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TECHNICAL MEMORANDUM

DATE: Saturday, September 08, 2012

TO: Michele Koehler, Seattle Public Utilities

FROM: Derek Booth, Stillwater Sciences

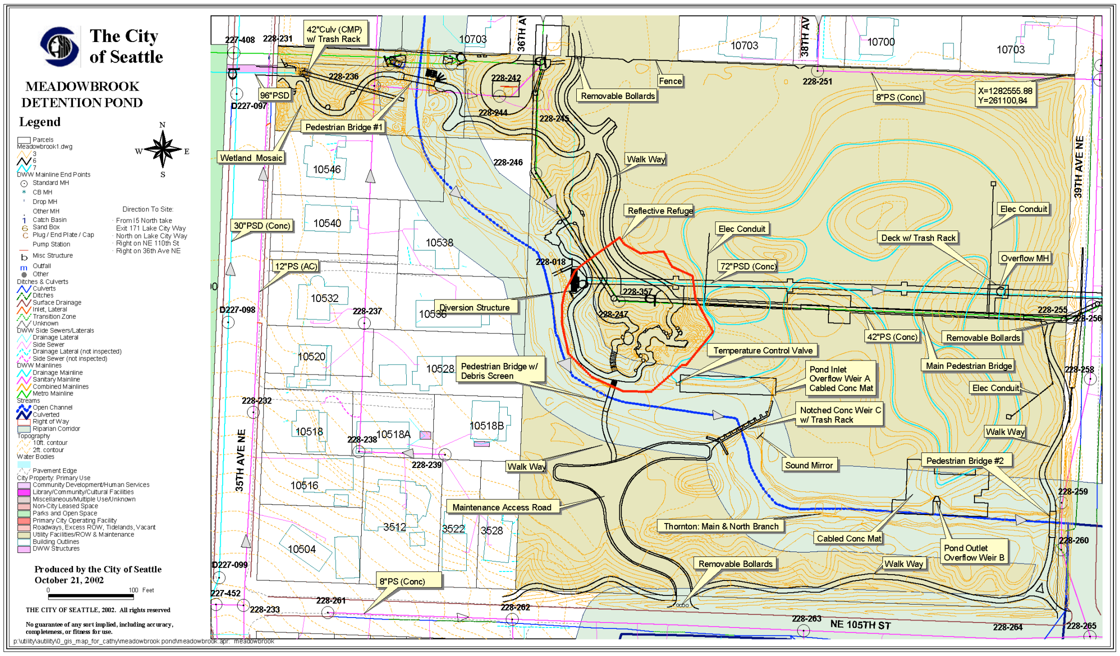
SUBJECT: Meadowbrook Pond conceptual analysis for sediment-related issues

1 BACKGROUND

Meadowbrook Pond is a 2.5-acre stormwater pond in northeast Seattle, located immediately downstream of the North and South branches of Thornton Creek. It captures about 6840 acres of the upstream watershed, nearly 90% of the total drainage area of Thornton Creek. The facility was fully reconstructed in 1999 from its prior condition as an abandoned wastewater treatment plant. The goals of the facility are to "Provide detention, sedimentation and flow diversion to reduce downstream flooding, streambed scouring and deposition of sediments at the outfall of the creek at Lake Washington" (City of Seattle memo, 28 December 2001).

Recent attention to the performance of the pond, particularly with respect to sediment deposition throughout the Thornton Creek channel network, has prompted a reevaluation of the pond's current and potential role in trapping sediment. The goals of any such reconfiguration would be to increase the pond's sediment-trapping capacity and efficiency, and to alleviate flooding in the surrounding neighborhood. The sediment-trapping goal is predicated on the assumption that more sediment can and should be entrained at the pond where dredging is less environmentally damaging than farther downstream in the channel network. A secondary goal of any such reconfiguration would be to improve water quality (particularly summer temperatures and, presumably, nutrients).

A schematic of the pond has been provided by Seattle Public Utilities (SPU), including locations of field photos referenced in the next section (red numbers):



2 FIELD RECONNAISSANCE

On 31 January 2008, I visited Meadowbrook Pond with the specific intention of reviewing patterns of sediment deposition and potential alternatives for pond reconfiguration. This visit was the latest of several dozen visits I have made since the facility was completed, and conditions were generally quite representative of prior observations.

