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CONSULTING GROUNDWATER GEOLOGISTS

DRAFT

August 29, 2001

Mr. John Johnson
Public Works Director
Town of Windsor
P.O. Box 100
Windsor, California 95492-0100

Re: Phase I Preliminary Hydrogeologic Evaluation
Feasibility Study for Off-River Well Sites,
Groundwater Development Project,
Town of Windsor

Our Job No. S2027

Dear Mr. Johnson:

Presented in this letter-report are the findings, conclusions and recommendations of our hydrogeologic evaluation of the feasibility of constructing new water well(s) within six properties owned by the Town of Windsor (Windsor) that are located east of the Russian River but outside of the boundaries of the Town. The purpose of this evaluation is to determine the potential of the off-river wells, at sites designated by Windsor, for the drilling and construction on new municipal-supply water wells to supplement Windsor's current water supply.

Plate 1 - Geology, Property and Well Location Map - illustrates the location of the six Windsor-designated properties. Plate 1 also shows surface geologic conditions, the approximate political boundary of Windsor, the historic locations of wells in the vicinity of Windsor as mapped by the U.S. Geologic Survey (Cardwell, 1958), and the locations of more recent wells selected from review of the California Department of Water Resources (DWR) records. Table 1 - Selected Historic Information on Windsor Area Wells - lists information for each mapped well with respect to available driller's log, well owner, total depth, and annual production volumes as outlined in Cardwell (USGS, 1958).

Scope of Services

Our scope of services as identified in our March 7, 2000 proposal to you included the following:

- Collection and review of geologic and hydrogeologic data, including maps and reports, driller's logs, electric logs (if available), water levels and water-quality data for the area.

- For existing off-river Windsor wells, we also collected and reviewed PG&E well-efficiency test data, their history of rehabilitation including liner installation and sealing of perforations, and information on depths of pump intakes.
- Location of properties owned by Windsor, location of local parks, and other landmark areas described by Windsor personnel as existing or potential well sites.
- Identification of known sites of potential contaminants, based on California Regional Water Quality Control Board (RWQCB) electronic data files
- Hydrogeologic analyses of the collected data and information.
- Preparation of this letter-report.

The basic purpose of this project is to identify as many as three suitable locations for new wells on the six subject Windsor properties in order to supplement Windsor's water supply. These new wells would serve to augment the following existing Windsor wells: Bluebird Well No. 3 (also called Bluebird Meadows well); the Shiloh well (Shiloh Ranch well owned by Shiloh Ranch Associates); the Keiser Park well; and the Esposti Park well. Based on our conversations with Windsor personnel, it is our understanding that former Windsor wells (Mutual No. 1, Starrview No. 2, Well No. 4 and Lakewood No. 5) have each been previously destroyed.

We were provided with water production records for only three Windsor wells (Bluebird No. 3, Keiser Park and Esposti Park) for the years 1987 to 2000, inclusive. In 1999 and 2000, the only off-river well apparently still in production was Bluebird No.3. The existing Shiloh, Keiser Park and Esposti Park wells may be in production for Windsor park irrigation purposes, but their output is not included in the production data Windsor personnel provided to us We also received data for the Shiloh well, which is located near the intersection of Shiloh Ridge Road and Faught Road, about one-half mile southwest of the Shiloh property. No historic production data were available from Windsor for the Mutual No.1, Starrview No.2, Well No.4, or Lakewood No.5 wells.

References that were specifically reviewed for this project are listed at the end of this report.

TABLE 1
SELECTED HISTORIC INFORMATION ON WINDSOR AREA WELLS

State Well Number	Available Driller's Log	Well Owner	Total Depth (ft)	Pump Rate (gpm)	Annual Groundwater Production (AF)
08N08W30C1			154	200	>5
08N08W30A	Y				<5
08N08W30G1	Y				>5
08N08W30L1	Y				>5
08N08W30N2	Y				<5
08N08W30N1	Y				<5
08N08W31B1			210	50	<5
08N09W25B1			161	240	>5
08N09W26D1			464	485	>5
08N09W26L1	Y		265	60	<5
08N09W23E1			188	130	>5
08N09W27H			419	700	<5
08N09W27K1	Y		333	800	>5
08N09W27R2		Odd Fellows Recreation Club #2			
08N09W29F1					<5
08N09W29F2					<5
08N09W31C1		RRCWD #2			<5
08N09W31G3		Mirabel			<5
08N09W33N	Y				DRY HOLE
08N09W33J1	Y				
08N09W34R1	Y			900	<5
08N09W34R2,3	Y		491		>5
08N09W35M1			475	800	>5
08N09W35K1	Y				>5
08N09W36N1,2			185	150	>5
08N09W36P1	Y				>5
08N09W36L1	Y				>5
08N09W36K1			1325	500	>5
08N08W33J1		La Mancha			<5
08N09W13A02					
08N09W13A03					
08N09W14L02					
08N08W29B01					
08N08W29C03					
08N09W32M01					

NOTES: For Available Driller's Log; Y = Yes, Blank Space = No
Blank Spaces = No Data Available
AF = Acre Feet

Data adapted from Cardwell (USGS, 1958)

