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Subject: Candidate SASR Sites Hydrogeology
Walla Walla Basin Shallow Aquifer Recharge
K/J 036411.00

Dear Wade:

Kennedy/Jenks Consultants is pleased to present Economic and Engineering Services, Inc. (EES) with this letter report which constitutes our deliverable for Task 1 of our subconsulting agreement with EES (Work Order # 1-02-389). The objective of the work done under this agreement is to assess the hydrogeologic conditions at several potential test sites (test sites) that may be used for testing possible shallow aquifer storage and release (SASR) projects in the Washington portion of the Walla Walla Basin near Walla Walla, Washington. The results of this assessment are used to prioritize these potential test sites for possible pilot SASR testing.

This hydrogeologic assessment is based on previously existing and readily available information. The assessment was conducted by Dr. Kevin Lindsey LHG, supported by Ms. Victoria Johnson LG, and reviewed by Mr. Terry Tolan LHG, RG. The assessment focuses on the sedimentary strata hosting aquifers above the top of underlying basalt bedrock, in particular the upper 150 feet of the sedimentary sequence. These sedimentary strata, and the aquifers hosted by them, are referred to throughout the remainder of this letter report as the suprabasalt sediments and suprabasalt aquifer, respectively. Except for very limited site reconnaissance, no field work was done for this project. Geologic and hydrogeologic publications and literature used to prepare this letter report include:

Barker, R.A., and Mac Nish, R.D., 1976, Digital model of the gravel aquifer, Walla Walla River Basin, Washington and Oregon: Washington Department of Ecology Water-Supply Bulletin 45, 49 p.

Bauer, H.H., and Vaccaro, J.J., 1990, Estimates of ground water recharge to the Columbia Plateau regional aquifer system, Washington, Oregon, and Idaho, for predevelopment and current land-use conditions: U.S. Geological Survey Water Resources Investigations Report 88-4108, 37 p.

Bjornstad, B.N., 1980, Sedimentology and depositional environment of the Touchet Beds, Walla Walla River basin, Washington: Richland, Washington, Rockwell Hanford Operations RHO-BWI-SA-44, 116 p.

Busacca, A.J., and MacDonald, E.V., 1994, Regional sedimentation of Late Quaternary loess on the Columbia Plateau - sediment source areas and loess distribution pattern, *in* , Lasmanis, R., and Cheney, E.S., eds., Regional geology of Washington State: Washington Department of Natural Resources, Division of Geology and Earth Resources Bulletin 80, p. 181-190.

Bush, J.H., Jr., Morton, J.A., Anderson, J.V., Crosby, J.W., III, and Siems, B.A., 1973, Test-observation well near Walla Walla, Washington - description, stratigraphic relationships, and preliminary results: Washington State University, College of Engineering Research Report 73/15-66, 38 p.

Campbell, N.P., Lillie, J.T., and Webster, G.D., 1979, Surficial geologic map of the Walla Walla quadrangle, Washington: Washington Department of Natural Resources, Division of Geology and Earth Resources Open-File Report 79-13, 1 plate, scale 1:250,000.

Carson, R.J., and Pogue, K.R., 1996, Flood basalts and glacier floods - roadside geology of parts of Walla Walla, Franklin, and Columbia Counties, Washington: Washington Department of Natural Resources, Division of Geology and Earth Resources Information Circular 90, 47 p.

Carson, R.J., McKhann, C.F., and Pizey, M.H., 1978, The Touchet Beds of the Walla Walla Valley, *in*, Baker, V.R., and Nummedal, eds., The Channeled Scabland - a guide to the geomorphology of the Columbia Basin, Washington: U.S. National Aeronautics and Space Administration, p. 173-177.

Kienle, C.F., 1980, Geologic reconnaissance of parts of the Walla Walla and Pullman, Washington, and Pendleton, Oregon 1^0 x 2^0 AMS quadrangles: Seattle, Washington, Consultant report to U.S. Army Corps of Engineers, Seattle District, 76 p., 3 plates, scale 1:125,000.

Lindsey, K.A., 1996, The Miocene to Pliocene Ringold Formation and associated deposits of the ancestral Columbia River system, south-central Washington and north-central Oregon: Washington Department of Natural Resources, Division of Geology and Earth Resources Open-File Report 96-8.

Mac Nish, R.D., and Barker, R.A., 1976, Digital simulation of a basalt aquifer system, Walla Walla River Basin, Washington and Oregon: Washington Department of Ecology Water-Supply Bulletin 44, 51 p.

Mann, G.M., and Meyer, C.E., 1993, Late Cenozoic structure and correlations to seismicity along the Olympic-Wallowa Lineament, northwest United States: Geological Society of America Bulletin, v. 105, no. 7, p. 853-871.

Newcomb, R.C., 1965, Geology and ground-water resources of the Walla Walla River Basin, Washington and Oregon: Washington Department of Conservation, Division of Water Resources Water-Supply Bulletin 21, 151 p, 3 plates.

Pacific Groundwater Group, 1995, Initial watershed assessment water resources inventory area 32 Walla Walla River watershed: Washington Department of Ecology Open-File Technical Report 95-11, 47 p.

Piper, A.M., Robinson, T.W., and Thomas, H.E., 1935, Ground water in the Walla Walla Basin, Oregon-Washington: Transcript of Record, The State of Washington, Complainant vs. the State of Oregon; Supreme Court of the United States, October term, p. 72-142.

Price, C.E., 1960, Artificial recharge of a well tapping basalt aquifers, Walla Walla area, Washington: Washington Division of Water Resources, Water-Supply Bulletin 7, 50 p.

Reidel, S.P., and Tolan, T.L., 1994, Late Cenozoic structure and correlation to seismicity along the Olympic-Wallowa Lineament, northwestern United States (Discussion and Reply) - Discussion: Geological Society of America Bulletin, v. 106, no. 12, p. 1634-1638.

Reidel, S.P., Fecht, K.R., Hagood, M.C., and Tolan, T.L., 1989, The geologic evolution of the central Columbia Plateau, *in*, Reidel, S.P., and Hooper, P.R., eds., Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 247-264.

Rigby, J.G., Othberg, K.L., Campbell, N.P., Hanson, L.G., Kiver, E.P., Stradling, D.F., and Webster, G.D., 1979, Reconnaissance surficial geologic mapping of the late Cenozoic sediments of the Columbia Basin, Washington: Washington Department of Natural Resources, Division of Geology and Earth Resources Open-File Report 79-3, 94 p., 7 plates, scale 1:250,000.

