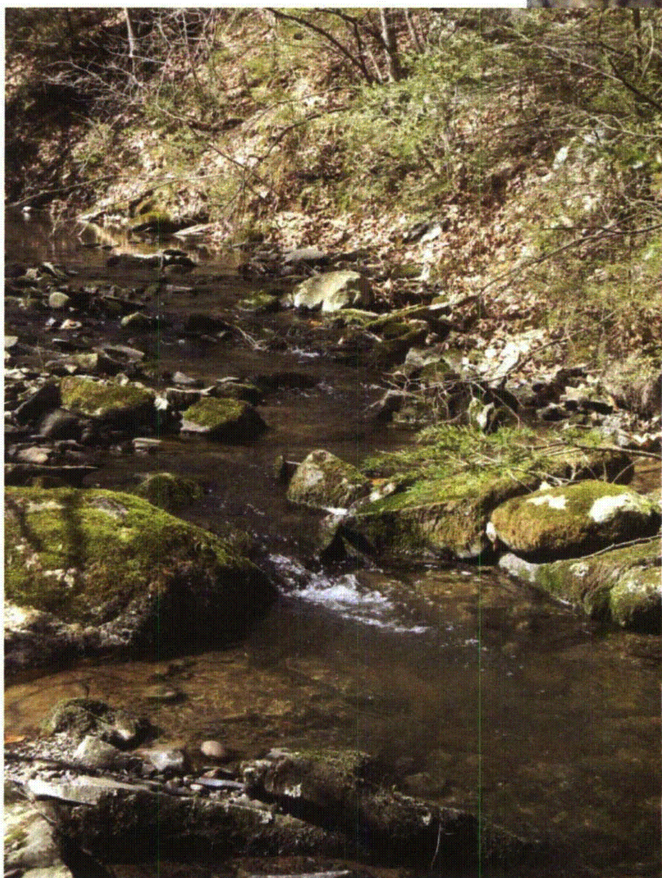
Walker Run
Trout Enhancement Plan



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Walker Run Trout Enhancement Plan

A. Introduction:

This Trout Enhancement Plan has been developed for the section of Walker Run (Luzerne County, Pennsylvania) extending from the upstream end at Beach Grove Road to the forested area just upstream of an existing beaver dam (see stream restoration conceptual design drawings).

The overarching goal of this Trout Enhancement Plan is to increase the area of desired habitat for adult and young brown trout, and the area of desired habitat for brown trout spawning. The Plan also incorporates an approach for re-populating the restored sections of Walker Run. This approach may involve a redistribution of wild brown trout, a trout egg planting program, a fingerling stocking program, or some combination of these efforts. A trout monitoring program is also essential to document the outcomes of these trout enhancement efforts.

The relatively low stream gradient also limits the degree to which excavation during restoration can reach historic gravels in the buried floodplain and streambed. While excavation to historic gravels can be accomplished in upstream reaches, it can make a tie-in difficult or impossible at the downstream reach area that is not being restored. Consequently, it will likely be necessary to import appropriate stream bottom substrate (i.e., gravels) to enhance and expand trout spawning habitat.

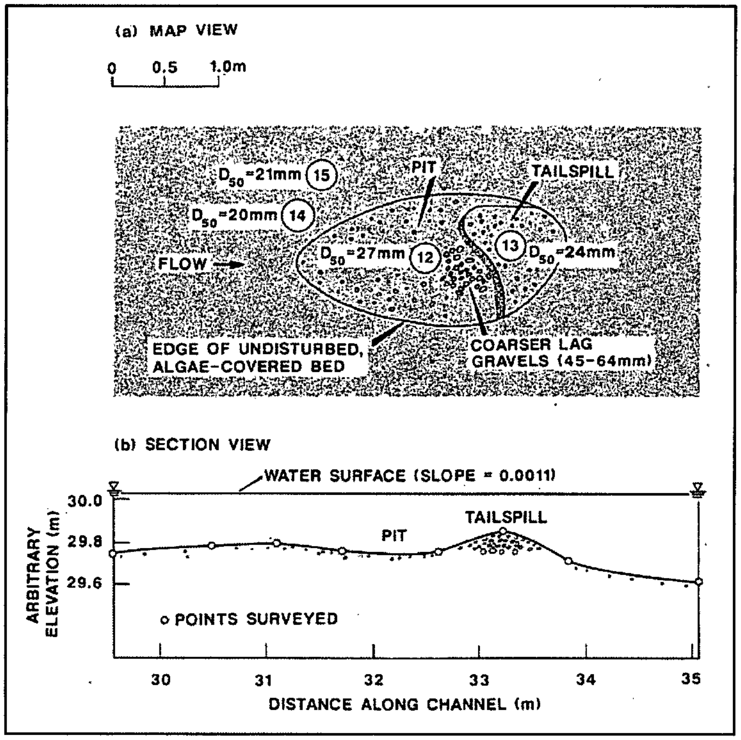
B. Brown Trout Spawning Habitat Criteria:

Brown trout spawn by creating depressions in gravel-dominated stream bottoms, where they lay and bury their eggs for protection and incubation. The female digs a pit (see Figure 1) by turning on her side and using her tail to create strong movements that cause smaller sized gravel and fine sediments to become entrained in the water and move downstream. The gravels will deposit downstream of the created pit in the tailspill area, while the fine sediments will be carried further downstream. After she creates the pit, the female will lay her eggs in the pit and they will immediately be fertilized by her accompanying male. Once the eggs are fertilized, the female will dig upstream of the pit so that her fertilized eggs are covered with gravel. The gravel provides protection for the eggs, and the interstitial spaces between the gravel allow for currents to provide dissolved oxygen to the eggs and carry away metabolic wastes when the eggs begin to develop (description from Kondolf et. al., 1993).[1]

Brown trout in Spring Creek, central Pennsylvania, were found to spawn between the last week in October to the middle of December, with peak spawning occurring in mid-November (Beard and Carline,

[1] Kondolf, G.M., M.J. Sale, and M.G. Wolman. 1993. Modification of fluvial gravel size by spawning salmonids. Water Resources Research, vol. 29 (7): 2265-2274.

Figure 1. Typical brown trout redd morphology. From Kondolf et. al. (1993).[1]



1991).[2] The eggs hatch and the young fry emerge by wriggling through the gravel spaces in the spring. Course sand and fine gravel can fill these gravel spaces and inhibit the emergence of the fry.

Kondolf and Wolman (1993)[3] found that spawning habitat selection by brown trout and other salmonids are based on a number of factors, including substrate gravel size, water depth and velocity, cover, and the presence of upwelling or downwelling currents.

Suitable spawning substrate (gravels) and cover were found to be the most important environmental variables influencing the density of age-0 brown trout in the Au Sable River in Michigan (McRae and Diana, 2005).[4]

Beard and Carline (1991)[5] found that the availability of spawning habitat was the primary factor influencing the density of brown trout in Spring Creek, central Pennsylvania, and that suitable spawning

[2] Beard, T.D. and R.F. Carline. 1991. Influence of spawning and other stream habitat features on spatial variability of wild brown trout. Transactions of the American Fisheries Society, vol. 120: 711-722.

[3] Kondolf, G.M. and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research, Vol. 29(7): 2275-2285.

[4] McRae, B.J. and J.S. Diana. 2005. Factors influencing density of age-0 brown trout and brook trout in the Au Sable River, Michigan. Transactions of the American Fisheries Society, vol. 134: 132-140.

[5] Beard, T.D. and R.F. Carline. 1991. Influence of spawning and other stream habitat features on spatial variability of wild brown trout. Transactions of the American Fisheries Society, vol. 120: 711-722.

habitat with a low percentage of fine particles in the stream substrate was a key factor influencing suitability. Spring Creek on average had 7% of the spawning substrate (i.e. redds) comprised of particles less than 0.8 mm.

The size of available streambed gravels can limit the spawning success of brown trout. The morphology of a typical brown trout redd (the area prepared by an adult brown trout for egg deposition, fertilization, and subsequent incubation and emergence) is shown in Figure 1. Gravels that are too large cannot be moved by the trout, and the pit where the eggs would be deposited cannot be constructed. An excess of fine sediments can fill in the interstitial spaces between gravels, inhibiting egg incubation and emergence by reducing water flows through the gravels which deliver dissolved oxygen to the eggs and carry off metabolic wastes. Fine sediment deposition between gravels can also block emergence of fish after hatching. An excess of fine sediments is a common problem when there is a source of fine sediment erosion from upstream sources such as agricultural runoff, road construction, streambank erosion, sediment deposition from dam construction, etc.

