Revised Geotechnical Engineering and Hydrogeologic Assessment
Wastewater Treatment Plant Improvements
Wasilla, Alaska

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REVISED GEOTECHNICAL ENGINEERING AND HYDROGEOLOGIC ASSESSMENT WASTEWATER TREATMENT PLANT IMPROVEMENTS WASILLA, ALASKA

1.0 INTRODUCTION

This report presents the results of geotechnical engineering and hydrogeologic studies conducted by Shannon & Wilson, Inc. (S&W) for improvements to the existing Wastewater Treatment Plant (WWTP) in Wasilla, Alaska. The findings and conclusions presented herein supersede those provided in the previous version of this report dated July 2016. The proposed improvements generally include an overland percolation and wetland/bioswale-type treatment area in a 70-acre parcel to the west of the existing facility. The purpose of these studies was to evaluate the available subsurface information at the site, conduct a hydrogeologic evaluation of the development options, and make geotechnical engineering recommendations to support design and construction of the project. This work supplements the data presented in our June 2016, *Revised Geotechnical Data Report, Wastewater Treatment Plant Improvements, Wasilla, Alaska*. S&W also provided support during prior phases of this project which were submitted in our May 2008 *Geotechnical Report, Wastewater Treatment Plant Percolation Cell, Wasilla, Alaska*.

To accomplish our objectives, we reviewed subsurface data from explorations at the project site, performed engineering studies to develop design recommendations for the proposed improvements, and developed a numerical groundwater model to evaluate the hydrogeologic site conditions under multiple development scenarios. Presented in this report are descriptions of the site and project, an interpretation of subsurface soil and hydrogeologic conditions, our geotechnical engineering recommendations, and the results and analysis from our groundwater modeling.

Authorization to proceed with this work was received in the form of a Subconsultant Agreement, signed by Mr. Dean Syta, P.E. of Stantec on March 6, 2015. Our work was conducted in general accordance with our July 7, 2014 proposal with the exception that several of the proposed boring locations were inaccessible due to shallow water and soft ground conditions. Five of the planned borings were not able to be advanced. In addition, wet and thawed conditions caused the project scope to change and additional funds were authorized by Mr. Syta and the City of Wasilla (Purchase Order 20822) on April 24, 2015.

2.0 SITE DESCRIPTION

The existing WWTP is located on Jude Drive in Wasilla, Alaska. The facility consists of several buildings, a four-cell aerated lagoon system, and nine percolation beds. Generally, the project area slopes down to the west and south from the area of the existing facilities. The existing buildings and facilities are at an approximate elevation of 250 feet. Immediately west lie the existing sewage lagoons and an undeveloped upland area which is at approximate elevation 245 feet. The elevation drops to the west of the undeveloped upland to approximately elevation 215 feet into the proposed, approximately 70-acre wetland treatment area. This area is subsequently referred to as the WWTP wetland. The WWTP wetland slopes gently down to the south until it intersects the southern property line and then turns eastward, roughly parallel to the property line. A stream runs along the southern property line at the toe of a 20 to 30-foot high bluff adjacent to the southern edge of the existing percolation beds. The stream acts an outlet to drain the WWTP wetland, and likely includes water derived from groundwater flowing into the wetland along its flanks and from an effluent seep that exists along the toe of the bluff above. At the time of explorations, the undeveloped upland area west of the existing facilities were thick with vegetation, including mature trees, brush, and grasses. The low-lying, WWTP wetland area was hummocky, boggy, and standing water was observed in numerous locations. A vicinity map showing the general project location is included as Figure 1. Prominent site features and exploration locations are shown on the site plan included as Figure 2.

3.0 PROJECT DESCRIPTION

The proposed improvements generally include an overland percolation and wetland/bioswale-type treatment area in the WWTP wetland. According to concept drawings, a distribution pipe will be constructed to transport primary treated effluent to designated discharge locations near the northern end of the WWTP wetland, where the effluent will be allowed to flow freely over the ground surface and into the wetland area. At the time of this report, pipe length and sizing had not yet been determined. We assume where the pipe will be buried below the ground surface it will be done so using a traditional open trench method.

We understand that three alternative scenarios are being considered for developments in the wetland to provide controls for effluent flow within the wetland area. These application scenarios are shown in Figures 3 through 5 and briefly described below:

- Application Scenario 1: Discharge to Unimproved Wetlands - Effluent would be discharged at designated discharge points and allowed to flow freely through the wetland area to a point of compliance at the southern wetland edge.

- Application Scenario 2: Discharge to Enhanced Wetlands - Berms are constructed in the WWTP wetland to encourage ponding, discourage channelization, and prevent rapid loss of effluent to the stream. Berms are 6 to 12 inches high and stretch across the wetland perpendicular to flow.

- Application Scenario 3: Discharge to Pond and Enhanced Wetlands - A large berm is constructed in the northern portion of the wetland to create a pond 4 to 5 feet deep. Additional, smaller berms, similar to those in Application Scenario 2 are constructed downstream for flow control.

At the time of this report, the project was in a conceptual design phase and specific details regarding the project elements were not yet determined. In addition to the effluent distribution system described above, we understand that other improvements associated with the project may include a small building structure near the pipe outfall and a pump building along the new discharge pipe in the upland portion of the site. We assume these buildings will be relatively lightly loaded, wood- or steel-framed structures supported on conventional shallow foundations. The structures may be unheated during the winter if wetland discharge is only conducted during the summer months. Gravel access roads may be constructed to provide access to the discharge outfalls and wetland area for construction and maintenance activities.

4.0 SUBSURFACE CONDITIONS

Several prior geotechnical explorations have been conducted at the project site. Subsurface explorations for the current project were conducted by Shannon & Wilson in March, May, and June of 2015 and February of 2016. These explorations consisted of drilling and sampling ten soil borings, installing three monitoring wells, and conducting infiltration tests in/near the WWTP wetland. Previous explorations were conducted at the site by Gilfilian Engineering in 1986 and Shannon & Wilson in 2007, primarily to support studies for improvement alternatives in upland portions of the site. The following subsections include a description of the subsurface conditions encountered by our explorations, along with descriptions of conceptualized geology and hydrogeology, groundwater conditions, and groundwater quality.

4.1 Soil Conditions

The soil conditions described below are based on our recent explorations in the area of the proposed development. As such, conditions in other portions of the site are not included in this report. The boring logs and laboratory test results are included in our June 2016 *Revised Geotechnical Data Report, Wastewater Treatment Plant Improvements, Wasilla, Alaska*. In general, subsurface conditions encountered during our recent explorations correlate well to the previous work by Gilfilian in 1986 and Shannon & Wilson in 2007. These prior explorations are discussed in further detail in our 2008 report.

In general, our borings in the WWTP wetland area encountered decomposed organic soil (swamp material) overlying granular material interbedded with occasional thin silt layers. The organic soil thickness ranged from about 2 to 13 feet. Penetration resistance was typically low (less than 2 blows per foot) in the organic layer and sample recovery was difficult. Two borings (Borings B-04 and B-09) were advanced in upland area along the eastern edges of the WWTP wetland and encountered approximately 2 to 3 feet of silt with sand and occasional organics at the surface. Boring B-14 was advanced in the upland area west of the wetland and encountered approximately 1 foot of organic material at the surface. Below the surface silts and organic/swamp material, thin (approximately 2 ½ to 6 feet thick) silt layers were found in several borings (Borings B-01, B-02, B-03, B-08, and B-13). Based on penetration resistance values, these silts were typically medium stiff to very stiff.

Granular materials encountered in our borings consisted of sand and gravel with varying amounts of silt. We identified interfingered zones of alluvium or outwash and glacial till, which were interpreted based on appearance, fines contents, and higher penetration resistance values. The granular materials were generally medium dense to very dense with occasional loose zones. Fines content within the granular soils ranged from 2 to 45 percent with the average at approximately 15 percent. In general, fines contents and penetration resistance values were higher in those materials interpreted as glacial till as compared to soils interpreted as alluvium or outwash.

4.2 Conceptual Geology and Hydrogeology

An understanding of the conceptual hydrogeology and geology of the project area is necessary for developing the groundwater model discussed in Section 6.0. The project area is located near the northern reaches of the Upper Cook Inlet basin, a low-lying structural trough bounded by faults along the Talkeetna and Chugach Mountains and overlying Tertiary rock formations and unconsolidated Quaternary deposits. Bedrock depths generally thicken from north to south in the Upper Cook Inlet area, ranging from exposure along the mountains to over 4,000 feet below the surface near the Susitna River floodplain. Based on mapping shown in Freethey and Scully (1980), bedrock depths in the project area are estimated to be on the order of 300 to 500 feet.

The topography surrounding the project area is the result of multiple glacial advances and retreats during the Pleistocene epoch (about 10,000 to 2 million years ago). The most recent events include the Knik Glaciation and the Naptowne Glaciation, both of which occurred within the past 75,000 years. The post-glacial ground surface exhibits landforms that transition from outwash in the Palmer area to ground moraine in the Wasilla area and westward.

Unconsolidated deposits left behind by these glaciations generally consist of glacial drift, which includes till, outwash stream deposits, and glaciolacustrine deposits. Locally, more modern non-glacial processes have also deposited loess (windblown silt), stream alluvium and fans, along with lacustrine and marine sediments. Unconsolidated deposits in the Wasilla area are dominated by mostly continuous sheets of till separated by outwash deposits. At least two or three sequences of till and outwash are thought to be present beneath the Wasilla area. The till units typically range from about 20 to 70 feet thick with occasional thicker sections. It is postulated that the thicker sections may represent two or more till units in contact. Till in the area is typically comprised of a relatively uniform mix of silt/clay, sand, and gravel, and is very compact. The till often contains thin lenses or stringers (often only a few feet thick) of sand and sandy gravel. Overall, the till is relatively impermeable and effectively impedes groundwater flow. The outwash units, typically sand, gravelly sand, and sandy gravel with relatively low fines contents (10 percent or less), are generally less than 50 feet thick.

For the purposes of our study, and based on interpretations made in previous reports and our explorations at the site, the hydrogeologic system of the WWTP area is divided into four primary layers: an upper unconfined aquifer, an upper "confining" layer with low hydraulic conductivity (aquitard), a middle confined or semi-confined aquifer, and a lower aquitard. The upper and middle aquifers consist of interbedded sand and gravel. In the project area, the surface organic layer that is present in the wetland is also included in the upper unconfined aquifer. The upper and lower aquitards consists of till or till-like deposits. Based on our understanding of the hydrogeologic conditions in the project area it is likely that the lower aquitard referenced in this report is underlain by additional aquifer/aquitard sequences. Only one of our borings for the project, and an onsite production well, encountered (but did not penetrate) the lower aquitard. Additional explorations would be needed to define the thickness and extent of the lower aquitard beneath the site. It is our opinion that the project is unlikely to affect or be affected by deeper aquifer zones. Local, discontinuous lenses of sand and gravelly sand are also present in the till aquitards. Figures 6 and 7 show conceptual hydrogeologic profiles of the project area.

Recharge sources to the aquifers primarily include infiltration of precipitation and seepage from lakes, ponds, and streams (Jokela, et. al. 1991). It is hypothesized that the deeper, confined aquifers may be recharged from water infiltration near the Talkeetna Mountains, although data supporting the hypothesis is currently lacking. Surface water features, such as streams or creeks, may either gain water from or lose water to the subsurface. Average annual precipitation in the Wasilla area is about 18 inches. We assume about 20 percent of the average annual precipitation is recharged to the aquifer, or about 3.5 inches per year. Evapotranspiration (ET) for the project area was estimated at 0.003 feet/day (ft/dy) based on a GIS dataset provided by University of Alaska Fairbanks (UAF) Scenarios Network for Alaska and Arctic Planning (SNAP).

Groundwater discharge in the area occurs mainly through seepage into streams/rivers, lakes, wetlands (Jokela, et. al. 1991), vertically into deeper aquifers, and groundwater pumping. The deeper aquifers may also interact with the surface water where the aquifers intersect deep lakes. The regional flow interactions of the deeper confined aquifer have not been fully evaluated. According to wetland classifications included in Matanuska-Susitna Borough (MSB) Geographic Information System (GIS) files, the WWTP wetland is classified as a discharge slope wetland, and as such is assumed to receive water from the shallow unconfined aquifer in the area. Numerous domestic wells exist near the project area. Pumping rates for these wells are unknown but were assumed at approximately 150 gallons per day (gpd), per well, for the purpose of our evaluation.

4.3 Groundwater Conditions

Based on studies presented in previous reports, the regional groundwater flow in the Wasilla area is from north to south. Local variations to this general trend may be present near lakes and streams. Based on our March 7, 2015 groundwater level measurements in piezometers installed at the site, groundwater depths range between 0 (at the surface) and 90 feet bgs, corresponding to elevations ranging between 209 and 229 feet. Higher elevations are typically associated with groundwater perched on top of relatively shallow till layers that are present beneath the eastern portion of the site, in the vicinity of the existing sewage lagoons. Local groundwater contours were drawn for the site using the March 7, 2016 observed water levels. Groundwater elevations were based on a top of casing survey conducted by Stantec on March 2, 2016. Groundwater contours for the March 7, 2016 observations are shown on Figure 2. Note, these contours exclude the perched zone located beneath the eastern portion of the site and, in our opinion, generally represent the piezometric level of the middle aquifer beneath the site, which appears to be closely related to the elevation of the upper unconfined aquifer present in the WWTP wetland area. Based on these contours, groundwater flow generally appears to be from north to south/southwest with flow locally converging toward the wetland along its flanks. Boring B-14, which has two, nested observation wells, had a static water level elevation of 215.5 feet in the shallow well and 219.2 feet in the deeper well. In addition, Boring B-06, advanced in the wetland area of the site, has exhibited artesian water flowing out of the monitoring well during multiple observations. Static water levels for measurements taken March 7, 2016 are presented in Table 1 below, and approximate monitoring well locations are shown on the site plan presented in Figure 2.

TABLE 1
STATIC WATER LEVELS – MARCH 7, 2016

Monitoring Well	Aquifer	Groundwater Elevation[2] (feet NAVD88)	Water Level (feet bgs)
20	Middle	215.90	11.29
21	Middle	215.59	22.74
22	Middle	216.38	34.82
23	Middle	216.34	33.63
26	Middle	215.72	14.66
27	Middle	215.75	26.15
28	??	219.54	31.96
33	Middle	216.03	16.03
34	Middle	216.65	24.40
39	Middle	216.46	26.47
B-01	Middle	216.07[4]	Frozen
B-03	Middle	216.12[4]	Frozen
B-04	Middle	217.66	14.88
B-06	Middle	215.89[4]	Frozen
B-08	Middle	215.10[4]	Frozen
B-09	Middle	215.25	13.55
B-11	Middle	214.98	3.73
B-13	Middle	210.84[4]	Frozen
B-14[3] Deep	Lower?	219.15	86.03
B-14[3] Shallow	Middle	215.47	89.82
MW-17	Middle	214.11	33.93
MW-18	Middle	213.42	36.05
MW-19	Middle	208.05	0.06
MW-20A Red	??	211.52	-1.37[1]
MW-20A Yellow	??	209.69[4]	Frozen
MW-21A High	??	212.91	2.46
MW-21A Low	??	212.74	2.61
TB-7	??	221.14	20.43
TW-1	??	228.32	13.00
TW-2	Perched	229.14	19.69
TW-3	Middle	217.18	33.55

Notes:
[1]Water flowing above the ground surface is shown with a negative value.
[2]Stantec survey data used in estimating groundwater elevations.
[3]Boring B-14 contains two nested piezometers for water level monitoring. The deep piezometer extends to approximately 149 feet bgs and the shallow piezometer extends to approximately 97 feet bgs. This boring was terminated in a dense, silty till layer (lower aquitard). It is unclear if water from a lower aquifer is present.
[4]Groundwater elevation assumed at approximate ground elevation due to frozen water conditions.

4.4 Groundwater Quality

In 2007, NTL Alaska, Inc. was retained to conduct an assessment of the capacity of the existing sewage lagoon system and establish effluent treatment parameters that can be used to evaluate the percolation capacity of the leach field system (ie. existing percolations beds). In their February 23, 2007 letter to Mr. Dean Syta of USKH (now Stantec), NTL noted that the water quality near the base of the slope below the percolation beds indicates the system may be performing at capacity between about 0.3 and 0.35 million gallons per day (mgd). This was largely based on nitrate and fecal coliform data of samples collected from the monitoring wells near the stream, which frequently exceeded Alaska Department of Environmental Conservation (ADEC) water quality standards of 10 milligrams per liter (mg/L) for nitrate and the 1996 ADEC waste disposal permit standard of 1 colony-forming unit (CFU) per 100 milliliters for fecal coliform (S&W 2008).

As part of our recent effort, Shannon & Wilson collected a total of five groundwater samples from Monitoring Wells (MW6, MW8, MW9, and B-14 deep/shallow). The samples from MW6, MW8, and MW9 were analyzed for Resource Recovery and Conservation Act (RCRA) metals by Environmental Protection Agency (EPA) Method SW6020, pH by EPA Method SM21 4500, and total nitrate/nitrite by EPA Method SM21 4500. The samples from B-14 were analyzed for nitrate and nitrite by EPA Method 300.0. Arsenic, barium, chromium, and lead were detected in the samples analyzed, but at concentrations below ADEC cleanup levels. The sample from MW9 had a total nitrate/nitrite concentration of 0.937 mg/L. Nitrate/nitrite was not detected in samples tested from MW6 and MW8. Nitrate was detected in samples from Boring B-14, at concentrations ranging from 0.126 to 0.380 mg/L. Nitrite was detected in the sample from B-14--shallow at a concentration of 0.0600 mg/L, which was less than the laboratory limits of quantification. In general, the analyte concentrations in the samples tested were consistent with expected background levels for the area. A summary of these test results is included in Table 2 below. Full laboratory test results are presented in our July 2016 data report.

TABLE 2
SUMMARY OF GROUNDWATER ANALYTICAL RESULTS

Parameter Tested	Drinking Water MCL/SDWR (mg/L)	Cleanup Level (mg/L)**	Sample ID Number^ and Water Depth in Feet bgs (See Figure 2)				
			Monitoring Well			Observation Well	
			MW6 -1.5~	MW8 -1.0~	MW9 15.8	B-14 Shallow# 89.8	B-14 Deep## 86.0
pH - SU	6.5 to 8.5	-	7.90	7.80	7.80	-	-
Total Nitrate/Nitrite - mg/L	10	-	<0.0500	<0.0500	**0.937**	-	-
Nitrate - mg/L	10	-	-	-	-	**0.380**	**0.126**
Nitrite - mg/L	1	-	-	-	-	**0.0600 J**	<0.0500
Dissolved RCRA Metals							
Arsenic - mg/L	0.010	0.010	**0.0126**	**0.00866**	**0.00375 J**	-	-
Barium - mg/L	2.0	2.0	**0.0176**	**0.0159**	**0.0285**	-	-
Cadmium - mg/L	0.005	0.005	<0.00100	<0.00100	<0.00100	-	-
Chromium - mg/L	0.10	0.10	**0.00144 J**	**0.00123 J**	**0.00638**	-	-
Lead - mg/L	0.015	0.015	<0.000500	<0.000500	**0.00129**	-	-
Mercury - mg/L	0.002	0.002	<0.000100	<0.000100	<0.000100	-	-
Selenium - mg/L	0.05	0.05	<0.0100	<0.0100	<0.0100	-	-
Silver - mg/L	-	0.10	<0.00100	<0.00100	<0.00100	-	-

Notes:

*	= See Appendix D of July 2016 data report for compounds tested, methods, and laboratory reporting limits
**	= Groundwater cleanup levels are listed in Table C, 18 AAC 75.345 (January 2016)
^	= Sample ID number preceded by "02452-" on the chain of custody form
mg/L	= Milligrams per liter
<0.000500	= Analyte not detected; laboratory limit of detection of 0.000500 mg/L
0.0126	= Analyte detected
-	= Not applicable
~	= Groundwater is above ground surface in the well casing
J	= Estimated concentration less than the limit of quantitation. See the SGS laboratory report for more details.
MCL	= Maximum Contaminant Levels
SDWR	= Secondary Drinking Water Regulation
SU	= Standard units
RCRA	= Resource Recovery and Conservation Act
bgs	= Below ground surface
#	= 02452 WWTP.100 in SGS Results Report
##	= 02452 WWTP.150 in SGS Results Report

5.0 ENGINEERING RECOMMENDATIONS

The project was in a conceptual design phase at the time of this report with several options being considered for developing the WWTP wetland area to support the proposed overland discharge. Geotechnical considerations associated with this project consist of controlling trench excavations, developing pipe bedding, addressing potential settlements, trench backfill and compaction, design of foundations for potential building structures, constructing gravel access roads, and potential development of berms in the WWTP wetland. Based on explorations at the site, the soils in the upland portions of the project area generally consist of a thin surface layer (1 to 2 feet thick) of silty soil with organics overlying relatively compact sands and gravels with various amounts of fines. The sands and gravels were consistent with soils described as glacial outwash to depths ranging between 13 and 28 feet bgs. Till-like soils were encountered beneath the outwash deposits. Conditions in the WWTP wetland consisted of 2 to 13 feet of organic soil overlying relatively compact silts, sands and gravels. In our opinion, the granular soils are relatively compact and should be adequate to support the proposed improvements. Special considerations will be needed for developing any improvements in the wetland area due to thick organic soils, which are unsuitable for supporting structures.