Richerson, P., and Cole, D., 2000, April 1999 Milton-Freewater groundwater quality study: Oregon Department of Environmental Quality, State-Wide Groundwater Monitoring Program, 17 p.

Schuster, J.E., 1994, Geologic map of the Walla Walla 1:100,000 quadrangle, Washington: Washington Department of Natural Resources, Division of Geology and Earth Resources Open-File Report 94-3, 18 p., 1 plate.

Shannon & Wilson, Inc., 1973, Geologic studies of Columbia River basalt structures and age of deformation - The Dalles-Umatilla region, Washington and Oregon, Boardman nuclear project: Portland, Oregon, consultant report to Portland General Electric Company, 1 vol., 2 plates.

Smith, G.A., 1993, Missoula flood dynamics and magnitudes inferred from sedimentology of slack-water deposits on the Columbia Plateau, Washington: Geological Society of America Bulletin, v. 105, no. 1, p. 77-100.

Swanson, D.A., Wright, T.L., Camp, V.E., Gardner, J.N., Helz, R.T., Price, S.M., Reidel, S.P., and Ross, M.E., 1980, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1139, scale 1:250,000.

Swanson, D.A., Anderson, J.L., Camp, V.E., Hooper, P.R., Taubeneck, W.H., and Wright, T.L., 1981, Reconnaissance geologic map of the Columbia River Basalt Group, northern Oregon and western Idaho: U.S. Geological Survey Open-File Report 81-797, scale 1:250,000.

Tolan, T.L. and Reidel, S.P., 1989, Structure map of a portion of the Columbia River flood-basalt province, *in* Reidel, S.P. and Hooper, P.R., eds., Volcanism and Tectonism in the Columbia River Flood-Basalt Province: Geological Society of America Special Paper 239, Plate 1, scale 1:576,000.

USDOE (U.S. Department of Energy), 1988, Site characterization plan, Reference Repository Location, Hanford Site, Washington - consultation draft: Washington, D.C., Office of Civilian Radioactive Waste Management, DOE/RW-0164, v. 1 - 9.

Waitt, R.B., Jr., O' Connor, J.E., and Benito, G., 1994, Scores of gigantic, successively smaller Lake Missoula floods through Channeled Scabland and Columbia valley, *in*, Swanson, D.A., and Haugerud, R.A., eds., Geologic field trips in the Pacific Northwest: Seattle, Washington, University of Washington Department of Geological Sciences, v. 1, p. 1k.1 - 1k.88.

WWC (Woodward-Clyde Consultants, Inc.), 1980, Seismological review of the July 16, 1936, Milton-Freewater earthquake source region: Consultant report prepared for Washington Public Power Supply System, Richland, Washington, 44 p.

Wozniak, K.C., 1995, Chapter 2 - Hydrogeology, *in*, Hydrogeology, groundwater chemistry, and land uses in the lower Umatilla Basin Groundwater Management Area, northern Morrow and Umatilla Counties, Oregon - Final Review Draft: Salem, Oregon, Oregon Department of Environmental Quality Report, p. 2.1-2.80.

WPPSS (Washington Public Power Supply System), 1981, Nuclear project No. 2 - final safety analysis report: Richland, Washington, v. 2, amendment 18.

Other data sources used for the project include:

- Washington Department of Ecology Water Well Reports (driller's logs) for water wells drilled in the project area. For this assessment it was assumed that the location of the well as indicated on the driller's log was correct and the locations of these wells were not field-verified.
- Interviews and conversations with people who have some knowledge and/or experience with area groundwater, including Washington Department of Ecology (Ecology) staff.
- Reconnaissance visits to all potential test sites.

Hydrogeologic elements described for each test site include, to the extent possible given the information sources used, depth to groundwater and groundwater flow direction, aquifer host strata physical and hydrologic properties, and conditions in nearby springs and creeks that may reflect local groundwater conditions. Additional elements described for each site include proximity to homes, canals, transportation infrastructure, and surface water.

This letter report is subdivided into sections that: (1) summarize the background which lead to the consideration of SASR as one part of a comprehensive strategy for managing water resources in the Walla Walla Basin (the Basin), (2) introduce the geographic setting of the project area, (3) provide a brief overview of the regional geologic and hydrogeologic setting, (4) summarize test site locations/landuses, geologic and hydrogeologic conditions at the potential test sites, (5) review regulatory, operational, and monitoring needs common to all potential test sites, and (6) provide final recommendations. This letter report includes 7 attachments, which include:

- Location map, Attachment 1
- Structure-contour and isopach maps of selected geologic units (Attachments 2 through 5)
- Table summarizing geologic and well information for wells used in the assessment (Attachment 6)
- Copies of well logs used in assessment (Attachment 7)
- Outline SASR Test Plant (Attachment 8)

Background

Both surface water and shallow groundwater in the Basin display a high degree of hydraulic connection (Newcomb, 1965) and it is generally accepted that groundwater and surface water use in the Basin has increased greatly in the past 50 to 60 years. Some of the consequences of this are thought to be declining shallow groundwater levels, diminished spring creek flows, and reduced baseflow, reduced river flow, and increased water temperature in the Walla Walla River. The U.S. Army Corps of Engineers (COE) with the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are examining four options for enhancing Walla Walla River flows, including: (1) offstream storage, (2) water rights purchase/lease, (3) water transfer from the

Columbia/Snake Rivers, and (4) irrigation efficiency. These options are notable in that they do not include groundwater storage and acknowledge the close relationship between surface water and groundwater in the Basin.

SASR testing discussed in this letter report is being considered by the WRIA 32 Planning Unit (WPU) and others, including the Walla Walla Basin Watershed Council (WWBWC) and Walla Walla Watershed Alliance (WWWA) as a fifth alternative to the four flow enhancement options in the COE/CTUIR study. At least locally SASR has the potential to:

1. Recharge shallow groundwater,
2. Reverse trends seen in declining spring creek flows, and
3. Increase stream baseflow and decrease the water temperature in the Walla Walla River.

