APPENDIX D
Background Materials on Test Cases for Workshop Participants

Jackson Park Project

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Background and Problem Statement:

Jackson Park is an 18 hole public golf course (with a short nine) owned and operated by the Seattle Parks Department. It is located on the northern city limits of the City of Seattle near the headwaters of the north branch of Thornton Creek. It has a water right to divert water from the creek for its irrigation needs.

Three detention ponds with a combined storage capacity of 25 acre-feet were constructed in the Jackson Park Golf Course in 2003. The purpose was to attenuate peak flows in Thornton Creek by storing water in the ponds for future use to irrigate the golf course. In practice, the ponds do not provide sufficient storage for irrigation during the summer so diversions during periods of low flow in the creek are still required. Seattle Public Utilities has recently conducted an analysis of the ecological benefits of eliminating these diversions and increasing summer flows in the upper reaches of the creek, (*Reference 1, below).*

The irrigation diversions at Jackson Park represent approximately half of the flow upstream of the diversion point and 15% of the flow at the mouth of Thornton Creek mainstem during August. In an effort to quantify the ecological benefits of increased summer flows, two estimates were made: (1) the amount of additional aquatic habitat expected under fully restored base flows (i.e., no diversion), and (2) the amount of fish produced by this additional habitat.

Summer low flows measured downstream of the ponds in 2005 averaged approximately 0.7 cfs. Eliminating the creek withdrawals during the summer would about double the flow, providing a fully restored base flow of 1.4 cfs. Based on approximations of stream channel and hydraulic parameters, the effect of doubling the flow could increase creek depth up to 0.75 of an inch (minimal change in wetted width), or increase the wetted width of new aquatic habitat by up to 6 feet (minimal change in depth), depending upon the shape of the channel. Assuming a trapezoidal channel, the most reasonable estimate is that creek depth would increase by an average of 0.3 inch and wetted width would increase by 3 feet. The analysis concluded that this increase in habitat could result in an increased fish production of about 460 to 970 adult fish per year. The majority of these would be trout (90%), with much smaller numbers of coho salmon (mostly likely planted), bluegill, and crayfish. Assuming a value of $10/ adult trout (Ray Timm, Habitat Complexity PDP, 2005), this would have an estimated economic benefit of $4,600 to $9,700 per year.

Other non-monetized benefits of increased base flows would include:

Increased habitat value, particularly in the downstream wetland. Pool habitat, a critical rearing area, is very limited in Jackson Park and most of it occurs in a wetland immediately downstream. Increased base flows would provide deeper pools and more wetted area for spawning and benthic insect (i.e., food) production.

Reduction in summer water temperatures. In evaluating the summer temperature data over the last three years, it appears that the amount of time that the creek temperature exceeds 16°C (Ecology's threshold for temperature) is decreasing. The maturing riparian vegetation at the site is providing increased shading and cooling. Water temperatures could be further reduced by allowing the full creek flow to continue through the golf course. However, the magnitude of the temperature reduction that might be expected has not been quantified.

Summary of Potential Benefits of Eliminating Jackson Park Diversion from Thornton Creek:

Cessation of withdrawals for irrigation could double stream flows through Jackson Park and provide roughly 15% more flow farther down Thornton Creek during summer and early fall. Average increases of 0.3 inch in creek depth and 3 feet in creek width through Jackson Park might be achieved. Expected environmental benefits include:

- Increased fish production by 460 to 970 adult fish per year;
- Increased creek habitat value, particularly in the North Branch wetland; and
- Further reduction in summer creek temperatures.