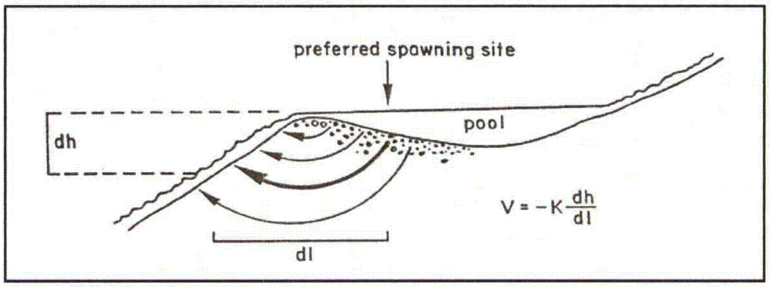
Kondolf and Wolman (1993)[1] found the median gravel size for brown trout redds in 17 studies to be about 18 mm. However, **the size range for gravels in these redds typically ranged from a 25th percentile of about 13 mm to a 75th percentile of about 22 mm**. In general, they conclude that salmonids can spawn in gravels with a median diameter up to about 10 percent of their body length.

Another important aspect of substrate for brown trout and other salmonids is that the substrate size has to be moveable by an adult trout for redd construction. There is therefore **an upper limit to the substrate sizes, which is generally about 10 percent of the adult body length**. It should be noted that an area can still be utilized for spawning if it has only one or a few larger rocks that can remain if there is adequate gravel substrate surrounding those rocks. Space needs to be available adjacent to these rocks, however, for the female to excavate the pit for egg deposition.

The absence of downwelling or upwelling currents can result in trout not spawning in areas with seemingly adequate gravel sizes (cited by Kondolf, 2000). **Upwelling currents can be important for spawning success in gaining streams** where the stream bottom surface is at or slightly below the water table. **Downwelling currents, which can also be important for spawning success**, can occur where the lower elevation of the downstream riffle creates a hydraulic gradient that induces the downward flow of water at the tail end of the pool (see Figure 2).

A significant accumulation of fine sediments (less than 1 mm) can reduce permeability of the substrate to upwelling or downwelling currents (Kondolf, 2000)[6]. The absence of these currents can lead to inadequate dissolved oxygen levels between the gravels, and inadequate exchange of metabolic wastes from the gravels to the overlying water.

Figure 2. Typical groundwater flow (downwelling) through redd gravels. From Kondolf (2000).[6]



After eggs hatch, the alevins live in the intergravel environment for a period of time, and then migrate through the gravel to the surface. Pore spaces between the gravels need to be connected for successful emergence. If fine sediments block these pore spaces, the alevins cannot reach the overlying water. Kondolf (2000)[6] cited data indicating that sediments between 1 mm and 10 mm can block these interstitial pores and inhibit trout emergence.

Kondolf (2000)[6] found that **the percentage of spawning substrate less than 1 mm in size was 14%** for a 50% fry emergence rate for salmonids, which is close to the 12% standard cited by others as the threshold for positive incubation effects. The accumulation of fine sediment particles between larger gravel particles is the primary factor influencing successful spawning of brown trout. Beard and Carline (1991) [7] **recommend that a measure of substrate embeddedness be included in habitat suitability analyses for brown trout** because of the negative impacts of the filling of interstitial spaces between gravel particles. Substrate embeddedness is defined as the degree to which fine sediments surround course substrates on the surface of a streambed (Sylte and Fischenich, 2002).[8] We have completed an extensive sediment embeddedness survey of Walker Run and its unnamed tributary to capture this key spawning habitat characteristic.

Other characteristics for suitable spawning habitat, in addition to suitable gravel composition, a low percentage of fine particles (less than 1 mm), and sufficient upwelling or downwelling to maintain interstitial pores for fry emergence and oxygen/metabolic waste exchange, include: water velocity, water depth, and cover. Brown **trout spawning typically occurs in the pool to riffle transition** (see Figure 2 for an example diagram), in an area where there is a grade change that can facilitate downwelling or upwelling currents. Riffle and pool habitats were the preferred habitat types for brown

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[6] Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society, vol. 129: 262-281.

[7] Beard, T.D. and R.F. Carline. 1991. Influence of spawning and other stream habitat features on spatial variability of wild brown trout. Transactions of the American Fisheries Society, vol. 120: 711-722.

[8] Sylte, T. and C. Fischenich. 2002. Techniques for measuring substrate embeddedness. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-36), Ecosystem Management and Restoration Research Program, U.S. Army Corps of Engineers, Research and Development Center, Vicksburg, Mississippi.

trout found by Zimmer and Power (2006)[9] in the Credit River, Ontario. They also found that upstream segments of the Credit River were preferred over downstream segments for spawning.

Zimmer and Power (2006)[9] documented water depths in brown trout redds to range from 27 to 52 cm, and water velocities to range from 23 to 50 cm/sec for the Credit River in Ontario. Beard and Carline (1991)[10] found **average water depths of 28 cm** and **average water velocities of 37 cm/sec** for brown trout in Spring Creek, central Pennsylvania. They did not find a strong correlation between redd densities and stream gradient (ibid).

Woody debris and undercut banks were the preferred types of cover for brown trout spawning areas found by Zimmer and Power (2006)[9] in the Credit River, Ontario, although the majority of spawning areas in their study had no available cover.

C. Brown Trout Habitat Criteria – Adult and Young Fish:

Beard and Carline (1991) [10] found that wild brown trout densities in Spring Creek, central Pennsylvania, were not correlated to habitat criteria such as water depth, pool area, cover, and substrate. They found that brown trout densities were poorly correlated with the habitat variables in the brown trout habitat suitability index (HIS) model. They did find, however, that **brown trout densities were correlated with redd densities,** which were strongly influenced by **spawning substrate suitability**. They concluded that brown trout do not disperse widely from their natal areas.

McRae and Diana (2005)[11] found a positive relationship between the density of juvenile brown trout and emergent vegetation. The majority of brown trout in their study of the Au Sable River, Michigan, were collected from vegetated habitats. In addition to **cover from predatory pressures**, macroinvertebrate production is typically higher in vegetated habitats in this river and thereby provides a critical food base for the trout. Also important to brown trout survival in the summer are suitable water temperatures, indicating that **canopy cover is critical for summer trout survival**.

Stoneman and Jones (2000)[12] found **water temperature to be the most important factor** influencing trout biomass. Other important predictive habitat factors influencing trout biomass were the **percentage of pool habitats**, substrate size, and cover.

The importance of water temperature during summer, spawning substrate, cover, and percentage of pool habitat to brown trout populations are therefore the focus for enhancing Walker Run for juvenile and adult brown trout.

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[9] Zimmer, M.P. and M. Power. 2006. Brown trout spawning habitat selection preferences and redd characteristics in the Credit River, Ontario. Journal of Fish Biology, vol. 68: 1333-1346.

[10] Beard, T.D. and R.F. Carline. 1991. Influence of spawning and other stream habitat features on spatial variability of wild brown trout. Transactions of the American Fisheries Society, vol. 120: 711-722.

[11] McRae, B.J. and J.S. Diana. 2005. Factors influencing density of age-0 brown trout and brook trout in the Au Sable River, Michigan. Transactions of the American Fisheries Society, vol. 134: 132-140.

[12] Stoneman, C.L. and M.L. Jones. 2000. The influence of habitat features on the biomass and distribution of three species of southern Ontario stream salmonines. Transactions of the American Fisheries Society, vol. 129: 639-657.

D. Walker Run Brown Trout Habitat - Existing Characteristics:

The spring 2009 fisheries and habitat assessment surveys provide important information on the trout distribution in Walker Run and the habitat quality. Six reaches were surveyed, shown in Figure 3. Three of those reaches (1 through 3) were upstream of Beach Grove Road, and are outside of the proposed stream restoration segment. The next two reaches (4 and 5) are within the proposed stream restoration segment, while reach 6 is downstream of the proposed stream restoration segment.

The number of collected brown trout decreased as you move downstream in Walker Run (Figure 4). The one exception to this decreasing trend is reach 5, where 17 trout were collected from the upstream end of that reach.

