Appendix A – EPA Nine Elements for Watershed-based Plans

Guidance from the Environmental Protection Agency (US EPA, 1998) lists nine components required to be included in watershed-based management plans to restore waters impaired by nonpoint source pollution. The following describes the nine required elements and where they are found in this plan:

1. An **identification of the causes and sources** or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this WBMP (and to achieve any other watershed goals identified in the WBMP), as discussed in item (2) immediately below is located in **Section 5.**
2. An **estimate of the load reductions** expected for the management measures described under (3) below is described in **Section 7**.
3. A description of the **NPS management measures** that will need to be implemented to achieve the load reductions estimated under (2) above (as well as to achieve other watershed goals identified in this WBMP), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan are located in **Sections 5.4, 6.2 and Section 6.3**.
4. An estimate of the amounts of **technical and financial assistance** needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan is described in **Section 6.3**.
5. An information/**education component** that will be used to enhance public understanding of the project is located in **Section 6.2**.
6. A schedule for implementing the NPS management measures identified in this plan is in **Section 6.3**.
7. A description of interim, **measurable milestones** for determining whether NPS management measures or other control actions are being implemented can be found in **Section 7.3**.
8. **A set of criteria** that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards water quality standards; and if not, the criteria for determining whether this WBMP needs to be revised is in **Section 7.3**.
9. A **monitoring component** to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (8) above is can be found in **Section 8.2**.

Appendix B – Supplemental Water Quality Data

Great Works River Watershed Coalition Data (2004 and 2006) at Sampling Location GB73 (on Goodall Brook).

Date	Water Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	*E.coli* (colonies/100mL)	Total Phosphorus (ppb)
5/22/2004*	--	--	--	**> 400**	**75**
6/5/2004*	9	8.3	71.8	--	--
6/19/2004	12	7.8	72.4	84	**40**
7/3/2004	12	7.7	71.4	92	< 10
7/17/2004	12	7.9	73.3	60	< 10
7/31/2004	14	8.2	79.5	**> 400**	--
8/14/2004*	14	--	--	80	18
8/28/2004	15	8.7	86.3	11	< 10
9/11/2004*	15	7.4	73.4	**> 400**	< 10
5/20/2006	11	9.8	88.7	--	--
6/3/2006*	12	8.8	80.4	**360**	--
6/17/2006	11	10.2	92.7	14	--
7/1/2006	11	10	90.9	38	--
7/15/2006	13	--	--	**400**	--
7/29/2006	21	8.6	98.4	138	--
8/12/2006	11	12.6	11.6	94	--
8/26/2006	11	10.5	95.9	180	--
9/9/2006	11	10.5	94.8	--	--

Values in bold indicate an exceedance of the recommended water quality standards:
E.coli = 236 colonies/100 mL instantaneous sample;
Total Phosphorus = 30 ppb (EPA guidelines)

2012 monitoring data for Goodall Brook, collected by York County Soil and Water Conservation District. Values below the state water quality standards for dissolved oxygen in Class B streams (7.0 mg/l; 75% saturation), are flagged with an asterisk (*).

Site	Collection Time	Number of Observations	Mean Temperature (°C)	Mean DO (mg/L)	Mean DO (%)	Mean Specific Conductivity (µS/cm)
GB1	AM	4	12.8	9.5	89.3	493.8
GB1	PM	4	14.3	9.3	90.3	455.8
GB2	AM	4	12.5	**6.9**	**65.1**	534.8
GB2	PM	4	14.5	7.5	**73.5**	511.3
GB3	AM	4	12.5	**5.4**	**50.8**	514.0
GB3	PM	4	13.8	7.7	**74.3**	572.5
GB4	AM	4	12.4	8.6	80.4	484.3
GB4	PM	4	13.3	8.8	83.6	461.8
GB5	AM	0	--	--	--	--
GB5	PM	0	--	--	--	--
GB6	AM	1	14.1	9.5	93.9	347.0
GB6	PM	0	--	--	--	--

2013 monitoring data for Goodall Brook, collected by York County Soil and Water Conservation District. Values below the state water quality standards for dissolved oxygen in Class B streams (7.0 mg/l; 75% saturation), are flagged with an asterisk (*).

Site	Collection Time	Number of Observations	Mean Temperature (°C)	Mean DO (mg/L)	Mean DO (%)	Mean Specific Conductivity (µS/cm)
GB1	AM	9	14.1	9.5	92.2	379.8
GB1	PM	9	15.2	8.7	86.9	578.0
GB2	AM	9	13.9	6.8*	66.0*	436.2
GB2	PM	9	15.0	7.0	68.2*	580.0
GB3	AM	9	13.3	5.1*	50.1*	441.2
GB3	PM	9	14.7	7.0	66.8*	610.0
GB4	AM	9	13.1	8.8	84.4	464.4
GB4	PM	9	13.8	8.6	83.5	465.0
GB5	AM	4	19.0	8.9	87.0	133.3
GB5	PM	3	18.7	9.2	91.3	--
GB6	AM	3	17.1	9.5	92.2	243.3
GB6	PM	3	17.9	9.1	90.2	--

Fluvial Geomorphic Assessment of Goodall Brook in Sanford, Maine

Prepared for

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EXECUTIVE SUMMARY

A reconnaissance-level fluvial geomorphic assessment was completed of Goodall Brook in Sanford, Maine to determine the impact of urbanization on channel morphology and identify methods for restoring aquatic habitat and channel stability. Three distinct reaches were identified on the brook with the two upstream reaches (extending from Route 11/201 at the upstream end to Malcom Avenue) most impacted by historical and ongoing human activities. The high percentage of impervious cover in the watershed does not appear to be altering channel morphology because the low-gradient channel and wide floodplain prevent excess stream power from being generated in the channel. However, historical channelization, floodplain fill, culverts, berms, remnants of old dams, and other structures along and across the channel have severely altered the channel's dimensions and planform, compromised floodplain connectivity, and impaired natural flow patterns and stream channel function.

