IDAHO DEPARTMENT
OF WATER RESOURCES

W CANAL RECHARGE PROJECT SITE CHARACTERIZATION AND RECHARGE FEASIBILITY REPORT GOODING COUNTY, IDAHO

July 24, 2007

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Prepared for

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EXECUTIVE SUMMARY

The Idaho Water Resource Board (Board) is evaluating the feasibility of managed aquifer recharge on the Eastern Snake River Plain (ESRP). The W Canal Recharge Site (the Site), located in Gooding County, Idaho, was selected by the Board as a potential recharge site based on land ownership, proximity to water delivery systems, and other site characteristics. The North Side Canal Company has indicated willingness to convey water supplied by the Board to the Site via the W Canal.

Brown and Caldwell (BC) and SPF Water Engineering, LLC (SPF) were selected to evaluate soil and hydrogeologic conditions at the Site. The Board's goal for this evaluation was to (1) determine the soil and geological characteristics influencing potential managed recharge and (2) make recommendations about how managed recharge can best be accomplished at this and other similar sites on the ESRP.

This report (Task 4) summarizes the results of three previous investigation reports including a literature review (Task 1), soil characterization (Task 2), and bedrock assessment (Task 3). This report also discusses alternative managed recharge options and a recommended recharge strategy for the W Canal Site. Finally, this report provides a list of recommendations for additional investigation activities.

The W Canal Site warranted investigation of managed recharge potential because of land availability, water availability, relatively thin soils, and because additional ground water recharge would benefit the ESRP aquifer in this area. The least expensive managed recharge strategy would be the use of one or more spreading basins to enable natural infiltration. However, results of the soil investigation indicated the widespread presence of low-permeability soils. The bedrock investigation revealed the extensive low-permeability stratigraphic layers. The W Canal Site is therefore thought to be unsuitable for managed recharge via surface infiltration at the desired recharge rates. Similar constraints will likely limit large-volume managed recharge at other similar ESRP recharge sites.

An engineered recharge facility will likely be required at the W Canal Site to meet the Board's recharge goals because of the low natural soil and basalt permeability characteristics. Engineered recharge approaches may include (a) replacing existing soil with higher hydraulic conductivity soil; (b) injection of surface water deeper into the vadose zone; and/or, (c) injecting treated surface water directly into the regional aquifer.

We believe that the most effective approach to ground water recharge at the Site will be direct injection of surface water into the regional aquifer system. This approach will allow recharge at the desired rates and allow control of potential water quality constraints. Direct injection is also an approach that can be considered for other ESRP sites. Water treatment can be implemented via the use of a slow sand filter, where filtration is enhanced by a biological layer that develops on the wetted top surface of sand. The advantage of the direct injection approach is the potential for greater recharge rates than could be achieved otherwise (because of the low hydraulic conductivity soil and rock found at the Site). It also eliminates the uncertainty of water filtering characteristics of the subsurface, as all water is treated in an above ground system.

A small pilot-scale test of direct injection and associated treatment is recommended for the Site. This would include construction of a settling pond and small slow sand filter to evaluate the water filtration capabilities using water obtained from the W Canal. Additional testing of the aquifer hydraulic conductivity with high capacity pumping equipment in one or two injection/pumping wells is recommended to verify that aquifer conductivity values are high enough to accept large quantities of water in this location. Completion of a pilot test will allow for determination of filtration equipment sizes and associated costs.

1.0 INTRODUCTION

The Idaho Water Resource Board (Board) is evaluating the feasibility of managed aquifer recharge on the Eastern Snake River Plain (ESRP). Managed aquifer recharge has been proposed for the ESRP to preserve or increase the water supply within the regional aquifer. Spreading basins are the ideal, low-cost method for introducing recharge water to the subsurface. Spreading basins are surface-water impoundments where water seeps into the shallow subsurface and infiltrates vertically until reaching the regional water table. Soil and underlying strata provide a medium for filtration of bacteria or other harmful biological organisms.

The hydraulic conductivity of the soil and rock beneath the spreading basin controls the rate of recharge from spreading basins. Areas underlain with low vertical hydraulic conductivity strata require a larger spreading basin than areas underlain with high vertical hydraulic conductivity strata. Typically, medium- to coarse-grained sediments allow relatively rapid infiltration rates and effective removal of harmful organisms (depending on sediment thickness).

Alternatives to surface-basin infiltration, such as excavated trenches or injection wells, can be used for aquifer recharge in areas where soil and rock conditions do not allow adequate natural infiltration. Injection wells can be used to introduce water to the aquifer zone or to unsaturated permeable strata above the aquifer zone. Ideally, water introduced to the unsaturated strata will have an unobstructed path downward to the aquifer. However, such direct or indirect injection may not allow sufficient natural filtration to remove potential biological contaminants. Pre-treatment of recharge water may be required to maintain aquifer water quality.

1.1 PURPOSE AND OBJECTIVES

The Board selected the W Canal Recharge Site (Site), in Gooding County, Idaho as a pilot aquifer recharge site. Figure 1 is a vicinity map showing the W Canal Recharge Site location relative to surrounding regional features. The Site was selected by the Board based on a review of land ownership, proximity to water delivery systems, and other site characteristics. The Site is in close proximity to the W Canal; the North Side Canal Company has indicated willingness to convey water supplied by the Board to the Site. The Site geology was recognized by the Board as being similar to many ESRP areas. The site geology includes fine-grained silt or clay soil, underlain by thick sequences of basalt bedrock.

Brown and Caldwell (BC) and SPF Water Engineering (SPF) was selected as third party consultants to:

1. Review literature relevant to managed aquifer recharge on the eastern Snake River Plain.

2. Characterize unconsolidated soils at the W Canal Recharge Site.

3. Characterize geologic materials at the W Canal Site, and

4. Prepare a technical report summarizing findings and making recommendations regarding the viability of recharge at the W Canal site with a conceptual design for the preferred recharge method.

The BC/SPF team has presented three previous reports on various aspects of managed recharge at the Site (BC/SPF, 2006, 2007a, and 2007b). This report summarizes the findings of the previous reports, discusses various feasible managed recharge strategies, and provides a recommended approach to managed aquifer recharge at W Canal and similar areas on the ESRP.

1.2 REPORT ORGANIZATION

This report provides a summary of the Task 1 Literature Review Report, Task 2 Soil Characterization Report, and Task 3 Bedrock Characterization Report (BC/SPF, 2006, 2007a, and 2007b). The scopes of the previous investigations are presented in Section 2.0. Findings from the three previous investigations are summarized in Section 3.0. Section 4.0 includes a description of the recharge potential at the W Canal site and more broadly on the ESRP. Section 5.0 presents viable managed recharge options followed by a recommended recharge option described in Section 6.0. Section 7.0 presents recommendations for additional investigation activities to better evaluate the recommended recharge option. References listed in this report are presented in Section 8.0.

2.0 DESCRIPTION OF PREVIOUS REPORTS

The site characterization work was conducted in three separate tasks, each of which was summarized in a separate report. The following sections present the work scopes of these three previous tasks.

2.1 TASK 1 - LITERATURE REVIEW REPORT

The Literature Review Report was submitted to the Board on November 15, 2006. The report described the rationale for aquifer recharge in the ESRP and the Board's objective to investigate the feasibility of managed recharge at the W Canal Site and other ESRP locations. The report described the general physical and hydrogeologic setting of the W Canal Site and provided brief summaries of selected, relevant references. The report also listed some general conclusions about managed aquifer recharge based on the literature review. The conclusions of the Literature Review Report are summarized in Section 3.1 of this report.

