Penobscot River
Phosphorus Waste Load Allocation

May 2011

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Summary

This Phosphorus Waste Load Allocation (P-WLA) is the initiation of an Adaptive Resource Management approach to address Dissolved Oxygen (DO) non-attainment on the Penobscot River. This document serves as the basis for establishing water quality based phosphorus limits for several industrial discharges along the river. The decision to pursue an adaptive approach is based on the complicating nature and scale of eutrophication (nutrient enrichment) related impacts that have been experienced on the Penobscot River. Eutrophication is the primary driver of measured DO non-attainment in the river and this P-WLA is intended to prevent the recurrence of enriched conditions. The Department expects that implementation of this plan will prevent future DO non-attainment from recurring.

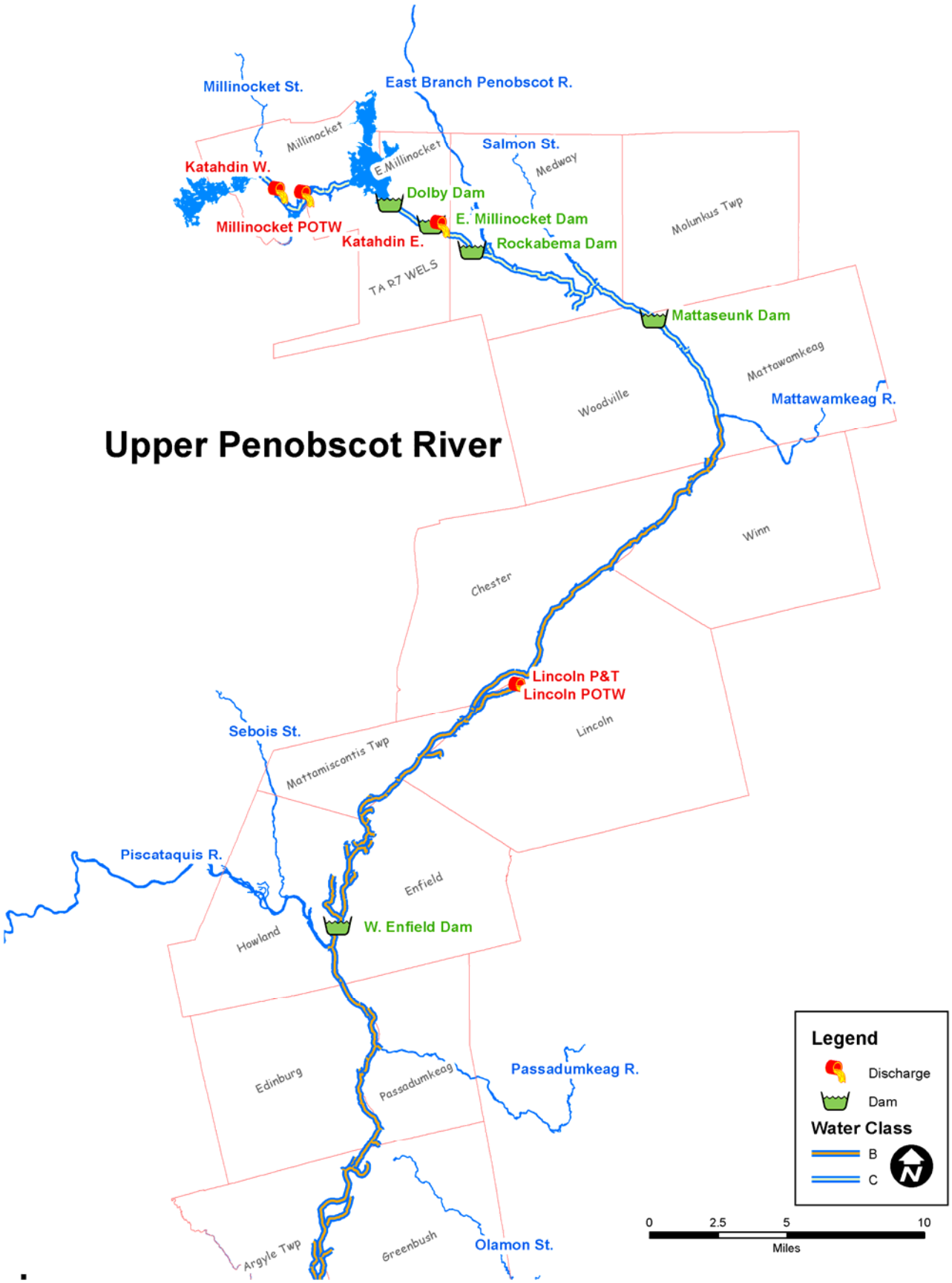
This P-WLA imposes phosphorus limits on all industrial discharges located above head-of tide (old Bangor Dam). The specific eutrophication related responses that are targeted by this P-WLA are not expected to persist into the tidally influenced portion of the Penobscot River. However, water quality improvements associated with this P-WLA are expected to extend into the tidally influenced section of the river.