TABLE 1
SELECTED HISTORIC INFORMATION ON WINDSOR AREA WELLS

State Well Number	Available Driller's Log	Well Owner	Total Depth (ft)	Pump Rate (gpm)	Annual Groundwater Production (AF)
08N09W01M1	Y				<5
08N09W01J1		Weske			<5
08N09W11B2	Y		216	359	<5
08N09W11B3		Evergreen #2			
08N09W03P1	Y				>5
08N09W09H1	Y				>5
08N09W09H2		Windsor #6			<5
08N09W09H3		Windsor #7			<5
08N09W09H4		Windor#8			<5
08N09W15D1	Y				>5
08N09W11L2	Y			300	<5
08N09W11P1	Y				>5
08N09W11P2	Y	Windsor School	506	800	<5
08N09W12M1	Y		251	40	<5
08N09W12M2		Windsorland			<5
08N09W12P1	Y		187	40	<5
08N09W12Q2		Lakewood #5	500	70	<5
08N08W07G	Y	Thiens	444	20	<5
08N08W05P1			147	37	<5
08N08W17L1			278	10	<5
08N08W17L2	Y	United Builders	854	50	<5
08N08W18F1			130	25	<5
08N08W18E1			147	20	<5
08N08W18L4		Royal #1	133	11	<5
08N09W13J2		Bluebird #3	340	150	<5
08N09W13J8			400		<5
08N09W13K2	Y				<5
08N09W13K3		MCC #1			<5
08N09W13N1	Y				>5
08N09W13C1	Y				<5
08N09W13D1		Mutual			<5
08N09W-14B1	Y	Keiser Park			<5
08N08W-18F2?		Pleasant Oak Park	130	25	<5
08N09W-14B2	Y		206	24	<5
08N09W14L1			265	220	>5
08N09W14P1			264	400	>5
08N09W14P2	Y		347	50	<5
08N09W23G1			225	200	>5
08N09W23L1	Y		429		>5
08N09W24E1			330	600	>5
08N08W19E1			142	125	>5
08N09W24L1			150	125	>5
08N09W24J	Y	Piombo	415	500	<5
08N08W19M1	Y				<5
08N08W19N1			249	290	>5
08N08W19H4		Oakcreek			<5
08N08W20B2			231	20	<5
08N08W20M1		MHE #1			<5
08N08W20N2		Colonial #2	130	210	<5
08N08W20Q1	Y	DWR			>5
? (Shiloh Well)	Y	Shiloh Ranch Associates	589	100	<5
08N08W28Q1		Citizens			<5
08N08W33D4		Citizens			<5
08N08W28N1	Y	Citizens	462	400	<5
08N08W34D1		Redwood			
08N08W29C1	Y				<5
08N08W29C4		Mark West Est.			
08N08W29D1	Y				<5
08N08W29M1		Stonegate			

Location of Subject Properties. The addresses and designation of the six Windsor-selected properties that were evaluated for this project are listed below along with their Township, Range and Section designations:

Address	Report Designation	Township, Range, Section
3501 Shiloh Ridge Road	(Shiloh Property)	T8N/R8W, Section 16
7641 Windsor Road	(Windsor Property)	T8N/R9W, Section 23
3575 Slusser Road	(Slusser Property)	T8N/R9W, Section 23
7710 Starr Road	(Starr Property)	T8N/R9W, Section 23
6942 Eastside Road	(Eastside Property)	T8N/R9W, Section 28, 33
6921/6977 Trenton/Healdsburg Road	(Trenton Property)	T8N/R9W, Section 34,33

The Shiloh property comprises the southwesternmost corner of Section 16, Township 8 North, Range 8 West, Mt Diablo Baseline and Meridian (T8N/R8W-16, SBB&M), within Sonoma County, California. This property is located within the Healdsburg Fault system (see Plate 1). This fault is rated as an active fault for which there is an Alquist-Priolo Special Studies Zone Map available from the State of California. The Windsor and Slusser properties are small properties located along Pool Creek just west of Windsor Golf Club, in the east half of Section 23 (T8N-R9W). The Starr property (about 90 acres) is located adjacent to Windsor Creek at its confluence with Pool Creek, in the central portion of the west half of Section 23 (T8N/9W). The Eastside property (about 160 acres) is located at the confluence of Windsor Creek with Mark West Creek, primarily in the west half of Section 28, (T8N/R9W). The Trenton property (about 80 acres) is located between Windsor Creek and the Russian River, primarily in the east half of Section 34, (T8N/R9W).

General Geologic Conditions

The surface geologic conditions depicted on Plate 1 have been adapted from work by: Cardwell (1958) for the USGS and; Huffman and Armstrong (1980) for the California Division of Mines and Geology (CDMG), prepared in cooperation with the Sonoma County Planning Department (SCPD). As identified on Plate 1, Local surficial geologic conditions consist of the following units from geologically oldest to youngest:

Cretaceous to Jurassic Rocks, undifferentiated: comprised by the Franciscan Assemblage rocks (denoted by map symbol KJu). These geologically ancient rocks are exposed at the surface along the Russian River and Mark West Creek, with an outcrop proximal to Eastside Road just west of Windsor Golf Club. Franciscan rocks also occur at the surface northeast of Foothill Regional Park. Wells located along the Russian River indicate the river is underlain by Franciscan rocks at relatively shallow depths (100 ft or less). Franciscan sedimentary strata consist predominantly of gray to blue or green sandstone and shale with minor conglomerate, chert and limestone. Locally, masses of serpentenite, greenstone, metamorphic minerals and rocks may also occur. These rocks are often sheared, shattered and veined with various minerals. Franciscan assemblage rocks are considered to be nonwater-bearing bedrock for municipal or large-scale agricultural purposes. The specific yield of these rocks is considered to be only 1 to 3 percent.

Tertiary Volcanic Rocks, undifferentiated: comprised by the Sonoma Volcanics of Pliocene age (map symbol Tsv). These rocks are exposed at the surface northwest of the Windsor area (west of Westside Road) and east of the area along the Healdsburg Fault system. Strata of the Sonoma Volcanics are comprised by basalt, andesite and rhyolite flow rocks with intercalated ash-flow tuff, associated agglomerate and interbedded volcanic sedimentary deposits. Moderate to excellent yields can be obtained locally from thick assemblages of fractured flow rocks or tuffaceous sediments. The specific yield is highly variable, ranging to as high as approximately 15%.

