GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

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Groundwater Monitoring Plan

HDD FM Alignment – Assessment of a Safe Setback from Water Wells

Prepared For:

Comox Valley Regional District (CVRD)

Prepared By:

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GW Solutions Inc. General Conditions and Limitations

1 BACKGROUND

The Comox Valley Regional District (CVRD, client) has commissioned upgrades to the regional wastewater facilities, as part of the CVRD Liquid Waste Management Plan. Several routes were considered for piping wastewater from the Courtenay Pump Station on Comox Road to the Treatment Plant on Brent Road, Comox. However, due to a topographic high, a horizontally directional drilled solution through Lazo Hill is preferred.

GW Solutions Inc. (GWS) has presented a work plan for monitoring groundwater quantity and quality prior to, during, and after construction of the proposed liquid waste pipe (HDD Line). This work has been presented in reports in July 2021, and September 2021.

As a supplement of the monitoring program design, the current report summarizes the steps we took to estimate a safe setback distance from the HDD line to nearby private water wells (used for domestic water supply) to help inform the alignment of the tunneled pipeline.

2 METHODOLOGY

The study area covers an area of approximately 1.9 km^2 and contains 88 reported private water wells. The safe setback distance was estimated based on the groundwater travel times from the HDD line to the private wells in the main sand aquifer (Aquifer #408). Travel time was estimated based on the aquifer properties (hydraulic conductivity, transmissivity, and storage coefficient) estimated with a pumping test conducted nearby in Aquifer #408.

The methods used to estimate the three aquifer properties (hydraulic conductivity, transmissivity, and storage coefficient) needed to calculate average linear velocity and travel time were based on geologic and hydrogeologic information determined from previous investigations.

The risks of impact to wells are dependent on two factors:

1. The distance of the wells to the HDD line, in particular whether pumping from a well may pull water from the aquifer at the right of HDD line. Calculating the radius of influence of a well provides information on the estimated safe distance a well should be from the HDD line.

2. The time it takes for groundwater to travel to a well. Breakdown, natural filtration and treatment processes of pathogens and potential contaminants originating from a potential leak of the HDD line are functions of the medium and the groundwater regime. The longer the travel time, the less the chance of having a risk of negative impact on the water quality of the pumped water. Therefore, travel times were estimated.

It is our understanding that the CVRD tries to enhance the design of the alignment to meet the applicable regulations in addition to implementing the preventive measures in place. According to Section 8 of the Health Hazard Regulation:

"A person who installs a well, or who controls a well installed on or after July 20, 1917, must ensure that the well is located at least

(a) 30 m from any probable source of contamination,

(b) 6 m from any private dwelling, and

(c) unless contamination of the well would be impossible because of the physical conformation, 120 m from any cemetery or dumping ground."

The present report summarizes the safe distances to secure the water quality in the nearby water wells, based on the aquifer characteristics, typical domestic pumping rates, well radius of influence, groundwater travel times and relative distance from the HDD line.

In the absence of pumping test results from the wells in the project area, the aquifer characteristics (hydraulic conductivity, transmissivity, and storage coefficient) were estimated based on a former pump test at a different location within Aquifer #408. In addition, generic assigned aquifer characteristics from the literature for fine-grained sand formations and previously published reports for Aquifer #408 were used for confirmation of the estimated values.

2.1 Travel Times

The equation used to obtain average linear velocity of groundwater moving through a porous media (Lohman, 1972, p. 10) is:

$$v = -\frac{K}{n} \times \frac{dh}{L}$$

Equation 1

Where:

- v is the average linear velocity of groundwater (m/s);
- K is the hydraulic conductivity of the aquifer (m/s);
- n is the effective porosity (%); and,
- $\frac{dh}{L}$ is the horizontal hydraulic gradient (m/m).
- The negative sign indicates that the direction of movement is downgradient. Travel time along any given segment of a flow line is obtained from:

$$t_v = \frac{L}{v}$$

Equation 2

Where:

- t_v is the travel time; and,
- L is the length of the flow-line segment (m)

The parameters used in the equation are shown in Figure 1.

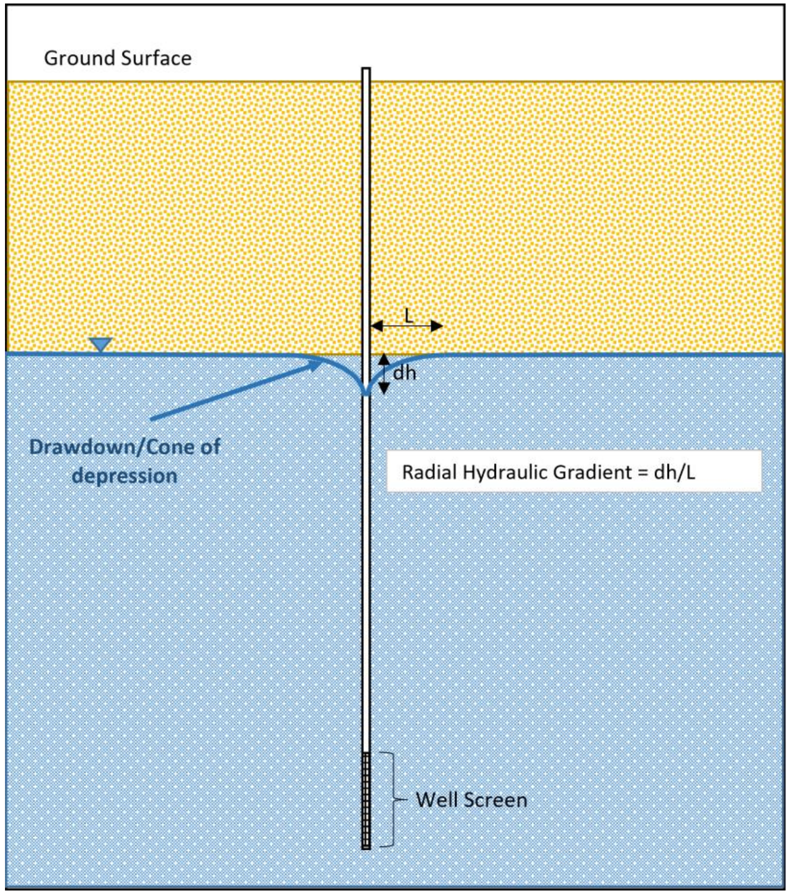

Figure 1. Schematic View of The Parameters in Travel Time Calculations

2.2 Flow in the Unsaturated Zone

2.2.1 Process

As shown in Figure 2, Aquifer #408 is unconfined and is directly connected to an unsaturated (vadose) zone above the water table. The alignment is reportedly designed to be installed within the unsaturated zone (compact dry sand), on average 10 m above the water table. As such, any potential leakage from the sewage line would percolate through the unsaturated zone before reaching the water table and mixing with the groundwater in the saturated zone (the aquifer).