The number of young brown trout, less than 100 mm, also decreased as you move downstream in Walker Run (Figure 5). This decreasing trend also had an exception in reach 5, where 5 trout less than 100 mm were collected from the upstream end of that reach.

The habitat assessment results show two different stream segments in Walker Run. The segment of Walker Run upstream of Beach Grove Road has optimal or near-optimal habitat quality (Table 1), while the downstream segment (reaches 4 through 6) has marginal habitat quality. With the exceptions of the trout collected in the upstream end of reach 5, the trout collection results corroborate the habitat assessment results.

Significant habitat quality differences between these two stream segments center on significantly higher embeddedness, greater sediment deposition, poor bank stability, poor vegetative protection, and narrow riparian vegetation widths in the downstream section (Table 1). These marginal to poor habitat characteristics are important to brown trout spawning, particularly substrate embeddedness and sediment deposition. Poor bank stability can also be a source of sediment deposition in the stream.

A sediment embeddedness and substrate characterization survey was conducted at 7 locations on Walker Run in the fall 2009. Seven transects, across the stream and perpendicular to stream flow, were surveyed at each location. The seven transects were located at 25 ft increments over a 150-ft stretch of stream at each location. Nine survey points were located across each transect, for a total of 441 sediment embeddedness and substrate characterization survey points. Survey results for sediment embeddedness are summarized in Table 2. Survey results for substrate characterizations are also summarized in Table 2. Only two of the seven Walker Run stream segments had embeddedness ratings greater than 3 (indicating relatively low embeddedness). These two segments were located upstream and immediately downstream of the Beach Grove Road crossing with Walker Run. The remainder of the Walker Run stream segments had poor sediment embeddedness, and high percentages of fine particles. The average gravel component of the stream substrate was also below 10 percent at these seven downstream stream segments.

These existing habitat characteristics, particularly sediment embeddedness and stream substrate composition, for the segment of Walker Run downstream of Beach Grove Road document the need for trout habitat enhancement through stream restoration. Sediment embeddedness, sediment deposition,

spawning gravels, pool habitats, cover, riparian zones, and canopy cover all need to be addressed in the trout habitat enhancement plan.

E. Brown Trout Habitat Enhancement Recommendations:

The existing habitat issues of sediment embeddedness, sediment deposition, inadequate spawning gravels, scarce pool habitats, inadequate cover, narrow riparian zones, and open to partially open canopy cover all need to be addressed in the trout habitat enhancement plan for Walker Run. The segment of Walker Run targeted for habitat enhancements extends from the Beach Grove crossing to the lower Market Street crossing. Reference to the stream restoration conceptual design plans provides details on how these habitat enhancements will be implemented.

The analysis in this plan indicates that spawning gravels of an appropriate size range, coupled with low substrate embeddedness and adequate upwelling or downwelling, are key spawning habitat characteristics for wild brown trout populations. The findings of McRae and Diana (2005)[13] and Beard and Carline (1991)[14] document that suitable spawning habitat is the most critical predictor of wild brown trout spawning success and population densities. The presence of adequate cover, pool habitats, and canopy cover in riparian zones are habitat characteristics that are presently lacking in the restoration segment of Walker Run. Additionally, streambank erosion is significant in much of the restoration segment of Walker Run, and causes the movement of sediment through the stream and temporary deposition in some areas of the stream.

Restoration and Creation of Spawning Habitat. A cornerstone to this trout enhancement plan for Walker Run is the expansion of appropriate spawning areas. The stream restoration conceptual design has divided the stream into upper and lower restoration reaches. The upper restoration reach extends from the Beach Grove Road crossing downstream to the first Market Street bridge (see conceptual restoration design drawings). The downstream restoration reach begins at that point and extends downstream to the beginning of the existing forest, which is just upstream of the existing beaver dam. The beaver dam is to be removed in the stream restoration project.

[13] McRae, B.J. and J.S. Diana. 2005. Factors influencing density of age-0 brown trout and brook trout in the Au Sable River, Michigan. Transactions of the American Fisheries Society, vol. 134: 132-140.
[14] Beard, T.D. and R.F. Carline. 1991. Influence of spawning and other stream habitat features on spatial variability of wild brown trout. Transactions of the American Fisheries Society, vol. 120: 711-722.

Figure 3. Location of fish sampling and habitat assessment reaches (sites) on Walker Run for surveys completed in the spring 2009.

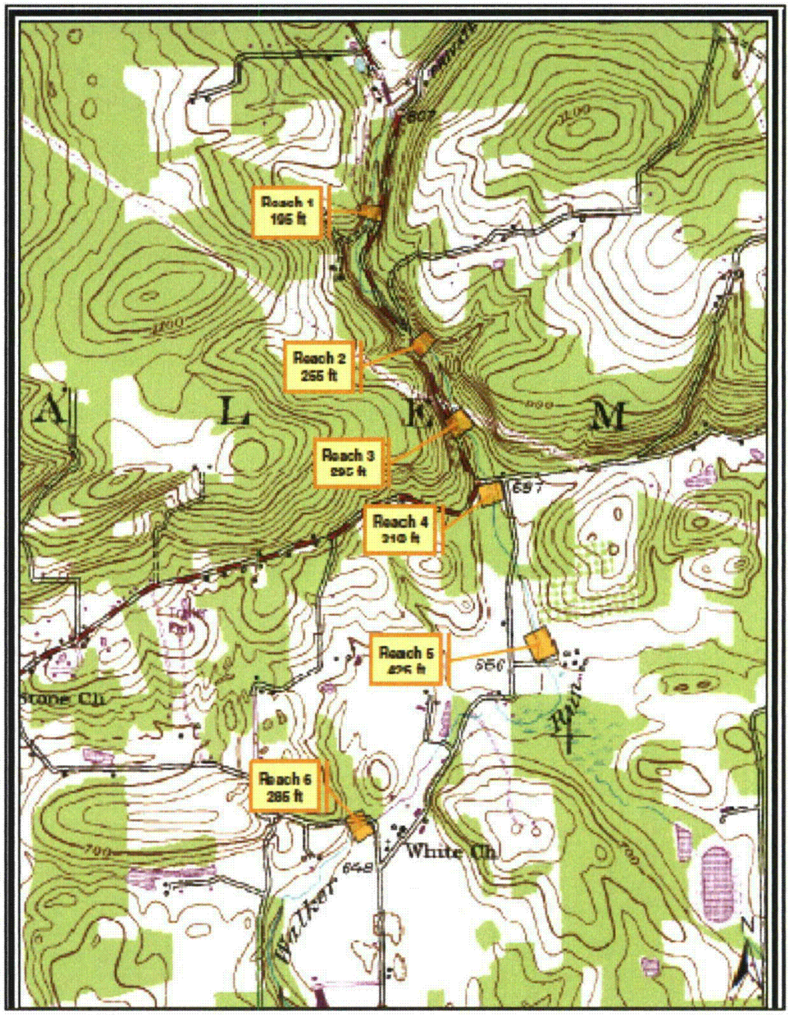

Figure 4. Brown trout captured during March 2009 electrofishing survey of Walker Run. Site 1 is the most upstream site, at 0 miles.

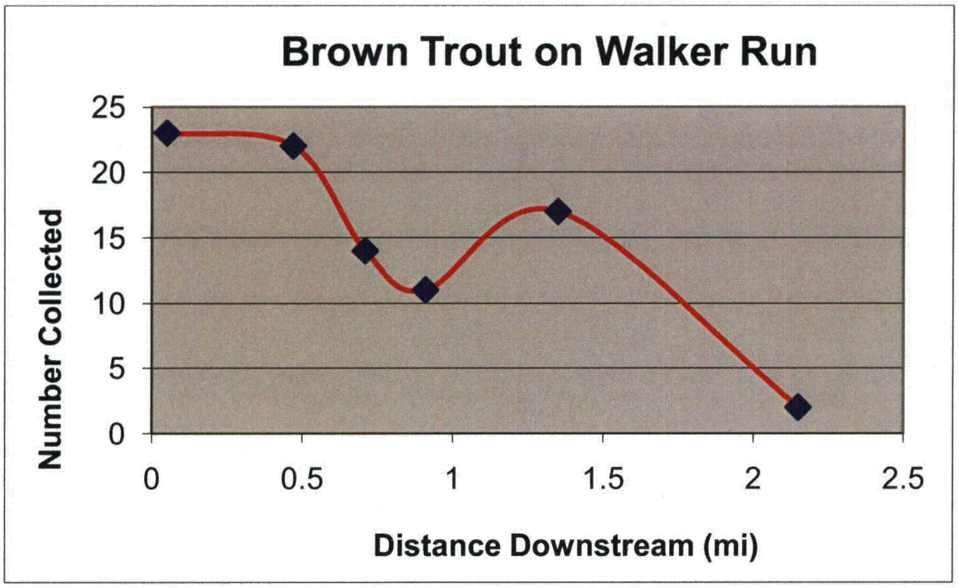

Figure 5. Brown trout less than 100 mm captured during March 2009 electrofishing survey of Walker Run. Site 1 is the most upstream site, at 0 miles.