Proposed Reclaimed Water Project:

Several ways of providing Jackson Park with substitute water are currently under consideration. One proposal would bring reclaimed water from the Brightwater Wastewater Treatment Plant to Jackson Park. The Brightwater plant will produce up to 21 mgd of class A reclaimed water when it is completed in 2011. Phase 1 of the Brightwater Reclaimed Water Backbone Project (the Backbone) - also under construction - will bring reclaimed water within 3.6 miles of Jackson Park. The Jackson Park Reclaimed Water project would involve running 3.6 miles of purple pipe from the Ballinger Way Portal to the northern boundary of Jackson Park (see map). Pumping would be necessary as would extension of and improvements to Jackson Park's irrigation system. Estimated costs are as follows:

Costs:

Preconstruction (1 yr)	$585,000
Design (1 yr)	$1,220,000
Construction (1.5 yrs)	
Pipe (100 yr life)	$6,861,000
Pumps (25 yr life)	$322,000
Annual O&M	$30,000*
Jackson Park Infrastructure	
Meter	$60,000
Booster Station	$150,000
Pipe	$200,000
Other	$50,000

* Includes annualized cost of pump replacement every 25 years

Note that Jackson Park internal costs are based on half a mile of new 12" pipe on the property capable of delivering 1,200 gpd peak flow. It is assumed that reclaimed water could not be stored in the third irrigation pond and then pumped through the existing system. If that was allowed, shorter lengths of smaller pipe would be required with maximum peak flow of 750 gpd. This would reduce Jackson Park's onsite costs by more than half.

Some costs associated with the Backbone should probably also be included as project costs. For the purpose of this analysis, Phase 1 is assumed to be already constructed and is thus a sunk cost with no costs assignable to Jackson Park. However, getting reclaimed water to Jackson Park will also require that Phase 2 of the Backbone be build. Phase 2 consists of pumps to pressurize the west segment of the Backbone and would involve $13 million in capital costs and $430,000 in annual O&M costs. King County has stated that Phase 2 will not be built until sufficient demand is demonstrated. It is therefore appropriate to allocate a portion of these costs to the Jackson Park Project. Since Jackson Park represents about 9% of total potential demand identified along the west segment, at least 9% of Phase 2 costs ($1,170,000 CIP and $39,000 annual O&M) should be allocated to Jackson Park. (This assumes that all potential customers actually hook up to the Backbone. If not all do, then Jackson Park's share of Phase 2 costs would be larger.)

Water Demand:

Metered water use data is available from Jackson Park for the past several years. Consumption has varied between 29.8 MG in 2005 (a relatively cool wet summer) and 32.5 MG in 2006 (hot and very dry summer weather). The irrigation season runs from around the first of May through the first part of October. Peak days can reach half an mgd while average use over the irrigation season is about 0.2 mgd. This works about to about 40,000 to 43,000 ccf per season.

If reclaimed water were available, Jackson Park would still continue to withdraw some water from Thornton Creek, mostly in May and June during times of higher flows. Consumption of reclaimed water would take place mostly in July through September and probably total about 25,000 to 30,000 ccf.

Reclaimed Water Proposal Summary:

Likely Consumption of Reclaimed Water:	25,000-30,000 ccf per year
Quantified Environmental Benefit:	$4,600-$9,700 per year
Unquantified Benefits:	-Improved aquatic habitat -Reduced stream temperature -Reduced discharge of Class A water in Puget Sound (25,000-30,000 ccf/yr)
Capital Costs:	$9,448,000
Annual O&M Costs:	$30,000
Share of Backbone Phase 2 Costs:	$1,170,000 CIP + $39,000 annual O&M
Unquantified Costs:	-Concern over EDCs in runoff returning to Thornton Creek

<u>Alternative Projects – Potable Water:</u>

An alternative to using reclaimed water as a substitute for diversions from Thornton Creek would be for Jackson Park to purchase potable water from Seattle Public Utilities. This would involve tapping into SPU's existing water main along NE 145th Street which runs along the northern boundary of the park. Jackson Park's onsite costs would be similar to the reclaimed water alternative: $460,000. As with reclaimed water, these costs could be cut in half if the potable water could be stored in the third irrigation pond. But also as with the reclaimed water option, this would probably not be allowed because of the risk of (in this case) chlorinated water overflowing from the pond into Thornton Creek.

The short term variable costs of supplying additional water, (pumping, chemicals, treatment, etc.) are very low, less than $0.10 per ccf. The variable cost of 30,000 ccf would be under $3,000 per year.

