Technical Memorandum

To: Melanie Kleiss, Lower Phalen Creek Project

From: Jonathon Kusa, PE and Ben Swanson, PhD, Inter-Fluve

Project: Lower Phalen Creek Daylighting Feasibility Study

Date: October 25, 2017

The Lower Phalen Creek Project (LCPC) retained Inter-fluve, Inc. (Inter-Fluve) to assess the feasibility of daylighting lower Phalen Creek, which is currently conveyed in storm sewer for much of its length between Lake Phalen and the Mississippi River. Based on available data and input from stakeholders, we identified two discrete reaches of Phalen Creek (Reaches 5 and 7) that are recommended for further investigation and analysis for potential daylighting.

Reach 4 is the stream segment within Swede Hollow, which is currently open channel, and is anticipated to be integrated into the daylighted system with future perennial baseflow. Some reconstruction of the Swede Hollow stream segment is anticipated, but not analyzed as a part of this feasibility study. The ultimate goal would be to daylight segments of the creek to restore ecological function, provide recreational and educational opportunities, and improve watershed health.

This memo summarizes the collected data and identifies potential reaches feasible for daylighting. The desktop analysis completed includes proposed stream profiles, alignments, and cross-sections; an opinion of estimated project costs by reach; and the general water quality benefits of daylighting streams. Field review and a more detailed engineering evaluation for each potential stream reaches is recommended.

Existing Conditions

To assess the technical feasibility of daylighting lower Phalen Creek, Inter-Fluve collected available electronic spatial data from the City of Saint Paul (City), the Minnesota GeoSpatial Commons, the Capitol Region Watershed District (CRWD), and the Ramsey Washington Metro Watershed District (RWMWD). The data included the following:

- Transportation Network (roads, railroads, etc)
- Geology (surface geology, bedrock geology, soils)
- Topography (LiDAR, contours)

- Tax Parcels (attributed)
- General Land Use
- Tax Parcels
- Stormwater Sewer
- Sanitary Sewer

The data was compiled graphically and is summarized in the attached appendices. We have included a brief summary below of each appendix figure and the associated analysis.

Transportation Network –Appendix A

The Phalen Creek corridor runs through an urban area crossed by city streets, highways, and a railroad. The three reaches proposed for daylighting will flow under 9 roads, 2 trails, and one set of railroad tracks. The proposed pipe will be buried under an additional 9 roads, 3 trails, and another set of railroad tracks.

Topography – Appendix B

Local elevations range between 700ft and 900ft above mean sea, with a distinct upland between 850 and 900ft, moderately steep valleys along the I-35E and Phalen Boulevard corridors, and a relatively steep drop through riverside bluffs to the Mississippi River floodplain below. The Lower Phalen Creek corridor will likely begin at approximately 860ft elevation and end in a pipe at approximately 608ft. After emerging under a rise at Earl St, it will gradually steepen until it reaches Swedes Hollow, where it will fall 100ft to the floodplain downstream of I-94 (Figures 1 and 2).

Bedrock Geology– Appendix C

Bedrock geology indicates potential historical stream alignment locations based on underlying bedrock indicators, includes location of exposed bedrock of various types and known stratification of the local geologic layers. In this area, locations that have eroded through the Platteville-Glenwood Limestone to the underlying Jordan Sandstone provide evidence of water-influenced erosion of the landscape, similar to what is visible in the Mississippi River gorge.

Surficial Geology – Appendix D

Surficial geology provides evidence of more recent former locations of drainage paths through the landscape, based on more recent geological and climatic changes that influence the shallow surficial geology of the evaluated area. Several areas show evidence of Meltwater Stream Sediment within the surficial geology, providing evidence of former stream alignments.

Soil Types – Appendix E

The lower Phalen Creek corridor begins above the Prairie Du Chien dolostone and turns west across the Jordan Sandstone and Platteville Limestone. It then spills back through Swede Hollow, which comprises Pleistocene stream sediments over more dolostone. Most of the rock is overlain by glacial meltwater sediments that form sandy loam soils. However, the soils are highly disturbed urban soils and often covered by fill and(or) impervious surfaces.