Merced Formation (Wilson Grove Formation): of Pleistocene to Pliocene geologic age (map symbol QTm). These sediments are exposed in the vicinity of Mark West Creek and the Russian River in the southwestern portion of the Windsor area. Strata of the Merced (Wilson Grove) Formation are shallow marine deposits primarily comprised by fine-grained partly-tuffaceous sandstone with minor clay and abundant fossils usually recorded as "clamshells" or "oysters" on driller's logs. Zones of poorly consolidated very fine-grained sand are common and may be reported as "quicksand" on driller's logs.

The upper part of this unit may be interbedded with the partly-contemporaneous but overlying deposits of the sedimentary Glen Ellen Formation, particularly in the vicinity of the surface contact as shown on Plate 1. The lower part of the Merced (Wilson Grove) Formation has been reported to be interbedded with the Sonoma Volcanics to the southeast in the Petaluma area (Cardwell, 1958). Other than the alluvial sediments at the Russian River, the Merced (Wilson Grove) Formation together with the Glen Ellen Formation (see below) comprise the major aquifer systems in the Windsor area. The specific yield for this unit is high, ranging from 10% to 20%. Currently, Windsor derives most of its water supply from the alluvial sediments

Glen Ellen Formation: of Pleistocene to late Pliocene geologic age (map symbol QTge). These sediments are exposed extensively at the surface in the Windsor area, east of Eastside Road. This unit is comprised by partially-cemented gravel, sand, silt and clay, with interbedded tuff in the lower part of the formation. These strata represent older but more consolidated, alluvial fan deposits. Due to cementation of the gravel zones and the high clay content of the sediments, well yields are low and many wells are reportedly dry. The specific yield is reported to be low, ranging from 2 or 3% to perhaps 7%.

Younger Alluvium: of Holocene geologic age (map symbol Qyal). These sediments consist of unconsolidated interbedded clay, silt, sand and gravel. Lenses of very fine-grained sand within these deposits frequently cause sanding problems in poorly-designed and/or -constructed water wells. Surficial younger alluvium is generally found in the floodplain deposits of the Russian River, in and along larger stream channels, and in small stream valleys in the area. Specific yield ranges from 3% to 15%, depending on the amount of clay and the thickness of the deposit. Stream channel deposits of sand and gravel along the Russian River are unconsolidated and have a relatively high specific yield of 15% to perhaps 25%.

Geologic Structure

Windsor is located at the northern apex of the Santa Rosa valley, which occupies a northwest-trending structural depression in the southern part of the Coast Ranges of northern California. This depression divides the Mendocino Range on the west from the Mayacamas and Sonoma Mountains on the east (not shown on Plate 1). To the northwest, the Santa Rosa valley adjoins the Russian River plain, to which it is connected by a narrow gap in the hills in the vicinity of Trenton, southwest of the Sonoma County Airport. The Russian River flows southward along the northwestern edge of the Santa Rosa valley, then flows west near Wilson Grove toward the Pacific Ocean. The Windsor area occupies the wedge-shaped floodplain between the north-trending Russian River and the west-trending Mark West Creek. The area is traversed by Windsor Creek, Pool Creek and Mark West Creek, all of which have their headwaters in the Mayacamas Mountains to the east and flow southwest and west toward the Laguna de Santa Rosa (south of Trenton); from there, these tributaries flow north and discharge into the Russian River.

As shown on Plate 1, the Windsor syncline is a major structural fold in the area and extends from northwest of Windsor south to the vicinity of the town of Fulton. The dominant geologic structural features of the Windsor area, however, are several major fault zones. The Healdsburg fault zone is an extensively faulted zone roughly one mile wide along the northeast side of the Santa Rosa valley which traverses Foothill Regional Park, Shiloh Ranch Regional Park, and eastern Santa Rosa, then continues to the southeast into the Rodgers Creek fault zone. A potentially active branch of the Rodgers Creek fault has been mapped (Huffman and Armstrong, 1980) northwest across the western Santa Rosa area to Trenton and may continue across the Russian River into a group of faults north of Rio Dell.

Geologic Information from Off-River Water Wells

Bluebird No. 3, Keiser Park, Esposti Park and Shiloh Wells

Windsor reports that four off-river wells exist; however, only Bluebird No. 3 appears to be actively used for municipal water-supply purposes. The Bluebird No. 3, Keiser Park and Esposti Park wells are located within existing Windsor boundaries; the Shiloh Ranch Associates

well is located east of Windsor's limits, in the vicinity of the intersection of Shiloh Ridge Road and Faught Road, in the western portion of the Healdsburg fault zone.

Bluebird No. 3 Well. The Bluebird No. 3 well is located in the Windsor Creek/Pool Creek floodplain, just east of Highway 101 and is designated as State Well No. 8N/9W-13J2 by DWR. Geologic materials at this location are comprised by thin (less than 60 ft) alluvial sediments underlain by the Glen Ellen Formation. Review of the driller's log indicates that perforations were placed: in a thick sand and gravel zone from 260 to 324 ft below ground surface (bgs); in a thin gravel zone from 332 to 336 ft bgs; and in the lower part (380 to 400 ft bgs) of a zone from 350 to 400 ft bgs reported as "sticky blue clay." Perforations appear to be entirely within the Glen Ellen Formation; total well depth is 400 ft bgs. Although the driller reported a yield of 500 gallons per minute (gpm) when the well was drilled in 1972, a pumping test in 1984 revealed a flow rate of 150 gpm. Further, the well was reported to be only 340 ft deep, which suggests that there was no contribution to flow during the pumping test from the "sticky blue clay" zone at the bottom of the original hole. About 2000 ft northwest of the Bluebird No. 3 is a relatively-shallow well which also encountered alluvial sediments underlain by Glen Ellen Formation. The Windsor Mobile County Club (a.k.a. Windsor Golf Club) well (8N/9W-13K3) perforated four 20-ft zones and one 40-ft zone between 58 and 278 ft bgs; reported flow rate for this well is only 40 gpm.