2.2 TASK 2 - SOIL CHARACTERIZATION REPORT

The Soil Characterization Report was submitted to the Board on February 12, 2007. To conduct the soil characterization, a truck-mounted drill rig was used to advance 10 soil borings from ground surface to the top of bedrock. Soil samples were collected at 5-foot intervals for soil classification and laboratory hydraulic conductivity tests. Soil infiltration tests were conducted in several areas using a single ring infiltrometer. Results of the soil investigation were reviewed to evaluate the suitability of Site soil for managed aquifer recharge, and are discussed in Section 3.2.

2.3 TASK 3 - BEDROCK CHARACTERIZATION REPORT

The Bedrock Characterization Report was submitted to the Board on May 22, 2007. The bedrock characterization consisted of using an air rotary drill rig to advance five borings to depths ranging from 80 feet to 220 feet below ground surface (bgs). An Idaho-registered professional geologist was present during drilling, recording depth to bedrock, rock type, and other lithologic characteristics. Following drilling, a downhole camera was used to further evaluate the lithologic characteristics of the bedrock, including rock type, frequency of jointing and fracturing, openness of fractures, and frequency, thickness and lithology of sedimentary interbeds.

Rock types were divided into five different types (competent basalt, fractured basalt, cinders, sand interbeds and clay interbeds) based on visual observations of drill cuttings. Hydraulic conductivity testing was conducted on the various rock types using single or double packer tests. The hydrogeologic conditions observed were evaluated with respect to the Site's capability for managed recharge. Results of the bedrock investigation are presented in Section 3.3.

3.0 SUMMARY OF RESULTS

Conclusions from the Literature Review (Task 1), Soil Characterization (Task 2), and Bedrock Characterization (Task 3) are summarized in this section.

3.1 SUMMARY OF LITERATURE REVIEW

The general conclusion from the Literature Review Report was that the W Canal Site warranted additional investigation for managed recharge potential because of the availability of land with suitable topographic characteristics, potential availability of recharge water, relatively thin soils, and because additional ground water recharge would benefit the ESRP aquifer in this area. However, several potential constraints were also identified that may limit large-volume managed recharge at this and other potential ESRP recharge sites.

In general, the W Canal area is underlain by approximately 10 feet to 15 feet of silty and sandy loam with low to moderate hydraulic conductivity. Shallow soils in the W Canal Site area are underlain by Snake River basalt, Glenn's Ferry sediments, and Banbury basalt that in aggregate extend hundreds of feet bgs. Individual basalt flows in the W Canal Site area likely range in thickness from about 4 feet to 50 feet. Based on well driller's reports from local wells, depth to ground water in the vicinity of W Canal ranged from 91 feet to 212 feet, with a median of about 160 feet.

The success of managed recharge at the Site will depend on the infiltration rate of water through soils and basalt. In general, silt and sandy loams on the majority of the ESRP have lower infiltration rates than those needed for large-scale managed recharge (Blew and Robbins, 2005). Infiltration through basalt depends on the degree of fracturing and jointing and the hydraulic conductivity properties of clay, sand, and cinder interbeds. Fracture and joint characteristics of shallow basalt underlying the W Canal Site were unknown at the start of the project. The site is also likely underlain by at least some low-permeability, unfractured, unjointed basalt. The saturated basalt in the Wendell vicinity is highly transmissive and would likely not impede the horizontal movement of managed recharge water.

Several research reports (Morris et al., 1964, Barraclough et al., 1965, 1976, 1981) document substantial recharge to aquifers in the Idaho National Laboratory area, located in the northeast portion of the ESRP. The recharge occurred in coarse alluvial sediments in upgradient areas (e.g., Lost River Basin) which have excellent infiltration capacity. These sediments are not present at the W Canal Site. Coarse-grained alluvial sediments on the ESRP are uncommon, and generally limited to a few major river drainages. The fine-grained soil and bedrock characteristics at W Canal are similar to large areas of the ESRP.

Lateral movement of water through unsaturated soil and bedrock may be substantially greater than vertical flow. Unfractured basalt or low-permeability sediments between basalt flows may inhibit the vertical infiltration rate and contribute to perched aquifer conditions. Low permeability units within the vadose zone basalt can result in substantial lateral spread of infiltration water. Ground water flow in perched aquifers may be in directions other than that of regional ground water flow. There is a chance that lateral flow in newly-created perched aquifers resulting from managed recharge could lead to unintended off-site seeps. If recharge source water is not treated, lateral migration may also lead to water quality changes in nearby drinking water wells.

Water quality will be an important consideration for managed aquifer recharge on the ESRP. Recharge source water and ground water monitoring will be necessary to verify that ground water impacts from a recharge basin do not exceed established regulatory drinking water standards. Some reports (Barraclough et al., 1976, 1981, USGS, 2002) noted water quality changes in ground water up to several miles from infiltration sites. Site-specific data will be necessary for an evaluation of possible water quality effects of managed recharge at the W Canal Site.

Data from other areas on the ESRP (Blew and Robbins, 2005) suggest that the hydraulic conductivity of soil at the W Canal Site may be too low to support managed recharge. Furthermore, based on experiences in other areas, the permeability of W Canal Site soils and bedrock may decrease over time with continuous recharge because of pore clogging, chemical precipitation, and other factors.

Engineered recharge facilities have been constructed when soil or bedrock hydraulic conductivity values are too low. Engineered recharge approaches may include (a) replacing existing soil with higher hydraulic conductivity soil; (b) injection of surface water deeper into the vadose zone; and/or, (c) treating recharge water to remove contaminants prior to direct aquifer recharge.

3.2 RESULTS OF SOIL CHARACTERIZATION

Ten (10) soil borings were drilled to investigate soil conditions at the W Canal Site (Figure 2). Exposed basalt bedrock was present in several areas of the Site, including areas west of BH-4 and BH-10 and in several isolated outcrops in the northeastern quarter of the Site (exposed bedrock precluded soil borings in these areas). Elsewhere, depth of soil ranged from 2.75 feet in boring BH-7 to 16.5 feet in boring BH-10, with an average soil thickness of approximately 5 feet. Samples collected from 10 soil borings indicated that soil consisted of fine-grained silty sand, non-plastic silt, slightly plastic silt, silty clay, and moderately plastic clay. Silt with fine sand or fine-grained silty sand was predominant in the upper 3 feet of the borings. Clay was distributed throughout the Site (8 of 10 borings) with the top of the clay beginning at depths ranging from approximately 2.5 feet (BH-10) to 7 feet bgs (BH-9). No clay was observed in borings BH-4 and BH-7. The average depth to the top of clay, where present, was approximately

5 feet and the thickness ranged from 1 foot to 9.5 feet. A calcium cemented soil was noted on the boring logs in borings BH-1 and BH-8 at depths of 6 feet to 8.5 feet bgs.

Results of infiltrometer testing conducted in the field are presented in Table 3-1. Soil hydraulic conductivity values ranged from 19 cm/day to 37 centimeters per day (cm/day), with an average hydraulic conductivity of 26 cm/day.

