7.4.2 Water Quality Compliance

Monitoring of water quality may be conducted to satisfy requirements of the 401 Water Quality Certification and/or WDR for projects involving dredging and/or discharge of sediment into state and federal waters. Generally, compliance is determined by not exceeding Effluent Limitations, Receiving Water Limitations, and/or not exceeding specified thresholds relative to ambient conditions. Monitoring requirements may include visual observations, field measurements using *in situ* instruments, and/or sample collection for laboratory analyses (more detailed review in Section 5.5.1.1, Appendix C).

7.4.3 Turbidity Monitoring

The following questions of interest to the CSMW are addressed in this report section:

- *What level and type of turbidity monitoring before, during, and after sediment management activities is appropriate in order to more directly relate turbidity levels to biological effects?*
- *Can kelp or other species sensitivity to turbidity plumes be used as an indicator species defining limitations on sediment management activities?*

Turbidity will be generated during any sediment management activity that includes dredging and/or discharge in the aquatic environment. However, the magnitude and extent of turbidity will vary depending on project-specific factors such as substrate characteristics, project volume, construction equipment, and construction methods (Section 5.5). The effects of turbidity require consideration of the above project-specific factors, schedule, and site-specific conditions such as hydrodynamics and existing biological resources.

The following types of biological effects related to different aspects of turbidity are of potential concern:

- Light reduction that adversely affects photosynthesis and growth of aquatic vegetation.
- Reduction in water clarity that interferes with foraging success of sensitive, terrestrial species (e.g., California brown pelican, California least tern) that forage in near surface waters aquatic environments. Foraging success requires consideration of both the acquisition of prey as well as the travel distance to obtain food.
- Elevated suspended sediment concentrations that adversely affect foraging, respiration, development, and/or migratory behavior of aquatic invertebrates, fish, and marine mammals.

Turbidity impact concerns generally increase as project volume and duration increase (Clarke and Wilber 2000.). Therefore, it seems reasonable that monitoring requirements should reflect level of impact concern. Important questions with respect to identification of impact concerns include:

- How large an area will be affected by turbidity?
- What concentrations may be expected?
- How long will elevated turbidity last?
- Will turbidity plumes occur in areas where sensitive habitats and/or resources occur?

Level and type of monitoring relevant to biological impacts of concern are further discussed below followed by a review of considerations with respect to use of indicator species to define sediment management limitations. Several mitigation measures may be employed to reduce turbidity (Section 6.4) and should be considered when answering the above questions. This should help ensure that monitoring data is useful for evaluation of impact of concern as well as effectiveness of mitigation measure.

7.4.3.1 Level of Monitoring

Water quality and turbidity monitoring requirements for sediment management projects in California have varied with respect to constituents, sampling designs (number and distance of sampling locations, frequency of sampling), and compliance criteria (Section 5.5.1.1). These inconsistencies limit the usefulness of resulting data to support science-based evaluations of plume characteristics and ecological consequences of plumes.

It is recommended that level of monitoring should address both spatial and temporal scales of impact. Spatial scale considerations include turbidity plume dimensions, differences in plume characteristics along the near- to far-field gradient from the source, and ambient water characteristics outside the plume. Spatial considerations also include characterization of the plume in the vertical dimension of the water column relevant to the impact issue of concern.

Temporal considerations include differences in plume characteristics associated with environmental conditions during project implementation and verification of plume dissipation after construction is completed. Generally, 401 Water Quality Certification and/or WDR compliance monitoring specifies daily monitoring (Appendix C.1). Daily monitoring is justified as a control strategy to ensure compliance. It also makes sense from an environmental standpoint based on changeable weather conditions.

Depending on receiving environment, it may be appropriate to take measurements more than once a day or at alternate times of day when measurements are taken on consecutive days, if there are substantial changes in plume characteristics due to time-of-day differences in environmental conditions (e.g., winds, currents, tidal stage). Characterizing plume characteristics under different environmental conditions is considered preferable to only obtaining information on maximum plumes. For example, eelgrass response to light limitation depends on the number of hours per day of irradiance-saturated photosynthesis (Zimmerman et al. 1991). Therefore, understanding whether turbidity plumes occur over an eelgrass bed only under maximum plume versus all plume conditions associated with a project is an important distinction with respect to impact evaluation.

7.4.3.2 Types of Monitoring

Different methods of monitoring turbidity plumes and biological relevance of different methodologies have been reviewed by Puckette (1998), Thackston and Palermo (2001), and Davies-Colley and Smith (2001). Puckette (1998) summarized that an effective suspended-sediment plume monitoring program will first identify the locations and dimensions of the plume and then measure the appropriate parameters dependent on the goals of the monitoring.