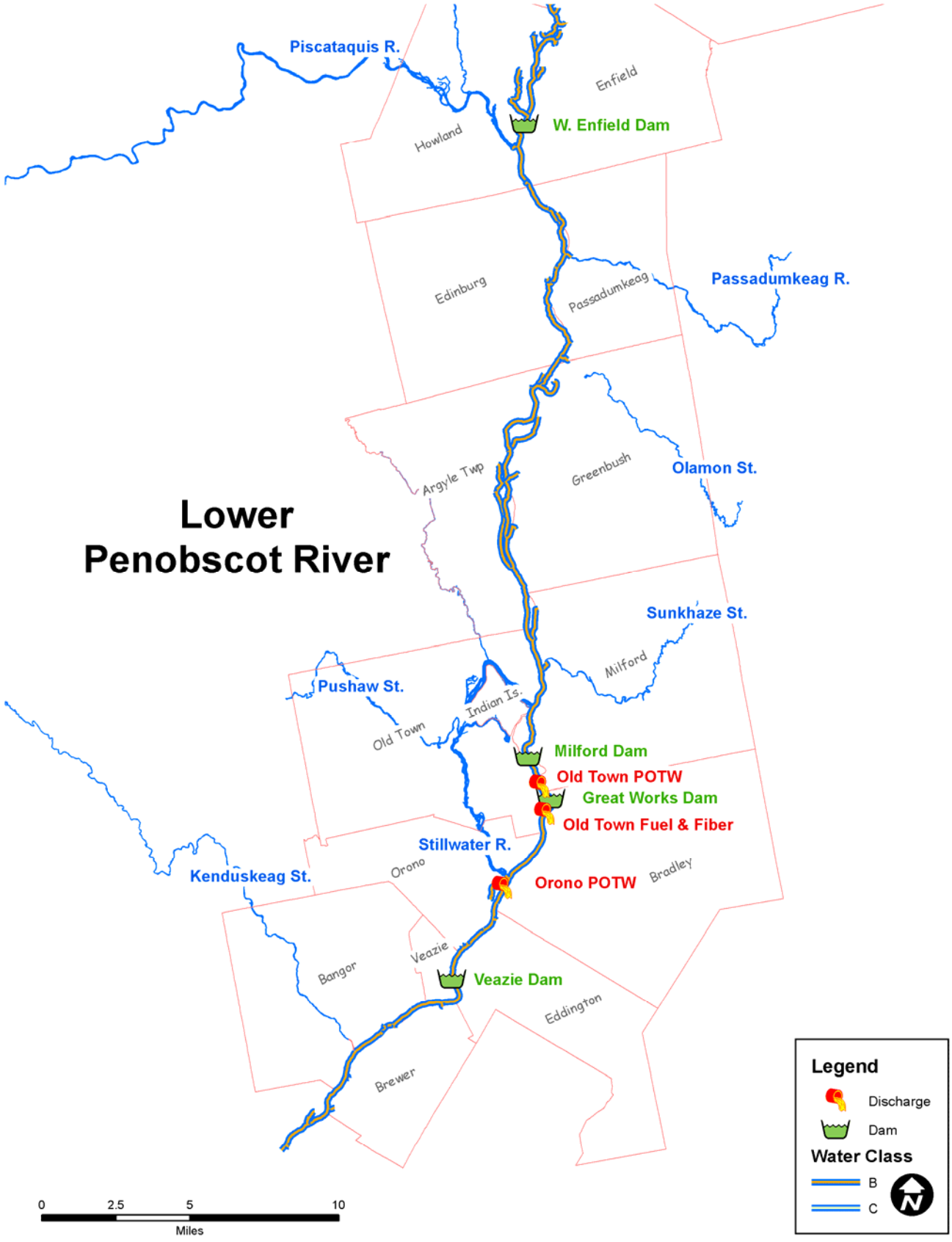
Other river restoration efforts are coincident with this P-WLA. The Penobscot River Restoration Trust (PRRT) has finalized plans to remove the two lowermost dams on the Penobscot River. These dams are expected to be removed in 2011 (Great Works Dam) and 2012 (Veazie Dam). Removal of these dams will restore approximately five miles of impounded river to free flowing conditions. These river restoration efforts are expected to result in additional river DO improvements by increasing atmospheric reaeration and reducing the residence time influence of Biochemical Oxygen Demand (BOD) and Sediment Oxygen Demand (SOD).