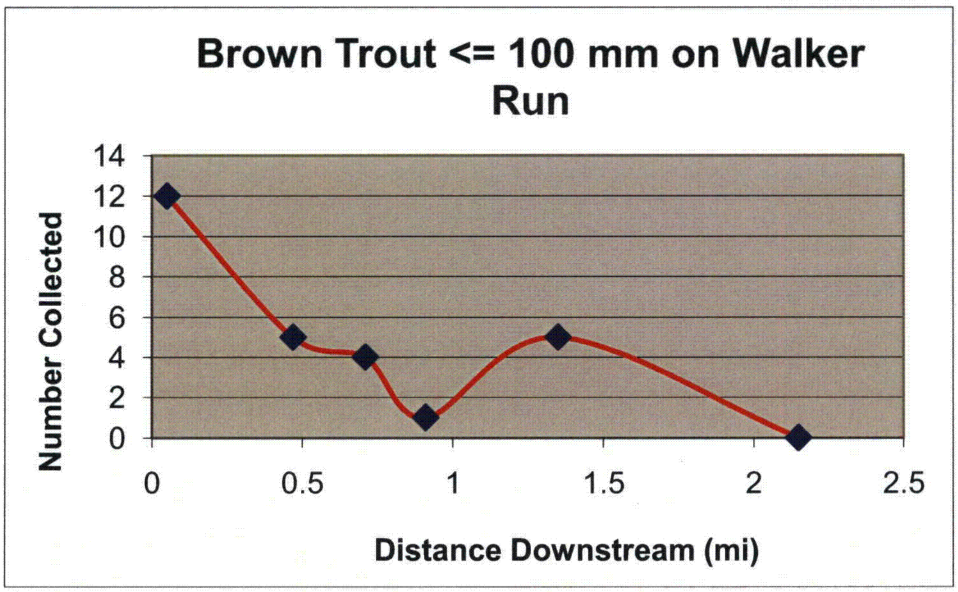

Table 1. Habitat assessments on six reaches of Walker Run.

Table 5. Habitat assessments of Walker Run using EPA's RBP parameters and characterizations.

Habitat Category	REACH 1	REACH 2	REACH 3
Epifaunal substrate / available cover	14	12	13
Embeddedness / Pool Substrate (LG)	15	12	14
Velocity / Depth Regime / Pool Variability (LG)	17	14	14
Sediment deposition	16	12	13
Channel Flow Status	12	11	13
Channel alteration	20	20	20
Frequency of Riffles	14	18	14
Bank stability	19	18	15
Vegetative protection	18	18	20
Riparian vegetation zone width	20	20	15
Average Score:	**17**	**16**	**15**

Habitat Category	REACH 4	REACH 5	REACH 6	Scoring Descriptions
Epifaunal substrate / available cover	12	10	9	
Embeddedness / Pool Substrate (LG)	9	7	7	
Velocity / Depth Regime / Pool Variability (LG)	9	6	7	
Sediment deposition	12	7	8	
Channel Flow Status	11	18	11	Optimal: 20 to 16
Channel alteration	17	6	13	Suboptimal: 15 to 11
Frequency of Riffles / Channel Sinuosity (LG)	7	3	11	Marginal: 10 to 6
Bank stability	5	5	4	Poor: 5 to 0
Vegetative protection	7	7	5	
Riparian vegetation zone width	5	6	8	
Average Score:	**9**	**8**	**8**	

LG denotes low gradient streams (sites 4 through 6)

Figure 6. Location of stream embeddedness survey reaches on Walker Run for surveys completed in the fall 2009.

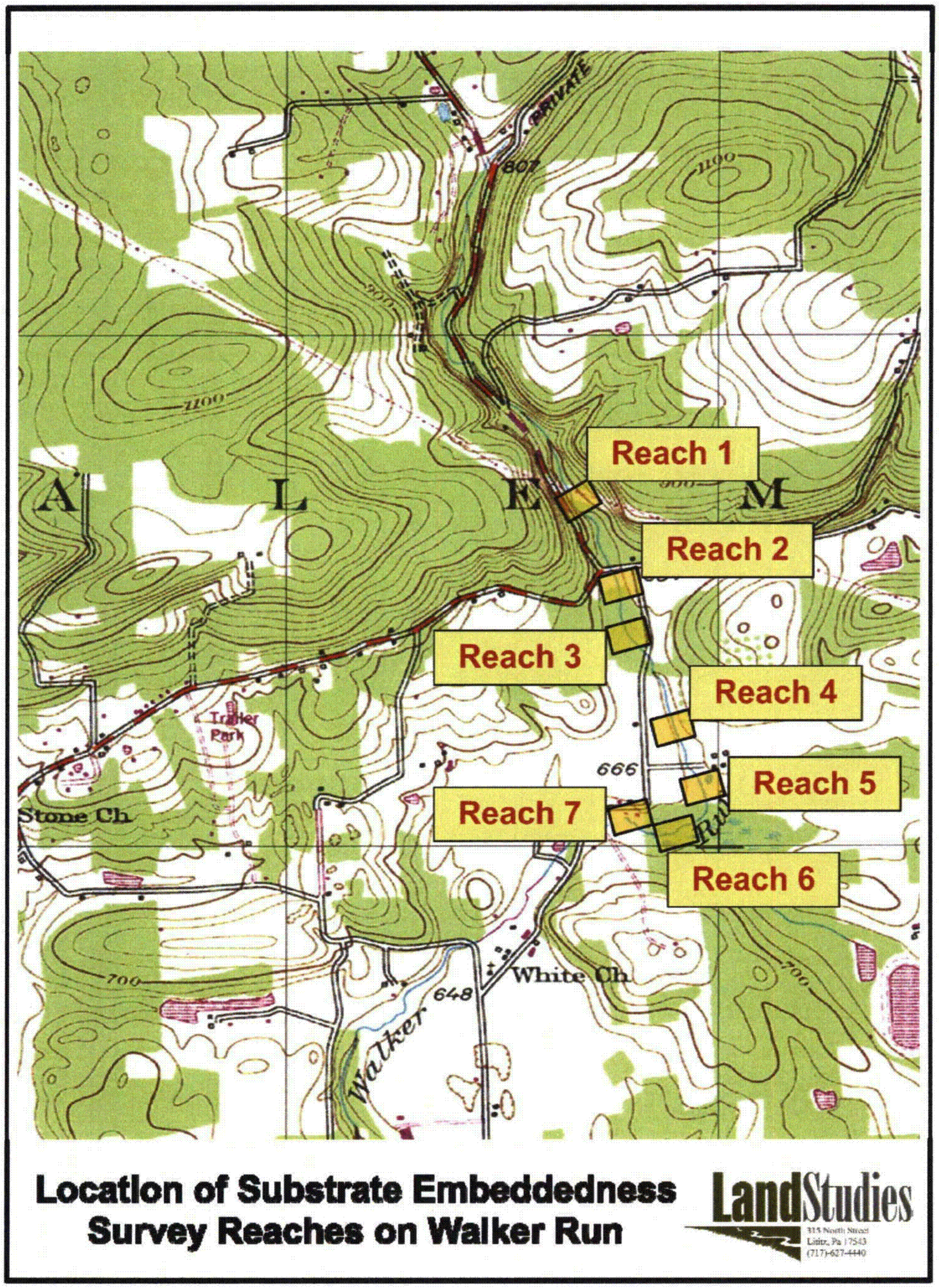

Table 2a. Sediment embeddedness and stream substrate composition survey results (page 1 of 2).

