	9	3.24	4.50
PW-07	5179.65979	1862.10429	203.00	23887	9	3.07	4.50
PW-08	5177.21493	1864.45506	203.00	23833	9	3.05	4.50
PW-09	5174.80631	1866.82421	203.00	23817	9	3.23	4.50
PW-10	5178.17086	1870.32344	203.00	23851	9	3.39	4.50

Pumping flow and pressure distribution calculated at the base of the well.

6. Calculated values (steady state). Total pumping flow rate and flow distribution in each well.

Figure 7 shows the generic curves of calculated water table drawdowns, both in the pumping wells and in the series of "virtual piezometers". It can be seen for example that, mathematically, piezometer number 21, located in the center of the excavation, shows a drawdown of 11.51 meters. Therefore, the target drawdown would be achieved.



Drawdown Curves

Pumping wells (calculated drawdown levels)

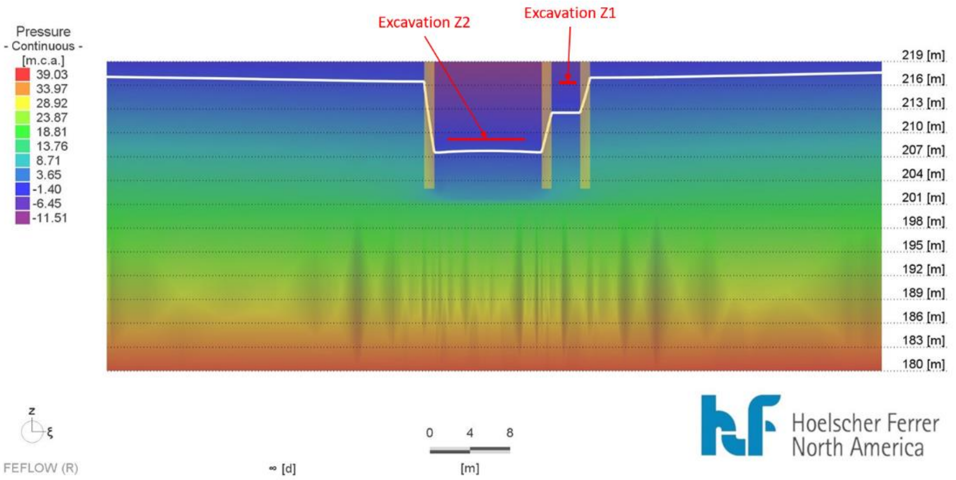
Pumping Well	X	Y	Z	Node	Slice	Pressure (mWC)
PW-01	5181.54	1873.82	219.00	124	1	-11.51
PW-02	5183.97	1871.48	219.00	10	1	-11.51
PW-03	5186.41	1869.13	219.00	32	1	-11.51
PW-04	5188.85	1866.79	219.00	59	1	-11.51
PW-05	5185.49	1863.29	219.00	106	1	-11.51
PW-06	5182.12	1859.79	219.00	4	1	-11.51
PW-07	5179.66	1862.10	219.00	135	1	-11.51
PW-08	5177.21	1864.46	219.00	81	1	-11.51
PW-09	5174.81	1866.82	219.00	65	1	-11.51
PW-10	5178.17	1870.32	219.00	99	1	-11.51

Virtual monitoring wells (calculated drawdown levels)

Virtual Monitoring Wells	X	Y	Z	Node	Slice	Pressure (mWC)
1	5183.15	1880.05	219.00	73	1	-2.03
2	5194.95	1868.30	219.00	15	1	-2.11
3	5183.09	1856.07	219.00	117	1	-2.33
4	5171.24	1867.94	219.00	21	1	-2.26
5	5183.15	1882.93	219.00	78	1	-1.99
6	5197.99	1868.26	219.00	107	1	-2.07
7	5183.15	1853.02	219.00	77	1	-2.31
8	5168.10	1868.18	219.00	68	1	-2.24
9	5183.15	1888.24	219.00	79	1	-1.87
10	5203.05	1868.18	219.00	123	1	-1.98
11	5183.15	1847.90	219.00	76	1	-2.25
12	5163.02	1868.18	219.00	113	1	-2.18
13	5183.05	1898.46	219.00	2	1	-1.60
14	5213.21	1868.18	219.00	55	1	-1.76
15	5183.15	1837.66	219.00	75	1	-2.09
16	5152.87	1868.18	219.00	24	1	-2.00
17	5183.15	1913.82	219.00	72	1	-1.16
18	5228.56	1868.18	219.00	5	1	-1.43
19	5183.15	1822.30	219.00	71	1	-1.83
20	5137.63	1868.18	219.00	115	1	-1.73
21	5183.15	1868.18	219.00	74	1	-11.51

