Appendix A

Description of Groundwater Modeling

This page intentionally left blank

A1.0 Modeling Codes

Groundwater flow in the Building 100 area is simulated with the finite-difference code MODFLOW, as developed by the U.S. Geological Survey (McDonald and Harbaugh 1988, Harbaugh and McDonald 1996). The particle tracking module MODPATH (Pollock 1989) is employed to delineate flow paths in the ground water system. Combined use of these codes is managed within the graphical user interface (GUI) known as Groundwater Vistas, Version 4 (ESI 2005).

A2.0 Model Construction

Determination of the area to be included in the model takes into account the predominant east-southeast flow direction for ground water in the Building 100 area. In particular, the axis of the model grid is oriented in this direction to minimize adverse grid orientation effects (Huyakorn and Pinder 1983), which tend to be manifested as spurious values of computed hydraulic head.

The model's northwest border is established several hundreds of feet hydraulically upgradient of construction sites in an areas where dewatering operations are expected to exert little to no influence on water level. The northeast and southwest borders of the model are also selected to be hundreds of feet from dewatering operations. Selection of the model's southeast border is more problematic. Though it is desirable to set this boundary sufficiently far downgradient of the construction that dewatering is unlikely to affect nearby water levels, lack of hydrogeologic information regarding the surficial aquifer to the east and south of the site renders such an approach infeasible. As a consequence, the downgradient boundary is established along a north-northeast trending line located only about 350 feet (ft) east-southeast of the intersection of Belcher Road and Bryan Dairy Road, and boundary conditions along the line are determined by extrapolating measured water levels at on-site wells near the two roads using an assumed hydraulic gradient of about 0.003 east-southeast from those locations.

The model contains two layers, with the upper layer representing the shallow surficial aquifer (Layer 1) and the lower layer representing the deep surficial aquifer (Layer 2). The top and bottom elevations of Layer 1 are set respectively at 20 and 0 ft above mean sea level (amsl). The top and bottom elevations of Layer 2 are set at 0 and –20 ft amsl, respectively.

The finite-difference grid for the flow model contains cells that range in size from as small as 1 ft square to as large as 10 ft square. All of the model cells are treated as active.

A3.0 Hydraulic Parameters

A uniform horizontal hydraulic conductivity of 3 ft/day is used to represent Layer 1, and 2 ft/day is applied uniformly to Layer 2. The horizontal-to-vertical anisotropy of hydraulic conductivity is assumed to be 10, resulting in vertical hydraulic conductivities of 0.3 and 0.2 ft/day in Layers 1 and 2, respectively. A storativity of 0.02 is used throughout the flow model and effective porosity is assigned a value of 0.15, or 15 percent.

General head boundary (GHB) conditions (McDonald and Harbaugh 1988) are invoked along all four edges of the model domain. Instead of prescribing constant ground water levels at these boundaries, this condition allows the model itself to determine hydraulic heads along the model's borders in response to pumping as well as the flows across them. The far-field hydraulic heads assigned to the GHB cells located on STAR Center property are based on ground water levels measured at wells close to the cells. Comparable hydraulic heads at all other GHB locations are estimated using appropriate on-site water levels and an assumed ambient hydraulic gradient of about 0.003 toward the east-southeast.

It is assumed in the model that recharge from rainfall and runoff in on-site areas occurs only in locales that remain unpaved or are not used for ponds under current site conditions. In other words, no attempt is made to account for how such recharge might vary with location. With this approach, a constant, uniform inflow rate of 5.5 in/yr (0.00126 ft/day) is assigned to all Layer 1 cells that fall within the unpaved category and zero recharge is assumed along the footprints of Belcher and Bryan Dairy roads and their intersection. Because little is known about the distribution of paved and unpaved land in parts of the model domain located east of Belcher Road and south of Bryan Dairy Road, zero recharge is arbitrarily assigned to these areas as well. It is believed that this latter approach has little effect on flow model calibration. Zero flow conditions are assumed across the model base (i.e., at the bottom of Layer 2).

River (RIV) boundary conditions (McDonald and Harbaugh 1998) are assigned to Layer 1 cells within the footprints of the South and Southwest ponds. Using this type of condition in lieu of treating the ponds as prescribed head boundaries makes it possible to account for some shallow-zone ground water migrating below the pond beds, which are above the base of the aquifer's shallow zone. Parameters used in the flow model to account for both ground water discharge to the ponds as well as seepage from the ponds are based on cell dimensions, an assumed riverbed thickness of 0.5 ft, and the horizontal hydraulic conductivity assigned to Layer 1 (3 ft/day).

A4.0 Ambient Flow Field

The model was roughly calibrated such that computed steady-state water levels in Layers 1 and 2 on STAR Center property generally matched corresponding average hydraulic heads observed in the Building 100 area during the last few years. Initial hydraulic head used in the calibration simulations consisted of a uniform value that was approximately midway between the heads used to establish GHB conditions at the northwest and southeast model borders. Calibration was achieved primarily by adjusting far-field hydraulic heads at GHB cells. As a result of the adjustments, the model was capable of duplicating the flow divergence that is typically seen near the southeast corner of the STAR Center. This phenomenon tends to cause contamination moving southward from beneath the building's south wall to form a plume lobe that is distinctly separate from another lobe that extends east-southeastward from beneath the building's east wall.