General Land Use – Appendix F and Tax Parcels – Appendix G

Most of the area around Phalen Creek is residential, but the general corridor that includes the existing pipe and proposed alignment is primarily parkland or undeveloped property, with some industrial and commercial use. The proposed alignment is primarily in land designated as park or preserve, although some sections within proposed pipe reaches may be through undeveloped or industrial property. The proposed Phalen Creek alignment primarily flows through property currently controlled by Ramsey County and the City of Saint Paul.

Storm Water Sewer – Appendix H and Sanitary Sewer – Appendix I

The storm and sanitary sewer systems cover the entire urban area within the Lower Phalen Creek corridor, and all the existing channel and tributary channels are conveyed within storm sewer. The Beltline Stormwater Interceptor is within the upstream end of the corridor, south of Lake Phalen. The Beltline Interceptor crosses the proposed channel alignment at Jessamine Ave. The Phalen Creek storm sewer runs along the proposed alignment for most of its length.

Water Table Elevations – Appendix J and Depth to Groundwater – Appendix K

Between Phalen Lake and the Mississippi River, the water table elevation falls from around 860feet to 680 feet. Groundwater is close to ground surface around the lake and the river, but along the river bluff, south and east of the project area, depths to groundwater are often greater than 100 feet. Along Phalen Creek, depth to groundwater ranges between 0 and 35 feet below ground surface, and seeps in Swede Hollow are actually above ground surface.

Proposed Conditions

Channel Alignment and Profile

The topography, surface geology, landuse, parcel, and utility data through the lower Phalen Creek corridor, along with digital imagery, allowed for the development of an initial channel alignment describing the route and profile of a new, daylighted Phalen Creek channel (Figures 1 and 2). As described in the existing conditions section, the proposed channel will be a mix of buried and open sections. Three potentially daylighted sections (Reaches 5 and 7) were determined based on adjacent landuse and infrastructure (i.e., width available for a channel and floodplain), as well as excavation volumes and their associated costs of removal. Proposed slopes range between 0.003ft/ft to 0.025ft/ft. Steeper sections will likely require larger bed and bank materials to account for higher energy flows. See Table 1 for a summary of evaluated technical elements.

Based on experience with similar projects, Inter-Fluve recommends constructing a diversion structure at the outlet of Lake Phalen, which would allow for control of water entering the proposed daylighted segment of Phalen Creek. Utilizing a diversion, the system will be "off-line" from the existing stormwater system and designed to have consistent base-flow that fluctuates within a narrow range. The proposed system will supplement the existing storm sewer network and not replace the conveyance capacity currently available. As an "off-line" channel, the proposed stream can be designed as a typical spring-fed stream, which have small channel widths and minimal floodplains. The limited scale of the proposed system will be required given the limited area available in some segments.

Channel Cross-Section

An initial channel cross-section was designed as a trapezoid channel with a bottom width of 4-feet, side slopes of 4:1 (horizontal:vertical), and channel depths equal to excavation from existing ground surfaces. At a design flow depth of 2 feet, the proposed channel could pass flows from 50cfs to 314cfs, at slopes from 0.003ft/ft to 0.1ft/ft, respectively (Appendix L). If a bypass is designed for approximately 1 cfs, which is a reasonable flow to maintain ecological integrity of the stream, the proposed channel dimensions will allow for vegetation, large wood, and other flow restricting habitat features. It would also allow for encroachment in some areas for public access and bridge crossings.

The side slope can be flattened depending on space and aesthetic desires. Additionally, a floodplain bench (10-foot minimum) is desired where space allows. The bench provides an area for important soil and vegetation interactions with floodwater and runoff, as well as space for storing water during high flows. Although desired, adding a floodplain will not be critical since the proposed flow diversion will reduce the "flashiness" of storm runoff to the channel.

Recommendations

Based on available data, Inter-Fluve recommends three discrete reaches of Phalen Creek, Reaches 5 and 7, for further investigation and analysis for potential daylighting. The following section provides a brief description of each recommended daylighting reach.

Reach 7

This reach was selected based on proximity to the water source, depth of excavation, and land ownership. First, the segment is located at the upper reach and could be constructed as a "stand-alone" segment of the system. The proposed reach would include reconstruction of the lake outlets to allow for a diversion of base-flow into the proposed stream channel under East Shore Drive or Wheelock Parkway. At the terminal point of Reach 7, the water would be diverted back into the Beltline Sewer system (estimated channel invert = 851.5ft, estimated Beltline Sewer Invert = 847.7ft). The area is City-owned park space, which may be more accessible for a stream construction project. The Reach would require relatively shallow excavation depths (approximately 6 feet) to construct the channel.