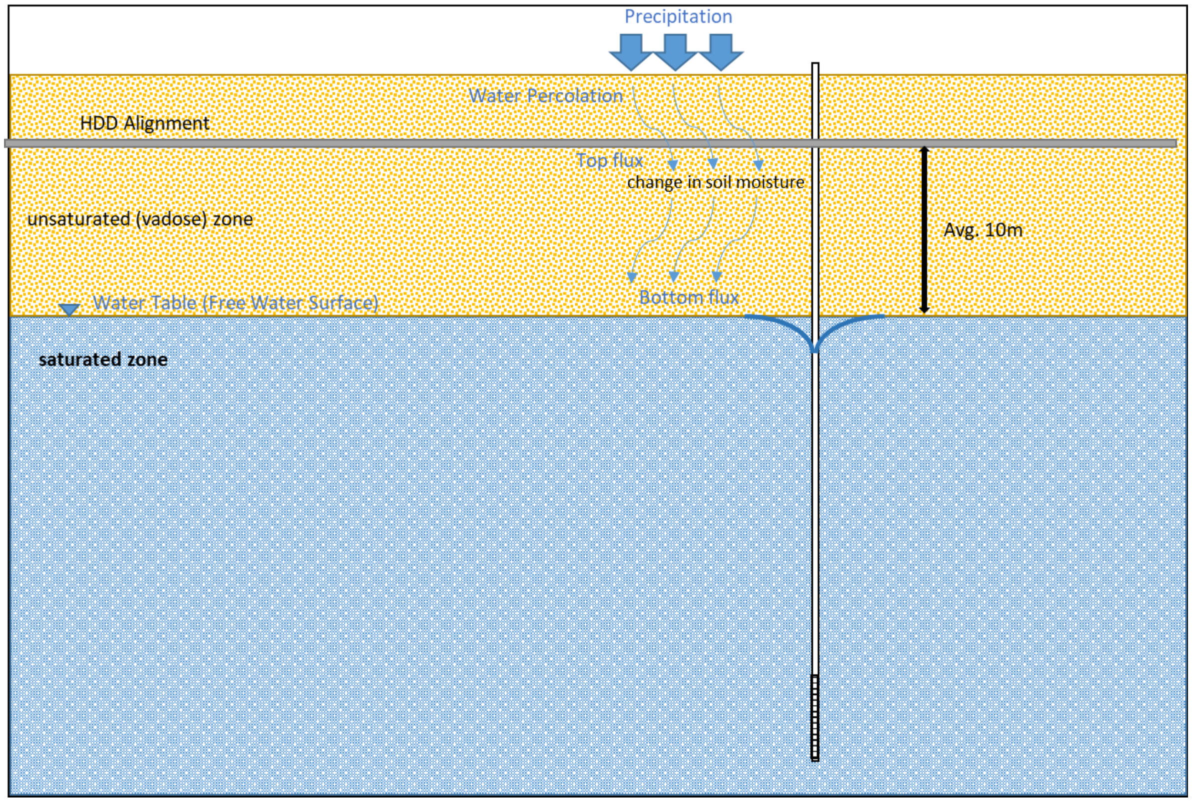

Figure 2. Schematic View of the Vadose Zone Processes

In the vadose zone, gravity-driven downward seepage of water is induced by precipitation or recharge events. Therefore, water flow is anticipated to be higher in the wet season and lower in the dry season. Following a precipitation event, water percolates into the soil and increases the soil moisture. The increased soil moisture results in higher number of saturated pores, inducing the water flow through the porous medium.

2.2.2 Hydrus 1-D Model

We modelled the movement of water within the vadose zone using the HYDRUS-1D Software. HYDRUS-1D is an open source software package for simulating water, heat, and solute movement in one-dimensional variably-saturated media. The software has been verified against a large number of test cases. To estimate the water travel time from the HD alignment depth to the water table, the results of water flux in the top and bottom sections of the vadose zone were used.

The HYDRUS program numerically solves the Richards equation for variably saturated water flow and advection-dispersion type equations for heat and solute transport. The program may be used to analyze water and solute movement in unsaturated, partially saturated, or fully saturated porous media. Flow and transport can occur in the vertical, horizontal, or a generally inclined direction. The water flow part of the model can deal with prescribed head and flux boundaries, boundaries controlled by atmospheric conditions, as well as free drainage boundary conditions. The governing flow and transport equations are solved numerically using Galerkin-type linear finite element schemes. HYDRUS also includes a Marquardt-Levenberg type parameter optimization algorithm for inverse estimation of soil hydraulic and/or solute transport and reaction parameters from measured transient or steady-state flow and/or transport conditions.

A modified van Genuchten model was used to solve the hydraulic equations. The inputs were soil material (fine sand) characteristics and monthly precipitation statistics for Comox from January 2020 to January 2021. Constant pressure head boundary conditions were set for both upper (negative pressure head) and lower (atmospheric pressure) model domain boundaries. The model was solved for a 10 m long column of unsaturated sand to mimic the average distance between the sewer line and the free water surface of the saturated zone of the aquifer.

2.3 Aquifer Characteristics – Saturated Zone

An aquifer is characterized by its transmissivity (*T*) and storativity (*S*). These parameters are the determining factors in groundwater flow. The transmissivity represents the ability of the aquifer to transmit water (related to pore diameter, connection, etc.). The transmissivity also represents the rate at which groundwater can flow through an aquifer section of unit width. The transmissivity is related to the hydraulic conductivity (K) according to the following relationship:

$$T = K \times b$$

- *b* being the aquifer thickness in a confined aquifer.
- The transmissivity and hydraulic conductivity were estimated from a 24-hour pumping test within aquifer #408, using the USGS Cooper-Jacob analysis spreadsheet.
- The average distance between the top of Quadra sand formation and the top of the underlying low-permeability formation was chosen as the aquifer thickness, *b*.
- The storativity is the value calculated based on the results of the former pumping test completed in Aquifer #408.

2.4 Groundwater Flow Direction and Well Capture Zones – Saturated Flow

Within the saturated portion of the aquifer, groundwater travels in a predominantly horizontal direction from a higher hydraulic head towards a lower head. Laminar (non-turbulent) groundwater flow in the vertical direction is usually approximated to be ten times slower than in the horizontal direction. This is due to a lower hydraulic conductivity in the vertical direction caused by the natural flattening of geologic materials in that direction.

We modelled the regional and local groundwater flow directions and well capture zones. The open-source WhAEM software was used for this purpose. WhAEM is an analytical element model, which solves steady state groundwater flow in a single aquifer, based on the Dupuit-Forchheimer approximation. It has been produced by Haitjema Software, a subdivision of Haitjema Consulting, Inc. under contract with the USEPA. The program consists of a Visual Basic (VB6) Graphical User Interface (GUI) and an analytical element code written in Fortran to provide the groundwater flow solutions.

The model inputs includes the aquifer characteristics (see section 3.1), upper and lower boundary conditions, and typical domestic well pumping rates.

At the watershed scale, the water elevation in Brooklyn Creek was used as the upper boundary condition and the water level in the Lazo Marshlands east of the subject areas was used as the lower regional boundary condition. Both of these boundary conditions were refined in the vicinity of the subject areas to calibrate the model with the foregoing water levels in the observation wells.

At the local scale, model boundaries were calibrated and modified using the groundwater elevations measured in four deep wells in the area in April and May 2021. These wells and the head difference between the measured and modelled values are listed in Table 1. As shown, the difference between the observed and modelled groundwater heads is between 3 to 19 cm, which is an acceptable (up to 1.8%) variance.

Table 1. Flow Model Calibration

Label	Obs. Head (m)	Model Head (m)	Head Diff. (m)	Percent Difference
74271	10.69	10.50	0.19	1.8%
Well 13	11.40	11.34	0.05	0.5%
Well 12	9.06	9.10	0.04	0.5%
67556	12.50	12.53	0.03	0.3%

3 RESULTS

3.1 Fluid Movement in the Unsaturated Zone

The unsaturated zone model was solved for a 1-year duration, with time steps as listed in Table 2. The model start time is January 31, and it continues to simulate the water flow for one year (January 31 next year). As such, the quarterly time steps correspond to the end of April, July, October, and January of the next year.

As shown in Figure 3 and Figure 4, both soil water content and the fluid movement (flux) within the vadose zone are highly dependent on precipitation.

In Figure 3, at the depth of 10 m the water content reaches 0.45 which is equal to the maximum porosity of the soil at the top of the aquifer.

It is observed that in the wet seasons and/or following a large precipitation event, water content and fluxes increase substantially.

We ran the model for a range of possible characteristics of fine-grained sand (i.e. soil porosity (n) and hydraulic conductivity (K)). The results from different model runs are shown in Figure 5 and summarized in Table 3. As seen, for different sand characteristics, the simulation results are consistent, with minimum, maximum, and average travel times of 36, 330, and 70 days in the unsaturated zone, respectively.

Table 2. Time Steps of Unsaturated Model

Time Step	Days After Model Start	Month (end of)
T1	90	April
T2	180	July
T3	270	October
T4	360	January

