External Review of "*PROPOSED AMENDMENT TO THE WATER QUALITY CONTROL PLAN FOR CALIFORNIA OCEAN WATERS TO ADDRESS DESALINATION FACILITY INTAKES, BRINE DISCHARGES, AND TO INCORPORATE OTHER NONSUBSTANTIVE CHANGES*"

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Instructions to external reviewers

Reviewers are not limited to addressing only the specific conclusions presented above, and are asked to contemplate the following questions:

1. *In reading the Substitute Environmental Document that also comprises the Staff Report and proposed amendment language, are there any additional scientific findings that are part of the scientific basis of the proposed rule not described above?*
2. *Taken as a whole, is the scientific portion of the proposed rule based upon sound scientific knowledge, methods, and practices?*

Reviewers should also note that some proposed actions may rely significantly on professional judgment where available scientific data are not as extensive as desired to support the statute requirement. In these situations, the proposed course of action is favored over no action.

The preceding guidance will ensure that reviewers have an opportunity to comment on all aspects of the scientific basis of the proposed Board action. At the same time, reviewers should recognize that the Board has a legal obligation to consider and respond to all feedback on the scientific portions of the proposed rule. Because of this obligation, reviewers are encouraged to focus feedback on scientific conclusions that are relevant to the central regulatory elements being proposed.

Conclusion 1: A receiving water salinity limit of two parts per thousand (ppt) above natural background salinity is protective of marine communities and beneficial uses.

Background

Typical brine from a reverse osmosis (RO) desalination facility will have a salinity concentration approximately twice that of seawater. The Southern California Coastal Water Research Project assembled a panel of experts that reviewed the effects of elevated salinity on marine organisms. The panel concluded that elevated salinity may adversely impact marine organisms when salinity is elevated 2-3 ppt above natural background. A detailed summary of these findings can be found in the Brine Discharge Panel Report (link below). A hyper-salinity toxicity study was performed by the University of California, Davis, Department of Environmental Toxicology (Granite Canyon Study) using U.S. EPA west coast toxicity test methods. The study showed red abalone, purple urchins, and sand dollars were most developmentally sensitive to brine. Developmental effects were seen in red abalone at increases of 1.6 ppt above ambient salinity. Based on the review by the Brine Discharge Panel and the results of the Granite Canyon study, staff proposed a salinity limit of no more than 2 ppt above natural background salinity. The proposed receiving water limit for salinity would apply only to desalination facilities. Discussion of this conclusion can be found in the "Issues and Alternatives" Section 8.7 of the Staff Report.

Reviewer Comment

Based on the documents provided for review (Jenkins et al. 2012, Phillips et al. 2012, Jenkins and Wasyl 2013 & the Draft Staff Report) and my knowledge of this research area (Roberts, Johnston & Knott 2010), I believe that a salinity limit of two parts per thousand above natural background salinity would be an appropriate limit to protect the marine communities of California.

The review of desalination and its discharge and the environmental effects provided in Jenkins et al. (2012) and the toxicological study by Phillips et al. (2012) were appropriate, thorough and well carried out.

Jenkins et al. (2012) provided an excellent background to the issues related to desalination and the possible mechanisms available to reduce potential impacts. This review was representative of the current scientific literature on desalination issues and potential effects. The recommendation from this report of a salinity limit of 2 ppt above background levels[1] is in-line with the research published to date.

It should be noted that Jenkins et al. (2012) indicates that the salinity limit requires a compliance point (or a spatial scale) in order to be useful. Jenkins et al. (2012) suggested that the edge of the mixing zone would be an appropriate regulatory point from which the 2 ppt limit could be assessed. They further suggest that this zone could be set at 100m from the discharge point and extend through the water column from the sea floor to the surface. This appears to be acknowledged in the draft amendments (Water Quality Control Plan 2014: Receiving Water Limitation for Salinity).

Jenkins et al. (2012) also point out that there are very few (or no) published field studies (i.e. real-world assessments of desalination discharges) that cover sites in Californian or local Californian species. Hence, they indicate that it will be important to carry out monitoring of organisms exposed to the discharge and the water quality in the discharge area. They provide clear guidance on necessary monitoring that should be required to demonstrate that the 2 ppt limit is appropriate in California (e.g. water quality and ecological monitoring). Outlining the monitoring requirements in greater detail in the amendments would be useful.