Steady-state ground water elevations generated for Layer 1 of the model as a result of the calibration are shown in Figure A−1. As indicated by this figure, the ground water elevation in areas just north of Bryan Dairy Road and west of Belcher Road, where dewatering is planned, is about 13.5 ft amsl.

A5.0 Dewatering Simulations

Computed heads comprising the steady-state ambient flow field mentioned above and illustrated in Figure A–1 are used as initial conditions in all simulations of dewatering designs. Each simulation is conducted for a period of 40 days under the assumption that continuous dewatering over this duration would be required to complete the necessary construction.

A6.0 References

ESI (Environmental Simulations, Inc.), 2005. *Guide to Using Groundwater Vistas*, Version 4, Herndon, Virginia.

Harbaugh, A.W., and M.G. McDonald, 1996. *User's Documentation for MODFLOW-96, an Update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model.* U.S. Geological Survey, Open-File Report 96-485.

Huyakorn, P.S., and G.F. Pinder, 1983. *Computational Methods in Subsurface Flow*, Academic Press, Inc.

McDonald, M.G., and A.W. Harbaugh, 1988. *A Modular Three-dimensional Finite-Difference Ground-water Flow Model*, U.S. Geological Survey, Techniques of Water Resources Investigations, Chapter 6, A1, 586 p.

Pollock, D.W., 1989. *Documentation of Computer Programs to Compute and Display Pathlines Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. USGS Open File Report 89-391, 188 p.

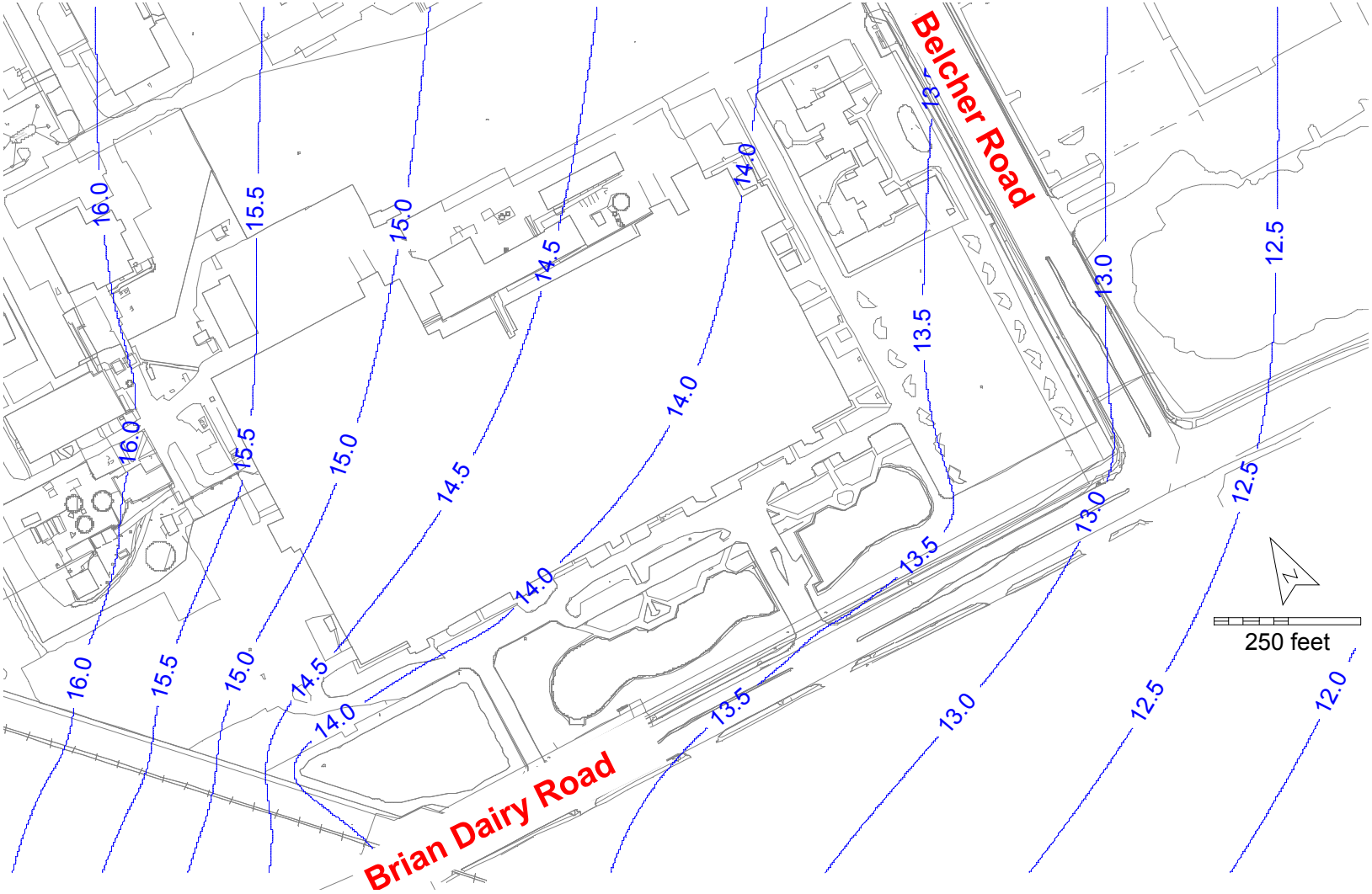

Figure A–1. Computed Steady-state Water Levels (ft amsl) in Layer 1 Under Ambient Conditions