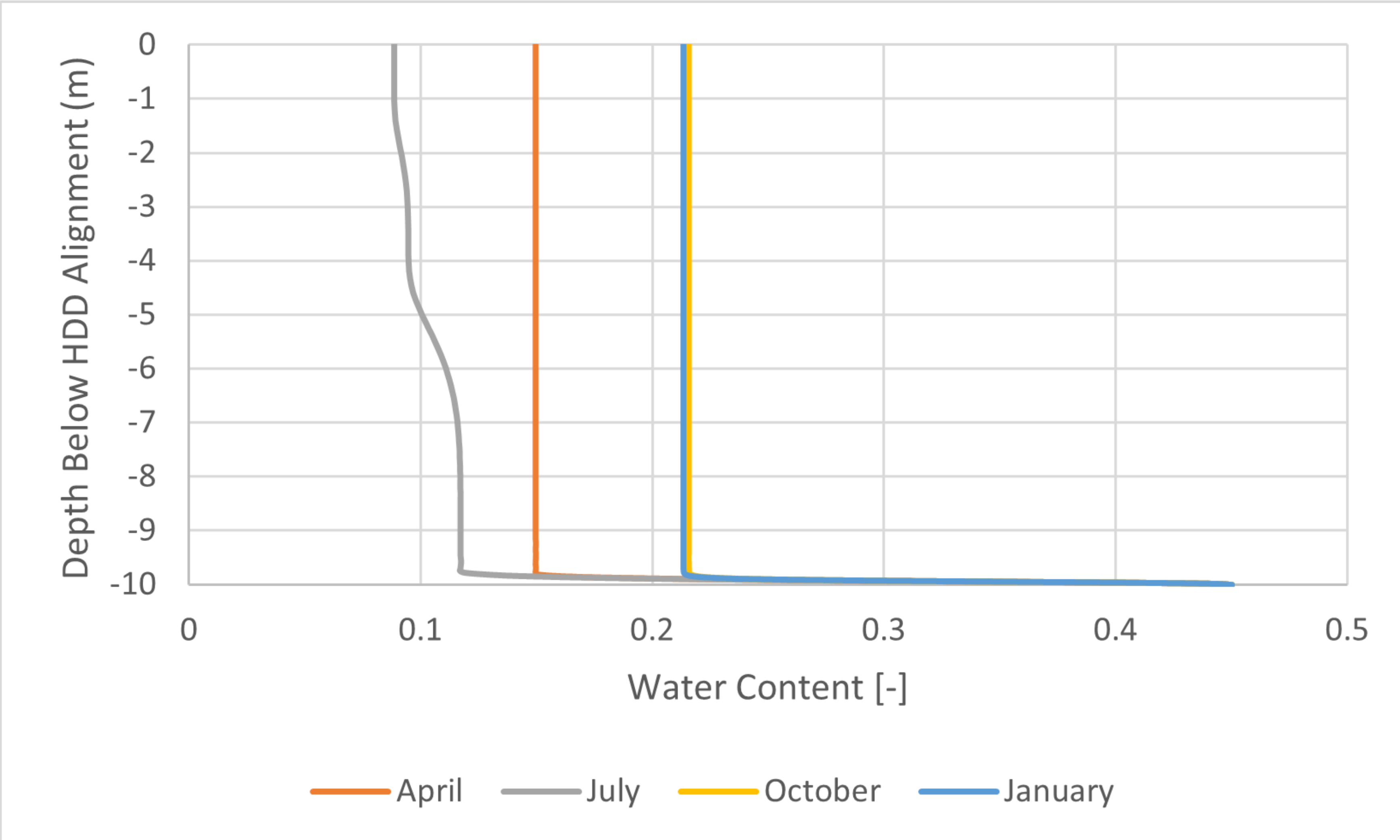

Figure 3. Water Content vs. Depth

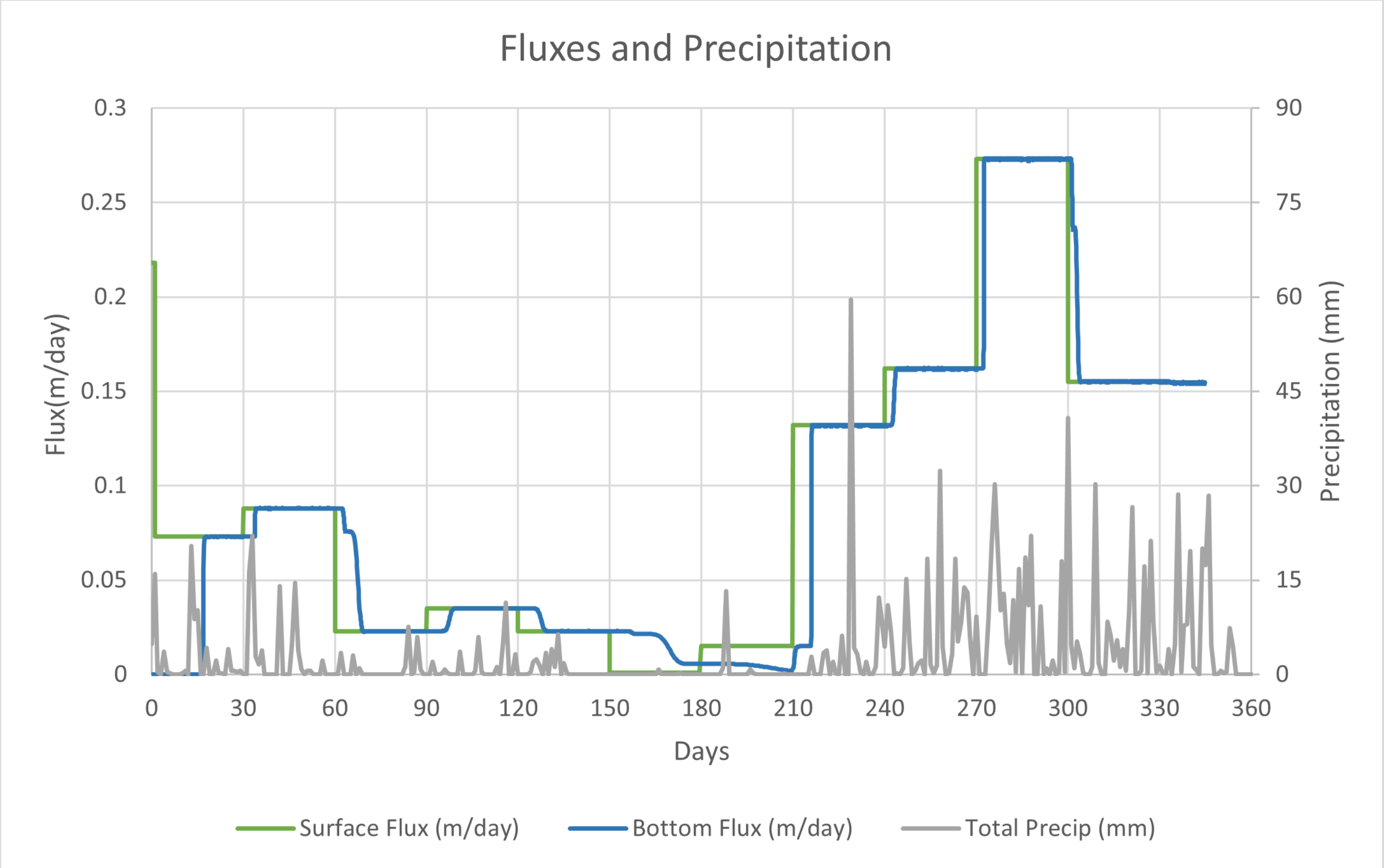

Figure 4. Fluxes in the Vadose Zone – Daily Precipitation

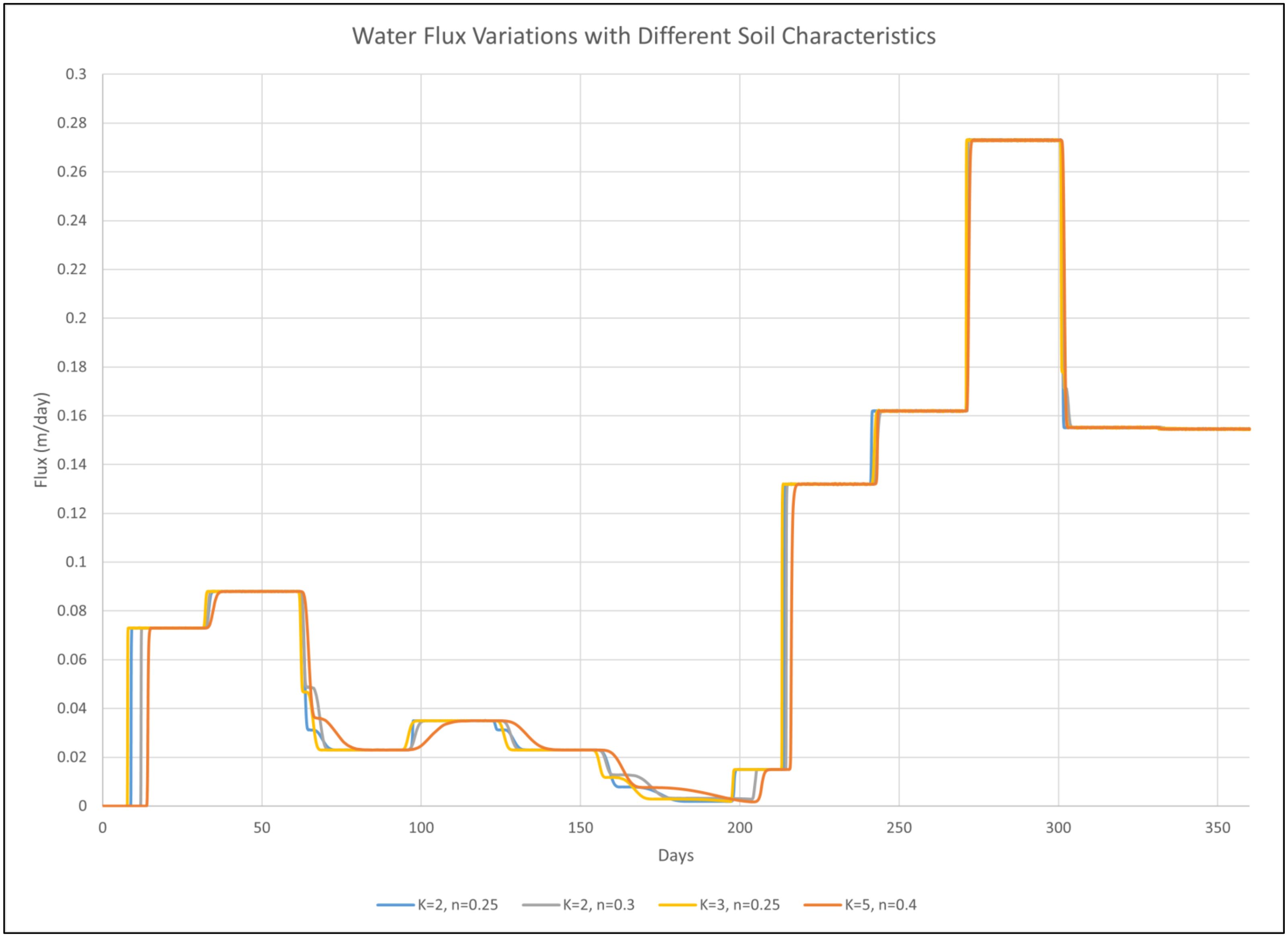

Figure 5. Flux Variations in Different Model Runs

Table 3. Water Fluxes and Travel Time within the Vadose Zone

K (m/day)	n [-]	Max Flux (m/day)	Min Travel Time (Days)	Min Flux (m/day)	Max Travel Time (Days)	Average Flux (m/day)	Average Travel Time (Days)
2	0.25	0.27	36	0.03	330	0.15	70
2	0.3						
3	0.25						
5	0.4						

3.2 Aquifer Characteristics

The Cooper-Jacob analysis was used to estimate the hydraulic conductivity and transmissivity of the aquifer. A pump test conducted on a well in Williams Beach in April 2020 was used for this purpose. This well was completed in Aquifer #408 and its distance from the shoreline is similar to the current project location. The results were compared to other published reports on the hydraulic conductivity of Aquifer #408, and other literature to confirm the estimated value. Figure 6 shows the log-log drawdown vs. time plot of the Cooper-Jacob analysis. Based on these, the hydraulic conductivity and transmissivity of the aquifer will have the ranges summarized below:

Aquifer Thickness	b =	~40	m
Hydraulic conductivity	K =	2.5 to 5	m/day
Transmissivity	T =	100 to 207	m^2/day
Storativity	S =	7.2E-03	(-)

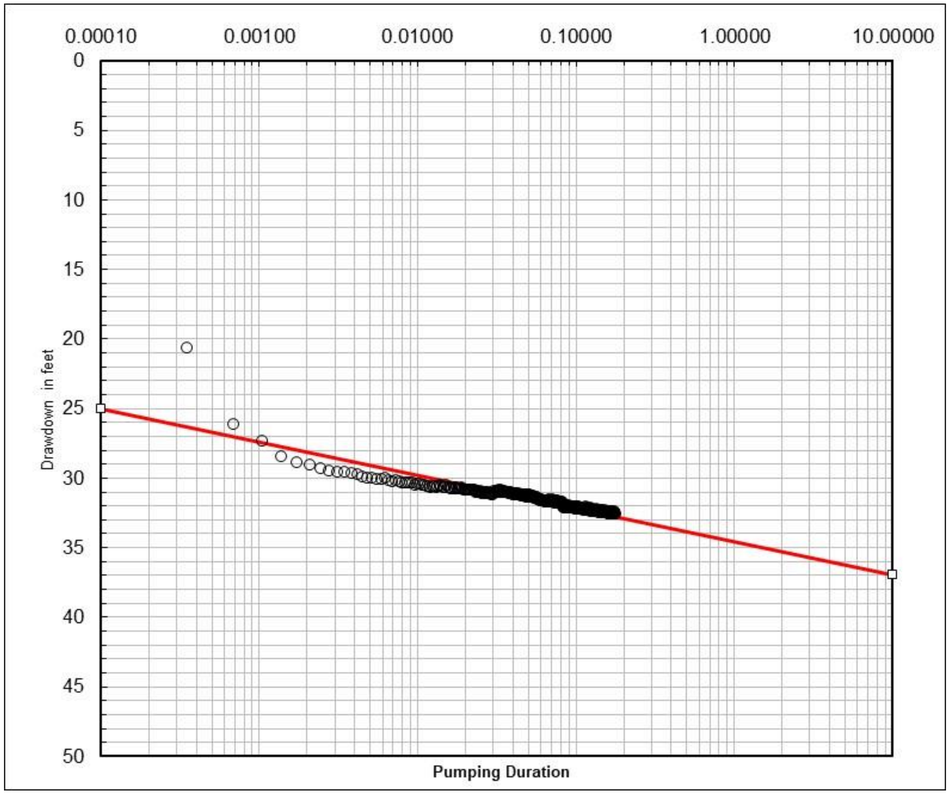

Figure 6. Cooper-Jacob Fitting Curve

3.3 Drawdown Curve and Radius of Influence (ROI)

Based on the estimated values of the hydraulic conductivity, transmissivity and storage coefficient, the average ROIs for different pumping rate and duration scenarios were estimated. In the absence of reported pumping rates for the wells in the area, we assumed the average of 0.5, 1, 2, and 3 USgpm and the average pumping durations of 1, 2, 3, and 5 hours per day, which cover a typical range of pumping rates and durations for domestic water wells.

The results are compared in Table 4 and shown in Figure 7. A drawdown of >1 cm was chosen as the criteria for defining the ROI and thus drawdowns of <1 cm are deemed outside of the ROI. The 1 cm line is thus marked on the chart in Figure 7.

As shown in Table 4, in the most extreme scenario, the drawdown at the constant pumping rate of 3 USgpm, for the 5 hours pumping duration was estimated at approximately 0.9 cm at a distance of 60 m. Therefore, 60 m was estimated to be the approximate ROI for this pumping rate and duration. However, this pumping rate and duration is considered conservative and is presented in this report only for comparison.

