ATTACHMENT 8

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SUMMARY AND MAJOR CONCLUSIONS CONCERNING THE ECOLOGICAL IMPACT OF THERMAL EFFLUENT FROM THE SOUTH BAY POWER PLANT DURING THE PERIOD SEPTEMBER 1972 - JULY 1973

The results of three earlier studies by Environmental Engineering Laboratory during the period July 1968 - March 1971 indicated that in late summer of these years, thermal effluent from South Bay Power Plant generating units 1, 2, and 3 had adverse effects on marine organisms within the Cooling Channel, particularly within about 1000 yards of its inner end. However, no adverse effects were evident beyond the end of this channel in the outer part of the discharge pattern (outward from Station F4). It is important to note in this regard that the Cooling Channel is considered to form part of the power plant discharge system, rather than a natural part of the bay. Thus, the staff of the San Diego Regional Water Quality Control Board has reasonably concluded that adverse ecological effects are allowable within all parts of the Cooling Channel itself. The significance of such adverse effects shown to occur within the Cooling Channel should be interpreted accordingly. It also was evident that the adverse effects of thermal discharge from three generating units during this initial study period were most severe during the high water temperature conditions of the late summer months. These effects were diminished during the winter and spring, as a function of declining ambient water temperatures and a resulting decrease in both the extent of the thermal field and the mean temperatures at any given point within it.

A similar monitoring study was conducted in August 1971, just a few weeks after a fourth, larger generating unit was placed in commercial service at the South Bay Power Plant. The results of this study indicated that ecological effects of expanded power plant operations at that time were essentially the same as during previous late summer periods in 1968 and 1970.

In the present study, the benthic marine plants and invertebrates inhabiting intertidal and subtidal areas in south San Diego Bay, their environmental conditions, and the effects on them of cooling water effluent from the South Bay Power Plant and other environmental variables were investigated every three months during the period September 1972 - July 1973. This work represents a direct continuation of ecological monitoring in the area initiated in July 1968.

Standardized quantitative methods of biological, physical, and chemical sampling developed in the earlier studies were employed at 18 subtidal stations during the period September - July, and at 7 intertidal stations during the period September - April. Benthic plants and invertebrates were censused by means of replicate grab samples subtidally, and by means of replicate core samples in the intertidal. Complete descriptions of these methods of sampling, associated laboratory analyses, and possible sources of error were given.

Comprehensive and reasonably specific descriptions were provided of the physical environment and the past and present biological characteristics of south San Diego Bay. The latter included consideration of fishes, aquatic birds, and other groups on which information was obtained in earlier studies, but not in 1972 - 1973.

As in the pre-1972 studies, many specific lines of evidence were used to evaluate ecological effects of the thermal plume. A more comprehensive evaluation also was attempted than in previous studies of the quantitative relationships between characteristics of the plant mat and the benthic invertebrate fauna and pertinent physical environmental data, particularly by means of multiple correlation analysis (Ford and Chambers, 1973) and statistical comparisons among stations and between years.

Seasonal differences in physical conditions, and primarily those of ambient and discharge induced temperature conditions, were reflected by seasonal biological changes within and outside of the discharge pattern area, which were described. Evidence concerning the ecological effects of thermal effluent were obtained through specific consideration, at individual station locations and for major sectors within and outside the discharge pattern, of: 1) species composition; 2) number and diversity of species; 3) distribution, abundance and biomass of species and major groups; 4) size of individuals; and 5) the quantitative relationships of these to temperature and other environmental factors.

The results obtained suggest that the species composition of benthic plant and invertebrate associations remained moderately stable throughout the year in south San Diego Bay, although there were some evident seasonal changes. In general, numbers of species and densities were lowest during the warm water conditions of late summer-fall.