Keiser Park Well. The Keiser Park well (8N/9W-14B1) is located about 300 ft south of Windsor River Road, at the Park entrance, near the west-central portion of Windsor's boundary. Review of driller's logs for two wells about one-half mile to the northwest display approximately the same geologic section, including the rocks to be found below the total depth of 520 ft bgs in the Keiser Park well. The Starr School well (8N/9W-11P2) and the Argonaut Construction well (8N/9W-11L1) describe the same "blue clay", "cemented gravel" and sand with "streaks of clay" from roughly 100 ft to 520 ft bgs that are noted in the Keiser Park well. The deeper Argonaut Construction well then reveals "blue rock" from 549 ft to a total depth of 637 ft bgs. These descriptions can be interpreted as the Glen Ellen Formation (shown at ground surface on Plate 1 at this location) to about 550 ft bgs; these materials are underlain by "blue rock" of the Franciscan Assemblage.

The Glen Ellen Formation is known for its extensive zones of "blue clay" and highly variable "sandy clay," sand and gravel ("cemented gravel," "gravel streaks"). The Keiser Park well perforated only three 10-foot and one 20-foot gravel zones between the depths of 57 ft and 520 ft bgs, and its reported flow rate is between 60 and 120 gpm. A hand-drawn resistivity log for this well to 350 ft bgs suggests several additional zones that could have been tested to possibly improve flow results. For example, a well just west of the park (the Roslyn Ket well, 8N/9W-14B2) with a total depth of 206 ft perforated what appears to be the equivalent of the Keiser Park well's 192 to 200 ft "cemented gravel" zone. In the Ket well, this zone lies at 197 to 202 ft bgs and the well reportedly produced a flow of 24 gpm. In the Keiser Park well, this zone is visible on the resistivity log, but was not perforated. Considering the reported low flow rates that are characteristic of many Glen Ellen Formation wells, the addition of several such zones could make the difference between an acceptable well and one that would be destroyed due to low production. The Argonaut Construction well was cased to a depth of 558 ft bgs; test pumping reportedly indicated a flow rate from 300 to 475 gpm. The Starr School well was cased to 502 ft bgs and extensively perforated in nine zones ranging from 19 to 25 ft thick, with a tenth zone approximately 50 ft in thickness. The entire perforated interval occurred between the depths of 62 ft and 502 ft bgs. This well was reportedly tested by the driller at 800 gpm, which (if accurate) would be considered exceptional for a well producing from the Glen Ellen Formation .

Esposti Park Well. The Esposti Park well is within the park, which is located at the intersection of East Shiloh Road and Old Redwood Highway. The park is situated within the Pool Creek/Mark West Creek floodplain, adjacent to the southeastern Windsor boundary. Review of the driller's log indicates alluvial sediments to 70 ft bgs which are underlain by the Glen Ellen Formation to the total well depth of 300 ft bgs. The well is perforated in two thick Glen Ellen zones (100 to 220 ft bgs and 240 to 300 ft bgs), which are comprised mainly by gravel with blue or brown clay. This well was reportedly tested by the driller at 230 gpm. The driller's log for the nearby Merner well (8N/8W-19(?)) indicates that this well encountered approximately the same geologic sediments to total depth of 340 ft bgs. This well contains two zones of 40-ft perforatons, between 62 and 162 ft bgs, followed by three 20-ft zones between 182 and 282 ft bgs, and finally a 35-ft zone at the bottom of the well. The lower zones are perforated in "gray clay with streaks of gravel." The two upper zones are perforated in "blue clay with streaks of gravel" and "blue sandy clay." The Merner well was reportedly tested by the driller at 738 gpm. Com-

parison of the driller's logs for these two wells with the zones perforated and the disparate flow rate results suggests that the fine-grained nature of the Glen Ellen sediments can be deceptive and that zones described as "clay" or "sandy clay" may contain sediments that may be able to yield relatively large volumes of water to wells.

Shiloh well. The Shiloh well (owned by Shiloh Ranch Associates) is located east of Windsor's boundary, near the intersection of Faught Road and Shiloh Ridge Road. The driller's log describes "hard volcanic rock" from 3 ft to 589 ft bgs, which suggests that the entire well is within the Sonoma Volcanics. This well is located in the western part of the broad Healdsburg fault zone. The Glen Ellen Formation is mapped at the surface just to the west of this area (see Plate 1). Windsor personnel also provided a drawing of the well that has been annotated with depth and brief descriptions of various volcanic units ("green tuff," "brown lava"). Unfortunately, the annotations begin at a depth of approximately 430 ft bgs to continue to a total depth of 589 ft bgs; the upper part of the well is not described. The well is perforated from 389 to 589 ft bgs, all of which is within rocks of the Sonoma Volcanics, and it was reportedly tested by the driller at 100 gpm.

Wells Proximal to the Off-River Properties

The locations of certain historically-recorded, more recent water-supply wells in the area are also illustrated on Plate 1. Selected wells for which information is available on the geologic conditions encountered during drilling are discussed below, with particular attention to those wells proximal to the six Windsor off-river properties that are being evaluated as future well sites.

