# Aquatic Assessment & Habitat Enhancement Plan
# The South Platte River
# Lake George Company
# Park County - Colorado

Prepared by

FIN-UP Habitat Consultants, Inc.


J. Peter Gallagher
220 Illinois Ave
Manitou Springs, CO 80829
(719) 685-9768 (Office)
(719) 332-2550 (Cell)
pete@fin-up.com


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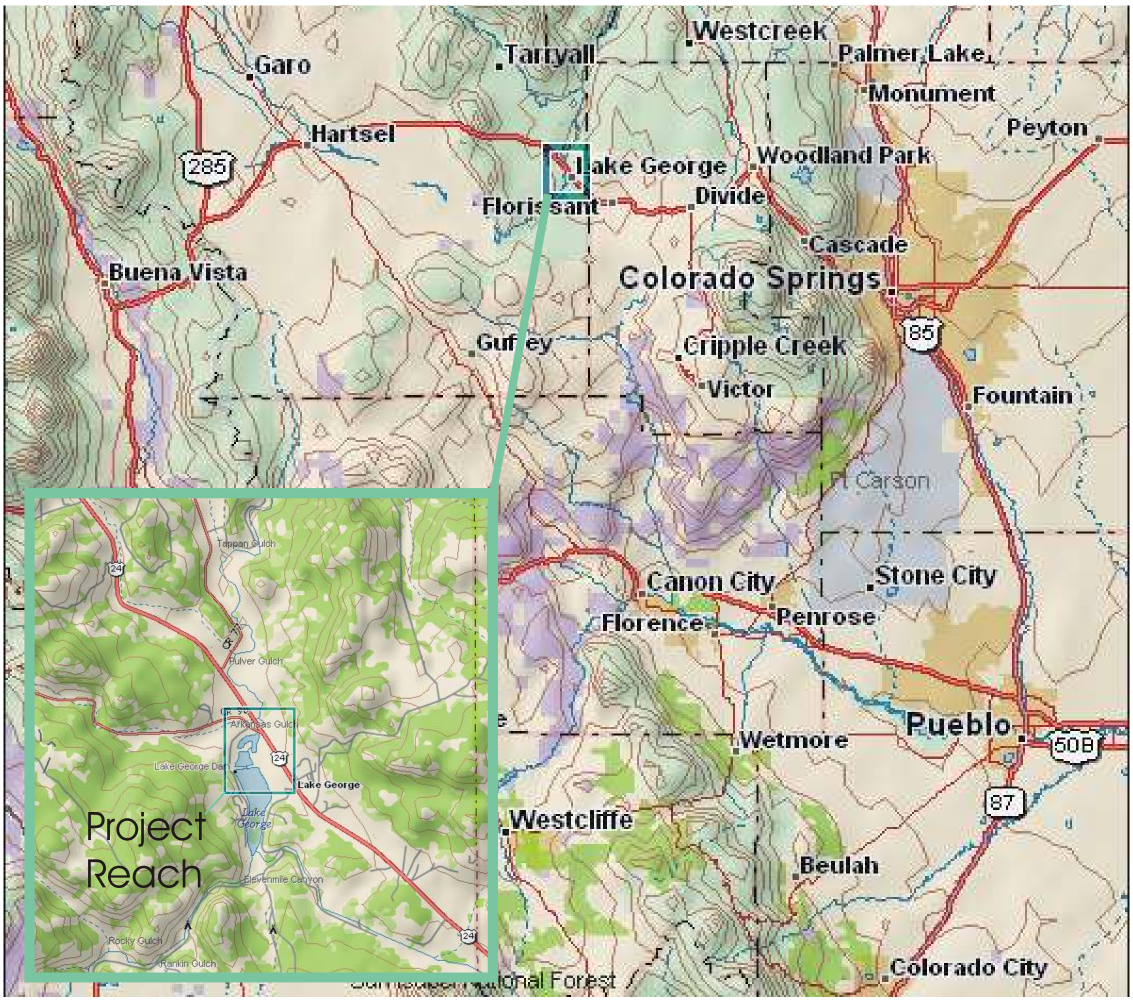
In October 2008, FIN-UP Habitat Consultants, Inc. was contracted by Barton Johnson, an owner of the Lake George Company, to conduct an assessment of a recently completed stream improvement project the South Platte River, where it runs through property belonging to the Lake George Company. The assessment included a survey of existing channel morphology, a condition assessment of previous structural work that had been attempted in the reach, and development of a restoration plan to improve habitat quality and complexity in the reach. This document summarizes the results of the assessment, and our recommendations for future enhancement work and management of the stream and adjacent riparian corridor.




Map 1: Location of project on the South Platte River - Lake George Company, Park County, CO.

The Lake George Company property is located immediately west of the town of Lake George, in Park County, CO. The study reach begins at a closed county road bridge immediately upstream of the US 24 highway bridge west of the Town of Lake George, and extends 1,945 feet upstream to a concrete “fish ladder” drop structure installed in the river channel. The project location is shown in Map 1 above.

## Watershed and Hydrology

The South Platte River watershed upstream of the project reach has a contributing drainage area of approximately 1,084 square miles. Flows through the project reach are significantly influenced by the operation of the Eleven Mile Reservoir Dam, approximately 8 ½ miles upstream. One other significant 6th level watershed contributes flow between the dam and project area. This watershed, consisting of Twin Creek and it's major tributaries, Grape Creek and Fish Creek, enters the South Platte River less than ½ mile upstream of the project reach.

The US Geological Service (USGS) Hydrologic Unit of the watershed is 101900010401. The nearest automated stream gauge to the project area is located 8 1/4 miles upstream of the Lake George Company, and is maintained by Colorado Division of Water Resources. The location of this gauge is at Latitude 38°54'19",Longitude 105°28'22", in the SW¼ sec. 20, T.13 S., R.72 W., Park County, 700 ft. downstream of the Eleven Mile Reservoir Dam. The watershed area upstream of this gauge is approximately 963 square miles. A 79 year record of flow data is available at this site. For the period of record, peak yearly flows have ranged from a minimum of 46 cubic feet per second (cfs) to 2,820 cfs. The median peak flow during the period of record at the gauge was 390 cfs. The bank full stage in Eleven Mile Canyon has been estimated at 475 cfs (USFS 2003).

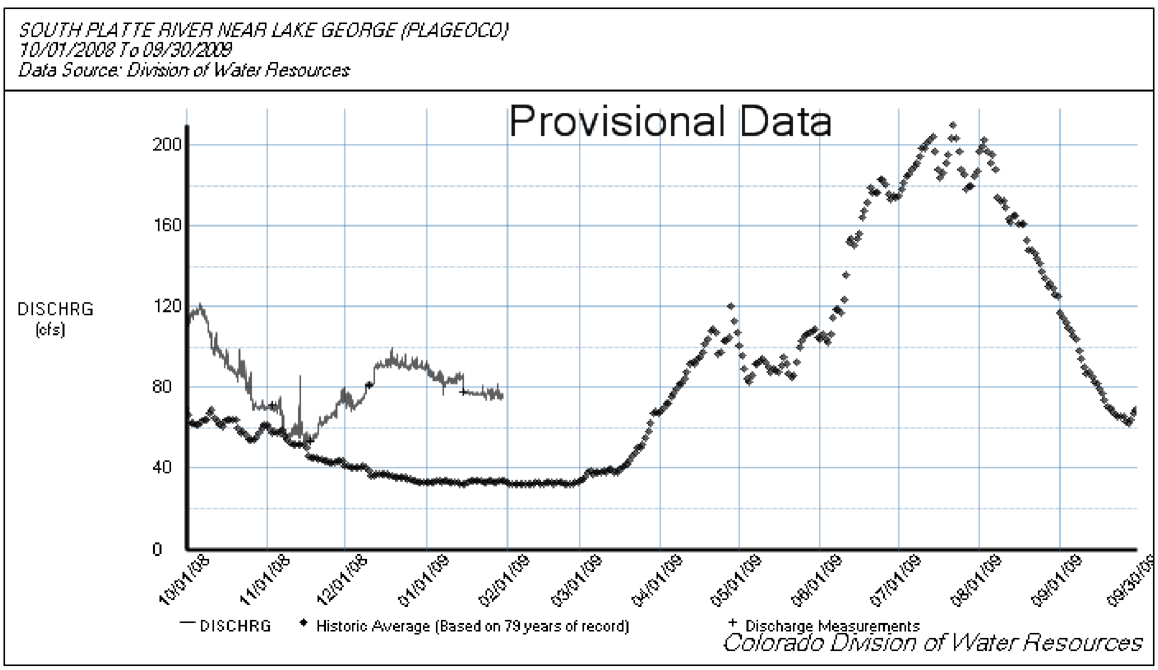



Chart 1: Water Year Historic Average Flows – The South Platte River @ Eleven Mile Dam, eight and ½ miles upstream of the project site.

The bank full stage (two year flood return interval) was determined for the study reach using a combination of field observations and analysis of cross section hydraulics. Peak flow modeling was done at Cross-Section #8, which represented a uniform, trapezoidal channel within a glide habitat form, with relatively laminar flow and few channel obstructions. Stream flow was measured at Cross-Section #8, using a Marsh-McBirney FlowMate 2000 flow meter, and was calculated to be 92 cfs. Table 1 shows the calculated stage/discharge of the cross-section from the measured flow (92 cfs @ 1.88ft) through the predicted bank full (BF) stage. The bank full stage of the study reach was estimated to be 690 cfs.

| STAGE (ft) | SLOPE (ft/ft) | Mannings n | VAVG (ft/s) | Q (cfs) | SHEAR (psf)) |
|---|---|---|---|---|---|
| 1.84 | 0.001 | 0.04 | 1.40 | 91.43 | 0.08 |
| 1.88 | 0.0012 | 0.04 | 1.55 | 104.10 | 0.10 |
| 1.92 | 0.0013 | 0.039 | 1.70 | 117.31 | 0.11 |
| 1.96 | 0.0015 | 0.039 | 1.84 | 131.12 | 0.13 |
| 2.00 | 0.0016 | 0.038 | 1.99 | 145.59 | 0.15 |
| 2.04 | 0.0018 | 0.038 | 2.14 | 160.73 | 0.16 |
| 2.08 | 0.0019 | 0.038 | 2.29 | 176.60 | 0.18 |
| 2.12 | 0.0021 | 0.037 | 2.44 | 193.21 | 0.20 |
| 2.16 | 0.0022 | 0.037 | 2.60 | 210.62 | 0.22 |
| 2.20 | 0.0024 | 0.037 | 2.75 | 228.86 | 0.24 |
| 2.24 | 0.0025 | 0.036 | 2.91 | 247.96 | 0.26 |
| 2.28 | 0.0027 | 0.036 | 3.08 | 267.86 | 0.29 |
| 2.32 | 0.0028 | 0.035 | 3.24 | 288.54 | 0.31 |
| 2.36 | 0.003 | 0.035 | 3.40 | 309.98 | 0.33 |
| 2.40 | 0.0032 | 0.035 | 3.57 | 332.41 | 0.35 |
| 2.44 | 0.0033 | 0.034 | 3.74 | 355.85 | 0.38 |
| 2.48 | 0.0035 | 0.034 | 3.91 | 380.35 | 0.40 |
| 2.52 | 0.0036 | 0.033 | 4.09 | 405.95 | 0.43 |
| 2.56 | 0.0038 | 0.033 | 4.27 | 432.70 | 0.45 |
| 2.60 | 0.0039 | 0.033 | 4.45 | 460.64 | 0.48 |
| 2.64 | 0.0041 | 0.032 | 4.64 | 489.81 | 0.50 |
| 2.68 | 0.0042 | 0.032 | 4.83 | 520.28 | 0.53 |
| 2.72 | 0.0044 | 0.032 | 5.03 | 552.09 | 0.56 |
| 2.76 | 0.0045 | 0.031 | 5.23 | 585.29 | 0.59 |
| 2.80 | 0.0047 | 0.031 | 5.43 | 619.32 | 0.61 |
| 2.84 | 0.0048 | 0.03 | 5.64 | 654.20 | 0.64 |
| 2.88 | 0.005 | 0.03 | 5.84 | 690.58 | 0.67 |