As in previous studies conducted in the South Bay, evidence obtained from both subtidal and intertidal sampling during 1972-1973 suggests that high temperatures caused by the thermal discharge in the late summer-fall, and to a lesser extent in July, had adverse effects on the numbers, diversity, and abundance of many groups of species within the cooling channel itself (Stations E5, E7, and F4). However, these effects were much less obvious during the winter and spring periods when both ambient water temperatures and those within the thermal discharge pattern were lower. Much the same general pattern appeared to hold for both the intertidal and subtidal areas, which also share a majority of their species in common. These adverse effects are allowable because, for regulatory purposes, the cooling channel forms a part of the discharge system for the power plant. During all seasonal periods, the adverse effects appeared to be confined primarily to the inner portion of the cooling channel.

The results of statistical comparisons between the control and outer discharge pattern areas suggest that during the late September - October period of 1972, and to a lesser extent in July 1973, this portion of the thermal plume beyond the end of the cooling channel (Station F4) apparently had some adverse effects on the benthic invertebrates found there. This was reflected by lower numbers of invertebrate species, involving primarily polychaetes and crustaceans, and a lower number of species and of species diversity for all invertebrates combined. The trends in these values and associated trends in distribution and abundance were obvious within the station pattern. They suggested that the adverse effects detected by these tests were confined primarily to stations in the main part of thermal effluent flow beyond the end of the cooling channel. It is important to note, however, that most of these differences were relatively small, suggesting that the adverse effects apparently were mild ones. The individual species involved were identified and their patterns of distribution and abundance described.

In contrast, the numbers of species which formed the plant mat were significantly greater within the outer discharge area than the control area during this same period. If this represents a true difference, then it may suggest that conditions for plants during this period were somewhat better within the outer portion of the thermal plume than they were beyond it. This could be interpreted as a beneficial effect.

There were no statistically significant differences for numbers and diversity of species between the outer discharge and control areas in either January or April 1973. This suggested strongly that the adverse effects described above were confined only to the summer and early fall period of high ambient and effluent water temperatures. During the cooler winter and spring periods, no such adverse effects on the number or diversity of species apparently occurred.

As in the pre-1972 studies, numbers of species, indices of species diversity, and abundances for several invertebrate groups sampled during the September - October and January periods showed significant inverse (negative) correlations with sediment and water temperatures (Ford and Chambers, 1973). The number of individual groups which showed such correlation was reduced during the January and April sampling periods of lower water temperatures. However, as for the earlier periods, the total number of invertebrate species continued to show these inverse correlations. These correlation results further indicated that, with the exception of sediment sediment characteristics, no other physical factors considered had significant relationships to number and diversity of species, and abundance, of the kind shown for these effluent temperature characteristics. This tended to confirm that there was, in fact, a meaningful temperature effect on these biological characteristics, rather than one involving some other physical variable separately or in parallel with temperature. The fact that sediment grain size and chemical characteristics were relatively uniform throughout the study area probably explains why there were few significant correlations with these physical variables.

As in the pre-1972 studies, these significant inverse correlations with temperature indicated that higher sediment and water temperatures induced by the cooling water effluent had adverse effects on several major groups of benthic invertebrates by reducing the number and diversity of species and, in a few cases, their abundances at a given location. The statistical comparisons among station groups, discussed earlier, indicated that these adverse effects were restricted primarily to the area within the cooling channel and varied seasonally. In contrast, the abundances of some major groups showed significant direct correlations with temperature.

The results of statistical comparisons suggested very strongly that there were no significant adverse effects of the thermal plume on the biomass of nearly all major groups of organisms inhabiting the outer discharge pattern area beyond the end of the cooling channel. Only the biomass values of decapod crustaceans and gastropod molluscs were significantly lower in the outer discharge area than at the control stations in July 1973. This generalization applied for all of the four seasonal sampling periods. In fact, the opposite appeared to be true during the winter and spring because, in all cases where there was a significant difference, the biomass values in question were greater in the outer discharge area than in the control area. The individual groups that showed this difference besides benthic plants were coelenterates (primarily Diadumene sp. A), oligochaete worms, amphipods, isopods (primarily Paracerceis sculpta), ostracods, gastropod molluscs, and the brittlestar Amphipholis pugetana. Two other major groups, the polychaete worms and bivalve molluscs, did not, although they showed the same trend. The specific patterns involved in these differences and trends for these major groups were described.