Table 3-1. Field Soil Infiltration Rates and Hydraulic Conductivity Test Results

Sample ID	Soil Type	Initial Infiltration Rate (cm/day)	Final Infiltration Rate (cm/day)	Final Hydraulic Conductivity (cm/day)
BH-1	Silt	472	243	19
BH-5	Silt	472	284	37
BH-7	Silt	396	232	24
BH-8	Silt	244	204	27
BH-9	Silt	354	266	24
BH-10	Silt	381	151	27
AVERAGE		387	230	26

Note: In unsaturated soil, the infiltration rate decreases over short term infiltration test intervals as air-filled voids between soil particles fill with water and unsaturated soil particles absorb water. When a soil reaches saturation, the infiltration rate approaches the hydraulic conductivity value of the soil (Bouwer, 2002). This phenomenon is apparent in the test results shown in Table 3-1, with initial infiltration rates being consistently higher than the infiltration rates measured at the end of the test (Final Infiltration Rate-after approximately one hour of testing). The reported Final Hydraulic Conductivity is a calculation presented in Bouwer (2002) that provides an estimate of a theoretical hydraulic conductivity if soil saturation were achieved via infiltration over a longer time interval.

The hydraulic conductivity values measured in the infiltration tests were from the surface silt. Due to the short-term nature of the test, infiltration only occurred in the upper 1 foot to 2 feet of soil. Therefore, the field infiltration tests likely provide a hydraulic conductivity of the most highly conductive soil at the Site.

The hydraulic conductivity of the underlying clay is reflected in the laboratory hydraulic conductivity values, as shown in Table 3-2.

Table 3-2. Results of Soil Laboratory Hydraulic Conductivity Tests

Sample ID @ depth (ft)	Soil Classification	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (cm/day)
BH-1 @ 5.5 to 6	Clay	1.7×10^{-4}	15
BH-3 @ 0.5 to 1	Silty Sand	5.5×10^{-4}	48
BH-9 @ 15.5 to 16	Sandy Clay	2.5×10^{-5}	2
BH10 @ 7.5 to 8	Clay	1.2×10^{-5}	1

Hydraulic conductivity values of clay ranged from 1 cm/day to 15 cm/day, with an average hydraulic conductivity of 6 cm/day.

Bouwer (2002) discussed several factors that cause active managed recharge facilities to have lower long-term infiltration rates than those predicted by short-term infiltration tests. These include, but may not be limited to, clogging of the bottom of the infiltration basin by organic or inorganic solids, chemical precipitates, algal mats or other biological processes. In that regard, managed recharge sites are often designed with multiple cells to mitigate for potential clogging. At these locations water is directed into one cell while other infiltration cells are allowed to dry out. The bottom of the exposed cells may then be scarified, deleterious sediments or deposits removed, or otherwise prepared for acceptance of additional recharge water when the infiltration rate slows in the active cell.

Hydraulic conductivity rates in soils measured at the Site were compared to other sites on the ESRP. Infiltration tests conducted by the Idaho Department of Water Resources (IDWR) at the X-1 Canal Site, located approximately 1.25 miles north of the Site yielded soil hydraulic conductivity values ranging from 24 cm/day to 35 cm/day (Blew et al., 2005). Blew and Robbins, (2005), described infiltration rates in a variety of soil and rock types, including silt, sand, gravel, and basalt. Infiltration rates in various locations across the ESRP ranged from 4.9 cm/day to 67 cm/day. Based on the range of hydraulic conductivity values reported elsewhere on the ESRP, the hydraulic conductivity values measured at W Canal appear to be similar to other sites covered with fine grained soils.

Results of the soil evaluation indicate that the W Canal Site is not suitable for managed recharge via surface infiltration because of the low soil hydraulic conductivity values. The size of the W Canal basin is approximately 12 acres, and the Board has targeted a recharge capacity of 30 cubic feet per second (cfs). The recharge volume resulting from a recharge rate of 30 cfs over an assumed one-month period is approximately 1,800 acre feet (af). Assuming all 12 acres could be used simultaneously for managed recharge, and assuming a hydraulic conductivity of 26 cm/day, BC calculated a recharge capacity for W Canal of only 5.2 cfs (Appendix A). At this 5.2 cfs recharge rate, the total recharge volume would be only about 300 acre-feet, much less than the desired 1,800 acre-feet. The calculation to support the recharge capacity number is presented in Appendix A. If coarser-grained soil were available, the area required for managed recharge would decrease. However, coarse-grained sediments on the ESRP are generally limited to the Snake River and tributary stream channels, such as the Lost River and Wood River. The fine-grained soils observed at the Site are the dominant soil types throughout the ESRP (Johnson, 2002).

3.3 RESULTS OF BEDROCK CHARACTERIZATION

Five exploratory wells were drilled at the W Canal Site to characterize bedrock conditions (Figure 2). The bedrock lithology observed from drill cuttings and the camera surveys were used to produce boring logs where bedrock units were categorized into five predominant rock types. Figure 3 depicts the lithologic cross-sections produced using the lithologic logs (BC/SPF, 2007b).

The Site bedrock is characterized by large intervals of competent basalt, separated by thinner layers of fractured basalt and cinders. Clay and sand interbeds were very infrequent. Changes between competent basalt and fractured basalt are gradational and subjective. However, grouping provides a basis for comparing the relative percentages of the various lithologies. Based on an aggregate of 711.5 feet of drilling, the following percentages of soil and rock units were intercepted in the five borings:

- *Soil Above Bedrock (9 percent of the aggregate boring distance):* Soil consisted of fine-grained silty sand, non-plastic silt, slightly plastic silt, silty clay, and moderately plastic clay. Soil thicknesses ranged from 6 feet (MW-1) to 25 feet (MW-5). The average soil thickness, including the 5 borings completed for the bedrock investigation (BC/SPF, 2007b), plus the 10 soil borings advanced for the soil investigation (BC/SPF, 2007a) was 10 feet.

- *Competent Basalt (61 percent of the aggregate boring distance):* Competent basalt was aphanitic and vesicular. Vesicularity ranged from very low to dense. Vertical and high-angle fracturing were common with no separation on fracture surfaces. Competent bedrock thicknesses ranged from 1 foot (several areas) to 47 feet (MW-2), with an average thickness of approximately 13 feet.

- *Fractured Basalt (12 percent of the aggregate boring distance):* Vesicular basalt contained open vertical and/or high-angle fractures with fracture separations ranging from 2 centimeters to 10 centimeters. Fractures are variably filled with silt or clay or else were open. Fractured basalt intervals sometimes contained cavernous openings. Fractured bedrock units ranged in thickness from 1 foot to 15 feet, with an average of 5 feet.

- *Cinders (12 percent of the aggregate boring distance)*: Cinders consisted of scoriaceous basalt appearing as individual grains or as highly fractured matrix, commonly with clay or silty clay in interstices. Cinder thicknesses ranged from 1 foot (several areas) to 20 feet (MW-1), with an average thickness of 5 feet.

- *Sand Interbeds (4 percent of the aggregate boring distance):* Fine- to coarse-grained sand interbeds. Characteristic “red sand” lithology was fine- to medium-grained, well sorted sand and occurred in beds up to several feet thick. Thicknesses of sand interbeds ranged from 2 feet (MW-4) to 10 feet in MW-1), with an average thickness of 7 feet. Only four sand interbeds were intercepted, and only in borings MW-1, MW-4 and MW-5.