Deposition, channel narrowing, and flow complexity developed around wood that has naturally fallen into the channel suggests that the construction of marginal log jams along the straightened and overwidened channel could be valuable in restoring natural channel dimensions and sinuosity. However, complete restoration of geomorphic and ecological function would depend on floodplain reconnection and would further require the partial removal of berms and resizing of culverts. Additional studies are needed to corroborate the findings of this initial assessment of geomorphic conditions on Goodall Brook and to further develop restoration plans. Such studies should include: 1) topographic surveying of channel dimensions and floodplain features; 2) detailed mapping of channel constraints such as berms; 3) archival research and sedimentological descriptions of test pits to confirm the presence of floodplain fill; and 4) hydraulic modeling to identify the most appropriate culverts and other channel constraints to resize or remove in order to maximize the restoration of natural flow patterns at minimal cost. These additional studies will be critical in developing a sound management plan for restoring natural geomorphic function, and in turn, for achieving the sustainable habitat improvements necessary for Goodall Brook to meet state water quality standards.

1.0 INTRODUCTION

The following report presents the findings and recommendations resulting from a reconnaissance-level fluvial geomorphic assessment of Goodall Brook in Sanford, Maine (Figure 1). Goodall Brook has a total watershed area of only 0.6 mi^2 within the Town of Sanford and is approximately 2.5 mi long, flowing from a small forested area between U.S. Route 202 downstream to the Great Works River (MEDEP, no date). The surrounding watershed is heavily developed with over 35 percent impervious cover, likely a significant contributing factor for why the stream does not meet the State's water quality standards as pollutant and sediment-laden stormwater flows to the brook (MEDEP, no date). The geomorphic assessment was conducted to determine whether increased sediment and water discharge or other impacts of urbanization are adversely effecting channel stability (i.e., erosion and flooding) and physical aquatic habitat (e.g., pools and cover).

After contrasting the current channel condition with the likely pre-urbanized state of the brook, the following report discusses the likely impacts on channel morphology of four conditions associated with urbanization: channelization, floodplain fill, channel constraints, and impervious cover. The report concludes with a discussion of potential actions that could be taken to restore geomorphic function and aquatic habitat and help Goodall Brook meet water quality standards in the future. The geomorphic assessment was based on a single day in the field and a review of readily available maps, photos, and historical archives. Consequently, the conclusions expressed herein are largely based on best professional judgment and should be corroborated by additional studies recommended in the conclusions.

2.0 CURRENT AND HISTORIC CONDITIONS

Goodall Brook was subdivided into 3 reaches of uneven length from the upstream end of the northern branch to the Kennebec River confluence (Figure 2). The upstream most reach, Reach 1, extends from Lebanon Street (Route 11/202) at the upstream end to the downstream end of Goodall Park (i.e., ballpark) just downstream of Roberts Street. The downstream end of Reach 2 is where Malcom Avenue approaches the brook and Reach 3 extends to the confluence with the Great Works River. Only the upper portion of Reach 3 was assessed, so conditions may vary closer to the Great Works River confluence. Currently, the channel in Reaches 1 and 3 are relatively narrow with some sinuosity (Figure 3) in comparison to the much wider and straighter Reach 2 (Figure 4). The narrowness and sinuosity of Reach 3 is due to natural confinement by (what are likely) glaciogenic deposits, while Reach 1 conditions are likely altered by human influences (see below). Reach 2 has a very wide floodplain as did Reach 1 prior to human alteration. The gradient in Reach 2 is very low, suggesting that under natural conditions with high wood loadings that this reach (and possibly Reach 1 as well) was, at least in part, marshy with a poorly defined channel. The earliest topographic map surveyed in 1889 (Web citation 1) shows a single channel, but some channelization may have already occurred by this point.

3.0 CHANNELIZATION

An engineering plan from the early 1970's entitled "Goodall Brook Channel Improvement" provided by the Town of Sanford details how the channel was slightly deepened (as shown on the longitudinal profiles) and perhaps significantly widened (as suggested by the representative cross section) approximately 40 years ago. The plans also show where wood plankings were to be removed where the proposed grade for the work in the 1970's was lower than the plankings installed as part of another channelization project believed to have occurred in the 1930's. In addition to the deepening and widening of the 1970's, the straight planform in Reach 2 (Figure 4), particularly between Emerson Street and Berwick Road, is indicative of artificial straightening, a common practice in New England throughout the 18th and early 19th century (Field, 2007). A narrower more sinuous channel would be expected naturally across the wide low-gradient floodplain. The straightening was likely completed as part of a wetland drainage program as narrow parallel channels or furrows are observed running perpendicular to Goodall Brook on recent aerial photographs (Figure 4a). The straightening likely occurred when the wood planking was installed as part of channelization in the 1930's but may have also occurred earlier. The resolution and quality of the historical topographic maps (Web citations 1 and 2) and aerial photographs (Web citation 3) available for this study were insufficient to more closely refine the dates of channel straightening.

4.0 FLOODPLAIN FILL

While the straightened channel throughout most of Reach 2 has very low banks (less than 2 ft high), one or both banks along portions of Reach 1, particularly the left bank (looking downstream) at Goodall Park, are 5 ft or higher (Figure 5a). These banks may be artificially high due to the placement of floodplain fill at Goodall Park between the channel and the higher glaciogenic surface on which Town Hall rests (Figure 5b). If true, the parking area shown in Figure 5b and the ball park rest on artificial fill with the original unaltered lower floodplain surface still present on the right bank (Figure 5a). Archival information available for this study is not sufficient to confirm whether artificial fill was placed in this area in the past, but such documentation may be available in town records or a local historical society. The narrowing of the floodplain resulting from the placement of artificial fill on the left bank would increase flow velocities in the channel and on the lower floodplain surface on the right bank (Figure 5a) and may be why scour is observed along the right bank across from the ball park (Figure 6).

5.0 CHANNEL CONSTRAINTS

In addition to the floodplain fill, Reaches 1 and 2 are constrained in a number of other ways. The floodplain fill at Goodall Park may also have extended into and further constrained the channel, explaining, at least in part, why the channel is much narrower in Reach 1 (Figure 5a) than in the straightened channel downstream (Figure 4b). The "Goodall Brook Channel Improvement" plan calls for material removed from the channel to be disposed of largely along the edge of the channel to create berms that are observed today along portions of Reach 2. As a consequence, floodwaters are unable to access portions of the floodplain at bankfull discharge. The exact location and height of berms was not determined as part of this study, so the degree to which floodplain connectivity has been compromised is unknown. In other areas, a sewer line and other structures paralleling the channel act similarly to berms by further blocking floodplain access (Figure 7a).