Shiloh Property. The closest wells to the Shiloh property are the Shiloh well (described above) and the United Builders well (8N/8W-17L2), both of which are on the western edge of the Healdsburg fault zone. These two wells occur where the Glen Ellen Formation is exposed at the surface (Plate 1), near and along the contact with the alluvial floodplain sediments of Windsor Creek, Pool Creek, and Mark West Creek. Review of the driller's log for the United Builders well suggests that Sonoma Volcanics underlies the Glen Ellen Formation from at least 312 ft ("fractured rock") to the total well depth of 854 ft bgs; the contact between the Glen Ellen sediments and the underlying Sonoma Volcanics could be as shallow as 144 ft bgs

where the driller reported "fractured multi-colored rock." Almost the entire well is perforated, (perforations are from 54 ft to 714 ft bgs, and from 735 ft to 854 ft bgs). However, the driller's flow rate test reportedly resulted in only 50 gpm. The poor flow rate tests of these two wells may relate to their location within the Healdsburg fault zone.

Windsor and Slusser Properties. The closest wells to the Windsor and Slusser properties are the wells described for the Keiser Park area, and wells reported by Cardwell (USGS, 1958), together with limited data that are available for a few wells in Sections 23 and 24 (8N/9W). These wells are on trend along the Windsor syncline (Plate 1) and all were constructed to various total depths into sediments of the Glen Ellen Formation. The Glen Ellen Formation appears to extend to depths of about 500 ft to perhaps 600 ft bgs, and is underlain by nonwater-bearing rocks of the Franciscan Assemblage. These wells appear to be too far to the northeast of the known surface exposures of the Merced (Wilson Grove) Formation to be able to encounter these water-bearing sediments interbedded with the Glen Ellen Formation within a depth of several hundred feet in a new onsite well.

The deepest well reported by Cardwell (1958) in Section 24 is the Balbi well (8N/9W-24E1), with total depth of 330 ft bgs and a reported flow rate of 600 gpm. The deepest well in Section 23 is the Wright well (8N/9W-23L1), with total depth of 429 ft bgs and a reported flow rate of 750 gpm. Both wells wee drilled into thin deposits of alluvial sediments that are underlain by the Glen Ellen Formation. There are no historic water quality data reported for the Balbi well, but the Wright well is reported in Cardwell (1958) and in DWR Bulletin 118-4 (1982) as an example of a well that displays elevated boron concentrations in the Windsor area. The Wright well reported a concentration of 22 milligrams per liter (mg/l) of boron in July 1950. The well was plugged back to 227 ft bgs in September 1950 and sampled again, yielding a boron concentration of to be 0.44 mg/l. It is possible that boron in groundwater below 227 ft bgs in this well is associated with the fault shown on Plate 1 proximal to the well. From our experience with anomalous boron levels in wells, it is also possible that the initially high boron concentration in this well was related to sampling and/or laboratory testing protocol.

Starr Property. Test well(s) drilled on the northeastern portion of the Starr property are expected to encounter approximately the same geologic sediments as described for the

Windsor and Slusser properties. To the southwest, there is the potential to encounter the Merced (Wilson Grove) Formation at depth. Cardwell (1958) mapped a fault across the property (Plate 1) that shows the northeast side of the fault to be downthrown relative to the southwest side of the fault. Wells southwest of this fault encounter Merced (Wilson Grove) Formation sediments partially interbedded with the Glen Ellen Formation, which may be due to the effect of older sediments upthrown on the fault block to the southwest. The surface exposure of Franciscan Assemblage rocks adjacent to Eastside Road (Plate 1; confirmed by a field check) is likely caused by upthrown older rocks southwest of the fault. The Merced (Wilson Grove) Formation sediments rise to the southwest, and are exposed at the surface in the vicinity of Wilson Grove, Eastside Road and Mark West Station Road.

The Faught well (8N/9W-27K1) reportedly encountered interbedded Merced and Glen Ellen sediments from 6 ft bgs to total depth of 333 ft bgs. The perforation intervals were not reported, but the driller's log only contains two zones described as water-bearing; "sand and gravel" from 50 ft to 52 ft bgs, and "gravel with clam shells" from 303 ft to 333 ft bgs. The "clam shell" zone is characteristic of sediments within the Merced (Wilson Grove) Formation. A flow rate of 800 gpm was reported for this well, much of which may be derived from the 30-foot Merced Formation zone near the bottom of the well.

About 1000 ft upstream along Windsor Creek from the Faught well is the Knecht well (8N/9W-27H?). Review of the driller's log for the Knecht well suggests that the Glen Ellen Formation occurs to a depth of 148 ft bgs, followed by Glen Ellen sediments that are interbedded with the Merced Formation to a total depth of 419 ft bgs. Although no "clamshells" were noted, the location near the Faught well, and the increase in sand and gravel zones, indicate the probable presence of interbedded Merced Formation at depth. This well was perforated from 100 ft to 419 ft bgs and was reportedly tested by the driller at a flow rate of 700 gpm. Data between the Knecht well and the southwest boundary of the Starr property is too limited to determine depth and extent of possible Merced Formation interbedding with the Glen Ellen Formation.

Trenton and Eastside Properties. The Trenton property is located along Windsor Creek roughly at the surface geologic contact between the Glen Ellen Formation and Merced (Wilson Grove) Formation. South of Mark West Creek, which forms the southern boundary of

the Trenton property, are surface exposures of ancient Franciscan Assemblage rocks. For the southern portion of this property, Franciscan Assemblage rock can be expected to underlie the Merced Formation at a relatively shallow depth (100 ft to 300 ft bgs). The driller's log for the Emert well (8N/9W-33J1) indicated Franciscan Assemblage rock at 285 ft; however, the perforation interval is not recorded and a flow rate of 60 gpm was reported. Another Emert well (8N/9W-33H1) is proximal to 8N/9N-33J1. That well was drilled to 120 ft into Merced Formation sediments and had a reported flow rate of 50 gpm. Other wells in this area tend to be equally shallow: the Stanley well (8N/9W-34D1), with a 150 ft total depth and reported flow rate of 60 gpm; the Muchow well (8N/9W-34E1), also 150 ft total depth, but with a flow rate not reported.