Substituting potable water for diversions from Thornton Creek would increase the demand for water from SPU's current supply sources. This would not be expected to pose a problem for water supply, however. Firm yield from SPU's sources is estimated at 171 mgd while current demand is around 130 mgd. SPU's latest demand forecast projects that demand will not reach current supply capacity until some time after 2060. Even pessimistic scenarios involving greater-than-expected demand growth and adverse supply impacts of global climate change don't foresee a need for additional supply capacity before 2040. So, one option would be to provide potable water to Jackson Park with no effort to mitigate the impact on potable water supplies.

Another option under consideration is to provide potable water to Jackson Park and then offset the increase in demand by improving irrigation efficiency at Jackson Park and Seattle's three other public golf courses. Various conservation measures involving weather stations, flow sensors, increased automation, increased turf aeration, and replacement of leaky irrigation mains are estimated to cost about $610,000 while actually reducing O&M costs at the four golf courses. Total annual savings from these measures are estimated at 26,000 ccf per year, enough to offset Jackson Park's anticipated demand for potable irrigation water.

Potable Water Proposals Summary:	**Without Conservation**	**With Conservation**
Likely Consumption of Potable Water:	25,000-30,000 ccf/year	0 ccf/yr net
Quantified Environmental Benefit:	$4,600-$9,700 per yr	$4,600-$9,700 per yr
Unquantified Benefits:	-Improved habitat -Reduced temperatures	-Improved habitat -Reduced temperatures
Capital Costs:	$460,000	$1,070,000
Variable Water Costs:	< $3,000 per year	$0
Unquantified Costs:	-Concern over chlorinated runoff -Impact on potable supplies	-Concern over chlorinated runoff

References

1. *Ecological Benefits of Increased Summer Flows in the North Branch of Thornton Creek*, Internal SPU memorandum from Keith Kurko, Manager, Natural Resources and Fisheries, dated December 30, 2005.

2. *Final Technical Memorandum on Reclaimed Water Opportunities*, from Brown and Caldwell to Seattle Public Utilities dated July 13, 2006. Published as Appendix E in the Water Resources Appendices of the Draft Seattle Public Utilities 2007 Water System Plan.

3. *Draft White Paper – Reclaimed Water Backbone Project, Version 3.0*, King County Department of Natural Resources and Parks, Wastewater Treatment Division, March 2006.

4. *Jackson Park Water Reports - 2005 & 2006*, provided by Robert Maddox, Seattle Parks Department.

5. Personal communication with Robert Maddox, Senior Golf Course Technician at Jackson Park, Andy Soder, Golf Director, Seattle Parks Department, and Scott Kuhn of Kuhn Associates, October 13, 2006.

6. Personal communication with Rich Gustav, Al Dietemann and Jenna Smith in Seattle Public Utilities, Resource Conservation, October 12-14, 2006.

Seattle Public Utilities

Memorandum

Date: December 30, 2005

To: Al Dietemann

From: Keith Kurko

Re: Ecological Benefits of increased summer flows in the North Branch of Thornton Creek

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Seattle Parks and Recreation (Parks) is requesting Seattle Public Utilities' (SPU's) financial support to purchase supplemental city water in exchange for stopping water withdrawals from the North Branch of Thornton Creek in Jackson Park Golf Course during critical summer low flow periods. The purpose of this analysis is to outline the environmental benefits of maintaining flows in Thornton Creek during the summer, and where possible, monetize those benefits. This memorandum provides a preliminary assessment of environmental benefits and is not intended for use in Asset Management documentation. Site specific physical and biological data would need to be collected to construct a business case.

