Presented below are water quality standards that are in effect for Clean Water Act purposes.

EPA is posting these standards as a convenience to users and has made a reasonable effort to assure their accuracy. Additionally, EPA has made a reasonable effort to identify parts of the standards that are not approved, disapproved, or are otherwise not in effect for Clean Water Act purposes.

MEMORANDUM FOR THE RECORD

FROM: Warren A. Kimball, Environmental Engineer

DATE: June 9, 1992

SUBJECT: Thermal Discharge/NPDES Review

The attached chart outlines a screening procedure for NPDES permit review of thermal discharges to inland waters. The following provides the rational for this approach.

In the review of NPDES Permits for thermal discharges the following should be considered for inland waters.

	Ecological Requirement	Criteria
1.	Maintain natural daily and seasonal cycles of temperature	Limit the temperature change from ambient, Δ T: Δ 5°F warm water Δ 3°F cold water Δ 3°F lakes
2.	Do not exceed maximum temperature for a balanced aquatic community	Limit maximum temperature, T max: 83°F max warm water 68°F max cold water
3.	Avoid short term adverse effects within a mixing zone	Limit maximum mixing zone temperature: 90°F maximum
4.	Provide a zone of passage for migrating organisms (particularly in anadromous or catadromous fish runs)	Limit the spacial extent of the mixing zone: In critical areas the mixing zone (total of all discharges) shall not exceed 50% of the cross sectional area nor 50% of the surface distance from bank to bank of the receiving water
5.	Avoid large day-to-day variations and rapid rates of change	Require flow equalization over a 24-hour period, no routine shutdowns during the winter months (December-May)

In order to assess thermal water quality the following equation is used

$$\Delta T_r = \frac{Q_e}{Q_r}(T_e - T_r) \quad \text{(Equation 1)}$$

ΔT_r = Change in receiving water temperature
Q_e = Effluent flow rate
Q_r = Receiving water flow rate
T_e = Temperature of effluent
T_r = Temperature of receiving water

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Two factors contribute maximum ΔT_r's in a receiving water:

1. Low receiving water flows which tend maximize the expression $\frac{Q_e}{Q_r}$; or

2. effluent temperatures much greater than receiving water temperatures, which maximizes the expression $(T_e - T_r)$.

These factors do not tend to be coincidental: low flows tend to occur in the summer; maximum temperature differences tend to occur in the winter. If both are assumed to occur at once the resulting model will be very conservative. This model can be used to screen permits in order to determine that the discharge does not have the potential to violate the ΔT_r criterion.

The analysis of an NPDES permit can proceed as follows:

1. Mixing Zone Analysis - The maximum temperature tolerance for a number of indigenous species tends to occur around 90°F. In order to insure no short-term adverse effects to organisms passing through the mixing zone, the limit must be met at the end of the pipe or within a very short distance of it. For this screening procedure a maximum end-of-pipe temperature of 95°F is recommended. Combined with other conservative assumptions in the remaining steps of the procedure, this will assure 90°F within a short distance of the pipe.

   Note that a 90°F maximum temperature in the mixing zone is a conservative assumption. In a site-specific analysis of an outfall, the actual time exposure history of organisms passing through the zone can be determined. Higher mixing zone temperatures may be allowable where mixing zone size is very small.

2. Rate of Change Analysis - Large day-to-day variations in temperature and excessive rates of temperature change in a receiving water can be minimized by prohibiting batch discharges and requiring flow equalization of an effluent over some suitable (usually a 24-hour) period. Other large changes in temperature can result from discontinuing a heated discharge in the winter months resulting in a rapid decrease in receiving water temperatures. Routine shutdowns of the effluent should be prohibited during the period of December through March.

   Steps 1 and 2 (above) apply to all permits. Therefore, together they can be considered Best Available Treatment (BAT) for thermal discharges (i.e., 95°F maximum end-of-pipe limit and flow equalization over a 24-hour period).

3. ΔT_r Analysis - In order to facilitate this analysis a graph is attached. This allows the reviewer to screen this parameter for potential impact with only the following information:

   Q_r = Critical receiving water flow (7Q10)
   Q_e = Permit discharge flow
   $\Delta T = T_e - T_r$ or the difference between effluent temperature and the receiving water temperature

The graph plots the ratio $F = \frac{Q_r}{Q_e}$ on the Y axis (note this is the inverse of the expression in Equation 1) verses $T_e - T_r$ on the X axis. Three lines are plotted for:

$$\Delta T_r = \Delta T/F \text{ (Equation 2)}$$

These represents ΔT_r's of 1°F, 3°F and 5°F, respectively.

Assuming the worst case condition to be an effluent temperature of 95°F and a receiving water temperature of 32°F then $\Delta T = (95°F - 32°F) = 63°F$.

On the plot it can be seen that the required receiving water to effluent flow factor, F = 63 when ΔT_r = ~~10°F~~ 1°F
F = 21 when ΔT_r = 3°F
F = 12.6 when ΔT_r = 5°F

For the purpose of this screening procedure, these factors can be rounded off to 50, 20 and 10, respectively.