Phillips et al. (2012) provided a clear indication of the salinity levels likely to affect the development of a representative cross section of the Californian biological diversity expected to be exposed to desalination discharge. This toxicological study found similar results to previous studies (cited therein) which provide further confidence that the effects and tolerances they found were reliable. The most sensitive taxa, red abalone, showed developmental effects above 0.9-1.6 ppt above background salinity levels (i.e. NOEC-LOEC), while the other sensitive taxa (purple urchin and sand dollar) tended to show developmental effects from 1.5-4.6 ppt and several other species showed effects at much high levels (although measures other than development were assessed with these taxa). Hence, a salinity limit of 2 ppt above natural background salinity would appear to be appropriate to confidently limit the effects of short-term exposure to brine discharges on Californian marine species and is in-line with other salinity studies published worldwide (Roberts et al. 2010).

Phillips et al. (2012) also raised two important points in relation to salinity effects:

a) that exposure to desalination discharge for some organisms may be chronic within the near and far mixing zones, hence, longer term ecotoxicological tests may be required to assess the potential effects of this kind of chronic exposure;

b) that desalination discharges have been proposed to be comingled with treatment works effluent and industrial cooling water. They suggest this should require further assessment to evaluate whether elevated salinity may interact with other constituents within the mixtures. Furthermore, I would also suggest that temperature may influence the effects of salinity and that for situations where brine is discharged with cooling water that assessments would be needed to determine whether effects occur at lower salinity levels with increased water temperature.

Phillips et al. (2012) also point out the need to assess the potential effects of desalination discharges into estuarine systems – especially if this scenario (estuarine discharge) is going

[1] This report also referred to a limit of 2 practical salinity units (psu; which can be used interchangeably with parts per thousand, ppt) and also a limit of not exceeding 5 % of background salinity levels.

to be covered and possibly permitted by the current amendments[2]. This comment is appropriate; however, their tests did cover a range of estuarine species (e.g. bay mussel and mysid shrimp) and species that inhabit estuaries as well as the open coast (e.g. sand dollar and top smelt). So, to some degree they have provided an initial assessment of this. Nonetheless, Höpner and Windelberg (1996) and Roberts et al. (2010) have indicated that siting is a key factor in relation to desalination discharge effects and that estuarine habitats were generally considered to be inappropriate locations for discharge.

The Jenkins and Wasyl (2013) study was a useful site specific assessment of potential advantages and disadvantages of discharging desalination effluent using an offshore diffuser system or in-plant dilution (and comingling with cooling waters). Nevertheless, this report provided little to assist in making a determination on the appropriateness of the 2 ppt salinity limit.

Beneficial uses have not been defined in the documents provided for review and may be outside my area of expertise, hence, I have not commented on this aspect of the conclusion.

Conclusion 2: A subsurface seawater intake will minimize impingement and entrainment of marine life.

Background

Desalination facilities can withdraw seawater through surface or subsurface intakes. A surface water intake system consists of a submerged open or screened pipe that withdraws ocean water into the desalination facility. Surface water intakes pull in or entrain marine organisms along with the source water. If the intake pipe is screened, fish and other biota can become trapped against the screens or impinged. Impinged organisms may survive, but mortality is assumed to be 100 percent for entrained organisms.

A subsurface intake pulls in water from below the ground or seafloor either through a well or infiltration gallery. Studies have shown that impingement and entrainment are minimized or eliminated through the use of subsurface intakes because the sediment acts as a natural filter and barrier in preventing organisms from being pulled into the facility. Typically, intake flow rates at subsurface intakes are too low to impinge organisms at subsurface intakes. Under the assumption that a subsurface intake results in negligible impingement and entrainment, the draft amendment proposes that facilities be required to evaluate whether subsurface intakes are a feasible method of obtaining seawater before selecting an intake system. This requirement is discussed in Section 8.3 of the Staff Report.

Reviewer Comment

Missimer et al. (2013) is the only publication presented for the external review for this conclusion, although there is also some coverage of the grey literature within the Draft Staff Report. Nonetheless, the review provided by Missimer et al. (2013) (published in a peer-reviewed journal) indicates that subsurface intakes have been used to pre-filter and collect water from rivers over many centuries and has also been used more recently to provide clean seawater for desalination plants in many places around the world. Conceptually the system seems feasible and it would appear that the large area that the intakes draw water from should mean that the pressures are probably fairly low – hence, unlikely to draw large animals into the sediments or the system itself (e.g. adult and juvenile fish). Nevertheless, I would like to see more information provided on whether this is the case – presumably no field studies on associated impacts exist. Also, would the intake volumes and rates for desalination systems be similar to river systems?