Ambient monitoring is an integral component of this plan and will be used to measure the effectiveness of the P-WLA. The effectiveness of these nutrient load reductions will be assessed through routine ambient monitoring, in accordance with a supplemental ambient monitoring plan.

History

The Penobscot River is Class C from the outlet of Ferguson Pond (on the West Branch) to the confluence of the Mattawamkeag River (on the main stem). Class C DO criteria include an instantaneous minimum of 5 mg/l or 60% saturation (whichever is higher) and a monthly average of 6.5 mg/l. This stretch of river is presently considered to be in attainment for DO, but is frequently below the 7 mg/l instantaneous minimum for the next highest standard (Class B). It is particularly sensitive to algae (phytoplankton) blooms; three blooms have been documented since 2000 (2001, 2004 and 2007). Algae blooms are a definitive biological indicator of nutrient enrichment. There are two industrial discharges (43 MGD and 33 MGD) and one municipal discharge (2.33 MGD) located on this stretch of river. The nutrient loadings and respective algae blooms that originate in this Class C section of river are a significant contributor to the measured DO non-attainment in downstream reaches of the river. The 2007 bloom resulted in a Department issued Consent Agreement that imposed total-phosphorus discharge limits of 0.5 mg/l for the Katahdin West papermill located in Millinocket.


Upper Penobscot River
Millinocket St.
East Branch Penobscot R.
Millinocket
E.Millinocket
Salmon St.
Medway
Katahdin W.
Dolby Dam
E. Millinocket Dam
Millinocket POTW
Katahdin E.
Rockabema Dam
Molunkus Twp
TA R7 WELS
Mattaseunk Dam
Mattawamkeag
Mattawamkeag R.
Woodville
Winn
Chester
Lincoln P&T
Lincoln POTW
Lincoln
Sebois St.
Mattamiscontis Twp
Piscataquis R.
Enfield
W. Enfield Dam
Howland
Passadumkeag R.
Passadumkeag
Edinburg
Argyle Twp
Greenbush
Olamon St.
Legend
Discharge
Dam
Water Class
B
C
N
0
2.5
5
10
Miles


Lower
Penobscot River
Piscataquis R.
Enfield
W. Enfield Dam
Howland
Edinburg
Passadumkeag
Passadumkeag R.
Argyle Twp
Greenbush
Olamon St.
Sunkhaze St.
Milford
Pushaw St.
Indian Is.
Old Town
Milford Dam
Old Town POTW
Great Works Dam
Old Town Fuel & Fiber
Stillwater R.
Kenduskeag St.
Orono
Orono POTW
Bradley
Bangor
Veazie
Veazie Dam
Eddington
Brewer
0
2.5
5
10
Miles
Legend
Discharge
Dam
Water Class
B
C
N