Stream Station	Transect No.	Stream Width (ft)	Average Water Depth (ft)	Habitat Type	Dominant Substrate Type	Median Embeddedness (%)	Transect Embeddedness Rating	Percent Fines*	Median Percent Silt and Clay	Median Percent Sand (< 3/32")	Median Percent Gravel (3/32" to 2.5")	Median Percent Cobble (2.5" to 10")	Median Percent Rubble (10" to 12")	Median Percent Boulder (> 12")
REACH 1 - UPSTREAM OF BEACH GROVE ROAD														
S1	TA	10.5	0.15	Riffle	cobble/gravel	18.0	4.3	7.5%	0.0%	15.0%	25.0%	60.0%	0.0%	0.0%
S1	TB	13.6	0.24	Riffle	cobble/gravel	30.0	3.7	17.5%	10.0%	15.0%	30.0%	40.0%	0.0%	0.0%
S1	TC	19.5	0.24	Riffle	cobble/gravel	25.0	3.9	15.0%	5.0%	20.0%	40.0%	40.0%	0.0%	0.0%
S1	TD	10.3	0.29	Riffle	gravel/cobble	20.0	4.2	15.0%	5.0%	20.0%	25.0%	20.0%	0.0%	0.0%
S1	TE	9.2	0.43	Shallow Pool	cobble/sand	60.0	2.5	17.5%	5.0%	25.0%	10.0%	40.0%	0.0%	0.0%
S1	TF	8.1	0.20	Riffle	gravel/cobble	15.0	4.5	7.5%	0.0%	15.0%	40.0%	30.0%	0.0%	0.0%
S1	TG	7.8	0.32	Glide	cobble/gravel	30.0	3.7	30.0%	20.0%	20.0%	20.0%	45.0%	0.0%	0.0%
S1	**7**	**11.3**	**0.27**	**Riffle**	**cobble/gravel**	**28.3**	**3.8**	**15.7%**	**6.4%**	**18.6%**	**27.1%**	**39.3%**	**0.0%**	**0.0%**
REACH 2 - JUST DOWNSTREAM OF BEACH GROVE ROAD (Restoration Site 5)														
S2	TA	11.0	0.16	Riffle	cobble/gravel	35.0	3.5	40.0%	32.5%	15.0%	35.0%	40.0%	0.0%	0.0%
S2	TB	8.5	0.13	Riffle	gravel/cobble	30.0	3.7	35.0%	25.0%	20.0%	50.0%	30.0%	0.0%	0.0%
S2	TC	6.0	0.24	Riffle	gravel/cobble	40.0	3.4	15.0%	0.0%	30.0%	35.0%	30.0%	0.0%	0.0%
S2	TD	5.8	0.38	Riffle	cobble/sand	50.0	2.9	17.5%	0.0%	35.0%	15.0%	30.0%	0.0%	0.0%
S2	TE	7.0	0.34	Riffle	gravel/cobble	45.0	3.2	16.3%	5.0%	22.5%	37.5%	30.0%	0.0%	0.0%
S2	TF	5.0	0.26	Riffle	gravel/cobble	22.5	4.1	7.5%	0.0%	15.0%	50.0%	25.0%	0.0%	0.0%
S2	TG	6.4	0.36	Shallow Pool	silt/sand	75.0	1.9	62.5%	50.0%	25.0%	5.0%	15.0%	0.0%	0.0%
S2	**7**	**7.1**	**0.27**	**Riffle**	**gravel/cobble**	**42.5**	**3.2**	**27.7%**	**16.1%**	**23.2%**	**32.5%**	**28.6%**	**0.0%**	**0.0%**
REACH 3 - UPSTREAM OF UPPER MARKET STREET CROSSING - WETLANDS (Restoration Site 5)														
S3	TA	8.5	0.15	Shallow Pool	sand/silt	90.0	1.4	57.5%	30.0%	55.0%	10.0%	0.0%	0.0%	0.0%
S3	TB	7.4	0.19	Run	sand/gravel	70.0	1.7	30.0%	10.0%	40.0%	25.0%	0.0%	0.0%	0.0%
S3	TC	7.3	0.55	Shallow Pool	sand	85.0	1.5	20.0%	5.0%	30.0%	5.0%	0.0%	15.0%	0.0%
S3	TD	8.3	0.63	Pool	rubble/silt	100.0	1.0	10.0%	10.0%	0.0%	0.0%	0.0%	90.0%	0.0%
S3	TE	10.2	0.66	Shallow Pool	silt	100.0	1.0	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
S3	TF	8.2	0.44	Shallow Pool	silt/sand	100.0	1.0	80.0%	70.0%	20.0%	10.0%	0.0%	0.0%	0.0%
S3	TG	6.5	0.75	Shallow Pool	silt	100.0	1.0	70.0%	70.0%	0.0%	0.0%	0.0%	0.0%	0.0%
S3	**7**	**8.1**	**0.48**	**Shallow Pool**	**sand/silt**	**92.1**	**1.2**	**52.5%**	**42.1%**	**20.7%**	**7.1%**	**0.0%**	**15.0%**	**0.0%**
REACH 7 - UPSTREAM OF LOWER MARKET STREET CROSSING (Restoration Site 3)														
S4	TA	7.7	0.24	Riffle	rubble/cobble	70.0	2.2	11.3%	10.0%	2.5%	2.5%	12.5%	20.0%	0.0%
S4	TB	7.9	0.32	Run	silt/cobble	100.0	1.0	60.0%	50.0%	20.0%	0.0%	25.0%	0.0%	0.0%
S4	TC	7.5	0.44	Run	cobble/sand	100.0	1.0	22.5%	15.0%	15.0%	0.0%	20.0%	0.0%	0.0%
S4	TD	10.3	0.35	Run	sand/silt	100.0	1.0	47.5%	30.0%	35.0%	0.0%	0.0%	0.0%	0.0%
S4	TE	8.3	0.45	Run	cobble/sand	85.0	1.5	20.0%	5.0%	30.0%	0.0%	37.5%	15.0%	0.0%
S4	TF	12.1	0.43	Shallow Pool	sand/rubble	100.0	1.0	42.5%	15.0%	55.0%	0.0%	0.0%	20.0%	0.0%
S4	TG	10.5	0.78	Pool	cobble/sand	90.0	1.4	27.5%	20.0%	15.0%	0.0%	40.0%	0.0%	0.0%
S4	**7**	**9.2**	**0.43**	**Run**	**cobble/sand**	**92.1**	**1.3**	**33.0%**	**20.7%**	**24.6%**	**0.4%**	**19.3%**	**7.9%**	**0.0%**
REACH 6 - FORESTED AREA UPSTREAM OF S4 (Restoration Site 4)														
S5	TA	9.1	0.27	Run	sand/silt	100.0	1.0	70.0%	40.0%	60.0%	0.0%	0.0%	0.0%	0.0%
S5	TB	9.5	0.35	Shallow Pool	sand/silt	100.0	1.0	70.0%	40.0%	60.0%	0.0%	0.0%	0.0%	0.0%
S5	TC	9.5	0.32	Shallow Pool	sand/silt	100.0	1.0	65.0%	30.0%	70.0%	0.0%	0.0%	0.0%	0.0%
S5	TD	8.2	0.36	Shallow Pool	sand/silt	100.0	1.0	70.0%	40.0%	60.0%	0.0%	0.0%	0.0%	0.0%
S5	TE	8.6	0.41	Shallow Pool	sand/silt	100.0	1.0	65.0%	30.0%	70.0%	0.0%	0.0%	0.0%	0.0%
S5	TF	13.0	0.33	Shallow Pool	sand/silt	100.0	1.0	67.5%	35.0%	65.0%	0.0%	0.0%	0.0%	0.0%
S5	TG	9.0	0.26	Shallow Pool	sand/silt	100.0	1.0	62.5%	25.0%	75.0%	0.0%	0.0%	0.0%	0.0%
S5	**7**	**9.6**	**0.33**	**Shallow Pool**	**sand/silt**	**100.0**	**1.0**	**67.1%**	**34.3%**	**65.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Table 2b. Sediment embeddedness and stream substrate composition survey results (page 2 of 2).