Ecological Context for the Analysis:

Flow is a key variable shaping stream habitat and the biological communities they support. Low summer and fall flows can limit biotic communities in streams through reducing the amount of aquatic habitat. Summer and fall also correspond to the peak period of growth and production for aquatic invertebrates and juvenile fish. Thus, increasing minimum summer flows can 1) increase food availability (benthic invertebrate production) and 2) increase the physical space in which fish can forage for food and hide from predators. Although the relationship between stream volume and fish density is non-linear, there is good evidence that trout densities can be highly influenced by changes in summer low flows. For example, water diverted from a Montana stream (90% reduction in discharge) during the summer caused a 60% reduction in trout density in the partially dewatered sections (Kraft, ME.1972. Effects of controlled flow reduction on a trout stream. *J. Fish. Res. Bd. Can.* 29: 1405-1411).

Urban stream ecosystems are thought to be severely impacted by winter high peak flows. However, summer low flows also are likely to play a large role in shaping stream productivity and biology. Biotic communities in urban streams would be expected to benefit from higher base flows due to increased aquatic habitat and food production. This analysis is a preliminary step to quantify those benefits.

Background:

Three detention ponds with a combined storage capacity of 25 acre-feet were constructed in the Jackson Park Golf Course (JPGC) in 2003. The purpose was to attenuate peak flows in Thornton Creek by storing water in the ponds for future use to irrigate the golf course (Jackson Park Detention Project Phase 2 project description, memo from Laura Scharf to Eleanor Jackson, July 23, 1999). In practice, the ponds do not provide sufficient water for irrigation during the summer. Parks has now approached SPU about purchasing supplemental city water for irrigation at JPGC.

Currently, flow is diverted at a point located just upstream of the detention ponds (Figure 1), and is split approximately 50:50 between the ponds and the creek under a water right held by Parks. Table 1 presents summer flow data gathered by the SPU Surface Water Monitoring Team. The table gives a range of summer flows in Thornton Creek North Branch immediately upstream and downstream of the diversion, and also where the creek leaves JPGC. Summer flows measured at the mouth of mainstem Thornton Creek provide an indication of how much the North Branch flows contribute to the total flow levels in Thornton Creek.

Table 1 indicates that summer instream flows tend to be 12% - 45% lower downstream of the ponds than above the diversion. Flows diverted into the ponds during the 2005 summer low flow period ranged between 0.42-0.75 cfs (Table 1), which represents approximately half of the flow upstream of the diversion and 15% of the flow at the mouth of Thornton Creek mainstem during August and early September of 2005.