5.1 Utility Trenches

Trenches will be needed to extend the new discharge piping to the discharge points along the edges of the WWTP wetland. Recommendations provided below for trenches assume that they will be constructed within the upland areas only and not extend into the wetland. Trenches excavated for installation of these pipes should be generally constructed as presented in Figure 8. The bedding and structural fill material around the buried pipes should be densely compacted to support and hold the pipe firmly in place.

The soils in this area are generally granular and moist with variable fines contents. Excavation slopes will tend to stand steeply at first, and then ravel over time to flatter slopes (i.e., to about 1.5 H to 1 V or shallower). The actual slope and excavation bottom conditions should be made the responsibility of the contractor, who will be present on a day to day basis and can adjust efforts to obtain the needed stability. The contractor should be prepared to use shoring or a trench box as necessary to protect their workers in accordance with state and federal safety regulations (including OSHA) which require slope protection for trenches deeper than 4 feet bgs.

Below areas that are receiving structures, trench backfill should be placed in maximum 6 to 8-inch loose lifts and compacted to at least 95 percent of maximum density, as discussed in Section 5.6. The lift thickness may be increased to up to 12 inches if it can be shown that the lift is adequately compacted at depth. In areas where no structural support is needed less compaction is required and material may be placed in thicker lifts (12 inches) and moderately compacted to achieve at least 90 percent compaction. The bedding and fill material around buried pipes should also be compacted to at least 95 percent of maximum density or per manufacturer recommendations to support and hold the pipe firmly in place. Utility trenches should be backfilled with existing inorganic soils as much as practicable. This procedure limits the contrast between trench backfill and the surrounding soil conditions that can lead to adverse settlement or frost heave behavior. Bulking of backfill into trenches should be discouraged as this can cause voids and lead to large future surface settlements.

5.2 Building Foundations

Design of the foundations for support of the proposed buildings must consider the bearing capacity of the soils, expected settlements, lateral earth pressures, frost conditions within the subsurface soils, and constructability issues. Based on the soil conditions encountered in the upland portions of the site, conventional shallow foundations would, in our opinion, provide suitable support for the proposed new structures provided they are constructed in the upland areas of the site and the site is prepared as outlined below in Section 5.2.1.

5.2.1 Site Preparation

In order to prepare the site for construction, trees and shrubs should be cleared and grubbed, and organic material and soils containing organics should be scraped from the ground surface before excavating for foundations or placing fill. According to explorations at the site, organic soils are generally limited to the upper 1 to 2 feet of soil, with the exception of the WWTP wetland area where organic soils may extend to depths of 13 feet bgs. Organic material should not be re-used as fill beneath the roadways, pipelines, or structures at the site, and should be removed from the site or used as topsoil in landscaping.

Once the above site preparation is completed the exposed ground surface in areas that will support structures should be proof rolled and then observed by an experienced geotechnical engineer to look for soft or loose zones. If loose or soft zones are discovered, they should be locally compacted or excavated and replaced with compacted, structural fill material. The resultant grade should be smooth, consistent, and unyielding.

If areas of the site need to be raised after site preparation, backfill material should consist of materials that generally conform to Alaska Department of Transportation & Public Facilities (DOT&PF) gradation requirements for a Modified Selected Material Type A or better. Fill placed and compacted for site grading should be done as described in Section 5.6. We recommend that a qualified laboratory be retained to perform fill density testing during the grading process at the site.

5.2.2 Footing Embedment and Allowable Bearing Capacity

We recommend that new buildings be supported on spread or continuous strip footings bearing on firm native soils, or Modified Selected Material Type A structural fill. The recommended minimum footing width is 18 inches for continuous strip footings and 24 inches for spread footings. The base of exterior footings and unheated interior footings should be buried sufficiently to prevent structural damage resulting from frost action. We recommend that perimeter footings in heated buildings be placed a minimum of 48 inches below the ground surface. If all or portions of the proposed buildings are to be unheated, the minimum burial depth for footings should be increased to 60 inches bgs for frost protection.

Based on the expected footing dimensions, depths, and site preparation recommendations, we recommend that foundations for the proposed buildings be designed with an allowable soil bearing pressure of 3,000 pounds per square foot (psf). Localized loose or soft areas, whether resulting from existing conditions or disturbance during construction must be corrected prior to casting footings, or damaging differential settlements could occur. The above bearing value may be increased by one-third for short-term wind or seismic loading. A typical footing detail is included in Figure 9.

5.2.3 Floor Slabs

Concrete floor slabs may be utilized on the interior of the building structures. We recommend that the exposed soils within the building footprint be probed to locate materials that may be naturally loose or have become loosened or disturbed due to the filling and grading process. If loose areas are encountered, we recommend that they be excavated and replaced. We recommend pouring the concrete slab on a minimum of 4 to 6 inches of compacted Modified Selected Material Type A fill. In unheated buildings, we recommend at least 24 inches of Modified Selected Material Type A fill be placed beneath the floor slab for frost protection. Depending on where the buildings are located, some of the soils encountered in explorations at the site appear to meet or come close to meeting the general gradation requirements for Modified Selected Material Type A but may contain particles greater than 3 inches in diameter. The structural fill placed beneath the floor slab should be placed and compacted in accordance with the recommendations included in Section 5.6. Provided the recommendations discussed above are adhered to by the contractor, a subgrade reaction modulus of at least 150 pounds per square inch per inch (psi/in) should be attainable on the recommended support soils. In areas to receive floor coverings, we recommend installing a vapor retarder directly beneath the concrete slab.

5.2.4 Estimated Building Settlements

The magnitude of the settlements that will develop at the building site is dependent upon the applied loads and density of the support material. Assuming the site is prepared as recommended and the subgrade beneath footings is protected from moisture while exposed, we estimate that total maximum settlements will be about 1 inch or less with differential settlements being about 1/2 of the total settlements over the length of the structure. The greatest amount of settlement should occur during construction, essentially as fast as the building loads are applied, such that long term differential settlements of the building will be relatively small and within tolerable limits.

5.2.5 Lateral Earth Pressures and Lateral Resistance

Building walls below ground that support earth fills and floor slabs should be designed to resist horizontal earth pressures. The magnitude of the pressure is dependent on the method of backfill placement, the type of backfill material, drainage provisions, and whether the wall is permitted to deflect after or during placement of backfill.

If the walls are allowed to deflect laterally or rotate an amount equal to about 0.001 times the height of the wall, an active earth pressure condition under static loading would prevail and an equivalent fluid weight of 35 pounds per cubic foot (pcf) is recommended for design of the walls. For rigid walls that are restrained from deflecting at the top, an at-rest earth pressure condition would prevail and an equivalent fluid weight of 55 pcf is recommended. To simulate seismic loading (from soils adjacent to the foundation) a rectangular pressure prism with a magnitude of 14 psf per foot of wall height should be applied to the below-grade walls. Note that these values reflect free-draining, compact, granular backfill with no hydrostatic forces acting on the wall, and also assume that the soils within the zone of frost penetration behind the wall (about 6 to 8 feet horizontal) are non-frost-susceptible. These values do not include a factor of safety.

Lateral forces from wind or seismic loading may be resisted by passive earth pressures against the sides of footings. These resisting pressures can be estimated using an equivalent fluid weight of 250 pcf. This value includes a factor of safety of 1.5 on the full passive earth pressure and assumes that backfill around the footings is densely compacted.

Lateral resistance may also be developed in friction against sliding along the base of foundations placed on grade such as footings or floor slabs. These forces may be computed using a coefficient of 0.4 between concrete and soil.

5.3 Gravel Access Roads

Gravel access roads may be constructed to support construction activities or for permanent access to portions of the site. We anticipate that these roads will primarily experience low volumes of traffic by slow moving, moderately loaded service vehicles, but that more heavily loaded vehicles may use the road during construction. In our opinion, with the exception of organic soils and soft surface silts, the granular subgrade soils observed in our explorations at the site will provide suitable subgrade support for a road. We recommend that roads be developed by removing surface organics, organic soils, and soft or compressible soils from the ground surface and excavating, if necessary, to accommodate the structural section recommended below. Once the subgrade elevation is reached the surface should be bladed flat and proof rolled to provide a firm unyielding surface upon which to place road subbase and structural section fills. In areas where the grade needs to be raised, it should be done by using Selected Material Type B, placed and compacted as recommended in Section 5.6. At a minimum, we recommend that the structural section for new access roads consist of 12 inches of Selected Material Type A placed over existing granular soils or imported Selected Material Type B (or better) fill. For a smoother driving surface and serviceability, we recommend placing 4 to 6 inches of E-1 surface course on top of the Selected Material Type A layer. Fills placed for the roadway should be done so in accordance with the recommendations included in Section 5.6. Gradation requirements for E-1 surface course are included in Figure 11. Fill slopes for materials placed using moisture/density control may be established no steeper than 2 horizontal (H) to 1 vertical (V). We envision that the access road will require occasional grading maintenance. The amount and frequency of the maintenance will depend on the amount of traffic the road experiences.

5.4 Berm Construction

Scenarios 2 and 3 include construction of berms in the WWTP wetland to reduce channelization and slow the surface flow of effluent discharged to the wetland. Figures 4 and 5, based on preliminary drawings provided by Stantec, show a conceptual berm layout in plan view. In scenario 2, several berms would be constructed across the wetland, perpendicular to the direction of flow. After construction, these berms would be 6 to 12 inches high above the existing ground surface, will range in length from about 400 to 800 feet, and will be constructed over wetlands and organic soils. The width at the top of the berms is anticipated to range between 4 and 10 feet wide, depending on the final design. Scenario 3 includes construction of two earthen dikes, approximately 7 feet high above the existing ground surface, which would facilitate formation of a 4 to 5-foot deep pond in the northern portion of the wetland. Several smaller berms, similar to those described for scenario 2, would be constructed downstream of the larger impoundment. We have not provided recommendations in this report for the larger earthen dikes since our groundwater modeling suggests that a larger, deeper pond feature would have adverse affects on adjacent domestic wells (see Section 6 for discussion). Note that the location, dimensions, and elevations described in this report are for conceptual design; if the project is taken through design, several of the parameters presented herein should be re-evaluated using actual values used in the design.

We envision that the berms will be constructed over the organic wetland soils to reduce disturbance of the wetland and construction effort. In developing the berms over surface organics, the existing grade should be prepared by disturbing the organic surface as little as possible. Trees and shrubs should be cut approximately 6 inches above the ground surface, leaving the surface mat largely intact. A woven geotextile fabric (see Section 5.5) should then be placed on the bog surface prior to placing berm fills to provide separation and strength during construction activities.

5.4.1 Summer Construction

We recommend that berm fills should consist of Selected Material Type B, or better, for use in wet/boggy areas. We recommend that fill placed in berms for this project should be well blended to provide a relatively consistent material. Fill in berms should be placed and compacted by tracking with equipment until rutting and pumping is minimal. For estimating material quantities we recommend assuming settlements at least equal to the berm height for a 6 to 12 inch high berm. That is, for a berm with a final height of 6 inches above the bog, the total berm fill thickness will need to be approximately 12 inches to account for approximately 6 inches of settlement. Similarly, a berm that is to be 12 inches above the bog surface would require a total berm fill thickness of approximately 24 inches to accommodate approximately 12 inches of settlement. For planning purposes, we recommend that the berm slopes be designed no steeper than 4 horizontal (H) to 1 vertical (V).

5.4.2 Winter Construction

Due to the soft nature of the surface organic soils in the wetland area, it may be advantageous or necessary to construct the berms in the winter as shown on Figure 10. Preparation of the ground surface should be carried out as described above, and should include snow removal. Snow should be removed from the ground surface to the extent practicable so as not to disturb the organic mat. No more than 6 inches of loose or packed snow should be left on the ground surface prior to embankment development. If ice is present the snow should be cleared to the ice surface. We recommend augering through the ice in a few locations to establish an average ice thickness in areas where ice is on top of the ground surface. If the ice thickness is greater than 1 foot effort should be undertaken to remove the ice so there is not more than 1 foot of ice over organic surface materials. After snow is removed, a separation geotextile should be spread on the ground surface as recommended above. The base of the embankment fill should be constructed by placing a 2-foot thick lift of Selected Material Type B over the fabric. Berm side slopes should be established at 4H to 1V. A smooth drum roller should be used to condition the surface to as smooth a state as practicable. Snow should be allowed to fall and accumulate on the resultant embankment surface, but should be removed prior to breakup to encourage thawing of the embankment fill and subgrade and avoid saturation of the fill materials as they thaw.

During and after thawing of the fill and underlying organic materials, consolidation and settlement will occur. Based on our observations on site and experience, we believe that the final berm top surface will be approximately 6 to 12 inches above the natural ground surface after the thaw settlement (assuming a 2-foot lift is constructed). The resultant surface will be relatively loose and uneven and will require re-leveling to achieve the desired grade. The berm surface should be bladed smooth and compacted by tracking with light, low ground pressure equipment. If needed, additional Selected Material Type B should be imported to bring the grade of the berm top up to the desired elevation.

5.4.3 Long Term Berm Performance

Regardless of the construction method, the berm will experience long-term settlement due to consolidation of the underlying peat soils. We believe that the rate of settlement may be relatively slow, likely less than 1 inch per year, after the first year of installation. We recommend that the facility owner and operator establish a method to confirm the top elevation of the berms (through annual surveys or visual observation) to evaluate the need for adding fill to re-establish the desired berm elevation. Likewise, regular observations of the berms should be made, especially after severe weather events, to detect areas that may have been damaged by erosion caused by high surface water flows. Long term performance may be improved by establishing vegetation or placing erosion resistant materials (such as a rock blanket) on the berm slopes.

5.5 Geotextile Separation Fabric

We have recommended the use of geotextile separation fabric (geofabric) beneath berm fills placed on top of organic soils in the wetland area. This geofabric layer should prevent intermixing of the berm fills with the underlying organics, thereby improving fill placement/compaction efficiency, and reducing and equalizing settlements. After the area to be treated with geofabric has been prepared within the fill limits as described previously, the geofabric should be placed over the organic subgrade material before the first lifts of fill are placed. Geofabric used for this project should consist of Mirafi RS380i, or equivalent.

The manufacturer's recommendations should be used for placement of geofabric. In the absence of manufacturer recommendations, recommendations included in DOT&PF SSHC and the Federal Highway Administration (FHWA), *Geosynthetic Design and Construction Guidelines, Publication No. FHWA-HI-95-03* should be followed.

5.6 Structural Fill and Compaction

Backfill will be required for foundations, floor slabs, gravel roads, and utility trenches. Structural fill that is placed should be clean, well-graded, granular soil to provide drainage and frost protection. Selected Material Type A structural fill as defined by the DOT&PF generally meets these requirements and may be placed in both wet and dry conditions. We have also recommended the use of Selected Material Type B for portions of the site that may need to be raised after site preparation work. Gradation requirements for Selected Material Type A and B are provided in Figure 11.

The outwash materials encountered in borings in upland portions of the site generally contained between 2 and 10 percent fines, with occasionally higher fines contents. Some of these soils meet or come close to meeting the requirements for Selected Material Type A and B based on fines content, but may be too sandy in places to fully meet these requirements. These sandier soils can be used as unclassified fill in utility trench backfill, under the foundation of the proposed structures where the soil will be protected from freezing, and in nonstructural areas. The fine-grained soils in the upper 1 to 2 feet of the ground will likely be moisture sensitive and special handling techniques (i.e. moisture control/protection, reduced traffic, etc.) may need to be implemented if they are to be re-used. Re-use will be dictated by the contractor’s ability to place and compact the material with proper moisture density control. In addition, moisture sensitive materials that are exposed at the bottom of excavations during site preparation activities should be protected from excess moisture prior to construction.

Structural fills below roadways and beneath footings and floor slabs should be placed in lifts not to exceed 12 inches loose thickness, and compacted to 95 percent of the maximum density as determined by the ASTM D 1557. Non-structural fills should be placed in similar lifts and compacted to at least 90 percent of ASTM D 1557. We recommend that our services be retained to inspect the quality of fill compaction during construction.

When backfilling within 18 inches of the building walls where the wall is not supported on both sides, material shall be placed in layers not to exceed 6 inches loose thickness and densely compacted with hand operated equipment. Heavy equipment shall not be used as it could cause increased lateral pressures and damage walls.

6.0 GROUNDWATER MODELING

Based on S&W’s explorations at the site and conceptual hydrogeologic model described in Section 4.2, we constructed, calibrated, and ran a numerical model to estimate the impact the proposed development scenarios might have on local groundwater conditions, including gradient, flow, degree of mounding/runoff, and contaminant fate and transport. The following subsections provide a description of the model setup and a summary of the modeling results. Modeling result figures are presented in Appendix A.

6.1 Modeling Approach

The model was constructed using numerical modeling techniques to simulate groundwater flow system for the project area. The model approach included:

- Selecting an appropriate numerical model and the supporting software.
- Constructing a three-dimensional representation of the model area that includes the hydrogeologic framework, hydraulic properties, and boundary conditions.
- Calibrating the model to existing groundwater data.
- Performing simulations for various development scenarios.
- Evaluating model results.

We used the USGS numerical groundwater flow code MODFLOW-2005 to simulate the groundwater flow system in the project area. MODFLOW is a three-dimensional, numerical computer model originally published by the U.S. Geological Survey (McDonald and Harbaugh, 1988) with updates in 2000 and 2005. MODFLOW is a robust model capable of simulating the diverse hydrogeologic conditions found in the project area. It is widely used and accepted by the groundwater modeling profession and is considered appropriate for this application. We used Groundwater Vistas Version 6 (Rumbaugh and Rumbaugh, 2011), a graphical interface program, as a pre- and post-processor to create and manage model input and output files for MODFLOW-2005. The model produced a groundwater flow field in which we then used MODPATH, also operated within Groundwater Vistas, to track the path-lines of conservative particles which represent potential pollutants. The conservative particle approach only tracks a water particle; other factors affecting contaminant transport such as dispersion, dilution, retardation, and degradation are not incorporated. We believe that this approach is appropriate as little to no nitrate removal occurs once the nitrates reach low oxygen water tables below the ground surface.

The spatial representation of the project area was initially constructed by defining the physical dimensions of the model domain and dividing it into a grid with distinct rows, columns, and layers. This division produces numerous cells that may be individually assigned specific attributes or properties that reflect the natural groundwater system. The groundwater flow system of the study area was numerically simulated to set the initial local aquifer conditions, and the initial conditions were then used to simulate the groundwater system under the proposed development scenarios.

6.2 Model Design

As shown in Appendix A, Figure A-1, we used a model domain measuring 14,000 feet (east-west) by 14,000 feet (north-south) to simulate the groundwater system in the vicinity of the WWTP area. Horizontally, the model grid consists of 166 rows and 154 columns and variable grid spacing with rows and columns ranging from 50 to 100 feet in width. We used the smallest width of 50 feet in the immediate WWTP wetland area to provide better resolution for the evaluation of the local hydrogeology. The model's upper surface (top of layer 1) was established by interpreting a 10-meter resolution digital elevation map (DEM) dataset for the area to the final model grid. The DEM files were provided by the MSB from lidar mapping conducted in 2011. Vertically, the model is about 115 feet thick in the project area but varies with topography (as shown in the example model cross sections in Appendix A, Figures A-3 and A-4). The vertical thickness of the model is divided into four layers based on the conceptual hydrogeologic profiles and project needs. Horizontal and vertical extents were chosen to be sufficiently large to capture elements of the groundwater flow system that might be affected by potential boundary effects. Table 3 presents model layers and associated hydraulic parameters. Hydraulic parameters are discussed in further detail in Section 6.4.