The SASR testing concept discussed in this letter report is based on the assumption that the capture of winter-spring peak flows on the Walla Walla River (and other streams in the Basin) can be used to successfully recharge a portion of the depleted shallow aquifer system and at least locally provide benefit to the interconnected groundwater and surface water system. The proposed SASR testing is essentially looking at ways to mimic the natural water cycle as it existed historically in the Basin prior to river channelization, implementation of irrigation efficiency projects (e.g., ditch lining and piping that reduce groundwater recharge), and the advent of significant groundwater and surface water use.

Geographic Setting

The area encompassed by the hydrogeologic assessment (study area) described in this letter report consists generally of the southern portion of Walla Walla County south, southeast, and southwest of Walla Walla, Washington (Attachment 1). The study area is bounded on the north, south, east, and west respectively by the Walla Walla River and Yellowhawk Creek, the Washington-Oregon border, Hood and Cottonwood Roads, and by the R34E-R35E boundary.

The western portion of the study area, west of the East Little Walla Walla River, consists of a generally flat flood plain near the Walla Walla River and dissected low rolling hills and broad shallow valleys between the Walla Walla River flood plain and the Stateline (Attachment 1). Land surface elevations in this area generally decrease from the south towards the north and west. The predominant land uses in this area are a mix of irrigated farming, dryland farming, stock raising, and low density rural residential. Many of the spring feed creeks in this area have experienced diminished flows in the past several years.

The central part of the study area, between the East Little Walla Walla River valley and Braden Road (Attachment 1) consists of a mix of irrigated farming, rural residential, and urban housing developments (which become more common closer to the city of Walla Walla). The Walla Walla River flows through the central part of this area before turning west. The lower reach of Yellowhawk Creek lies within this area. This part of the study area generally consists of a gently rolling to flat surface that slopes towards the Walla Walla River. The reach of the Walla Walla River near the Stateline is commonly reported to have very low flows during Summer and early Fall months.

The eastern portion of the study area (east of Braden Road) lies along Cottonwood Creek at the base of the Blue Mountains (Attachment 1). Along Cottonwood Creek the land surface is relatively flat, although in the stream reach near Hood Road, Cottonwood Creek has incised as much as 15 feet into the valley floor. Landuses along the creek are predominantly irrigated farming and low density rural residential. However, in the northwestern part of the area, housing density increases. No springs are indicated on the topographic map for this portion of the study area (Attachment 1) or noted in Newcomb's (1965) study.

Based on our meetings and conversations with EES staff and others (including WWBWC staff and people active in the WWWA), and the review of study area conditions presented in this assessment report, four potential SASR test sites were chosen for further evaluation . These four potential test sites are (Attachment 1):

- A gravel pit located at the intersection of Locher and Stateline Roads in the western part of the study area.
- Property near the East Little Walla Walla River used by a local land owner for shallow aquifer recharge during the winter of 2002/2003.
- The general area near the confluence of the Walla Walla River and Yellowhawk Creek.
- An area along Cottonwood Creek between Powerline Road and Hood Road.

Overview of the Study Area Geologic Setting

The most recent comprehensive geologic investigation of the suprabasalt sediments in the Basin, the strata which are the focus of this assessment, is Newcomb (1965). Our review of area geology is based on Newcomb (1965), more recent insights into area geology taken from reports describing regional suprabasalt sediment geology (Smith and others, 1989; Lindsey, 1996), and our ongoing work in the area on other projects. Since the emphasis of this hydrogeologic assessment is on upper 150 to 200 feet of the suprabasalt aquifer system, this section will focus primarily on the sedimentary strata and only briefly introduces the underlying Columbia River basalt.

Generally, suprabasalt sediments found in the Walla Walla Basin include (Figure 1):

- Holocene to Pliocene (?) alluvial gravel
- Pleistocene Cataclysmic Flood deposited sand and silt (Touchet Beds)
- Pleistocene loess (Palouse Formation)
- Miocene to Pliocene (?) conglomerate, sand, silt, and clay

Newcomb (1965) also described several terrace sequences within the Basin. These are not described in this letter report because they typically do not host aquifers. The basic physical characteristics and distribution of suprabasalt sediments across the study area are briefly summarized in the following sections.

Holocene to Pliocene (?) Alluvial gravel

Basaltic, uncemented and nonindurated gravelly strata is found at the Earth's surface and in the shallow subsurface across much of the Basin. Based on the few outcrops of these strata described in reports (e.g., Newcomb, 1965), these gravely deposits are probably moderately to well bedded, have a silty to sandy matrix, and are generally uncemented. Our interpretation of borehole logs in the study area suggests these uncemented gravels vary from absent to almost 100 feet-thick beneath the study area (Attachments 1, 2, and 3). This variation in thickness is probably the result of both paleodepositional conditions and post-deposition erosion.

The age of these uncemented gravel deposits is not well constrained. Depending on where one is at in the Basin, they appear to predate, and be both contemporaneous with and younger than, the Palouse Formation and Touchet Beds. If this is the case, these uncemented gravelly strata may be late Pliocene to Holocene in age (e.g., greater than 2 million years to less than a few thousand or even hundreds of years old). For the purpose of this assessment we refer to all of these uncemented, post late Pliocene (?) alluvial gravelly strata as Holocene to Pliocene (?) alluvial gravel, or simply alluvial gravel.

The alluvial gravel as used here is generally equivalent to Newcomb's (1965) younger alluvial sand and gravel. The alluvial gravel unit is interpreted to record deposition of sand and gravel in the Walla Walla Basin by streams draining off the adjacent Blue Mountains. These ancient streams are probably the recent ancestors of many of the modern streams in the Basin, including the Walla Walla River, Mill Creek, and Cottonwood Creek. The distribution of coarse channel deposits in this unit should reflect the orientation of the ancient streams in which these materials were deposited.

Pleistocene Cataclysmic Flood Deposits (Touchet Beds)

During the Pleistocene, Cataclysmic Floods (e.g., Missoula or Bretz Floods) periodically inundated the Basin between approximately 1,000,000 and 12,000 years ago (Waitt and others, 1994). Sand and silt deposited in the Basin by these flood waters consist of well stratified, normally graded, interbedded felsic silt and felsic to basaltic fine to medium sand (Figure 2). Finer grained layers tend to be brown to tan colored, coarser layers brown to gray-brown colored. Individual beds (or layers) range from a few inches to less than 3 feet-thick. These strata do not commonly display significant cementing, although some pedogenic calcium carbonate (caliche or hardpan) is commonly observed in the upper parts of these deposits where they are exposed at the Earth's surface. A range of soft-sediment deformation features and cross-cutting clastic dikes are commonly found in this unit (Fecht and others, 1999).