As with previous visits, the bed immediately upstream of the pedestrian bridge is sand (Photo 1, next page). Immediately downstream, it grades to sand with scattered gravel, and then gravel out to the first left-bank point bar with D_{50} = 30 mm (Photo 2). The bed is again sand-dominated down to the area of the intake structure, where a plug of coarser gravel (D_{50} = 50 mm) has collected (Photo 3). Sand and gravel continue on the bed down to the debris screen; sand is dominant immediately under and beyond the bridge, but a prominent gravel bar has collected in the first forebay (D_{50} = 30 mm) (Photo 4). A minor amount of gravel is carried through the notched weir (Weir C) (Photo 5) out to the creek bypass of Meadowbrook Pond, but the vast majority of gravel is surely trapped in the forebay. Sand is presumably suspended across the overflow weir (Weir A) (Photo 6), continuing to settle near and beyond the steps. I see only silt deposited past the bypass pipeline (Photo 7), but a very high silt and sand load during turbid high flows is readily imagined.

Down the bypass creek reach to the 39th Avenue NE bridge crossing, the bed is sand-dominated but with a moderate gravel component. Just downstream of the bridge, the gradient steepens markedly and the bed is fully gravel-covered (Photo 8).

Several observations merit particular note:

1. The distribution of grain sizes on the bed is spatially discontinuous. Either gravel is carried past the zones of sand deposition, sand buries the gravel in these areas during waning or low flows, or gravel is so sparse that it is only visible where concentrated by local hydraulics. I favor the second option—namely, a long, sandy tail to sediment-transporting events, coupled with a relatively low fraction of gravel relative to sand that is reaches this point in the channel network (given the extensive upstream flats, e.g. at “Dredge Site #9” on the South Branch, just downstream of 30th Avenue NE).
2. Gravel is carried through the forebay and into the bypass creek reach (i.e., through the notched Weir C, from the site of Photo 4 to downstream of Photo 5). This must occur infrequently, and only with massive deposition of gravel in the forebay, suggesting a fairly stable and possibly cemented bed in this downstream reach.
3. The creek rapidly picks up a gravel load in the bypass reach (i.e., between Photo 5 and Photo 8). The only credible source is local bank erosion, plus whatever passes through the forebay and Weir C. Given the modest volumes involved, the coarse sediment present in this channel must have a relatively long residence time; the gravel is probably immobile under most conditions, and the bed therefore well-cemented.

The hydraulics of the trash rack (just upstream of Photo 4) and the forebay presumably encourage some degree of local deposition just upstream of the rack, local scour through beneath it, and a substantial loss of sediment load as the flow widens out in the forebay and then splits through Weir C and over Weir A. Backwater from the pond surely also encourages deposition here. At high flows, the overflow weir (Weir A; Photo 6) is presumably drowned out and provides only modest limitation to sediment passage; the forebay surely lacks sufficient volume to efficiently settle out the sand and finer load under conditions of high flow.

3 ADDITIONAL INFORMATION ON MEADOWBROOK POND

3.1 Watershed properties and pond size

The two branches of Thornton Creek collectively drain 27.7 km^2 (6840 acres), based on a GIS analysis of the USGS 10-m DEM for the area. This is 88% of the total basin area, using the value of 12.1 mi^2 (7744 acres) reported by the USGS at Gage 12128000 (“Thornton Creek near Seattle, WA”) about a quarter-mile upstream of Lake Washington.

Meadowbrook Pond itself has an SPU-reported surface area of 2.5 acres, a live storage volume of 300,000 ft^3 and a dead (permanent) storage volume of 350,000 ft^3 (6.9 and 8.0 acre-ft, respectively). The average pond depth is thus about 3 feet.

The USGS gage has only 18 (discontinuous) years of record. Maximum recorded discharge is 575 cfs on 20 October 2003. The total average annual discharge is equivalent to 12.55” of runoff per year, a surprisingly low amount for an urban watershed in a climate with 40” of annual rainfall. Reported discharges at the USGS gage capture only a fraction of the flow from the Thornton Creek watershed, however, because varying water volumes are collected by the 72” bypass pipeline at Meadowbrook Pond and are routed directly to Lake Washington. By comparison, the discharge record at the USGS gage for Mercer Creek (Gage 12120000), only a few miles away in west Bellevue and draining a nearly equivalent-sized watershed (but with no bypass pipeline) shows 25.52” annual runoff, about double that of Thornton Creek. The 20

October 2003 discharge at the Mercer Creek gage was 754 cfs, nearly 200 cfs greater than at the mouth of Thornton Creek. This difference matches a crude estimate of the bypass pipe capacity reasonably well, which depending on the actual pipe material and head losses would be several hundred cubic feet per second at full capacity.

3.2 Comparison with water-quantity and water-quality guidelines

Existing publications offer some indication of the likely effectiveness of Meadowbrook Pond at controlling the quantity and quality of runoff from the contributing watershed. Using the measured tributary area (6840 acres) and the pond's live storage volume (300,000 ft^3), the pond has only 0.012 "watershed inches" of detention volume. Based on analyses of other watersheds using continuous simulation modeling (e.g., Booth and Jackson 1997), this is a negligible control volume. Any significant attenuation of flows to the downstream system, at least at high discharges, is almost certainly a result of bypass through the 72" pipe, not detention.