Actual pumping duration in domestic single family household wells typically does not exceed 1 USgpm for 3 to 5 hours per day. Thus, the pumping rate at 1 USgpm for 5 hours daily was considered the most representative and still a conservative scenario. The drawdown of less than 1 cm at this pumping rate and duration was estimated to be reached at a distance of approximately 15 m from the well. Due to the inherent uncertainty associated with this calculation, we recommend a 25% safety factor leading to a ROI of 20 m. This setback radius is shown in Figure 8. Figure 9 shows a cross-section through the study area with well depths, water table elevation, and the proposed HDD line's depth.

The cross section shows that the shallow domestic wells (less than 10 m depth) in the vicinity of the HDD line are not likely to be affected by a potential leakage (wells No. 16377, 12439, 12001, 12343, Well 15), as the bottom of these wells is located 8 to 25 m above the HDD line. The only exception is Well 12315, with a bottom elevation located approximately 2 m above the HDD line. However, this well is located at a horizontal distance of approximately 60 m up-gradient from the HDD line and thus it is highly unlikely for this well to be affected by a potential leakage from the HDD line.

The radius of influence estimated by this analytical model assumes a zero natural groundwater velocity in the domain. This model does not consider the movement of groundwater and therefore, estimates an ROI that is conservative in that the actual ROI will be less. While the results of this model are acceptable for a general setback from the wells, a more realistic model for groundwater flow should include the groundwater flow velocity to estimate a well capture zone around and towards a well. This becomes more important when the pumping rates are low and groundwater movement has a significant effect on the water movement near the well bore. In reality, groundwater velocity plays an important role in the fate and transport phenomena. As such, we created a numerical model which takes the local groundwater velocity and direction into consideration and gives a more realistic result to estimate the groundwater travel time towards the wells.