TABLE 3
MODEL/STRATIGRAPHIC LAYERS AND SIMULATED HYDRAULIC PROPERTIES

Layer Number	Horizontal Hydraulic Conductivity (K_h) (feet/day)	Vertical Hydraulic Conductivity (K_v) (feet/day)	Model Layer Thickness at WWTP Wetland (feet)	General Soil Description	Hydrogeological Unit
1a	1	0.1	14	Peat/Decomp-osed Organics	Upper Unconfined Aquifer
1b	40	4	N/A	Sand and Gravel	Upper Unconfined Aquifer
2a	0.4	0.004	N/A	Till or till-like soil (Silty Sand and Gravel)	Upper Confining Aquitard
2b	40	4	17	Sand and Gravel	Upper Unconfined Aquifer

Layer Number	Horizontal Hydraulic Conductivity (K_h) (feet/day)	Vertical Hydraulic Conductivity (K_v) (feet/day)	Model Layer Thickness at WWTP Wetland (feet)	General Soil Description	Hydrogeological Unit
2c	1	0.1	14	Peat/Decomp-osed Organics	Upper Unconfined Aquifer
3	40	4	28	Sand, Sand with gravel	Middle Aquifer
4	0.4	0.004	55	Till or till-like soil (Silty Sand and Gravel)	Lower Confining Aquitard

6.3 Boundary Conditions

Boundary conditions are fixed values of hydraulic head (groundwater elevation) or groundwater flux (inflow/outflow rate) defined within or along the edges of the model domain. The boundary conditions used in the model include constant head boundaries, general-head boundaries, and drains. The boundary conditions applied to our model are presented in Appendix A, Figure A-2.

General-head boundaries allow the water level elevation to be assigned in a cell; the water level is maintained in the cell by adding or removing water to the model from an unlimited source/sink using a specified conductance term. General-head boundaries are similar to constant-head boundaries except the conductance term is used to regulate the quantity of flow entering or exiting the model. General-head boundaries were used to represent areas where recharge may occur from Wasilla Lake and Cottonwood Creek in the northwestern portion of the model. General-head boundaries were also used in the upland area west of the WWTP wetland and along a portion of the eastern model extent to simulate local variations in the groundwater levels, based on our explorations and water level observations at the WWTP site. These boundary condition additions supported the model calibration and resulted in a closer approximation of the observed groundwater conditions. A constant head boundary was used along the southern model extent to represent a groundwater sink where water could exit the model. This corresponds to locations of groundwater discharge toward Knik Arm.

Drains were used to represent seepage along the WWTP bluff south of the existing infiltration cells and to simulate runoff during simulation of the proposed development scenarios. Drain boundary conditions have an elevation assigned to a cell. If the water level in a nearby cell is greater than the assigned elevation in the drain boundary cell then water will flow out of the model. If the water elevation is lower than the assigned elevation in the drain boundary cell, there is no flow out of the drain. Drains do not allow water to flow into the model. Outflows in the drains are controlled by specified elevations and conductance terms. Drain elevations were selected based on the conceptual pond levels shown in the proposed development scenarios.

6.4 Hydraulic Parameters

Material properties of the soil units are specified on a cell-by-cell basis in the model. Hydraulic parameters used in the model include hydraulic conductivity and porosity. Hydraulic conductivity describes the ability of a soil to transmit water. Hydraulic conductivity values were estimated based on empirical correlations with grain size test results from samples collected during Shannon & Wilson’s 2008 and 2015/16 subsurface explorations at the site, 2008 slug test results, 2015 infiltration test results, and professional judgment. The values used in the calibrated model were generally consistent, within one order of magnitude, with the values calculated from these various sources. Values for horizontal hydraulic conductivity for various aquifer materials represented in the model are included in Table 3. We assumed the same horizontal hydraulic conductivity for all units in all directions (isotropic conditions). We also assumed anisotropic conditions for the vertical component of hydraulic conductivity with a 10:1 ratio of horizontal to vertical hydraulic conductivity. Aquifer porosity of 0.25 was used for all model layers.

6.5 Model Calibration

Calibration is a process whereby the model results are compared to observed groundwater data and modifications are made to input parameters in order to best match the data set. The numerical model was calibrated to steady-state conditions using the groundwater level data collected on March 7, 2016. The steady-state calibration data sets for the model consisted of observed groundwater levels in the sixteen observations wells at the site (B-01, B-03, B-04, B-11, B-14, 28, 33, 34, 39, MW-6, MW-8, MW-9, MW-17, MW-18, MW-20, and MW-21). For calibration purposes we assumed that the existing steady-state hydraulic conditions at the site include an effluent discharge of approximately 350,000 gpd to the existing infiltration beds. Figure A-5 in Appendix A shows the observed versus modeled groundwater levels for six observation wells in the model area. Overall, the modeled versus observed piezometric level match is satisfactory for the purpose of this analysis.

6.6 Model Simulation

Using our model, we simulated the three design alternatives presented in Section 3.0. Based on information provided by Stantec, each scenario was run using application rates of 350,000, 500,000, and 1,000,000 gpd. Our model scenarios are as follows:

- Application Scenario 1a – Discharge to unimproved wetlands, application rate of 350,000 gpd
- Application Scenario 1b – Discharge to unimproved wetlands, application rate of 500,000 gpd
- Application Scenario 1c – Discharge to unimproved wetlands, application rate of 1,000,000 gpd
- Application Scenario 2a – Discharge to enhanced wetlands, application rate of 350,000 gpd
- Application Scenario 2b – Discharge to enhanced wetlands, application rate of 500,000 gpd
- Application Scenario 2c – Discharge to enhanced wetlands, application rate of 1,000,000 gpd
- Application Scenario 3a – Discharge to pond and enhanced wetlands, application rate of 350,000 gpd
- Application Scenario 3b – Discharge to pond and enhanced wetlands, application rate of 500,000 gpd
- Application Scenario 3c – Discharge to pond and enhanced wetlands, application rate of 1,000,000 gpd

The simulations assumed that the existing infiltration cells are not in service simultaneously with the wetland application. While the use of the existing infiltrations cells and wetland application were not modeled in concurrent operation in this case, it is our opinion that contoured groundwater elevations (see Appendix A figures) would shift slightly south due to mounding around the existing beds if effluent was discharged to both locations concurrently. Some additional mounding could also occur in the northern portion of the WWTP wetland which could result in increased groundwater flows to the west and north from the northern lobe of the wetland. The effects on flows emanating from the southern portion of the wetland would be minimal. The degree of these effects will vary with the split of flow between the wetlands and existing beds.

Forward particle tracking was performed with MODPATH assuming particles released from near the center and/or edges of the WWTP wetland area. A summary of model inputs and results is included below in Table 4. Simulated groundwater levels and particle tracking results are shown in Appendix A, Figures A-6 through A-15.

TABLE 4
MODEL INPUT AND RESULTS

Model Scenario	Recharge (ft/day)			ET	Estimated Allocation (%)		
	Areal	Wetland	Flow Path/Ponds		Infiltration	Runoff	ET
Scenario-1a	0.0008	0.007	0.070	0.003	**57%**	**37%**	**6%**
Scenario-1b	0.0008	0.010	0.100	0.003	**49%**	**44%**	**7%**
Scenario-1c	0.0008	0.020	0.200	0.003	**41%**	**54%**	**5%**
Scenario-2a	0.0008	0.006	0.060	0.003	**63%**	**27%**	**10%**
Scenario-2b	0.0008	0.009	0.087	0.003	**51%**	**41%**	**8%**
Scenario-2c	0.0008	0.012	0.123	0.003	**43%**	**51%**	**6%**
Scenario-3a	0.0008	0.004	0.032	0.003	**82%**	**4%**	**14%**
Scenario-3b	0.0008	0.005	0.045	0.003	**71%**	**17%**	**12%**
Scenario-3c	0.0008	0.009	0.090	0.003	**47%**	**47%**	**6%**

ET - Evapotranspiration

7.0 ANALYSIS AND CONCLUSIONS

We used the model zone budget function to estimate the distribution of discharge waters applied to the wetland in three categories: 1) recharging to the aquifer through infiltration, 2) flow downstream out of the wetland through runoff, and 3) lost through evapotranspiration. As indicated in Table 4, for Scenario 1a, model results indicate that about 57% of the applied water infiltrates into the aquifer, about 37% flows downstream as runoff, and about 6% was lost through evapotranspiration. In comparing Scenario 1a (350,000 gpd) with 1b (500,000 gpd) and 1c (1,000,000 gpd), the percentage of water infiltrating into the aquifer decreases as larger amounts of water are applied to the wetland. The decreases in infiltration are due to the fact that the infiltration rate is primarily controlled by hydraulic conductivity of the aquifer area of infiltration, and gradient. When a larger amount of water is applied to the aquifer, it reaches the infiltration potential, therefore, reducing the percentage of infiltration and increasing the percentage of runoff. The model results indicate similar patterns for Scenarios 2 and 3 when compared to the different application rates within each scenario.

Comparing all three scenarios, the model results show that infiltration percentages increase when the water is allowed to be impounded in the wetland, with higher infiltration percentages corresponding to greater impounded area and depth. For example, percentages of infiltration range from 57% to 41% with minimum impoundment as in Scenario 1a through 1c, compared to percentages of infiltration ranging from 63% to 43% with medium impoundment as in Scenario 2a through 2c and 82% to 47% with maximum impoundment as in Scenario 3a through 3c. In Scenarios 2 (a, b, and c) and 3 (a, b, and c) the applied water is impounded in the wetland due to proposed construction of a series of berms and ponds. The berms and ponds increase the hydraulic head and keep the water in the wetland longer, therefore increasing the percentages of infiltration. It should be noted that the Scenario 1c and 2c (1 mgd application rate) results show a buildup of the hydraulic head in the northern end of the wetland area. This is due to modeling constraints at that application rate whereby enough excess recharge is not able to escape from the surface of the model using the drain boundary conditions. Therefore the estimated runoff percentage is likely higher than indicated, while the infiltration percentage is likely lower than indicated.

We used forward particle tracking to estimate the flow path of water recharged into aquifer through the WWTP wetland in order to evaluate the potential impact of recharged water on the water quality of the underlying aquifer, particularly the impact on the domestic wells located west of the WWTP wetland. As the particle tracking results show in Appendix A, Figures A-7 through A-15, the flow path of recharged water varies under different application rates and impoundments. Recharged water did not reach the domestic wells under Scenarios 1a through 1c, and 2a. Therefore, it is our opinion that the water applied to the wetland under these scenarios would not have an adverse impact on the water quality of the domestic wells. Particle tracking results for Scenarios 2b and c suggest that recharge water may reach some of the domestic wells south and west of the wetland recharge area. It should be noted that the particle tracking results for Scenarios 1c and 2c (1 mgd application rate) are not representative of an actual condition due to the modeling limitations described in the preceding paragraph. It is our opinion that the results for Scenarios 1c and 2c would be more closely represented by the respective Scenario 1b and 2b results. Results for Scenarios 3a, b, and c suggest that the recharged water flowed toward and reached the domestic wells due to the recharge from the proposed pond area in the northern end of the wetland. On the basis of these particle tracking results, Scenario 3, at any application rate, does not appear to be a viable development option for the project. Note that the domestic wells discussed in our results represent only those wells that are searchable through the Alaska Department of Natural Resources (DNR) Well Log Tracking System (WELTS) database, as shown on Figure 2 and the Appendix A figures, and may not include all domestic wells in the project vicinity.

We also used the model results to estimate flow and velocity within the aquifer beneath the site. Excluding discharged effluent, the analysis suggests that the aquifer transmits on the order of 50,000 to 100,000 gpd through the project area. Average groundwater velocities typically range from about 0.5 to 1 feet per day (ft/d), with locally higher and lower values.

8.0 MODEL LIMITATIONS AND FUTURE CONSIDERATIONS

Our model provides a framework for estimating how much water may be able to be infiltrated into the wetland by an overland discharge system and where water discharged to the wetland will migrate once it reaches the groundwater system. The capacity of the wetland discharge system cannot fully be evaluated based on our modeling results since virtually any amount of water could plausibly be discharged to the wetland, depending on the amount of runoff that is acceptable. Perhaps, a greater determinant in evaluating the capacity of the wetland is in the ability of the wetland to scrub and uptake potential contaminants.

As discussed above, particle tracking results suggest that water applied to the wetland should not have an adverse impact on the nearby domestic wells under Scenarios 1 (application rates up to 1 mgd) and 2a, but could possibly have an impact to these wells under Scenarios 2b and 2c, and would likely have an impact to these wells under Scenario 3 (any application rate). The flow path of recharged water suggests that wells further downgradient to the south/southeast of the WWTP may be impacted by water discharged to the wetland over time. The particle tracking results also show that some of the water recharged to the wetland under Scenarios 1b/c, 2, and 3 would flow north and west out of the WWTP wetland. According to the particle tracking results, flows to the north generally extend less than about 1,000 feet before they are captured by the regional gradient and redirected toward the southeast. Flows to the west are generally associated with a westward trending drainage that exits the northern end of the WWTP wetland and off the WWTP property after a relatively short distance. According to our analysis, these flows represent approximately 10 to 15 percent of the discharged effluent.

The conclusions provided in this report are based on computer modeling and natural local variations in hydrostratigraphy, groundwater gradients, and surface effects may exist that are unknown or unaccountable for in a computer model. We understand that the City of Wasilla may conduct a pilot study in the WWTP wetland prior to moving forward with design and implementation of the scenarios described in our report. Shannon & Wilson recommends collecting additional data prior to and during the pilot study to refine our understanding of the site conditions and support potential model refinement, if needed, before final design and construction of the project. At a minimum we recommend that the City incorporate the following:

Pre- Pilot Study

- Establish additional monitoring points along the west and south edges of the WWTP wetland to support water level measurements and water quality sampling and testing.

- Establish, at a minimum, monthly water level monitoring in existing piezometers and monitoring wells at and around the site.
- Conduct additional groundwater sampling to establish baseline water quality data in the WWTP wetland. If possible, collect baseline water quality samples from area domestic wells.

During the Pilot Study

- Measure and record application rates and locations.
- Measure and record surface flow rates in the outlet stream at the downstream end of the WWTP wetland.
- Observe and record the effluent flow path and other flow characteristics, as appropriate, through the wetland.
- Record hourly or daily water levels in select observation wells.
- Continue water quality sampling and testing.

Post- Pilot Study

- Continue pre-pilot study groundwater level monitoring.
- Refine and continue a sampling and testing plan to monitor water quality parameters
- Refine groundwater model, if necessary.

9.0 CLOSURE AND LIMITATIONS

The analyses, conclusions, and recommendations contained in this report are based on site conditions as they presently exist, and further assume that the explorations are representative of the subsurface conditions throughout the site; that is, the subsurface conditions everywhere are not significantly different from those disclosed by the explorations. If subsurface conditions different from those encountered in the explorations are encountered or appear to be present during construction, we should be advised at once so that we can review these conditions and reconsider our recommendations, where necessary. If there is a substantial lapse of time between the submission of this report and the start of construction at the site, or if conditions have changed because of natural forces or construction operations at or adjacent to the site, we recommend that we review our report to determine the applicability of the conclusions and recommendations.

Within the limitations of scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical engineering principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied. These conclusions and recommendations were based on our understanding of the project as described in this report and the site conditions as observed at the time of our explorations.

Unanticipated soil and water conditions are commonly encountered and cannot be fully determined by taking soil samples from test borings or water level measurements from piezometers and monitoring wells. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs. Shannon & Wilson has prepared the attachments in Appendix B *Important Information About Your Geotechnical/Environmental Report* to assist you and others in understanding the use and limitations of the reports.

Copies of documents that may be relied upon by our client are limited to the printed copies (also known as hard copies) that are signed or sealed by Shannon & Wilson with a wet, blue ink signature. Files provided in electronic media format are furnished solely for the convenience of the client. Any conclusion or information obtained or derived from such electronic files shall be at the user's sole risk. If there is a discrepancy between the electronic files and the hard copies, or you question the authenticity of the report please contact the undersigned.

We appreciate this opportunity to be of service. Please contact the undersigned at (907) 561-2120 with questions or comments concerning the contents of this report.

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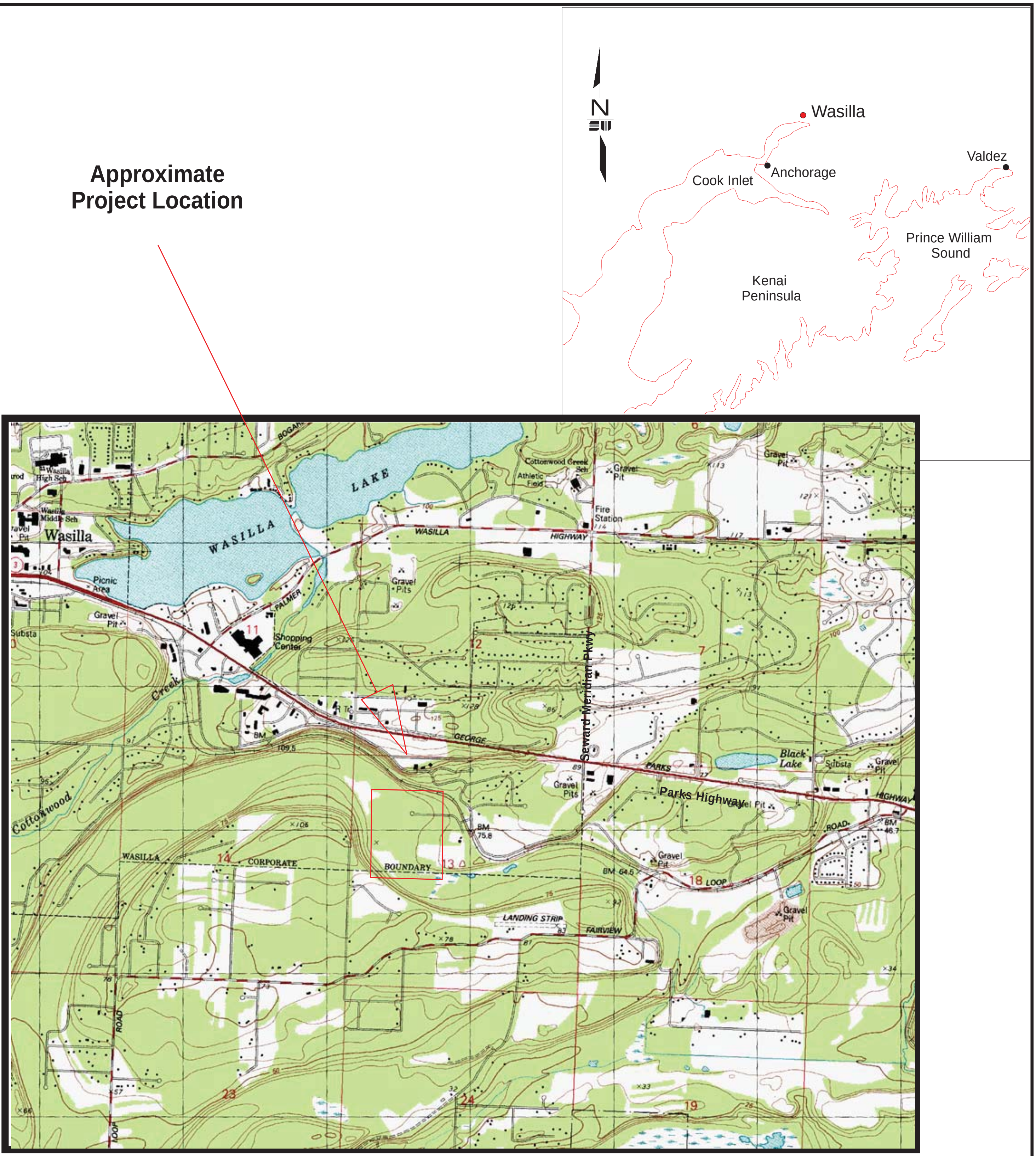