Similarly, the water-quality benefits of the pond are severely constrained by the pond volume relative to the size of the watershed. For example, the WADOE water-quality design storm (1.2") generates 100 times the total runoff volume as the dead storage volume of the pond. Even with some degree of losses from infiltration and evapotranspiration between the watershed and the pond, removal efficiencies at the pond are almost certainly less than 10% for all but the coarsest of sediment particles (e.g., Horner et al. 1994, p. 121; Minton, 2005).

4 CONCEPTUAL DESIGN RECOMMENDATIONS

4.1 Primary goal—enhanced sedimentation in the pond

The primary goal of any reconfiguration is presumably to induce more sediment deposition. This would be most effective during that period when the majority of the sediment load is being transported, namely during the wintertime, and at the site of most abrupt reduction in flow velocity, namely in the forebay upstream of Weirs A and C. Deposition of sediment in this area would be encouraged by the following types of measures:

- Ensuring minimal backwater in the channel of Thornton Creek upstream of the forebay (this is presumed, but information is needed).
- Blocking the upstream diversion structure inlet, on the assumption that the capacity of the Thornton Creek channel downstream to the pond is no less than its capacity immediately upstream (and so flow splitting is not needed to safely convey flows in the channel).
- Increasing the separation between the trash rack at the forebay entrance and Weir C, by increasing the size of the forebay.
- Constructing a baffle to block direct flow-through (i.e., "short-circuiting") from the trash rack to Weir C. If effective, this would have the consequence of further starving the bypass channel of the creek of most sediment, which in turn might lead to some greater degree of bank erosion in the reach downstream to 39th Avenue NE (i.e., between Photo 5 and Photo 8). This is not anticipated to be a severe problem (because only modest volumes of sediment are presumed to move down this channel at the present time) but the potential should be investigated.
- Raising the level of Weir A to increase the dead storage in the forebay. This effect would need to be balanced against the increase fraction of flow that would be diverted through

Weir C and down the bypass channel of Thornton Creek, whose capacity and/or erosional stability would need further investigation.

- Deepening the forebay to increase sediment storage, depending on whether a deeper dredging might result in any stability problems for the banks and adjacent structures.
- Regular sediment removal in the forebay. If dredging can occur during the summer months each year, the amount of sediment that can be trapped in this area during winter storm will be determined by the amount of sediment supply and the volume emptied during the summer through mechanical dredging. The more volume dredged during the summer, the higher trapping efficiency the area will have during the winter storm event. If the amount of bedload supplied during the winter is higher than the dredging pond volume, the sediment will build up to or close to the pre-dredging condition, allowing bedload to pass through Weirs A and C into Meadowbrook Pond and lower Thornton Creek. The ideal situation is to have a dredging pond large enough to contain all the winter bedload supply that can be dredged out during the summer low-flow months.

  The total annual sediment load from the upper watershed is presumably no greater than other urban watersheds; using a representative value of 50 tonnes/km^2/yr (about 140 tons/mi^2/yr) (Nelson and Booth, 2002), the average annual delivery should be on the order of 1000 cubic yards, minus what is trapped higher in the drainage network. Only about half of volume is probably available in the forebay with its present configuration.

4.2 Secondary project goals

4.2.1 Reduce summertime heating

To lower temperatures in the pond, the open water area would need either a reduced surface-to-volume ratio (i.e., deepening), an increased fraction of the surface area receiving south-side shading (i.e., a more E–W linear pond with large trees on the south bank), or greater flushing by summertime flows from Thornton Creek. However, the concern over high temperature is presumably directed more towards the downstream reach of Thornton Creek than the pond itself.

Under the present discharge regime, the summertime low flow (about 3 cfs at the downstream USGS gage) is adequate to replace the dead storage of the pond in a bit more than one day. With much of that flow bypassing the pond via Weir C, however, the turnover rate is probably much less and the resulting heating of the pond much greater. When summertime storms do occur, the heated water from the pond is presumably flushed out Weir B and down Thornton Creek.

Better protecting lower Thornton Creek from pond-heated water could be readily achieved; it would require only a reduction of discharges passing through the pond into the Creek. This could be achieved by some combination of raising the overflow weir (Weir A) and closing off the pond outflow (Weir B).