On the reasonable assumption that the control and outer discharge area stations were similar in characteristics other than temperature, then these results concerning biomass could legitimately be interpreted as a beneficial or enchancing effect of the thermal plume on these groups of marine organisms. This depends somewhat on one's viewpoint and how a "beneficial effect" is defined. Species abundances showed similar trends.

In any case, the effect definitely appeared to be related to temperature conditions within the plume, and was most pronounced during the winter and spring periods of low ambient water temperatures. The most probable cause of these higher biomass values is the effect of higher temperatures in enchancing the growth rates of the organisms involved. Other possible alternative or additional explanations for both the biomass and abundance effects include enchanced reproductive success and, less likely, the attraction of these organisms to warm water and their concentration there.

The biomass values for several major groups showed significant direct correlations with temperatures during each of the quarterly sampling periods. This was most pronounced during the spring (March - April) period. These results seemed to provide additional evidence of a "beneficial" effect of the thermal plume.

The results of similar comparisons between station groups suggested that, as in the case of numbers and diversity of species, the biomass of many major groups was lower within the cooling channel than in the control area, presumably because of high cooling water temperatures present there. Because the cooling channel is considered a part of the power plant discharge system, rather than a natural part of the bay, the adverse effects on biomass observed within it should not be interpreted as adverse effects on the subtidal benthic community of the bay itself.

Comparison of data between the summers of 1968-1970 and winter-early spring 1971 indicated that the biomass of the plant mat on the sediment was markedly reduced and its condition poor during the latter period. Many of the changes in species composition, distribution, and abundance of small bottom fishes and invertebrates dependent upon the mat, which were observed between these two periods, were thought to be related to its decline.

This apparently was caused in part by seasonal lowering of water temperatures, a natural effect that is quite accentuated in south San Diego Bay. In addition, because it is a shallow area of silty sediment and much particulate matter, it experiences high water turbidity during windy periods in the winter and spring through wind wave action. This undoubtedly caused a marked reduction in the light available to benthic plants and could contribute to the decline of the plant mat.

A comparison of total mean biomass values for benthic plants within the station pattern suggested that these data showed somewhat greater variation among stations during 1972-193 than during 1968 and 1971. Statistical analysis used to determine if plant biomass differed significantly between the September - October, January, April and July sampling periods of 1972-1973 showed a significant difference attributable to lower values in July 1973. This suggested that the type of major seasonal change in the mat observed in 1968-1971 had not occurred during 1972-1973. Without additional, specific information on water turbidity and other factors, it would be difficult to assess the cause of this apparent difference between years. However, it is quite possible that seasonal changes in the plant mat may vary from year to year.

In general, the intertidal organisms showed trends which paralleled those of the very similar subtidal community. Analysis of the intertidal data was hampered because of the very limited numbers of stations and their placement. The difficulty of obtaining an adequate group of representative samples from this habitat, because of the soft, cohesive nature of the sediment, further compounded the problem. For these reasons, intertidal sampling was not continued beyond the April 1973 sampling period.

Statistical comparisons between 1968, 1972, and 1973 involving numbers of plant and invertebrate species, invertebrate species diversity, and biomass values for these groups obtained during July - October, suggested that these characteristics remained relatively stable over this five year period. This, in turn, provided general evidence that changes in the characteristics of the thermal discharge associated with the addition of Unit 4 had not resulted in major shifts in the numbers, diversity, or standing crop of plant and invertebrate species, which are major components of the subtidal community.

There are several general conclusions that can be drawn from the evidence considered above. The results of this seasonal monitoring study in 1972-1973 have shown that thermal effluent from the South Bay Power Plant had some adverse effects on benthic organisms in the area, but that these were restricted primarily to the cooling channel area and to warmer periods of the year. Some effects of the thermal plume that could be interpreted as beneficial to the benthic community also were demonstrated. It is our opinion that thermal effluent from this power plant had no major adverse effects on the benthic communities beyond the end of the cooling channel, and that its operation was, on balance, not detrimental to these communities during September 1972 - July 1973.