There are almost no subsurface data in the vicinity of the Eastside property. Merced (Wilson Grove) Formation sediments are exposed at the surface; however, extensive nearby exposures of Franciscan Assemblage rock suggests that Merced Formation at this location is a thin remnant overlying the older Franciscan rocks. Sediments of the Merced Formation will tend to become thicker to the east/southeast but are not likely to be thicker than about 300 ft anywhere on the property.

Local Groundwater Quality Conditions

Water quality data obtained from the California Department of Health Services (DHS) CD-ROM water-quality database dated February 2001 are available for wells in the Windsor area within T8N/R8W and T8N/R9W. Water quality analyses for Bluebird No. 3, the Shiloh, and the Keiser Park wells were provided by Windsor personnel. No analyses were available for the Esposti Park well. These data were examined to evaluate the character of the water quality that might be expected in new wells drilled into the Glen Ellen and Merced (Wilson Grove) Formation, and/or the Sonoma Volcanics in the local area. Shallow wells producing only from alluvial sediments and wells in areas likely to be producing groundwater water from Franciscan Assemblage rocks were omitted from consideration. The following provides a summary of groundwater quality conditions in the DHS database for the Windsor area:

1) The character of groundwater extracted from local wells has historically ranged from a sodium bicarbonate ($Na\text{-}HCO_3$) character for wells perforated in the Glen Ellen Formation, to calcium-magnesium-bicarbonate ($Ca\text{-}Mg\text{-}HCO_3$) character for wells perforated in Sonoma Volcanics. In the Windsor area,

wells perforated in Merced (Wilson Grove) Formation are usually also perforated in interbedded Glen Ellen Formation and display a mixed calcium-sodium-bicarbonate (Ca-Na-HCO_3) character.

2) Total dissolved solids (TDS) concentrations have ranged from about 150 to 450 mg/l. Without exception, the detected TDS concentrations do not exceed the State Secondary Recommended Maximum Contaminant Level (MCL) of 500 mg/l.

3) The pH of groundwater has historically ranged from 6.6 to 8.2 pH units, with the majority of the measured pH values being between 7.0 and 7.9.

4) Nitrate (as NO_3) concentrations have generally ranged from not detected (ND) to 19 mg/l. The detected concentrations have all been below the State Primary MCL of 45 mg/l for nitrate.

5) Iron (Fe) concentrations have historically ranged from ND to 2.8 mg/l. Manganese (Mn) concentrations have historically ranged from ND to 2.9 mg/l. Each of these constituents has occasionally been above its respective secondary MCL of 0.3 mg/l for Fe and 0.050 mg/l for Mn.

6) Arsenic in groundwater appears to be present in elevated concentrations in the Windsor area, with concentrations ranging from 0.001 mg/l to 0.065 mg/l. Arsenic in the region could possibly be associated with branches of the Rogers Creek and Healdsburg fault systems that appear to extend on northwest-southeast trends across the Windsor area to connect into the extensive faulting west of the Russian River. The MCL for arsenic is currently 0.050 mg/l but this MCL is in the process of being revised.

7) Boron is not reported by DHS, but it is widespread in the Windsor area and has been reported in the literature by the USGS, where it appears to be related primarily to faulting, and may be associated with the distribution of arsenic seen in the area. Limited boron data for the Windsor area ranges from 0.6 mg/l (8N/9W-10R1 and -23G1) to 22 mg/l (8N/9W-3L1). Boron is extremely important in agriculture since amounts greater than 2 mg/l are toxic to most plants. For many plants, such as citrus, grapes, apples and walnuts, boron is toxic in amounts less than 1 mg/l. A boron concentration less than 0.5 mg/l is generally considered safe for all crops.

Water quality data from the Bluebird No. 3 well, when sampled in February 2000, indicated that the TDS concentration was 260 mg/l. The overall water quality character of groundwater is Na-HCO_3 for this well. Iron ranged from 0.1 mg/l in 2000, to 2.5 mg/l in 1997; manganese values ranged from 0.03 mg/l in 2000, to 0.93 mg/l in 1991. The reported values prior to 2000 are above the recommended secondary MCLs limits of 0.3 and 0.05 mg/l, respectively. This well has an elevated arsenic concentration, which ranged from 0.010 mg/l in April

1991 to 0.032 mg/l in February 2000. The well was not tested for boron; however, a boron concentration in proximal well 8N/9W-13J8 was reported at 1.4 mg/l (DWR, 1982). Total depth reported for 8N/9W-13J8 is 400 ft; thus the perforation interval is within sediments of the in Glen Ellen Formation, similar to those within Bluebird No. 3.

Northwest of the Bluebird No. 3 well was Windsor Lakewood No .5 well (8N/9W-12Q2); it also displayed elevated arsenic concentrations, ranging from 0.013 mg/l in 1991 to 0.026 mg/l in 1987. Review of the driller's log for the Lakewood No. 5 indicates perforations at intervals in six thin sand and gravel zones (each 10 to 20 ft thick) between the depths of 270 ft and 495 ft bgs. The description of zones encountered in Lakewood No. 5 indicates the perforations are all in Glen Ellen Formation sediments. In the same area was the Windsor well Mutual No. 1 well (8N/9W-13D1), for which no driller's log is available. Arsenic concentrations in the Mutual No. 1 well ranged from 0.010 mg/l in 1987 to 0.031 mg/l in 1991. Water quality for Lakewood No. 5 and Mutual No. 1 was obtained from the DHS 2001 water quality database, which does not report boron. There is no water production reported by Windsor for either well after 1990; both wells have apparently been abandoned or destroyed.