Plume Dimensions

Information on plume dimensions is needed to address three types of objectives: (1) spatial scale questions relative to permit compliance, (2) spatial scale questions with respect to biological impact concerns, and (3) spatial scale questions with respect to effectiveness of mitigation measures.

Plume dimensions from the source (upcurrent, downcurrent, and offshore if applicable) should be determined. Time of day and environmental conditions at the time plume dimensions are determined should be recorded, such as weather (temperature, wind speed, cloud cover, rain) and surf conditions (wave height, swell). In addition, any operational and/or construction method strategies used to control turbidity should be recorded.

It is recommended that if sensitive habitats are in the vicinity, a determination of whether the plume occurs over SAV or reef habitat should be made. If turbidity plumes occur over sensitive habitats, additional monitoring of plume characteristics may be warranted.

Different methods may be associated with measurement of turbidity plumes. For example, RGP 67 (USACE) specifies that turbidity plumes will be visually estimated by a qualified observer from a high vantage point (e.g., lifeguard tower), and that the daily maximum plume area shall be mapped and documented with digitial photographs. Visual observation and determination of the extent of turbidity plumes is a common monitoring requirement of WDRs and/or 401 Water Quality Certifications (Appendix C.1).

More accurate determination of turbidity plume dimensions outside the surf zone and/or in embayments may be accomplished with a vessel equipped with a standard fathometer that has been adjusted to optimize display of backscatter combined with *in situ* measurements of turbidity and Secchi disk depth (Puckette 1998). Acoustic Doppler sensors (e.g., ADCP, PLUMES) sensors provide detailed information on the structure of the plume (see Figure 5.5-11) and on currents affecting the plume. ADCP may be warranted in areas near sensitive habitats where more detailed plume tracking is desired.

Plume Characteristics

It is well understood that suspended sediment concentrations decrease with increasing distance from the turbidity source (LaSalle et al. 1991, Newell et al. 1998). Most water quality monitoring programs associated with WDRs or 401 Water Quality Certifications specify taking measurements at certain distances from the turbidity source (Appendix C.1). Some monitoring compliance requirements focus on determination of whether turbidity at a certain distance from the source is within 20% of ambient (Appendix C.1). Other requirements may specify obtaining measurements at several locations at increasing distance from the source with criteria also based on whether turbidity at a specified distance from the source is within 20% of ambient.

Review of collected data from several monitoring programs indicate that near- and far-field differences in plume characteristics often are not adequately described by the sampling designs that have been used to-date, usually because of an insufficient number of sampling locations (Section 5.5.3). In addition, the spatial scale of the plume has not been demonstrated with sampling designs that do not include measurements beyond 500 ft (150 m) downcurrent (Section 6.3.5.1).

Better understanding of near- and far-field differences in plume characteristics is needed to improve evaluations of adequacy of buffer distances and biological impact assessments. Standardizing monitoring requirements with respect to distance upcurrent and downcurrent of the dredge or discharge would facilitate comparisons among projects. This is desired to increase understanding of plume characteristics under different project-specific and environmental conditions.

RGP 67 (USACE 2006) requires mapping of the maximum extent of the plume with compliance criteria based on whether plume dimensions > one-half mile downcoast and offshore persist for more than two days and up to five days. If turbidity plumes exceed that criterion for more than two days, turbidity monitoring is to be conducted at a minimum of four locations: as close to the discharge site as practicable and one-half mile upcoast, downcoast, and offshore. RGP 67 specifies that light transmission is to be measured at mid-depth in the water column.

Monitoring Considerations:

Based on review of monitoring data from several beach nourishment projects, it appears that suspended sediment concentrations may be elevated in the surf zone over distances ranging from < 1,000 ft to 6 mi (10 km) long and 50 to 1,000 ft (15 to 300 m) wide depending on environmental conditions and operational controls (Sections 5.5.3, 6.3.5.1). Therefore the offshore component of the plume criterion for RGP 67 would not be expected to be within the plume. The length component of the monitoring criterion would be expected to be within the plume at least in the downcurrent direction based on persistent mapping of the plume beyond that distance. Limiting the monitoring to a minimum of the four stations specified in RGP 67 will not permit distinction of near-field and far-field plume characteristics associated with beach nourishment projects.

Review of monitoring data collected at several offshore borrow sites and during many harbor dredging projects indicates data gaps with respect to turbidity plume extent and near- and far-field characteristics with many of the WDRs that have been used to-date.