Table 4. Drawdowns at Different Flow Rates, Pumping Durations, and Distances

Flow (USgpm)	Transmissivity (m^2/s)	Storage (-)	Pumping Duration (hours)	Drawdown (cm)	Distance (m)
0.5	2.40E-03	7.2E-03	1	0.8	1
0.5			2	0.9	1
0.5			3	0.9	1
0.5			5	0.7	5
1			1	0.8	8
1			2	0.9	8
1			3	0.9	10
1			5	0.9	15
2			1	0.9	18
2			2	0.9	25
2			3	0.9	30
2			5	0.7	50
3			1	0.8	30
3			2	0.6	50
3			3	0.8	50
3			5	0.9	60

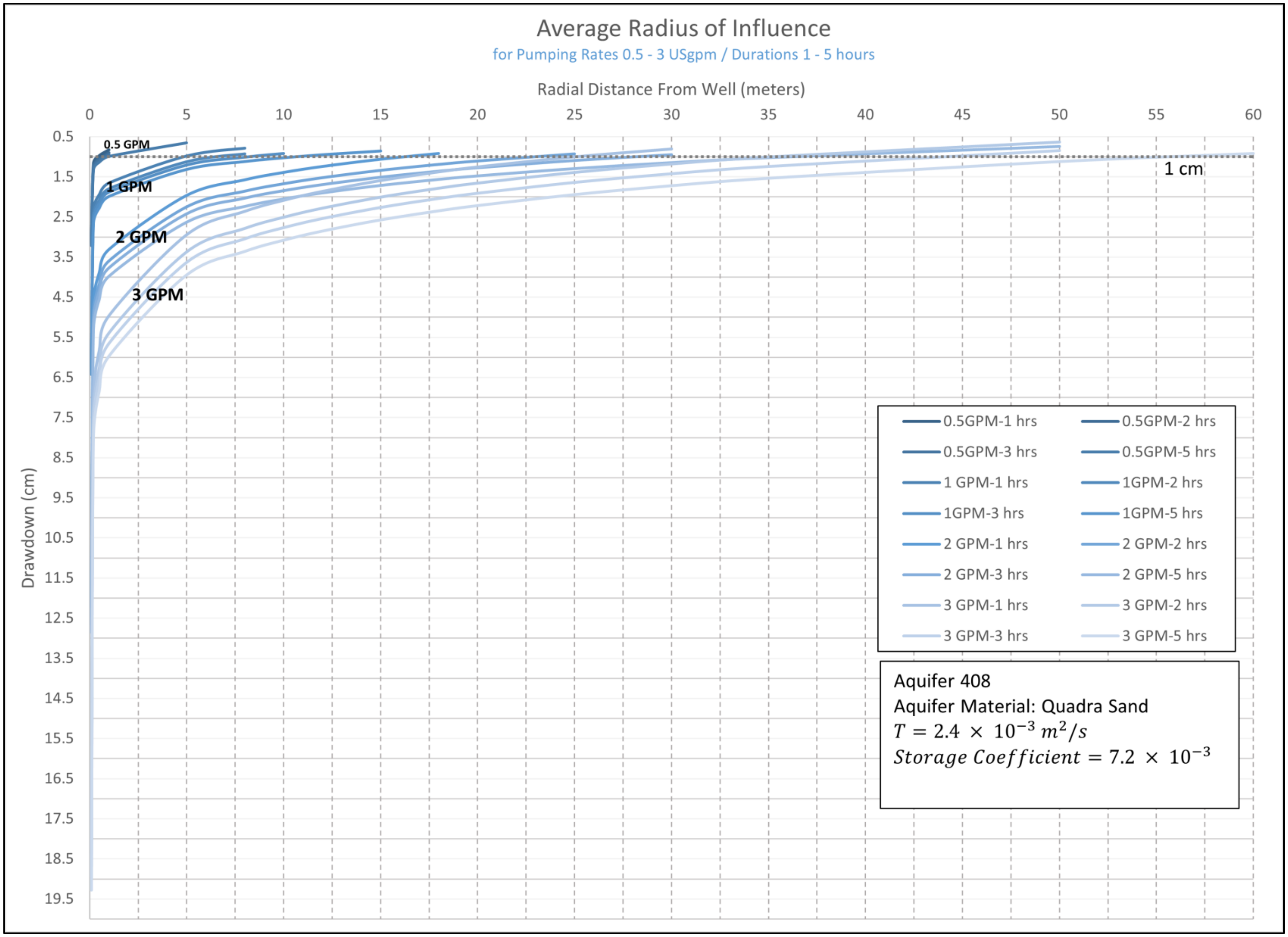

Figure 7. Average Estimated ROI Diagram for Different Pumping Rates and Durations