At least 4 culverts, all with openings narrower than the channel's width, cross the stream channel (Figures 2 and 7b), leading to stagnant flow conditions upstream. Fine sediment deposits in the channel are locally more than 2.0 ft thick (before a harder substrate is encountered at depth) with the culverts at least partially responsible for this deposition. While scour pools often form downstream of culverts, none were observed along Goodall Brook due to limited stream power in the low gradient system and perhaps due to backwatering from the next downstream culvert. A sewer pipe runs across the channel in at least one location (near the downstream end of Reach 2), impounds flow during higher discharges, and has caused deposition along the margins of the channel both upstream and downstream (Figure 7c). This has caused a narrowing of the low flow channel, although the bankfull width remains largely unaltered. Similar deposition and channel narrowing has occurred where trees have fallen in the channel (Figure 8), creating short lengths where flow is visibly moving in an area otherwise characterized by stagnant low flow conditions. Near the upstream end of Reach 1, the remnants of an old earthen dam block most of the floodplain (Figure 7d). The channel is split into multiple flow paths upstream of the former dam, but a single flow path is present where the channel has breached the dam and continues as a single flow path downstream. The various channel constraints present on Goodall Brook (Figure 7) alter flow conditions in a variety of ways to cause deposition, bank erosion, and complex flow patterns.

6.0 IMPERVIOUS COVER

Impervious cover in a watershed increases runoff and peak discharges that can lead to channel incision and bank erosion (Booth, 1990). Although the approximately 35 percent of impervious cover present in the Goodall Brook watershed is sufficient to engender a channel response in many settings, no channel incision is observed on Goodall Brook. The lack of incision is likely related to the low gradient channel and wide floodplain that prevent excess stream power from being generated by the increased runoff draining to the channel. While the channel does not seem to be responding to excess discharge, urbanization in the watershed could also be increasing sediment delivery to the channel, possibly contributing to the considerable fine sediment accumulating in the wide channelized portions of Reach 2. Furthermore, the impacts of the excess runoff from the urbanized watershed on water quality could be significant, but were not assessed as part of this study.

7.0 CONCLUSIONS

While excess runoff associated with impervious cover does not appear to be altering channel morphology on Goodall Brook, several other activities associated with urbanization have significantly altered the channel. The original stream channel was straightened and the adjacent wide, likely marshy, floodplain was drained in the 1930's or even earlier. A recurrence of channelization to remove fine sediment accumulated in the channel occurred at least once afterwards in the 1970's at which time berms were built along the channel with the excavated sediment. The channel and floodplain are further constrained by culverts, sewer pipes, floodplain fill, remnants of former dams, and other structures. These constraints have in some cases induced channel deposition along the margins of the channel, narrowing the flow during low-flow conditions (Figure 7c) and mimicking flow patterns generated by wood.

The restoration of more natural conditions, whereby a narrower more sinuous channel is flowing through a wide marshy floodplain, could be partially achieved through wood additions in the channel. The use of marginal log jams alternating on different sides of the channel would encourage narrowing of the channel, lead to less stagnant flow, and develop a more sinuous flow path. Natural wood accumulating in the channel (Figure 8) provides an analogue of how constructed log jams would respond in the channel. More comprehensive restoration attempting to fully reconnect the channel and floodplain, would also have to consider berm removal, infilling of floodplain drainage swales, replacement of culverts with stream crossings that reduce flow impoundment in the channel and on the floodplain, and, where practicable, removal of artificial fill on the floodplain. The slow episodic process of natural meander reformation that would be encouraged by wood additions and removal of channel and floodplain constraints is as important to the restoration of geomorphic function and habitat complexity as the final fully meandering equilibrium condition that would develop over time. Consequently, imposing constructed meanders on the system as part of a more active, and expensive, restoration plan is not recommended.

Considerable additional study is needed to corroborate the initial findings of this geomorphic assessment and refine the conceptual restoration ideas presented in the preceding paragraph. Topographic surveying of the channel and floodplain is necessary to document the current channel dimensions, the extent and depth of the parallel floodplain drainage swales (Figure 4a), and the degree to which deposition has narrowed the low-flow channel where the sewer pipe crosses the channel (Figure 7c) and wood has fallen into the channel (Figure 8). Surveying would be best completed in the early spring when the floodplain swales would be most visible. Mapping of channel features using a GPS embedded tablet computer is needed to detail the distribution of berms along the channel, the extent of bank erosion and its relationship to floodplain fill and other channel constraints, and the location and depth of accumulated sediment in the channel. Confirmation of the presence of floodplain fill and history of channelization could be achieved through a careful analysis of archival information and historical maps and photographs. The presence of floodplain fill could be further documented through an analysis of soil maps, well logs, and sedimentological descriptions of test pits that could be excavated in Goodall Park or adjacent residential areas. Finally, hydraulic modeling will be essential for quantifying the degree and extent to which culverts and other channel and floodplain constraints are altering flow patterns. The modeling will also inform final restoration designs by identifying which channel and floodplain constraints would be most critical to remove or resize in order to best restore natural flow conditions along Goodall Brook.

9.0 REFERENCES

Booth, D.B., 1990, Stream-channel incision following drainage-basin urbanization: Journal of the American Water Resources Association, v. 26, p. 407-417.

Field, J., 2007, The recreation of meanders along artificially straightened stream channels: Geological Society of America Abstracts with Programs, v. 39, p. 243.

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Web citations

Web citation 1: http://docs.unh.edu/ME/brwk93ne.jpg
Web citation 2: http://docs.unh.edu/ME/brwk58ne.jpg
Web citation 3: http://earthexplorer.usgs.gov/metadata/4660/AR1M00000090012/