The Keiser Park well is located about one-half mile west of the Mutual No.1 well. Water quality sampling in 1981 and in May 2000 did not yield data for arsenic or boron. Iron (0.63 mg/l and 2.8 mg/l) and manganese (1.1 mg/l and 2.9 mg/l) on both sampling dates were above the recommended secondary limits for those constituents of 0.3 and 0.05 mg/l, respectively. TDS was reported in May 2000 to be 360 mg/l; the well displayed a Na-HCO_3 character. Perforations are in two shallow gravel zones (above 102 ft bgs), and in two thin deeper gravel zones (246 to 256 ft and 418 to 428 ft bgs); all these perforations appear to be in the Glen Ellen Formation. Water quality data are available also for the Starr School well (8N/9W-11P2; now called Windsor Immersion School), located about one-half mile northwest of Keiser Park. This well was perforated in numerous zones, some of which appear to be about the same as those in the Keiser Park well. The driller's log for 8N/9W–11P2 is similar to Keiser Park; both wells appear to be perforated entirely within sediments of the Glen Ellen Formation. Arsenic concentrations in groundwater samples from the Starr School well ranged from 0.022 mg/l in 1995 to 0.024 mg/l in 1998; this well is currently inactive.

Although there are no water quality data for the Esposti Park well, the DHS database contains information on the Oak Creek well, located proximal to the park in 8N/8W-19H4, just west of Old Redwood Highway and north of Shiloh/East Shiloh Road. Based on geologic sediments encountered in the Esposti Park well and in the nearby Merner well (8N/8W-19?), the sediments encountered at this location are comprised by alluvium to about 75 ft bgs which is in turn underlain by the Glen Ellen Formation to a depth of at least 400 ft bgs. No driller's log is available for the Oak Creek well, but it is likely that this well produces from some of the same Glen Ellen Formation zones that are perforated in the Esposti Park well. Although no boron data are available, DHS reported an arsenic concentration for the 1987 sampling at 0.010 mg/l. TDS was reported to be 250 mg/l; the well displays a Na-HCO_3 character. The iron concentration was reported to be 0.27 mg/l; the manganese concentration was not reported.

Water quality analyses for the Shiloh well reported arsenic less than 0.010 mg/l for sampling in 1986 and in 1987. Boron was not reported in 1987; in 1986, its concentration was reported at 0.09 mg/l. TDS ranged from 340 to 360 mg/l; the well displayed a calcium-magnesium-bicarbonate (Ca-Mg-HCO_3) character. Iron ranged from 1.2 to 1.9 mg/l; manganese ranged from 0.12 to 0.13 mg/l; both are above their recommended secondary limits of 0.3 and 0.05 mg/l, respectively. The driller's log for this well reports the perforation interval (389 to 589 ft) to be in the Sonoma Volcanics.

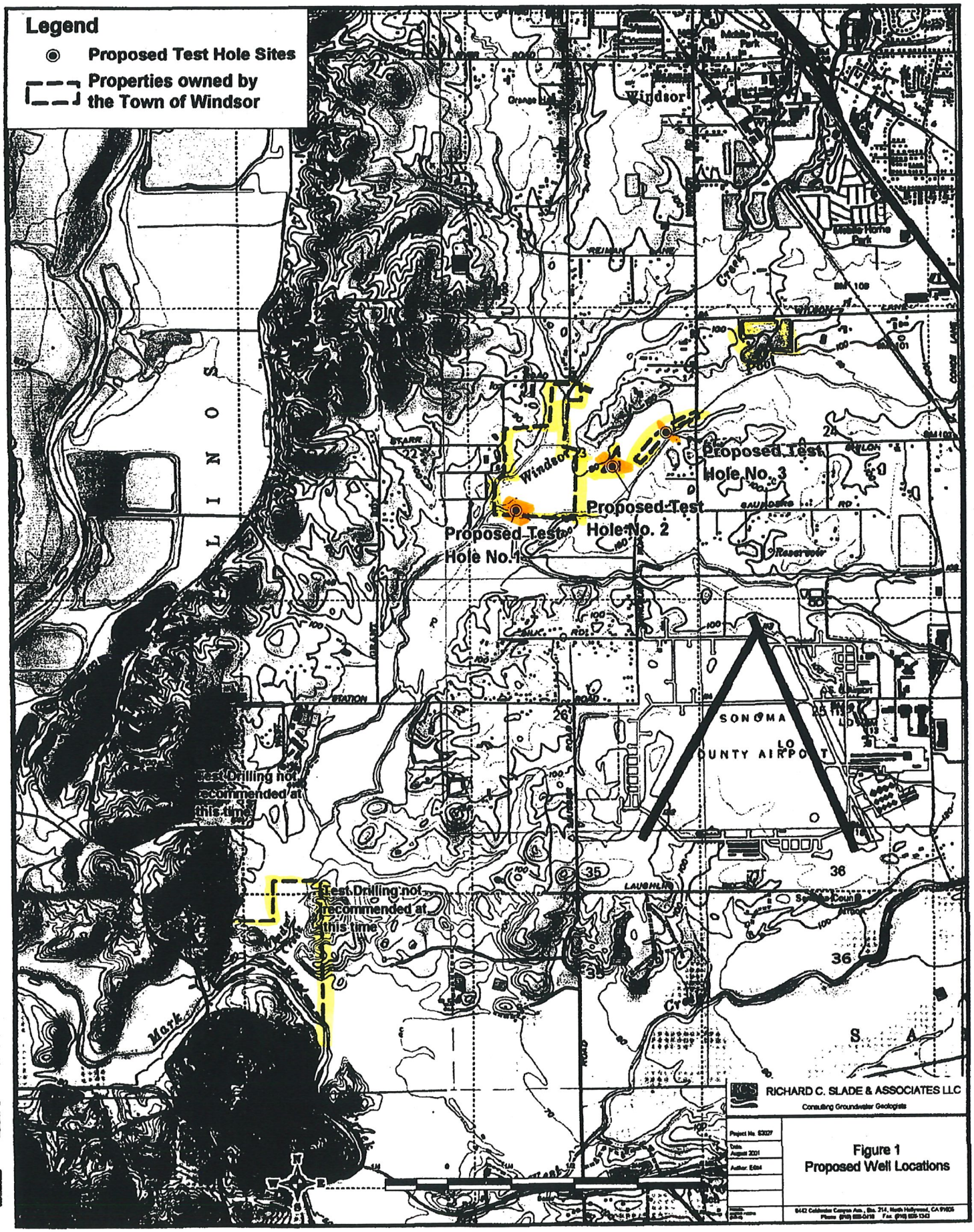
Preliminary Conclusions and Recommendations