The Penobscot River is Class B from the confluence of the Mattawamkeag River (in Mattawamkeag) to the confluence with Reeds Brook (in Hamden). Class B DO criteria are an instantaneous minimum of 7 mg/l or 75% saturation (whichever is higher). This section of river has experienced measured DO non-attainment at various locations during periods of low flow and high water temperature. Measured DO non-attainment is predominantly early morning readings in sections of river with significant diurnal DO swings. These significant diurnal DO swings are caused by nutrient enrichment and resulting plant growth. There are two industrial discharges (16.3 MGD and 24.4 MGD) and five significant municipal discharges (1.07 MGD, 1.7 MGD, 1.84 MGD and 0.35 MGD) in the non-tidal portion of this section of river.

Implications of Nutrient Enrichment on the Penobscot River

Phosphorus is usually the limiting nutrient for freshwater algae (phytoplankton and periphyton), and point sources on the Penobscot have historically discharged excessive amounts of phosphorus. This point source phosphorus fuels excessive algal growth, which has resulted in measured DO non-attainment. The significance of eutrophication relative to DO on the Penobscot River is summarized as follows;

- Phytoplankton (floating algae) blooms originate in the Dolby impoundment and continue downstream. A 13-mile stretch of river from Dolby Pond (in Millinocket) to the Mattaseunk Impoundment (in Weldon) is particularly susceptible to phytoplankton blooms due to a series of 4 dams, where hydraulic conditions of more laminar flow and extended hydraulic residence times are conducive to phytoplankton growth. The phytoplankton that are propagated in this upper portion of the river have difficulty surviving in a 27 mile stretch of more turbulent and free-flowing river below Mattaseunk. The phytoplankton die off below Mattaseunk imposes a significant pollutant loading (BOD) to the river as living water column biomass is converted to degrading organic matter. A further complicating aspect of algal die off is the uncertain DO kinetics associated with stressed algae; specific respiration and production rates may not be consistent with conventional literature rates, and the spatial relevance relating to how fast this conversion occurs is unknown. The Department has a high level of confidence that implementation of this P-WLA will dramatically curtail phytoplankton growth, to the point where it will be a negligible influence on DO.
- Periphyton (bottom attached algae) growth in the lower reaches of the non-tidally influenced section of the river (Mattaseunk Dam to the old Bangor Dam). The DO in this 67-mile section of river is mostly influenced by periphyton as a result of the predominant hydraulic conditions where shallower water allows light to penetrate to the river bottom, and more turbulent flow inhibits competition from phytoplankton. Significant periphyton growth can produce significant diurnal swings in water column DO as a result of daylight photosynthetic oxygen production and non-daylight respiration/consumption. The Department has measured large diurnal DO swings of 2 mg/l at various locations on this section of the river. The larger diurnal swings produce an early morning minimum DO that is the primary driver of measured DO non-attainment. The Department is confident that implementation of this P-WLA will lessen the magnitude of diurnal DO swings, which will result in less extreme early morning low DO excursions.

This P-WLA report focuses only on phosphorus and not other oxygen consuming pollutants, such as BOD, because the hydraulic complexities of the river make model calibration very difficult for phosphorus and BOD simultaneously. The Department has collected three comprehensive water quality survey datasets over the past 15 years (1997, 2001, and 2007),

but eutrophication related inconsistencies and uncertainties have prevented us from achieving a predictive model calibration with a significant level of confidence. Specific issues include;