These Cataclysmic Flood deposits, also known as Touchet Beds, form most of the small hills located across the Walla Walla valley floor and along the base of the Blue Mountains (Attachment 4) to an elevation of approximately 1100 feet above mean sea level (msl). The

Touchet Beds are typically absent from the flat bottomed valleys separating these hills.

Pleistocene loess (Palouse Formation)

Pleistocene loess (also called the Palouse Formation) consists of eolian (wind-deposited), massive to poorly stratified silt and very fine sand deposits that display evidence of pedogenic (soil forming) modification (Figure 3; Busacca and others, 2002). Pedogenic calcium carbonate may also be found in these loess deposits. Palouse Formation loess can range from less than 1 foot to several tens of feet-thick in the study area (Newcomb, 1965). These loess deposits are thought to range from greater than 1 million years old to less than 10,000 year old, making it older than, and age-equivalent to, the Touchet Beds (Busacca and others, 2002).

The Palouse Formation may be present in the western to central parts of the study area intercalated within Touchet Beds. However, we suspect loess is rare to absent in this area because of a lack of loess outcrops. The Palouse Formation does crop out along the edge of the Cottonwood Creek Valley, but it is not thought to underlie Cottonwood Creek. Some of the strata mapped on Attachment 2 may be part of the Palouse Formation, but it was not differentiated from the Touchet Beds because of a lack of borehole log information.

Mio-Pliocene strata

Variably indurated, at least locally very well cemented conglomerate, sand, silt, and clay is found in the subsurface beneath much of the Basin. Based on limited outcrop descriptions (Newcomb, 1965), field reconnaissance, and borehole log descriptions these strata beneath the study area consists of indurated gravel and sand, may locally have a caliche cap, and is predominantly basaltic in composition (Figure 4). Based on drill-cuttings collected from wells recently drilled near Milton-Freewater, Oregon, these strata may also contain some mica and quartz. These indurated gravelly strata (conglomerate) are continuous beneath the entire study area (Attachment 5) range between approximately 75 and 250 feet-thick, and are differentiated from younger alluvial gravel by physical characteristics, including a greater degree of induration, cement, and weathering.

These mixed conglomerates, sands, silts, and clays are assigned a Miocene to Pliocene age (approximately 10 to 2 million years old) based on degree of induration, evidence of greater weathering, and stratigraphic position (Smith and others, 1989). However, to our knowledge no absolute age dates are available for this unit. These indurated strata, referred to through the rest of this report as Mio-Pliocene conglomerate, probably record deposition by the ancestral Salmon/Clearwater/Snake and Walla Walla River systems and include river channel deposits, overbank and flood plain deposits, and lake deposits. The distribution of coarse channel deposits in this unit should reflect the orientation of the ancient streams in which these materials were deposited.

The Mio-Pliocene conglomerate is generally equivalent to Newcomb's (1965) old gravel unit and old clay units. Newcomb (1965) placed the old gravel unit stratigraphically above the old clay unit. However, review of driller's logs across the study area and on the Oregon-side of the

Basin reveal: (1) the presence of interstratified silt and gravel lithologies throughout entire thickness of the Mio-Pliocene strata, (2) areas where strata correlative to one of the two units, old gravel and old clay, are absent, and/or (3) areas where the inferred contact between the old gravel and clay units varies greatly in depth over distances of less than one mile. Given this, it is likely that the top of the old clay unit and bottom of the old gravel unit is not a single, continuous surface as suggested by Newcomb (1965). It is more likely that these strata interfinger and that a distinctive old gravel unit and old clay unit can not always be differentiated.

Columbia River Basalt Group

The basalt flows that underlie the sediment sequence in the Basin belong to the Miocene Columbia River Basalt Group. The top of the Columbia River basalt surface is generally found to lie at greater depths from east (150 to 250 feet below ground surface) to west (700 to 800 feet below ground surface) across the study area. Because of the depth at which this unit is generally found within the study area, it is assumed for the purposes of this assessment that it is likely that the Columbia River basalt does not exert a significant influence over the hydrogeologic behavior of the shallow suprabasalt sediment aquifer system.

Structural Geology

The Walla Walla Basin is a structural basin that began to develop during Miocene time (approximately 16 million years ago) and has continued to develop to the present day (Kienle, 1980; USDOE, 1988). The Basin is bounded on the south by the Horse Heaven Hills, the east by the Blue Mountains, and to the north by the Palouse Slope. The southern and eastern edges of the Basin are fault controlled. The uppermost basalt which crops out around the edge of the Basin on the Horse Heaven Hills and Blue Mountains is down dropped at these bounding faults. The faults, and associated folds, found on the southern and eastern edge of the Basin probably extends into the subsurface beneath the Basin (Kienle, 1980; Swanson and others, 1981). The presence of these faults beneath the Basin may in part explain discontinuities seen in the distribution of suprabasalt sediments, especially Mio-Pliocene sedimentary strata.

Overview of the Study Area Hydrogeologic Setting

Groundwater in the Basin is found in two primary aquifer systems: (1) the suprabasalt sediment aquifer system which is primarily hosted by Mio-Pliocene conglomerate and to a lesser extent, the overlying alluvial gravel and (2) the underlying Columbia River basalt aquifer system. Few details are known about this hydrologic system in the Basin, forcing us to speculate to some degree about its nature with little supporting data. The suprabasalt aquifer is the focus of this section.

Physical properties

The majority of the suprabasalt aquifer is hosted by Mio-Pliocene conglomerate unit while the uppermost part of the aquifer is found, at least locally, in the younger alluvial gravel unit. The suprabasalt aquifer is generally characterized as unconfined, but it does, at least locally, display confined conditions. Variation between confined and unconfined conditions within the aquifer system is probably controlled by sediment lithology (e.g., facies – coarse versus fine) and induration (e.g., cementation, compaction). Groundwater movement into, and through, the suprabasalt aquifer also is inferred to be controlled by sediment lithology and induration.