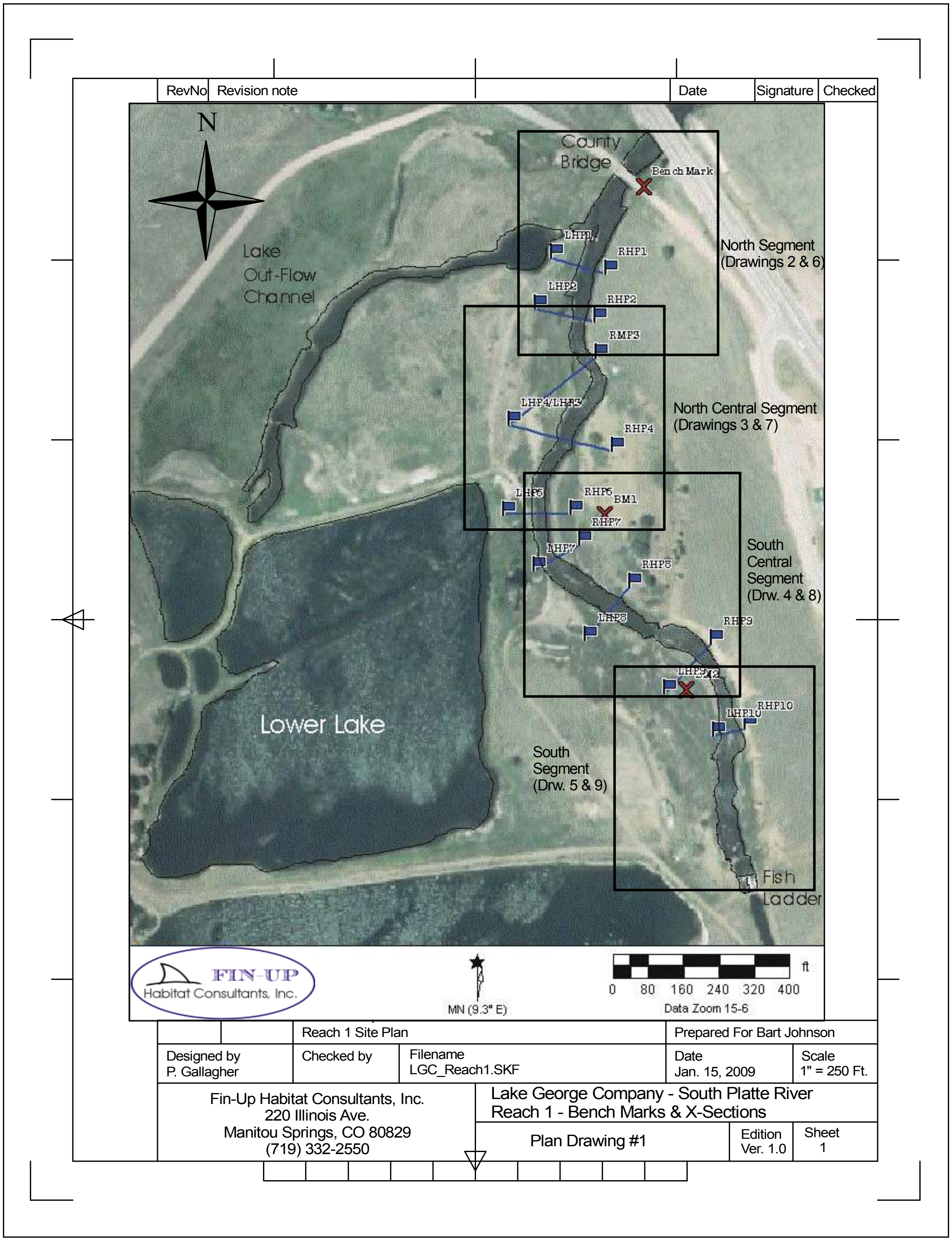
Table 1: Calculation of Stage/Discharge within Cross-Section #8 (WinXSPro v.3).

**Existing Fish Populations**

The South Platte River contains resident populations of both native and non-native fishes. The greenback cutthroat trout (*Oncorhynchus clarki stomias* - federal and state threatened) is native to the South Platte basin, but is not known to exist in the project reach. Brown trout (*Salmo Trutta*) and rainbow trout (*Oncorhynchus mykiss*) are the most common non-native salmonids in the South Platte River watershed, and have been observed in the project reach. Additionally, brook trout (*Salvelinus fontinalis*) are occasionally stocked by private individuals, and may remain resident in the river. No electro-fishing data has been collected within the project area.

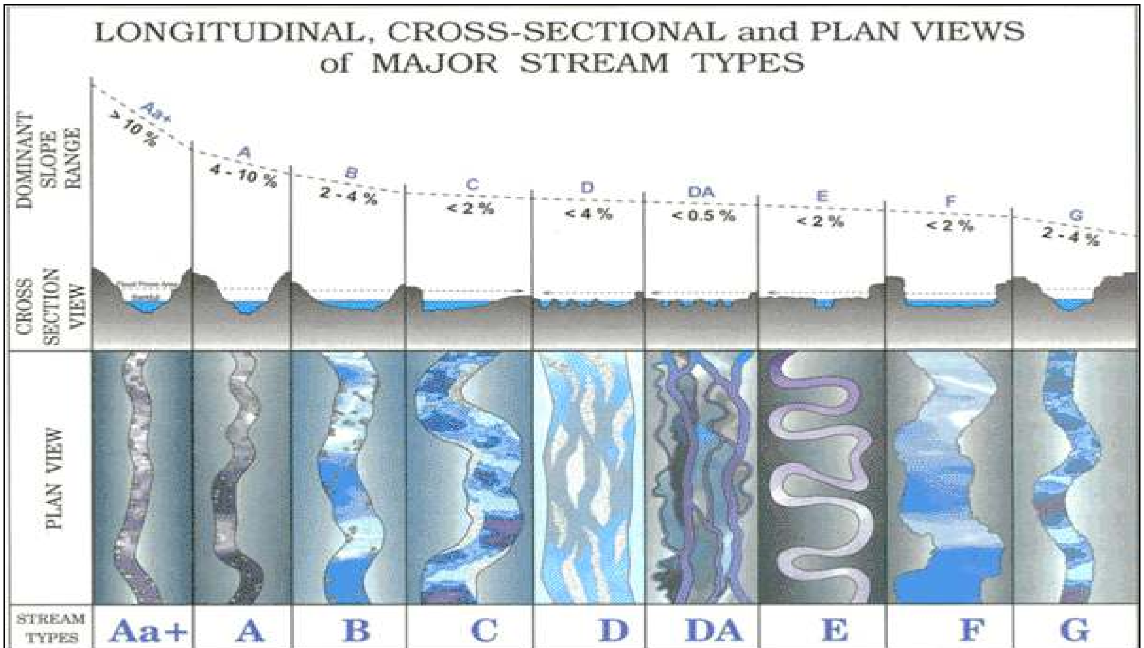
**Stream Channel and Habitat Assessment Methods**

For the purposes of this assessment, The South Platte River through the Lake George Company property was delineated into distinct reaches, or segments, based on valley type, channel morphology, perennial vs. intermittent flows, and administrative or physical boundaries. Reaches were numbered consecutively, beginning at the furthermost downstream ranch boundary, and continuing upstream to the headwaters. One existing USGS benchmark was identified and three new permanent benchmarks were established along the study reach. Nine cross-sections were located along the project reach in various different habitat and channel types. The location of the project reach, bench marks and cross-sections is shown in Drawing #1.




Drawing #1: Locations of the study reach, benchmarks, and cross-sections on the The South Platte River – Lake George Company, Park County, CO.

**Rosgen Stream Classification System**
The project reach was classified using the Rosgen Stream Classification System (D.L. Rosgen, CATENA, 1994). The Rosgen classification system groups streams by similar channel geomorphology, gradient, sinuosity and function. The classification system is stratified into three progressive levels, based on channel form, dominant substrate, and gradient. A graphic depiction of the Level 1 classification is shown in the diagram below.



Rosgen, David L. "A classification of natural rivers." Catena 22 (1994): 179. www.wildlandhydrology.com

Generally, A type channels are typically found near the headwaters of mountain streams. Lower gradient B channels are characteristic of streams flowing though alluvial plains and broad mountain valleys below the headwaters. C and E channels tend to be found in lower elevation reaches with broad floodplains and low gradients. Each of these channel type supports different assemblages of aquatic habitats, and each can be important in providing habitat complexity for trout. F and G channels are typically found in areas that have been subjected to some disturbance, such as a flood or significant down-cutting of the stream channel. Frequently, in recovering F type channels, a new C channel will begin to form in the flat bottom of the F channel, establishing a new floodplain at a lower elevation. The Rosgen classification system has been widely adopted by river professionals throughout the west, and is a useful tool for evaluation and comparative analysis of similar stream channels and habitat conditions.

**Stream Channel Morphology:**
For the purposes of the stream channel morphology study, nine cross-sections were established in representative channel types, and numbered consecutively beginning at the downstream boundary of the property and continuing upstream. During the course of data collection, we determined that Cross-Section #5 was likely redundant, and dropped it from further study. Cross-sections were located in order to validate channel type

classification, bank full elevation estimates in the different channel habitat unit types (pool, riffle and glide), and to document existing condition and elevation of structures that had previously been placed in the channel. All directional references to stream banks and cross-sectional head pins for the channel geometry study are from a hydrologist's perspective, with left and right banks determined looking downstream along the channel.

A longitudinal profile (LP) of the stream channel was surveyed for the project reach in December, 2008. The river within the project reach was delineated by channel unit type (pool, riffle, and glide), with channel thalweg depth, water surface elevation, and bank-full elevation being surveyed at each transition between channel units. Additional, intermediate measurements were collected in areas where existing stream structures or other features of interest were present. Detailed plots of the longitudinal profile can be found in the Appendix to this document. The longitudinal profile is characterized by very low channel, water surface, and bank full gradient; with little evidence of entrenchment, and pool frequency consistent with a “C” channel. The average slope of the channel, water surface and bank full elevation throughout the profile in Reach 1 was 0.4%. Riffle slopes ranged from 0.3% to 1%. Stream channel sinuosity was on the lower side of moderate (channel length / valley length = 1.3) in Reach 1.

Plots of each of the nine cross-sections in the project reach can be found in the Appendix. The channel profile in each of the cross-sections exhibits only slightly entrenched characteristics within the reach. Entrenchment ratios of greater than 2.3 were observed at all of the cross-sections. Width/depth ratios ranged from 25 to 49, indicating some over-widening of the channel throughout the reach. W/D ratios were slightly higher than what would be expected to occur in an undisturbed “C” channel.

Based on the reach longitudinal profile survey, the channel cross-section analysis, and an ocular estimation of stream substrate composition, the channel in the project reach was classified as a “C4” type. The channel may be somewhat unstable due to the recent installation of numerous randomly placed large boulders, which appear to be creating high shear forces along actively eroding unstable and unvegetated stream banks and road fill slopes adjacent to the river in several segments of the reach. Sediment from these eroding banks, and from sources upstream, has begun to accumulate behind many of the boulders and other velocity shelters in the channel in Reach 1, and may have a negative effect on the quantity and quality of useable habitat for resident trout.

Photo 1: Typical Random Boulder Cluster Structure in Reach 1, South Platte River.