Reach 5

This reach was selected based on relatively shallow required excavation depths, available public and private undeveloped land, and localized stormwater discharge capture potential. Reach 5 generally requires excavation between 3 and 11 feet vertically to achieve proposed channel grades. While each of the nine subreaches has unique impacts to properties, they generally lie within either publically owned greenspace or undeveloped privately owned parcels. To achieve consistent base-flow, Reach 5 would require construction of approximately 4,300 linear feet of 12 –inch sewer pipe to convey water from Reach 7. However, Reach 5 does have an estimated three local stormwater sewershed basins that discharge towards the proposed creek alignment. A portion of the flow from these sewersheds could be redirected to the proposed stream to create an ephemeral stream flow, in the absence of perennial flow from Lake Phalen. In addition, the sewersheds could be treated within new BMPs, which could be constructed as a part of the project.

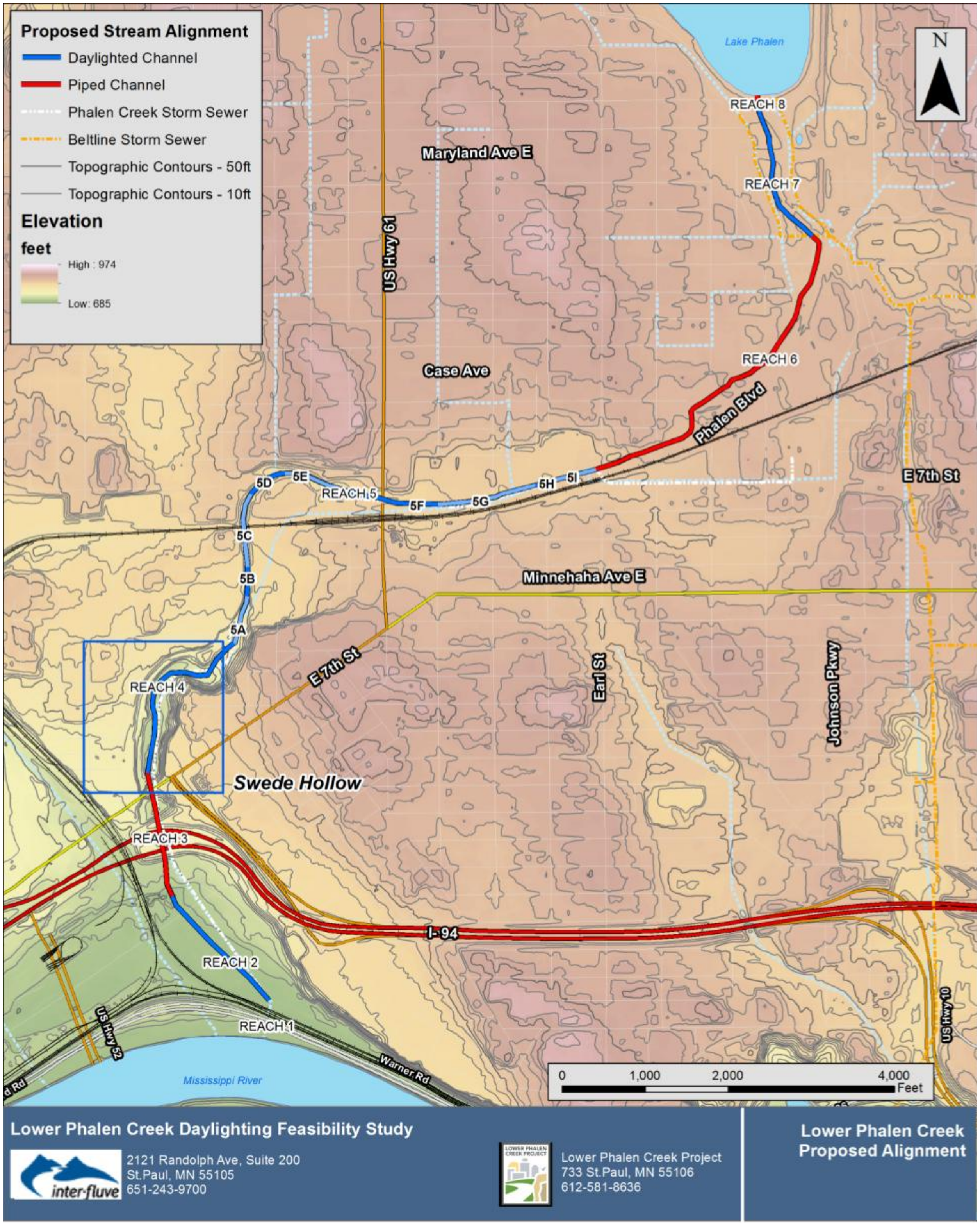

Figure 1. Location map of the Lower Phalen Creek daylighting project.

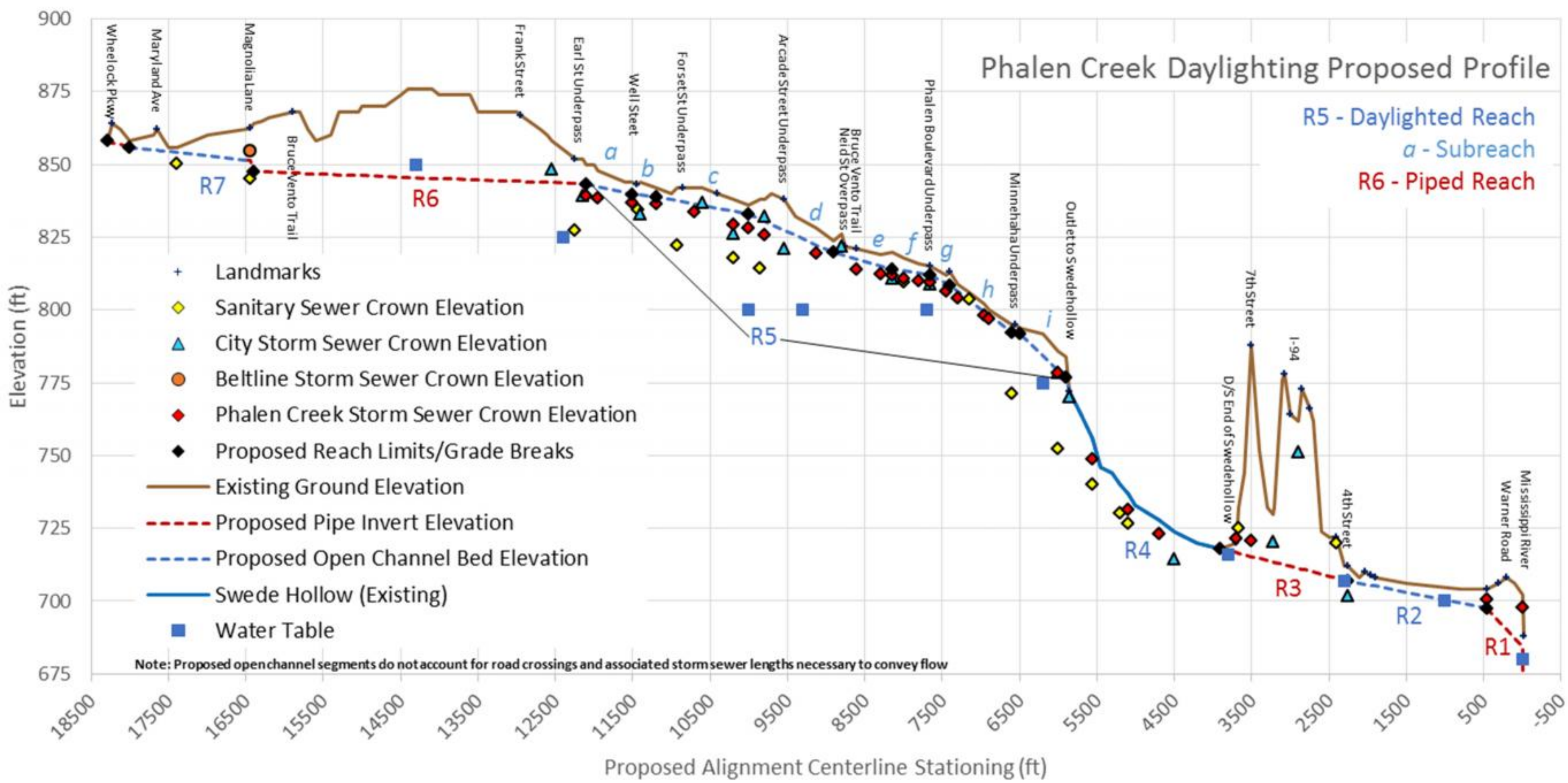

Figure 2. Profile of existing land surface and proposed Lower Phalen Creek channel. Reach 4 represents Swede Hollow, which is already an open-channel.

