Load Duration Curve Analysis

BBE 5533
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Load Duration Curve Analysis

- Facilitates characterizing water quality concentrations/loads for different flow regimes
- Provides visual display of relation between flow and loading capacity
- Accounts for how seasonal streamflow variation affects water quality
- Provides link between water quality concerns and key watershed processes
- Does not itself account for fate and transport mechanisms; load duration curve analysis by itself assumes that flow is the primary driver of water quality variation
- If processes other than flow affect the loading then one needs to consider the use of additional assessment tools
Construction of Flow Duration Curve

Salt Creek near Greenview, IL
Flow Duration Curve
USGS Gage: 05582000

USGS Flow Data

1,804 square miles
Climate Effect on Flow Duration

Rio Puerco near Guadalupe, NM
Flow Duration Curve
USGS Gage: 08334000

Flow (cfs)

0.1
1
10
100
1000
10000

Flow Duration Interval (%)

0 10 20 30 40 50 60 70 80 90 100

Potential Zone A

Potential Zone B

Potential Zone C

Dry Conditions with No Flow

69 cfs

3.8 cfs

USGS Flow Data

420 square miles
Construction of Load Duration Curve; for targeted conditions

Salt Creek near Greenview, IL
Load Duration Curve

- High Flows
- Moist Conditions
- Mid-range Flows
- Dry Conditions
- Low Flows

Nitrate (tons per day)

$440 \text{ cfs} \times 10 \text{ mg/L} \times 0.002695 = 11.86 \text{ tons/day}$

Flow Duration Interval (\%)

$1,804 \text{ square miles}$
Hydrologic condition, zone patterns, seasonal effects, stormflow effects

- Storm flows
- Season

Box and whiskers representation

Target TMDL

GM=geometric mean

SF=storm flow

Box and whiskers representation
Hydrologic condition, zone patterns, seasonal effects, stormflow effects

• Violations at low flows generally indicate point sources, that is, sources that are continuous even without rainfall
  - high fecal levels at low flows might indicate failing septics
  - generally sediment levels will be low at low flows
• Violations at high flows generally indicate non-point sources, that is, sources driven by surface runoff events
  - high fecal levels at high flow might indicate runoff from confined animal operations
  - high sediment loads could indicate erosion from exposed soils or failure of streambanks
How to assign the margin of safety (MOS)

**Table 2-1.** Approaches for Developing TMDL “Margin of Safety”

<table>
<thead>
<tr>
<th>Type of Margin of Safety</th>
<th>Approaches</th>
</tr>
</thead>
</table>
| Explicit                 | - Set numeric targets at more conservative levels than analytical results indicate  
                          | - Add a safety factor to pollutant loading estimates  
                          | - Do not allocate part of available loading capacity; reserve for MOS |
| Implicit                 | - Conservative assumptions in derivation of numeric targets  
                          | - Conservative assumptions when developing numeric model applications  
                          | - Conservative assumptions when analyzing prospective feasibility of practices and restoration activities. |
Load Allocation Representation

Jones River
TMDL Summary

Load Allocation

Waste Load Allocation — Wastewater Treatment Facilities

Flow Duration Interval (%)
Representation of stream flow variability by time

Mississippi River at Winona


Watershed Size: 59,200 square miles
Variability of flow duration curve by month or by season

Mississippi River at Winona (1970 - 2004)

Flow Duration Interval (%)

Month

April - May - June - July - August - September - October

April-Oct

Zone

Median = 9%

High

90th

Median = 46%

Moist

75th

Mid

25th

Dry

10th

Low

Watershed Size: 59,200 square miles
Flow Duration Curve for Hydrograph Components

LaPlatte River at Shelburne Falls
Storm Flow Duration Curve (1990 - 2005)

Note: Increased fraction of surface runoff under high flow conditions
Relative importance of source area contributions based on hydrologic condition

**Table 4-1.** Example Source Area / Hydrologic Condition Considerations

<table>
<thead>
<tr>
<th>Contributing Source Area</th>
<th>Duration Curve Zone</th>
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<tbody>
<tr>
<td></td>
<td>High Flow</td>
</tr>
<tr>
<td>Point Source</td>
<td></td>
</tr>
<tr>
<td>On-site wastewater systems</td>
<td></td>
</tr>
<tr>
<td>Riparian Areas</td>
<td></td>
</tr>
<tr>
<td>Storm water: Impervious Areas</td>
<td></td>
</tr>
<tr>
<td>Combined sewer overflows</td>
<td></td>
</tr>
<tr>
<td>Storm water: Upland</td>
<td></td>
</tr>
<tr>
<td>Bank erosion</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Potential relative importance of source area to contribute loads under given hydrologic condition (*H*: High; *M*: Medium)
Targeted Activities: Construction Site Runoff Control
Assigning the load allocation (LA) and wasteload allocation (WLA)