FIGURES

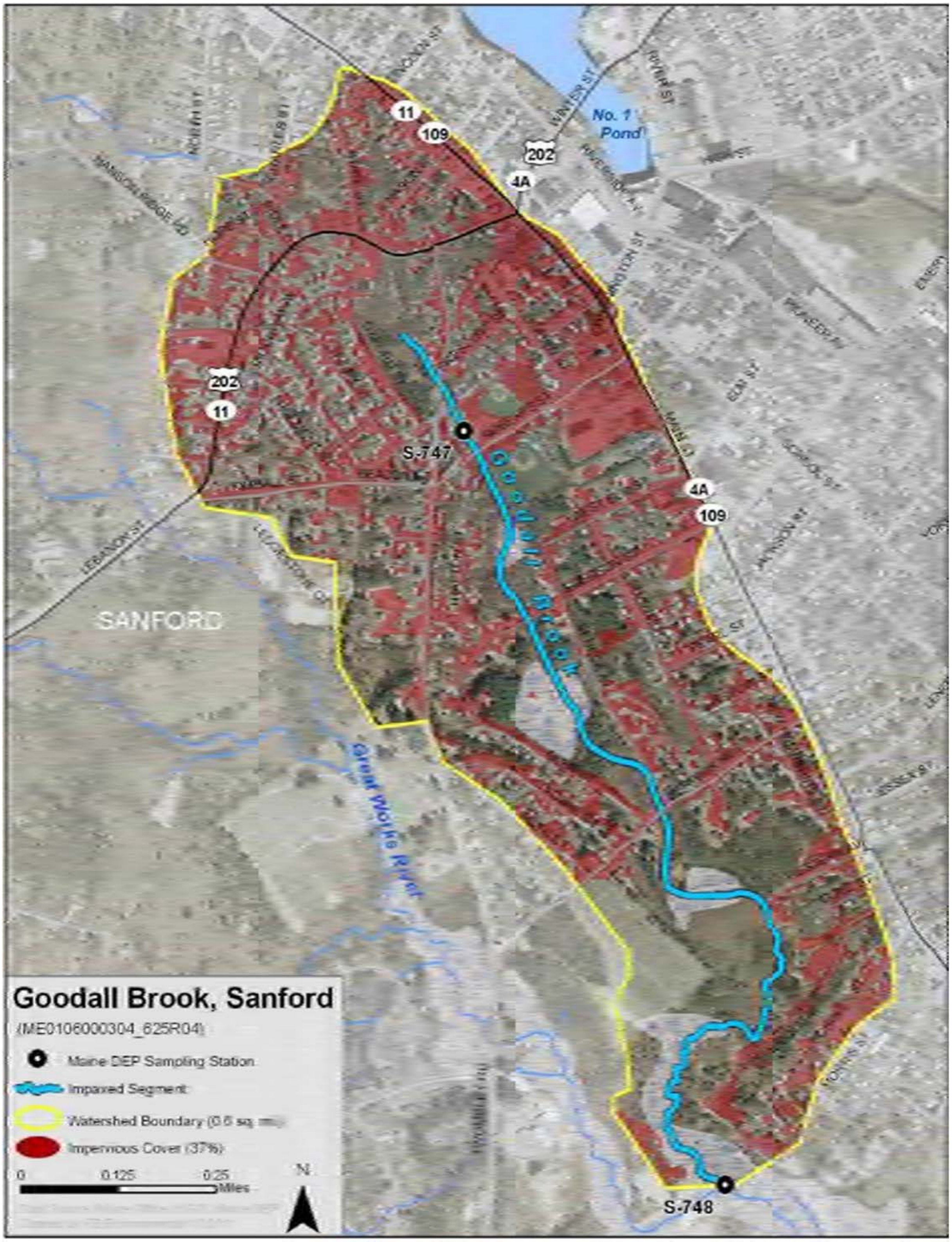


Figure 1. Goodall Brook location map showing locations of impervious cover. From MEDEP (no date).

Figure 2. Location of reaches on Goodall Brook. Note that labeled points are at downstream end of given reach with red "x" representing upstream end of channel.

Figure 3. A relatively narrow channel with a sinuous planform characterizes Reach 3.

a)

b)

Figure 4. A wide straight channel is typical of Reach 2 as seen on a) aerial photographs and b) ground photographs. Note only some of the parallel floodplain drainage swales are highlighted on aerial photo.

a)

b)

Figure 5. At Goodall Park the a) high banks on the left bank compared to the right bank may be due to b) the placement of artificial fill between the channel and higher surface on which Sanford Town Hall is built.

Figure 6. Bank scour on the right bank across from the Goodall Park ball field may be associated with artificial fill placed on the left bank floodplain.

Figure 7. Channel constraints on Goodall Brook include: a) berms and other structures paralleling the channel and blocking the floodplain; b) culverts, c) sewer pipes, and d) remnants of an earthen dam.

Figure 8. Deposition and channel narrowing is associated with wood that has fallen into the channel.

TMDL Assessment Summary

Goodall Brook

Watershed Description

This TMDL assessment summary applies to Goodall Brook, a 2.5-mile stream located in the Town of Sanford, Maine. Goodall Brook, a small tributary to the north branch of the Great Works River, begins in a small forested area between U.S. Route 202 and Oxford Street in Sanford. The stream travels south-east parallel to the Little League fields at Benton Park. It passes under Roberts Street and flows adjacent to the baseball field at Goodall Park. After the Brook passes under Berwick Road it flows into a large forested area. Goodall Brook continues adjacent to St. Ignatius Cemetery before it passes several abandoned sand pits. Shortly thereafter it continues into a large forested wetland before flowing into the Great Works River between Daylight Avenue and Twombley Road near Margaret Chase Smith Elementary School, in Sanford. The Goodall Brook watershed covers 384 acres in the Town of Sanford.

- Stormwater runoff from impervious cover (IC) is the largest source of pollution and stream channel alteration to Goodall Brook. Stormwater falling on roads, roofs and parking lots in developed areas flows quickly off impervious surfaces, carrying dirt, oils, metals, and other pollutants, and sending high volumes of flow to the nearest section of the stream.
- A number of Roberts Street storm drains, which are linked directly to Goodall Brook, funnel runoff from roads and parking lots down to the stream.
- The forested wetlands of the Goodall Brook watershed absorb and filter stormwater pollutants, and help protect both water quality in the stream and stream channel stability.
- The Goodall Brook watershed has a very high percentage of developed area (85%).

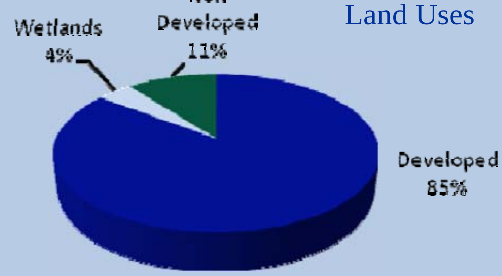
Definitions

- TMDL is an acronym for Total Maximum Daily Load, representing the total amount of a pollutant that a water body can receive and still meet water quality standards.
- Impervious cover refers to landscape surfaces (e.g. roads, sidewalks, driveways, parking lots, and rooftops) that no longer absorb rain and may direct large volumes of stormwater runoff into the stream.