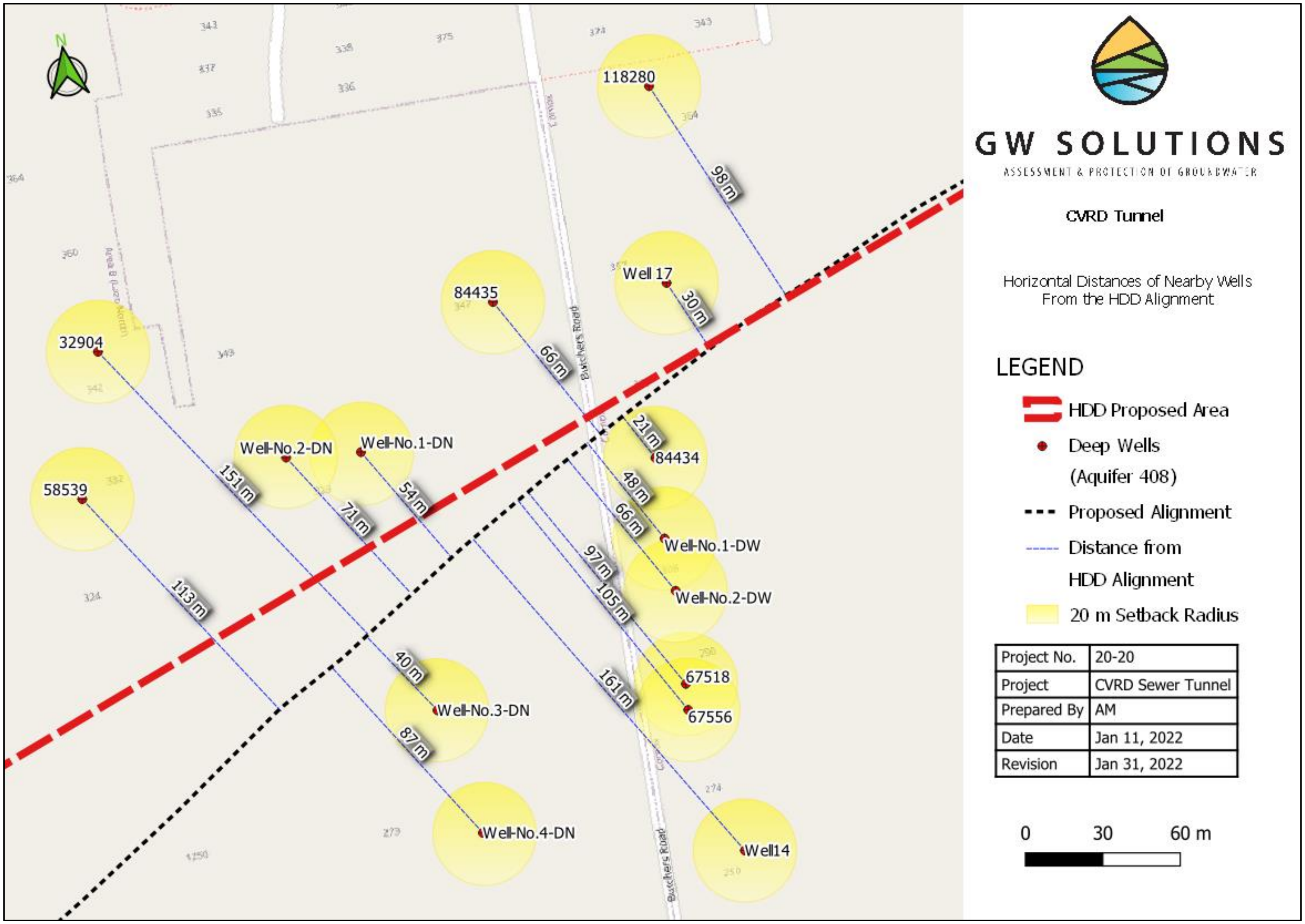

Figure 8. Horizontal Distances from HDD Line

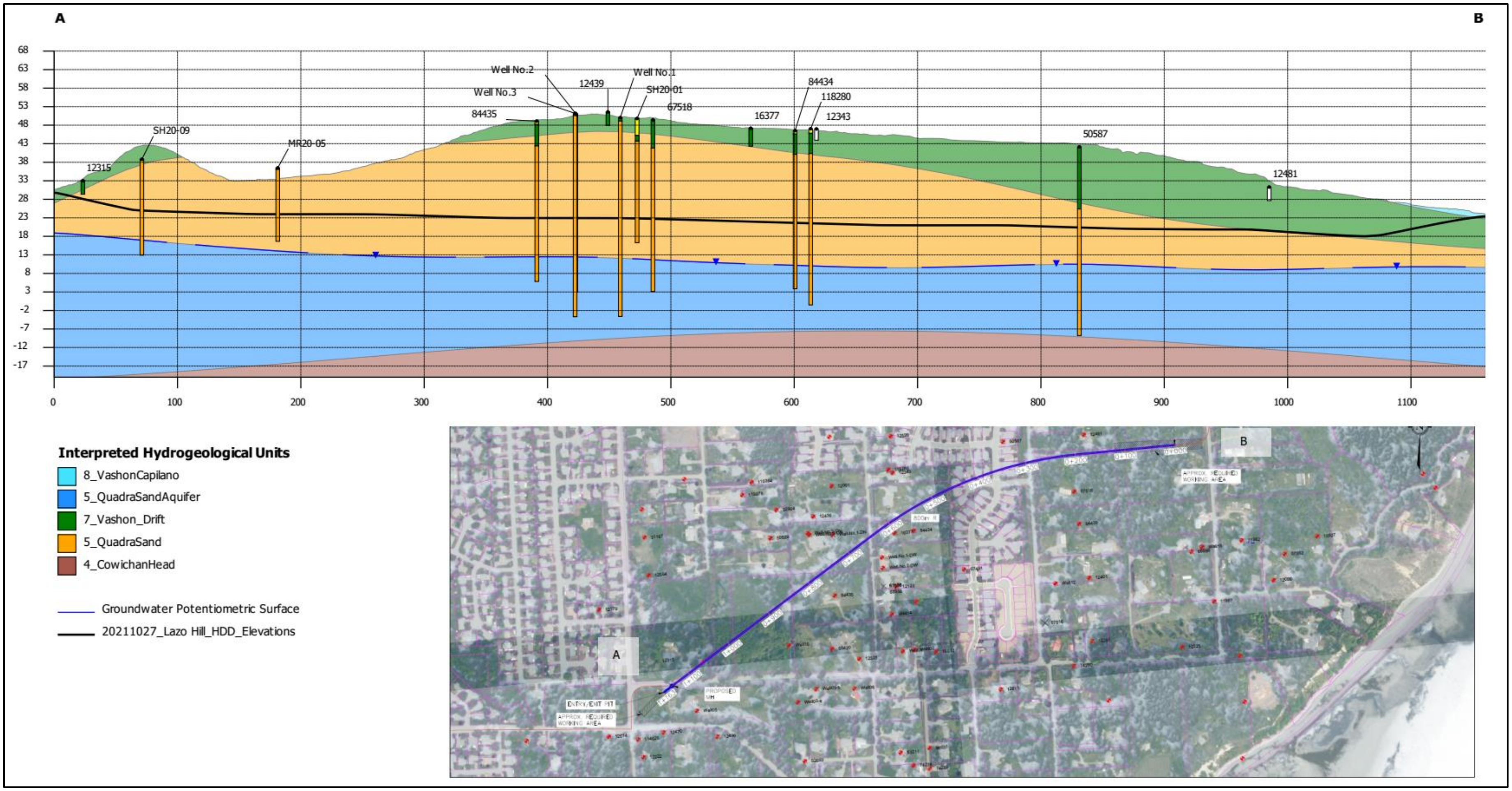

Figure 9. Cross-Section view of the proposed HDD line and nearby wells

3.4 Groundwater Flow Direction and Well Capture Zones

3.4.1 Regional Groundwater Flow Direction

As mentioned in Section 2.4, the water level at the upper and lower boundaries determines the groundwater flow direction and velocity. In the current case, Brooklyn Creek represents the upper boundary and the marshlands east of the subject areas as well as the coastline to the south were used to define the lower boundary conditions. As expected, the modelled regional groundwater flow direction is from northwest towards south and southeast (towards the ocean), as shown in Figure 10.

3.4.2 Local Groundwater Flow Direction

Due to the heterogeneity of the porous medium, anisotropies in different flow directions (horizontal and vertical), local geological and hydrogeological variations, the groundwater flow direction in a local scale may partially deviate from the regional pattern. The outcome of this direction change can be seen in groundwater fluctuations in the water levels in wells. As such, water levels in four wells in the area were used for the refinement of the local groundwater flow direction (see Table 1). The results of this refinement of boundary conditions and local groundwater flow directions are shown in Figure 11. Note that in this model, the different arrow sizes indicate the magnitude of velocity at each location. As seen, while the general flow direction is still following the regional pattern from northwest to south and southeast, the effect of local groundwater recharge locally modifies the groundwater movement.

We conclude that based on the general groundwater flow direction, the wells located upgradient (north) of the HDD alignment are very unlikely to be affected by a potential leakage from the alignment.