Given the physical properties of the alluvial gravel (non-indurated sand and gravel) versus those of the Mio-Pliocene conglomerate (e.g., finer matrix and the presence of naturally occurring cement), Mio-Pliocene conglomerate probably has generally lower permeability and porosity than the alluvial gravel. Consequently, suprabasalt aquifer groundwater flow velocities are inferred to be less where the water table lies within the Mio-Pliocene conglomerate than where it lies within the younger, more permeable alluvial gravel. In addition, where the alluvial gravel is saturated, this uncemented, high permeability gravel and sand could form preferred pathways for groundwater movement and areas of increased infiltration capacity in the shallow parts of the suprabasalt aquifer system.

Very little hydraulic property information is available for the suprabasalt aquifer. Newcomb (1965) reports average effective porosity of 5 percent in the old gravel (e.g., the Mio-Pliocene conglomerate and sand). Given the physical characteristics of the overlying alluvial gravel, we suspect average effective porosity in it is higher. Modeling work by Barker and MacNish (1976) report estimated hydraulic conductivity and transmissivity of 1.5×10^{-4} feet/second to 7.6×10^{-3} feet/second and 10,000 feet^2/day to 60,000 feet^2/day, respectively, for the entire shallow aquifer. As with Newcomb's (1965) effective porosity estimate, we suspect hydraulic conductivity and transmissivity would be higher in saturated alluvial gravel than in saturated Mio-Pliocene conglomerate.

Groundwater levels and flow direction

Groundwater flow in the suprabasalt aquifer study area is generally thought to be from east to west. There probably also is a component of groundwater movement towards the Walla Walla River where the suprabasalt aquifer water table is higher than the river. Where this occurs, the Walla Walla River is, in part, feed by groundwater discharge. However, along the course of the Walla Walla River through the study area, the suprabasalt water table may at least locally be below the bed of the river during the driest part of the year. When and where this occurs, such reaches of the river probably lose water to the suprabasalt aquifer.

There is little recent and comprehensive data showing suprabasalt aquifer water table elevations in the study area. Water level data reported on well logs, and the few reports written for the Basin, suggest groundwater levels near the Walla Walla River (and many of the spring creeks) historically were relatively shallow, commonly less than 5 feet deep. With increased groundwater use over the past 20 years these water levels are generally though to have declined, at least locally. A review of the U.S. Geological Survey water well level database for this area (available online) also suggests this. This groundwater level decline is thought to account for, at least in part, the reduction in spring creek flow reported by many land owners in the Basin. Based on Barker and MacNish (1976), water table elevations in the study area range from approximately 1,050 feet above msl in Cottonwood Creek valley, to approximately 725-750 feet above msl near College Place, Washington, to approximately 625 feet above msl beneath the western part of the study area. We did not find an up-to-date map that modifies this earlier mapping.

Aquifer recharge

Natural recharge to the suprabasalt aquifer is described by Newcomb (1965) to be from infiltration of surface water into the ground near the edge of the Basin where streams leave the adjacent basalt highlands and flow out onto the basin floor. The majority of this recharge probably occurs in the spring when streams flowing into the Basin reach peak discharges. Precipitation on parts of the Basin floor where the alluvial gravel and older, Miocene-Pliocene strata lie at, or near, the surface may also provides some natural recharge. With flood control and channelization of the Walla Walla River and smaller streams, natural recharge via infiltration from surface waters has probably decreased with continued development.

Artificial recharge of the suprabasalt aquifer has become an important component of the hydrologic system since the 1920’s and 1930’s. This recharge is thought to have historically contributed water to at least some shallow water wells and springs (Newcomb, 1965). Artificial recharge probably occurs through irrigation ditch leakage and infiltration past the root zone in irrigated fields. With the advent of ditch/channel lining and reduction in the practice of flood irrigation, this type of recharge has probably decreased.

Reduced natural and artificial recharge will, and probably does, account for decreased suprabasalt aquifer water table levels. Decline in water table levels in-turn probably account for reduced spring flows and base level discharge to the Walla Walla River. The objective of the proposed SASR project is to attempt to locally replenish groundwater in the suprabasalt aquifer and restore some spring flows and Walla Walla River baseflow.

Water Quality

No up-to-date groundwater quality data for the study area was found. However, an Oregon Department of Environmental Quality (ODEQ) report (Richerson and Cole, 2000) prepared for the northern portion of Umatilla County, immediately adjacent to the Stateline bordering the southern edge of the study area, does provide insights into likely groundwater quality conditions.

Two water quality parameters presented in the ODEQ report suggest groundwater quality in the uppermost suprabasalt aquifer near the Stateline is relatively good with regard to ODEQ standards. These parameters, total dissolved solids (TDS) and nitrate-N, range from 150 to 250 mg/l and 0.5 to 4.5 mg/l, respectively on the Oregon side of the Stateline. Concentrations of these parameters decrease from north to south toward where the Walla Walla River enters the valley. This trend suggests the introduction of low nitrate-N and TDS surface water into the groundwater system and supports Newcomb’s (1965) conclusion that surface water recharge of shallow groundwater occurs where the Walla Walla River enters the Basin. The increase in TDS and nitrate-N concentrations as suprabasalt groundwater moves north into the Basin is inferred to be, at least in part, the result of the relative increase in recharge from irrigation water reaching the suprabasalt aquifer.

If this water quality trend seen in Oregon continues into Washington, one would expect groundwater quality parameters at the westernmost two potential test sites to be similar to those seen in Oregon near the Stateline. Along lower Yellowhawk Creek, water quality parameters may be slightly elevated relative to those observed in Oregon because groundwater has moved under more heavily irrigated lands. Beneath Cottonwood Creek, which lies near the base of the basaltic upland, it is possible that groundwater quality may mimic trends observed in Oregon.

Site-Specific Conditions

As stated in the previous sections, little detailed, site-specific hydrogeologic information is available for the suprabasalt aquifer. However, based on the information found during this hydrogeologic assessment, it is possible to make some basic hydrogeologic conclusions about specific test sites and provide a basis for planning future SASR tests. This section presents site-specific hydrogeologic descriptions and other information about each potential test site, including water delivery infrastructure and water rights that might be available for use at each potential test site. Each test site description concludes with a summary of how the test site might operate.

Locher Road and Stateline Road Gravel Pit Site

Location - A gravel pit at the junction of Locher Road and Stateline Road is a potential SASR test site (Attachment 1). This gravel pit is located at the northwest corner of the road junction (Figure 5). The gravel pit is generally rectangular shaped, being approximately 800 feet long (north-south) and 300 feet wide (east-west). The depth of the gravel pit appears to range between 15 and 20 feet. The north end of the gravel pit is less than 200 feet away from the Burlingame Ditch.