Stream Station	Transect No.	Stream Width (ft)	Average Water Depth (ft)	Habitat Type	Dominant Substrate Type	Median Embeddedness (%)	Transect Embeddedness Rating	Percent Fines*	Median Percent Silt and Clay	Median Percent Sand (< 3/32")	Median Percent Gravel (3/32" to 2.5")	Median Percent Cobble (2.5" to 10")	Median Percent Rubble (10" to 12")	Median Percent Boulder (> 12")
REACH 5 - BACKWATER SEGMENT ABOVE BEAVER POND (Restoration Site 4)														
S6	TA	15.0	2.26	Pool/Backwater	silt/sand	100.0	1.0	85.0%	70.0%	30.0%	0.0%	0.0%	0.0%	0.0%
S6	TB	14.5	1.91	Pool/Backwater	silt/sand	100.0	1.0	85.0%	70.0%	30.0%	0.0%	0.0%	0.0%	0.0%
S6	TC	21.5	1.73	Pool/Backwater	silt/sand	100.0	1.0	85.0%	70.0%	30.0%	0.0%	0.0%	0.0%	0.0%
S6	TD	16.0	2.46	Pool/Backwater	silt/sand	100.0	1.0	95.0%	90.0%	10.0%	0.0%	0.0%	0.0%	0.0%
S6	TE	14.5	2.31	Pool/Backwater	silt	100.0	1.0	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
S6	TF	16.0	2.39	Pool/Backwater	silt	100.0	1.0	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
S6	TG	15.4	2.32	Pool/Backwater	silt/sand	100.0	1.0	95.0%	90.0%	10.0%	0.0%	0.0%	0.0%	0.0%
S6	**7**	**16.1**	**2.20**	**Pool/Backwater**	**silt/sand**	**100.0**	**1.0**	**92.1%**	**84.3%**	**15.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
REACH 4 - CHANNELIZED SEGMENT ABOVE ACCESS ROAD (Restoration Site 4)														
S7	TA	7.8	0.79	Pool/Backwater	sand/silt	100.0	1.0	75.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%
S7	TB	8.9	0.73	Run	sand/silt	100.0	1.0	50.0%	30.0%	40.0%	0.0%	0.0%	0.0%	0.0%
S7	TC	7.4	0.46	Run	sand/silt	100.0	1.0	50.0%	30.0%	40.0%	0.0%	0.0%	35.0%	0.0%
S7	TD	5.9	0.34	Run	sand/gravel	72.5	2.1	25.0%	0.0%	50.0%	12.5%	0.0%	0.0%	0.0%
S7	TE	4.4	0.61	Run	sand/gravel	100.0	1.0	36.3%	5.0%	62.5%	10.0%	0.0%	5.0%	0.0%
S7	TF	4.3	0.45	Riffle	sand/gravel	87.5	1.4	33.8%	2.5%	62.5%	15.0%	10.0%	7.5%	0.0%
S7	TG	4.5	0.20	Riffle	sand/gravel	70.0	2.2	22.5%	0.0%	45.0%	30.0%	20.0%	0.0%	0.0%
S7	**7**	**6.2**	**0.51**	**Run**	**sand/silt/gravel**	**90.0**	**1.4**	**41.8%**	**16.8%**	**50.0%**	**9.6%**	**4.3%**	**6.8%**	**0.0%**

** Percent fines (particles < 1.0 mm) calculated as the sum of the median percent silt and clay and 1/2 the median percent sand.*

The upper stream segment is targeted as the primary focus area for enhancing trout spawning habitat. This is based on the extent of existing riparian forest in this segment. Spawning areas will be established using a wider width to depth ratio in the stream channel (averaging 12 to 16 ft wide) with water depths averaging 0.6 to 1.1 ft deep. These water depths are based on reference reaches for Walker Run and existing trout spawning habitat upstream of Beach Grove Road. In the literature review for this study, Zimmer and Power (2006)[15] documented water depths in brown trout redds to range from 27 to 52 cm, and water velocities to range from 23 to 50 cm/sec for the Credit River in Ontario. Beard and Carline (1991)[16] found average water depths of 28 cm and average water velocities of 37 cm/sec for brown trout in Spring Creek, central Pennsylvania. The water depths for spawning areas in this restoration project correspond to these literature findings.

Kondolf and Wolman (1993)[17] found the median gravel size for brown trout redds in 17 studies to be about 18 mm. However, the size range for gravels in these redds typically ranged from a 25th percentile of about 13 mm to a 75th percentile of about 22 mm. We recommend that the 25th to 75th percentiles for imported spawning gravels for Walker Run be 10 mm to 20 mm in length. Median body length of adult trout captured in Walker Run in spring 2009 was 24.0 cm, with the minimum adult body length for spawners assumed to be 20 cm. Consequently the upper size range for imported gravel for restored or created spawning beds should be 2.4 cm (10 percent of the body length). We therefore recommend that imported gravel for spawning beds have an upper limit of 1 inch. Given the trout sizes in Walker Run, the 25th to 75th percentiles for imported spawning gravels has been slightly lowered from the Kondolf and Wolman (1993) findings.

The absence of downwelling or upwelling currents can result in trout not spawning in areas with seemingly adequate gravel sizes (cited by Kondolf, 2000[18]). Upwelling currents can be important for spawning success in gaining streams where the stream bottom surface is at or slightly below the water table. Downwelling currents, which can also be important for spawning success, can occur where the lower elevation of the downstream riffle creates a hydraulic gradient that induces the downward flow of water at the tail end of the pool. Spawning areas in this upper restoration reach will be designed to reflect the intergravel movement of water as illustrated in Figure 2.

Reduction in Sediment Deposition and Sediment Embeddedness. Kondolf (2000)[19] found that the percentage of spawning substrate less than 1 mm in size was 14% for a 50% fry emergence rate for salmonids, which is close to the 12% standard cited by others as the threshold for positive incubation effects. The accumulation of fine sediment particles between larger gravel particles is the primary factor

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[15] Zimmer, M.P. and M. Power. 2006. Brown trout spawning habitat selection preferences and redd characteristics in the Credit River, Ontario. Journal of Fish Biology, vol. 68: 1333-1346.
[16] Beard, T.D. and R.F. Carline. 1991. Influence of spawning and other stream habitat features on spatial variability of wild brown trout. Transactions of the American Fisheries Society, vol. 120: 711-722.
[17] Kondolf, G.M. and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research, Vol. 29(7): 2275-2285.
[18] Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society, vol. 129: 262-281.
[19] Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society, vol. 129: 262-281.

influencing successful spawning of brown trout. Floodplain restoration in both the upper and lower restoration reaches of Walker Run will reduce streambank erosion and the deposition of fine sands among spawning gravels. This should reduce substrate embeddedness and help assure the quality of imported gravels for enhancing spawning habitat in the upper restoration reach.

Streambank erosion is currently significant in the lower restoration reach as well. Floodplain restoration will reduce erosion and transport of fine sands and silts from this reach.

Pool and Cover Habitat. Riffle and pool habitats were the preferred habitat types for brown trout found by Zimmer and Power (2006)[20] in the Credit River, Ontario. Additionally, woody debris and undercut banks were the preferred types of cover for brown trout spawning areas found by Zimmer and Power (2006), although the majority of spawning areas in their study had no available cover. McRae and Diana (2005)[21] found a positive relationship between the density of juvenile brown trout and emergent vegetation. The majority of brown trout in their study of the Au Sable River, Michigan, were collected from vegetated habitats. In addition to cover from predatory pressures, macroinvertebrate production is typically higher in vegetated habitats in this river and thereby provides a critical food base for the trout.

We have utilized these findings to increase the area of habitat, particularly in the lower restoration reach, to increase trout habitat and cover. Stream channels in the lower reach will have a narrower width to depth ratio (averaging 8 to 12 ft wide) with water depths averaging 0.8 to 1.3 ft deep. These narrower channels will be designed with undercut banks and overhanging vegetation to provide shallow pool habitat with significant cover and channel-edge canopy. A higher sinuosity will be incorporated in the lower restoration reach, further providing for undercut bank habitat with vegetative cover.

The existing beaver dam will be removed with the stream restoration, so that the significant existing backwater from that dam will be eliminated and trout habitat with suitable substrate for macroinvertebrate food production will be established.

Trout habitat structures will be installed in both the upper and lower restoration reaches. Examples of anticipated fish habitat structures are provided in the concept restoration plan for Walker Run. Habitat structures to be installed include root wad deflectors, mud sills, log vane deflectors, rock vane deflectors, and rock cross vanes. These habitat structures are critical features in that they provide cover for juvenile and adult brown trout. It was clear from the March 2009 fisheries electrofishing survey of Walker Run that the majority of the juvenile and adult trout were concentrated in a few areas with adequate water depth and cover. These habitat structures, coupled with the stream channel design criteria for the two restoration reaches, will significantly enhance the cover and habitat available for brown trout in this segment of Walker Run.