Furthermore, Missimer et al. (2013) suggests that far less plankton (e.g. bacteria, algae and larvae) are drawn into the desalination system when using subsurface intake systems. This

[2] Though this clearly not an optimal situation – see Roberts et al. (2010) and Höpner and Windelberg (1996) for details on important issues with discharge site selection.

maybe the case, but it is likely that many micro-organisms (e.g. plankton) are still drawn into the sediments and trapped there. So, it may not be without effect, although it is most likely a smaller effect than in comparison with other intake systems.

Overall this system seems promising, though I feel more targeted research on the ecological implication needs to be carried-out. For example, I would suspect that the drawing of water through sandy sediments would change the infaunal community substantially (e.g. from a deposit feeding dominated community to a suspension feeding dominated community), though this may be an acceptable impact without great consequence on the local ecosystem.

Conclusion 3: A 0.5 mm, 0.75 mm, 1.0 mm, or other slot sized screens installed on surface water intake pipes reduces entrainment.

Background

Surface water intakes entrain biota when withdrawing seawater. Intake entrainment is considered to be fatal for any organism drawn into the RO facility. Wedgewire screening technologies have been used at power plants and desalination facilities to reduce entrainment. Studies have shown that wedgewire screens are effective at reducing entrainment. There are many studies that have reviewed entrainment at variable screen slot sizes and have shown 0.5 mm, 0.75 mm, 1.0mm, and other slot sized screens can reduce entrainment at varying degrees. Screens with small slot sizes (0.5 mm, 0.75 mm, and 1.0 mm) are assumed to be feasible and a protective mechanism to prevent marine life entrainment from a surface water intake. The State Water Board intends to select a single slot size, but is soliciting comments on whether 0.5 mm, 0.75 mm, 1.0 mm, or some other slot size is most appropriate to minimize intake and mortality of marine life. This conclusion is discussed in Section 8.3 of the Staff Report.

Reviewer Comment

I have little direct experience with intake screens, however, conceptually I understand what they attempt to do. The reports provided for review indicate that the use of screens with 0.5 mm slots appear to be appropriate.

Conclusion 4: Multiport diffusers and commingling brine with other effluents can dilute brine discharge and provide protection to aquatic life.

Background

Discharge of undiluted brine can create dense, negatively buoyant plumes that settle on the seafloor and adversely affect the benthic ecosystem. To prevent these plumes, the amendment would require brine to either be discharged through multiport diffusers or commingled with other wastewater effluents to meet the salinity receiving water limit. Commingling with a sufficient volume of wastewater can dilute brine to non-toxic levels prior to discharge and would result in either positively or neutrally buoyant plumes. Alternatively, facilities could use multiport diffusers to achieve the necessary dilution within a relatively small area. Although recent studies have found that diffusers may shear organisms and result in marine life mortality, the mortality is less than would be expected with a third brine dilution strategy, flow-augmentation. Flow-augmentation is a type of in-plant dilution where additional seawater is withdrawn from the ocean to dilute brine prior to discharge. Currently, flow-augmentation intake systems are not designed to keep organisms in the intake water alive; however, it may be possible to design a flow-augmentation system to facilitate the passage of live biota through the system and still achieve adequate brine dilution.

The Expert Review Panel on Intake Impacts and Mitigation (ERP III) was asked to compare marine life mortality that occurs as a result of diffusers to that which would occur as the result of flow augmentation. ERP III concluded that multiport diffusers and commingling brine with *wastewater are the most protective methods for disposing of brine, while acknowledging the possibility of a flow augmentation design that is as protective as discharging through multiport diffusers or commingling brine with wastewater. Consequently, the draft amendment allows for alternative technologies, such as flow-augmentation, to be used if project proponents can demonstrate them to be as environmentally protective as diffuser discharge. Brine discharge methods are discussed in Section 8.6 of the Staff Report.*

Reviewer Comment

For multiport diffusers, the first component of this conclusion – that they are capable of diluting brine discharge to a suitable level (e.g. to within 2 ppt of background levels within 100m) – is relatively straightforward and well supported by a range of studies covering modelling data and field observations. For the situation of commingling brine with other effluents it would seem feasible that dilution would occur, but only one example was given in the documents provided (e.g. Jenkins and Wasyl 2013; though no indication was provided on how this was determined). This is not to say that commingling would not reach the dilution standard, but rather that few examples were provided to indicate that this is a suitable or reliable approach. It would appear, therefore, that modelling and field studies would be necessary to demonstrate that this form of discharge can provide comparable levels of protection (e.g. to dilute the discharge to within 2 ppt of background levels within 100m).