Taken from Anchorage C-7 SE
U.S. Geological Survey Quadrangle

0 2500 5000 10000

APPROXIMATE SCALE IN FEET

Wastewater Treatment Plant Improvements
Wasilla, Alaska

VICINITY MAP

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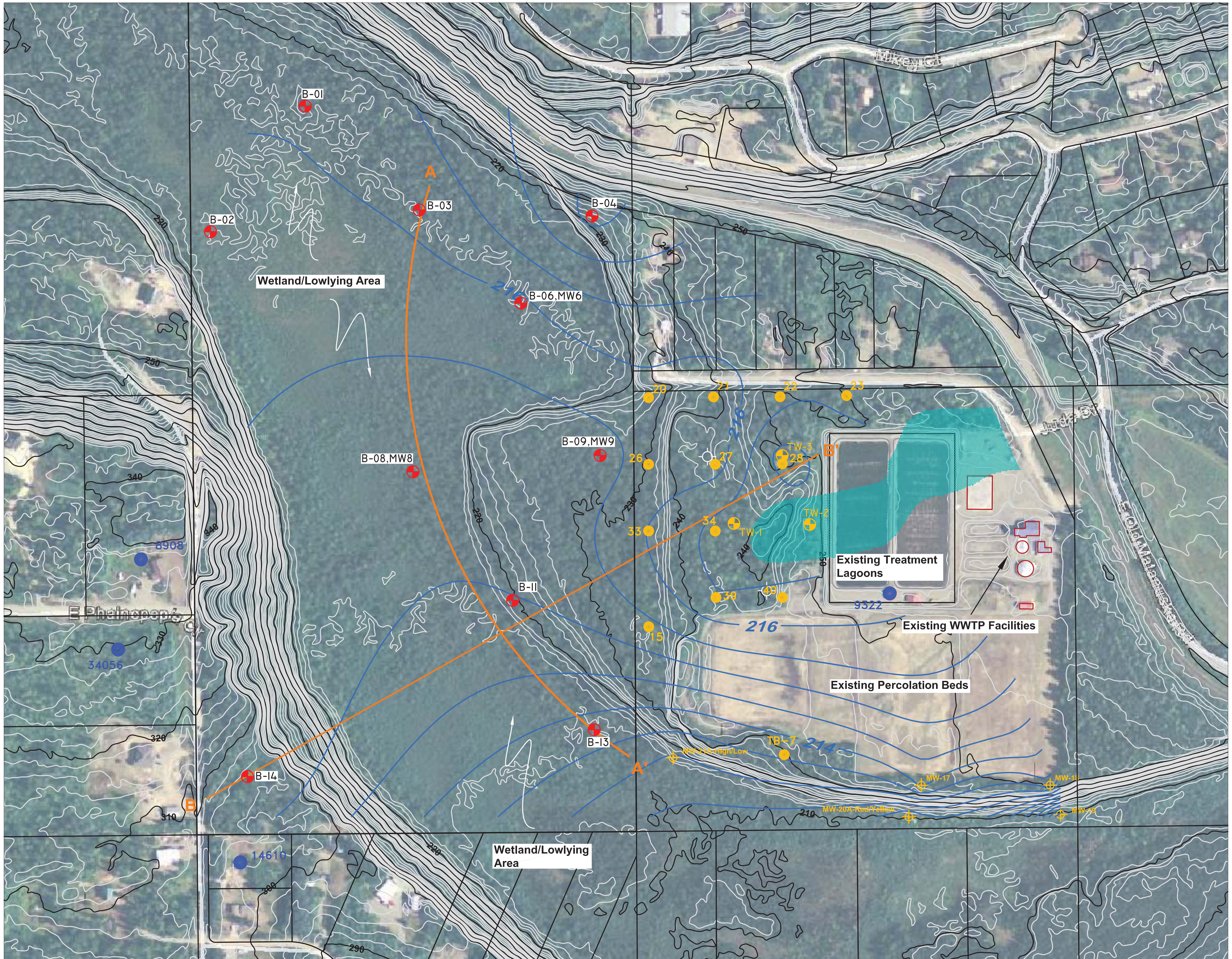
FIG. 1



LEGEND

- B-01 Approximate location of Boring B-01 advanced by Shannon & Wilson, Inc., March/May 2015 and February 2016
- TW-2 Approximate location of Boring and Monitoring Well TW-2 advanced by Shannon & Wilson, Inc., August 2007
- 15 Approximate location of Test Boring 15 by Gilfilian Engineering, Inc., May/October 1986
- MW-17 Approximate location of Monitoring Well MW-14 installed by MWH, February 2003
- 3908 Approximate location of domestic well 3908
- Topographic Contours, 2-foot Interval.
- Groundwater Contours, 0.5-foot Interval.
- Perched groundwater zone as estimated by S&W 2008 report and data.
- B — B' Profile line B - B'. See Figures 6 and 7 for conceptual hydrogeologic profiles.

NOTES

1. Basemap imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth™ Mapping Service.
2. Topographic contours from MatSu Borough GIS online database.
3. Groundwater contours adapted from measurements taken 3/7/2016.
4. Parcel boundaries from MatSu Borough GIS online database and should be considered approximate.

0 150 300 600

APPROXIMATE SCALE IN FEET

N

Wastewater Treatment Plant Improvements
Wasilla, Alaska

SITE PLAN

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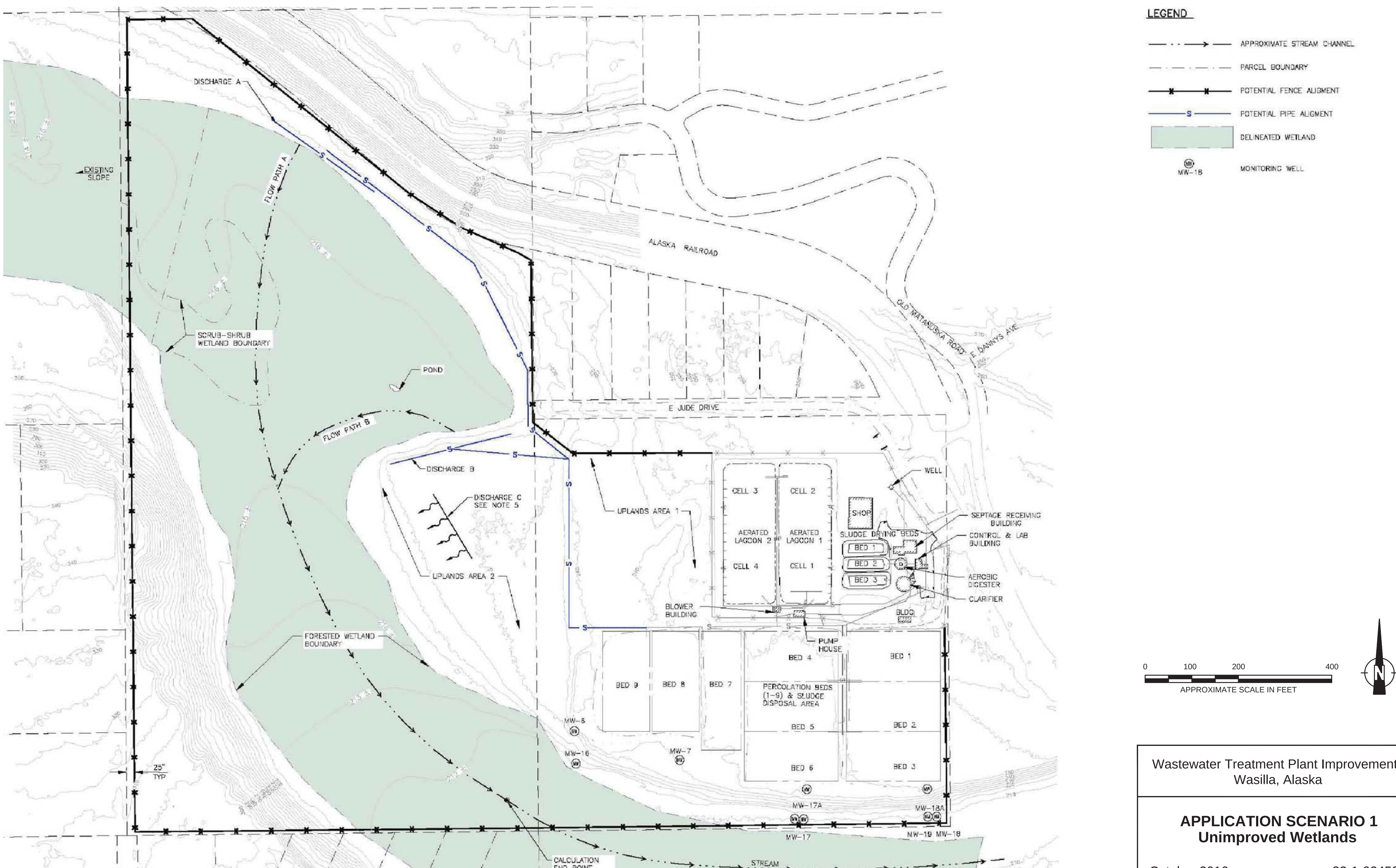
FIG. 2



Drawing provided by Stantec to indicate conceptual effluent application scenarios. Drawing date February 18, 2016.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

APPLICATION SCENARIO 1
Unimproved Wetlands

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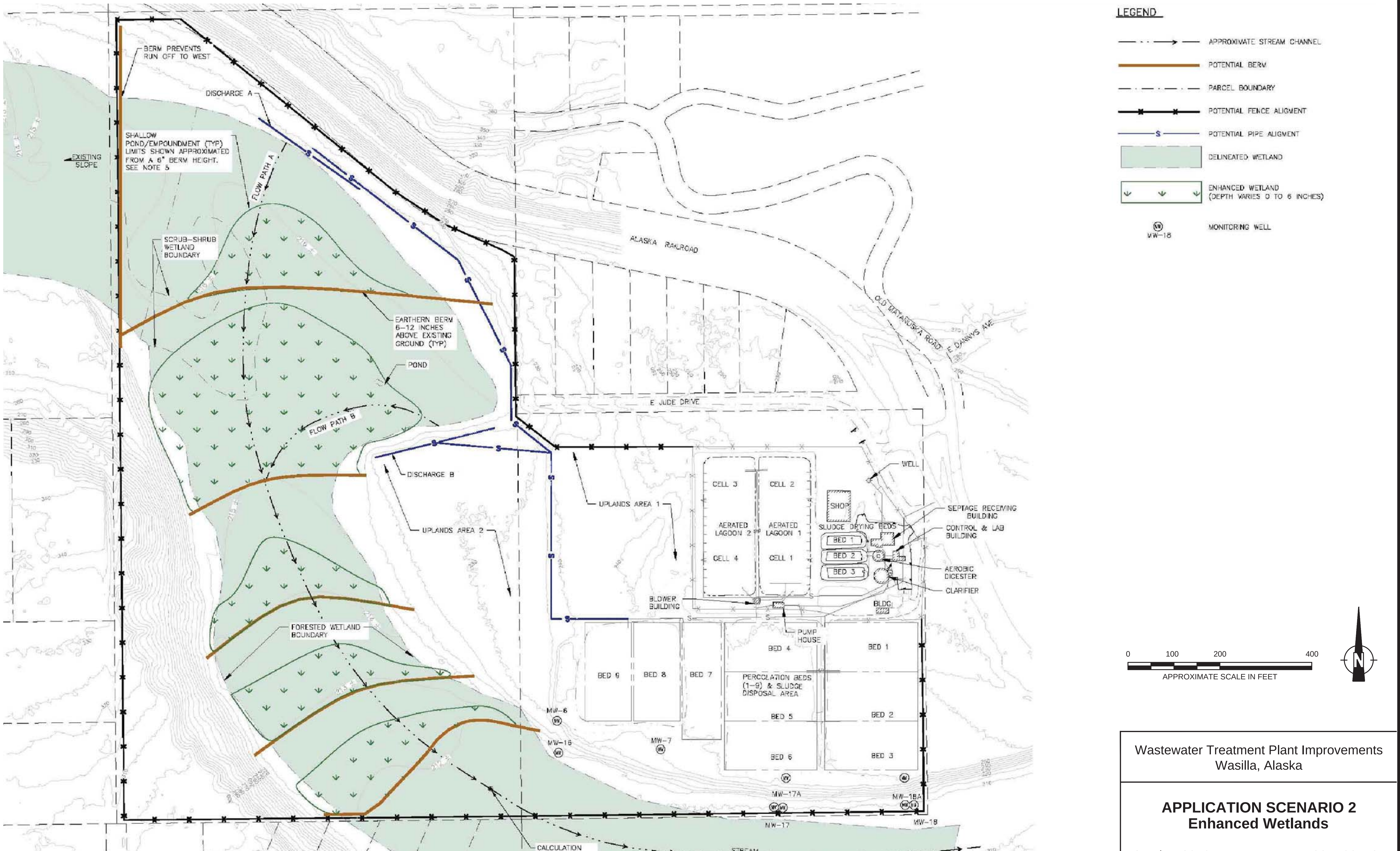
FIG. 3



Drawing provided by Stantec to indicate conceptual effluent application scenarios. Drawing date February 18, 2016.

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Wasilla, Alaska

APPLICATION SCENARIO 2
Enhanced Wetlands

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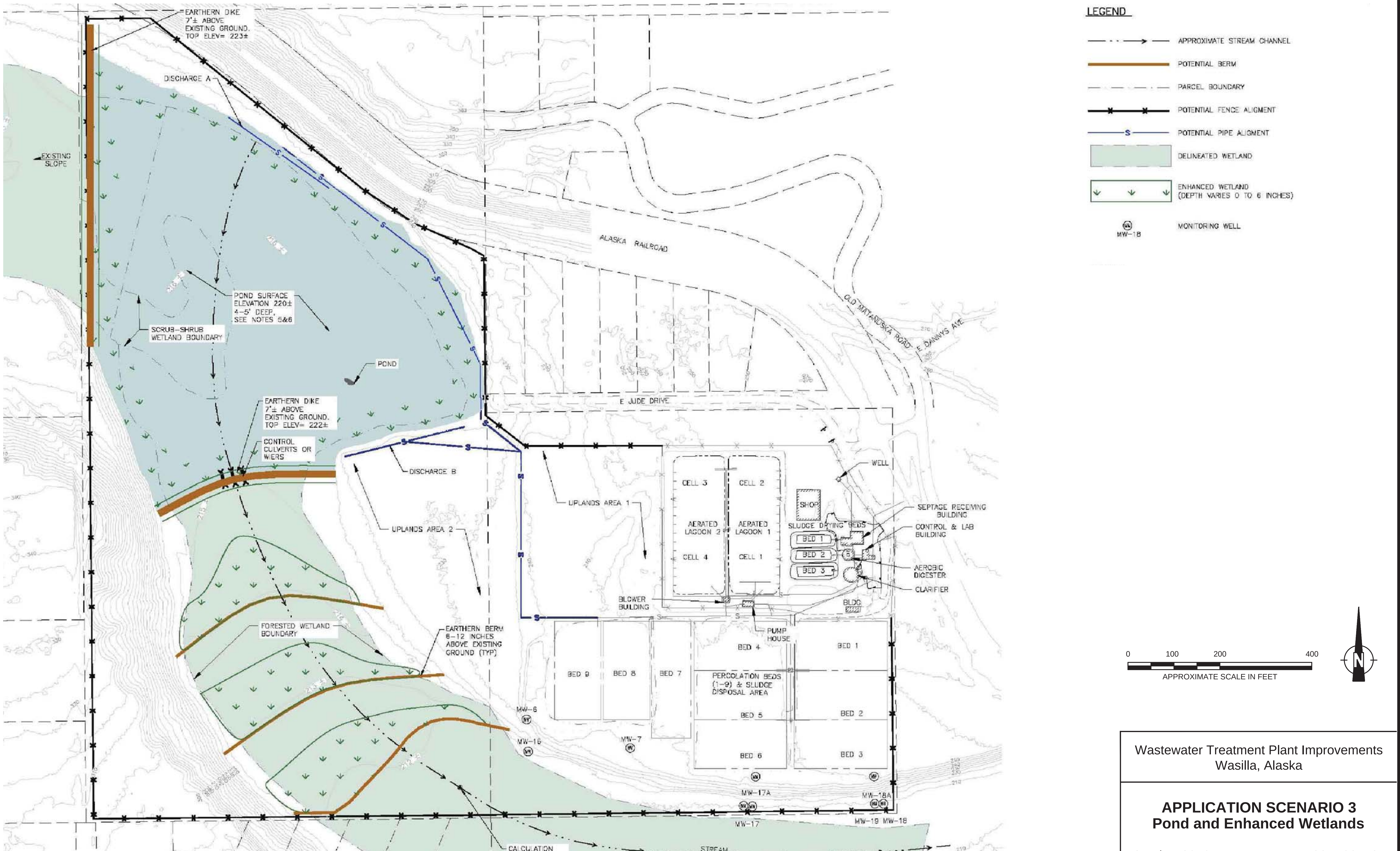
FIG. 4



Drawing provided by Stantec to indicate conceptual effluent application scenarios. Drawing date February 18, 2016.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

APPLICATION SCENARIO 3
Pond and Enhanced Wetlands

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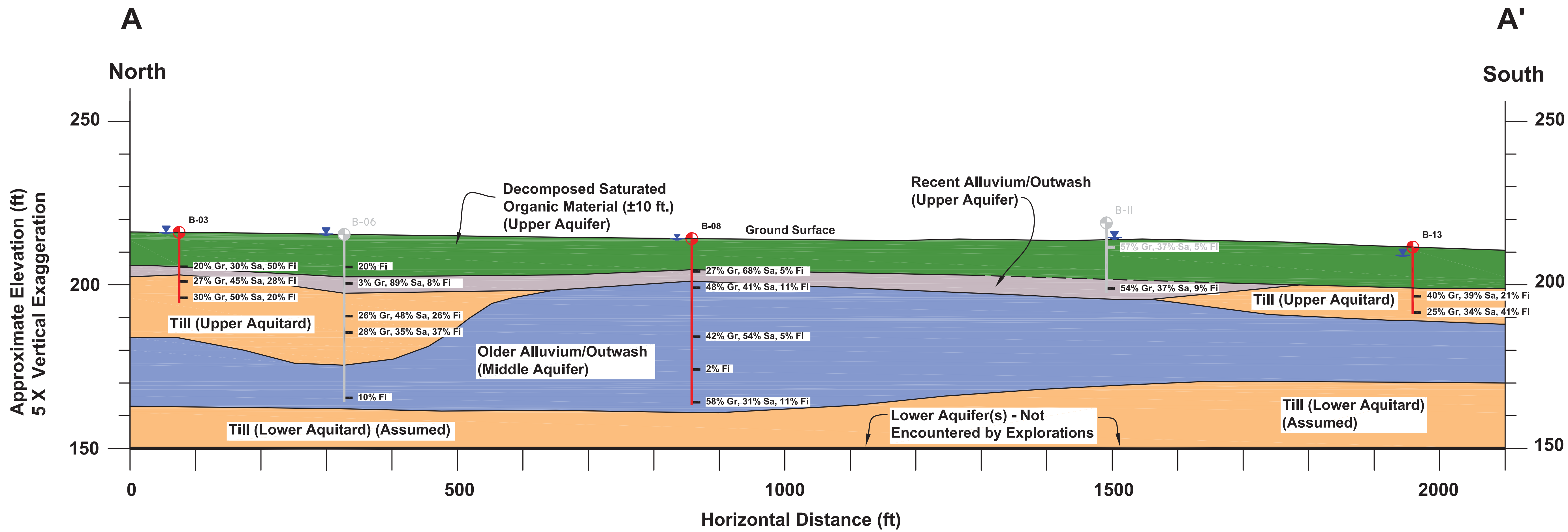
FIG. 5



LEGEND

B-03 — Approximate Location of Boring B-03 advanced by Shannon & Wilson, March/May 2015.

B-06 — Approximate Location of Boring B-06 advanced by Shannon & Wilson, March/May 2015. Gray due to increased offset from profile line.

20% Gr, 30% Sa, 50% Fi — Laboratory test results indicating 20 percent gravel, 30 percent sand, and 50 percent fines (silt and clay) by weight.

Approximate static water level measured on March 7, 2016.