Table 1. 2005 Summer flow data at Jackson Park Golf Course

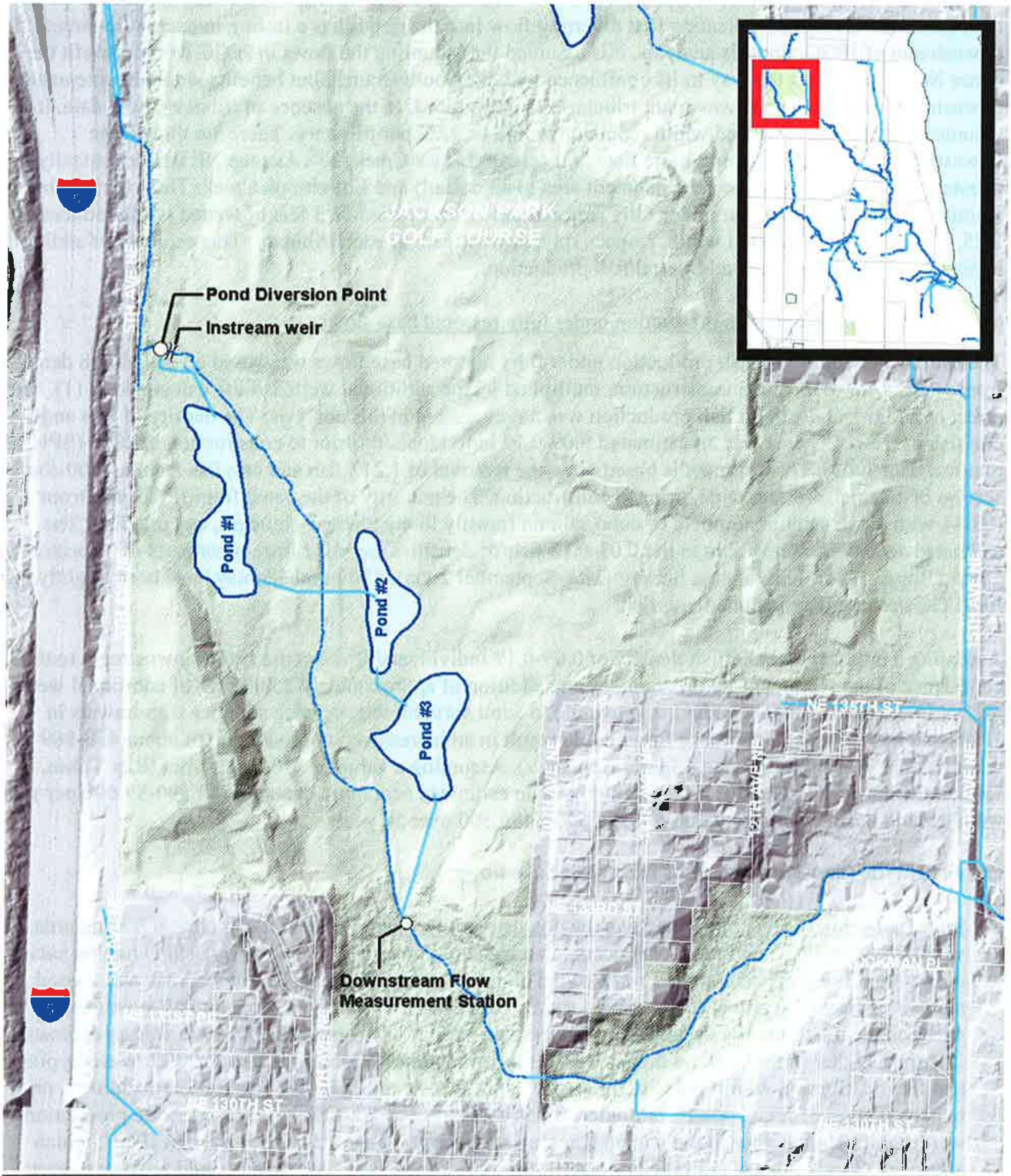
Date	Total Flow Entering JPGC, cfs (gpd)	Flow Split at Diversion, cfs (gpd)		Total Flow Down-stream of JPGC, cfs	Total Flow at Mouth of Thornton Creek mainstem, cfs
		Pond	Creek		
8/4/2005	1.13 (729,206)	0.49 (317,122)	0.64 (412,084)	1.0	3.8
8/12/2005	1.31 (844,947)	0.61 (397,367)	0.69 (447,580)	0.85	4.5
8/17/2005	1.44 (932,841)	0.75 (487,683)	0.69 (445,158)	0.95	4.5
8/23/2005	1.39 (897,151)	0.70 (450,875)	0.69 (446,276)	0.78	4.3
9/2/2005	1.44 (933,803)	0.71 (461,450)	0.73 (472,353)	0.79	4.5
9/6/2005	1.28 (824,230)	0.67 (432,297)	0.61 (391,933)	1.0	4.5
9/13/2005	0.77 (497,177)	0.42 (268,377)	0.35 (228,800)	1.14	10

Analysis of Monetized Environmental Benefits:

In an effort to monetize the ecological benefits of increased summer flows, two estimates were made: (1) the amount of additional aquatic habitat expected under fully restored base flows (i.e., no diversion), and (2) the amount of fish produced by this additional habitat.

(1) Estimate of additional wetted width and depth under fully restored base flows

Summer low flows measured downstream of the ponds during 2005 ranged between 0.35-0.73 cfs, with a median value of 0.69 (Table 1). For this analysis, a median flow value of 0.69 cfs was assumed to represent base flow downstream of the diversion. Under the scenario that creek withdrawals would cease during the summer, this would in effect double the flow, providing a fully restored base flow of 1.38 cfs. Based on approximations of stream channel and hydraulic parameters, the effect of doubling the flow may increase creek depth up to 0.75 of an inch (minimal change in wetted width), or increase the wetted width of new aquatic habitat by up to 6 feet (minimal change in depth), depending upon the shape of the channel. Assuming a trapezoidal channel, the most reasonable estimate is that creek depth would increase by an average of 0.3 inch and wetted width would increase by 3 feet. These values were used in the analysis for additional fish production below. Calculations and assumptions for these estimates are detailed in the Appendix.