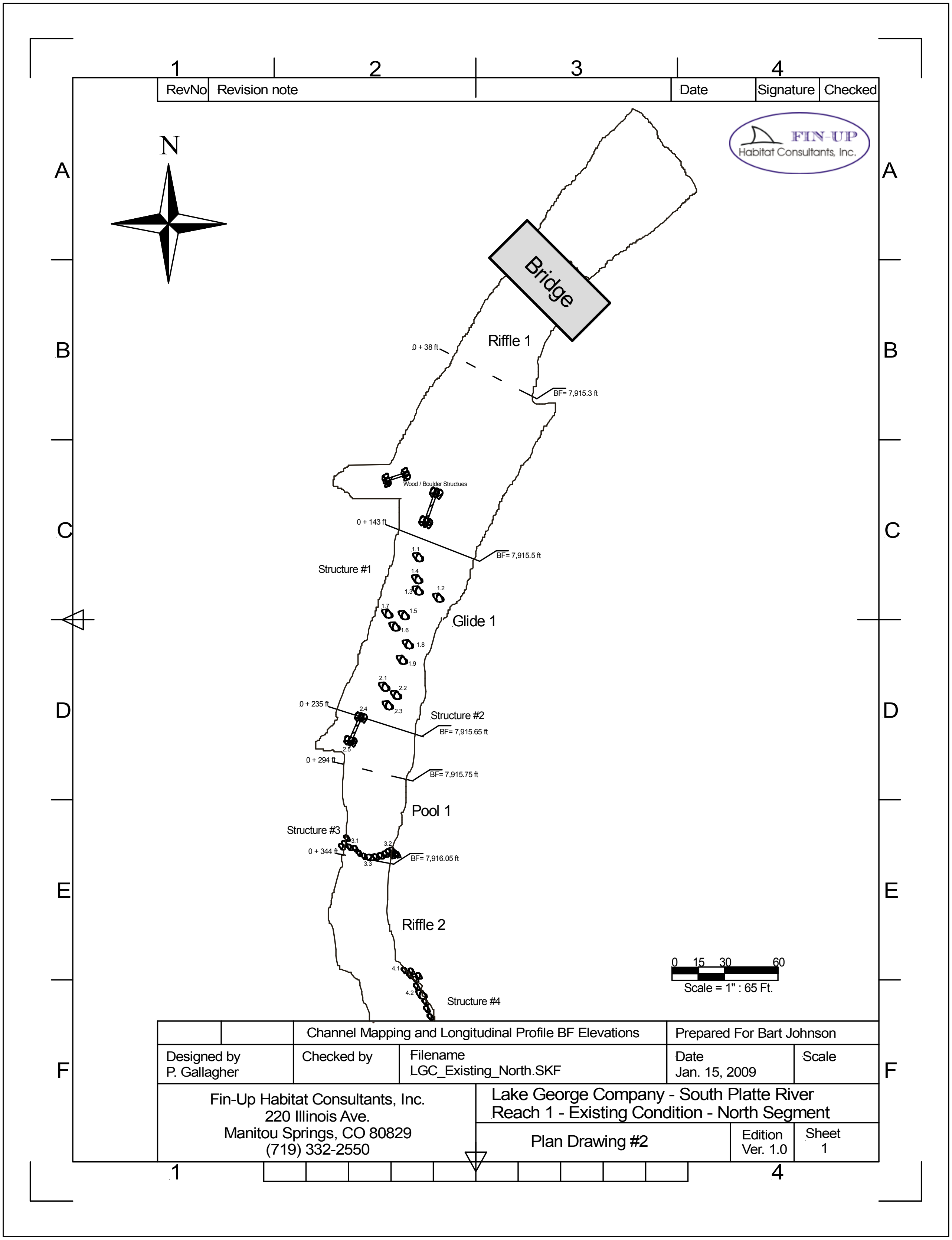
**Existing Condition Aquatic Habitat Structure Assessment:**
In addition to the channel morphology study, an assessment of the current condition of the existing structures was conducted to examine the suitability, location, and elevation, relative to the bank full stage, of each of the existing in-channel structures in the reach. The purpose of the assessment was to quantify the total fill volume, analyze the risk and consequence of failure, and determine the changes that may be needed to of each structure, in order to bring the project into compliance with the provisions of Nationwide Permit #27 – Wetlands and Aquatic Habitat Enhancement, and the Colorado Regional Conditions to NWP#27, as authorized by the federal Clean Water Act (1972, rev. 2007).

The pre-existing habitat enhancement treatments in the project reach consist mostly of randomly placed boulders within the river channel. Several boulder weirs, spanning the entire bank full channel width are also found in the reach, as well as some bank rip-rap and stream bank boulder groins/vanes. For the purpose of this assessment, seventeen separate "structures" were delineated in the reach, numbered consecutively beginning at the downstream boundary and extending upstream to the concrete fish ladder. Plan maps of the structures are shown in Drawings #2 through #5, detailing specific segments of the project reach. An overview of the location of these detailed segments can be found in Drawing 1.

Each structure is described in detail, including an estimation of total fill below the bank full stage, the elevation of major features in the structure, as it relates to the bank full and the ½ bank full elevation of the channel at the structure location. USFS data collected upstream in Eleven Mile Canyon has indicated that in-channel object cover structures that do not exceed ½ of the bank full stage exhibit more efficient scour and depth than structures installed between ½ and the bank full stage (Winters, et al, 2007)

**Undesignated Structure:**
This structure consists of two pieces of large wood and twelve boulders placed in the center of the stream channel in Glide #1 and near the confluence with the lake outflow channel. The estimated fill below the bank full elevation of these structures is $14yd^3$. Both structures are aligned parallel to the direction of flow, and provide little, if any velocity shelter. Sediment has accumulated under the logs, and they no longer provide cover for trout.

**Structure #1:**
This structure consists of eleven large boulders randomly placed throughout the middle of Glide #1. The estimated fill below the bank full elevation of these structures is $17yd^3$. Nine of the boulders were surveyed to determine elevation, with one boulder found to be at precisely bank full stage, and the others ranging from 0.1 to 1.75 feet higher than bank full. See Table 3 and 4 in the Appendix for individual boulder elevations in the project reach. While stream bank stability and riparian composition is relatively good on both banks along Glide #1, these boulders can be expected to exert pressure on the river banks during high flows, and may result in gradual over-widening of the channel through this habitat. Some sediment deposition behind the boulders is becoming evident, as is lateral channel scour on either side of these features.



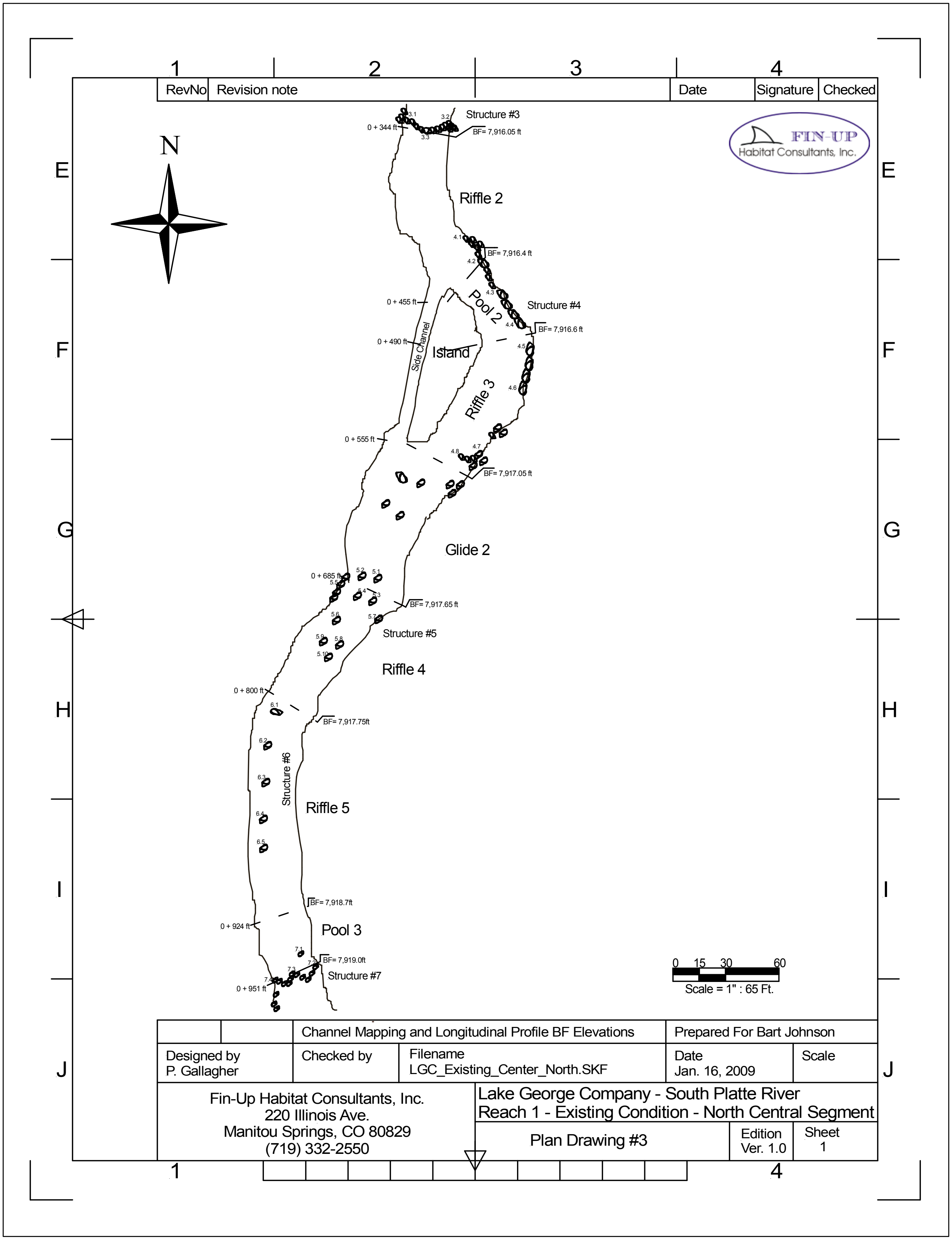

Drawing #2: Reach 1 Existing Condition – North Segment.

**Structure #2:**
This structure consists of three large boulders placed in a cluster near the upstream boundary of Glide #1. Additionally, a log/boulder cluster consisting of a small log and three boulders has been installed adjacent to a small back-water area along left bank. The estimated fill below the bank full elevation of these structures is 7yd$^3$. Six of the boulders were surveyed to determine elevation. Three boulders were found to be higher than the bank full elevation, ranging from 1.1 to 1.45 feet above bank full. The boulder cluster in Structure #2 exhibits similar scour patterns, sedimentation effects and risk factors as Structure #1. The log/boulder structure has filled in with sediment, and should probably be removed.

**Structure #3:**
Structure #3 consists of an inverted "V" boulder cross-vane, spanning the entire bank full channel width, near the upstream boundary of Pool #1. The structure consists of fifteen boulders, with an estimated fill below the bank full elevation of 12yd$^3$. Boulders at each edge of the bank full channel, and the lowest boulder in the center (thalweg) of the structure were surveyed to determine elevation. The center of the structure was close to the optimal ½ bank full elevation (+0.25 ft), however the boulders where the structure ties into the river bank ranged from 0.85 to 1.73 feet higher than bank full. The structure was constructed without any footing boulders, and is likely at risk for failure in the center, due to scouring of fine grained substrates under the center boulder. Vane/bank angle of the structure is greater than 45$^o$ on both banks, increasing the risk of bank failure and channel widening downstream of the structure. Stream bank stability and riparian composition is relatively good on both banks; however, some lateral migration and bank failure can be expected during high flows, due to the high elevation of boulders on the bank and inadequate anchoring of the structure into the banks.

**Structure #4:**
This structure consists of approximately 100 feet of stream bank boulder revetment, with one boulder groin/vane extending into the river channel near the upstream boundary of the structure. There are twenty-nine large boulders in the structure, with an estimated fill below the bank full elevation of 31yd$^3$. The fill/foot of stream bank is estimated to be 0.21 yd$^3$/feet. Seven boulders were surveyed at intervals along the bank to determine elevation. Additionally, the lowest boulder in the groin/vane was surveyed to determine elevation related to ½ bank full. All of the bank-side boulders were found to be higher than the bank full elevation, ranging from 0.68 to 3.15 feet above bank full. The groin/vane boulder was found to be 1 foot higher than optimal. The boulders forming the stream bank revetment are not tightly placed together, and the river has begun to erode the bank within the gaps. Stream bank stability and riparian composition is relatively poor along this bank, and further erosion and bank failure can be expected in this segment.