Waterbody Facts

- Segment ID: ME0106000304_625R04
- City: Sanford, ME
- County: York
- Impaired Segment Length: 2.5 miles
- Classification: Class B
- Direct Watershed: 0.6 mi^2 (384 acres)
- Watershed Impervious Cover: 37%
- Major Drainage Basin: Portsmouth Harbor to Salisbury Beach

Watershed Land Uses



Why is a TMDL Assessment Needed?

Goodall Brook, a Class B freshwater stream, has been assessed by DEP as potentially not meeting water quality standards for aquatic life use. Results from another sampling season are needed to confirm attainment status. The brook was first assessed in 2004 and did not meet Class B aquatic life criteria (benthic macroinvertebrate assessment). Pending further sampling results, DEP anticipates listing Goodall Brook on the 2012 303(d) list (Maine DEP, 2010a). The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

Goodall Brook downstream of Station 747.
(Photo: DEP Biomonitoring Program)

Goodall Brook starts in the most built out area of Sanford and follows through dense development for nearly its entire course. This development, especially in the form of impervious cover, has a negative impact on the stream. The impervious cover TMDL assessment for Goodall Brook addresses the probable impairments to aquatic life uses (benthic macro-invertebrate and stream habitat assessments). These impairments are associated with a variety of pollutants in urban stormwater as well as erosion, habitat loss and unstable stream banks caused by excessive amounts of runoff.

Sampling Results & Pollutant Sources

Sampling Station	Sample Date	Statutory Class	Model Results
S-747	7/14/2004	B	NA

DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C conditions. Biologists use the model results and supporting information to determine if samples comply with standards of the class assigned to the stream or river (Davies and Tsomides, 2002).

Goodall Brook was sampled for the first time by DEP in the summer of 2004 near the stream crossing on Roberts Street, across from Goodall Park (S-747). The results for that sampling event displayed that Goodall Brook did not meet Class B water quality for aquatic life criteria (DEP, 2004). DEP felt that it would need another year of sampling data before Goodall Brook could be officially classified as impaired. The Brook was sampled again in the summer of 2010. The results of that sampling event have not yet become available (DEP, 2010).

Impervious Cover Analysis

> 8% IC represents an approximate 78% reduction in stormwater runoff volume and associated pollutants when compared to existing pollutant loads.

Increasing the percentage of impervious cover (%IC) in a watershed is linked to decreasing stream health (CWP, 2003). Because Goodall Brook's impairment is not caused by a single pollutant, % IC is used for this TMDL to represent the mix of pollutants and other impacts associated with excessive stormwater runoff. The Goodall Brook watershed has an impervious surface area of 37% (Figure 1). DEP has found that in order to support Class B aquatic life use, the Goodall Brook watershed may require the characteristics of a watershed with 8% impervious cover. This WLA & LA target is intended to guide the application of Best Management

Practices (BMP) and Low Impact Development (LID) techniques to reduce the impact of impervious surfaces. Ultimate success of the TMDL will be Goodall Brook's future compliance with Maine's criteria for habitat assessment.

Impervious Cover GIS Calculations

The Impervious Cover Calculations are based on analysis of GIS coverage's presented in Figure 1. The impervious area is derived from 2004 1 meter satellite imagery and the watershed boundary is an estimation based on contours and digital elevation models.

NextSteps

Because Goodall Brook is an impaired water, specific sources of stormwater runoff in the watershed should be considered during the development of a watershed management plan to:

- Encourage greater citizen involvement (e.g. through the Great Works River Watershed Coalition and/or Bauneg Beg Lake Association) to ensure the long term protection of Goodall Brook;
- Address existing stormwater problems in the Goodall Brook watershed by installing structural and applying non-structural best management practices (BMPs); and
- Prevent future degradation of Goodall Brook through the development and/or strengthening of local stormwater control ordinances.