Seattle Public Utilities

Produced by the City of Seattle
December 22, 2005

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0 100 200 300 Feet

Figure 1. Jackson Park Golf Course Flow Monitoring Sites

STREAMS
Open Channel
Culvert/Stormdrain
Detention Pond
Park

Table 1 shows that summer 2005 instream flows tended to be 12% - 45% lower downstream of the ponds than above the diversion, indicating that diverting flow into the ponds has a lasting impact on in-stream flows downstream of JPGC. For this analysis, it is assumed that doubling the flows in JPGC would benefit the entire North Branch all the way to its confluence with the South Branch, but benefits would be attenuated downstream as flow from downstream tributaries is introduced. In the absence of tributary flow data, it was assumed that the rate of wetted width reduction would be 25% per tributary. There are three large downstream tributaries (draining more than 250 acres): Littles Creek, 20th Avenue NE (not technically a tributary, it is a large drainage subcatchment area to an outfall) and Littlebrook Creek. Thus, the maximum amount of new aquatic habitat under fully restored base flows would be 3 feet of wetted width reduced to 2.25, 1.5 and 0.75 feet wetted width, respectively, downstream of each tributary. This estimate of additional habitat was used to calculate additional fish production.

(2) Estimate of additional fish production under fully restored base flows

The estimate of additional fish production under fully restored base flows was based on actual fish densities from JPGC prior to the 2003 construction, multiplied by the additional wetted width calculated in (1). The effect of additional depth on fish production was not evaluated in this analysis. The density of fish and crayfish in the JPGC area was an estimated 0.09-0.19 individuals/ft^2 prior to construction in 2003 (SPU fish removal data 2003). This estimate is based upon the removal of 1,212 fish and crayfish from a 1600-foot section of channel, 4-8 feet wide, prior to construction. The majority of the catch from JPGC was trout (93%), with much smaller numbers of coho salmon (mostly likely planted), bluegill, and crayfish. The estimated density is comparable to the 0.03-0.18 fish/ft^2 densities recorded from other parts of Thornton Creek (Roger Tabor, Icthyofauna Survey Data, September 2005). The numbers may have been slightly higher for JPGC because they included crayfish.

Assuming a uniform juvenile fish density of 0.09-0.19 individuals/ ft^2 from the JPGC downstream to the confluence of the North and South branches, the addition of approximately 25,000 ft^2 of additional wetted habitat in the North Branch, and a 20% juvenile to adult survival rate, ceasing summer withdrawals in JPGC and increasing summer base flows could result in an increased fish production of about 459-969 adult fish per year (Tables 3 and 4 in the Appendix). Assuming a value of $10/ adult trout (Ray Timm, Habitat Complexity PDP, 2005), this would have an estimated economic benefit of $4,590-$9,690 per year, which would be an estimated value of $229,500-$484,500 over 50 years.

Other benefits (non-monetized) of increased base flows:

- Increased habitat value, particularly in the downstream wetland. Pool habitat, a critical rearing area, is very limited in JPGC and most of it occurs in a wetland immediately downstream (SPU habitat survey data 2000). The wetland contains some of the highest quality habitat in Thornton Creek and a good amount of spawning gravel (SPU habitat survey data 2000). The active channel width averages 18 feet with connection to the floodplain and good riparian habitat. Fish abundance in 1999 was an estimated 2-5 times higher in the wetland than it was in the golf course (Washington Trout, 2000. Water typing and fish distribution within the City of Seattle. Draft Report to SPU, May 18, 2000). In addition, prior to construction of JPGC ponds, biological integrity scores (based on benthic invertebrate production) were significantly higher in the wetland, averaging 20 over 4 years, than they were in JPGC, which averaged 13 over 3 years (SPU B-IBI data, 1998-2001). Increased base flows would provide deeper pools and more wetted area for spawning and benthic insect (i.e., food) production.