### Table 5-1. Example TMDL Summary Using Duration Curve Framework

<table>
<thead>
<tr>
<th>TMDL SUMMARY</th>
<th>Loads expressed as (tons per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>TMDL¹</td>
<td>173.35</td>
</tr>
<tr>
<td>Allocations</td>
<td>118.32</td>
</tr>
<tr>
<td>Margin of Safety</td>
<td>55.03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Implementation Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Development BMPs</td>
</tr>
<tr>
<td>Streambank Stabilization</td>
</tr>
<tr>
<td>Erosion Control Program</td>
</tr>
<tr>
<td>Riparian Buffer Protection</td>
</tr>
<tr>
<td>Municipal WWTP</td>
</tr>
</tbody>
</table>

Note: 1. Expressed as a “daily load”, represents the upper range of conditions needed to attain and maintain applicable water quality standards.
Representation of implementation effectiveness

Figure 5-2. Documenting Erosion Control Program Results
Using Load Duration Curves to Develop the TMDL

The TMDL equation:

\[ \text{TMDL} = \sum WLA + \sum LA + MOS \]
Step 1: Develop Flow Percentages for the WQ monitoring station

• Use flow data available at the location where the water quality parameter is measured
• Estimate flow data using a flow estimation procedure;
  - Use a nearby gaging station that has flow data coincident with the WQ monitoring data; apply correction for contributing area
  - Fill in gaps in flow data at the WQ monitoring station using a nearby stream gage
  - Use data from a gage upstream or downstream of the WQ monitoring station; apply correction for contributing area
Step 2: Develop Flow Duration Curve from the Flow Percentages

- Represents the fraction of the flows that exceed a given value
- Usually derived using at least one year of flow data; the longer the record the better
- The slope of the flow duration curve is a reflection of the variability of the flow
- Subdivide the flow domain (the percentages) into several hydrologic conditions; e.g. dry, somewhat dry, moist, very moist, wet.
Example flow duration curve

Salt Creek near Greenview, IL
Flow Duration Curve
USGS Gage: 05582000

USGS Flow Data
1,804 square miles
Step 3: Estimate Point Source Loading

\[ PSL = PSQ \times PSC \times \text{units conversion} \]

\[ PSL = \text{point source load} \]

\[ PSQ = \text{point source discharge} \]

\[ PSC = \text{point source concentration} \]
Step 4: Estimate Current Loading and Identify Critical Conditions

- Associate the concentrations measured at the water quality monitoring station with the corresponding stream flow that existed when measurements were taken.
- Determine the mean and the other percentiles (e.g., box-whiskers plots) for the measured concentrations within a given hydrologic condition interval.
- The loading for any given hydrologic condition can then be determined by associating it with the upper limit of allowable concentration; e.g., if the water quality target can be exceeded 5% of the time, than the upper limit will be the concentration associated with 5% exceedance.
- Identify critical conditions by finding the flow regimes in which the WQS is exceeded.
Step 5: Develop the Load Duration Curve

- Assimilative capacity of a water body depends on the flow, and maximum allowable load depends on flow rate; one can use a constant value of concentration, or that concentration could vary with hydrologic condition.
- TMDL = WQS * Flow * unit conversion factor
- Superimpose measured data onto the curve accounting for the upper percentile of interest. These values of load that exceed the TMDL are considered to be violations.

*This accounts for the stated exceedances allowed in the WQS. So if you are allowed to exceed a given concentration 10% of the time, than the upper percentile would be the 90% one.*
Step 6: Specify the MOS and Develop the Reduced LDC

There are a number of ways to specify the MOS; implicit or explicit specifications are possible.
Step 7: Calculate the WLA

- WLA is associated with point sources
- WLA sources can be either wastewater discharges (continuous sources), or they can be stormwater discharges (MS4 guidelines)

For wastewater:

\[ WLA = WQS \times WWQ \times \text{units conversion} \]

\[ WWQ = \text{wastewater discharge} \]

For MS4s: Derived from Percent Reduction Goal from the LDC as part of the non-point source pollution reduction goal.
Step 8: Calculate the LA

\[
\sum LA = TMDL - \sum WLA - MOS
\]

- This load allocation is for all non-point sources in the contributing area and includes the contributions from MS4s
Jones River
TMDL Summary

Load Allocation

Waste Load Allocation – Wastewater Treatment Facilities

Flow Duration Interval (%)
Step 9: Calculate reduction in WLA

- No reduction required for wastewater discharges if they are already regulated
- Reduction for MS4s are specified by the reduction for non-point sources given in Step 10
Step 10: Calculate reduction in LA

- The reduction in LA is the difference between the existing load and the allowable LA.
- The reduction is calculated for each of the hydrologic conditions, and the maximum reduction is used for specification.
- The load reduction for MS4s are part of the calculated load reduction.