7. General and specific calculated drawdowns in virtual wells and piezometers.

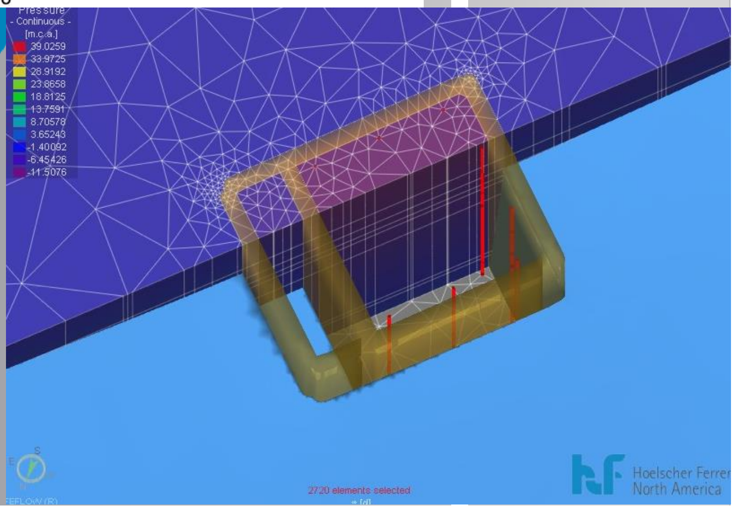
Figure 8A above shows a section of the computed downslope (white line), and 8B below its three-dimensional image, with the sole intention of better approximating the understanding of the effect.



Continuous pressure – Section A-A’
White line = pressure 0

8A. Calculated water table drawdown section

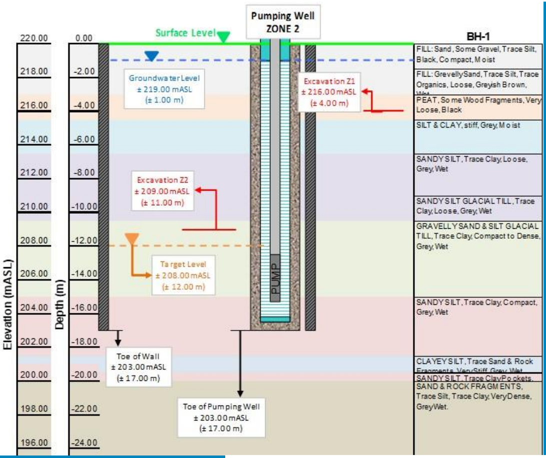
8B. Calculated 3D drawdown



EXECUTION AND INSTALLATION OF LOW-CAPACITY WELL SYSTEM

At the time of our intervention (HFNA), the excavation had a depth of around 6 meters. Prior to the execution of the pumping wells, it was necessary to backfill the excavation to surface level for safe access of machinery and work equipment.

Once the excavation was backfilled and in accordance with the theoretical design, the 10 low-capacity wells were constructed. According to the design shown in Figure 9 left, diameter 244 mm (10"), casing 140 mm (5.5"), filter pipe, centering devices and bottom cover, the wells were equipped with 4" submersible electric pumps. The drilling system used was roto-percussion with hammer at the bottom, dual, with simultaneous advance of auxiliary pipe and drill string, with cleaning sweep with compressed air, avoiding the use of muds that could alter the natural permeability of the ground. The equipment used is shown in Figure 9 right.



9-Left. Well design. Stratigraphy; 9-Right. DUAL system drilling rig.

FINAL CONSIDERATIONS. RESULTS.

- The construction of the wells became extremely complicated, given that the soil on which they were working had been backfilled, without compaction or natural cohesion, which caused excessive differential settlements of the rig.
- Due to schedules and job award dates, there were days of work at temperatures below - 20°C (- 4°F), which conditioned some of the processes and undoubtedly reduced production.
- The wells made inside the enclosure confined by the screen piles are not intended and designed to cause a lowering of the level outside the enclosure. It so happened that occasional, but significant, water leaks also manifested themselves through the secant piles. To compensate for this effect, a series of boreholes were drilled outside the perimeter.
- The theoretical flow model (calculated) resulted in a pumping flow rate somewhat lower than the actual (measured) flow rate, evidently and at a minimum, due to contributions from vertical preferential pathways and seepage through the screen piles. Against all hindrances, the pumping flow rate was kept within the limits of the project permits.

The system operated correctly and water table control was achieved on schedule, resolving any unforeseen issues that arose with the collaborative solutions between JB Enterprises and HFNA.

10. Photograph of the resulting excavation of the project, showing the low capacity well (LCW) system operating satisfactorily.