- Increased value of the hyporheic zone. The hyporheic zone is the wetted subsurface habitat associated with the streambed and edges of the stream where surface water and groundwater mix (Reidy, A.R. 2004. Variability of hyporheic zones in Puget Sound Lowland streams. Master of Science thesis. University of Washington.). It is an important component of aquatic habitat because of its contribution to invertebrate production, temperature regulation, downwelling, nutrient recycling, and water filtering capabilities. The hyporheic zone also provides beneficial spawning habitat where downwelling provides eggs with oxygen and carries away wastes and silt. In addition, the emergence of aquatic insects from the hyporheic zone can be an important food source for fish (Stafford, J.A., J.V. Ward and B.K. Ellis 1994. Ecology of the alluvial aquifers of the Flathead River, Montana. *In* J. Gilbert, D.L. Danielpol and J.A. Stanford eds. *Groundwater Ecology*. Academic Press, N.Y., N.Y.). Altered sediment inputs or hydrology can impact hyporheic habitat and the strength of its connection to surface water. For example reduced flow discharge and channelization can reduce subsurface flows, hydraulic conductivity, and the size of the hyporheic zone (Naiman RJ and RE Bilby. 1998. *River Ecology and Management*. Springer, N.Y., N.Y.)

- Reduction in summer water temperatures. In evaluating the summer temperature data over the last three years, it appears that the amount of time that the creek temperature exceeds 16°C (Ecology's threshold for temperature) is decreasing (SPU's Surface Water Monitoring Team). The maturing riparian vegetation at the site is providing increased shading and cooling. Water temperatures could be further reduced by allowing the full creek flow to continue through the golf course, however, the reduction has not been quantified. Due to exceedences of Ecology's temperature threshold, the Surface Water Monitoring Team has worked out a trial mitigation plan for summer 2006 in which the pond levels would be lowered, through irrigation or blocking off the diversion, so that the ponds could absorb more of a summer storm without having to discharge their warmer water to the creek. This effort, in addition to the effect of the maturing riparian corridor, may further reduce the creek temperatures below 16°C without additional flow.

Conclusion:

There is value to both SPU and aquatic organisms in the North Branch of Thornton Creek of stopping creek withdrawals during the summer low flow periods. Benefits of increased summer flows include:

- Additional 0.42-0.75 cfs in creek in JPCG, 15% of overall Thornton Creek flow during summer and early fall;
- Average increase of 0.3 inch in creek depth and 3 feet in creek width through JPGC;
- Increased fish production, valued at $229,500-$484,500 over 50 years;
- Increased creek habitat value, particularly in the North Branch wetland;
- Increased hyporheic zone benefits; and
- Further reduction in summer creek temperatures.

Appendix: Assumptions for estimating the amount of additional aquatic habitat (based on wetted width) with full base flow

For this analysis, current summer base flow was assumed to be 0.69 cfs. The estimate of change in wetted width that the doubling of flow (due to ceasing creek withdrawals) would create was based on the following assumptions:

- Based on visual observations and best professional judgment, average wetted channel width and depth in JPGC at current summer low flow conditions, was estimated as 5 - 6 feet and 1.5 inch, respectively. These estimates were provided by those taking the flow measurements, since there are no current measurements of in-channel wetted widths or depths during the summer low flows.
- A trapezoidal channel was assumed and estimates of the parameters for the current conditions (Scenario 0) were made based on visual observations and best professional judgment. These estimates are shown in the first row of Table 2. Manning's equation was used to estimate bottom (w_b) and wetted widths (w_t), in the creek channel.
- Without a more detailed analysis and field data, it is unclear how the channel would actually respond to a doubling of flows, in particular how much the depth would increase versus how much the flow would spread out. It is assumed that the bottom width is not fixed, because the channel width is on average 12 feet wide, but is primarily limited by volume of flow. Three scenarios (bottom 3 rows in Table 2) were evaluated to look at how different assumptions in depth would affect the change in wetted width (Δw_t). Scenario 1 assumed the flow depth would not change, but would spread out across the channel. Scenario 2 assumed a depth at which the bottom width minimally changes. Scenario 3 assumed a change in depth somewhere in between the previous two scenarios. This last scenario seemed most reasonable based on the limited information that we have, and is what was used in the analysis for change in wetted width.