SUMMARY AND MAJOR CONCLUSIONS CONCERNING THE ECOLOGICAL IMPACT OF THERMAL EFFLUENT FROM THE SOUTH BAY POWER PLANT

The results of three earlier studies by Environmental Engineering Laboratory during the period July 1968 - March 1971 indicated that in late summer of these years, thermal effluent from South Bay Power Plant generating units 1, 2, and 3 had adverse effects on marine organisms within the cooling channel, particularly within about 1000 yards of its inner end. However, no adverse effects were evident beyond the end of this channel in the outer part of the discharge pattern (outward from Station F4). It is important to note in this regard that the cooling channel is considered to form part of the power plant discharge system, rather than a natural part of the bay. Thus, the staff of the San Diego Regional Water Quality Control Board has reasonably concluded that adverse ecological effects are allowable within all parts of the cooling channel itself. The significance of such adverse effects shown to occur within the cooling channel should be interpreted accordingly. It also was evident that the adverse effects of thermal discharge during this initial study period were most severe during the high water temperature conditions of the late summer months, and diminished during the winter and spring as a function of declining ambient water temperatures and a resulting decrease in both the extent of the thermal field and the mean temperatures at any given point within it.

A similar monitoring study was conducted in August 1971, just a few weeks after a fourth, larger generating unit was placed in commercial service at the South Bay Power Plant. The results of this study indicated that ecological effects of expanded power plant operations at that time were essentially the same as during previous late summer periods in 1968 and 1970.

In the present study, the benthic marine plants and invertebrates inhabiting intertidal and subtidal areas in south San Diego Bay, their environmental conditions, and the effects on them of cooling water effluent from the South Bay Power Plant and other environmental variables were investigated every three months during the period September 1972 - April 1973. A fourth quarterly survey will be completed in July 1973. This work represents a direct continuation of ecological monitoring in the area initiated in July 1968.

Standardized quantitative methods of biological, physical, and chemical sampling developed in the earlier studies were employed at 18 subtidal and 7 intertidal stations. Benthic plants and invertebrates were censused by means of replicate grab samples subtidally, and by means of replicate core samples in the intertidal. Complete descriptions of these methods of sampling, associated laboratory analyses, and possible sources of error were given.

Comprehensive and reasonably specific descriptions were provided of the physical environment and the past and present biological characteristics of south San Diego Bay. The latter included consideration of fishes, aquatic birds, and other groups on which information was obtained in earlier studies, but not in 1972 - 1973.

As in the pre-1972 studies, many specific lines of evidence were used to evaluate ecological effects of the thermal plume. A more comprehensive evaluation also was attempted than in previous studies of the quantitative relationships between characteristics of the plant mat and the benthic invertebrate fauna and pertinent physical environmental data, particularly by means of multiple correlation analysis and statistical comparisons among stations and between years.

Seasonal differences in physical conditions, and primarily those of ambient and discharge induced temperature conditions, were reflected by seasonal biological changes within and outside of the discharge pattern area, which were described. Evidence concerning the ecological effects of thermal effluent were obtained through specific consideration, at individual station locations and for major sectors within and outside the discharge pattern, of: 1) species composition; 2) number and diversity of species; 3) distribution, abundance and biomass of species and major groups; 4) size of individuals; and 5) the quantitative relationships of these to temperature and other environmental factors.

The results obtained suggest that the species composition of benthic plant and invertebrate associations remained moderately stable throughout the year in south San Diego Bay, although there were some evident seasonal changes. In general, numbers of species and densities were lowest during the warm water conditions of late summer-fall.