Reach		Stationing		Proposed Slope	Rounded Excavation Depth (ft)			Top Width (ft)			Technical Hurdles associated with Proposed Open Channel Segment								
		From	To		Min	Ave	Max	Min	Ave	Max	Space Available for Max Top Width at 4:1 Side Slope	General Lateral Width Available (ft)	Limiting Station Limits	Structure Impacts	Tree Impacts	Over/Near Phalen Creek Sewer	Road Crossings	Railroad Crossings	Public Property
7		18000	16500	0.3%	2.0	5.0	11.0	20	44	92	Y	>100	N/A	N	Y	N	1	0	Y
5	a	12100	11600	0.6%	4.0	6.0	7.0	36	52	60	N	30 to >100	12100- 11900	Potential	N	Y	0	0	Y
	b	11600	11400	0.3%	3.0	4.0	4.0	28	36	36	Y	>100	11500-11400	N	N	Y	1	0	Y
	c	11400	10200	0.5%	2.0	4.0	6.0	20	36	52	N	25, 10, 40 feet from D/S to U/S	10850-10550	Potential	N	N	2	0	Y
	d	10200	9125	1.2%	3.0	7.0	11.0	28	60	92	N	40 to >100	10200-9600	N	N	Y	1	0	Y
	e	9125	8300	0.75%	3.0	4.0	7.0	28	36	60	Limited	40	8800-8300	Bruce Vento Trail	Y	Y	1	0	Y
	f	8300	7800	0.4%	3.0	4.0	6.0	28	36	52	Limited	30	N/A	Bruce Vento Trail	Y	Y	0	0	Y
	g	7800	6900	2.0%	2.0	3.0	5.0	20	28	44	Y	40	7450-7350	Bruce Vento Trail	Y	Y	1	1	Y
	h	6900	6550	0.5%	3.0	3.0	3.0	28	28	28	Y	30	N/A	Bruce Vento Trail	N	Y	1	0	Y
	i	6550	6000	2.5%	2.0	6.0	8.0	20	52	68	Y	40 to >100	6550 - 6400	Bruce Vento Trail	Y	Y	0	0	Y

Table 1. Summary of proposed daylighted channel segments and associated technical issues.

Channel Excavation

Along the two proposed daylighting sections, expected excavation depths range from 2- to 11-feet, with average depths of excavation between 3 feet and 7 feet (Table 1). Excavation volumes were calculated using the area defined by the design cross-section with the average excavation depth at each section of each reach and the length of each section. Excavation volume estimates for each proposed reach are provided below (Table 2).

Reach		Excavation Depth (ft)				Channel Length (ft)	Excavation Volume (CY)
		Min	Avg	Max			
7		2	5	11	120	1500	6667
5	a	4	6	7	168	500	3111
	b	3	4	4	80	200	593
	c	2	4	6	80	1200	3556
	d	3	7	11	224	1075	8919
	e	3	4	7	80	825	2444
	f	3	4	6	80	500	1481
	g	2	3	5	48	900	1600
	h	3	3	3	48	350	622
	i	2	6	8	168	550	3422

Table 2. Estimated channel dimensions and excavation volumes for proposed reaches.

Opinion of Probable Project Costs

The opinion of probable daylighted channel costs are based on the initial excavation volume estimates (Table 1) compounded by typical infrastructure, landscaping, and survey /engineering/permitting/design costs as a percentage of the estimated earthwork cost. The analysis completed meets Class 5 criteria per the American Association of Cost Engineers (AACE) International standards; consequently, the costs could vary between -50% to +100% from the values provided. Based on our experience providing similar estimates, Inter-Fluve recommends and has applied a 50% cost contingency for each proposed project reach.