- *Clay Interbeds (2 percent of the aggregate boring distance):* Interbedded or interstitial clay. Commonly light grey to light reddish orange. Moderately to highly plastic. Clay interbeds were encountered in only one 1-foot interval in boring MW-2, and two locations in boring MW-3 with thicknesses of 1 foot and 13 feet, respectively.

Based on the packer testing conducted in the boreholes, hydraulic conductivity ranged from 4 cm/day to more than 225 cm/day (Table 3-3). In some cases, the formation accepted all the water that could be pumped using the available field equipment. Pumping pressures averaged approximately 3 psi, a low pressure intended to simulate infiltration (Brown and Caldwell/SPF, 2007b). In those instances, the results are reported as greater than the calculated value derived from the amount of water pumped.

Table 3-3. Summary of Apparent Hydraulic Conductivity Test Results (from Packer Tests)

Sample ID/ Test Depth (feet)	Lithologic Description	Apparent Hydraulic Conductivity (cm/sec)	Apparent Hydraulic Conductivity (cm/day)
MW-1: 64 to 75	Fractured Basalt*/Sand Interbed	> $3 X 10^{-3}$	> 290
MW-1: 118.8 to 129.8	Fractured Basalt*/Cinders	> $2 X 10^{-3}$	> 146
MW-2: 108 to 119	Fractured Basalt*/Competent Basalt	> $2 X 10^{-3}$	> 194
MW-2: 147 to 158	Competent Basalt*	$3 X 10^{-4}$	26
MW-3: 72.8 to 83.8	Clay Interbed*/small cinder zone	$3 X 10^{-4}$	25
MW-3: 178 to 186	Competent Basalt/Cinders*	> $6 X 10^{-4}$	> 51
MW-4: 40.5 to 51.5	Competent Basalt*/Red Sand Interbed*	$8 X 10^{-5}$	7
MW-4: 87.7 to 98.7	Competent Basalt*	$7 X 10^{-5}$	6
MW-5: 35.3 to 46.3	Competent Basalt*	$5 X 10^{-5}$	4
MW-5: 65 to 80	Sand / Competent Basalt*	$6 X 10^{-5}$	5

Note: cm/sec is converted to cm/day by multiplying cm/sec by 86,400 (number of seconds in a day)
Note: Asterisk (*) represents the lithology (or lithologies) likely to have controlled the hydraulic conductivity in each test.
Note: All test intervals in double packer tests were a length of 11 feet. The tests in MW-3 between 178 feet and 186 feet and in MW-5 between 65 feet and 80 feet were single packer tests covering test intervals of 8 feet and 15 feet, respectively. The tests are more completely described in Brown and Caldwell/SPF, 2007b.

Testing results (see Table 3-3) indicate that competent basalt, some cinder units, and sand and clay interbeds have hydraulic conductivity values that are too low to discharge sufficient quantities of recharge water to meet the Board's objectives. Hydraulic conductivity values in these strata ranged from 4 cm/day to 22 cm/day, which is within the range of low hydraulic conductivity values measured in Site soil. When combined with an aggregate soil thickness of 9 percent (based on drilling observations), low hydraulic conductivity lithologies comprise approximately 76 percent of the strata intercepted in the five borings. Assuming a hydraulic conductivity range of 4 cm/day to 22 cm/day over the entire W Canal site, the 12-acre Site could accept between 0.8 cfs and 4.4 cfs of recharge by surface infiltration (Appendix A).

Fractured basalt and cinder zones, which (in aggregate) account for 24 percent of bedrock strata encountered, yielded hydraulic conductivity values that were higher than what could be measured by the pumping equipment available during testing. In these cases, a maximum pumping rate was utilized (24 gallons per minute [gpm] to 64 gpm), and no resistance to water flow was noted. Flow rates within these more conductive units ranged from greater than 74 cm/day to greater than 215 cm/day. The upper hydraulic conductivity limits of these strata were not determined.

Based on the results of the bedrock characterization, surface infiltration does not appear feasible at the Site. Direct injection of water into permeable units in the vadose zone or directly into the aquifer via injection wells will likely be more effective managed recharge strategies. However, hydrogeologic testing of the aquifer will be necessary to evaluate the number of injection wells necessary to meet the Board's recharge requirement of 30 cfs. Water quality considerations, such as evaluation of water quality in the W Canal and evaluation for pre-treatment facility strategies will also be necessary.

4.0 RECHARGE POTENTIAL

This section presents a discussion of the W Canal Site's potential for managed recharge, the similarity of the W Canal with other areas on the ESRP, and general criteria for successful managed recharge.

4.1 W CANAL RECHARGE POTENTIAL

Assuming that the soil hydraulic conductivity values measured at the Site (2 cm/day to 26 cm/day) reflect general Site conditions, the Site soil would only be capable of accepting approximately 0.4 cfs to 5.2 cfs of recharge via surface infiltration over a 12-acre area (Appendix A). This is much less than the Board's desired recharge capacity of 30 cfs. Recharging 30 cfs using surface infiltration through similar low-permeability soils would require an area ranging from 70 acres to 900 acres (Appendix A).

Underlying the soil, the W Canal Site bedrock is characterized by large intervals of competent basalt, separated by thinner layers of fractured basalt and cinders. Clay and sand interbeds were very infrequent. Apparent hydraulic conductivity values for much of the underlying stratigraphy are low (see Table 3-3). Competent basalt zones yielded hydraulic conductivity values ranging from 4 cm/day to 26 cm/day. Two tests conducted on packer test intervals containing sand interbeds indicated apparent hydraulic conductivity values ranging from only 5 cm/day to 7 cm/day. A single packer test conducted on clay interbeds measured an apparent hydraulic conductivity of 25 cm/day. Low hydraulic conductivity units account for 76 percent of the soil and bedrock profile, based on the aggregate thickness percentage of low hydraulic-conductivity strata (i.e., soil [9 percent], competent basalt [61 percent], sand interbeds [4 percent], and clay interbeds [2 percent]). Thus, the majority of strata encountered during drilling would restrict the free flow of water from ground surface to the underlying aquifer. The competent basalt, sand interbeds, and clay interbeds have permeability characteristics that are as low as or lower than Site soil (BC/SPF, 2007b).

The only units of significantly greater permeability (i.e., those strata having higher hydraulic conductivity values) were zones consisting of cinders and fractured bedrock. Tests in zones containing cinders yielded apparent hydraulic conductivity values ranging from 25 cm/day to > 146 cm/day, while apparent hydraulic conductivity values in fractured basalt ranged from > 146 cm/day to > 290 cm/day. Examples of high hydraulic-conductivity intervals within the vadose zone included fractured basalt and sand in boring MW-1 between 64 feet and 75 feet, fractured basalt and cinders in MW-1 between 118.8 feet and 129.9 feet, and fractured basalt and competent basalt in boring MW-2 between 108 feet and 119 feet. Some of these zones may have even greater permeability characteristics – the testing was limited by flow rates of potable test water.

Results of the soil and bedrock investigations conducted at the W Canal indicate that the hydraulic conductivity of Site soil is too low to support managed aquifer recharge without employing a recharge strategy other than direct surface infiltration. Higher conductivity bedrock units, such as fractured basalt and cinder zones may be appropriate for recharge via injection wells. However, fracture-flow systems may provide insufficient filtration opportunity to remove biological contaminants from surface water. Pre-treatment will likely be necessary to protect ground water quality.