Table 2. Channel parameters and changes in wetted width estimates.

Scenario	Q, cfs	S, %	Z	d, in	n[1]	w_b, ft	w_t, ft	Δw_b, ft	Δw_t, ft
0	0.69	1.0	5	1.5	0.04	5.3	6.6		
1	1.38	1.0	5	1.5	0.04	11.3	12.6	6.0	6.0
2	1.38	1.0	5	2.2	0.04	5.4	7.2	0.1	0.6
3	1.38	1.0	5	1.8	0.04	8.1	9.6	2.8	3.0

1. King County, 1998 Surface Water Design Manual

Q – Flow, S – slope, Z – channel side slope, d – flow depth, n – channel roughness, w_b – channel bottom width, w_t – channel wetted width, Δw_b – change in bottom width, Δw_t – change is wetted width

Scenario 0 – current conditions (with flow diversion)

Scenario 1 – flow depth doesn't change, flow spreads out across channel

Scenario 2 – flow depth changes, bottom width of flow changes minimally

Scenario 3 – best guess, flow depth and width changes at a midpoint between Scenarios 1 and 2

Table 3. Estimate of annual **maximum** benefit to fish production of increased summer flows in Thornton Creek

Assume juvenile fish density (# fish/ft^2) of:	0.19						
Section of Thornton NB (distance from confluence of North and South Branches)	Length of Stream Impacted, ft	Weighted Impact of Flow on Wetted Width	Estimated Increase in Wetted Width (ft)	Maximum Additional Habitat (ft^2)	Maximum # Juvenile Fish in New Habitat	# Fish with 20% Juvenile to Adult Survival Rate	Maximum Benefit assuming $10/fish
JPG Ponds to Littles (11000-14000 ft)	3,000	100%	3.00	9,000	1,710	342	$3,420.00
Littles to 20th Ave Outfall (9000-11000 ft)	2,000	75%	2.25	4,500	855	171	$1,710.00
20th Ave Outfall to Littlebrook (2000-9000 ft)	7,000	50%	1.50	10,500	1995	399	$3,990.00
Littlebrook to Confluence w/ SB (0-2000 ft)	2,000	25%	0.75	1,500	285	57	$570.00
Totals				**25,500**	**4845**	**969**	**$9,690**
						Benefit over 50 years:	$484,500

Table 4. Estimate of annual **minimum** benefit to fish production of increased summer flows in Thornton Creek

Assume juvenile fish density (# fish/ft^2) of:	0.09						
Section of Thornton NB (distance from confluence of North and South Branches)	Length of Stream Impacted	Weighted Impact of Flow on Wetted Width	Estimated Increase in Wetted Width (ft)	Maximum Additional Habitat (ft^2)	Minimum # Juvenile Fish in New Habitat	# Fish with 20% Juvenile to Adult Survival Rate	Minimum Benefit assuming $10/fish
JPG Ponds to Littles (11000-14000 ft)	3,000	100%	3.00	9,000	810	162	$1,620.00
Littles to 20th Ave Outfall (9000-11000 ft)	2,000	75%	2.25	4,500	405	81	$810.00
20th Ave Outfall to Littlebrook (2000-9000 ft)	7,000	50%	1.50	10,500	945	189	$1,890.00
Littlebrook to Confluence w/ SB (0-2000 ft)	2,000	25%	0.75	1,500	135	27	$270.00
Totals				**25,500**	**2295**	**459**	**$4,590**
						Benefit over 50 years:	$229,500