Landuse - Farming and low density rural residential landuses predominate in the areas to the west, northwest, and southwest of this test site. Higher density rural residential and irrigated farming landuses predominate to the east of the gravel pit.

Geomorphology - The land surface in the test site area generally slopes gently downhill to the northwest from the gravel pit.

Geology – Touchet Beds and loess are not present in the gravel pit which has been excavated into alluvial gravel and red-brown stained (iron?), partially cemented gravel assigned to the Mio-Pliocene conglomerate (Figure 6). Based on outcrops in the gravel pit and interpretations of well logs in the area, the alluvial gravel unit is interpreted to be relatively thin (<10-15 feet-thick) around the gravel pit. Within the confines of the gravel pit, the alluvial gravel unit has been removed and the Miocene-Pliocene conglomerate unit extends from the gravel pit floor to a depth of as much as 260 feet based on Bush and others (1973).

Hydrogeology – Washington Department of Ecology has been measuring water levels in the suprabasalt aquifer at a well (commonly referred to as the “Ecology well”) near the pit. This data indicates the suprabasalt aquifer water table lies between approximately 25 to 41 feet below the ground surface and varies with the use of the nearby Burlingame Ditch. Anecdotal comments of people familiar with gravel pit history indicate that when water has been discharged into this pit, it rapidly infiltrates into the floor of the gravel pit. Based on such comments and the Ecology well records, it appears possible that the Mio-Pliocene conglomerate unit comprising the gravel pit floor is very permeable and permits rapid infiltration of water.

Groundwater gradient and flow direction in the gravel pit area is not known, but is inferred to be to the north and west. If this is the case, water introduced into the ground at the gravel pit would probably move in a generally westerly to northerly direction. If this water was to move north, our current subsurface geologic interpretation suggests it may flow towards a low spot in the top of the Mio-Pliocene conglomerate unit (Attachment 5), possibly increasing potential recharge deeper within these older strata. If recharge water flows to the west away from the gravel pit it would move towards low areas along Mud Creek approximately ¼ to ½ mile north and northwest of the gravel pit. This might result in increased groundwater discharge into Mud Creek.

Operation and Use – The most likely source for sufficient quantities of recharge water for this potential test site, assuming valid water rights are available, is Burlingame Ditch. Water could be diverted from Burlingame Ditch, which lies a few hundred feet north of the gravel pit, and gravity fed into the gravel pit where it would be allowed to infiltrate into the ground. Likely gravel pit modifications for this basic scenario include construction of a delivery pipe or ditch from Burlingame Ditch to the gravel pit, work as needed to mitigate against erosion where the diverted water enters the gravel pit, excavation of a series of trenches to aid in distributing water across the pit floor, grading of the gravel pit floor to promote drainage, removal of any trash and debris from the gravel pit, and fencing to restrict access.

Specific water rights that might be used for long-term SASR use at this potential test site have not yet been identified. However, a short term or preliminary water right might be obtained for testing by Gardena Farms Irrigation District, operator of Burlingame Ditch.

East Little Walla Walla River Site

Location – This potential test site is situated on pasture lands located on the Hall-Wentland property just south of the Oregon border in Sec 14, T6N, R35E. (Plate 1, Figure 7). In addition, Mr. Page has identified a property on the Washington side of the border that could be used as an alternative to the Hall-Wentland property.

Landuse - Landuse in the immediate vicinity of this test site consists almost entirely of farming and rural residential. Housing density increases to the east of the test site area.

Previous SASR Tests - In the winter of 2002/2003 informal SASR was conducted by Mr. Tom Page on this site. This SASR test included periodic measurement of water levels in several domestic and irrigation wells at the test site and between the test site and the Walla Walla River at the Burlingame Diversion. The objective of recharge at the test site was to replenish flows to McEvoy spring creek, located approximately 0.5 miles north of the recharge test site.

Recharge water was conveyed to the test site via a ditch extending from the East Little Walla Walla River to the test site. Although the upper reaches of the East Little Walla Walla (near

Milton-Freewater, Oregon) are operated by the Walla Walla Irrigation District (WWID) to deliver irrigation water, the lower reaches of this system (including the diversion point noted above) are not. The source of water diverted from the East Little Walla Walla River during Mr. Page's informal SASR test is thought to be spring flow into the East Little Walla Walla River upstream of the ditch diversion because no water was not being added to the East Little Walla Walla system by the WWID.

A 0.5 cubic foot per second (cfs) Oregon winter irrigation water right was used for the recharge water. This water is diverted from the East Little Walla Walla River onto the test site via existing irrigation infrastructure. The existing infrastructure that delivers water to this particular test site may be able to handle over 5 cfs, but the capacity of this infrastructure is not well known. At the test site, water was simply spread onto a grassy pasture where it infiltrated into the ground (Figure 8).

Geomorphology – The area of the test site is relatively flat. The ditch in which water flows onto the site is no more than 2 or 3 feet deep.

Geology - Alluvial gravel and Mio-Pliocene conglomerate underlies the test site. These are capped by a thin veneer of Touchet Beds. Based on well log interpretations, the Touchet Beds, alluvial gravel, and Miocene-Pliocene conglomerate are less than 10 feet-thick, approximately 20 feet-thick, and greater than 125 feet-thick, respectively in the immediate area of the test site. This trend generally persists to the north along the East Little Walla Walla River valley. However a few hundred yards north of the test site, the alluvial gravel unit completely pinches out and Mio-Pliocene conglomerate unit is found within a few feet of the ground surface (Attachment 5).

Hydrogeology – Based on regional information, suprabasalt aquifer gradient and flow direction in the test site area are probably to the north and west, along the course of the East Little Walla Walla River towards the Walla Walla River. Some recent water level data has been collected for this area by Mr. Page. This data indicates the suprabasalt water table beneath the test site area during the winter of 2002/2003 ranged from 8 to 10 feet deep. Within a few hundred feet to the north, in the inferred downgradient direction, the water table is approximately 20 feet deep. Near the location of McEvoy Spring groundwater appears to be less than 10 feet deep. These depths generally place the suprabasalt water table in the alluvial gravel unit. However, where this unit is absent, the water table would be in the Mio-Pliocene conglomerate unit.