4.2 W CANAL RECHARGE LIMITATIONS

Low permeability soil and bedrock, which occupies over 75 percent of the Site is the major limitation to managed recharge at W Canal Site. The soil and bedrock possess low hydraulic conductivity characteristics, too low to accept the Board's target of 30 cfs of recharge. Should surface infiltration be used for managed recharge at the Site, the area of the Site would need to be increased to at least 70 acres, or the volume expectations for recharge would need to be decreased. Managed recharge via injection wells holds preliminary promise. However, aquifer testing is required to better quantify the recharge potential, and pilot testing is also necessary to evaluate the need for water pre-treatment.

The challenge for managed recharge at the W Canal is the slow rate of infiltration through the low hydraulic conductivity soil and bedrock units. If the water intercepts an unsaturated, higher hydraulic conductivity layer, such as fractured basalt or a sand interbed, the water will migrate horizontally faster than it can infiltrate vertically. This may result in water spreading laterally beyond the boundaries of the recharge site. This lateral spreading could result in an unexpected surface water discharge at a lower elevation. Lateral spreading could also result in water flow into off-site wells, resulting in potential water quality changes. Studies at Idaho National Laboratory (Barraclough, et. al., 1981) indicate that perched layers below an infiltration site may extend laterally for several thousand feet.

4.3 SIMILARITIES OF W CANAL TO OTHER AREAS OF THE ESRP

The loess soils encountered at the W Canal are similar to those found on much of the ESRP. Lewis and Forsberg (1982) indicate that loess is present throughout most of the ESRP. The loess extends eastward from the Bruneau River area, with thicknesses of approximately 25 cm. Loess is reportedly continuous throughout the ESRP, except in areas of recent basalt flows such as those present near Craters of the Moon National Monument. Loess thickens to the east and south with areas south of the Snake River in southeast Idaho containing thicknesses of as much as 36 meters. In many areas, differing clay contents of the loess were attributed to multiple depositional episodes, likely associated with rapid Pleistocene climate changes. Thus, the loess soil observed at W Canal appears to be representative of much of the ESRP.

Basalt bedrock is similarly widely distributed on the ESRP. Lindholm, (1993) maps basalt bedrock of the Snake River Group in an area from King Hill, Idaho on the west, to approximately 60 miles to 80 miles northeast of Idaho Falls, Idaho on the east. The basalt extends from the Snake River on the south, to the northern margin of the ESRP, with an average width of 40 miles to 60 miles. Given the vast areas of basalt, which are overlain with loess except in areas of recent basalt flows, it is likely that hydrogeologic conditions similar to those found at the Site will be encountered in most portions of the ESRP.

4.4 CRITERIA FOR IDEAL MANAGED RECHARGE

Successful managed recharge requires a readily available water source, favorable hydrogeologic conditions for accepting recharge water, and the ability to deliver water to a useful portion of the aquifer. Some aspects of the W Canal Site are favorable to managed recharge, such as the presence of the W Canal, a suitable surface water source. The North Side Canal Company has indicated a willingness to provide surplus water to the Board for use in managed aquifer recharge. The Site's location on the ESRP is also favorable for managed recharge, being located upstream of the Thousand Springs aquifer discharge area.

From a hydrogeologic perspective, the ideal recharge Site would include open, coarse-grained soil, such as alluvial sand or gravel with high hydraulic conductivity values and good filtration characteristics. Recharge water would flow freely through the conductive soils to the aquifer below. Low permeability soil or rock, which restricts vertical water movement would be minimal. The recharge water would pass through a sufficient thickness of soil so natural filtration would remove harmful bacteria and other biological contaminants. From a hydrogeologic perspective, the W Canal Site does not contain favorable hydrogeologic conditions for surface infiltration. Soil and bedrock with low hydraulic conductivity values make up approximately 76 percent of the volume between ground surface and the aquifer.

5.0 RECHARGE OPTIONS

This section provides a discussion of possible recharge options available for the W Canal Recharge Site. Managed recharge options considered here include surface infiltration, water injection into vadose-zone strata with high permeability characteristics, and injection of surface water directly into the aquifer. Because of the similarity of hydrogeologic conditions at W Canal to other areas of the ESRP, recharge options available at W Canal may be applicable to many ESRP areas.

5.1 PASSIVE SURFACE INFILTRATION

Passive surface infiltration is often a preferred aquifer recharge option because of construction ease and relatively low development costs. Passive surface infiltration involves spreading water on the ground surface and allowing natural infiltration. Several spreading basins, consisting of bermed or diked shallow reservoirs (Norvitch, et al., 1969), can be constructed and utilized on a rotational basis. Accumulation of fine sediments, chemical precipitates, algal growth on the floors and sidewalls of infiltration basins typically result in a decrease in recharge potential with time (Norvitch, et. al., 1969). Therefore, rotation of spreading basins allows for desiccation, ripping, scarifying, or other rehabilitation of individual basins to maximize recharge.

One advantage of passive surface infiltration is its simple non-mechanical components. Engineered features are limited to the infiltration basin berms and the water conveyance system (pipes or ditches). Migration of water through soil would likely be sufficient to remove biological contaminants common to surface water, such as bacteria or protozoa. This would likely prevent the need for water pre-treatment. However, groundwater quality monitoring, including installation of downgradient monitoring wells, will be necessary for all recharge options.

The limitation to passive surface infiltration at the W Canal and many other areas on the ESRP is low-permeability soil and bedrock . Given the goal of 30 cfs of recharge, the 12-acre W Canal Site is not suitable for passive surface infiltration.

5.2 DIRECT AQUIFER INJECTION WITH CONSTRUCTED SURFACE FILTRATION

Direct injection involves the use of injection wells for direct aquifer recharge. Surface water is introduced into injection wells and water moves directly into an aquifer. The Snake Plain Aquifer is highly transmissive, and could likely accept large quantities of recharge water at this Site. In fact, storage of water in the Snake Plain Aquifer is likely less expensive than the permitting and construction of additional surface water impoundments. However, the use of surface water would almost certainly require surface filtration and/or disinfection to remove biological or possibly chemical constituents. An engineered sand filter at ground surface would likely be the most cost-effective approach for such water treatment. Pre-treatment adds to the costs of managed recharge.

The ESRP aquifer is known to be highly transmissive and capable of accepting large quantities of water. Aquifer transmissivity in the upper 200 feet of the regional aquifer was reported by Whitehead and Lindholm (1984) to be as high as 830,000 $feet^2$/ day. Calibrated transmissivity values from the ESRP aquifer model for the area within about 5 miles of the W Canal recharge site range from 690,000 to 1,100,000 ft^2/day, with a mean of 890,000 ft^2/day (Alan Wylie, 2007). The aquifer underlying the W Canal site would be capable of accommodating very large injection rates if the aquifer is as transmissive as these values suggest.

5.3 VADOSE ZONE INJECTION WITH CONSTRUCTED SURFACE FILTRATION

Vadose zone injection involves the use of injection wells to move surface water into high-permeability unsaturated zones (e.g., cinder and fractured basalt zones) underlying the Site. Water would then flow horizontally and vertically, eventually reaching the regional aquifer. The upper hydraulic conductivity limits of these unsaturated strata would need to be determined to evaluate this strategy (the upper permeability limits were not estimated because of testing-equipment limitations). An evaluation of the (1) water quality, (2) potential hydrogeologic consequences of developing perched water tables, and (3) determination of whether the selected formation could accept the necessary water volume would need to be conducted before using this method.