Based on the above considerations, the following monitoring considerations would improve characterization of turbidity plume characteristics.

- Beach nourishment – Two locations within plume: outside breaker zone within main part of plume and near but inside the offshore edge of the plume. Two locations at least 300 ft (150 m) outside the visible plume to serve as references for ambient conditions. Additional measurements at the following distances, if within visible plume (i.e., only would sample distances within visible plume): downcurrent at 100 ft, 300 ft, 500 ft, 1,000 ft, 1,640 ft, 2,500 ft, 3,281 ft, and upcurrent at 100 ft, 300 ft, 500 ft, and 1,000 ft (downcurrent at 30 m, 91 m, 150 m, 300 m, 500 m, and 1000 m; upcurrent at 30 m, 91 m, 150 m, and 300 m). Monitoring would not be necessary at distances that are outside the visible plume.

- Nearshore placement – Within visible plume at the following distances: downcurrent and upcurrent at 100 ft, 300 ft, 500 ft, 1,000 ft, 1,640 ft, and 1,640 ft (30 m, 91 m, 150 m, 300 m, and 500 m). Two locations at least 300 ft (150 m) outside the visible plume to serve as references for ambient conditions.
- Dredging - – Within visible plume at the following distances: downcurrent and upcurrent at 100 ft, 300 ft, 500 ft, 1,000 ft, and 1,640 ft (30 m, 91 m, 150 m, 300 m, and 500 m). Two locations at least 300 ft (150 m) outside the visible plume to serve as references for ambient conditions.

7.4.3.3 Compliance Criteria

Water quality compliance criteria generally specify that turbidity measurements at specified distances from the source to be within 20% of ambient conditions (Appendix C.1). Review of available data suggests that this criterion is protective of biological resources. However, values may exceed that criterion and still be within levels of relatively low turbidity (Section 5.5.3.6). In addition, out of compliance values may be below levels associated with biological effects.

Standard Measurements

Turbidity (NTU) - Measurements by a nephelometer are not directly relevant to biological impact concerns (Section 5.5.2.2). This is because turbidity is an optical property of water caused by the molecules of water, dissolved substances, and organic and inorganic suspended matter. However, there are no standard relationships between turbidity measurements and aspects of turbidity that may result in biological effects, such as light reduction, water clarity reduction, and/or increase in concentration of suspended sediment (Davies-Colley and Smith 2001). However, turbidity measurements are useful for providing useful, real-time data during construction for use as a control strategy (Thackston and Palermo 2000). For example, *in situ* measurements are used to support field assessments of whether water quality compliance requirements are being met and field decisions with respect to need to implement additional turbidity control measures.

Secchi disk – This method provides a relatively reliable measure of water clarity, rough estimate of light extinction, and may be useful under highly turbid conditions that may affect performance of *in situ* instruments (Davies-Colley and Smith 2001). Because of the widespread and historic use of the Secchi disk during water quality compliance monitoring in California, it is recommended that it always be included as part of any water quality monitoring program that includes *in situ* measurements. Secchi disk readings may be affected by lighting conditions; therefore, weather conditions should be reported. Relationships between Secchi disk, light transmission, and TSS must be empirically established during each project and/or when there is a substantial change in substrate characteristics (Davies-Colley and Smith 2001).

Light Reduction

Increased light attenuation due to turbidity may adversely impact photosynthesis, growth, and/or recruitment of kelp and seagrasses (Section 5.5.3.1). Light transmission and/or measurements of PAR provide relevant measures of light attenuation from turbidity effects. Transmissometers are reliable for measuring light transmission when particle concentrations are relatively low, but may become saturated at TSS levels above approximately 150 mg/L (Puckette 1988). PAR may be measured using a variety of sensors (e.g., LI-COR cosine-corrected sensors) (Dean 1985, Moore et al. 1996, Cabello-Pasini et al.. 2002). The Secchi disk provides a rough estimate of light extinction that may be useful under highly turbid conditions (Davies-Colley and Smith 2001).

If light reduction impacts are of concern, it is recommended that relevant measures of light transmission be monitored. Generally, projects spanning ≥ two weeks may be considered as being prolonged with respect to potential light limitation. Light transmission and Secchi disk depth measurements are recommended at several locations within the visible plume at different distances from the turbidity source to document the gradient of light limitation and also outside the visible plume to obtain ambient measurements (see plume characteristics).