**Structure #5:**
This structure consists of thirteen large boulders randomly placed throughout the middle of Riffle #4. The estimated fill below the bank full elevation of these boulders is 17yd$^3$. Ten of the boulders were surveyed to determine elevation. Six boulders were found to be

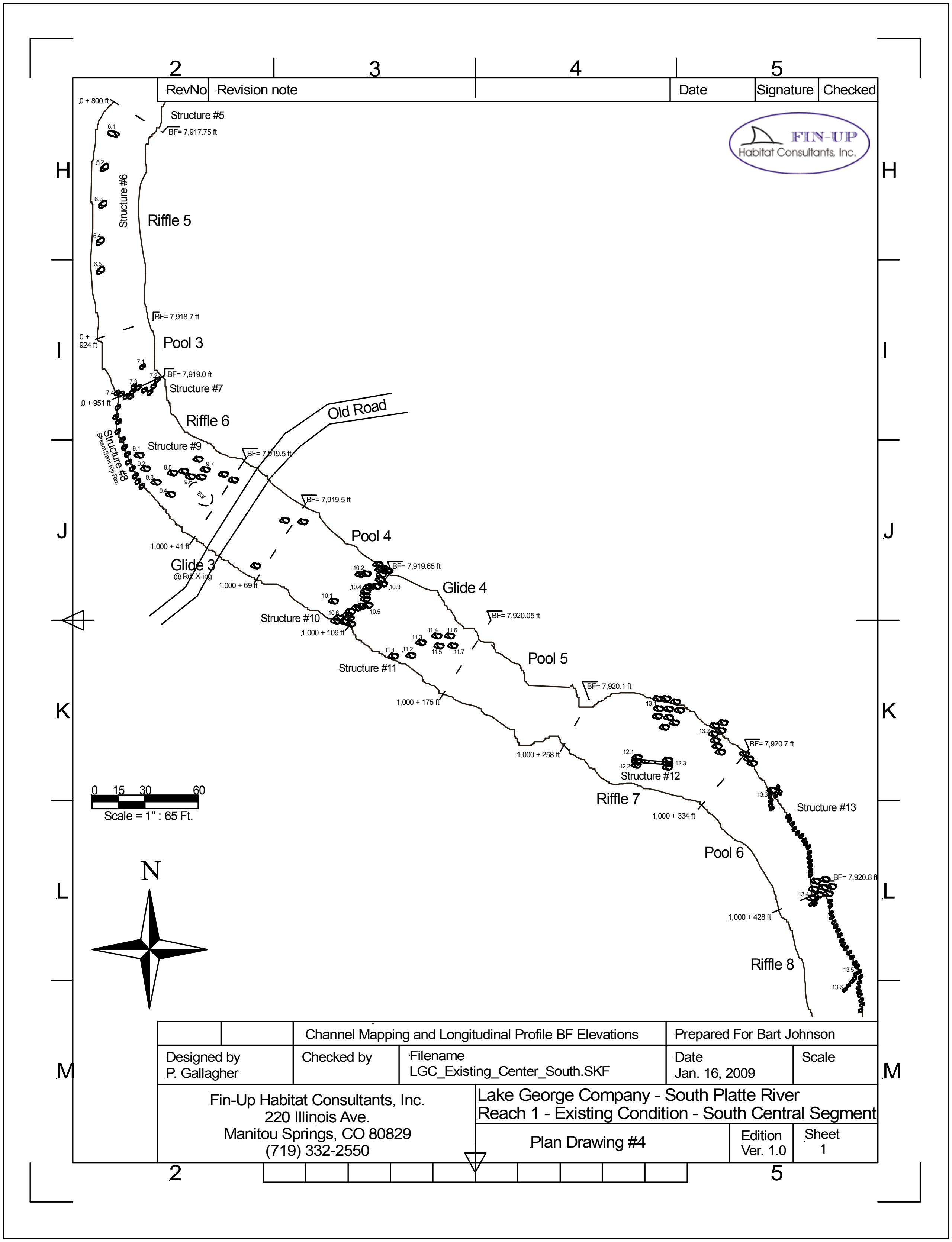



Drawing #3: Reach 1 Existing Condition – North Central Segment.

higher than bank full, ranging from 0.13 to 1.71 feet above the bank full elevation in this riffle. Although four of the boulders were found to be below the bank full stage, none were at the optimal elevation for this structure type. Stream bank stability and riparian composition is less than ideal along the west bank within Riffle #4, due to an un-rehabilitated access route and the proximity with a road accessing the lower lake. The boulders in Structure #5 will likely exert additional shear on this stream bank, and may result in gradual over-widening of the channel through this habitat. Some sediment deposition behind the boulders is becoming evident, as is lateral channel scour on either side of these features.

**Structure #6:**
Structure #6 is another series of randomly placed boulders within Riffle #5. The structure consists of 6 very large boulders placed in a line approximately 10 feet out from the left (west) bank. The estimated fill below the bank full elevation of these boulders is 12yd$^3$. Five boulders were found to be higher than bank full, ranging from 0.4 to 1.7 feet above the bank full elevation in this riffle. One of the boulders was nearly at the optimal elevation of ½ bank full, and was functioning reasonably well, with little evidence of deposition and adequate velocity shelter behind the feature. The close proximity of the access road adjacent to this riffle limits the width and function of the riparian zone on the left bank. The boulders in Structure #5 will likely to exert additional shear on the left stream bank during high flows, and may result in further degradation of the riparian buffer between the river and the road. Sediment deposition behind the boulders is evident, as is lateral channel scour on either side of each boulder.

**Structure #7:**
Structure #7 consists of a boulder "W" weir, spanning the entire bank full channel width, near the upstream boundary of Pool #3. The structure consists of ten boulders, with an estimated fill below the bank full elevation of 13yd$^3$. Boulders at each edge of the bank full channel, and the lowest boulder in the center (thalweg) of the structure were surveyed to determine elevation. One additional random boulder, placed immediately downstream adjacent to the right bank was also surveyed. The center of the structure was found to be 1.64 ft higher than the optimal ½ bank full elevation (0.39 higher than BF). The boulders located where the structure ties into the river banks were 2.64 and 2.58 feet higher than bank full. The random boulder was found to be 1.13 ft higher than the optimal elevation. The structure was constructed without any footing boulders, and is likely at risk for failure in the center, due to scouring of fine grained substrates under the center boulder. Additionally, the structure is not adequately tied into the right river bank, and there is a significant risk of lateral failure of the structure at this point. Vane/bank angle of the structure is greater than 60$^o$ on both banks, increasing the risk of bank failure and channel widening downstream of the structure. Stream bank stability and the riparian buffer is good on the right bank, but very poor on the left, due to the immediate proximity of the access road fill slope. It is likely that lateral migration of flow around the structure, with corresponding bank and road fill slope failure, can be expected during high flows, due to the high elevation of boulders on the bank and inadequate anchoring of the structure.




Drawing #4: Reach 1 Existing Condition – South Central Segment.

**Structure #8:**
This structure consists of approximately 100 feet of stream bank boulder rip-rap revetment along the left (west) bank of Pool #3 and Riffle #6. There are forty-five boulders of various size in the structure, with an estimated fill below the bank full elevation of $35yd^3$. The fill/foot of stream bank is estimated to be 0.12 $yd^3$/feet. Structure #8 provides protection to the access road fill slope, which is immediately adjacent and parallel to the left bank of the river. In several segments, the boulders forming the stream bank revetment are not tightly placed together, and the river has begun to erode the bank within the gaps. Stream bank stability and riparian buffer composition is very poor along this bank, and further erosion and bank failure can be expected in this segment.

**Structure #9:**
Structure #9 is another series of randomly placed boulders throughout Riffle #6. The structure consists of 12 large boulders in various locations within the riffle. Four of the largest boulders are placed in a line 8 to 10 feet out from the left (west) bank. The remaining boulders are in a series of clusters in the center of the channel near the top of the riffle. The estimated fill below the bank full elevation of these boulders is $16yd^3$. Seven of the largest boulders were surveyed to determine elevation. All were found to be higher than bank full. The ideal elevation for this structure type would be ½ of the BF, and these boulders ranged from 1.43 to 2.63 feet above this optimal elevation. A mid-channel bar has begun to form in the center of the channel as a result of the placement of these boulders, which has split the thalweg of the river, and is causing increased stress on both banks. Additionally, the four boulders placed in a line parallel to the left bank may cause an over-topping of the road during high flows. An over-topping event could result in lateral migration of the river into the road corridor, with potentially catastrophic consequences. Sediment deposition behind, and lateral channel scour along the sides of each boulder is evident throughout this feature.

Photo 2: Boulder Clusters in Structure #9 with Bank Structure #8 in background.

**Low Water River Crossing:**
There is a low water river crossing at 0+1,050 ft along the longitudinal profile of the project reach in Glide #3. This crossing was used to bring materials to the project site during the initial project construction. There is a relatively stable riffle crest at the transition with Riffle #9 and Glide#3, approximately 10 feet downstream of the low water crossing. As would be expected by this type of feature, the river channel is excessively over-wide at this point, and exhibits laminar flow and generally poor habitat complexity. The access routes leading to the low water crossing have not been rehabilitated, and may still provide a route for sediment input into the river at this point.

**Structure #10:**
Structure #10 consists of a boulder "W" weir, spanning the entire bank full channel width, near the upstream boundary of Pool #4. The structure consists of twenty-one boulders, with an estimated fill below the bank full elevation of $24yd^3$. Boulders at the left edge of the bank full channel, at the upstream "peaks", and at the center (thalweg) of the structure were surveyed to determine elevation. Two additional random boulders, placed approximately fifteen feet downstream of each of the "peaks" were also surveyed. The center of the structure was found to be 1.04 ft higher than the optimal ½ bank full elevation. The boulders at the "W" weir peaks were 0.26 and 1.51 feet higher than bank full. The boulder located where the structure ties into the left bank was 1.63 feet higher than bank full. The random boulders were found to be 1.51 and 0.28 ft higher than the bank full elevation, and 2.76 and 1.53ft higher than optimal. The structure has no footing boulders, and is likely at risk for failure in the center, due to scouring of fine grained substrates under the center. The structure is relatively well anchored to the river banks, and riparian condition is relatively robust in this area. Vane/bank angle of the structure is greater than $60^o$ on both banks, increasing the risk of bank failure and channel widening downstream of the structure. The high boulders at the left bank anchor point will likely result in lateral migration of flow around the structure during high flows, with a risk of corresponding bank failure.