NOTES

1. Profile taken along the A - A' line as shown on the Site Plan, Figure 2.
2. Conceptual layers interpreted from exploration observations and grouped based on our understanding of the site and its hydrogeologic conditions.
3. Contacts between layers on the profile are intended to be conceptual in support of the hydrogeologic modeling and should be considered approximate.
4. Borings shown above may not lie exactly on profile line as indicated on Figure 2. Subsurface conditions in some areas may be inferred from borings near the profile line.
5. Ground surface elevations from MatSu Borough GIS database and should be considered approximate.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

CONCEPTUAL HYDROGEOLOGIC PROFILE A - A'

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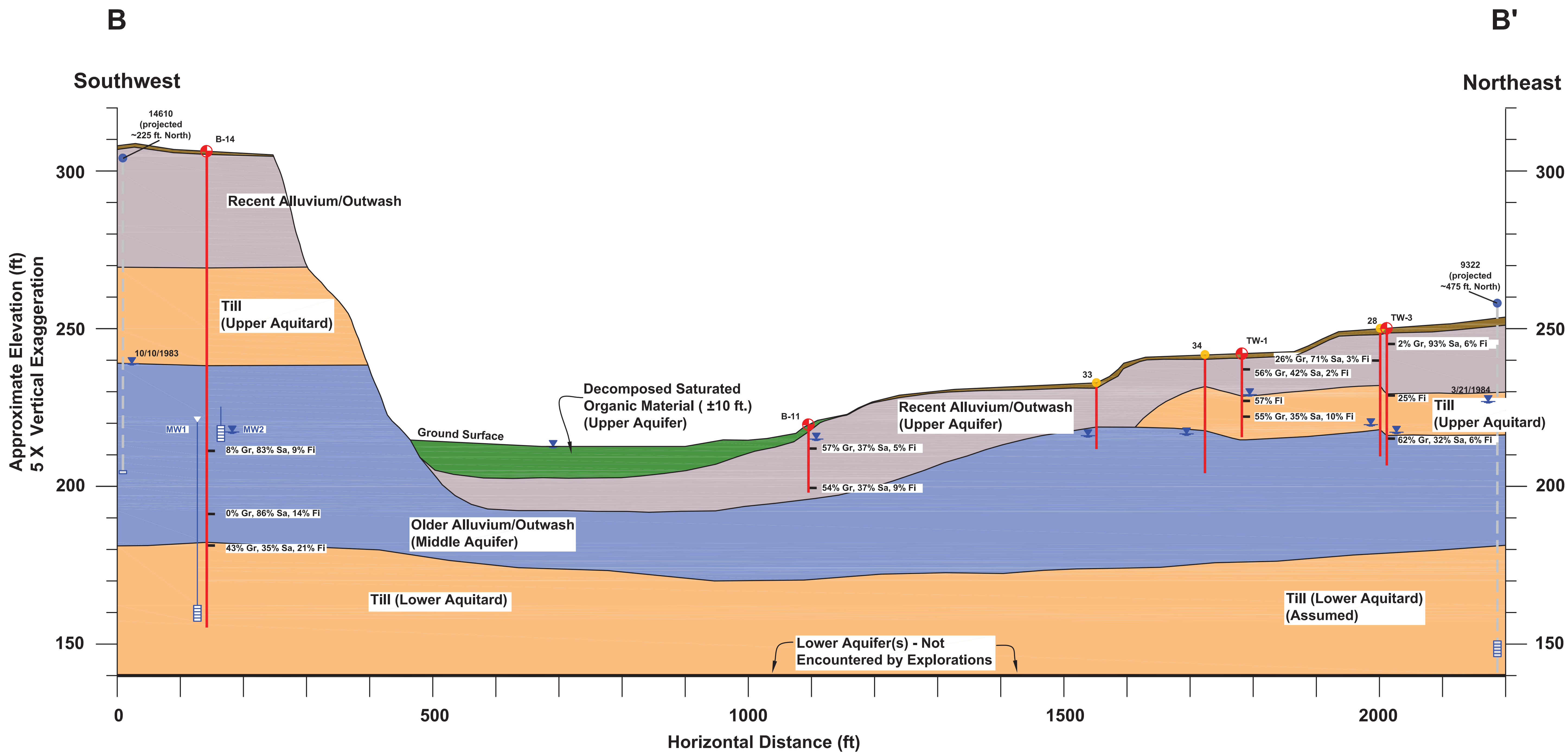
FIG. 6



LEGEND

B-11 — Approximate Location of Boring B-11 advanced by Shannon & Wilson, May 2015 and February 2016.

TW-1 — Approximate Location of Boring and Monitoring Well TW-1 advanced by Shannon & Wilson, August 2007

33 — Approximate Location of Test Boring 15 by Gilfilian Engineering, Inc., May/October 1986.

14610 — Approximate Location of Domestic Well 14610.

8% Gr, 83% Sa, 9% Fi — Laboratory test results indicating 8 percent gravel, 83 percent sand, and 9 percent fines (silt and clay) by weight.

Approximate static water level measured on March 7, 2016, unless otherwise noted.

NOTES

1. Profile taken along the B - B' line as shown on the Site Plan, Figure 2.
2. Conceptual layers interpreted from exploration observations and grouped based on our understanding of the site and its hydrogeologic conditions.
3. Contacts between layers on the profile are intended to be conceptual in support of the hydrogeologic modeling and should be considered approximate.
4. Borings shown above may not lie exactly on profile line as indicated on Figure 2. Subsurface conditions in some areas may be inferred from borings near the profile line.
5. Domestic wells included for presentation purposes only. Wells were projected various distances to the profile lines. Actual well locations, depths, and stratigraphy may differ from what is shown on this drawing.
6. Ground surface elevations from MatSu Borough GIS database and should be considered approximate.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

CONCEPTUAL HYDROGEOLOGIC PROFILE B - B'

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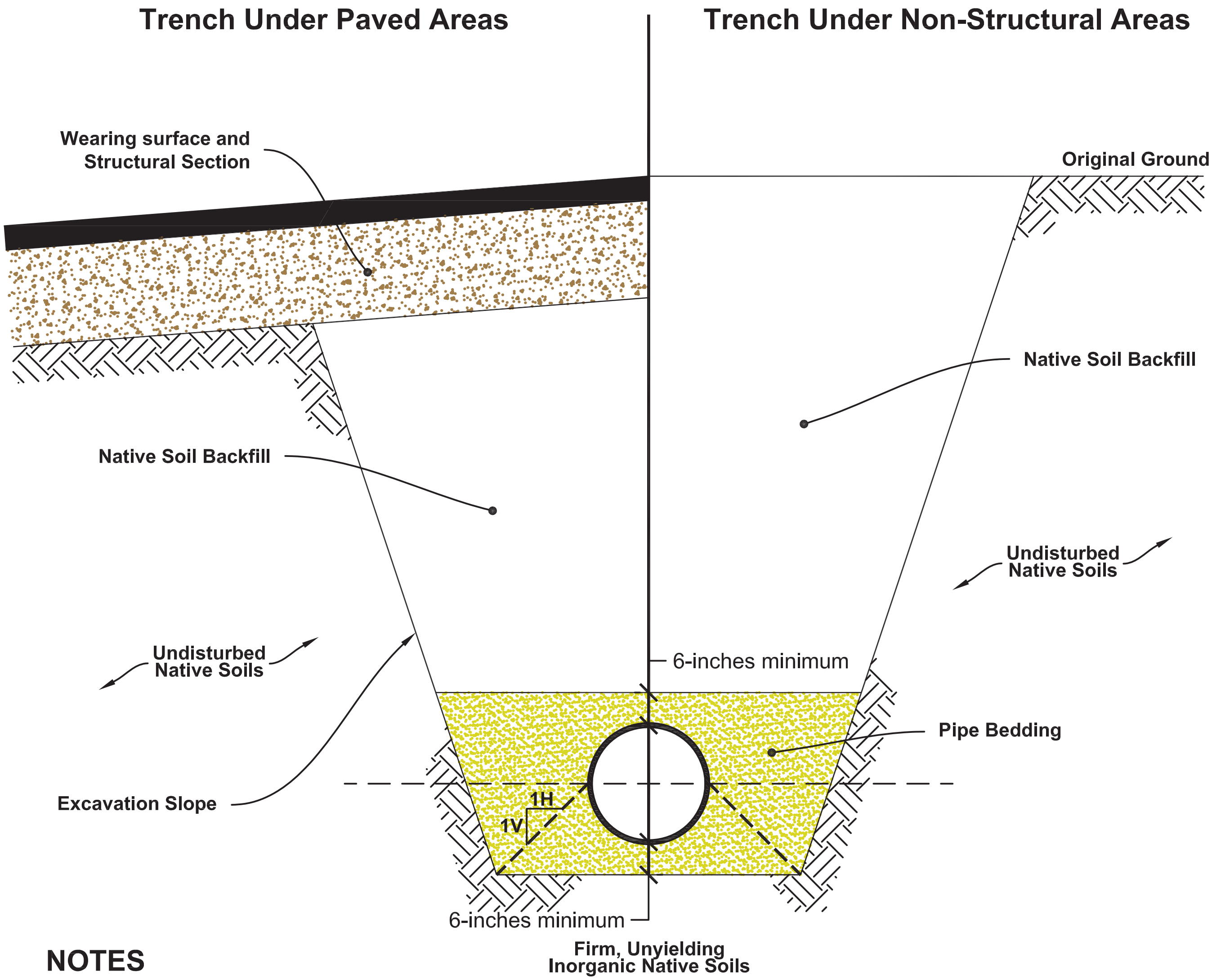
FIG. 7



NOTES

1. Trench backfill under paved areas should be placed in loose lifts not to exceed 12 inches and compacted to at least 95 percent of its maximum dry density as determined by ASTM D-1557.

2. Trench backfill under non-structural areas should be placed in loose lifts not to exceed 18 inches and compacted to at least 90 percent of its maximum dry density as determined by ASTM D-1557.

3. Pipe bedding should conform to Selected Material Type A bedding material or as recommended by pipe manufacturer.

4. Pipe bedding and cover thickness shown above should be used absent pipe manufacturer requirements.

5. OSHA requires slope protection and support for all trenches greater than 4 feet deep. Side slope requirements are variable depending upon soil type and the duration of time in which the trench remains open. The contractor should be made responsible for compliance to these regulations as he/she is at the project on a day to day basis, is aware of the changing conditions and has authority to direct work.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

UTILITY TRENCH DETAIL

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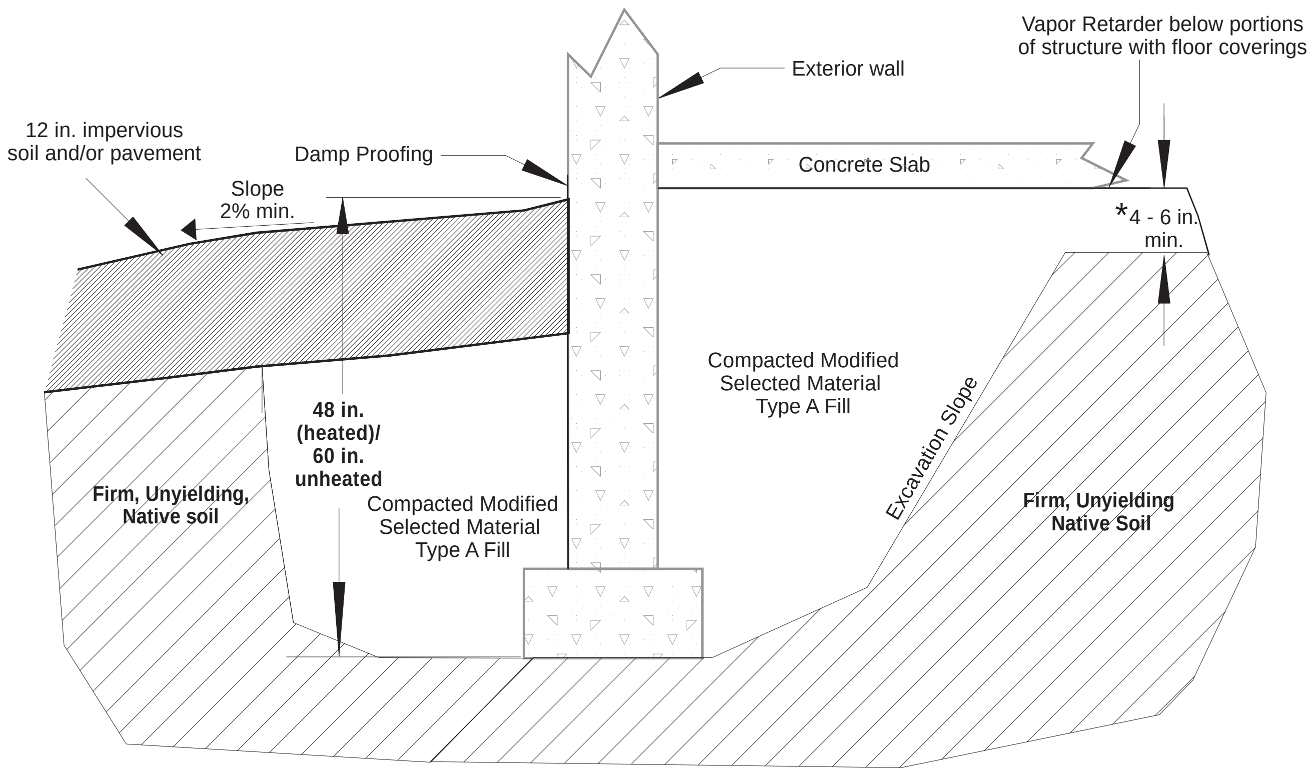
FIG. 8



NOTES:

1. If conditions render on-site soil unsuitable for compaction and drainage, backfill the footing excavation with granular soil containing no more than 6 percent by weight (based on minus 3-inch portion) passing No. 200 sieve (by wet sieving) with no plastic fines. Modified Selected Material Type A generally meets these requirements.

2. All backfill should be placed in layers not exceeding 12 inches loose thickness and densely compacted. Structural fill should be compacted to 95 percent minimum of ASTM D-1557.

3. Backfill within 18 inches of the foundation perimeter or subsurface vault walls should be placed in layers not exceeding 6 inches and densely compacted with hand-operated equipment. Heavy equipment should not be used for backfill, as such equipment operated near the foundation perimeter or subsurface vault walls could increase lateral earth pressures and possibly damage the wall.

4. OSHA requires slope protection and support for all trenches greater than 4 feet deep. Side slope requirements are variable depending upon soil type and the duration of time in which the trench remains open. The contractor who is at the project on a day to day basis, is aware of the changing conditions, and has authority to direct work, should be made responsible for compliance to these regulations.

* Sand and gravel below the floor slab should not contain particles greater than 3 inches in diameter and should be placed in maximum 6-inch loose lifts and compacted to 95 percent of its maximum density as determined by the Modified Proctor compaction procedure (ASTM D-1557).

DRAWING NOT TO SCALE

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Wasilla, Alaska

FLOOR SLAB AND FOOTING DETAIL

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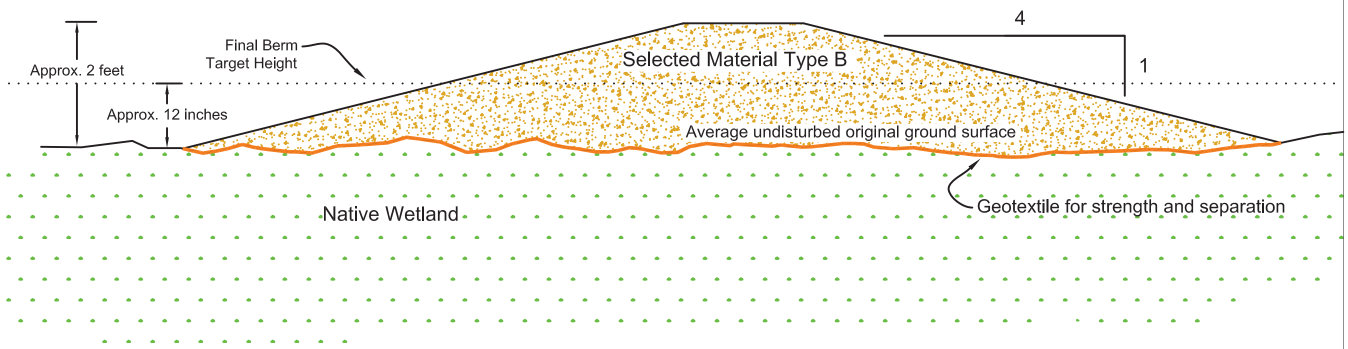
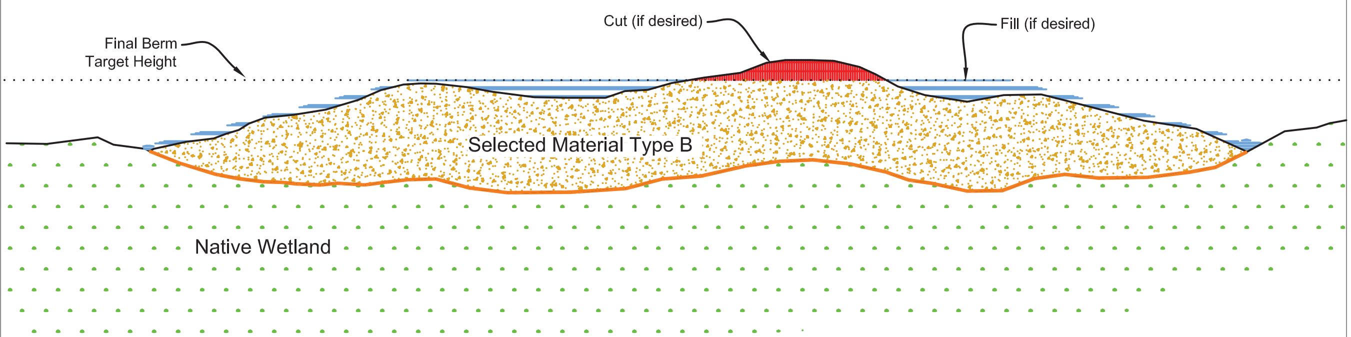
FIG. 9

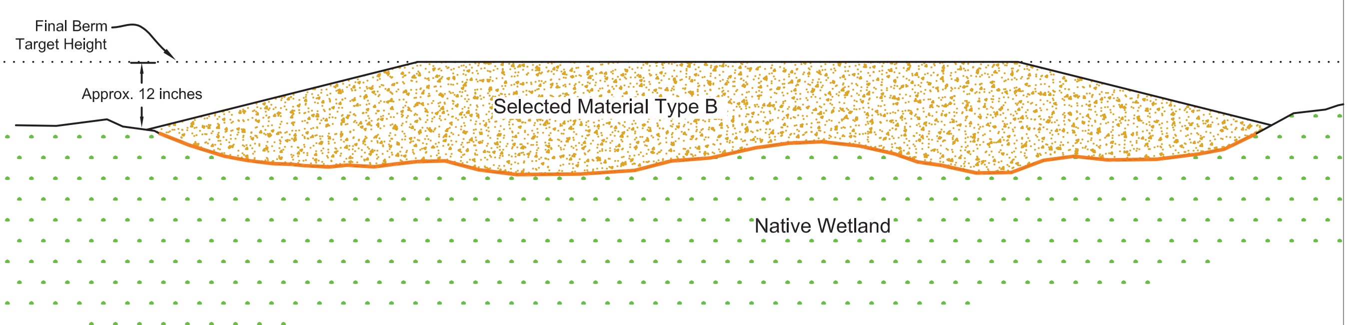
Initial Berm Construction (First Winter)



Typical Berm Consolidation (First Summer)



Final Berm



Notes:

1. Drawing not to scale.
2. See report text for berm construction details.
3. Initial berm thickness should be twice the target berm height or 3 feet maximum to accommodate for consolidation.
4. Consolidation after first seasonal thaw is shown for demonstration purposes only, actual consolidation may vary. Continuing consolidation will likely continue for several seasons.
5. Separation geofabric to conform to Mirafi RS380i product specifications or equivalent.
6. Selected Material Type B per ADOT&PF Standard Specifications for Highway Construction should be placed and compacted as outlined in text.
7. Berm material is permeable and is not intended to stop effluent. If greater impermeability is desired, a silt cap may be placed on the upstream side of the berm slope.
8. Additional grading and regular maintenance may be necessary as consolidation continues.

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TYPICAL BERM CONSTRUCTION

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FIG. 10

GRADATION AND DURABILITY REQUIREMENTS

After: Alaska Department of Transportation
Standard Specifications for Highway Construction (2015)

E-1 Surface Course

U.S. STANDARD SIEVE SIZE English	Metric	PERCENT PASSING BY WEIGHT
1 in.	25 mm	100
3/4 in.	19 mm	70 - 100
3/8 in.	9.5 mm	50 - 80
No. 4	4.75 mm	35 - 65
No. 8	2.36 mm	20 - 50
No. 50	0.300 mm	15 - 30
No. 200	0.075 mm	8 - 15

Selected Material Type A

U.S. STANDARD SIEVE SIZE English	Metric	PERCENT PASSING BY WEIGHT
No. 4	4.75 mm	20 - 55
No. 200	0.075 mm	6 Max. on minus 3-in. portion

Aggregate containing no muck, frozen material, roots, sod or other deleterious matter and with a plasticity index not greater than 6 as tested by WAQTC FOP for AASHTO T 89/T 90. Meet the gradation as tested by WAQTC FOP for AASHTO T 27/T 11.

Modified Selected Material Type A

U.S. STANDARD SIEVE SIZE English	Metric	PERCENT PASSING BY WEIGHT
3 in.	75 mm	100
No. 4	4.75 mm	20 - 55
No. 200	0.075 mm	6 Max. on minus 3-in. portion

Aggregate containing no muck, frozen material, roots, sod or other deleterious matter and with a plasticity index not greater than 6 as tested by WAQTC FOP for AASHTO T 89/T 90. Meet the gradation as tested by WAQTC FOP for AASHTO T 27/T 11.