Managed recharge involving surface infiltration or injection wells into vadose zone strata may result in perched water zones that develop between ground surface and the aquifer. Flow through perched aquifers extending beyond Site boundaries may intercept off-site wells. Many of the wells on the ESRP are not cased and water from a newly perched interval may cascade into existing wells. Such mixing may cause degradation of aquifer water quality.

Tortuous flow paths associated with flow through one or more perched zones to the regional aquifer may provide increased water filtration. However, such flow, especially if through coarse-grained interbeds and/or fractured basalt, may not provide sufficient filtration to protect ground water quality.

A disadvantage of water injection into vadose zone layers is that it could require a more detailed hydrogeologic investigation. Similar investigations may be required at other ESRP sites being considered for vadose injection.

6.0 RECOMMENDED RECHARGE APPROACH

Several components are necessary for successful managed recharge at the W Canal site or other possible ESRP sites:

1. An available surface water source;
2. A method of conveyance from the source to the recharge area;
3. Available recharge land near the surface water source;
4. A site capable of accepting a significant quantity of recharge (e.g., 30 cfs for W Canal); and,
5. A method of protecting ground water quality.

A goal of this investigation is to identify one or more effective methods for aquifer recharge at the W Canal and other sites. Based on our assessment of W Canal site conditions, we believe that the most effective approach to ground water recharge at the Site may be direct injection of surface water into the regional aquifer system. Depending on the results of additional feasibility studies (aquifer testing, water filtration testing, etc.) this approach may allow recharge at the desired rates and allow control of potential water quality constraints. Direct injection is also an approach that can be considered for other ESRP sites.

Water treatment will be required prior to direct injection. Slow sand filters are a proven engineered water-treatment strategy. Surface water from the canal would enter a settling pond to remove suspended sediments (Figure 3). The water from the settling pond enters the upper surface of the slow sand filter and percolates through the sand filter to an underdrain located at the base of the sand. The sand filtration is enhanced by a biological layer that develops on the wetted top surface of sand. The advantage of an engineered slow sand filter is that it can accept a much greater flow than the low hydraulic conductivity soil and rock found at the Site. It also eliminates the uncertainty of subsurface water filtering characteristics, as all water is treated in an above-ground system treatment system. Water leaving the slow sand filter is discharged via gravity or pumping into injection wells advanced into the aquifer.

The slow sand filter requires periodic maintenance. The biological layer, where fine sediment also accumulates will periodically become plugged, reducing the water capacity. Filter maintenance includes use of a small tractor or other equipment to scrape off a few inches of the biological layer and surface sand. The removed material may either be washed and reused, or disposed of onsite. Slow sand filter systems commonly contain multiple treatment cells. Therefore, one cell may be taken off-line for cleaning, while other cells remain operational.

Depending on the effectiveness of the slow sand filter, Idaho Department of Environmental Quality (DEQ) may require chemical disinfection of recharge water, such as with the use of chlorine. While chlorine is an effective remover of biological contaminants, the effects of disinfection by-products introduced into the aquifer will need to be considered if chemical disinfection is prescribed.

7.0 RECOMMENDATIONS FOR ADDITIONAL INVESTIGATION

Recommendations for next steps include the following:

1. Develop preliminary designs and construction cost estimates for a pilot-scale settling pond, sand filter, and direct-injection well.

2. Construct one or two new test wells (or deepen one of the existing test wells) to allow hydraulic testing of aquifer characteristics.

3. Evaluate geochemical compatibility of surface water and groundwater.

4. Construct a pilot-scale slow sand filter, conduct a pilot-scale filtration and injection test; optimize the filtration system.

5. Develop conceptual-level designs and construction cost estimates for a full-size direct-injection recharge system at the W Canal site.

Recommendations 1 through 3 would provide the basis for full-scale filtration system designs, one or more large diameter, fully penetrating injection wells, and monitoring wells. Several of these recommendations are discussed in further detail below.

7.1 PREPARATION OF A PRELIMINARY DESIGN FOR PILOT-SCALE SYSTEM

A preliminary design for a pilot-scale recharge facility would include designs for a settling pond, slow sand filter, associated piping, monitoring equipment, and injection wells, and would be based on the attached conceptual design. Projected costs for pilot-scale test components would be prepared. Completion of these feasibility tests would assist in the actual engineering design of an effective aquifer recharge system.

7.2 CONSTRUCT AQUIFER-TEST WELL, CONDUCT AQUIFER TESTING

This effort would begin with a more detailed hydraulic analysis of potential injection rates based on available aquifer data. The hydraulic analysis would be used to estimate the number and location of injection wells anticipated for direct injection, which in turn would be used support the development of preliminary pilot-scale and full-scale designs.

One or two wells should be installed to confirm anticipated aquifer characteristics. At a minimum, a single well could be used for single-well pumping tests and/or slug tests confirm anticipated aquifer characteristics. A two-well system could be used as a couplet for simultaneous pumping and injection. The wells would likely extend to depths between 50 feet to 100 feet into the regional aquifer. The well(s) would be pumped for a sufficient time to evaluate the hydraulic conductivity characteristics and possible hydraulic boundary conditions. Results of the aquifer testing, in conjunction with available production capacity data from local wells, would be used to evaluate the aquifer's ability to accept recharge water and to determine the size and number of injection wells required to accept 30 cfs of water from a slow sand filter system. Depending on well construction and location, these wells could possibly be used as subsequent injection and/or water-quality monitoring wells.

7.3 GEOCHEMICAL ANALYSES

The potential for formation of precipitate or other chemical reaction exists when water from one source is combined with another. To evaluate the potential geochemical interaction between these two waters, Brown and Caldwell proposes to collect samples of irrigation canal water and groundwater and submit these samples to our treatability laboratory located in Nashville, Tennessee to perform these analyses. Canal water, both treated and untreated, will be mixed with samples of groundwater and the chemical interaction will be evaluated. Initially these analyses should occur during this irrigation season. However, we also recommend that an analysis be performed that includes canal water from the early irrigation season next spring, which is likely when the proposed system will operate.

7.4 SLOW SAND FILTER PILOT TEST

A pilot test should be conducted to evaluate the suitability of slow sand filtration. Completion of a pilot test would aid in evaluating the size of the filtration equipment and associated costs. The time to develop an effective biological treatment layer within the slow sand filter is dependent on the surface water quality (turbidity, and chemical and biological constituents). The test would consist of pumping or gravity feeding water from the W Canal at a metered rate into a settling tank. The water would move from the settling tank into a pilot-sized slow sand filter. Water samples would be collected from the influent and effluent ends of the slow sand filter on a weekly basis. The water samples would be analyzed for total coliform and E. coli bacteria. The test would proceed until coliform was no longer present in the sand filter effluent. If coliform persists for long intervals, the effects of chemical disinfection may also be tested.

7.5 PRELIMINARY DESIGN FOR FULL SYSTEM

A preliminary design for a full-scale recharge system, consisting of designs for settling pond(s), slow sand filter(s), associated piping, monitoring equipment, and injection well(s). These designs would be based on the results of pilot-scale testing and tailored to specific site conditions. Conceptual-level cost estimates for a full-scale system would allow further refinement of a Board recharge strategy.