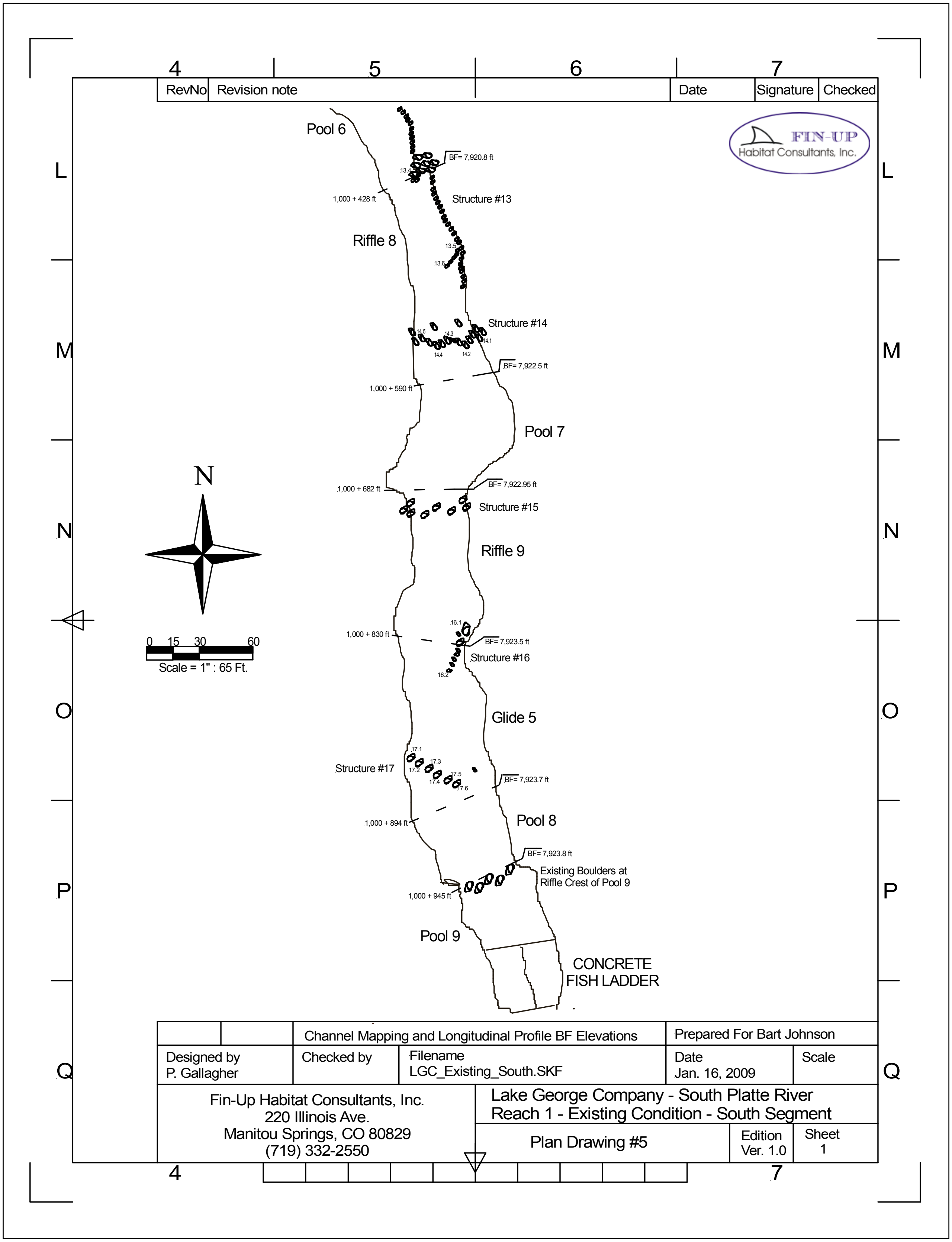
**Structure #11:**
This structure consists of seven large boulders randomly placed throughout the middle of Glide #4. The estimated fill below the bank full elevation of these boulders is $14yd^3$. Each of the boulders was surveyed to determine elevation. All seven boulders were found to be higher than optimal, ranging from 0.91 to 2.18 feet above the ½ bank full elevation in this glide. Stream bank stability and riparian composition is good within this segment of the stream. While the boulders in Structure #11 may exert additional shear on the stream bank in this segment, the risk of over-widening of the channel is probably slight, considering the health of the adjacent riparian zones. Some sediment deposition is becoming evident however, as is lateral channel scour on either side of the boulders, possibly limiting the life-spans of these habitat features.

**Structure #12:**
This structure consists of a piece of large wood and seven boulders placed off-center of the channel thalweg in Riffle #7. The estimated fill below the bank full elevation of this structure is $6yd^3$. Three of the boulders were surveyed to determine elevation. All were

found to be higher than bank full. The ideal elevation for this structure type would be ½ of the BF, and these boulders ranged from 1.73 to 2.31 feet above this optimal elevation. The structure is aligned parallel to the direction of flow, and provides little, if any velocity shelter. Sediment has accumulated under the log, and limiting cover for trout. Additionally, the placement of the structure, between a point bar and the thalweg, may be causing the river to widen excessively at this point.

**Structure #13:**
This structure consists of approximately 300 feet of stream bank boulder rip-rap revetment in Riffle #7, Pool #6, and Riffle #8. Five boulder groin/vanes extend into the river channel at various intervals along the length of the structure. The structure provides toe-slope stability to an unstable and sparsely vegetated 1:1 slope, approximately 25 feet high, that extends along the length of the large outside meander bend near the upstream boundary of the project reach. There are seventy-four boulders, ranging from medium to very large size, in the structure, with an estimated fill below the bank full elevation of 66yd$^3$. The fill/foot of stream bank is estimated to be 0.22 yd$^3$/feet. Five boulders were surveyed at intervals along the bank to determine elevation. Additionally, the lowest boulder in the upstream vane was surveyed to determine elevation related to ½ bank full. All of the bank-side boulders were found to be higher than the bank full elevation, ranging from 1.82 to 3.1 feet above bank full. The groin/vane boulder was found to be 0.78 foot higher than optimal. The boulders forming the stream bank revetment in the downstream half of the structure are not tightly placed together, and the river has begun to erode the bank within the gaps. Several segments in the middle and upstream segments are functioning effectively. The boulder groins/vanes, for the most part, are functioning at less than optimal efficiency, providing little protection to the stream banks and poor cover for trout. Stream bank stability and riparian composition is relatively poor, particularly in the downstream 100 feet of the structure, and further erosion and bank failure can be expected in this segment.

Photo 3: Structure #13 and Cross-Section #9 – Reach 1 – South Platte River.




Drawing #5: Reach 1 Existing Condition – South Segment.

**Structure #14:**
Structure #14 consists of a boulder "W" weir, spanning the entire bank full channel width, immediately downstream of the riffle crest defining the transition of Riffle #8 and Pool #5. The structure consists of eighteen boulders, with an estimated fill below the bank full elevation of 15yd$^3$. Boulders at the edges of the bank full channel, at the upstream "peaks", and at the center (thalweg) of the structure were surveyed to determine elevation. Two additional random boulders, placed approximately fifteen feet downstream of each of the "peaks" are also present, but were not surveyed. Cross-Section #10 transects the channel through the structure. The center of the structure was found to be 1.43 ft higher than the optimal ½ bank full elevation. The boulders at the "W" weir peaks were 0.73 and 0.88 feet higher than bank full. The boulders located where the structure ties into the banks were 2.08 and 3.49 feet higher than bank full. The structure has no footing boulders, and is likely at risk for failure in the center. The structure is relatively well anchored to the right river bank, and relatively poorly anchored on the left. Riparian condition is relatively robust. Vane/bank angle of the structure is greater than 60$^o$ on both banks, increasing the risk of bank failure and channel widening downstream of the structure. The high boulders at the left bank anchor point will likely result in lateral migration of flow around the structure during high flows, with a risk of corresponding bank failure.

Photo 4: Structure #14 and Cross-Section #10 – Reach 1 – South Platte River.

**Structure #15:**
Structure #15 consists of a mostly failed boulder "W" weir, spanning the entire bank full channel width, near the upstream boundary of Pool #7. The structure consists of nine boulders, with an estimated fill below the bank full elevation of 7yd$^3$. Due to the failed condition of the structure, no survey of boulders was conducted. The structure has no footing boulders, and has failed in the center.

**Structure #16:**
Structure #16 consists of a large boulder vane extending from the right bank upstream into Glide #5. The structure consists of nine boulders, with an estimated fill below the bank full elevation of 7yd$^3$. The largest "boulder", closest to the bank, is actually a large piece of recycled concrete with a brick veneer. This "boulder", and the boulder furthest

out into the channel were surveyed to determine elevation. The boulder located closest to the bank was 0.88 feet higher than bank full, and the boulder in the channel was 0.63 ft higher than the ½ BF elevation. The structure has no footing boulders, and is likely at risk for failure due to movement of boulders downstream. The structure is not anchored to the right river bank, and it is evident that high flows have eroded the bank behind and downstream of the structure. Vane/bank angle of the structure is greater than 30$^{o}$, likely increasing the risk of channel widening downstream of the structure.

Photo 5: Fish Ladder and Structure #16, at the Upstream Boundary of Reach 1.

**Structure #17:**

Structure #17 consists of a large boulder vane extending from the left bank upstream into Pool #8, near the concrete fish ladder that delineates the upstream boundary of the project reach. The structure consists of five large boulders forming the vane, and two minor random boulders in the center of the channel, and is estimated to consist of fill below the bank full elevation of 7yd$^3$. The five large boulders forming the vane were surveyed to determine elevation. The boulder located closest to the bank was 1.22 feet higher than bank full, and the boulder farthest out in the channel was 1.49 ft higher than the ½ BF elevation. The structure is constructed with large gaps between each boulder, with each boulder's elevation being somewhat random; not a continuous downward slope that would be expected from this structure type. The structure does not appear to have any footing boulders. The structure is reasonably anchored to the left river bank, which has been rip-rapped with small boulders at this point. Vane/bank angle of the structure is greater than 30$^{o}$, likely increasing the risk of channel widening downstream of the structure.

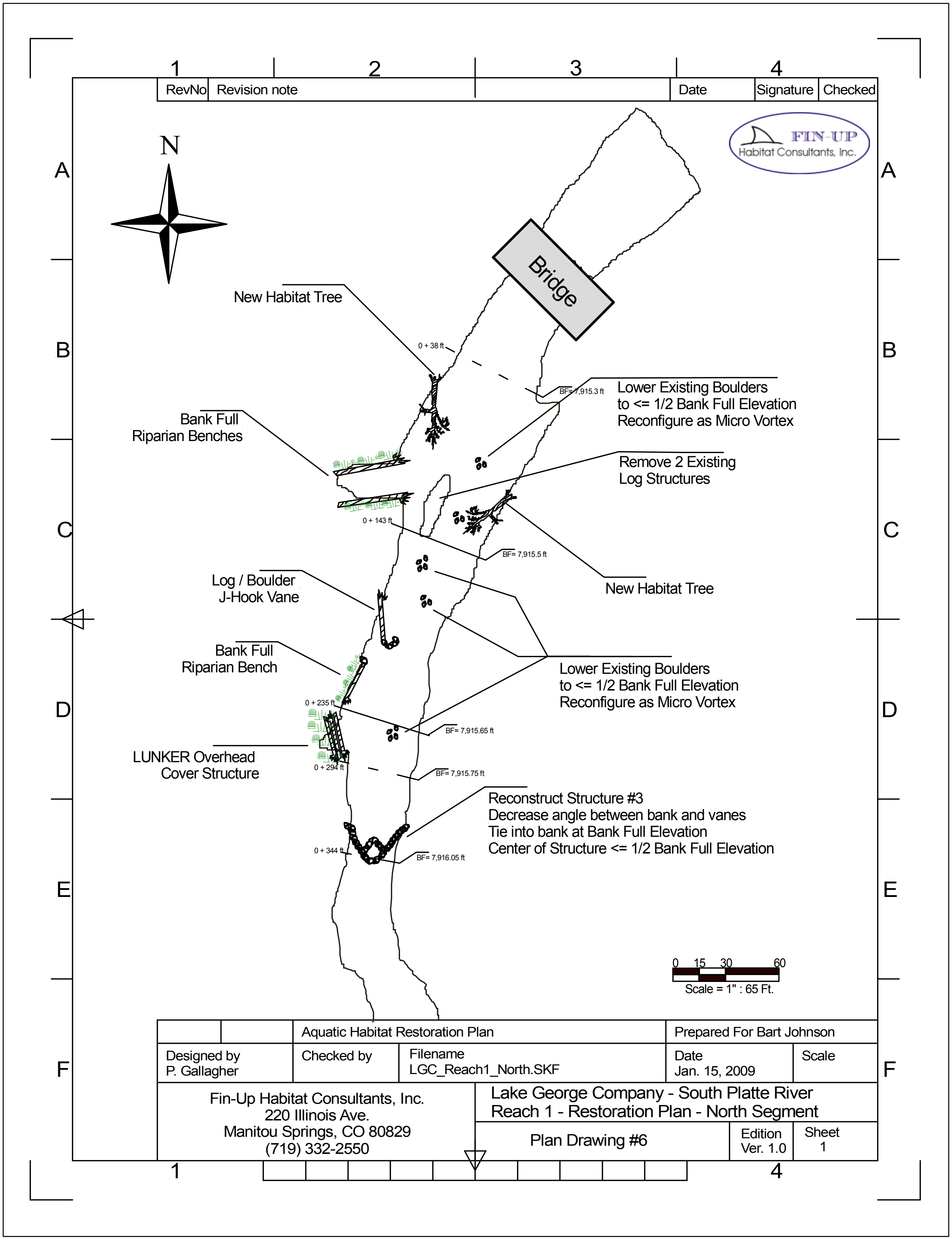
**Lake George Company - South Platte River**
**Recommended Corrective Action & Aquatic Habitat Enhancement Plan**

The existing condition assessment has documented several factors that may indicate that the previous aquatic habitat restoration work undertaken in Reach 1 of the South Platte River through the Lake George Company property is as risk of failure. There are, however, opportunities for significant enhancement to the existing project that may improve both hydrologic and habitat function, as well as provide additional benefit to the esthetic values within the reach. These treatments and modifications may also help to bring the existing project into compliance with the provisions of Nationwide Permit #27 – Wetlands and Aquatic Habitat Enhancement, and the Colorado Regional Conditions to NWP#27, as authorized by the federal Clean Water Act (1972, rev. 2007).