In addition to providing the total opinion of probable construction cost estimate for each reach, we have calculated the cost per linear foot, since the length of each reach varies. The cost per linear foot can be used as a rough metric for cost/benefit comparison between reaches. Our complete opinion of probable project costs for each reach is provided in Table 3.

In addition to the elements provided in the OPC, several other potential large project costs should be considered:

- Reach 6 Pipe: Approximately 4,300 LF of pipe is required to convey flow from Reach 7 to Reach 5 if a perennial stream is desired within the lower reaches. For conceptual cost purposes, the design team has assumed 15" round concrete pipe (RCP) will be installed, which has adequate capacity to convey the desired 1 cfs flow at the anticipated 0.1% slope. The estimated ballpark cost with a 50% contingency and accounting for engineering fees for this project element is $425,000. This estimate does not include any required property or construction easements.

- Lake Phalen Outlet Reconstruction: To divert consistent base-flow from the Beltline sewer to the proposed daylighted Phalen Creek, the existing outlet structures from the lake would need to be reconstructed. The outlet reconstruction would require engineering analysis, hydrodynamic stormwater modeling, structural engineering, and construction. A ballpark estimate for this project cost is $400,000, based on engineering judgment accounting for the complexity of the design and site logistics.

Reach		Earthwork Construction Cost Estimating			Other Project Cost Estimating									
		Longitudinal Length (ft)	Volume Excavation (cu yds)	Earthwork Cost ($30/cuyd)	Utilities (75% of earthwork)	Stream (50%)	Street/Sidewalk (25%)	Road / Rail Crossings ($50k / $100K)	Landscaping / Vegetation (15%)	Subtotal	Survey/ Design/ Permitting/ Oversight (50%)	Contingency (50%)	TOTAL	$/LF
7		1500	6667	$ 200,000	$ 150,000	$ 100,000	-	$ 50,000	$ 30,000	$ 530,000	$ 265,000	$ 265,000	$ 1,060,000	$ 700
5	a	500	3111	$ 93,400	$ 71,000	$ 47,000	$ 24,000	$ -	$ 15,000	$ 251,000	$ 126,000	$ 126,000	$ 503,000	$ 1,000
	b	200	593	$ 17,800	$ 14,000	$ 9,000	-	$ 50,000	$ 3,000	$ 94,000	$ 47,000	$ 47,000	$ 188,000	$ 900
	c	1200	3556	$ 106,700	$ 81,000	$ 54,000	$ 27,000	$ 100,000	$ 17,000	$ 386,000	$ 193,000	$ 193,000	$ 772,000	$ 600
	d	1075	8919	$ 267,600	$ 201,000	$ 134,000	-	$ 50,000	$ 41,000	$ 694,000	$ 347,000	$ 347,000	$ 1,388,000	$ 1,300
	e	825	2444	$ 73,400	$ 56,000	$ 37,000	$ 19,000	$ 50,000	$ 12,000	$ 248,000	$ 124,000	$ 124,000	$ 496,000	$ 600
	f	500	1481	$ 44,500	$ 34,000	$ 23,000	$ 12,000	$ -	$ 7,000	$ 121,000	$ 61,000	$ 61,000	$ 243,000	$ 500
	g	900	1600	$ 48,000	$ 36,000	$ 24,000	$ 12,000	$ 150,000	$ 8,000	$ 278,000	$ 139,000	$ 139,000	$ 556,000	$ 600
	h	350	622	$ 18,700	$ 15,000	$ 10,000	$ 5,000	$ 50,000	$ 3,000	$ 102,000	$ 51,000	$ 51,000	$ 204,000	$ 600
	i	550	3422	$ 102,700	$ 78,000	$ 52,000	$ 26,000	$ -	$ 16,000	$ 275,000	$ 138,000	$ 138,000	$ 551,000	$ 1,000

Table 3. Opinion of probable project cost for proposed daylighted channel segments.