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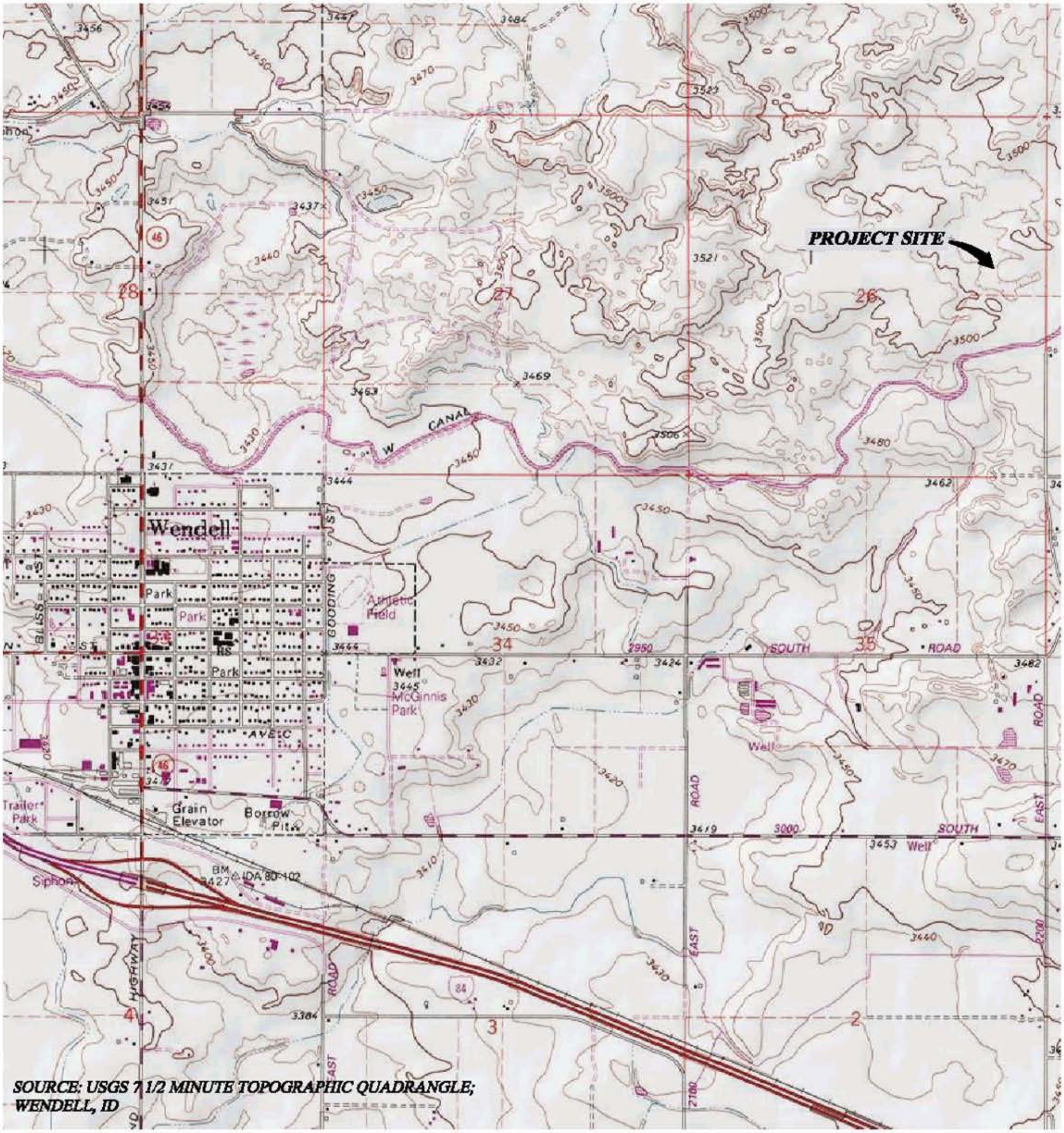
FIGURES