- Dolby Pond is the most critical element in the river system with regard to the phytoplankton related response. Phytoplankton growth is initiated in Dolby Pond, but responses associated with non-riverine hydraulics and other atmospheric influences appear to be significant drivers of phytoplankton growth. This is evidenced in the 2001 and 2007 datasets which exhibit mean chlorophyll-a (relative indicator of phytoplankton abundance) concentrations of 13 ug/l and 23 ug/l respectively, where the Department considers 8 ug/l of chlorophyll-a to be an algae bloom. Unfortunately the response in 2007 is reflective of a slightly lower phosphorus concentration and higher river flows, which defies conventional river modeling wisdom. This highlights the fact that Dolby Pond does not behave like a river, nor should it be expected to behave like a river (see Attachment A). Predicting an enriched phytoplankton response in Dolby Pond (and subsequent downstream reaches) with any degree of certainty will be difficult. That said, we believe this P-WLA will prevent the likelihood of any such significant phytoplankton response from initiating in Dolby Pond and adversely impacting downstream water quality.
- The conversion of living phytoplankton from Mattaseunk impoundment to dead organic matter below Mattaseunk Dam appears to be a fairly abrupt process that has a significant influence on downstream DO. However, the specifics with regard to how and where this occurs and the specific implications are relatively uncertain. This P-WLA is expected reduce this complicating aspect to a negligible proportion.
- The significant diurnal DO swings below Mattaseunk are clearly driven by periphyton. However, we have very little data relating to the specific quantification of this component (e.g. relative biomass and spatial extent). Data of this nature are very difficult and time consuming to gather. The P-WLA is intended to greatly reduce the significance of this influence and lessen the severity of early morning low DO excursions.

The Department is pursuing this P-WLA, because it is reasonably expected to address the DO non-attainment presently being experienced on the Penobscot River. The P-WLA will be considered part of an adaptive management based approach that will help the Department to more accurately assess point source BOD loadings should non-attainment continue to persist.

Derivation of Waste Load Allocations

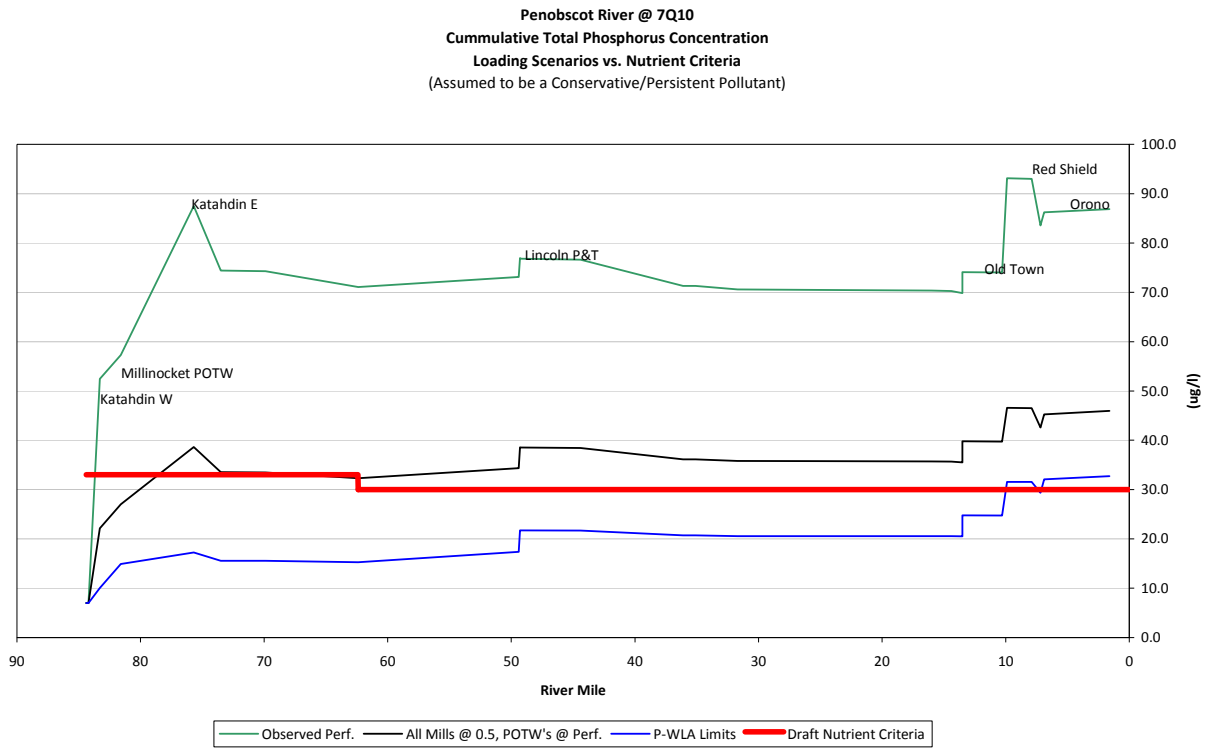
The Departments focus on industrial dischargers for this P-WLA is based on their relative proportion of influence in the targeted section of the river. Industrial dischargers have typically represented approximately 85 – 90 percent of the observed point source phosphorus loads to the river (based on 1997, 2001 and 2007 water quality surveys). The limits suggested in this P-WLA result in an approximate 50-50 percent allocation of phosphorus between industrial and municipal point source discharges.