Based on the information summarized above, water that infiltrates to the water table at this test site is inferred to move to the north, northeast, or northwest. However, due to the unknown effects from pumping of nearby water wells and the possibility of aquifer property changes (aquifer heterogeneities), groundwater flow direction(s) at this test site could be completely different. If this test site is selected for future use, more site investigation and monitoring will be needed.

Operation and Use – To continue using this location as a SASR test site, as was done in 2002/2003 with a winter irrigation right, no significant site-modifications are necessary. However, increased recharge at the test site will require additional water rights. In addition, construction of infiltration ponds or ditches may increase infiltration capacity at this test site resulting in a smaller foot print and a smaller impact on the landowner land use. Any site construction will require land owner approval and possible compensation for loss of use. Final approval for use of this site has not been sought.

Testing at this site should consider the use of additional water delivered to the lower Little Walla Walla River by WWID. Before this can be done though, cooperation of the WWID will be required and an assessment of the ability of the existing infrastructure to handle this additional water will need to be done. The use of the entire East Little Walla Walla River provides an additional benefit as additional water infiltration should be gained by operating the East Little Walla Walla River delivery system. Although the channel of this stream has been modified for irrigation water delivery, it was originally a natural gravel bedded stream along most, if not all, of its length from Milton-Freewater north into Washington. Today it is largely a gravel bedded ditch. Using it to deliver additional recharge water to the test site will result in water flowing along essentially the entire length of the East Little Walla Walla River as it did historically on at least a seasonal basis. Based on Newcomb's (1965) and Piper and others (1935) earlier analysis of flow in these streams and groundwater recharge, it appears likely that use of this of the East Little Walla Walla River in this manner would result in additional SASR along much of its length. Therefore, even though the water right used for recharge is relatively small, recharge along the delivery system when in use may be significant. Given this, if this site is used for future testing, a joint project with the WWBWC may provide a more comprehensive investigation.

Lower Yellowhawk Creek Site

Location -The Lower Yellowhawk Creek site encompasses an approximately one square mile area bounded on the north by Landgon Road, the west by Washington Highway 125, and extending approximately 1 mile east and south from the junction of these two roads (Attachment 1, Figure 9). Much of this site is owned by a single person, Mr. Bob Rupar.

Landuse - Although surrounded on all sides by relatively dense rural residential development, the test site area itself is devoted largely to agriculture (Figure 9).

Geomorphology – The test site area is relatively flat, but bordered by low hills to the south, east, and west. Yellowhawk Creek, which forms the northern border of this area is incised approximately 5 to 10 feet into the ground.

Geology – The test site area is underlain by Touchet Beds, alluvial gravel, and Mio-Pliocene conglomerate. Unlike the other potential test sites though, the Touchet Beds here appear to be relatively thick, ranging from 15 to 20 feet-thick in low lying areas and possibly up to 40 to 50 feet-thick beneath hills (Attachment 4). Around the edge of the test site the Touchet Beds are eroded out by Yellowhawk Creek and the Walla Walla River. Alluvial gravel appears to be thin to non-existent beneath the northern 1/3 of the area and 15 to 30 feet-thick beneath the rest of the test site area. The alluvial gravel appears to be thickest where it fills an elongate, east-west oriented low in the top of the underlying Mio-Pliocene conglomerate (Attachments 3 and 5).

Hydrogeology – No up-to-date water table information was found for this potential test site. Extrapolating from well log information, older water table maps, and antidotal information, the suprabasalt water table beneath this test site probably is shallowest near the Walla Walla River and Yellowhawk Creek and is increasingly deeper to the east. If so, the unconfined water table is inferred to generally lie a few feet below the surface near these streams and 20 or more feet-deep beneath the eastern part of the area. Groundwater flow directions are also not known for this test site, but they are probably generally from east to west. If the elongate low in the top of the Mio-Pliocene conglomerate mentioned above is real, the generally higher permeability alluvial gravel filling this depression may provide a preferred flow pathway for the shallow suprabasalt aquifer in the test site area.

The presence of several tens of feet of Touchet Beds across much of the test site area suggests that this site may not be an ideal candidate for surface recharge of the suprabasalt aquifer because such strata tend to have relatively low infiltration capacity. However, antidotal descriptions of relatively high infiltration capacity observed in this area suggests that at least locally the Touchet Beds has relatively high infiltration capacities, making it attractive for further consideration. This test site also is considered because of its small number of land owners, interest of these landowners in solving water issues, and its proximity to a reach of the Walla Walla River that does experience low flows.

Operation and Use – Some portion of the water rights currently being used for irrigation would need to be converted to recharge use, at least temporarily. Alternatively, a short term or temporary permit could be sought for recharge use. In either case, water could be applied to the ground simply through normal irrigation activities or via infiltration structures (ponds, basins, ditches) built specifically to promote infiltration. Except for the piping currently in use for field irrigation, all other infrastructure would need to be constructed. In addition, if a permanent infiltration structure(s) is built, the land it is built on will not be available for other uses.

Cottonwood Creek Valley Site

Location – This potential test site is located in the area adjacent to Cottonwood Creek between Powerline and Hood Roads (Attachment 1, Figure 10).

Landuse - The primary landuses in the immediate vicinity of the potential test site are low density rural residential and agriculture.

Geomorphology – The potential test site is situated on a gently west sloping alluvial surface ¼ to ½ mile wide.

Geology – The geology of the potential test site area generally consists of a thin Touchet Beds cover (<10 feet-thick) over alluvial gravel and Mio-Pliocene conglomerate. The Touchet Beds thin towards the creek where they are eroded out by the creek. Alluvial gravel that underlies the test site appears to thicken towards the creek and down valley to the west where it reaches 20 to 35 feet-thick. To the east at Hood Road, the alluvial gravel unit is thin to absent and the underlying Mio-Pliocene conglomerate unit is exposed in the creek bed.

Hydrogeology - No up-to-date groundwater level and gradient data was found for the test site area. No springs are noted to be present within the vicinity of the test site area (Newcomb, 1965). Based on historical water well records and scarcity of springs in this area, groundwater is inferred to be relatively deep, possibly greater than 20 feet below ground surface. If this is so, the unconfined water table is probably at, or near, the alluvial gravel and Miocene-Pliocene conglomerate contact. Based on available data, we infer that suprabasalt groundwater probably generally moves westwards toward Yellowhawk Creek and the Walla Walla River.