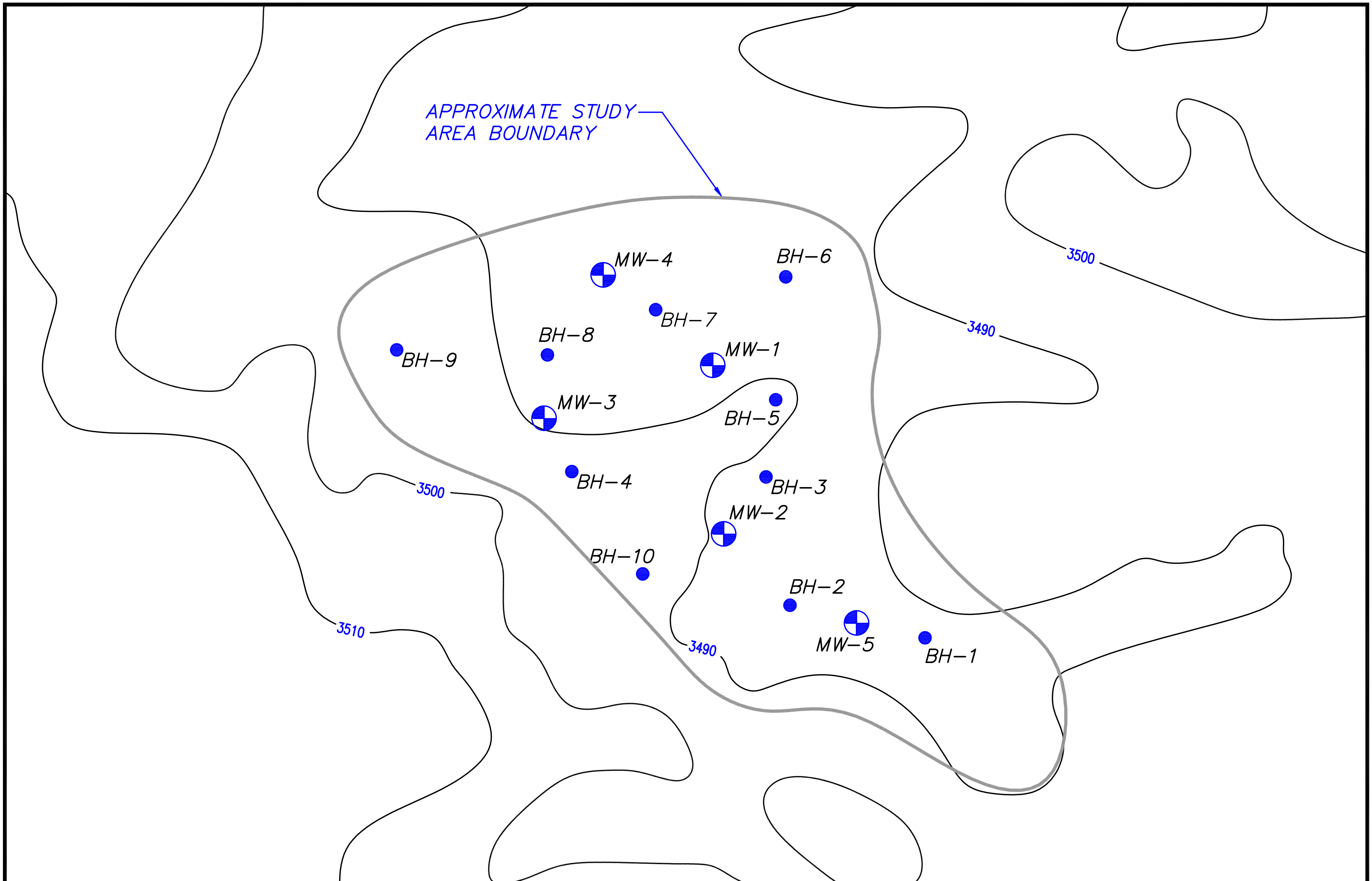
BROWN AND CALDWELL
Boise, Idaho

N

1000 500 0 1000 2000

SCALE: 1 INCH = 2000 FEET

FIGURE 1
SITE VICINITY MAP
IDAHO DEPARTMENT OF WATER RESOURCES
W CANAL
WENDELL, IDAHO



LEGEND

BEDROCK BORING LOCATION

SOIL BORING LOCATION

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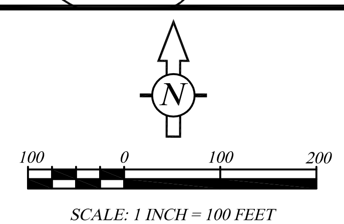
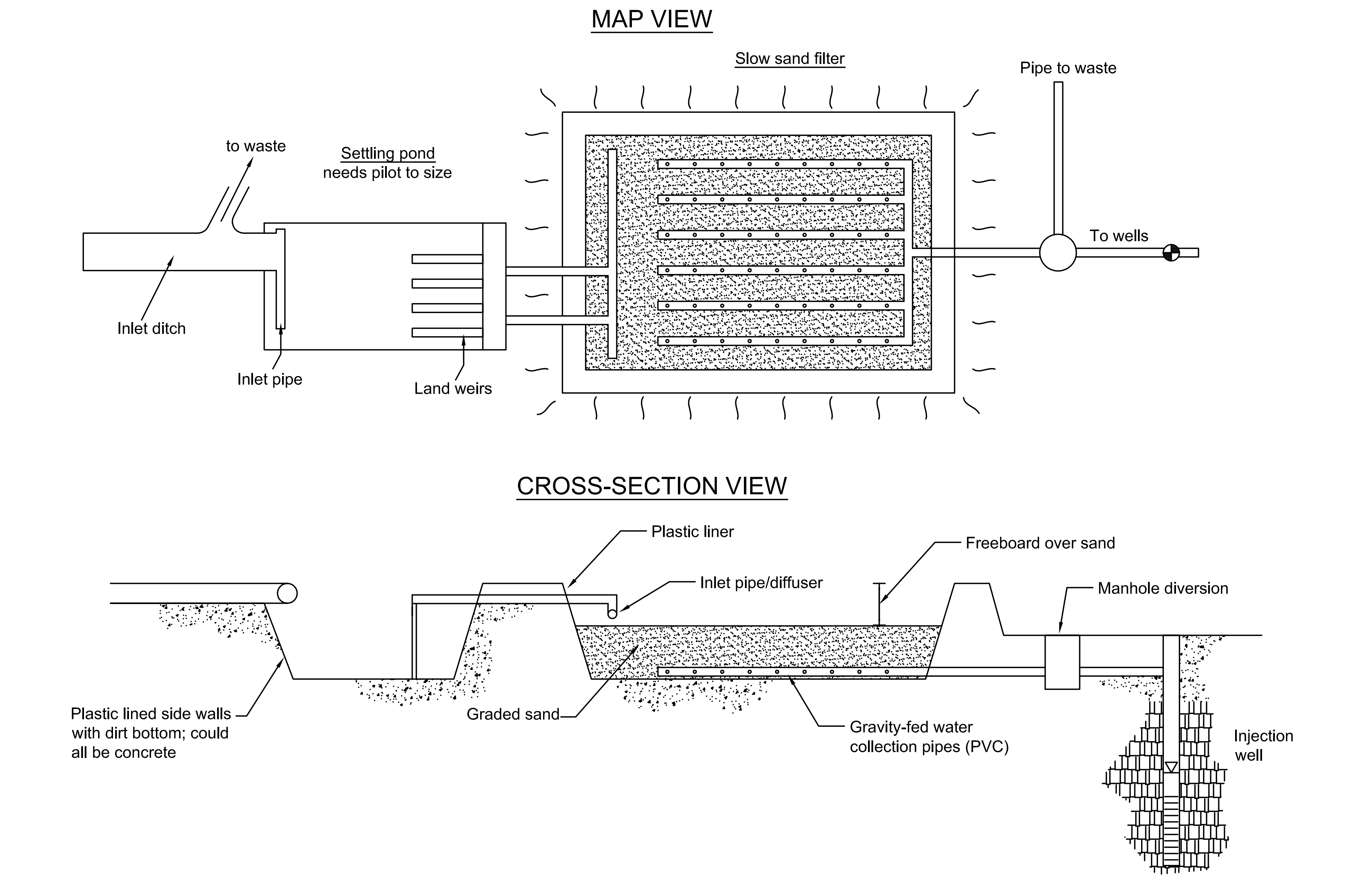


FIGURE 2
EXPLORATORY BORING LOCATIONS
IDAHO DEPARTMENT OF
WATER RESOURCES
W CANAL
WENDELL, IDAHO



LEGEND

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NOT TO SCALE

FIGURE 3
CONCEPTUAL DESIGN OF WATER TREATMENT FACILITY
IDAHO DEPT. OF WATER RESOURCES
W CANAL
GOODING COUNTY, IDAHO

APPENDICES

APPENDIX A

RECHARGE CAPACITY CALCULATIONS

Recharge Capacity Calculation Assuming Hydraulic Conductivity of 26 cm/day:

$$Q = KA\frac{\partial h}{\partial L} \rightarrow A = \frac{Q}{K\frac{\partial h}{\partial L}}$$, where

Q = Recharge Capacity
K = Hydraulic conductivity = 26 cm/day (assumed value based on testing results)
26 cm/day = 0.853 feet/day
A = Area
12 acres = 522,720 square feet
$\frac{\partial h}{\partial L}$ = hydraulic gradient= 1 (unsaturated vertical flow)

Assuming that (1) the vertical saturated and unsaturated hydraulic conductivity of the entire area is 26 cm/day and (2) infiltration basins create a uniform hydraulic gradient of 1, then the 12 acre Site would have a recharge capacity of approximately 446,000 cubic feet per day or 5.2 cfs. Using the same formula, the area required for a recharge rate of 30 cfs would be approximately 3,040,000 square feet, or 70 acres.

Recharge Capacity Calculation Assuming Hydraulic Conductivity of 4 cm/day:

K = 4 cm/day = 0.131 feet/day
A = 12 acres = 522,720 square feet
Hydraulic gradient = 1

Q = 0.131(522,720)(1) = 68,476 cubic feet/day = 0.8 cfs

Recharge Capacity Calculation Assuming Hydraulic Conductivity of 22 cm/day:

K = 22 cm/day = 0.721 feet/day
A = 12 acres = 522,720 square feet
Hydraulic gradient = 1

Q = 0.721(522,720)(1) = 377,290 cubic feet/day = 4.4 cfs

Recharge Capacity Calculation Assuming Hydraulic Conductivity of 2 cm/day:

K = 2 cm/day = 0.066 feet/day
A = 12 acres = 522,720 square feet
Hydraulic gradient = 1

Q = 0.066(522,720)(1) = 34,299 cubic feet/day = 0.4 cfs

Area Requirement to Recharge 30 cfs if Hydraulic Conductivity = 2 cm/day

Q = 30 cfs = 2,592,000 cubic feet/day
A = 2,592,000÷0.066 = 39,502,000 square feet = 907 acres