The complicated component of this conclusion is, however, whether these dilution techniques provide protection to aquatic life. My initial understanding of the operation of diffusers (primarily from the Sydney Desalination plant) is that they are designed to rapidly dilute the desalination discharge to within approximately 2 ppt of background levels within approximately 100m. In doing so they limit the size of mixing zone (c.f. low pressure releases; Roberts et al. 2010) and, hence, they limit the area affected ecologically by the discharge (where salinity levels are greater than 2 ppt above background and effects may be observed). Obviously the design aim of the commingled brine would similarly be to minimise the area exposed to desalination discharges greater than 2 ppt above background levels. So, aside from the 100m mixing zone, it would appear reasonable to consider diffusers and possibly commingled brine discharges as "providing protection to aquatic life" in comparison with other discharge strategies which dilute the discharges more slowly and maintain higher salinities over larger areas (Roberts et al. 2010).

An issue raised in one of the review documents (Jenkins and Wasyl 2013) was the potential for diffusers to create shear forces large enough to kill plankton and fish and that this could lead to substantial levels of mortality around the diffusers. Many of the assertions in Jenkins and Wasyl (2013) and also Tenera (2012) are, however, clearly refuted by Roberts (2013) and I agree with the responses provided in this report (Roberts 2013). In particular, that the plankton and fish mortality associated with the diffusers is of interest, however, its importance seems to be exaggerated in Jenkins and Wasyl (2013). Roberts (2013) explains that the diffusers are likely to cause impacts over a very small area around the jets with plankton only being exposed to this area for 10 - 50 seconds. Hence, they would be likely to have very limited effects on the planktonic assemblage passing near or at the diffusers. Diffusers are used in large desalination plants in Sydney and Perth (Australia; footage of the discharge can be seen at https://www.youtube.com/watch?v=X3fwQB-TRzE). It should be possible to assess the potential effects proposed in Tenera (2012) and Jenkins and Wasyl (2013) at these Australian desalination plants, if greater clarity is required on this potential issue. Anecdotal reports of the discharge at the Sydney desalination plant suggest that adult fish routinely move in and around the discharge plumes. It is likely that video of the fish movement and behaviour around the discharges when operating at full capacity may exist and could possibly be available to gain an understanding of the likelihood of effects on fish. It should also be noted that fish should be able to behaviourally modify their exposure to the discharges and I would suspect that adult or juvenile fish would avoid the discharges if the flow speeds were damaging.

A second issue highlighted in Tenera (2012) and Jenkins and Wasyl (2013) suggested that the fall of the discharge plume could cause the resuspension of soft sediments on the seafloor and that this could affect the local water clarity or turbidity (Jenkins and Wasyl 2013). It is conceivable that this could happen on soft sediment areas, especially considering that these kinds of effects were observed in the SONGS studies. Again the Sydney and Perth desalination plants could be used to evaluate experimentally whether these kinds of effects would be likely to occur considering the differing designs of the desalination diffusers (i.e. having an angle of 60˚) and those used to discharge cooling water from the San Onofre power station (i.e. having an angle of 20˚). Roberts and Vetter (2013) provide an overview of several turbidity studies – many of which are laboratory studies. However, the resuspension potential of the discharge plumes covers an extremely complex area of disturbance ecology and an enormous amount of wide ranging research has been carried out in relation turbidity, suspended sediments and sedimentation. A substantial review would be required and should focus on algae as well as invertebrates and vertebrates to provide an indication of the potential effects. Nevertheless, the impacts related to resuspension would be difficult to predict from such a review and I would expect that further research, specifically field studies, would be necessary considering the demonstrated vulnerability of Californian kelp to discharges observed in the SONGS studies. Similarly, the effects of the downward fall of the plume (in the mixing zone) could affect the settlement of larvae and algal propagules on rocky reefs and this should also be assessed and considered.

A third issue that I raised earlier (in relation to Conclusion 1) is the potential for interactions or synergistic effects between salinity, temperature and other constituents of comingled effluents. If comingled brines are to be the preferred approach to discharging desalination brine (see draft amendments) then I believe a strong understanding of any of these potential interactions should be well understood.

Conclusion 5: The Area Production Forgone (APF) method using an Empirical Transport Model (ETM) can effectively calculate the mitigation area for a facility's intakes.