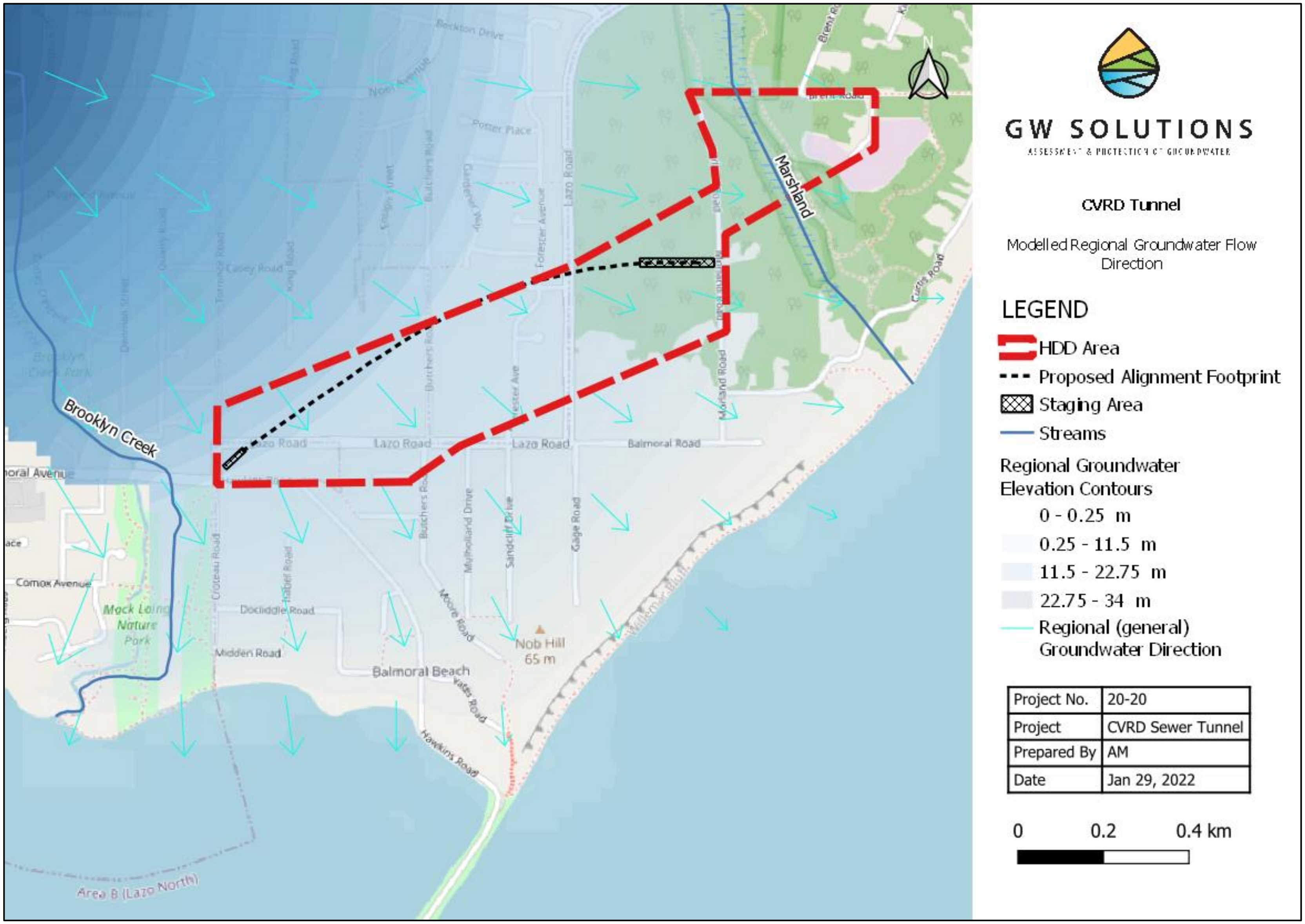

Figure 10. Regional Groundwater Flow Direction

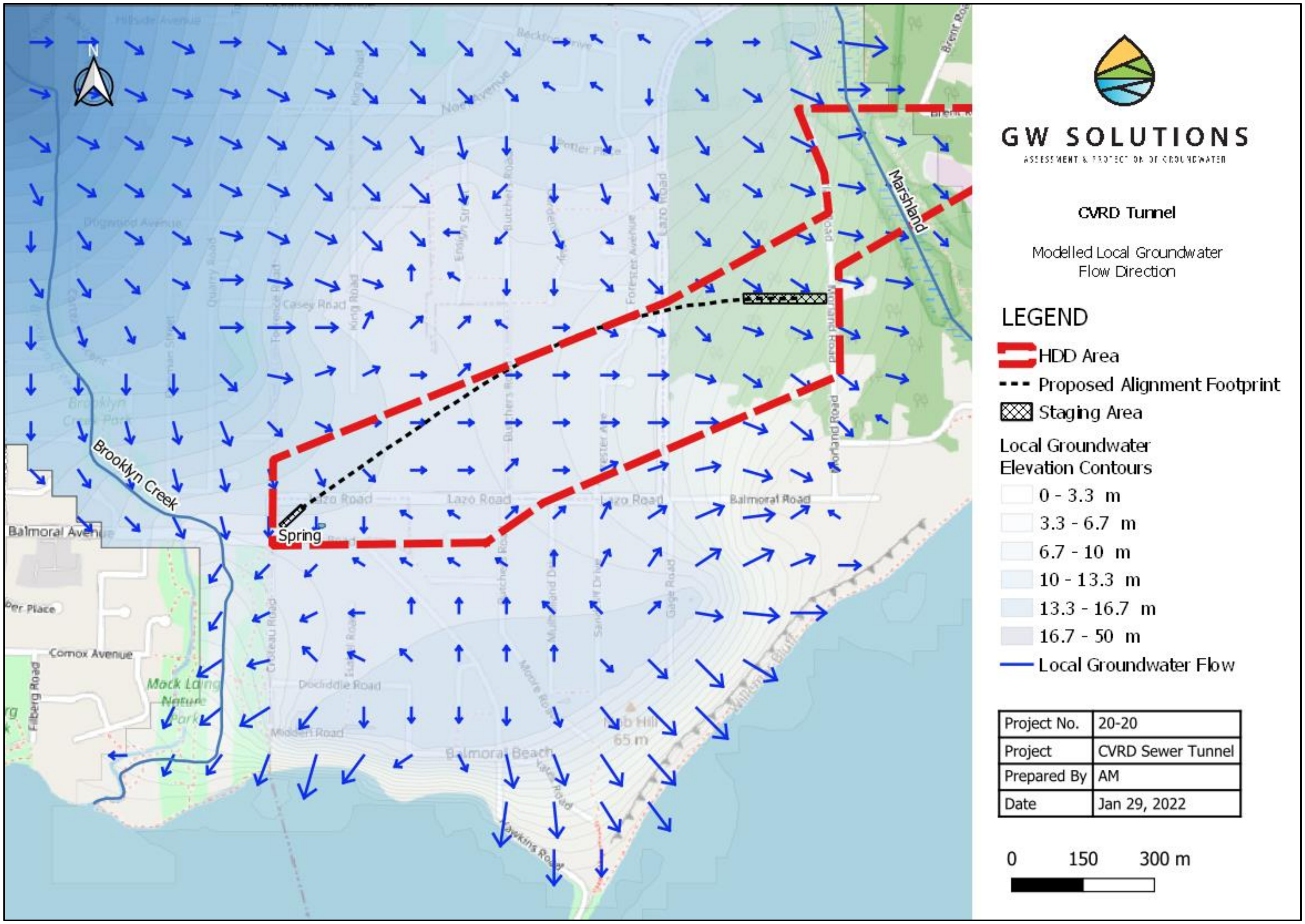

Figure 11. An Example of Modelling Results for The Local Groundwater Flow Direction

4 WELL CAPTURE ZONE AND TOTAL TRAVEL TIME

4.1 Radial Travel Time

Based on the well pumping rates as well as our estimations of the groundwater flow direction and velocity, we modelled the well capture zones to estimate the ROI of the wells, and the groundwater travel times from the HDD alignment to the wells. As mentioned before, the typical well pumping rate and durations used for domestic wells was 1 USgpm for 5 hours of daily pumping (Section 3.3).

We ran the model with different typical characteristics of a compacted sand aquifer (porosity, hydraulic conductivity) to compare the possible scenarios of groundwater velocity and travel times. The flow direction dictates the route and the distance that potential contamination would follow prior to reaching a well. Groundwater velocity determines how long it takes for the potential contamination to reach the well along that route. Table 5 summarizes the ranges and the average of flow velocity and travel times. For each hydraulic conductivity range and soil porosity range, the shortest, the longest and the average travel time for three different distances is estimated and presented. In each case, the values of travel time from Table 5, added to the travel time in the unsaturated zone (Table 3), is the estimate of the total travel time from the alignment to a well. Figure 12 schematically shows this approximation. Figure 13 shows the well capture zones and average travel time ranges within the saturated aquifer.

Table 5. Flow Velocity and Travel Times in the Saturated Zone

K (m/day)	n [-]	Distance (m)	Max V (cm/day)	Min V (cm/day)	Min Travel Time (days)	Max Travel Time (days)	Average Travel Time (days)
2.5 to 5	0.2 to 0.45	20	13 to 26	2 to 4	80 to 150	420 to 850	250 to 500
		30			115 to 230	640 to 1270	380 to 750
		45			170 to 340	1000 to 1905	620 to 1100

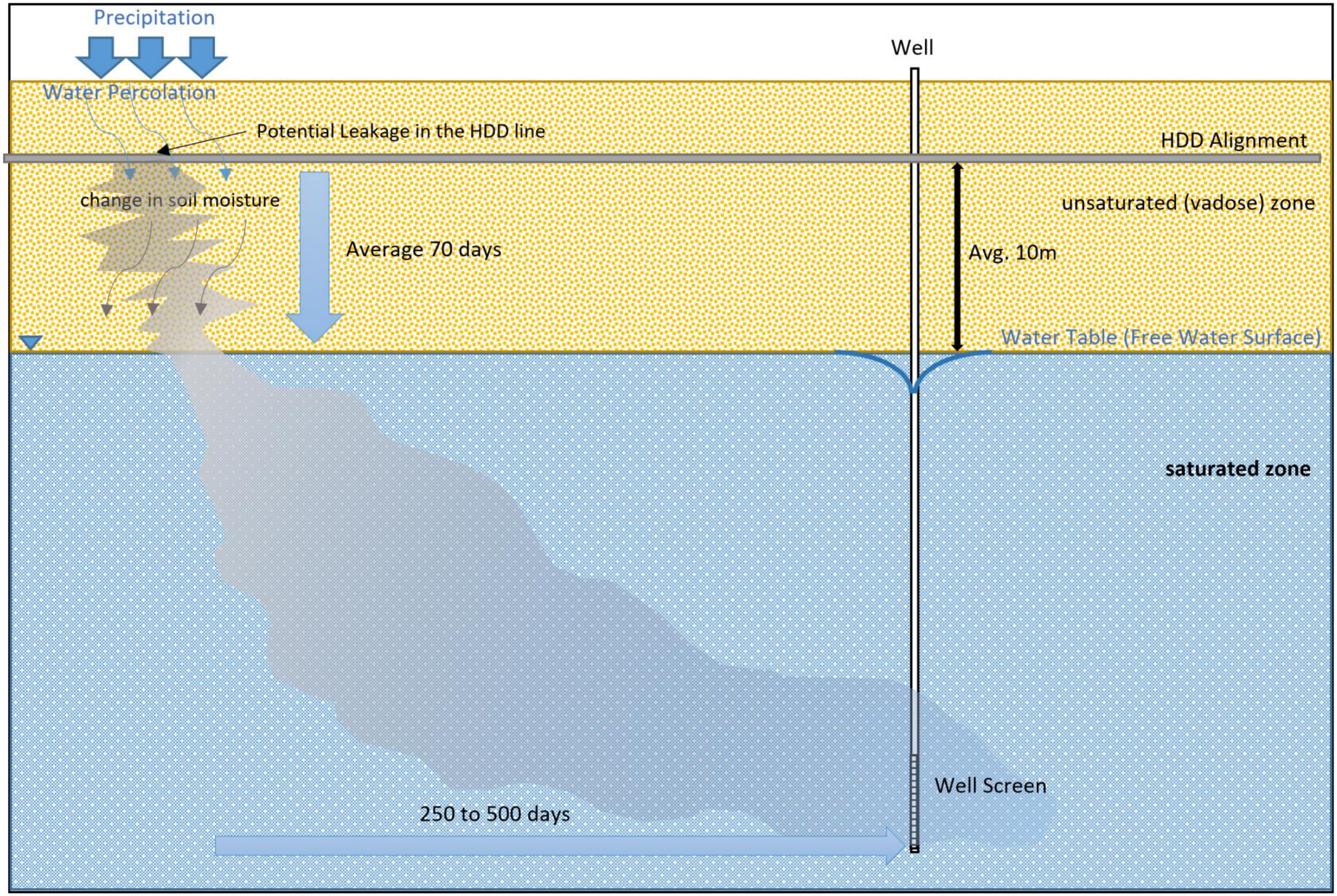

Figure 12. Schematic View of Fluid Movement and Travel Time within Different Zones (unsaturated and saturated) of the Aquifer