A discharge with BAT as described in this procedure will meet warm water criteria (ΔT_r = 5°F) when the stream flow is greater than or equal to 10 times the effluent flow rate; it will meet cold water criteria (ΔT_r = 3°F) when stream flows are equal to or greater than 20 times the effluent flow rate, and have no significant (measurable) impact when stream flows are equal to or greater than 50 times the effluent flow rate. The 1.0°F line can be used to measure the significance of an impact for antidegradation review.

These flow rate ratios serve as a conservative screening mechanism. Lower F ratios may meet standards, but a site-specific analysis needs to be conducted. In order to do this it is necessary to measure or estimate a T_r (monthly average of maximum daily temperatures) for each month and Q_r (expected minimum daily flow for the month) and solve equation 1 for each month of the year.

Q_r can be estimated from site-specific data or extrapolated from nearly USGS gaging sites. The Stream Gazetteer Reports list the minimum mean monthly flows for numerous sites.

T_r can be estimated from data collected year-round at a point or estimated from the formula"

$$T_{(d)} = M\left[1 + \cos\left(2\frac{\pi}{\tau}(d-209)\right)\right]$$

when $d-209 \leq \frac{\tau}{2}$, and

0°C when $d-209 > \frac{\tau}{2}$

Where t(d) = temperature in - °C on day number d, in days starting with January 1, and

$$M = 31.48 - 0.0025\,(E) - 0.4635\,(LAT)$$

Where (E) = mean basin elevation
(LAT) = Latitude and
$\tau = 1228.88-21.01\,(LAT)$.

Note that USGS has determined (E) and LAT) for 89 stream gaging sites in Massachusetts.

4. T_{max} Analysis - The temperature predicting model (above) was used to calculate maximum mean temperatures at 89 locations in Massachusetts. The average maximum mean temperature was 72.5°F with a standard deviation of 1.64. When the model was compared against an extended data base in Massachusetts the margin of error (root mean square deviation) averaged approximately 5°F. If this error is added to the maximum mean a fairly conservative estimate of 77°F is predicted as the maximum mean daily temperature. This would be applicable to all warm water fisheries (no cold water fisheries were represented in the sample, i.e., streams with (E)'s above 620). T_{max} of 83°F is 5°F above 77°F, therefore the ΔT_r analysis is protective of T_{max} in warm waters.

   In cold waters field data must be collected to estimate the monthly average of maximum daily temperatures for July and August. The model predicts day 209 or July 27th to have the warmest temperatures of the year. There is an expected phase shift for lakes so that data collection should take place in August and September. These estimates should be used as T_r and assess compliance with standards.

5. Zone of Passage Analysis - The zone of passage requirement ensures the passage of migratory species past a point. To ensure that a thermal block phenomenon is not encountered, a portion of the receiving water is left outside of the mixing zone. This is only really practical in larger streams because smaller streams tend to rapidly mix effluents bank to bank. The distance downstream to accomplish complete mixing is a function of the square of the width of the river:

$$X = \frac{MW^2\mu}{D} \quad \text{(Equation 3)}$$

   where

   X = distance to complete mixing
   M = outfall coefficient
   μ = velocity
   W = width of river
   D = lateral dispersion coefficient

   With this limitation in mind this policy recommends doubling the required dilutions necessary to achieve ΔT_r in order to ensure adequate zone of passage. Therefore the zone of passage requirement is met in warm water streams at F's equal to or greater than 20 and in cold water streams at F's equal to or greater than 40.

At dilutions less than these a site specific study must be used to ensure adequate zone of passage. Some professional judgment can be used here if there is some knowledge of the aquatic resources. It is recommended that at a minimum, a site specific study demonstrating adequate zone of passage requirement be conducted for all anadromous and catadromous fish runs. It is further recommended that 50 percent of the volume and 50 percent of the surface area from bank to bank be excluded from the mixing zone unless expert advise of a fisheries biologist is available for the specific case.

Lakes fall outside of this analysis. It is recommended that no more than 10 percent of the volume of the epilimnion be allowed for the total cumulative area of all mixing zones.

The attached table summaries all the recommendations by dilution factor. In this procedure it is assumed that the water that is heated and discharged originally comes from the receiving water. If the water comes from the outside source (i.e., groundwater) then the equation for the compliance lines on the graph becomes:

$$\Delta T_r = \Delta T/(F-1) \quad \text{Equation 4}$$

This results in a line one unit above the existing line having the same slope. The compounded conservatism of this procedure eliminates this as a practical consideration. Discharges that have the potential to violate standards will require site specific information.