Background

The draft amendment requires that an owner or operator proposing to use a surface water intake must employ impingement and entrainment avoidance technologies; however, residual entrainment will still occur. The ETM/ APF method estimates the area of habitat (in acreage) required to compensate for intake-related mortality. The ETM/APF method was recommended by the ERP II and III as the most appropriate method to use when determining the mitigation area to compensate for intake-related mortality. This conclusion is discussed in Section 8.5 of the Staff Report.

Reviewer Comment

This is a complex issue and the approach stated by Raimondi (2013) appears to be reasonable and workable. It has a reasonably long history in California in relation to cooling water mitigation (Raimondi 2013), so it seems justifiable to use it in a desalination context. Examples of mitigation are provided, however, most of these are for wetlands. It is seemingly less clear how mitigation would operate for the open coast, though one example of the creation of an artificial reef is given and other potential mitigation measures are mentioned. I do not, however, agree that the ubiquity of soft sediment habitats (and overlying water) on the open coast should be used as a reason not to carryout mitigation actions in this habitat. Possible mitigation actions could be funding research to (1) find out more about the functioning of the soft sediment habitats (and overlying water); (2) what may be lost due to the desalination activities in these areas; and (3) how these losses could be reduced in future. I believe that this would be a better strategy than creating an altogether different habitat as is currently suggested (e.g. a rocky reef or wetland seemingly just because this is possible).

I also believe the arguments made in Foster et al. (2012) and Foster et al. (2013) in regards to AFP being a better approach is appropriate. This is primarily because it takes into consideration all of organisms impacted by entrainment and impingement (and possibly discharge effects) and not just a select group such as fishes (e.g. EPRI 2004).

Additional issues: Discharge monitoring & Siting considerations

Despite the substantial knowledge that is currently available and has been reviewed and used to create the draft amendments for the Californian Ocean Plan (Water Quality Control Plan), there is a clear need to determine the actual ecological effects associated with the use of large desalination plants along the Californian coast. While enormous effort can go into preliminary assessments of potential impacts and improving the technological approaches to reduce these impacts, I believe that it will be crucial to carry out field studies to determine whether actual effects do take place or whether these plants operate as they have been designed (for example, to have discharges that are within two parts per thousand of the background salinity levels within 100m). This is clearly recognised in the current draft amendments (see Water Quality Control Plan 2014: Monitoring and Reporting Programs) and in the advisory panel report for the State Water Resources Control Board (Jenkins et al. 2012). The draft amendments for the Californian Ocean Plan (Water Quality Control Plan) indicate that Before-After-Control-Impact comparisons (e.g. Underwood 1994, Downes et al. 2002) are required to monitor the discharge plume and its potential ecological effects. Jenkins et al. (2012) suggest this monitoring should be carried out: 1) before construction of the plant, 2) after construction but before the plant is operating (so that construction impacts can be determined and to reduce the chances of confounding of desalination effects by any potential construction impacts) and 3) after the plant has been in operation. I would recommend that data from over a 3 year pre-construction stage and a 3 year operating stage be sampled, as well as the construction stage where possible. Importantly, for BACI analyses to be effective and statistically powerful, multiple references locations need to be sample (in order to provide a suitable background to compare against). In many cases, 4-10 reference locations are required to achieve a suitable level of statistical power. This power is essential in order to confidently demonstrate that any potential impacts are smaller than those deemed to be acceptable as part of the permitting of the project (Mapstone 1995, Keough and Mapstone 1997). Alternatively, without appropriate levels of statistical power, the assessment can be criticised for not being adequate to detect sizeable impacts and this would comprise the confidence in any such assessment (Mapstone 1995, Keough and Mapstone 1997). Such a scenario should clearly be avoided in order to maintain public support and confidence.

A key factor influencing the effects associated with desalination discharges is the discharge environment (Höpner and Windelberg 1996, Roberts et al. 2010). Logically, it appears that the energy and flushing levels of the environment play a significant role in diluting and dispersing the brine. This significance in relation to siting is covered to some degree in the Draft Staff Report and in Jenkins et al. (2012), however, seemingly there is no clear direction provided on high energy coastline being the priority areas for these plants to be sited. And, on the other hand, that low-energy embayments and lagoons should be avoided due to the increased difficulties in achieving appropriate levels of dilution and mixing. A more explicit direction on the kinds of environments where discharges should and should not be permitted would be useful.

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