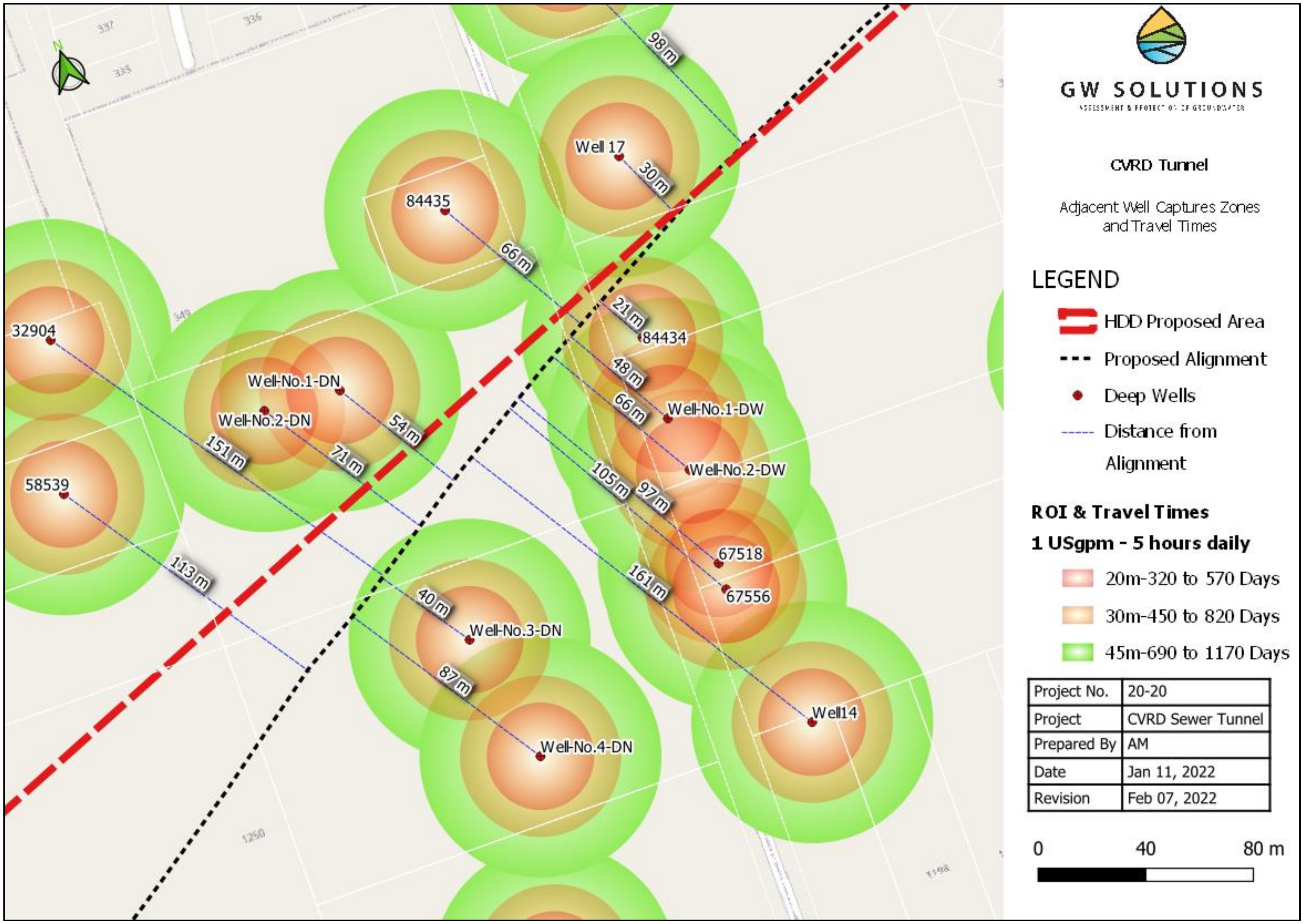

Figure 13. Radius of Influence and Total Travel Time (Saturated and Unsaturated)

4.2 Vertical Travel Times

The mode of deposition and vertical compression of aquifer materials generally results in an anisotropy in its permeability such that the vertical flow velocity is significantly less than the horizontal flow velocity. The vertical-to-horizontal hydraulic conductivity anisotropy ratio is given by Kz/Kr where Kz is the vertical hydraulic conductivity and Kr is the radial (horizontal) hydraulic conductivity. According to literature[1], values of Kz/Kr typically range between 0.1 and 0.5 for unconsolidated material, with lower values for fine-grained material.

In the current case, given the composition (fine-grained quadra sand) of the aquifer, an anisotropy ratio of 0.1 is chosen. As such, the estimated hydraulic conductivity in the vertical direction (Kz) will be the horizontal Hydraulic Conductivity (Kr) divided by 10. With this low an anisotropy ratio, the Dupuit-Forchheimer approximation, which neglects vertical flow, can be used.

[1] E.g. Todd, D.K., 1980. Groundwater Hydrology, 2nd ed., John Wiley & Sons, New York, 535p.

5 CONCLUSIONS

Based on the completed work, we draw the following conclusions:

- The groundwater flow and travel times to residential wells completed in Aquifer #408 have been estimated. Aquifer #408 is below the proposed HDD line separated by an unsatured zone. Several domestic wells are present within the study area. The aquifer characteristics were estimated as follows:

Hydraulic conductivity K =	2.5 to 5	m/day
Transmissivity T =	100 to 207	m^2/day
Storativity S =	7.2 E-03	(-)

- The radius of Influence (ROI) of the residential wells were calculated for pumping rates between 0.5 and 3 USgpm and pumping durations between 1 and 5 hours. The most representative and still conservative scenario is pumping at a rate of 1 USgpm for a maximum duration of 5 hours daily. With this scenario, the estimated horizontal ROI is 20 m which includes 25% of safety factor.

- The travel time within the unsaturated zone of Aquifer #408 was modelled by Hydrus 1D and estimated to be 70 days, on average. This process is mainly driven by recharge rom precipitation events. Local and recent data (Comox total daily precipitation for 2021) was used for the simulations.

- Well capture zones and travel times within the saturated zone of Aquifer 408 were modelled using WhAEM. Due to the difference in hydraulic gradient and groundwater velocity at different locations, the well capture zones vary by location. In the area closest to the HDD alignment, the travel time was estimated to be between 250 and 500 days for the modelled well capture zones.

- The total estimated travel time is the sum of travel times in both the unsaturated and saturated zones. For the wells nearest to the HDD alignment this time was estimated between 320 and 570 days. These estimates corresponds to a distance of 20 meters from HDD.

- The majority of the wells are at greater distances from the proposed alignment than the estimated ROI (20 m). The only wells reported to be within or adjacent to this distance are two shallow wells; Well12481, and Well 16377, which are highly unlikely to be affected by a potential contaminant migration from the sewer line, as their bottom depths are located above the proposed HDD line; therefore, it is highly unlikely for potential contaminants to migrate to these wells.

6 RECOMMENDATIONS

We make the following recommendations:

- A "sentinel" monitoring program should be designed to accompany the HDD line leak detection program to identify as quickly as possible a potential leak from the HDD line. The program should provide early warnings so that remediation measures could be implemented in time to prevent any negative impact to the water quality of nearby wells.

- Residents should be informed that domestic water wells should be located at distance greater than 20 m from the HDD line to reduce the risk of impact resulting from a potential leak from the HDD line.

Study Limitations

This document was prepared for the exclusive use of the Comox Valley Regional District (CVRD). The inferences concerning the data, site and receiving environment conditions contained in this document are based on information obtained during investigations conducted at the site by GW Solutions and others and are based solely on the condition of the site at the time of the site studies. Soil, surface water and groundwater conditions may vary with location, depth, time, sampling methodology, analytical techniques, and other factors.

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The CVRD may rely on the information contained in this memorandum subject to the above limitations.

7 CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this letter-report.

This letter report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix 1.

GW Solutions was pleased to produce this document. If you have any questions, please contact us.

Yours truly,

GW Solutions Inc.

Prepared by:

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8 REFERENCES

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APPENDIX 1

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these "General Conditions and Limitations".

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;

(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These

procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.