Several changes to the weirs during the summertime are thus suggested. The first option is to raise or close off the notch in the overflow weir (Weir A), which would force flows to bypass the pond altogether. In so doing, however, this alternative would eliminate any detention of summertime storms and also maintain a stagnant water body in the main pond all summer. A second option, closing off Weir B, would divert virtually all storm flows down the bypass pipeline. It would reduce flows into Thornton Creek but would maintain downstream water temperatures.

A hybrid approach could split flows between Weirs A and C at low flow, with near-constant summertime flows through C into Thornton Creek and all excess storm discharges passing through the pond and down the bypass pipeline into Lake Washington. This would require Weir C to be replaced by a constant (or near-constant) head discharge, presumably a submerged orifice that would substitute for discharge through the existing slot weir during the summer months. Weir B would be closed entirely during this period; the lake level would rise to the invert elevation of the overflow manhole and remain close to that level at all times.

4.2.2 Alleviate neighborhood flooding

Recommending improvements will require a detailed topographic survey and better understanding of the current (and future) hydraulic performance of the pond. Given the minimal benefits to water quality or detention during storms, the most obvious measure to improve this condition is to ensure that the bypass pipeline is running as full as possible as potential flood elevations are being approached. This could be accomplished most easily with a lowered overflow manhole invert. Although the current pond configuration, with its islands and proto-peninsula, strikes a compromise between performance and aesthetics, even full use of the available area for detention would probably not make a significant improvement in live-volume storage, relative to watershed inputs during storms. More extensive berms around the pond are presumably already under investigation by SPU.

Ultimately, however, reduced flow through the area of Meadowbrook Pond will require more aggressive flow-reduction strategies throughout the upper watershed.

4.2.3 Improve Water Quality

Improved suspended sediment reduction would require an increase in residence time, and this seems infeasible given the relative sizes of the site and the contributing watershed. Nutrient reduction would surely benefit from a reduction in waterfowl population; I assume that alum injection and duck harassment has been (or is being) considered by others. Better throughflow of Thornton Creek (by closing off Weir C, for example) would probably improve pond water quality, but at the likely expense of temperature and water-quality conditions downstream. Without active treatment at the pond, achieving improved water quality is likely to be elusive.

4.3 Recommended additional steps

Ultimately, the volume of the sediment load arriving at Meadowbrook Pond is a consequence of processes in the upper watershed, and a trap-and-dredge approach can never be fully successful. Source control of that sediment is mandatory to achieve long-term, sustainable improvements.

By cursory examination, the current sediment load of Thornton Creek is not particularly “excessive” by the standards of urban creeks. One of the most common sources of deposited sediment, the channel itself, is not producing voluminous quantities because the bed and banks are relatively stable, a predictable consequence of many decades of near-constant land use where most of that channel erosion has already occurred. This assumption is supported by the observed sediment loading of Meadowbrook Pond, which is overwhelmingly (though not exclusively) sand and silt. In some settings, this can reflect a discrete source of gully-generated sediment, and this alternative should be investigated (and likely ruled out) with the aid of geologic maps, topographic maps, and our long-standing understanding of what settings are most susceptible to rapid incision and the consequent production of voluminous in-channel sand loads.

More likely, the observed sand and silt reflects the wash-off from upland sources throughout the upper watershed, whose general source areas can also be predicted relatively efficiently through GIS data and some field observations. Their control is likely to be most effective through a combination of measures—both sediment-reduction and flow-reduction in nature—and guided by a better understanding of the relative importance of potential sources than currently exists (for the City or anywhere else). These potential sources include:

- Road ditches
- Construction sites
- Small landslides on private property or public right-of-ways
- Road sanding during the winter

All of these possible sources would benefit from on-site drainage management and flow reduction, but a more targeted and effective approach would require additional information on the watershed-scale distribution of susceptible source areas and their relative importance to sediment loadings. Information to accomplish this effort is readily at hand but has never been compiled and analyzed.

5 SUMMARY

The following actions are suggested for further consideration and engineering analysis:

1. Expansion of the forebay;
2. Blockage of the upstream-most diversion structure into the bypass pipeline;
3. Lowering the invert elevation of the overflow manhole;
4. Reconfiguring the forebay for greater volume;
5. Active summertime management of the weirs, particularly the partial or total blockage of Weir B; and
6. Analysis and control of sediment sources from the upper watershed.

A related concern articulated by SPU, that of high turbidity discharging from the mouth of Thornton Creek into Lake Washington, has no obvious on-site solutions (i.e, at the mouth itself). Reduction in this load might occur only by greater high-flow diversion into the bypass pipeline (thus shifting the site of impacts but obviously not eliminating them), enhanced deposition of sediment in Meadowbrook Pond (least effective, however, for the finest sedimentary particles), or improved source control throughout the contributing watershed. Although the latter is a daunting aproach, it is almost certainly the only one with any prospect of long-term success.