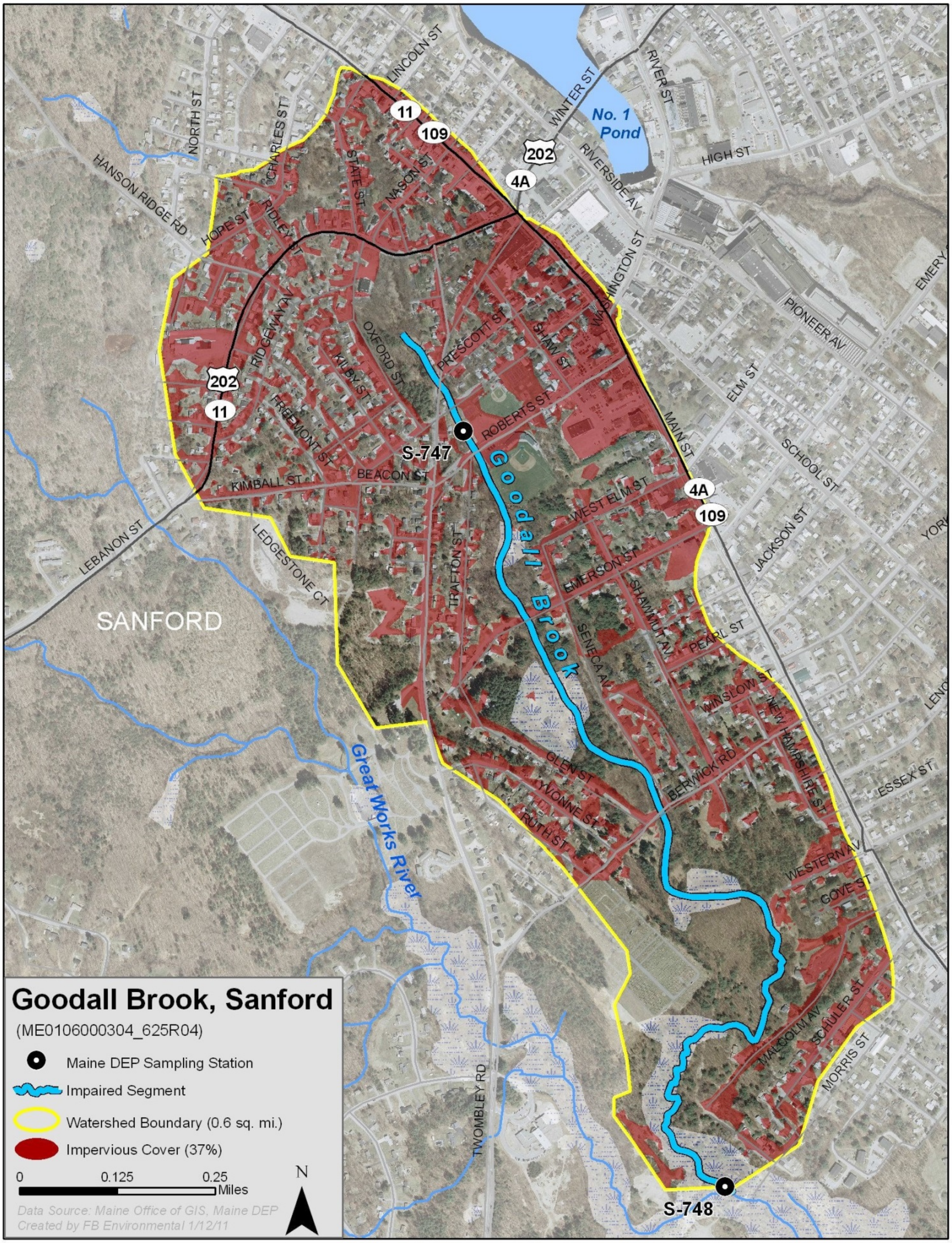


Figure 1: Map of Goodall Brook watershed impervious cover.

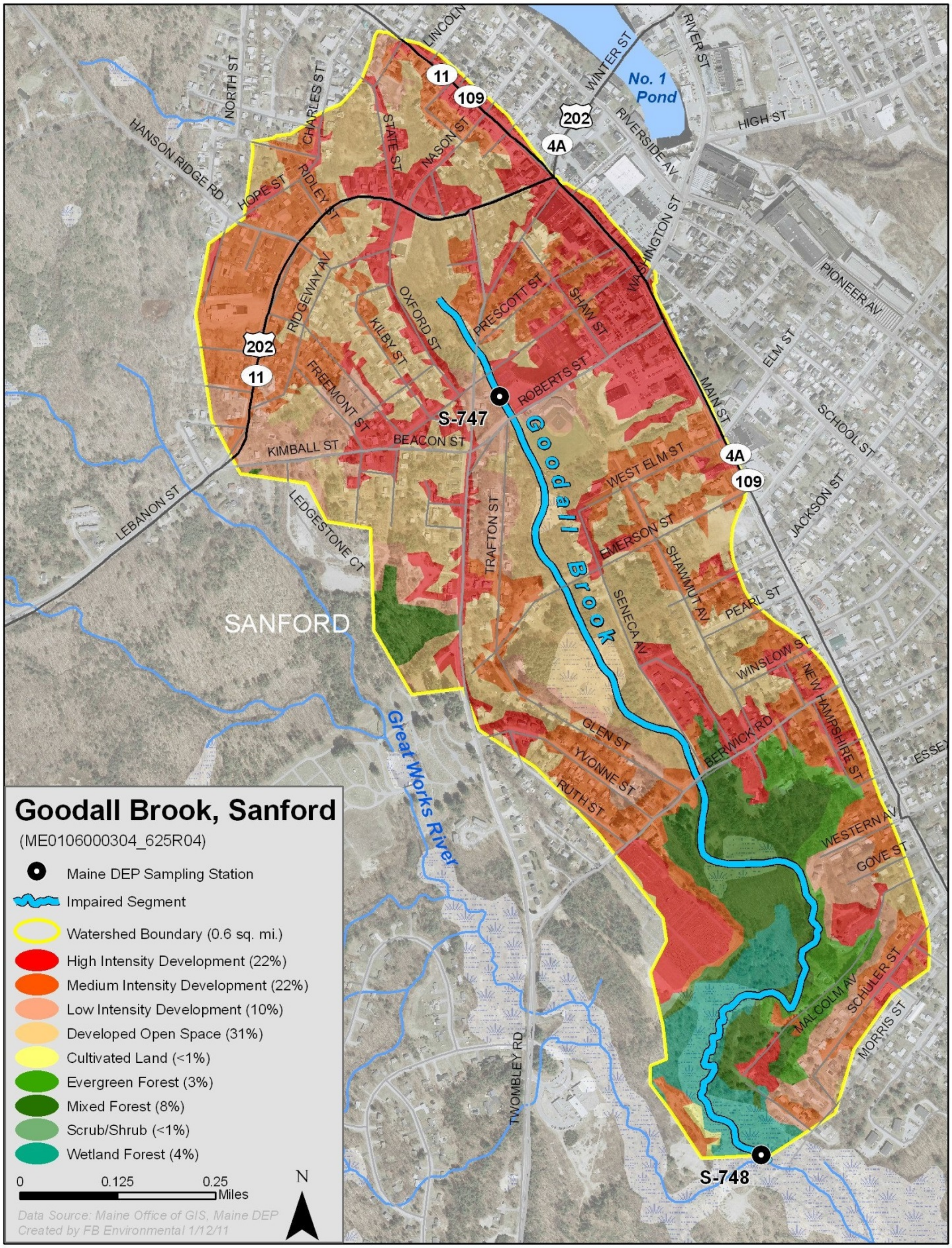


Figure 2: Map of Goodall Brook watershed land cover.

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Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1. Center for Watershed Protection, Ellicott City, MD. 142 pp.

Davies, Susan P. and Leonidas Tsomides. 2002. Methods for Biological Sampling and Analysis of Maine's Rivers and Streams. Maine Department if Environmental Protection. Revised August, 2002. DEP LW0387-B2002.

Maine Department of Environmental Protection (DEP). 2004. Biological Monitoring Unit, Aquatic Life Classification Attainment Report. Bureau of Land and Water Quality, Augusta, ME