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SCREENING PROCEDURE FOR NPDES PERMIT REVIEW

OF THERMAL DISCHARGES TO INLAND WATERS

Dilution Factor	Water Classification	Requirement
< 10	Warm Water	SS (Δ T_r, T_{max}, ZOP)
	Cold Water	SS (Δ T_r, T_{max}, ZOP)
	Lakes	SS (Δ T_r, T_{max}, ZOP)
10-20	Warm Water	BAT, SS (ZOP)
	Cold Water	SS (Δ T_r, T_{max}, ZOP)
	Lakes	SS (Δ T_r, T_{max}, ZOP)
20-40	Warm Water	BAT
	Cold Water	BAT, SS (ZOP)
	Lakes	BAT, SS (ZOP)
40-200	Warm Water	BAT
	Cold Water	BAT
	Lakes	BAT, SS (ZOP)
> 200 •	All	BAT

Dilution Factor = $\frac{Q_r}{Q_e}$

SS [ ] = Site-Specific Study

Δ T_r = Rise above ambient

T_{max} = Maximum receiving water temperature

ZOP = Zone of Passage

BAT = 95°F max end of pipe & flow equalization

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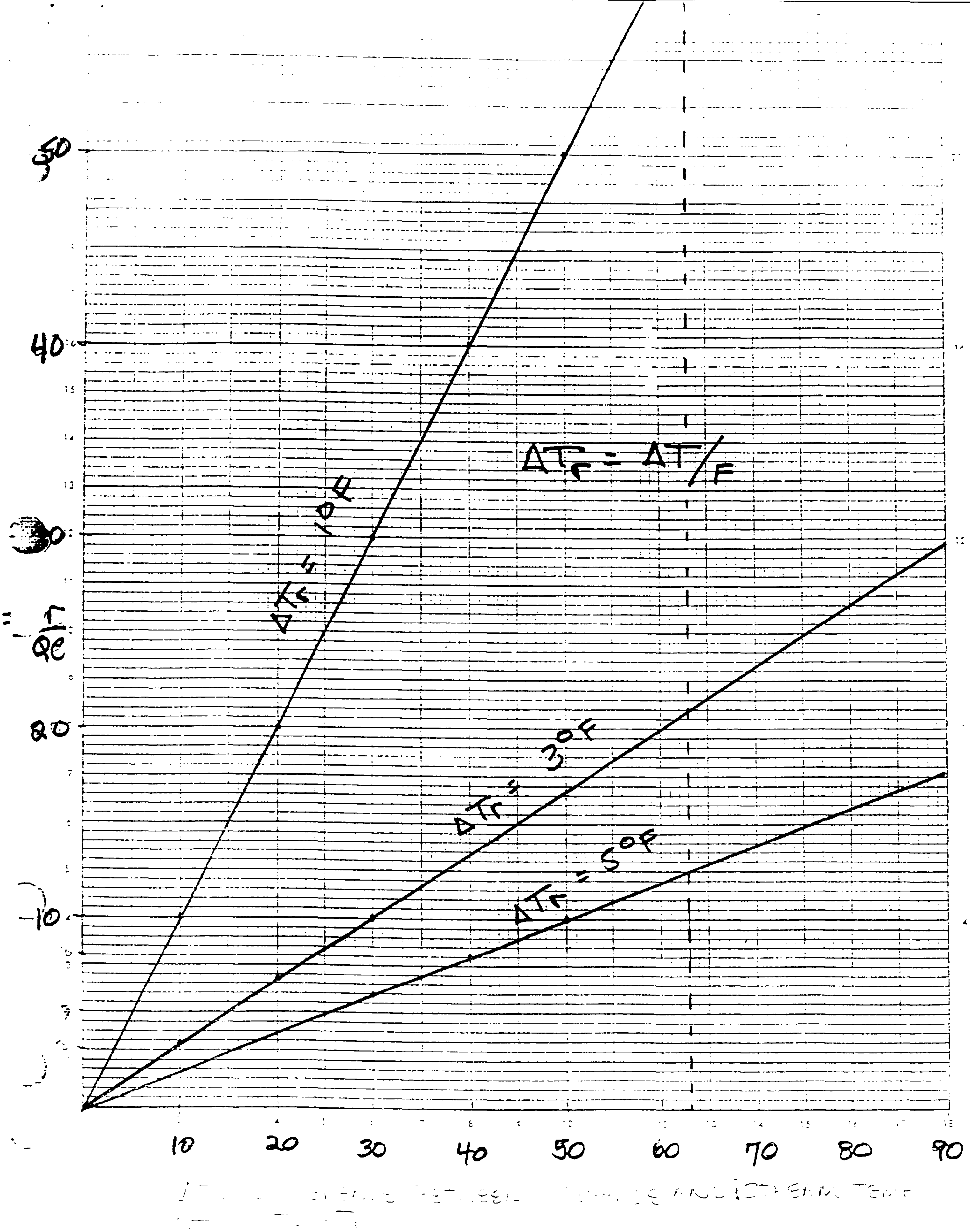

50
40
30
20
10
r/Qe
10
20
30
40
50
60
70
80
90
ΔTr = ΔT/F
ΔTr = 1°F
ΔTr = 3°F
ΔTr = 5°F