The primary objective of this P-WLA is to prevent in-stream Total Phosphorus (TP) from exceeding concentration thresholds that would result in non-attainment of the Water Quality Standards for each class of water. The results presented in this report are derived from a conservative mass balance based analysis of all point sources and non-point sources at 7Q10 river flow conditions. The Department has developed draft nutrient criteria for rivers and streams, which recommend thresholds of 33 ug/l and 30 ug/l TP for Class C and Class B streams respectively. These concentrations were used as the basis for the derived P-WLA's

(see following figure). Additionally, this P-WLA assumes that TP is a conservative pollutant, in the same manner that we evaluate toxics. The Department recognizes that there are periods of time where uptake/loss of phosphorus may occur, but significant losses are not predicted under steady state modeling of non-enriched conditions.

The results of the Department P-WLA recommend TP limits of 100 ug/l for the two Katahdin Mills (in Millinocket) and 500 ug/l for Lincoln Paper (in Lincoln) and Tissue and Red Shield (in Old Town). The basis for these limits is summarized in the following chart. The Department originally intended to have all industrial discharges at 500 ug/l, but there are a number of reasons why this was not possible;

1. 500 ug/l discharge limits for the Katahdin Mills would exceed the enrichment threshold and provide no room for downstream discharges. Limits of 100 ug/l provides for an equal allotment of proportional impact based on relative degree of dilution at the point of discharge.
2. Both Katahdin facilities are located on the West Branch of the Penobscot, therefore the associated dilution is less. The other two mills are located further downstream, below the confluence of the main stem and a number of significant tributaries, where there is more dilution.
3. The Katahdin facilities are located in the stretch of river that is particularly prone to algae (phytoplankton) blooms. The biological response to enrichment in Dolby Pond and the Mattaseunk impoundment is more similar to a lake-like system. Lakes have a significantly lower threshold response to phosphorus.