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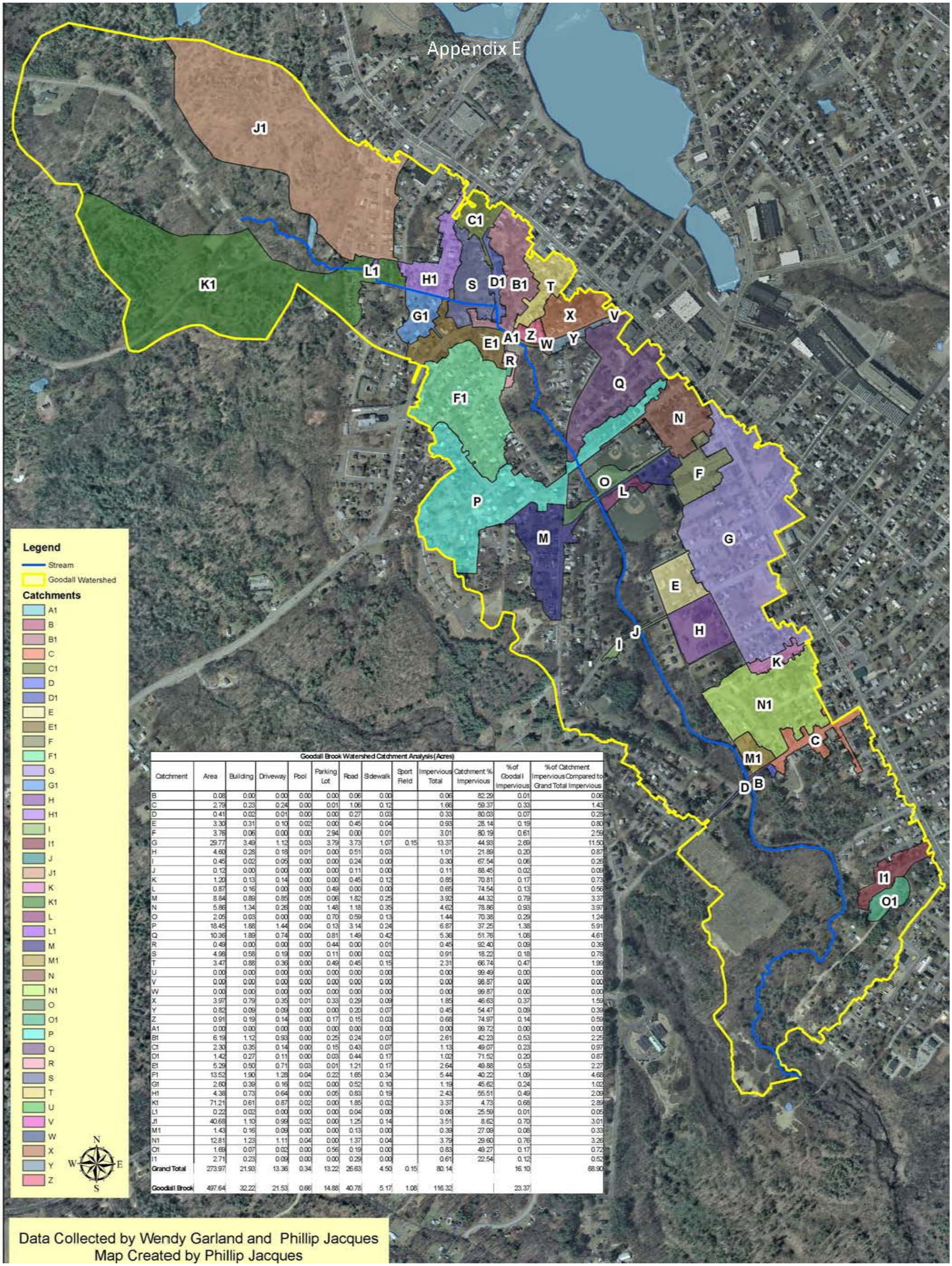
Appendix E



Goodall Brook Watershed Catchment Analysis (Acres)

Catchment	Area	Building	Driveway	Pool	Parking Lot	Road	Sidewalk	Sport Field	Impervious Total	Catchment % Impervious	% of Goodall Impervious	% of Catchment Impervious Compared to Grand Total Impervious
B	0.08	0.00	0.00	0.00	0.00	0.06	0.00		0.06	82.29	0.01	0.06
C	2.79	0.23	0.24	0.00	0.01	1.06	0.12		1.66	59.37	0.33	1.43
D	0.41	0.02	0.01	0.00	0.00	0.27	0.03		0.33	80.03	0.07	0.28
E	3.30	0.31	0.10	0.02	0.00	0.45	0.04		0.93	28.14	0.19	0.80
F	3.76	0.06	0.00	0.00	2.94	0.00	0.01		3.01	80.19	0.61	2.59
G	29.77	3.49	1.12	0.03	3.79	3.73	1.07	0.15	13.37	44.93	2.69	11.50
H	4.60	0.28	0.18	0.01	0.00	0.51	0.03		1.01	21.89	0.20	0.87
I	0.45	0.02	0.05	0.00	0.00	0.24	0.00		0.30	67.54	0.06	0.26
J	0.12	0.00	0.00	0.00	0.00	0.11	0.00		0.11	88.45	0.02	0.09
K	1.20	0.13	0.14	0.00	0.00	0.45	0.12		0.85	70.81	0.17	0.73
L	0.87	0.16	0.00	0.00	0.49	0.00	0.00		0.65	74.54	0.13	0.56
M	8.84	0.89	0.85	0.05	0.06	1.82	0.25		3.92	44.32	0.79	3.37
N	5.86	1.34	0.26	0.00	1.48	1.18	0.35		4.62	78.86	0.93	3.97
O	2.05	0.03	0.00	0.00	0.70	0.59	0.13		1.44	70.38	0.29	1.24
P	18.45	1.88	1.44	0.04	0.13	3.14	0.24		6.87	37.25	1.38	5.91
Q	10.36	1.89	0.74	0.00	0.81	1.49	0.42		5.36	51.76	1.08	4.61
R	0.49	0.00	0.00	0.00	0.44	0.00	0.01		0.45	92.40	0.09	0.39
S	4.98	0.58	0.19	0.00	0.11	0.00	0.02		0.91	18.22	0.18	0.78
T	3.47	0.88	0.36	0.00	0.49	0.45	0.15		2.31	66.74	0.47	1.99
U	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	99.49	0.00	0.00
V	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	98.87	0.00	0.00
W	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	99.87	0.00	0.00
X	3.97	0.79	0.35	0.01	0.33	0.29	0.09		1.85	46.63	0.37	1.59
Y	0.82	0.09	0.09	0.00	0.00	0.20	0.07		0.45	54.47	0.09	0.39
Z	0.91	0.19	0.14	0.00	0.17	0.15	0.03		0.68	74.97	0.14	0.59
A1	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	99.72	0.00	0.00
B1	6.19	1.12	0.93	0.00	0.25	0.24	0.07		2.61	42.23	0.53	2.25
C1	2.30	0.35	0.14	0.00	0.15	0.43	0.07		1.13	49.07	0.23	0.97
D1	1.42	0.27	0.11	0.00	0.03	0.44	0.17		1.02	71.52	0.20	0.87
E1	5.29	0.50	0.71	0.03	0.01	1.21	0.17		2.64	49.88	0.53	2.27
F1	13.52	1.90	1.28	0.04	0.22	1.65	0.34		5.44	40.22	1.09	4.68
G1	2.60	0.39	0.16	0.02	0.00	0.52	0.10		1.19	45.62	0.24	1.02
H1	4.38	0.73	0.64	0.00	0.05	0.83	0.19		2.43	55.51	0.49	2.09
K1	71.21	0.61	0.87	0.02	0.00	1.85	0.02		3.37	4.73	0.68	2.89
L1	0.22	0.02	0.00	0.00	0.00	0.04	0.00		0.06	25.59	0.01	0.05
J1	40.68	1.10	0.99	0.02	0.00	1.25	0.14		3.51	8.62	0.70	3.01
M1	1.43	0.16	0.09	0.00	0.00	0.13	0.00		0.39	27.09	0.08	0.33
N1	12.81	1.23	1.11	0.04	0.00	1.37	0.04		3.79	29.60	0.76	3.26
O1	1.69	0.07	0.02	0.00	0.56	0.19	0.00		0.83	49.27	0.17	0.72
I1	2.71	0.23	0.09	0.00	0.00	0.29	0.00		0.61	22.54	0.12	0.52
Grand Total	273.97	21.93	13.36	0.34	13.22	26.63	4.50	0.15	80.14		16.10	68.90
Goodall Brook	497.64	32.22	21.53	0.66	14.88	40.78	5.17	1.08	116.32		23.37	