One of the habitat features most notably absent from the existing project is the incorporation of large wood into the river channel. Extensive research has been conducted on the critical relationship between large wood recruitment and biotic health in western U.S. rivers and streams. Preliminary studies of the effectiveness of large wood recruitment in the South Platte River, as part of the U.S. Forest Service Trees for Trout Project upstream in Eleven Mile Canyon, indicate that large wood provides a greater biological response to a given in-channel object cover improvement than similar features constructed from boulders; with generally higher quality usable habitat, particularly for juveniles and young-of-the-year trout.

The following Corrective Action & Enhancement Plan is based on immediate restoration needs, maximization of in-channel habitat improvements, feasibility of implementation, and budgetary requirements for completing the work. Priorities include repair and/or reconfiguration of existing structures, stabilization of actively eroding stream banks, and increased in-channel stream habitat through strategic placement of boulder and large wood features in the river. The proposed treatments are outlined beginning at the downstream boundary of each reach and extending upstream. Plan maps of the recommended treatments are shown in Drawings #6 through #9, detailing segments of the project reach. An overview of the location of these detailed segments can be found in Drawing #1.

**Glide #1 / Structures #1 & #2**
The three existing log/boulder structures in this glide are not providing effective cover and velocity shelter for trout, and should be removed. To enhance large wood recruitment in this segment, we recommend installing two habitat trees on either side of the channel upstream of the riffle crest defining the transition between Riffle #1 and Glide#1. The habitat trees should be whole trees, with the root ball and as many branches as is practical still attached. Ideally, the trees will be ponderosa pine, approximately 30 – 40 ft long, with a basal diameter (DBH) of 18-24”. The trees should be placed in the channel with the root-ball embedded into the river bank, and extending upstream at an angle not to exceed 30$^{o}$ off of the stream bank. The elevation of the tree, where it meets the river bank, should not exceed the bank full stage of the channel at this point. Habitat trees are typically anchored near the root ball and at the end of the tree with large flat




Drawing #6: Reach 1 Restoration Plan – North Segment.

boulders, however, in this case, considering the proximity of the US 24 highway bridge, it is recommended that additional anchoring with Manta-Ray MR-1 dead-man anchors be used.

Bank full riparian benches, with large wood used to provide a stable toe slope, may be installed on either side of the lower lake outlet channel, where it joins the main stem of the river near the downstream boundary of Glide #1. These features will provide some overhead cover for trout in the slow water area, as well as providing additional bank stability in this area. Another BF riparian bench should be constructed on the left bank at 0+200ft along the longitudinal profile (LP) of the channel.

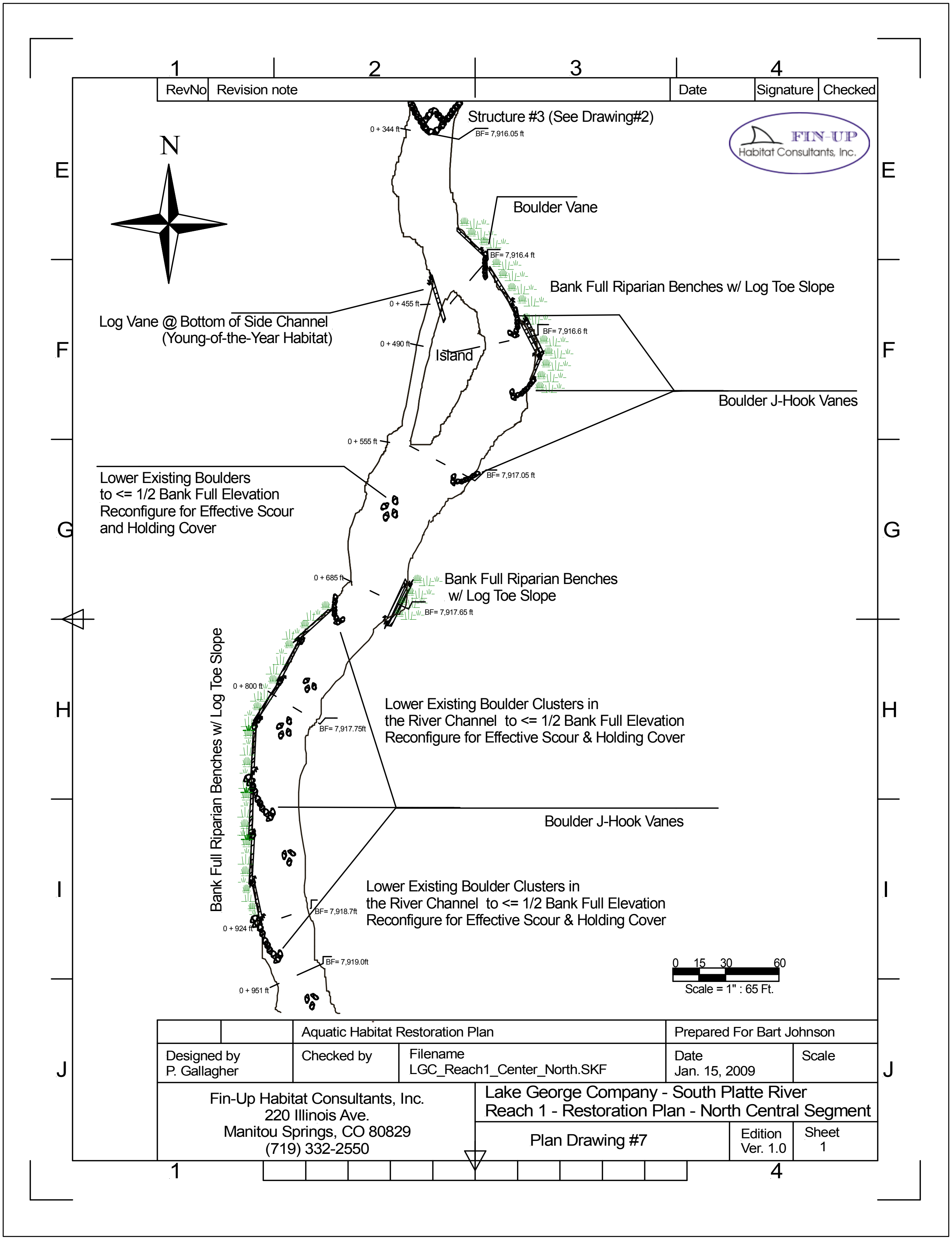
A LUNKER structure may be constructed in the small backwater pool that is formed on the left side of the channel, near the transition between Glide #1 and Pool #1. LUNKER structures provide significant overhead cover by mimicking an undercut stream bank. The structure will consist of several pieces of large wood perched immediately above the backwater pool feature. The top of these logs should not be greater than the bank full stage of the river at this point. A layer of geo-textile fabric is placed over the logs, and then the feature is covered with transplanted willow and sedge mats.

A log/boulder J-hook structure will be installed along the left bank of the stream at approximately 0+180ft along the LP, in order to direct the thalweg away from the bank, and to create additional velocity shelter. The log/boulder J-hook structure is, in some respects, similar to a habitat tree, but with the addition of a boulder "hook" on the end of the tree, which may create a small pocket of scour providing cover and velocity shelter for resident trout. Detailed plans for all of these structure types may be found in the Appendix. Nine trees will be required to complete the work in this segment and will consist of an additional $27yd^3$ of fill in the channel.

The existing boulders in Structure #1 and Structure #2 may be used to anchor the habitat trees, riparian bank full benches, and to construct the log/boulder J-hook vane. The remaining boulders should be reconfigured into small micro-vortex in-channel object cover clusters. The elevations of these boulders should be varied so as to look more natural in the river, however, none should exceed >= ½ of the bank full elevation of the river channel. Additionally, when possible, the top facet of each boulder should be tilted downstream between $5^o$ and $20^o$ to improve scour function in this habitat feature. No additional boulders are expected to be necessary in order to complete the work in this segment of the channel.

**Pool #1 / Structure #3**

Structure #3 should be reconstructed so that the vanes extend from the stream bank at no greater than $30^o$. It is recommended that footer boulders be added throughout the structure, and that a low footer inverse "V" be added to the center of the structure for increased stability. The vanes should be anchored at least five feet into the stream bank, and should not exceed BF (7,916.05ft at this point). The center of the structure should be set no higher than (7,914.35ft). An additional $6yd^3$ of boulders may be necessary to properly reconfigure this structure, and likely will be brought down from Structure #4.




Drawing #7: Reach 1 Restoration Plan – North Central Segment.

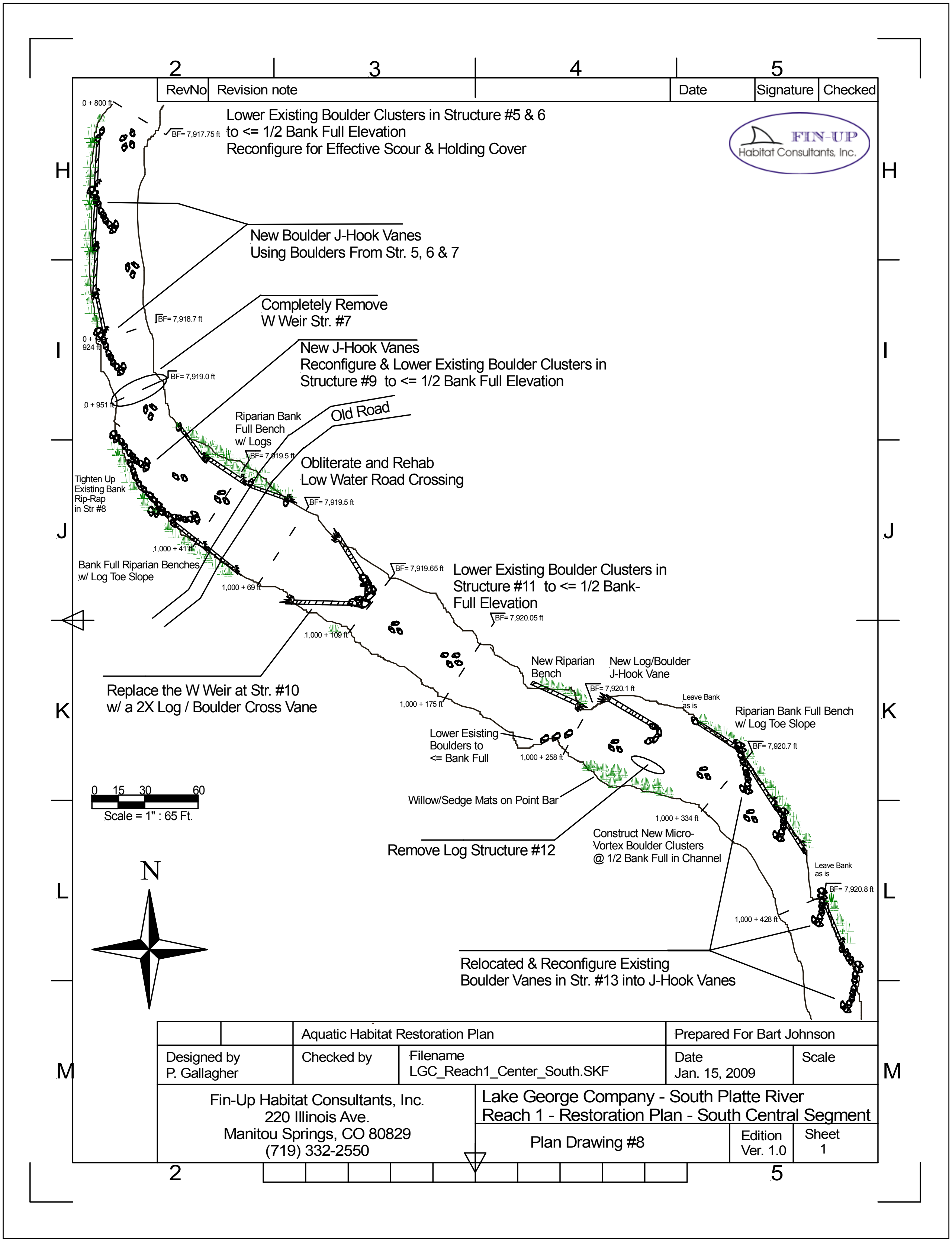
**Riffle #2, Pool #2, & Riffle 3 / Structure #4**
Structure #4 will be reconfigured using riparian benches with log toe slope stabilization, complimented by a series of boulder vanes and boulder J-hook vanes to reduce shear on this relatively tight meander bend in the river. The log toe-slope features should be placed so that the top edge of the tree does not exceed the bank full elevation of the channel. The natural bend of the log should be utilized so as to create an under-cut stream bank effect to provide additional cover and velocity shelter. Existing boulders will be used to build one new small boulder vane at 0+455ft, and three new boulder J-vanes at approximately 0+480ft, 0+510ft, and 0+555ft along the right bank of the river. Boulder vanes and J-hook vanes will be constructed according to the plan and profile drawings found in the Appendix, and should not exceed BF at the point were they tie into the river bank, or ½ of the BF stage at the in channel end of each structure.