As in previous studies conducted in the South Bay, evidence obtained from both subtidal and intertidal sampling during 1972-1973 suggests that high temperatures caused by the thermal discharge in late summer-fall had adverse effects on the numbers, diversity, and abundance of many groups of species within the cooling channel itself (Stations E5, E7, and F4). However, these effects were much less obvious during the winter and spring periods when both ambient water temperatures and those within the thermal discharge pattern were lower. Much the same general pattern appeared to hold for both the intertidal and subtidal areas, which also share a majority of their species in common. These adverse effects are allowable because the cooling channel forms a part of the discharge system for the power plant. During all seasonal periods, the adverse effects appeared to be confined primarily to the inner portion of the cooling channel.

The results of statistical comparisons between the control and outer discharge pattern areas suggest that during the late summer - early fall period of 1972, this portion of the thermal plume beyond the end of the cooling channel (Station F4) apparently had some adverse effects on the benthic invertebrates found there. This was reflected by lower numbers of invertebrate species, involving primarily polychaetes and crustaceans, and a lower number of species and of species diversity for all invertebrates combined. The trends in these values and associated trends in distribution and abundance were obvious within the station pattern. They suggested that the adverse effects detected by these tests were confined primarily to stations in the main path of thermal effluent flow beyond the end of the cooling channel. It is important to note, however, that most of these differences were relatively small, suggesting that the adverse effects apparently were mild ones. The individual species involved were identified and their patterns of distribution and abundance described.

In contrast, the numbers of species which formed the plant mat were significantly greater within the outer discharge area than the control area during this same period. If this represents a true difference, then it may suggest that conditions for plants during this period were somewhat better within the outer portion of the thermal plume than they were beyond it. This could be interpreted as a beneficial effect.

There were no statistically significant differences for numbers and diversity of species between the outer discharge and control areas in either January or April 1973. This suggested strongly that the adverse effects described above were confined only to the summer and early fall period of high ambient and effluent water temperatures. During the cooler winter and spring periods, no such adverse effects on the number or diversity of species apparently occurred. The information to be obtained during the fourth quarterly sampling period in July 1973 will be particularly valuable in delineating the extent of the summer-fall time interval during which mild adverse effects apparently occur in the outer discharge area.

As in the pre-1972 studies, numbers of species, indices of species diversity, and abundances for several invertebrate groups sampled during the September-October and January periods showed significant inverse (negative) correlations with sediment and water temperatures. The number of individual groups which showed such correlation was reduced during the January and April sampling periods of lower water temperatures. However, as for the earlier periods, the total number of invertebrate species continued to show these inverse correlations. These correlation results further indicated that, with the exception of sediment characteristics, no other physical factors considered had significant relationships to number and diversity of species,and abundance, of the kind shown for these effluent temperature characteristics. This tended to confirm that there was, in fact, a meaningful temperature effect on these biological characteristics, rather than one involving some other physical variable separately or in parallel with temperature. The fact that sediment grain size and chemical characteristics were relatively uniform throughout the study area probably explains why there were few significant correlations with these physical variables.

As in the pre-1972 studies, these significant inverse correlations with temperature indicated that higher sediment and water temperatures induced by the cooling water effluent had adverse effects on several major groups of benthic invertebrates by reducing the number and diversity of species and, in a few cases, their abundances at a given location. The statistical comparisons among station groups, discussed earlier, indicated that these adverse effects were restricted primarily to the area within the cooling channel and varied seasonally. In contrast, the abundances of some major groups showed significant direct correlations with temperature.

The results of statistical comparisons suggested very strongly that there were no significant adverse effects of the thermal plume on the biomass of any major group of organisms inhabiting the outer discharge pattern area beyond the end of the cooling channel. This generalization applied for all of the three seasonal sampling periods. In fact, the opposite appeared to be true during the winter and spring because, in all cases where there was a significant difference, the biomass values in question were greater in the outer discharge area than in the control area. The individual groups that showed this difference besides benthic plants were coelenterates (primarily Diadumene sp. A), oligochaete worms, amphipods, isopods (primarily Paracerceis sculpta), ostracods, gastropod molluscs, and the brittlestar Amphipholis pugetana. Two other major groups, the polychaete worms and bivalve molluscs, did not, although they showed the same trend. The specific patterns involved in these differences and trends for these major groups were described.