Relevant Reports:

- A light level of approximately 1% of surface irradiance (PAR of approximately 0.2 E $m^{-2}d^{-1}$) limits the distribution of giant kelp (Foster and Schiel 1985). Recruitment is limited at 0.4 E $m^{-2}d^{-1}$ and juvenile growth is limited at 0.4 to 0.9 E $m^{-2}d^{-1}$ (Neushul and Haxo 1963, Dean and Dyscher 1983, Dean and Jacobsen 1984, Deysher and Dean 1984, Dean 1985). Saturation levels are 0.8 E $m^{-2}d^{-1}$ for recruitment and 1.8 to 3 E $m^{-2}d^{-1}$ for juvenile growth. Therefore, prolonged light levels < 5% of surface irradiance may reduce recruitment and levels < 10% may adversely affect growth.
- A light level of approximately 10% of surface irradiance is considered a general indicator of eelgrass compensation depth (Dennison 1987, Fonseca 1989). Light levels below 20% surface irradiance may reduce growth and survival (Backman and Barilotti 1976, Burke et al. 1996). Minimum light thresholds vary with environmental conditions, ranging from 3 to 12 hours of photosynthetic-saturating irradiance per day (Dennison and Alberte 1985, Zimmerman 1990, Dennison et al. 1993, Orth et al. 2006). Therefore, critical thresholds may vary depending on site conditions.
- Light levels < 40% surface irradiance limit surfgrass distribution (Williams and McRoy 1982).

<u>Water Clarity for Visual Foragers</u>

Impacts to sensitive, visual foragers that target fish prey in the upper water column (e.g., California least tern, California brown pelican) may be of concern during sediment management projects. Water clarity measurements using a Secchi disk provide a fairly reliable measure of the optical quality of waters (Davies-Colley and Smith 2001).

Relevant Reports

- Davies-Colley and Smith (2001) recommend measuring visual water clarity (measured as Secchi or black disk visibility) instead of turbidity to provide a more accurate optical quantity with relevance to fish habitat, aesthetics, and contact recreation.
- Secchi disk was specified as the method for measuring reduction in water clarity with relevance to California least tern foraging during the 2001 San Diego Regional Beach Sand Project (USFWS 2000). A Secchi depth of < 3 ft (1 m) was the water depth threshold and 1 hectare (2.47 acres) was spatial threshold for turbidity plumes for that project.

Monitoring Considerations:

A Secchi disk depth of < 3 ft (1 m) was recommended by the USFWS (2000) as a threshold for delineating plume characteristics with the potential to affect least terns and brown pelicans.

Water clarity measurements may be appropriate for sediment management projects conducted within one mile of active nesting sites of least terns. Need for monitoring should consider seasonal breeding period of the species (April 1 to September 15). Monitoring may not be necessary if only for California brown pelican because their breeding sites are located on offshore islands and they have wide foraging range along the mainland.

<u>Total Suspended Solids</u>

TSS is the measure most commonly used during laboratory studies of the effects of suspended sediment on invertebrates and fish (Sections 5.5.3.2, 5.5.3.3). TSS is relevant to effects associated with physical abrasion, respiration, physiological stress, and foraging interference for planktivores, filter-feeders, and suspension-feeders. Therefore, TSS is the most directly comparable measure to the available biological effects data concerning turbidity effects to aquatic animals.

Relevant Reports:

- Thackston and Palermo (2000) reviewed that there is no standard conversion between TSS and turbidity. They recommended measurement of both TSS and turbidity early in the project to develop a project-specific TSS-turbidity correlation, which will enable accurate conversion of subsequent *in situ* turbidity measurements to TSS. Additional water samples for TSS analysis are recommended if substrate conditions change within the project area during construction so that the accuracy of the TSS-turbidity relationship can be updated, as necessary.

- Clarke and Wilber (2000) reviewed that many of the past investigations of suspended sediment effects focused on detrimental effects, but the dosages required to induce them often were well above those likely to occur during dredging. In addition, appropriately designed studies to address dredging impacts associated with sediment resuspension are very limited. They concluded that extrapolations from inappropriate concentrations or exposure durations is a widespread practice and may lead to false conclusions. They strongly recommended that any impact assessment consider not only the concentration aspect of the dosage issue, but also realistic estimates of the likelihood and duration of exposure above that threshold.

Monitoring Considerations:

TSS concentrations in turbidity plumes should be monitored in areas near sensitive spawning grounds and/or nursery areas if the sediment management activity is conducted during peak recruitment and/or productivity periods. Acoustic monitoring is recommended to provide accurate mapping of the plume. Field collected turbidity measurements using a nephelometer and water samples for TSS are recommended to establish site-specific turbidity-TSS-backscatter correlations. The number of TSS samples necessary to adequately establish empirical relationships will vary depending on project- and site-specific conditions (Section 5.5.1.2).