Selected Material Type B

U.S. STANDARD SIEVE SIZE English	Metric	PERCENT PASSING BY WEIGHT
No. 200	0.075 mm	10 Max. on minus 3-in. portion

Aggregate containing no muck, frozen material, roots, sod or other deleterious matter and with a plasticity index not greater than 6 as tested by WAQTC FOP for AASHTO T 89/T 90. Meet the gradation as tested by WAQTC FOP for AASHTO T 27/T 11.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GRADATION REQUIREMENTS

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FIG. 11

APPENDIX A

MODEL CONSTRUCTION, CALIBRATION AND SIMULATION RESULTS

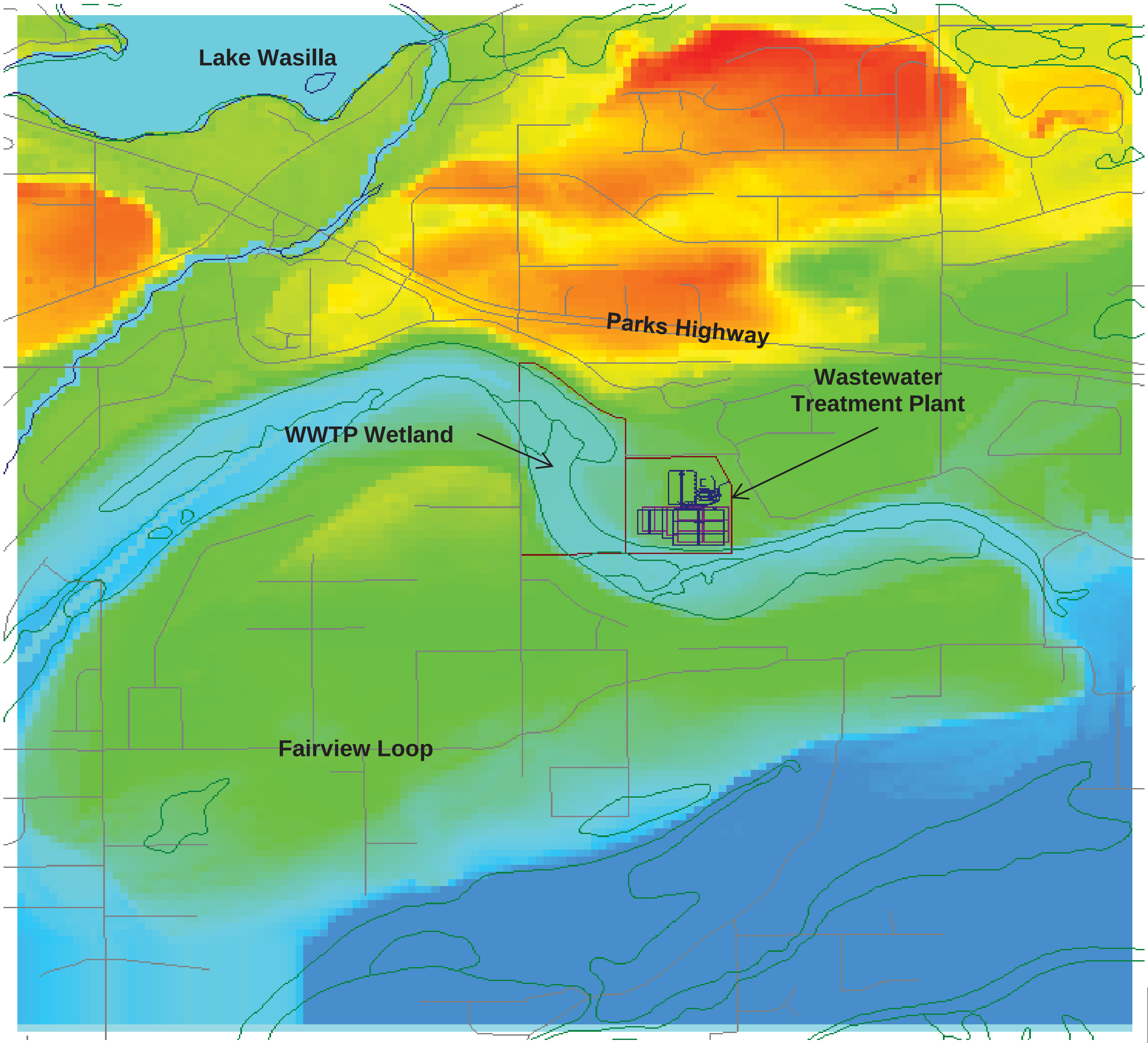
TABLE OF CONTENTS

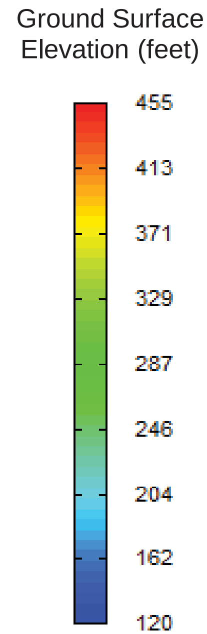
TABLE

FIGURES

TABLE A-1
GROUNDWATER MODEL CALIBRATION RESULTS

Model Run	Horizontal Hydraulic Conductivity (ft/day)				Recharge (ft/day)		Residual Mean	Absolute Residual Mean	Residual Std. Deviation	Sum of Squares
	Recent Alluvium	Till	Older Alluvium	Organic Material	Areal	WWTP				
Steadystate-1	40	0.1	40	1	0.0008	0.01	2.8	2.8	1.1	145.2
Steadystate-2	40	0.1	40	1	0.0008	0.02	-3.5	3.6	1.3	224.9
Steadystate-3	40	0.1	40	1	0.0008	0.015	-0.8	1.2	1.2	32.0
Steadystate-4	40	0.1	40	1	0.0008	0.013	0.7	0.9	1.1	27.7
Steadystate-5	40	0.1	40	1	0.0008	0.013	0.6	0.9	0.9	19.9
Steadystate-8	40	0.1	40	1	0.0008	0.07	0.3	1.1	1.3	28.2
Steadystate-9	40	0.1	40	1	0.0008	0.07	0.5	0.7	0.7	12.5





Legend

Wetlands

Roads

WWTP Parcel Boundary

Lakes and Streams

Notes:

1. Ground surface elevations adapted from Digital Elevation Model (DEM) provided by the Mat-Su Borough from lidar mapping conducted in 2011. DEM was resampled by Shannon & Wilson to 10 meter resolution.

2. Wetland, road, lakes/streams, and parcel linework adapted from GIS data provided by the Mat-Su Borough.

Not to Scale

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GROUNDWATER MODEL DOMAIN AND MAP KEY

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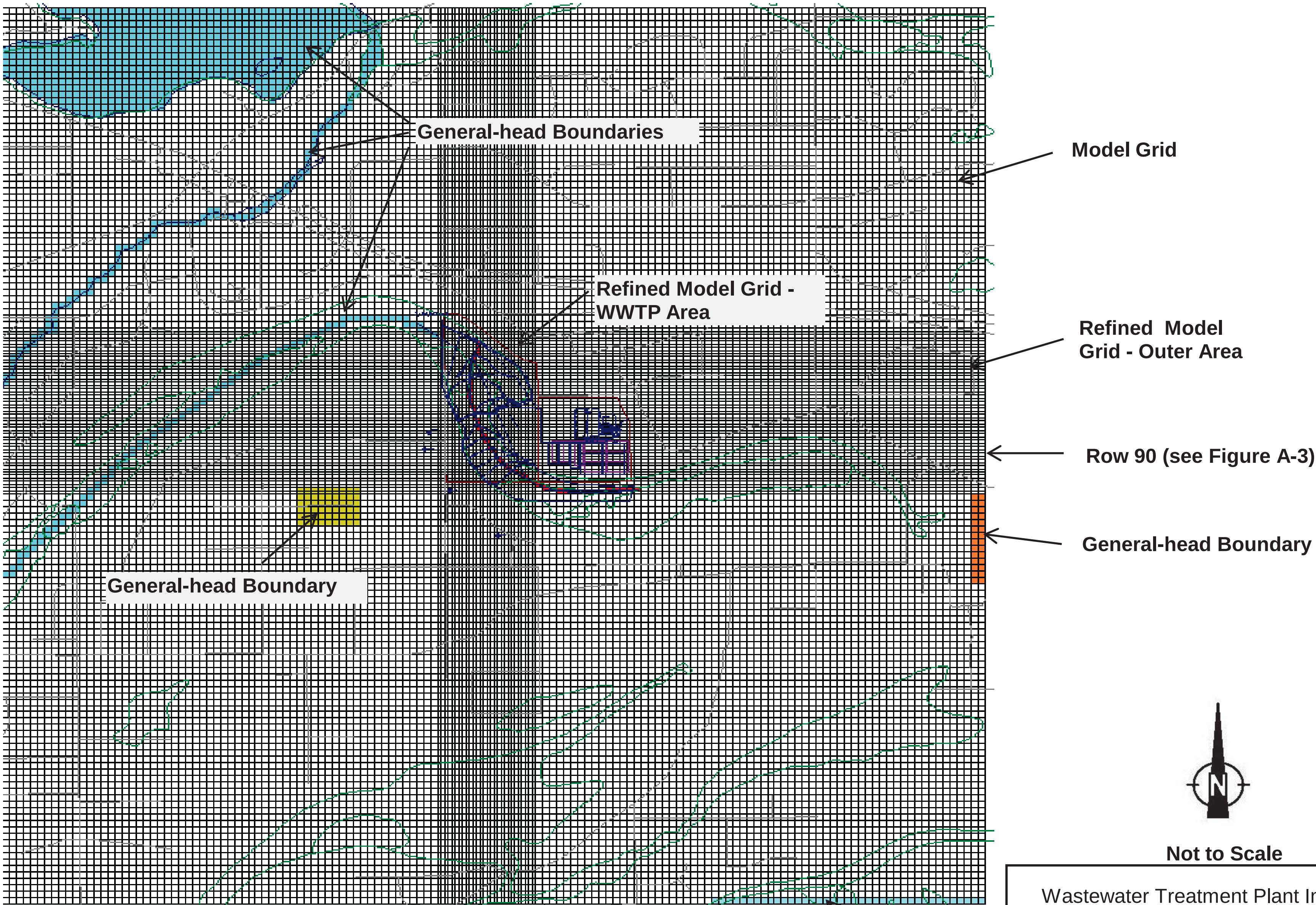
FIG. A-1



Notes:

1. See legend on Figure A-1 for key to basemap features.
2. See Sections 6.2 and 6.3 of report text for description of model grid and boundary conditions.
3. Model grid consists of 100-foot by 100-foot cells. Grid cells in outer refined areas are 50-foot by 100-foot. Grid cells in WWTP refined area are 50-foot by 50-foot.

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GROUNDWATER MODEL BOUNDARY CONDITIONS & GRID

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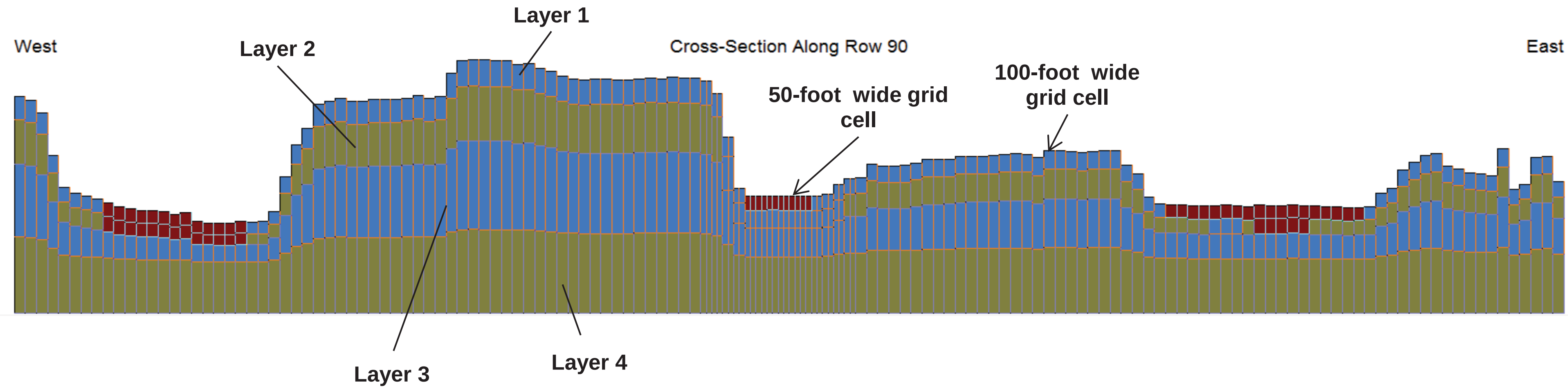
FIG. A-2



Layer	Sublayer	Horizontal Hydraulic Conductivity (ft/day)*	Generalized Soil Description
1	a	1	Peat/Decomposed Organics
	b	40	Sand and Gravel Alluvium/Outwash
2	a	0.4	Till or till-like soil
	b	40	Sand and Gravel Alluvium/Outwash
	c	1	Peat/Decomposed Organics
3	None	40	Sand and Gravel Alluvium/Outwash
4	None	0.4	Till or till-like soil

* See Table 2 of report text for additional hydraulic properties and soil and aquifer descriptions

Notes:

1. Cross section taken along Row 90 of the groundwater model grid. See Figure A-2 for approximate location of Row 90.

2. Vertical axis not to scale. Exaggerated for visual effect.

3. Layer boundaries are idealized for modeling purposes.

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GROUNDWATER MODEL PROFILE (WEST-EAST)

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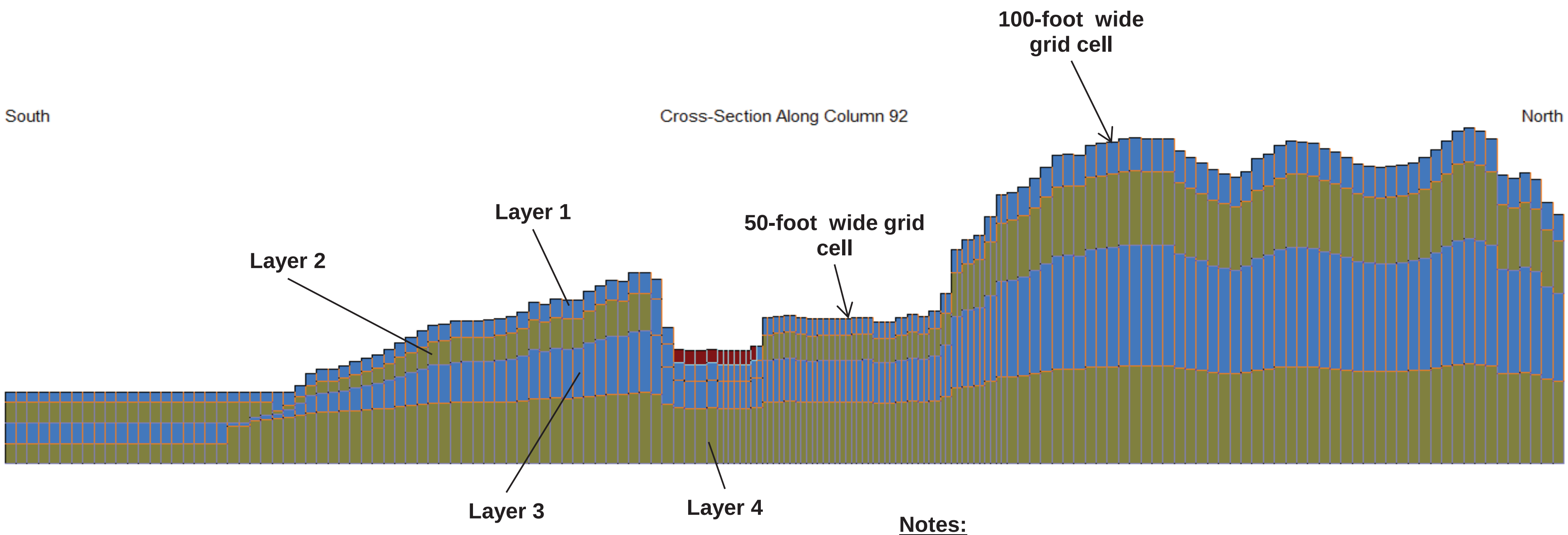
FIG. A-3



Layer	Sublayer	Horizontal Hydraulic Conductivity (ft/day)	General Soil Unit Description
1	a	1	Peat/Decomposed Organics
	b	40	Sand and Gravel Alluvium/Outwash
2	a	0.4	Till or till-like soil
	b	40	Sand and Gravel Alluvium/Outwash
	c	1	Peat/Decomposed Organics
3	None	40	Sand and Gravel Alluvium/Outwash
4	None	0.4	Till or till-like soil

* See Table 2 of report text for additional hydraulic properties and soil and aquifer descriptions

Notes:

1. Cross section taken along Column 92 of the groundwater model grid. See Figure A-2 for approximate location of Column 92.

2. Vertical axis not to scale. Exaggerated for visual effect.

3. Layer boundaries are idealized for modeling purposes.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER MODEL PROFILE (NORTH-SOUTH)

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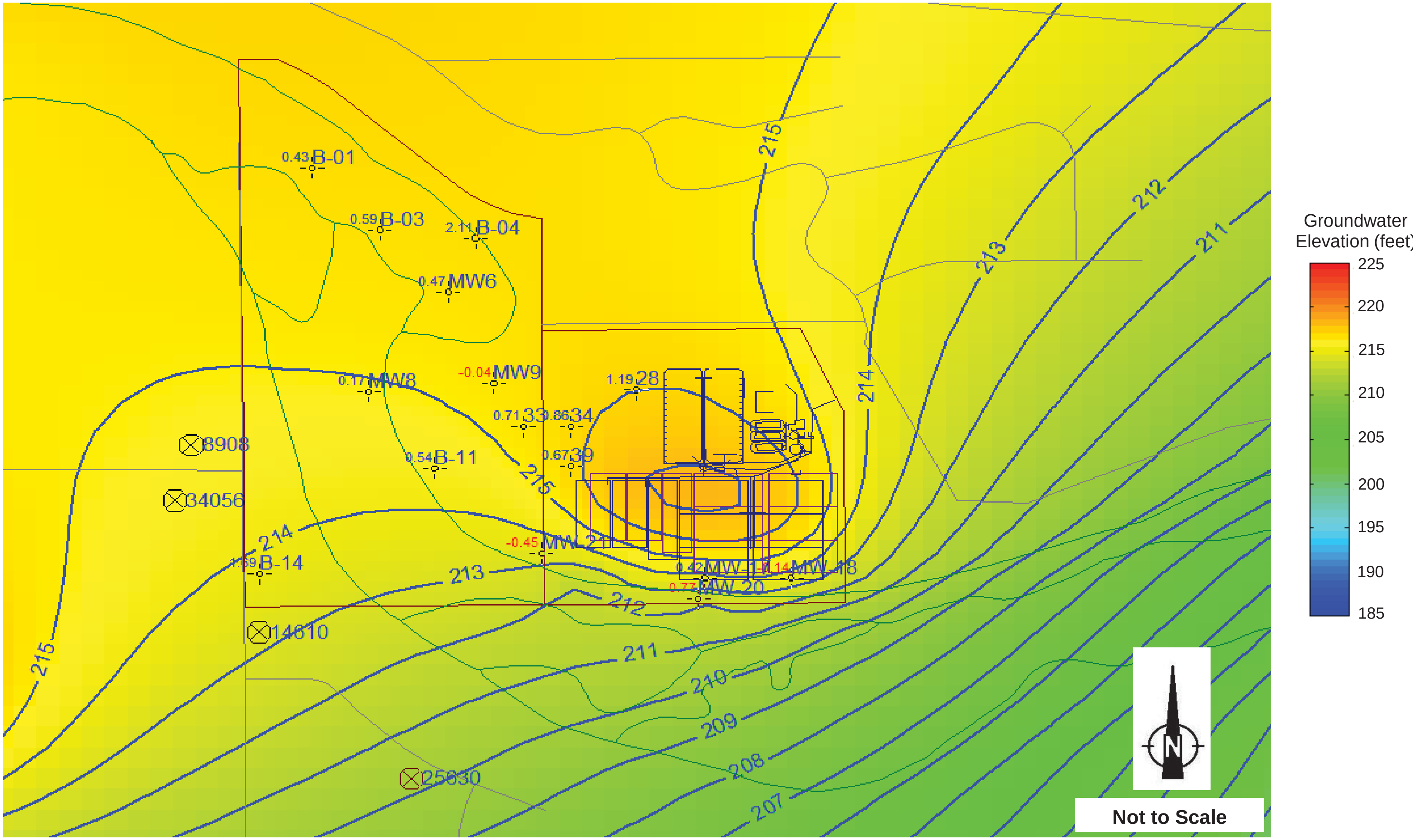
FIG. A-4