On the reasonable assumption that the control and outer discharge area stations were similar in characteristics other than temperature, then these results concerning biomass could legitimately be interpreted as a beneficial or enhancing effect of the thermal plume on these groups of marine organisms. This depends somewhat on one's viewpoint and how a "beneficial effect" is defined. Species abundances showed similar trends.

In any case, the effect definitely appeared to be related to temperature conditions within the plume, and was most pronounced during the winter and spring periods of low ambient water temperatures. The most probable cause of these higher biomass values is the effect of higher temperatures in enhancing the growth rates of the organisms involved. Other possible alternative or additional explanations for both the biomass and abundance effects include enhanced reproductive success and, less likely, the attraction of these organisms to warm water and their concentration.

The biomass values for several major groups showed significant direct correlations with temperatures during each of the quarterly sampling periods. This was most pronounced during the spring (March - April) period. These results seemed to provide additional evidence of a "beneficial" effect of the thermal plume.

The results of similar comparisons between station groups suggested that, as in the case of numbers and diversity of species, the biomass of many major groups was lower within the cooling channel than in the control area, presumably because of high cooling water temperatures present there. Because the cooling channel is considered a part of the power plant discharge system, rather than a natural part of the bay, the adverse effects on biomass observed within it should not be interpreted as adverse effects on the subtidal benthic community of the bay itself.

Comparison of data between the summers of 1968-1970 and winter-early spring 1971 indicated that the biomass of the plant mat on the sediment was markedly reduced and its condition poor during the latter period. Many of the changes in species composition, distribution, and abundance of small bottom fishes and invertebrates dependent upon the mat, which were observed between these two periods, were thought to be related to its decline.

This apparently was caused in part by seasonal lowering of water temperatures, a natural effect that is quite accentuated in south San Diego Bay. In addition, because it is a shallow area of silty sediment and much particulate matter,it experiences high water turbidity during windy periods in the winter and spring through wind wave action. This undoubtedly causes a marked reduction in the light available to benthic plants and could contribute to the decline of the plant mat.

A comparison of total mean biomass values for benthic plants within the station pattern suggested that these data showed somewhat greater variation among stations during 1972-1973 than during 1968 and 1971. Statistical analysis used to determine if plant biomass differed significantly between the September - October, January, and April sampling periods of 1972-1973 showed no significant differences. This suggested that the apparent major seasonal change in the mat observed in 1968-1971 had not occurred during 1972-1973. Without additional, specific information on water turbidity and other factors, it would be difficult to assess the cause of this apparent difference between years. However, it is quite possible that seasonal changes in the plant mat may vary from year to year.

In general, the intertidal organisms showed trends which paralleled those of the very similar subtidal community. Analysis of the intertidal data was hampered because of the very limited numbers of stations and their placement. The difficulty of obtaining an adequate group of representative samples from this habitat, because of the soft, cohesive nature of the sediment, further compounded the problem. For these reasons, it would be adivisable to discontinue intertidal work in future monitoring studies of the South Bay Power Plant.

Statistical comparisons between 1968 and 1973 involving numbers of plant and invertebrate species, invertebrate species diversity, and biomass values for these groups, suggested that these characteristics remained relatively stable over this four year period. This, in turn, provided general evidence that changes in the characteristics of the thermal discharge associated with the addition of Unit 4 had not resulted in major shifts in the numbers, diversity, or standing crop of plant and invertebrate species, which are major components of the subtidal community.

There are several general conclusions that can be drawn from the evidence considered above. The results of this seasonal monitoring study in 1972-1973 have shown that thermal effluent from the South Bay Power Plant had some adverse effects on benthic organisms in the area, but that these were restricted primarily to the cooling channel area and to warmer periods of the year. Some effects of the thermal plume that could be interpreted as beneficial to the benthic community also were demonstrated. It is our opinion that thermal effluent from this power plant had no major adverse effects on the benthic communities beyond the end of the cooling channel, and that its operation was, on balance, not detrimental to these communities during September 1972 - April 1973.