A log vane will be installed in the small secondary side channel on the left side of the river at 0+455 ft along the LP in order to provide additional slow water habitat at high flows for juvenile and young-of-the-year trout. The log should span the entire side channel, extending from the left bank at an angle not to exceed $30^{o}$. The end of the log will be embedded into the island that forms the right bank of the side channel. This end of the log should be flush with the existing grade of the side channel where it meets the island. The elevation of the log where it ties into the left bank will not exceed BF. This structure will form a small triangular pocket of slow water upstream of the left side of the log during higher flows, and will reduce shear on the left bank of the secondary side channel.

Five or six large ponderosa pine trees will be needed for the work in this segment. Existing boulders will be used for the vanes and to augment the cross-vane downstream. It is not expected that the total quantity of fill in this segment will significantly change from the existing condition.

**Glide #2, Riffle 4 & Riffle 5/ Structure #5 & #6**
A bank full riparian bench, with large wood used to provide a stable toe-slope, may be installed on the right bank of the river at 0+685ft, near the transition between Glide #2 and Riffle #4,. Additional BF riparian benching will be necessary on the left bank between 0+700ft and 0+924ft in Riffle #4 & #5, particularly in the downstream segment where the equipment access route approaches the river.

Existing boulders from Structure #5 and Structure #6 will be used to construct three new boulder J-vanes at approximately 0+690ft, 0+850ft, and 0+925ft along the right bank of the river. Boulder vanes and J-hooks should not exceed BF at the point were they tie into the river bank, or ½ of the BF stage at the in channel end of each structure. The remaining boulders will be reconfigured into small micro-vortex in-channel object cover clusters. The elevations of these boulders should be varied so as to look more natural in the river; however, none should exceed >= ½ of the bank full elevation of the river channel. These clusters should be placed at along the thalweg of the channel between the J-hook vanes, to provide additional pocket water complexity and velocity shelter in the segment, and to aid trout migration through the riffle at high flows.




Drawing #8: Reach 1 Restoration Plan – South Central Segment.

Photo 6: Habitat Trees near Riverside Campground – Eleven Mile Canyon.

**Pool #3/ Structure #7**

Structure #7 consists of a "W" weir placed in the channel near the center of a meander bend. This structure type is not typically used along a meander bend, and may not be appropriate in this location. Furthermore, the structure is constructed so that it may cause an undesirable lateral migration of the channel to the east, and should be removed. Boulders from this structure will be used to construct J-hook vanes and other features in the riffles upstream and downstream of this feature.

**Riffle 6 & Glide #3/ Structure #8, #9 & the Low Water Crossing**

The boulder rip-rap along Structure #8 needs to be adjusted to eliminate the gaps that are allowing the road fill slope to erode into the river. Boulders that are above BF will be lowered to the BF elevation, and additional transplanting of willow will be accomplished where feasible to create a buffer between the road and the stream. In order to obliterate the low water crossing, bank full riparian benches will be installed on the right bank of the river beginning at 0+975ft, and extending upstream to 1,000+60ft; and on the left bank, beginning at 1,000+0ft, and extending upstream to 1,000+55ft. The access roads on either side of the low water crossing will be ripped to eliminate compaction of the soil, and re-seeded using native riparian and upland seed mix as appropriate.

Boulders from Structure #7 and #9 will be used to build two additional boulder J-vanes at approximately 0+970ft, 1,000+0ft along the left bank of the river. These vanes will reduce the shear forces on the left bank, and reduce the possibility of the river migrating laterally into the road corridor at this point. A mid-channel bar that has formed due to the placement of the random boulders will be lowered so that a single thalweg is formed through the riffle. This work will be done without altering the existing riffle crest immediately downstream of the low water crossing in Glide #3. The channel profile at the mid-channel bar will be shaped so that the thalweg extends from its current location at the riffle crest to the "hook" of the first J-hook vane downstream of the crossing. The remaining boulders in Structure #9, and three additional random boulders that are in

Glide #3, upstream of the low water crossing, will be reconfigured into small micro-vortex in-channel object cover clusters to provide additional usable habitat in the riffle.

**Pool #4/ Structure #10**

Structure #10 consists of a "W" weir across the channel at Pool #4. This structure will be replaced with a double log/boulder cross-vane, in order to provide for additional incorporation of large wood into the project, and to create more effective scour in the pool. The new structure will consist of two large ponderosa pines, with root-balls embedded into the banks, extending upstream into the channel. The center of the structure will be constructed with boulders, using footer rocks as necessary, to form the top of the cross-vane. The trees will be anchored at least five feet into the stream bank, and should not exceed BF (7,919.65ft). Manta-Ray MR-1 dead-man anchors may be used to further anchor the trees within this structure. The center of the structure should be set no higher than (7,918.35ft). Boulders from the "W" weir will be used to construct the new feature, with any boulders not used being removed from the river. The total fill of this new structure is not expected to exceed that of the existing "W" weir.

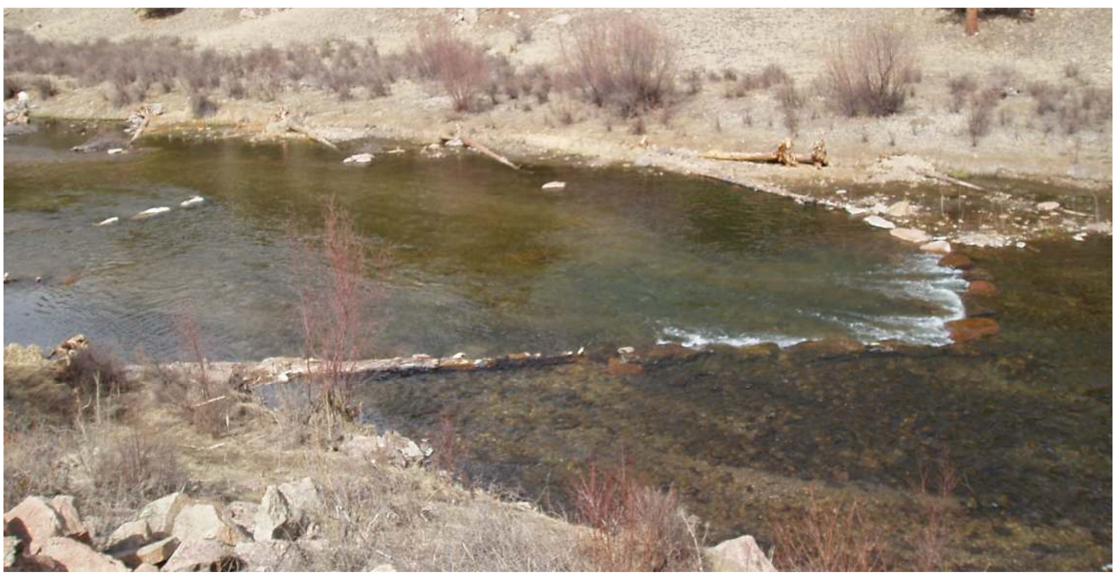


Photo 7: Double Log Cross-Vane Structure – Eleven Mile Canyon.

**Glide #4 & Pool #5 / Structure #11**

Existing boulders from Structure #11 will be reconfigured into micro-vortex in-channel object cover clusters. The elevations of these boulders should be varied so as to look more natural in the river, however, none should exceed >= ½ of the bank full elevation of the river channel. These clusters should be placed at along the thalweg of the channel to provide additional pocket water complexity and velocity shelter in the segment. The very large boulder on the left bank (boulder 11.1 in Drawing #4) will be removed from the river.

A bank full riparian bench, with large wood used to provide a stable toe slope, will be installed on the right bank of the river at 1,000+220ft, adjacent to Pool #5. This structure will be constructed so as to create a large pocket of under-cut bank cover. A LUNKER structure may be substituted here, in order to maximize the cover along this bank. Additionally, the three boulders forming a vane on the left bank of Pool#5 will be lowered to less than the bank full elevation. Additional fill, consisting of one or two trees (3 – 6 $yd^3$) may be required to complete the work in this segment.