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[20] Zimmer, M.P. and M. Power. 2006. Brown trout spawning habitat selection preferences and redd characteristics in the Credit River, Ontario. Journal of Fish Biology, vol. 68: 1333-1346.
[21] McRae, B.J. and J.S. Diana. 2005. Factors influencing density of age-0 brown trout and brook trout in the Au Sable River, Michigan. Transactions of the American Fisheries Society, vol. 134: 132-140.

Riparian Zones and Canopy Cover. Critical to brown trout survival in the summer are suitable water temperatures, indicating that canopy cover is critical for summer trout survival. Stoneman and Jones (2000)[22] found water temperature to be the most important factor influencing trout biomass. Significant canopy cover for Walker Run is crucial to maintaining the wild trout population. The presence of forested canopy in the upper restoration reach was a deciding factor for targeting that area for enhancing trout spawning habitat.

We will expand the forested tree canopy in the upper restoration reach through enhanced and restored forested wetlands, while the lower restoration reach will be dominated by emergent wetlands with fewer trees. There will be stream-edge canopy cover in the lower restoration reach from overhanging vegetation. The most downstream segment of the lower restoration reach will be a combination of forested and emergent wetlands, thereby providing more canopy cover there for summer temperature moderation.

F. Brown Trout Re-Population Plan for Walker Run:

A primary goal of the Walker Run stream and floodplain restoration project is to increase and improve habitat for wild brown trout in a 1.1-mile section of the stream. Long term, these stream improvements may result in greater trout population densities. The habitat recommendations discussed in the previous section will be implemented to provide suitable trout habitat for various life stages. The grade, shape, and sinuosity of the designed stream channel will stabilize streambanks and reduce erosion and substrate embeddedness. Native vegetation will be planted within the floodplain providing greater canopy cover to shade the stream and instream fish habitat structures will also be incorporated into the design.

There are several approaches regarding the brown trout repopulation of the restored section of Walker Run. Over time, wild brown trout will likely repopulate this stream section on their own. Additional approaches include the following:

- Natural redistribution of wild brown trout into the restored section from upstream and downstream areas,
- Replacement of wild brown trout by capturing the trout in the project section of stream just prior to restoration, then restocking those same trout into the restored section of stream,
- Assisted redistribution by capturing wild brown trout from upstream and downstream sections of stream and stocking them in the restored section of stream,
- Egg planting efforts, utilizing brood stock captured from Walker Run and similar local streams, for the restored section of stream,
- Fingerling stocking efforts, utilizing brood stock captured from Walker Run and similar local streams, for the restored section of stream.

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[22] Stoneman, C.L. and M.L. Jones. 2000. The influence of habitat features on the biomass and distribution of three species of southern Ontario stream salmonines. Transactions of the American Fisheries Society, vol. 129: 639-657.

Our recommendations are to utilize (1) natural redistribution, (2) replacement, and (3) assisted redistribution for the repopulation of the restored section of Walker Run. Egg planting and fingerling stocking are recommended to be used only if the monitoring (see next section) indicates that the three preferred approaches have been unsuccessful. There are higher economic costs for egg planting and fingerling stocking efforts, as well as genetic and competition risks associated with using hatchery stocks. Utilizing brood stock from Walker Run or other local wild brown trout streams would minimize genetic concerns, but could have an impact on the extant wild brown trout populations in the streams supplying the brood stock.

Replacement Approach. Before construction commences, wild brown trout within the project restoration reach will be collected by electroshocking and relocated to several deep pools north of Beach Grove Road. The large pools near Reach 1 and Reach 2 (see Figure 8) would be good locations to temporarily relocate these captured brown trout. It is expected that restoration activities will be completed in several weeks, so that the relocated brown trout could be recaptured and moved to the restored section of Walker Run shortly thereafter. After release, monitoring will begin according to the schedule listed in the next section of this report.

Assisted Redistribution. After restoration activities are completed on Walker Run, wild brown trout can be collected by electroshocking from upstream and downstream sections of Walker Run and relocated into the restored section of stream. We recommend that a cross-section of brown trout sizes be relocated into the restored section of stream. The number of trout to be redistributed will be determined based on population surveys of the upstream and downstream sections of Walker Run. Numbers will be determined so that impacts to populations in the upstream and downstream sections are minimal. The target number of redistributed trout will also be driven by the number of trout moved to the restored section of stream through the Replacement Approach.

Egg Planting and Fingerling Stocking Efforts. If stocking is considered necessary to reintroduce trout to the restored stream reach, the primary goal should be to supplement Walker Run's existing trout population while still preserving the genetic characteristics of the natural trout population.

Wunderlich and Pantaleo (1995)[23] found that "genetically related behavioral and physiological traits of fish have been altered within the first generation of hatchery experience, and these can cause poor performance in the natural environment and ultimately decrease survival and fitness of the stocked population." Further, they found "there is uncertainty regarding the degree to which behavior learned in the hatchery predisposes hatchery fish to higher risks of predation, lower feeding efficiency, or suboptimal habitat use. These negative characteristics can be passed to the native trout population through interbreeding" (Wunderlich & Pantaleo, 1995).

To maintain genetic character the ideal choice for brood stock is from the existing wild population (Wunderlich and Pantaleo, 1995). Brood stock from Walker Run could be used, with care, to avoid negative impacts to population levels in the stream and to minimize the chance for inbreeding effects.

[23] Wunderlich, R. and C. Pantaleo. 1995. A review of methods to re-introduce anadromous fish in the Elwha River. U.S. Fish and Wildlife Service. Found at: http://www.fws.gov/wafwo/fisheries/Publications/FP210.pdf

Project Number	Drawn By	Checked By	Date	Scale		Sheet Number
E-728-L8	JS	JS	December 2009	1" = 800'	PLAN SHEET	1 OF 1

Revisions No.	Date	Description
X	X	X

Project:
Bell Bend Nuclear Power Plant
Salem Township
Luzerne County, PA

Map:
Figure 7
Pressure Transducer Location Map

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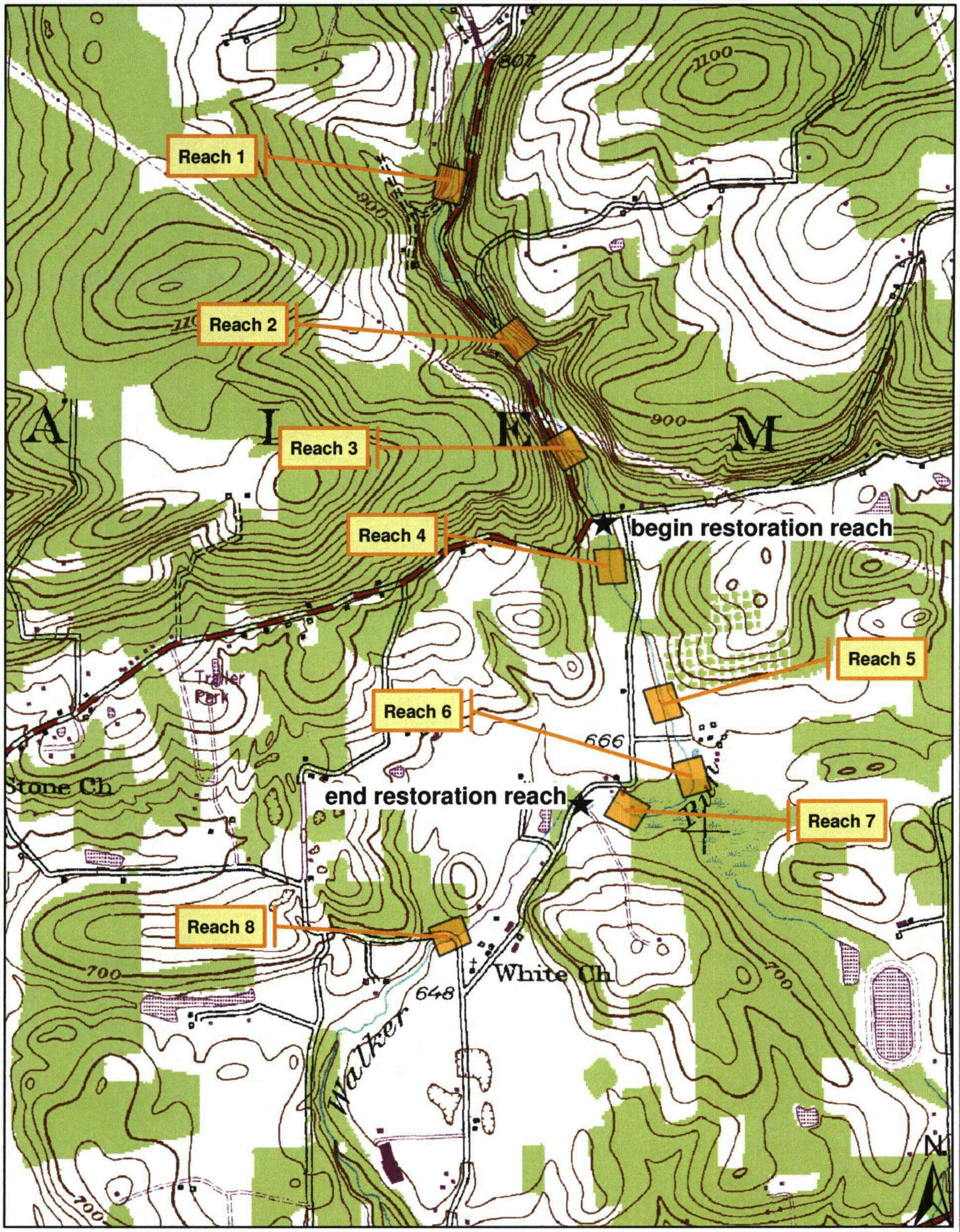