Appendix F – List of Priority Structural BMP Retrofits

Results of stormwater retrofit assessment of Goodall Brook, conducted in November 2013. Associated costs and prioritization ranking of remediation options are included. Catchment designations refer to map in Appendix E.

Map ID	Catch-ment	Location	Retrofit Goals	Catchment Area & IC%	BMP Options	Priority	Cost*
1	Several	Lebanon Street culvert	Habitat and channel protection	200 acres	Large storms have blown out channel at culvert outlet and piled riprap up at edge of plunge pool. Creates potential of blocking off main stream channel and shifting flows to side channel. Recommendations include enlarging plunge pool and lining with nonwoven geotextile and larger riprap. Set stones to ensure that normal flows use main channel and only high flows access side channel. No fish passage issues need to be considered.	**High**	Low
2	N	Outfall behind basketball court	Habitat improvement via flow attenuation and outfall protection	5.9 acres 78% IC	Stormwater outfall pipe hangs above stream and is causing bank and channel erosion and movement of bed substrate. Cut back pipe and riprap between outlet and stream channel. Help attenuate flow by installing a 8-10' deep manhole/catch basin sump surrounded by riprap. Could be cleaned out with vac truck periodically.	**High**	High
3	O	Between Kimball Street and Roberts Street	Habitat enhancement	2.05 acres 70% IC	Maintain vegetated buffer to slow parking lot runoff and sheet flow to stream. Enhance buffer with additional native plants and remove invasive species.	Medium	Low
4	O	Mainer's Parking Lot	Provide better treatment for parking lot and remove nutrients	2.05 acres 70% IC	Regrade parking lot corner and curb to force parking lot runoff into a focal point bioretention system adjacent to stream.	**High**	High
5	O	Tree Box Filter (Roberts NE)	Improve tree box to reduce phosphorus in runoff	2.05 acres 70% IC	Standing water in parking lot tree box. Could be plugged with sediment. Rehabilitate tree box to better handle runoff by removing surface media, placing with bark mulch and establishing cleaning schedule 1-2 times/year. Also, too much area drains to one tree box. Cut outlet holds in concrete to allow water to flow into riprap swale instead of street.	**High**	Low

Map ID	Catch-ment	Location	Retrofit Goals	Catchment Area & IC%	BMP Options	Priority	Cost*
6	O	Tree Box Filter (Roberts NW)	Enhance nutrient removal	2.05 acres 70% IC	Sediment blocking street inlet. Clean inlet and scrape top of media. Check flow during storms and compare with UNH design flow to test function.	Medium	Low
7	M	Tree Box Filter (Roberts SE)	Improve functionality of tree box filter	8.80 acres 45% IC	Tree box is functional. Some sediment accumulation (~1") on top of media. Scrape off and establish regular maintenance schedule.	Medium	Low
8	O	Outfall just south of Roberts St.	Erosion control	2.05 acres 70% IC	Build up substrate and/or lower height of outfall pipe to reduce erosive effects of discharge.	Medium	Low
9	M	Trafton St.	Treat road runoff that bypasses tree boxes	8.80 acres 45% IC	Currently some runoff going into catch basin where pipe is eroding streambank. Explore ownership at corner of Trafton and Roberts Streets. If possible, close off catch basin and install bioretention cell between road and stream.	Medium	Medium
10	G & E	West Elm	Attenuate flow, erosion control, nutrients	30 acres & 3.3 acres, 45% & 28% IC	Erosion below outfall with channel and sediment draining to stream. Change pipe near corner of pavement to direct outfall into a basin/spreader and allow treatment by wetland buffer.	Medium	Medium
11	H	Seneca	Phosphorus removal, stabilize outfall to stream	4.60 acres 22% IC	Riprapped plunge pool below outfall pipe. Could add stone across the lower edge of the plunge pool to create a level spreader. Landowner expressed interest in doing this work.	Low	Low
12	N1	Glenwood	Stabilize outfall to stream	12.80 acres 30% IC	18" outfall pipe is 75% full of sediment. Clean out and install plunge pool with level spreader.	Low	Low
13	N1	Glenwood	Phosphorus removal	12.80 acres 30% IC	Eroding slope at top of Pearl Street could be responsible for lower sediment accumulation. Could install rubber razor across driveway, armor slope with stone and install check dams down swale.	Low	Low
14	I1	Malcolm Street	Stabilize gully, reduce sedimentation to stream	2.71 acres 4% IC	Large gully between vacant church and stream. Install rain garden below outfall from church parking lot. Install wooden check dams in channel to trap sediment. Could install curbing or bioretention along edge of pavement, but pavement is broken.	Low	Medium

**The "Cost" field is estimated as follows - Low: Less than $5000; Medium: $5,000-$10,000; High: $10,000-$20,000; Very High: Over $20,000.*