Operation and Use - We were not able to identify a water delivery system in the test site area suitable for SASR purposes during this assessment. Therefore if this test site is considered for a future test, some strategy for securing water delivery to site will need to be developed and implemented. One possible strategy would be to investigate the feasibility of diverting some of the high Winter and early Spring flows from Cottonwood Creek into a series of infiltration structures.

Needs Common to All Sites

This section reviews additional factors and considerations for SASR testing at all of the test sites discussed above. Many of these factors are regulatory in nature. The regulatory issues are listed first. This is followed by a list of operational and monitoring issues that will need to be addressed in any test.

Regulatory

SASR will probably be governed by Department of Ecology rules for Aquifer Storage and Recovery (ASR) under WAC 173-157 and the Water Quality under WAC 173-200. If an infiltration structure is used that meets the Underground Injection Control rules, WAC 173-160, additional regulatory issues will need to be addressed.

Regulatory issues that will need to be addressed at each potential test site include:

- Are water rights available to use for Winter/Spring recharge? Water rights appropriate for recharge use at a particular test site will need to be secured, either via use of an existing right, a transfer, change in use, short term or temporary permit, or a new right.
- Under Washington's antidegradation policy (WAC 173-200-030), water quality protection will be an important part of any Ecology permit. Background groundwater quality and source water quality will need to be determined and with this data potential water treatment options addressed with Ecology and included in a permit.
- Given that one of the proposed uses of recharged groundwater is for it to discharge to surface waters, a NPDES permit under WAC 173-201A may be needed.
- A SEPA environmental assessment will be required to identify potential adverse conditions or potential impacts to surrounding ecosystem(s).
- Washington's current ASR rules are not designed for recharge of aquifers for later non-consumptive use. The local lead entity should be prepared to work with Ecology to develop policy and/or rule amendments to accommodate the SASR envisioned here.

Similar policy and/or rule amendments may need to be explored with respect to the water quality rules (WAC 173-201A).

- Construction permits probably will need to be secured from the County. Permission to use land and construct infrastructure and access will be needed from landowners.
- Fisheries management agencies and tribal stakeholders will need to be consulted under the various regulatory and statutory frameworks in place that involve water use.

Operational and Monitoring

Common operational and monitoring elements are listed below. Many of the monitoring elements listed below will probably be defined as permits issued by Ecology for SASR. Much of the monitoring will also be designed to detect groundwater changes caused by recharge that may cause problems for downgradient water users, entities, and private residents.

Operations and monitoring issues include:

- The entity/entities that are responsible for operations and maintenance will need to be identified.
- Site-specific characterization work to collect hydrogeologic data for the test site to use in designing monitoring and evaluating performance will need to be done.
- Baseline monitoring and subsequent operational monitoring for water level and quality will probably be called for by the final operations permit and included in a facility operations plan. In addition, the data collected will be very useful in evaluating the results of the tests and designing future SASR.
- Seasonal conditions will need to be factored into the tests. Since most of these tests will probably rely on Winter water, the most likely operational issues that will need to be planned for and addressed will deal with will be potential operational problems caused by adverse conditions (e.g., freezing temperatures, flood events).

Conclusions and Recommendations

Based on the information described in this hydrogeologic assessment, we recommend the following priority for the 4 tests sites: (1) East Little Walla Walla River site, (2) Locher Road gravel pit site, (3) Lower Yellowhawk Creek, and (4) Cottonwood Creek. The reasons for this are reviewed below.

The East Little Walla Walla site is ranked first for the following reasons:

- Site land owner has already done limited SASR and should be receptive to continued testing. In addition, Mr. Page already has gained support for testing from many of the area’s resident’s, facilitating any future efforts.
- A formal test would build on the information collected during “informal” testing conducted in the winter of 2002/2003.

- Although small in volume, potential use of the entire East Little Walla Walla River to supply additional water for SASR testing offers increased opportunity for suprabasalt aquifer recharge along its entire length.
- Use of this site will facilitate a Bi-State approach to the Bi-State issue of surface and groundwater declines.

The Locher Road site is ranked second because:

- A single owner controls the site and this person may be supportive of recharge testing, although this remains to be confirmed.
- Site access is easy and site modifications for testing are simple.
- The water supply is nearby and relatively easy to control.
- Residential density in area is relatively small, minimizing the chance for negative impacts on surrounding residences due to elevated water levels in suprabasalt aquifer.

The Lower Yellowhawk Creek site is ranked third largely because of inferred hydrogeologic conditions. These include: (1) the inferred thickness (10 to 20 feet) and (2) distribution across much of the site of Touchet Beds which could limit infiltration capacity and efficiency at the site. In addition, given the proximity of the site to the Walla Walla River and the unknown groundwater travel times in the area it is not known if testing would result in base flow to the Walla Walla River during dry summer months. If these factors can be resolved with some site-specific characterization work, the site might be elevated to second position because:

- It is owned by essentially one person, Mr. B. Rupar.

- Water rights and infrastructure are also owned by Mr. Rupar, facilitating permit changes and infrastructure use and modification (if necessary).

- It is located close to a reach of the Walla Walla River that would benefit from increased base flow because of low Summer flows commonly noted for it.

The Cottonwood Creek site is ranked fourth for the following reasons:

- A higher degree of hydrogeologic uncertainty associated with it.

- Potentially costly infrastructure work because of the apparent lack of existing infrastructure that could be modified for SASR.

- The site is located in an area where groundwater and spring flow problems have not been described (to the best of our knowledge),

Before any SASR work and/or testing is done in the Cottonwood Creek valley, site characterization work would need to be done and engineering plans to build SASR infrastructure would need to be prepared and evaluated.

This hydrogeologic assessment letter report will be followed by a general pilot SASR test plan that will discuss:

- Test site infrastructure and equipment
- Water quantities to be used
- Monitoring activities
- Data collection
- Ranges of possible project costs
- Regulatory needs

This general plan will serve as a template from which to develop site-specific test plans for the sites recommended above and/or additional, yet unidentified, sites.

If you have any questions regarding this report, please do not hesitate to contact Dr. Kevin Lindsey at our Kennewick office at (509) 734-9763.

It has been a pleasure working with you on this and we look forward to working with you in the future.

Very truly yours,

KENNEDY/JENKS CONSULTANTS

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Attachments

cc: file