**Riffle #7/ Structure #12**

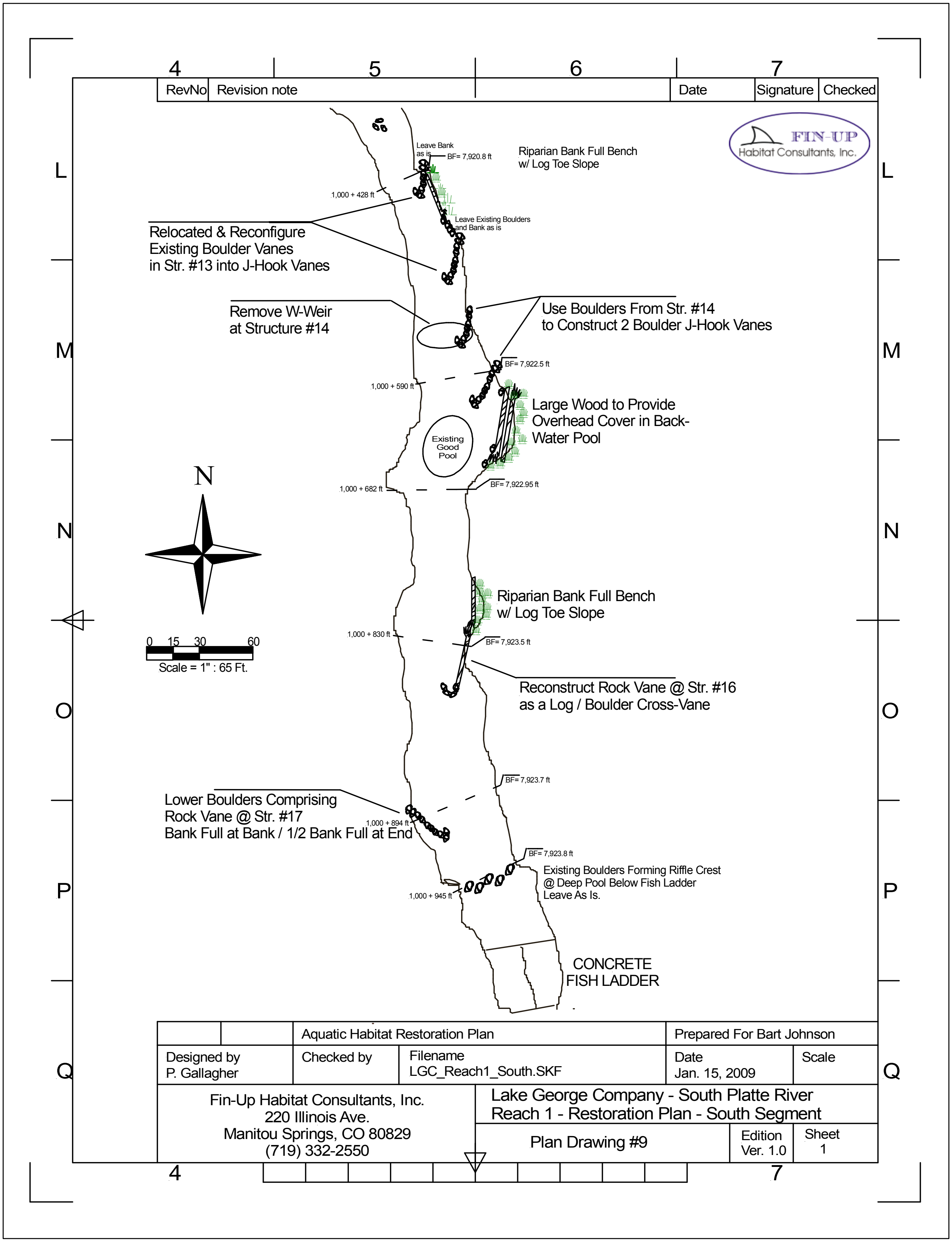
Structure #12 consists of a log/boulder cluster placed off-center of the thalweg on the inside of a large meander bend. The structure currently provides little or no effective usable habitat, and may be a contributing factor in a noticeable over-widening of the river channel at this point. The structure will be removed, and the downstream portion of the point bar forming the inside of the meander bend will be restored using sedge mats along the left bank to narrow the bank full width of the channel at this point. The fill volume of the sedge mats is not expected to exceed 0.15$yd^3$/ft, and will be harvested from the riparian meadow west of the project site.

A log/boulder J-hook structure will be installed along the right bank of the stream at approximately 1,000+265ft along the LP within Riffle #7. This feature will direct the thalweg into the pool downstream, improving scour while protecting the poorly vegetated bank immediately upstream, near the start of Structure #13. One large ponderosa pine will be required to complete the work in this segment, and will consist of an additional 4 - 6 $yd^3$ of fill in the channel.

**Riffle #7, Pool #6, & Riffle 8 / Structure #13**

Several segments of Structure #13 will be reconfigured using riparian benches with log toe slope stabilization, complimented by a series of boulder J-hook vanes, to reduce shear on this large meander bend in the river. Stable segments of the structure are shown in Drawing #8, and will be left "as is". The log toe slope features will be installed so that the top edge of the tree does not exceed the bank full elevation of the channel.

Photo 8: Bank Full Riparian Benching – Arkansas River, Freemont County.




Drawing #9: Reach 1 Restoration Plan – South Segment.

The natural bend of the log will be utilized so as to create an under-cut stream bank effect to provide additional cover and velocity shelter. Existing boulders will be used to build four new boulder J-vanes at approximately 1,000+334ft, 1,000+375ft, 1,000+428ft and 1,000+470ft along the right bank of the river. The J-hook vanes will be constructed not exceed BF at the point were they tie into the river bank, or ½ of the BF stage at the in channel end of each structure.

Six or seven large ponderosa pine trees will be needed for the work in this segment. Existing boulders from Structure #13 will be used for the vanes. The remaining boulders will be reconfigured into small micro-vortex in-channel object cover clusters to provide additional usable habitat in the riffle. It is not expected that the total quantity of fill in this segment will change significantly from the existing condition.

**Riffle #8/ Structure #14**
Structure #14 consists of a "W" weir placed in the channel downstream of the riffle crest of Riffle #8. This location is may not be appropriate for this structure type, and given the slope and substrate composition, it is unlikely that a pool can be forced here. The structure will be removed, and the boulders will be used to construct two J-hook vanes along the right bank at the beginning of the large meander bend, at 1,000+540ft and 1,000+590ft. The J-hook vanes will reduce shear along the outside of the meander bend, while providing additional pocket water cover and velocity shelter within this relatively higher gradient riffle.

**Pool #7/ Structure #15**
A bank full riparian bench, with large wood used to provide a stable toe slope, will be installed on the right bank of the river at 1,000+610ft, adjacent to the tail-out of Pool #7. This structure will be constructed so as to create a large pocket of under-cut bank cover. A LUNKER structure may be substituted here, in order to maximize the cover along this bank. Structure #15 consists of a failed "W" weir placed in the channel upstream of Pool #7. Pool #7 was one of the better quality pools observed in the reach, and probably does not require further enhancement effort to maintain effective scour and depth. Boulders from Structure #14 may be used to construct the riparian bench, and to augment Structure #16 upstream. Two pieces of large wood will be necessary to complete the work in this segment.

**Glide #5/ Structures #16 & #17**
Structure #16 consists of a boulder vane on the right side of the river, and will be reconstructed into a boulder J-hook vane. The structure will be properly anchored into the river bank, and a new bank full riparian bench, with large wood used to provide a stable toe slope, will be installed downstream of the J-hook vane on the right bank to repair the eroding bank. The bank full bench will be constructed so as to create pockets of under-cut bank cover. The boulder vane on the left bank, designated Structure #17, will also be converted into a J-hook vane. The boulders forming the tail-out between Pool #8 and Pool #9 will be left "as is", in order to preserve the velocity reducing function these boulders provide from flows exiting the concrete fish ladder. Existing boulders will be used to construct these features. An additional 10 -12 $yd^3$ of boulders may be necessary to complete this work.

**Glossary of Terms:**

**Benthic Zone** - The benthic zone is the lowest level of a body of water. It is inhabited mostly by organisms that tolerate cool temperatures and low oxygen levels, called benthos or benthic organisms.

**Cascade** - A meso-habitat type. Cascades are the steepest riffle habitat types, in terms of gradient, in streams. These riffles consist of alternating small waterfalls and shallow pools. These habitats may appear to have the characteristics of a Step-pool system. Cascades are characterized by swift current flows and often have exposed rocks and boulders above the water surface, which creates considerable turbulence and surface agitation. The substrate normally found in cascades is bedrock or accumulations of boulders.

**Cover** - Locations where fish prefer to rest, hide and feed are called cover. Cover serves to visually isolate fish, which increases the number of territories in the same space. Additionally, cover can create areas of reduced velocities providing critical resting and feeding stations for fish. The amount of cover available in a stream can influence the production of a number of fish and invertebrate species.

**Cross-Vane** - A structure spanning the entire width of the channel, constructed of large boulders and/or large wood, that provides vertical stability, increased scour, increased stage upstream, and reduced stream power. This structure type is commonly used as a diversion structure for irrigation ditches, as well as for treating active down cutting and head cuts in the stream channel.

**Embeddedness** - The degree to which the interstitial spaces between larger substrate particles are filled with finer sediments. Embeddedness tends to armor the substrate, thus limiting available habitat for benthic dwelling macroinvertebrates and spawning habitat for salmonids.

**Glide** - A meso-habitat type. Glides are those portions of streams which have relatively wide uniform bottoms, low to moderate velocity flows, lack pronounced turbulence, and have substrates usually consisting of either cobble, gravel or sand. Glides are usually described as stream habitat with characteristics intermediate between those of pools and riffles. These habitats are commonly found in the transition between a pool and the head of a riffle, however they are occasionally found in low gradient stream reaches with stable banks and no major flow obstructions.

**Green Line** - A narrow band of riparian plant species immediately adjacent to the stream bank in deeply entrenched streams. These are typically streams that have no identifiable flood plains.

**Head-Cut** - An area of active down-cutting in the channel where a river or stream is eroding down to a new, lower flood plain.

**Intermittent** - An intermittent stream is one that only flows for part of the year.

**Lotic** - Of, relating to, or living in moving water such as streams and rivers.

**Meso-Habitat** - A channel scale habitat form. Typically a pool, riffle, rapid, cascade or glide habitat. A meso-habitat occupies the entire width of the stream channel, and with few exceptions (most notably plunge pools in high gradient step-pool systems) is at least as long as the channel is wide.

**Micro-Habitat** - Micro habitats are small, site specific habitats within a meso-habitat form, and may include spawning redds, in-stream or overhead cover, and velocity shelters.

**Micro-Vortex** - A small rock cluster structure that replicates pocket water habitat in riffles, rapids and cascades.

**Over-Wintering Habitat** - Areas of a stream or water body exhibiting depths that may sustain a population through the winter months.

**Perennial** - A perennial stream is one that flows year round.

**Pocket Water** - A micro-habitat type. Pocket water habitats are typically found in higher gradient riffles, rapids, and cascades with large cobble, boulder, and large woody debris. These pocket water habitats provide small areas for velocity shelter and cover within these fast-water habitat forms.

**Pool** - A meso-habitat type. Pools are channel segments exhibiting areas of scour and deposition where the water is deeper and slower moving.

**Primary Producers** - Primary producers are those organisms in an ecosystem that produce biomass from inorganic compounds. In almost all cases these are photosynthetically active organisms.

**Rapid** - A meso-habitat type. Rapids are riffles associated with high gradients (greater than 4%) with swiftly flowing (greater than 1.5 ft/sec), moderately deep, and highly turbulent waters. These riffles are generally associated with boulder substrates, which protrude through the surface of the water.

**Residual Pool Depth (RPD)** - Residual pool depth is estimated as the depth of water which would be retained in a pool under highly reduced flows or the stoppage of flows in the stream. This area of pools would be utilized by fish in low flow conditions. Residual pools would also provide habitat for overwintering of fish when ice buildup restricts movement in riffles or glides between pools. Residual pool depth is calculated by locating and measuring the greatest depth of the pool at the riffle crest (deepest point of the downstream boundary cross-section of the pool), and subtracting this value from the greatest measured depth of the pool habitat. The difference in these measurements is described as the RPD. RPD may be difficult to determine in some habitats, particularly dam pools with woody debris structural associations. In many of these habitat units, the RPD may actually be a very low value or zero due to water flowing through these debris dams.

**Riffle** - A meso-habitat type. Riffles are those areas of the stream in which turbulence in the water column is the major identifying characteristic, as a result of relatively high gradients. These units contain moderately deep to shallow, swift flowing water, and are characterized by boulder or cobble substrates. Riffles are very important for macroinvertebrate production, due to the availability of light and oxygen, and the corresponding vegetative growth on the bottom substrate. The quality of riffles, including low sediment deposition and resulting embeddedness can have a direct impact on fish populations. The cleaner and healthier the vegetative growth and benthic macroinvertebrate community, the more food there is for the fish population.

**Salmonids** - Salmonidae is a family of ray-finned fish, the only family of order Salmoniformes. It includes the well-known salmons and trouts; the Atlantic salmons and trouts of genus Salmo give the family and order their names.

Subfamily - Salmoninae
- Brachymystax - lenoks
- Oncorhynchus - Pacific salmon and trout
- Salmo - Atlantic salmon and trout
- Salvelinus - Char and trout (Brook trout, Lake trout)

**Substrate** - Stream substrate (sediment) is the material that rests at the bottom of a stream.

**Thermal Refugia** - Micro habitats found in streams and lakes that provide thermal protection for cold water species such as trout. These may include shaded areas, cool water springs, and deep water habitats.

**Toe-Slope** - The foot, or bottom, of the sloping bank of a stream. This is the area of the highest sheer stress and erosion potential on a stream bank, and is typically the point of failure leading to mass wasting and collapse.

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