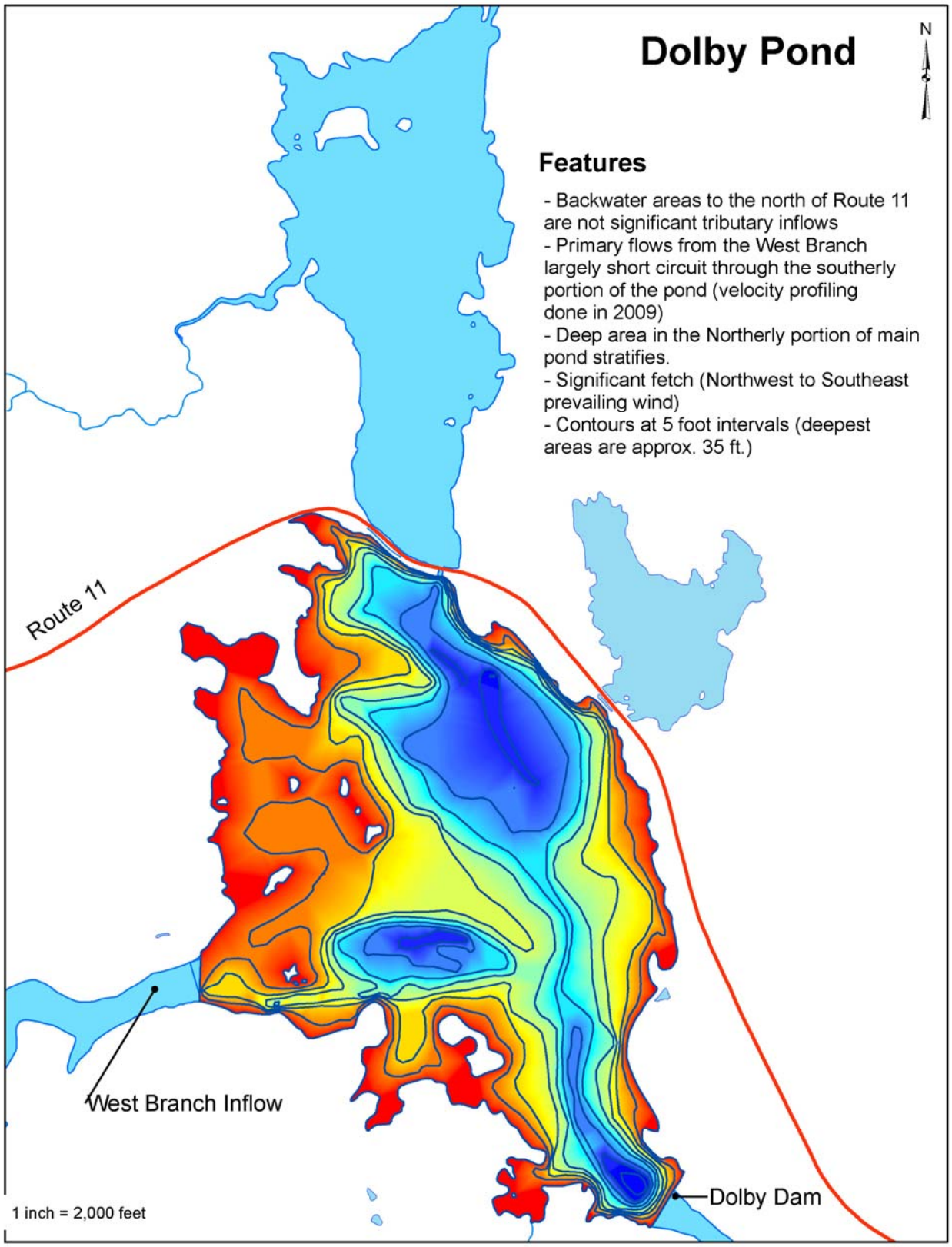
Monitoring

Ambient and effluent monitoring are integral components of this Adaptive Management approach. The Department is requiring that all significant dischargers perform total phosphorus testing of their effluent during summer months (June – September). These data will be necessary to assess actual loading conditions. The Department has developed an Ambient Monitoring Plan for the Penobscot River, which is specific to this P-WLA (May 2011). The primary intent of the Ambient Monitoring Plan is to assess the DO attainment status of the river to measure the effectiveness of this P-WLA. DO monitoring will comprise a network of 4 remote multiprobe sondes that will deployed in the river during summer months to more accurately assess the true diurnal DO response. The location of deployment for the remote sensors is intended to be somewhat flexible such that they can be moved around in a systematic approach to improve our understanding of the specific river response. Dischargers will be required to participate in the Ambient Monitoring in accordance with provisions specified in new MEPDES discharge licenses.

Conclusions

1. Implementation of this P-WLA is expected to eliminate the eutrophic conditions that are resulting in DO non-attainment.
2. Prescribed ambient and effluent monitoring will be used to assess water quality attainment status.
3. Ongoing monitoring will be used to assess the need for potential future nutrient and/or BOD load reductions.

ATTACHMENT A
(Dolby Pond Schematic)


Dolby Pond
N
Features
- Backwater areas to the north of Route 11 are not significant tributary inflows
- Primary flows from the West Branch largely short circuit through the southerly portion of the pond (velocity profiling done in 2009)
- Deep area in the Northerly portion of main pond stratifies.
- Significant fetch (Northwest to Southeast prevailing wind)
- Contours at 5 foot intervals (deepest areas are approx. 35 ft.)
Route 11
West Branch Inflow
Dolby Dam
1 inch = 2,000 feet