Figure 8: Monitoring Locations on Walker Run

Berwick USGS Topographic Quadrangle

1 inch = 1,500 feet

0 750 1,500 Feet

LandStudies

Wild brown trout from nearby populations that are living in a similar environment could also be used for the brood stock.

There are actions hatcheries can take to minimize effects on local populations. Wunderlich and Pantaleo (1995)[24] recommend the following be implemented to develop the brood stock that supplies the eggs and/or fingerlings:

- An adequate number of brood stock must be available to ensure that the genetic diversity is passed to offspring.
- A 1:1 male to female ratio should be followed to minimize inbreeding.
- Mating should occur randomly.
- Collect 25% or less of the population for the brood stock program to avoid adverse affects to the native population.
- Sample the entire stream for collecting brood stock without regard to sex, age, and other characteristics.
- Only keep the brood stock for one generation in order to minimize the selection for negative genetic characteristics.

In addition to genetics, the size and density of stocked trout and timing of release are important aspects to consider (Wunderlich and Pantaleo, 1995). Minimizing competition between the stocked and wild trout is essential. It is documented that stocked fish larger and further along in development than the wild fish have been known to outcompete and prey upon the wild trout population (Wunderlich and Pantaleo, 1995). On the other hand, stocked trout can be genetically deficient for survival in the wild reducing chances of continued existence and reproduction. Stocked trout can also be negatively impacted by the stress of transport from the hatchery to the stream. Other risks involving stocked trout include the possibility of introducing pathogens to the wild population (Wunderlich and Pantaleo, 1995).

Trout can be stocked as smolts or fingerlings. The advantage of stocking fingerlings as opposed to older fish include increased natural selection, sufficient time for imprinting, a larger gene pool size (smaller fish size means more can be released), and lower cost as a result of less time reared in the hatchery (Wunderlich and Pantaleo, 1995).

There are advantages to stocking eggs rather than fingerlings (Wunderlich and Pantaleo (1995). Stocking eggs eliminates the stress of transport and release on the fish, has potentially low maintenance and costs, potential for high survival rates, and the timing of emergence and behavior is more in tune with natural populations. There are numerous apparatus designed to improve the survival of eggs and sac fry or eggs can simply be placed in the streambed gravels. The Whitlock Vibert (WV) Box is design to hold eggs within the stream and allow stream flow to pass through the box. A study completed by Hashbarger and Porter (1982)[25] demonstrated a greater success rate in direct egg plants because of sediment accumulation in the WV box, stifling the eggs. Egg tubes have also been successful in

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[24] Wunderlich, R. and C. Pantaleo. 1995. A review of methods to re-introduce anadromous fish in the Elwha River. U.S. Fish and Wildlife Service. Found at: http://www.fws.gov/wafwo/fisheries/Publications/FP210.pdf

[25] Hashbarger, T.J. and P.E. Porter. 1982. Embryo survival and fry emergence from two methods of planting brown trout eggs. North American Journal of Fisheries Management, vol. 2: 84-89.

improving egg survival as well as streamside incubators (Wunderlich and Pantaleo, 1995). The survival of direct egg plants is unpredictable due to scouring and sediment filling the intergravel spaces, but can be successful.

It is anticipated that natural redistribution, replacement, and assisted redistribution will be successful in repopulating the restored section of Walker Run. The habitat improvements resulting from the stream and floodplain restoration project will encourage the existing trout population to redistribute in to the restored reach following project completion. Long term, the improved trout habitat should increase reproduction and native brown trout populations within Walker Run. If the monitoring efforts are showing unsuccessful or inadequate redistribution of the native population to the restored section of stream, then egg or fingerling stocking may be necessary. Using wild brown trout populations as brood stock is recommended to maintain the genetic characteristics selected for survival in Walker Run. Monitoring results may help determine whether stocking fingerlings, eggs or both will produce better survival rates.

G. Walker Run Wild Brown Trout Monitoring Plan:

Monitoring is imperative to determine whether brown trout are re-populating the restored section of Walker Run, and to determine the changes in populations of wild brown trout elsewhere in Walker Run.

The following biological and chemical monitoring activities are proposed prior to restoration activities, and for five years following the completion of the Walker Run stream and floodplain restoration project.

1. Continue monitoring water levels and stream water temperatures in Walker Run by maintaining, downloading, and analyzing data from the datalogging pressure transducers currently installed in Walker Run. Six pressure transducers are installed within the project restoration reach, with three additional transducers installed upstream and one transducer installed downstream of the restoration reach. See Figure 7 for the location of these ten pressure transducers on Walker Run, and six other pressure transducers installed on tributaries to Walker Run.
2. Perform a brown trout redd survey in mid-to late-November of each year at the reaches shown in Figure 8. This will provide a measure of the spawning success at the monitored reaches, including the project restoration reach.
3. Perform a fisheries survey in early-to mid-June, once fry are large enough to withstand electroshocking. The fisheries survey should be conducted at the reaches shown in Figure 8. All fish species should be identified, and brown trout should be measured and weighed as well.
4. Perform a macroinvertebrate survey each spring at the reaches shown in Figure 8.
5. Perform a substrate embeddedness survey in July or August at the reaches shown in Figure 8.
6. Monitor water quality in August or early September at the reaches shown in Figure 8. Water quality parameters should include dissolved oxygen, pH, specific conductivity, alkalinity, water temperature, ammonia, nitrite, nitrate, orthophosphate, total phosphorus, and total Kjeldahl nitrogen. Nutrient monitoring is included to document any changes in the stream from watershed land uses.
7. Visual habitat assessment at the reaches shown in Figure 8, using EPA's rapid bioassessment protocols (RBP).

Monitoring activities 2 through 7 will be completed at the eight reaches shown on Figure 8. Four reaches are within the project restoration section, three reaches are located upstream and two reaches are downstream of the restoration reach. This monitoring plan is a comprehensive way to evaluate the wild brown trout populations and habitat characteristics in Walker Run, and specifically to monitor the re-population of the restored section stream. The adaptive management approach advocated here requires that this monitoring information be collected and analyzed, so that decisions regarding re-population approaches can be revisited and adapted to the observed conditions in Walker Run.

Monitoring of the environmental factors known to influence trout populations is essential for interpreting population and distribution changes over time. These monitoring efforts will also allow us to document the success of restoring this section of Walker Run.

These surveys should be performed prior to the initiation of restoration activities. All surveys except the redd survey were completed in 2009. These efforts should continue annually as outlined here until restoration begins. The monitoring program should continue after restoration following the recommendations in this plan.

H. <u>References:</u>

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Sylte, T. and C. Fischenich. 2002. Techniques for measuring substrate embeddedness. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-36), Ecosystem Management and Restoration Research Program, U.S. Army Corps of Engineers, Research and Development Center, Vicksburg, Mississippi.

Wunderlich, R. and C. Pantaleo. 1995. A review of methods to re-introduce anadromous fish in the Elwha River. U.S. Fish and Wildlife Service. Found at: http://www.fws.gov/wafwo/fisheries/Publications/FP210.pdf.

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