Notes:

1. Blue lines represent groundwater elevation contours (in feet).
2. Calibration results are shown as residual values at each target (well). Residuals represent the difference (in feet).between March 7 , 2016 observed groundwater levels and calculated groundwater levels.
3. See legend on Figure A-1 for key to basemap features.
4. See Table A-1 in Appendix A for tabulated calibration results summary.
5. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
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GROUNDWATER MODEL CALIBRATION RESULTS

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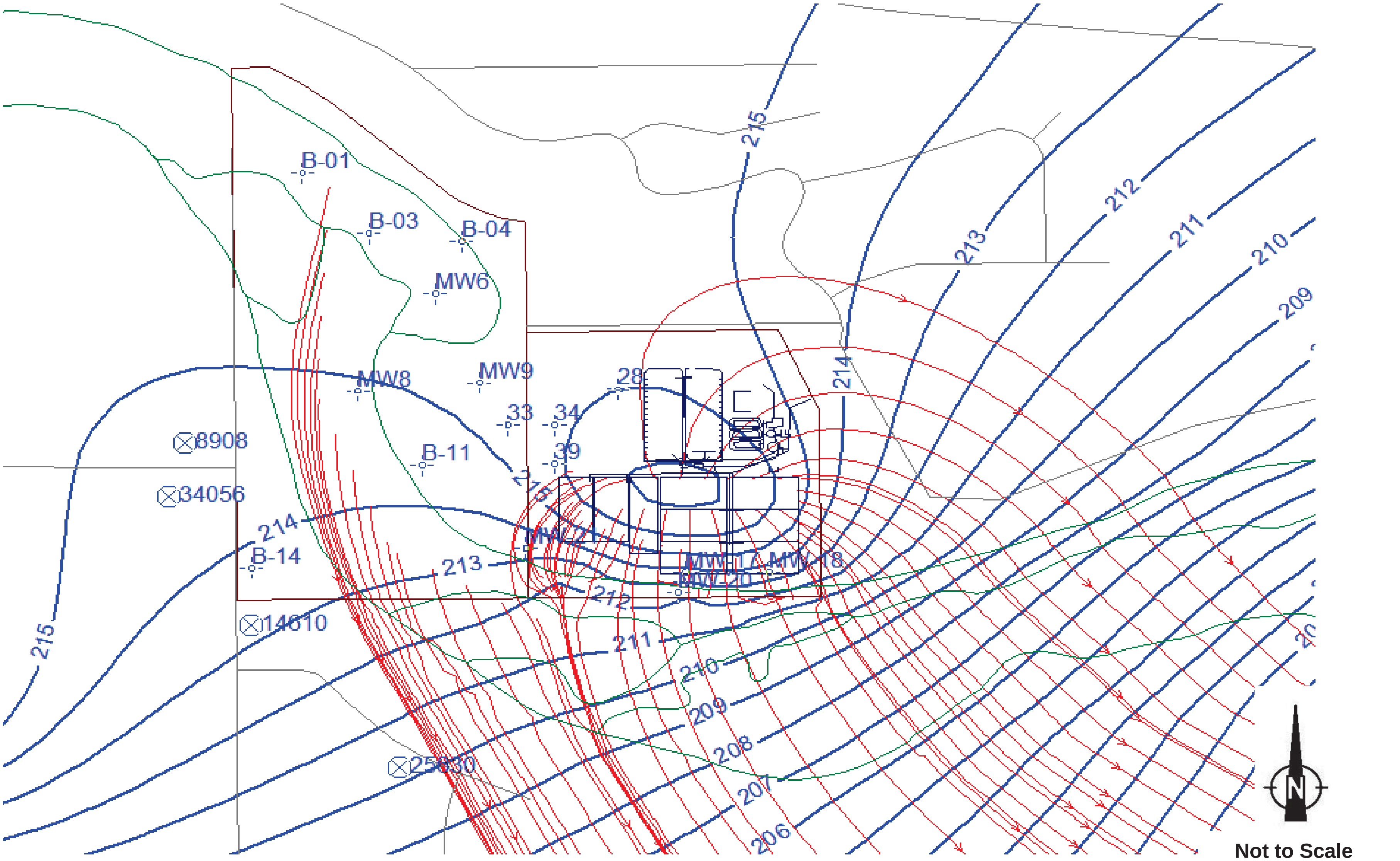
FIG. A-5



Discharge to Existing Percolation Beds- 350,000 GPD

Notes:

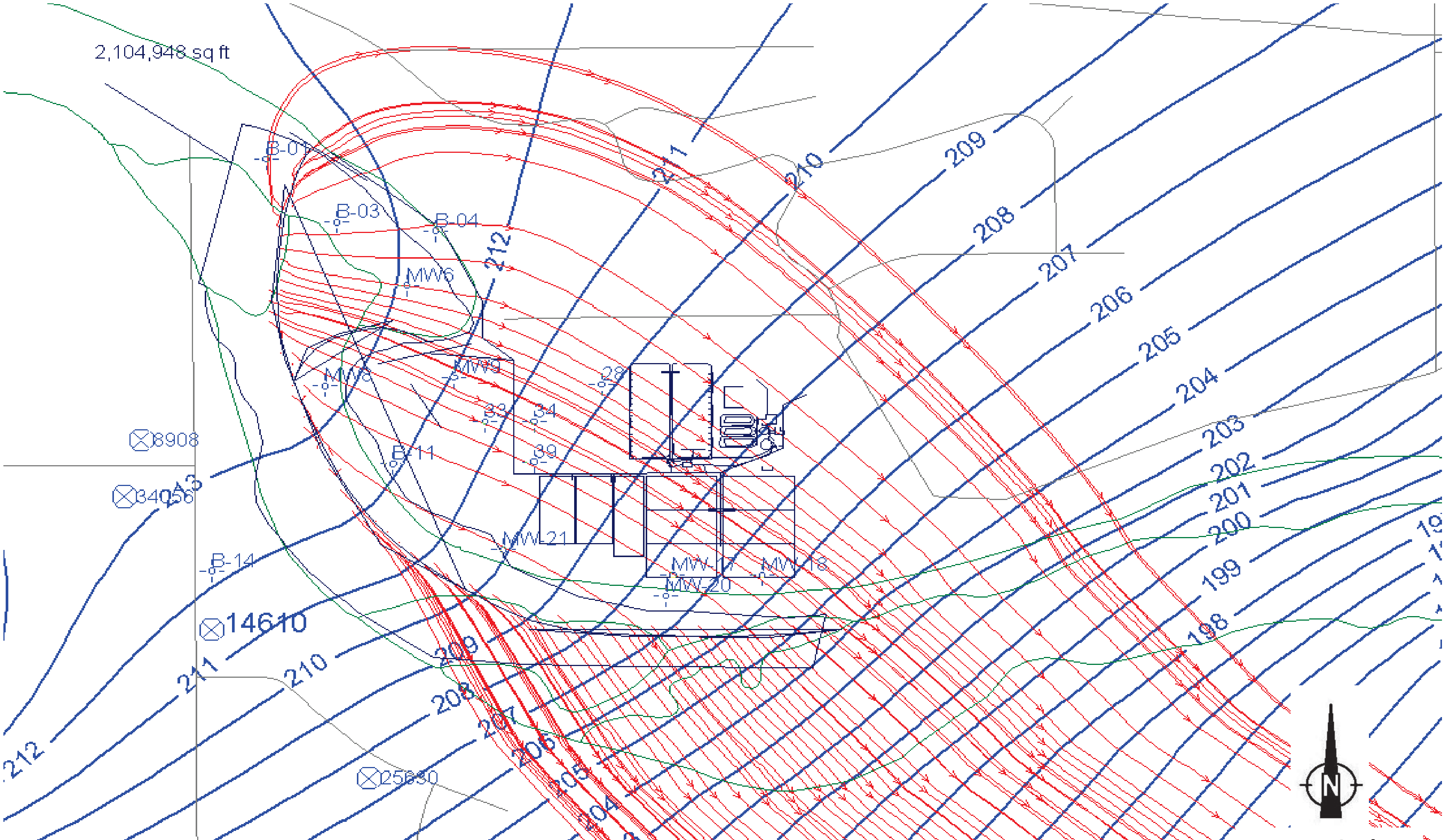
1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.

2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.

3. See legend on Figure A-1 for key to basemap features.

4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements Wasilla, Alaska	
GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING Existing Conditions	
October 2016	32-1-02452
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. A-6**



Discharge to Unimproved Wetlands - 350,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 1a

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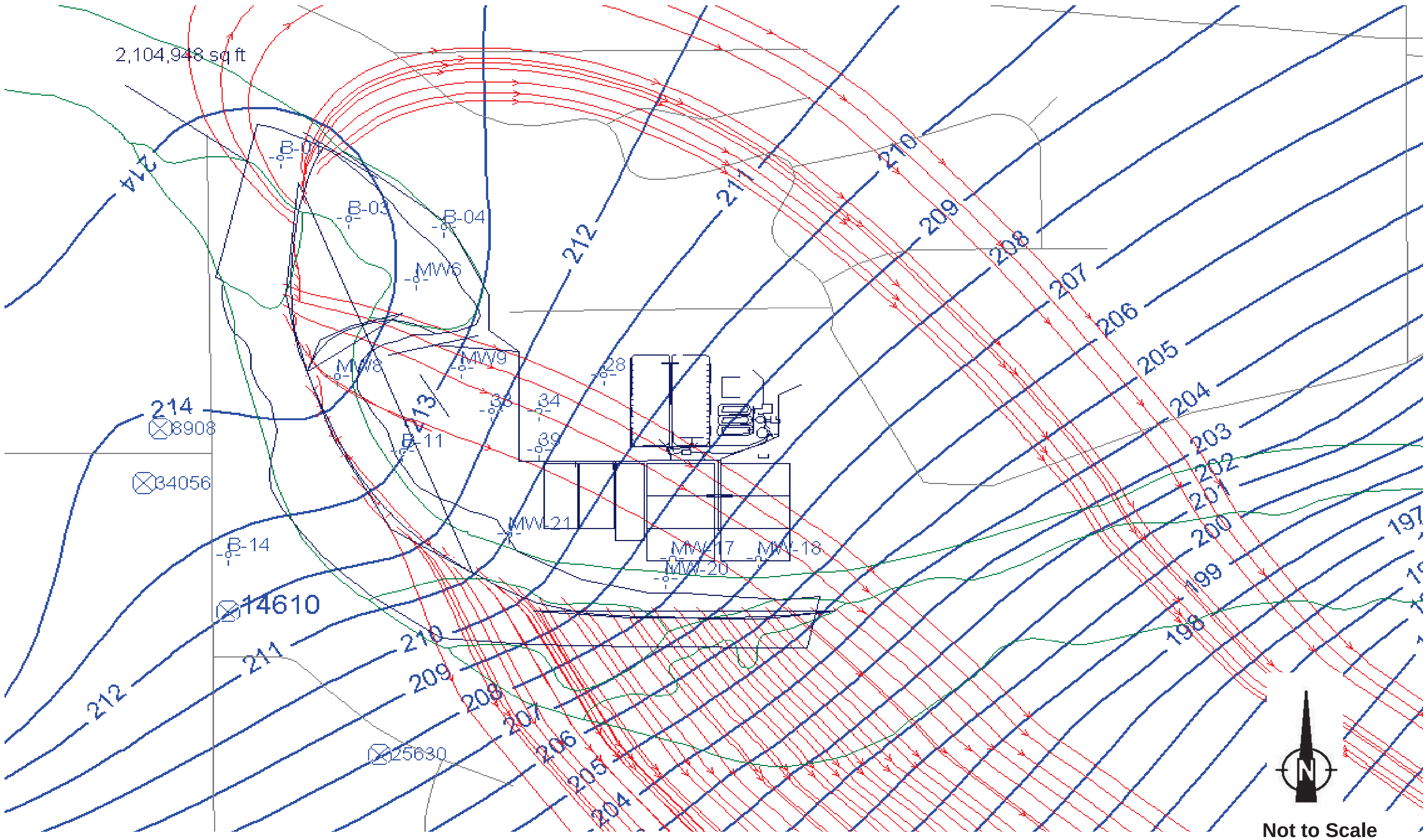
FIG. A-7



Discharge to Unimproved Wetlands - 500,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 1b

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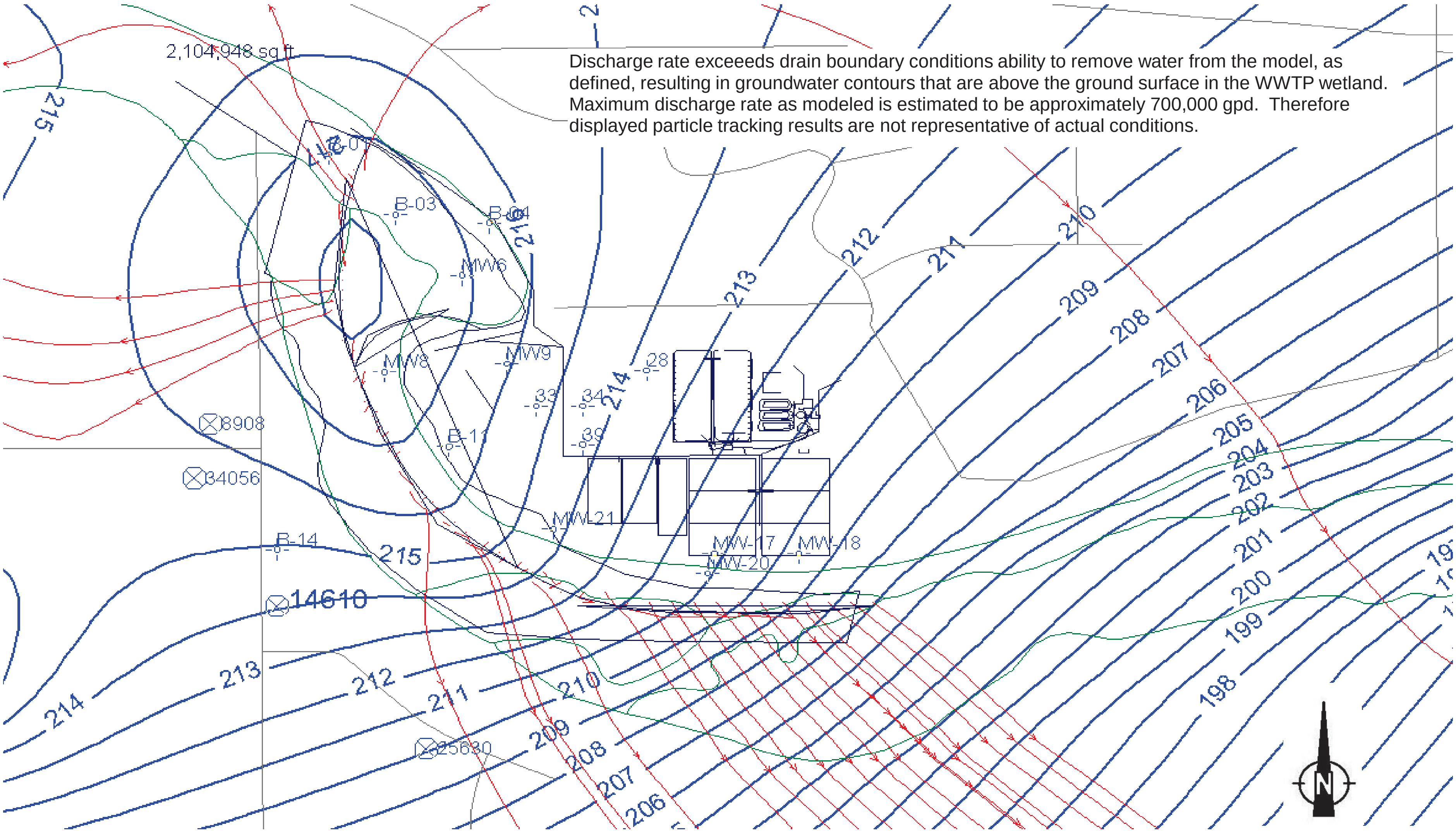
FIG. A-8



Discharge to Unimproved Wetlands - 1,000,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 1c

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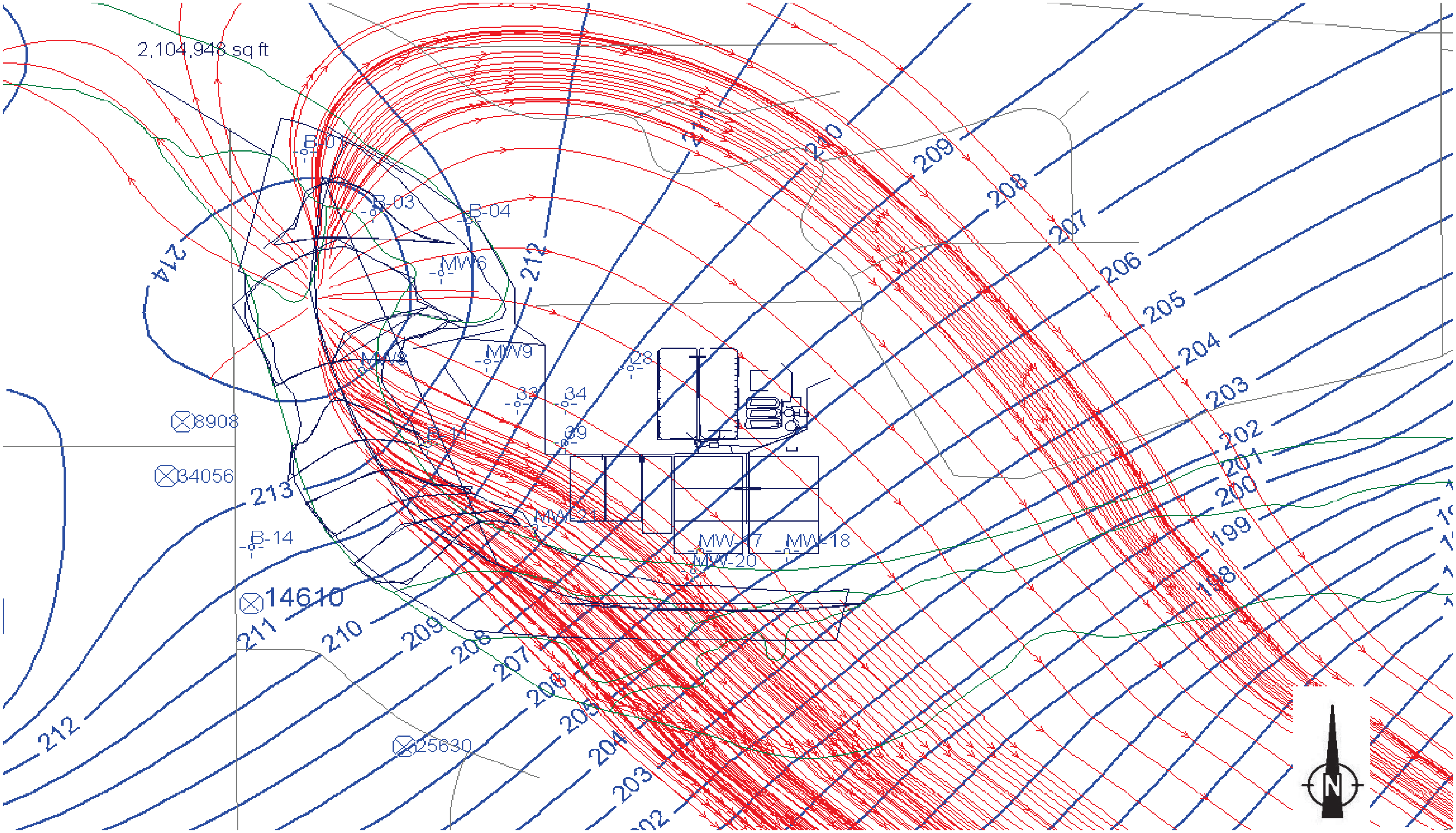
Geotechnical and Environmental Consultants

FIG. A-9



Not to Scale

Discharge to Enhanced Wetlands (several small berms,less than 12 inches tall) - 350,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 2a