Preliminary Conclusions

Based on review of limited data from published literature and from nearby and on-site water wells, our key conclusions are summarized as follows:

1. It is considered hydrogeologically feasible to drill and test pilot holes and possibly construct new municipal water-supply wells on the Windsor, Slusser, or the Starr properties. It is considered feasible to drill a test hole on the Trenton Property.

2. At the present time, we do not recommend drilling pilot holes on either the eastside property of the Trenton property due to the probable occurrence of nonwater-bearing bedrock at relatively shallow depths at both sides.


Legend
Proposed Test Hole Sites
Properties owned by the Town of Windsor
Windsor
Proposed Test Hole No. 3
Proposed Test Hole No. 2
Proposed Test Hole No. 1
Test Drilling not recommended at this time
Test Drilling not recommended at this time
SONOMA COUNTY AIRPORT
RICHARD C. SLADE & ASSOCIATES LLC
Consulting Groundwater Geologists
Figure 1
Proposed Well Locations

3. Three potential well site locations have been selected, as shown on Figure 1 – Proposed Well Locations. There are three priority sites, numbered in order of priority.

   - Location No. 1 is in the northern portion of the Starr Property. The geologic objective is Merced (Wilson Grove) Formation interbedded with the Glen Ellen Formation, although there may be no Wilson Grove sediments at this location. The pilot hole should be terminated when Franciscan Assemblage rock is encountered. Depth of the test hole is expected to be about 500 ft; the flow rate is likely to range from 200 gpm to as much as 400 gpm, if Merced Formation sediments are encountered.

   - Location No. 2 is situated near the middle of the Slusser Property. Location No. 2b is situated at the southwest end of the Windsor Property. The No. 2b location can be moved elsewhere on the Windsor Property, but depth will increase to the northeast, in the direction of the Windsor syncline axis. The geologic objective is the Glen Ellen Formation; no Merced Formation is expected at either location. The test hole shall be terminated when Franciscan Assemblage rock is encountered. Depth of the test hole is expected to be about 600 ft; flow rate is likely to range from 150 gpm to as much as 400 gpm.

Preliminary Recommendations

The following provides our recommendations with regard to drilling a new well within the Windsor area at the recommended well locations shown on Figure 1.

1. We recommend that test holes be drilled in the priority order and at the locations shown on Figure 1. Drill Site No. 1 should be drilled first, followed by Site No. 2a or 2b. Site No. 3 should be drilled last, if conditions at the first two sites are favorable. If the results at Site No. 3 are favorable, then Site No. 4 can be drilled.

2. Dual tube, air-rotary drilling methods are recommended for drilling a test hole at each proposed well site. It is anticipated that test hole drilling may be difficult. The drilling contractor will need to provide air compressor capabilities sufficient to provide the adequate pressure (in psi) and volume (in cfm) to lift cuttings from the test holes during drilling.

3. The test hole at each site should be drilled and geologically logged as drilling proceeds. After test hole drilling is complete, downhole geophysical surveys (electric logs) can be conducted in the open borehole.

4. During test hole drilling at each site, groundwater samples may be collected at specific depths by airlifting. The collected groundwater samples can then be

submitted to a laboratory and tested for general mineral and metals, including boron.

5. Following completion of test hole drilling at each site, the data and information gathered from geologic logging, electric logging, and from the airlifted groundwater samples should be examined and the feasibility of constructing a water well evaluated.

6. If the data for water quantity and water quality appear suitable for municipal-supply purposes, the borehole can then be reamed out, a well constructed, and the well developed and tested. If the downhole water quantity and water quality data indicate conditions are not favorable for a new well, then the test hole can be destroyed at that time without incurring any additional cost for well casing, gravel pack, etc.

7. If you do decide to drill test holes at any of the proposed well sites then, at your specific request, technical guidelines for the drilling, construction, development, and testing of a potential new well at each site can be prepared by our personnel. These guidelines will allow for borehole reaming, casing and gravel pack installation, well development by mechanical and pumping methods, aquifer testing and water-quality analyses. If you do decide to proceed with test hole drilling at any of the recommended well sites, we are also available to provide you with field monitoring services during test hole drilling and well construction.

Disclaimer

This report has been written for Mr. John Johnson of Windsor Public Works Department and solely with specific application to the proposed development of groundwater resources within Windsor-owned properties located outside the boundaries of Windsor and east of the Russian River. This report has been prepared in accordance with the care and skill generally exercised by reputable professionals currently working, under similar circumstances, in this or similar localities. No other warranty, either express or implied, is made as to the professional advice presented herein.

Should you require further information or have any questions regarding this letter-report, please contact us.

Very truly yours,

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Attachments

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