Water Quality Assessment

Numerous studies have focused on the impacts of stream daylighting on fish habitat (e.g. Pinkham 2000; Jones 2001), or the sociological, aesthetic, or economic reasons for daylighting (e.g. Pinkham 2000; Jones 2001; Shin and Lee 2006; Buchholz and Younos 2007; Sinclair 2012). Daylighting buried streams may foster a number of social, economic, and ecologic improvements, including, but not limited to, the following:

1. Relieve flooding issues by reducing "pinch" points at under-sized culverts and providing greater flow capacity by recreating a floodplain along the channel.
2. Reduce runoff velocities by increasing roughness and water storage/attenuation.
3. Improve water quality by exposing water to air, sunlight, vegetation, and soil
4. Recreate aquatic and riparian habitat and improve wildlife passage
5. Provide recreational, leisure, and(or) educational amenities
6. Beautify neighborhoods, attracting residents and visitors and possibly contributing to greater civic pride (Pinkham, 2000; Wilde et al. 2011).

In natural, open channels, sunlight and biological production play important roles in controlling normal levels of nutrients and even some pollutants. On its own, sunlight breaks down organic compounds to more biologically useful forms. Sunlight also provides the energy required for algae and other plant production, which in turn, drives the productivity and diversity of bacteria and grazer species that help use and breakdown nutrients and metals in the water. Natural, open streams also generally flow through a variety of stream side environments, resulting in heterogeneous channel forms and processes driven by varying bed materials (e.g., sand, gravel, wood), bed forms (e.g, pools and riffles), groundwater-surface water interactions, and floodplain-channel interactions. This physical channel heterogeneity generally increases residence times, connectivity, and transient storage of both water and sediment along the channel. Placing streams in underground pipes limits these ecological processes along the impacted reach, thereby reducing conditions conducive for supporting anticipated levels of bioproductivity and biodiversity; nutrient retention, uptake, and processing (e.g., denitrification); ecosystem metabolism and food web dynamics; and others (Pennino, et al 2010;Figure 3).

Restoration of open, channelized streams increases nitrogen use by plants and animals, storage in sediment (Bukaveckas 2007; Klocker et al. 2009) and denitrification (Kaushal et al. 2008b; Harrison et al. 2011), and enhances carbon processing (Lepori et al. 2005; Sivirichi et al. 2011). Few studies, however, have measured the direct effects of daylighting on stream biogeochemistry. Daylighting a buried stream drastically transforms the system, and opening the system to light and more natural channel conditions, likely dramatically improves biogeochemical processing. Added heterogeneity, especially if built into a restoration plan that includes riffles, pools, eddies, pocket water, etc. will add habitat for a range of fish, macroinvertebrates, and others, as well as provide areas for sediment and water retention and local groundwater-surface water interaction (i.e., hyporheic exchange). The few studies that have examined the impact of daylighting streams found decreases in fecal coliform levels and increasing taxa richness, (Charbonneau and Resh, 1992), and(or) a change in invertebrate composition from biofilm feeding collector-browser communities to algal grazer communities (Neale and Moffat 2016). Pennino, et al. (2010) reported stream burial reduced nitrate uptake rates by a factor of 8 and general primary production by a factor of 11 along impacted reaches of Maryland streams, and indicated that daylighting could alter these systems to improve both carbon and nitrogen processing.

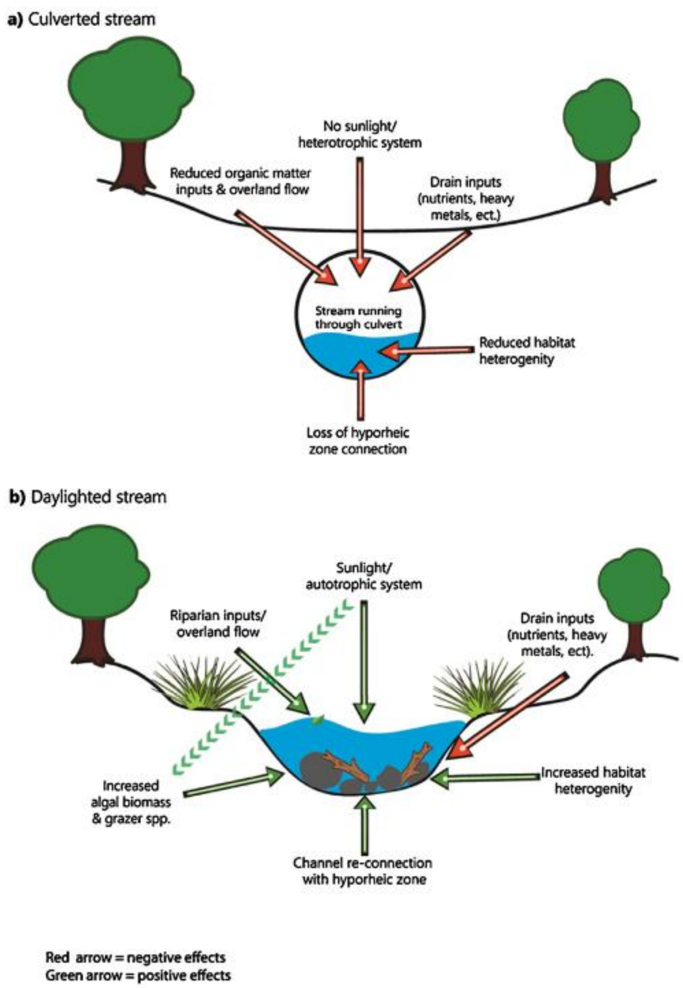

Figure 3. Conceptual diagram of the hypothetical changes in stream ecology arising from daylighting (From Neale and Moffet, 2016).

References

Buchholz, T., and T. Younos. 2007. Urban stream daylighting: case study evaluations. Virginia Water Resources Research Center, Blacksburg, VA.

Bukaveckas, P.A. 2007. Effects of channel restoration on water velocity, transient storage, and nutrient uptake in a channelized stream. Environmental Science and Technology 42.5: 1570-1576.

Charbonneau R, and V.H. Resh. 1992. Strawberry Creek on the University of California, Berkeley campus: a case history of urban stream restoration. Aquatic Conservation: Marine and Freshwater Ecosystems 4: 293-307.

Harrison, S.S.C., J.L. Pretty, D. Shephard, A.G. Hildrew, and C. Smith. 2004. The effect of instream rehabilitation structures on macroinvertebrates in lowland rivers. Journal of Applied Ecology 41: 1140-1154.

Jones, S.W. 2001. Planning for Wildlife: Evaluating Creek Daylighting as a Means of Urban Conservation. Dalhousie University, Halifax, Canada.

Kaushal, S.S., K. Delaney-Newcomb, S.E.G. Findlay, T.A. Newcomer, S. Duan, M.J. Pennino, G.M. Sivirichi, A.M. Sides-Raley, M.R. Walbridge, and K.T. Belt. Longitudinal changes in carbon and nitrogen fluxes and stream metabolism along an urban watershed continuum. Biogeochemistry.

Klocker, C.A., S.S. Kaushal, P.M Groffman, P.M. Mayer, and R.P. Morgan. 2009. Nitrogen uptake and denitrification in estored and unrestored streams in urban Maryland, USA. Aquatic Science 71.4: 411-424.

Lepori, F., D. Palm, and B. Malmqvist. 2005. Effects of stream restoration on ecosystem functioning: detritus retentiveness and decomposition. Journal of Applied Ecology 42.2: 228-238.

Neale, M.W., and E.R. Moffett. 2016. Re-engineering buried urban streams: Daylighting results in rapid changes in stream invertebrate communities. Ecological Engineering 87: 175-184.

Pennino MJ, Kaushal SS, Beaulieu JJ, Mayer PM, Arango CP. Effects of urban stream burial on nitrogen uptake and ecosystem metabolism: implications

Pinkham, R. 2000. Daylighting: New Life for Burid Streams. Rocky Mountain Institute, Colorado.

Shin, J.H., and I.K. Lee. 2006. Cheong Gye Cheon restoration in Seoul, Korea. Civil Engineering (Proceedings of ICE) 159: 162-170.

Sinclair, C. 2012. An exploration of stream daylighting and urban attitudes towards the einvironment. Trail Six 6: 68-79.

Sivirichi, G.M., S.S. Kaushal, P.M. Mayer, C. Welty, K.T. Belt, T.A. Newcomer, K.D. Newcomb, and M.M. Grese. 2011. Longitudinal variability in streamwater chemistry and carbon and nitrogen fluxes in restored and degraded urban stream networks. Journal of Environmental Monitoring 13.2: 288-303.

Wild, T.C., J.F. Bemet, E.L. Westling, and D.N. Lerner. 2011. Deculverting: reviewing the evidence on the daylighting and restoration of culverted rivers. Water and the Environment: 25.3: 412-421.