October 2016 | 32-1-02452

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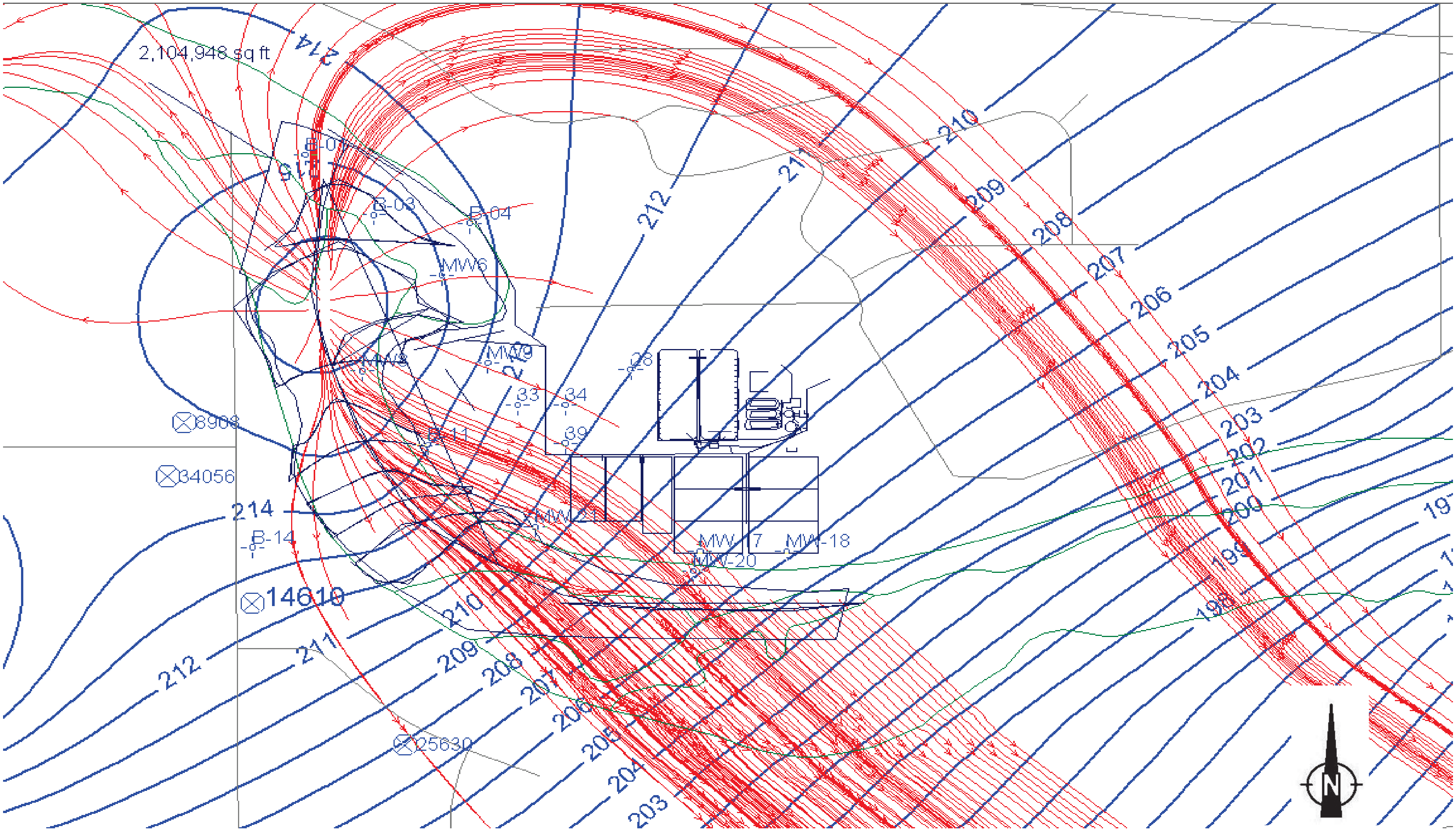
FIG. A-10



Discharge to Enhanced Wetlands Wetlands (several small berms,less than 12 inches tall) - 500,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 2b

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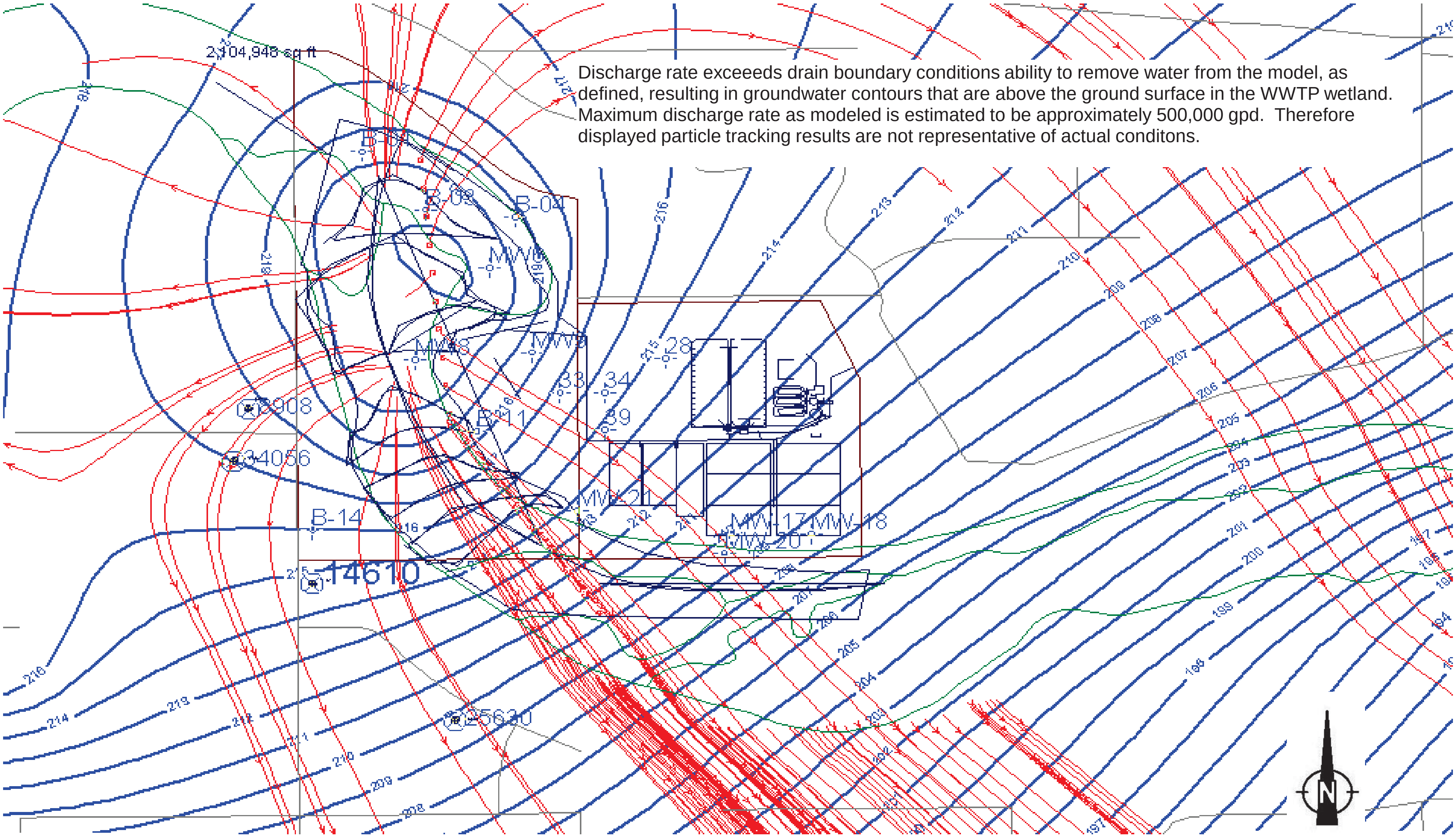
FIG. A-11



Discharge to Enhanced Wetlands Wetlands (several small berms,less than 12 inches tall) - 1,000,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 2c

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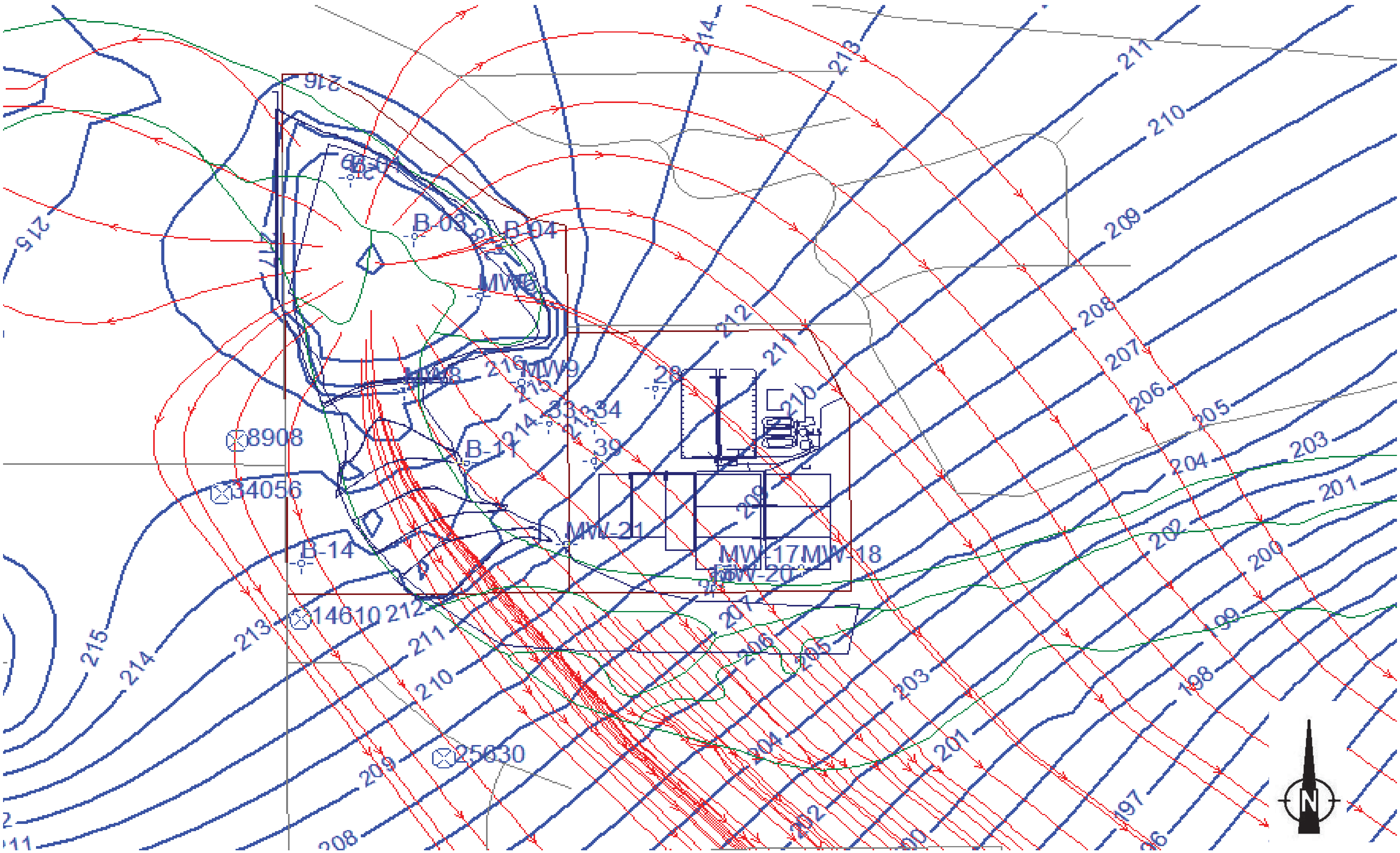
FIG. A-12

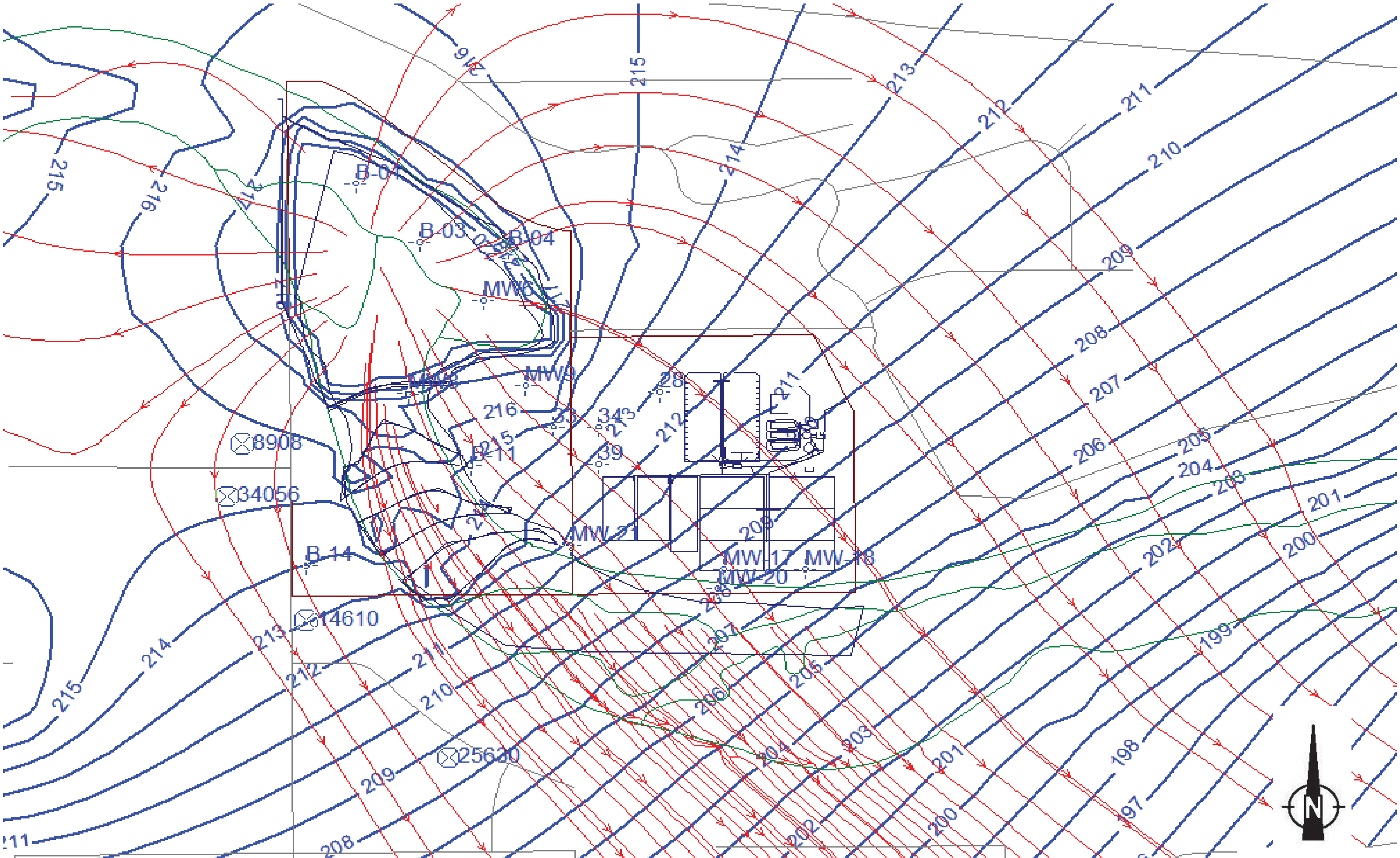


Discharge to Pond and Enhanced Wetlands (Pond 4 to 5 feet deep and several berms down gradient) - 350,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements Wasilla, Alaska	
GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING **Application Scenario 3a**	
October 2016	32-1-02452
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. A-13**



Discharge to Pond and Enhanced Wetlands (Pond 4 to 5 feet deep and several berms down gradient) - 500,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.

2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.

3. See legend on Figure A-1 for key to basemap features.

4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 3b

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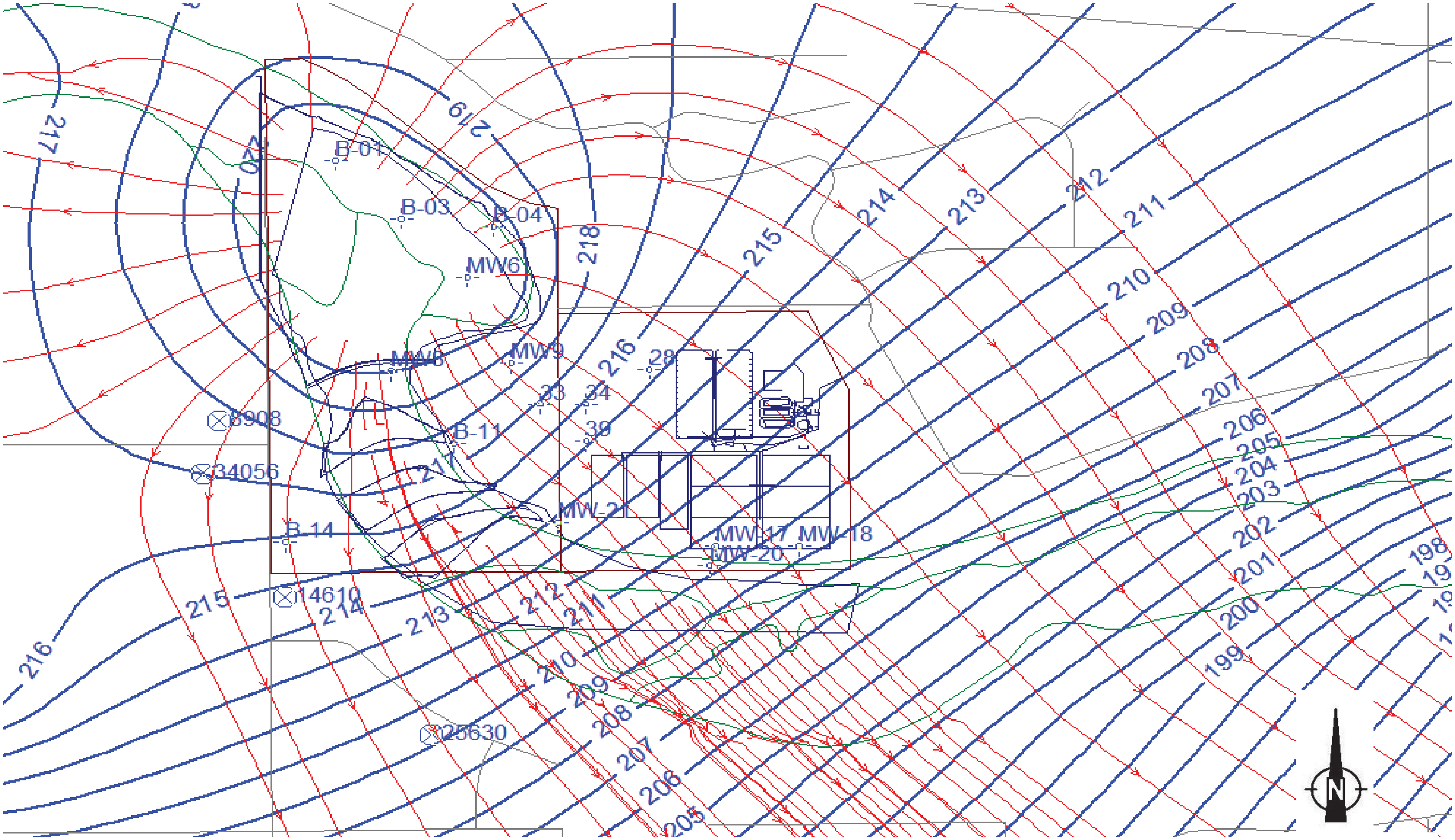
FIG. A-14



Not to Scale

Discharge to Pond and Enhanced Wetlands (Pond 4 to 5 feet deep and several berms down gradient) - 1,000,000 GPD

Notes:

1. Blue lines represent modeled groundwater elevation contours (in feet). Red lines are particle tracers, representing horizontal movement of potential contaminants inserted along the center of the WWTP wetland. Particle tracers only represent a discrete water particle and are intended to approximate the path of potential contaminants. Density of tracer lines does not indicate concentration, dispersion, or dilution of potential contaminants.
2. Approximate locations of known domestic wells are indicated by ⊗ symbol. Well name corresponds to AK Department of Natural Resources well log ID number.
3. See legend on Figure A-1 for key to basemap features.
4. See Figure 2 for descriptions of Borings, Monitoring Wells, and Domestic Wells shown on plot.

Wastewater Treatment Plant Improvements
Wasilla, Alaska

GROUNDWATER ELEVATION CONTOURS AND PARTICLE TRACKING
Application Scenario 3c

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FIG. A-15

APPENDIX B

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

Date: October 2016
To: Stantec
Re: Wastewater Treatment Plant Improvements, Wasilla, Alaska

Important Information About Your Geotechnical/Environmental Report

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors, which were considered in the development of the report, have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland