Low Impact Development White Paper for Permeable Pavements, Bioretention and Green Roofs

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Effectiveness Questions, and were they answered?

Ranked Topic Items and Questions for #’s 6, 7, and 11:

- Are LID measures effective at reducing flows and pollutant loads (#6 & 7)?
  And
- Are LIDs feasible in tight soils or shallow ground-water (#11)?

Are LIDs Effective at Reducing Flows and Loads?

- Yes, the literature answers the question, and
- Yes, LIDs are effective for reducing flows and loads.

But . . .

- a synthesis shows effectiveness for both <u>depends on facility sizing</u>.

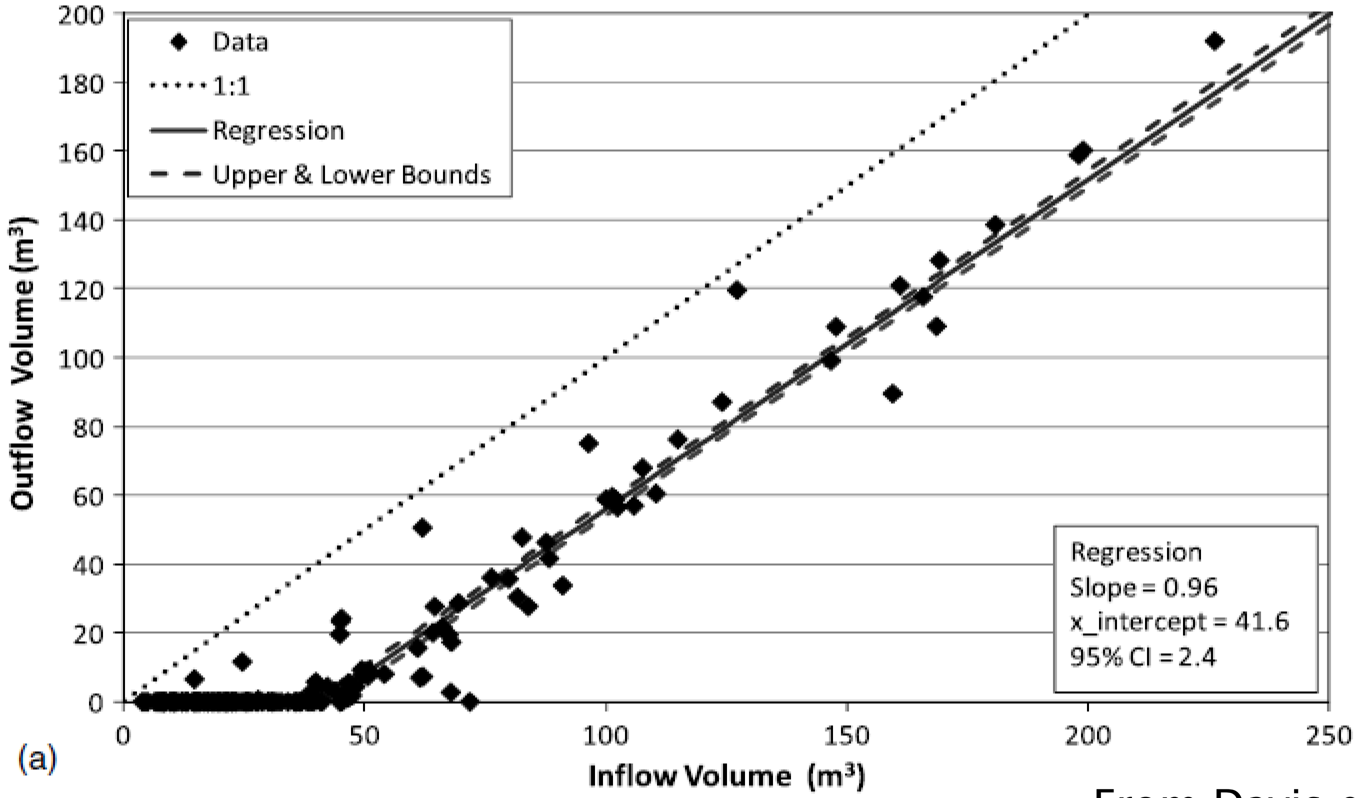
Summary of Design Sizing Affect on Flows and Loads

1. The literature reports a single value for % reduction in flow and a % reduction in load.

2. But, flow can be zero for small to medium storms, with increasing flows with increasing storm size.

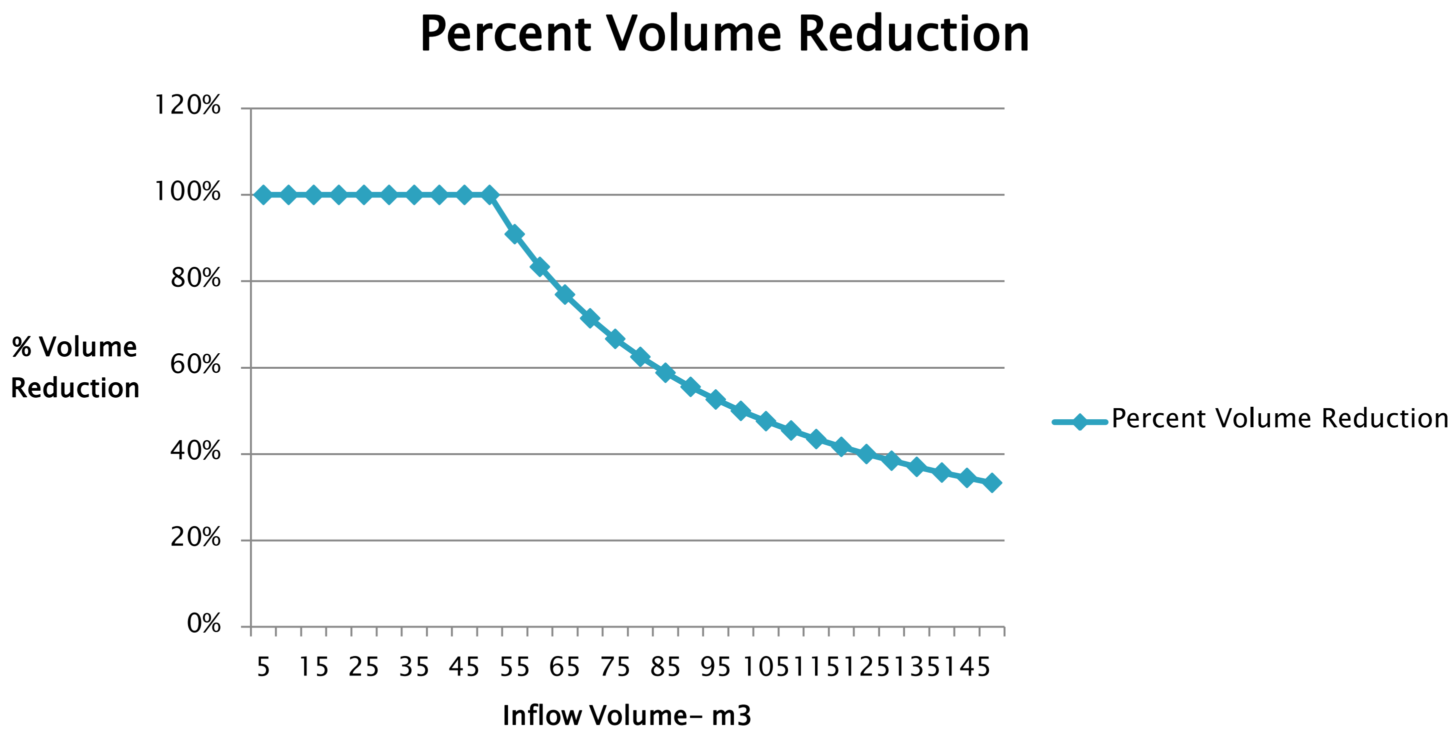
3. Flows will depend on "Bioretention Abstraction Volume" (BAV)

Example Flow Response Dependent on Abstraction Volume (BAV)



From Davis et al. (2012)

Example % Volume Reduction with a BAV of $50m^3$



Design Sizing Effect on Concentrations

1. Loads are the product of volume and concentration.

2. We’ve seen volume reduction is <u>not a constant %</u> of inflow volume, well . . .

3. Neither is concentration reduction – there are generally “irriducible concentrations” with decreasing inflows concentrations.

4. As an alternative, outflow concentrations can be presented not as a % reduction over inflow, but as a frequency of concentration.

Do LIDs Reduce Concentrations
(improve water quality / loads?)

1. Most of the parameters of interest are reduced in concentration by LIDs.
2. Much of the reduction is with reduced total suspended solids (TSS), and . . .
3. Many parameters are associated with TSS so are also reduced (metals, PAHs, bact., nutrients).
4. Nutrients are often seen to increase (N, P)
5. Load reduction and water quality benefit largely follow reduced low/medium flows.

Are LIDs feasible in tight soils?

- Yes. The literature showed consistently higher subsurface infiltration rates than expected.
- Subsurface areas may be heterogeneous or have “cracks and fissure”, allowing exfiltration.
- Exfiltration should be evaluated for Puget Sound local conditions.

Is LID Effective on Hydrology and Water Quality at the Basin Scale?

- Effects of LID use on receiving waters at the basin scale has not been documented.

- Modeling suggests LID is effective for basin scale hydrology:
  - for highly developed basins at high density of LID,
  - for small and medium-sized storms, and less for larger storms (again, depending on sizing).
  - Combined use with traditional large volume BMPs may be needed.

Recommended Effectiveness Studies

- Integrate different scales of effectiveness studies for overall LID implementation success:

1. "Internal" scale studies for design criteria internal to the facility (e.g. sizing, media composition, plant composition).

2. "External" studies to characterize local conditions relevant to the Puget Sound region (e.g. tight soil/lateral exfiltration, groundwater conditions).

3. "Watershed" scale studies to learn from implementation, and document effects on receiving waters (e.g. flow durations, channel geometry, biological communities).

4. "Organizational" scale study with a pilot jurisdiction to learn from the implementation of the watershed scale use of LIDs (e.g. institutional mandates, internal education, asset mngt).

Questions?

- Other LID topics to address?

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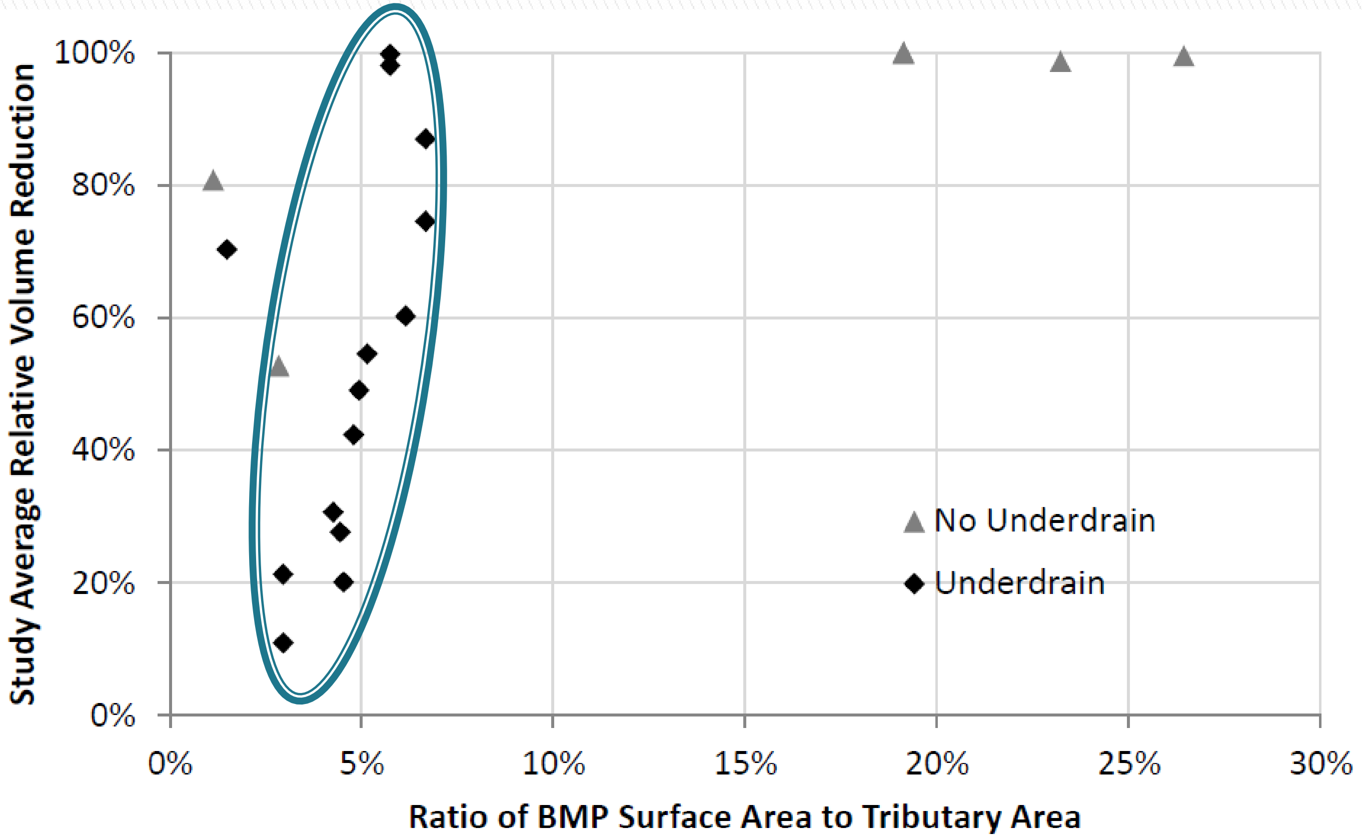


From International SW BMP Database (2012a)

Analysis Group	# of Studies	25th Pctl.	Median	75th Pctl.	Avg.
Bio-filter Grass Strip	16	18%	34%	54%	38%
Bio-filter Grass Swale (dry)	13	35%	42%	65%	48%
Bioretention (all studies)	20	42%	66%	98%	66%
Bioretention (no underdrain)	6	85%	99%	100%	89%
Bioretention (with underdrain)	14	33%	52%	73%	56%

Distribution of Project Volume Reductions

From International SW BMP Database
(2011, 2012a)

Which LID is most effective at reducing flows?

- Depends on sizing, but . . .

- indications are generally:
  - Bioretention (rain gardens)>
  - permeable pavement ≥
  - green roofs >
  - swales >
  - grass strips

- Underdrains appear to compromise flow reduction

Exceptions to Reductions in Concentrations

- Nutrients:
  - Phosphorus especially shows wide ranges in bioretention outflow; due to high compost or fertilizer concentrations in the soil media.
  - Ammonia and organic nitrogen is generally nitrified to NO_3^-; but accumulates without a "permanent" removal process, so can be washed out at higher concentrations (permeable pavements and bioretention).
- Metals
  - Metals (esp. copper) remain at irridducible concentrations; there may be internal sources from soil media and construction materials.

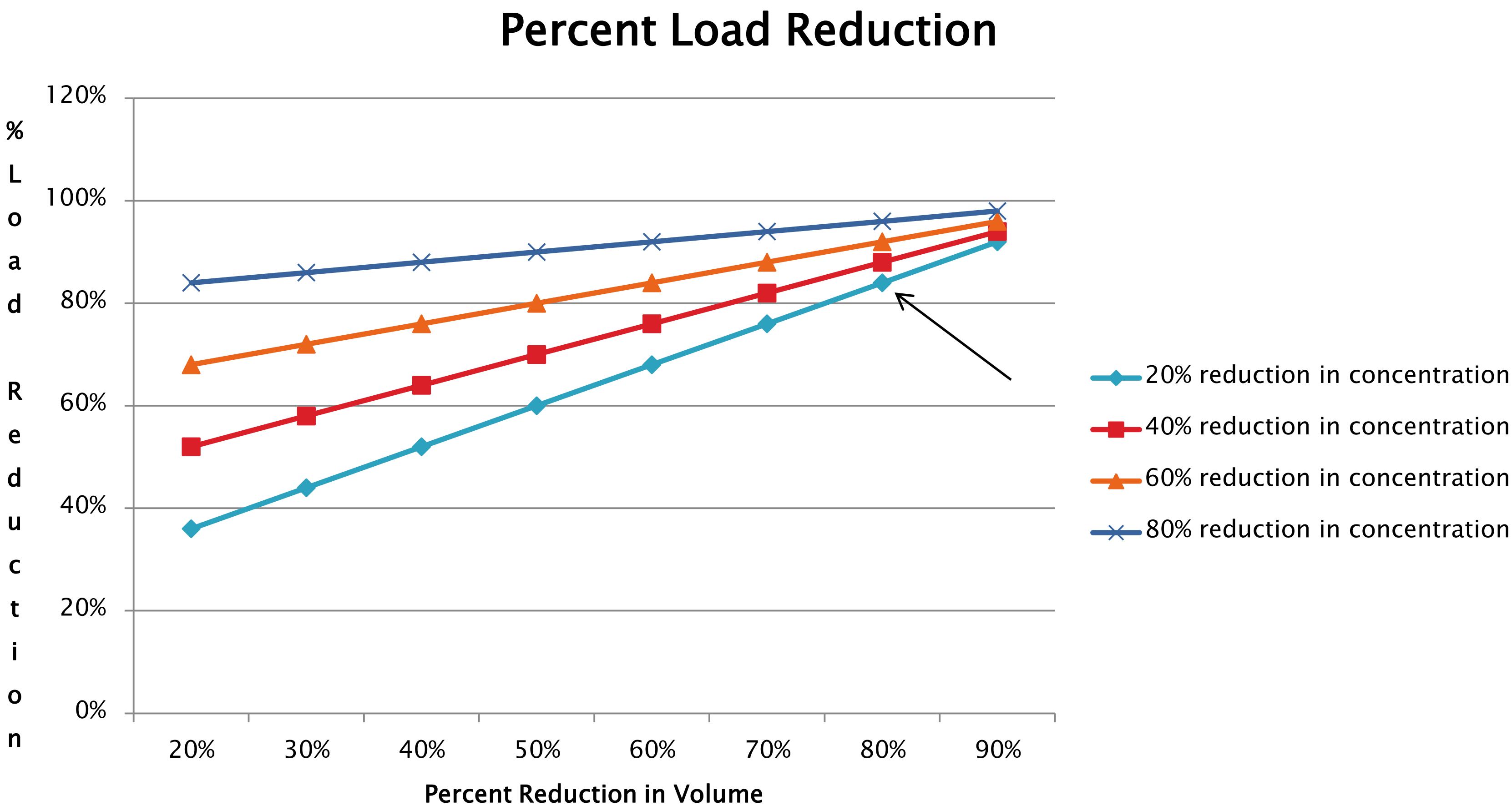
Using Concentration Frequency Distribution Rather than % Reduction

Table 2. Summary of inflow and outflow concentration percentiles for permeable pavements from the International Stormwater Database (2012c). (See Table 5 in LID White Paper for bioretention).

Porous Pavement	Flow*	TSS mgL^{-1}	P/TP mgL^{-1}	NO3-N mgL^{-1}	NH4-N** mgL^{-1}	TKN mgL^{-1}	Total Cu mgL^{-1}	Total Pb mgL^{-1}	Zn mgL^{-1}	FC
25th percentile										
In	--	18.30	0.09	0.22	--	1.00	8.70	1.99	27.00	--
Out	--	7.08	0.05	0.33	--	0.46	4.84	0.93	9.00	--
Median										
In	--	65.30	0.18	0.42	--	1.28	13.07	4.30	57.60	--
Out	--	13.20	0.09	0.71	--	1.05	7.83	1.86	15.00	--
75th percentile										
In	--	186.70	0.29	0.79	--	2.50	27.00	9.98	131.40	--
Out	--	27.00	0.14	1.36	--	1.30	12.62	4.93	26.70	--

From International SW BMP Database (2012c)

Combined effect of (gross) flow and conc. reduction on reduced load



Are LIDs feasible in areas with Shallow Groundwater?

- Groundwater did not appear to interfere with flow reduction in the literature reviewed.

- If high groundwater did occur, it would reduce the storage volume.

- Shallow groundwater affects on LID ought to be evaluated for Puget Sound local conditions.

What Type and Frequency of Maintenance Needed?

- Construction, operation and maintenance was seen as very important to long term performance of LIDs, in addition to sizing.

1. Long term maintenance of infiltration rates.
2. Long term media nutrient sorption capacity.
3. Soil media long term fertility for sustaining plant growth.

Recommended Effectiveness Studies

- Assumptions: be pragmatic and locally relevant.
  - Prioritize flow and pollutant reduction needs that are relevant to the region (e.g. hydrologic protection of stream channels, reduced copper concentrations).
  - Focus on targeted design issues that support implementation of LIDs under the NPDES permit (e.g. sizing analysis to meet hydrologic criteria, identify watersheds and density of use that will have an effect).
  - Don’t do more generalized flow and concentration mass-balance reduction studies.

Comments on the database

- Bit of a smattering of selected literature (e.g. too many bioretention, some swales, hardly any green roof)
- Specific questions could do better with a targeted academic literature database search
- The most recent papers help the most – so a literture review gets dated quickly.
- Recent papers provide past references to follow up on.
- Hardly any from PNW.
- Reading many papers helps synthesize ideas to move beyond what has been done.

Literature Data Quality Observations

- Good attention to flow monitoring
- Not much documentation of water quality QAQC.
- Frequent mention of equipment malfunction.
- 10% – 30% error in each still-error propogation always an issue.
- See WDOT Quality System Plan for good example.
- Not many QAPPs.